INVESTIGATION INTO AMMONIA EMISSION REDUCTION BY MANURE-PROCESSING INSTALLATION

Case control measurements at two farms

Report number: BL2012.5216.02-V04
27 March 2013

INVESTIGATION INTO AMMONIA EMISSION REDUCTION BY MANURE-PROCESSING INSTALLATION

Case control measurements at two farms

Report number: BL2012.5216.02-V04
27 March 2013

Nude 54 – 6702 DN Wageningen
telephone +31 (0)317 466699 – fax +31 (0)317 426111
e-mail info@buroblauw.nl – Internet www.buroblauw.nl

FOREWORD

Commissioned by Rinagro from Piaam, Buro Blauw has carried out an investigation into the ammonia emissions from pig stalls in which a manure processing plant has been installed. The implementation of the monitoring programme took place according to the instructions of the VERA protocol in close cooperation with Mr Arjen Dijkstra from Dijkstra Agrimarketing consultancy.

Arjen Dijkstra collected the zootechnical data required for the report. He is also responsible for reporting the zootechnical data in chapters 2 and 3 and has assessed the differences in the measured ammonia emission factors in the two stalls from a zootechnical point of view.

Buro Blauw has carried out the ammonia emission measurements and reported these, and is ultimately responsible for the entire report

Wageningen, 27 March 2013

Frans de Bree
Blue Blauw director

blauw
luchthygiëne
onderzoek en advies

SUMMARY

Commissioned by Rinagro from Piaam, Buro Blauw has carried out a measuring programme to determine the ammonia emissions reduction for fattening pig stall systems with a manure-processing installation.

The objective of the measurements is to determine the ammonia emissions from this installation which can be recorded in Livestock Breeding Ammonia Scheme (RAV). To this end, a measurement plan has been drawn up by Buro Blauw, which has a positive recommendation from the RAV Technical Advisory Committee. The measurement plan consisted of conducting ammonia emission measurements for 6 * 24 hours in two stalls with two identical units. This is the so-called case-control method. The measurements were conducted at the following livestock breeding farms:

1. Van de Beek – Putten
2. Van de Brandhof – Ede

The animal category in the premises where the measurements were carried out at Van de Beek in Putten falls under Rav code D.3.2.1.2. The emission factor of the reference unit of Van de Beek in Putten as measured by Buro Blauw is 6.3 Kg NH_3 per animal per year (incl. 10% lack of occupancy). This is higher than the emission factor that is included in appendix 1 of the Rav (4.0 kg NH_3 per animal per year). This can be explained by the fact that the pigs are already heavier than when they come into the units.

The animal category in the premises where the measurements were conducted at Van de Brandhof in Ede falls under Rav code D.3.2.1.1. The emission factor of the reference unit of Van de Brandhof in Ede as measured by Buro Blauw is 1.8 Kg NH_3 per animal per year (incl. 10% lack of occupancy). This is lower than the emission factor that is included in appendix 1 of the Rav (3.0 kg NH_3 per animal per year). This difference is explained by the newness of the stall.

The measuring programme was conducted in accordance with the measurement plan carried out in the period July 2011 to March 2012. The measurements ran trouble-free. At the two farms, measurements were conducted in the six parts of the growth cycle of fattening pigs. There were a total of four measurements carried out in the winter, four measurements in the summer, and four measurements in the spring or autumn. In respect of the growth stage, the measurements conducted at the two locations were reasonably distributed across the seasons. This fulfilled the organisational requirements for conducting the investigation.

An equal number of animals was involved at both farms in the case and control unit. There was also a small acceptable difference in weight of the animals in both units. With this, there was a successful measurement set-up for the case-control method.

A clear difference in the ammonia emission reduction at both farms emerged from the measurements. A mean reduction of 35% was measured at Van de Beek in Putten and 17% at Van de Brandhof in Ede. With this, a mean ammonia emission reduction of 26% was demonstrated.
The difference in the measured reduction in ammonia emission at Van de Beek and Van de Brandhof can be attributed to the influence of the new concrete on the manure

composition at Van de Brandhof in Ede. Moreover, a low ammonia emission factor was involved at Van de Brandhof. As a result, lowering the drain emission by means of the installation of manure processing only had a limited impact on the total emissions from the shed.

In the study there are various factors which may have affected the measured ammonia emission reduction investigated. These concern:

- the difference in weight of the animals between the case and control unit;
- the difference in ventilation flow rate of the case and control unit;
- the difference in manure composition between the case and control unit;
- the dilution of the manure due to the installation for processing.

Analysis of the measurement results shows that the measured ammonia emission reduction cannot be ascribed to the above-mentioned factors.

At Van de Beek, a methane emission reduction of 16% was measured. No nitrous oxide (laughing gas) emission reduction was measured. At Van de Brandhof, in the stall with the manure-processing installation, a 35% reduction in methane emissions and a 20% lower nitrous oxide emission was measured with respect to the reference unit. An mean methane emission reduction of 20% and a nitrous oxide emission reduction of 8% were measured at both farms.

The study concluded that the measured emission reduction of ammonia, methane and nitrous oxide must be attributed to the influence of the manure processing plant.

CONTENTS

1 INTRODUCTION.

Commissioned by Rinagro from Piaam, Buro Blauw has carried out an investigation into the ammonia emissions from pig stalls wherein the manure in the manure drain has been provided with AgriMestMix by the manure-processing installation. It concerns pig stalls with the fattening pigs' animal category (D.3.2.1.1 en D.3.2.1.2).

The objective of the measurements is to determine the ammonia emission reduction from the manure processing so that the ammonia emission reduction measured can be recorded in the Livestock Breeding Ammonia Scheme (RAV). To this end, a measurement plan has been drawn up by Buro Blauw, which has a positive recommendation from the RAV Technical Advisory Committee (RAV10063). The measurement plan consisted of the conducting of ammonia, nitrous oxide and methane emission measurements in accordance with the case-control method. With this, the ammonia emission was measured for 6 * 24 hours in two stalls with two similar units with which the manure in one unit was treated by the installation for manure processing (case unit) and in one unit it was not (control unit). Manure samples were also taken on the measurement days.
This concerned the following livestock breeding farms:
1. Van de Beek – Putten
2. Van de Brandhof – Ede

The measurements are divided over the growth cycle and conducted divided across the season, with spring and autumn being considered as equivalent seasons. The first measurement was carried out on 27 July 2011 and the last measurement was carried out on 5 March 2012.

The measurement results are detailed in this report. The investigation set-up is discussed in chapter 2. This addresses the stall system, the ammonia-reducing principle of the manure-processing installation, the operation management in the stalls during the measurements, the measurement setup and the methods used, and the data processing.

The results of the investigation are presented in Chapter 3. Here, the production data, the zootechnical data, the climate and ventilation of the stalls, and the results of the measurements are discussed.

The mean ammonia emission reduction for the manure-processing installation is determined in Chapter 4. This section also discusses the actual ammonia reduction of this installation and this is explained by the specified ammonia-reducing principle. It also looks at differences between the case and control unit and the potential impact of these differences on the measured ammonia reduction due to the manure-processing installation.

The conclusions of the investigation are formulated in Chapter 5.
The appendices contain detailed data on the stall systems, the agronomic parameters of the stalls during the measurement period, and the results of the measurements.

2. INVESTIGATION SET-UP

2.1 Business situation

The measurements were performed at two farms, namely:

- The pig farm of Mr J. van de Beek is located at Houtweg 5 in Putten. Primarily pigs are present on the farm. The measurements are carried in a stall with five units. The measurements were carried out in unit 3 (reference) and unit 5 (manure-processing installation). Mr Van de Beek's stall system in which the measurements were conducted is extensively described in appendix D. The position of the farm is shown in figure 2.1. The stall is indicated in the figure with a pin.

Figure 2.1 Overview photo of the position of the pig farm of J. van de Beek in Putten (photo taken from Google Earth).

Meetlokatie = Measurement location

- Mr D. van de Brandhof's pig farm is situated at Peteweg 9 in Ede. Only pigs are present on the farm. The measurements were carried out in unit 23 (reference) and unit 21 (manure-processing installation). Mr Van de Brandhof's stall system in which the measurements were conducted is extensively described in appendix D. The position of the farm is shown in figure 2.2. The stall where the measurements were conducted cannot be seen on the photo. The location where the stall has been built is indicated in the figure with a pin.

Figure 2.2 Overview photo of the position of the pig farm of D. van de Brandhof in Ede (photo taken from Google Earth).

Locatie stal = Stall location

2.2 Stall system description

2.2.1. System description

The stall systems of the two farms are described in the following paragraphs.
The operation of the manure-processing installation is described in appendix A.

2.2.2 Stall system of J. van de Beek in Putten

The stall has a half grid feed with a traditional manure disposal. Up to 400 pigs are housed here, divided over five units with a maximum of 80 pigs per unit. Each unit has eight pens; four on each side of the feeding aisle. The drinking water supply is unlimited. Per unit there is one ventilator available that is controlled by temperature in the stall. The intake of fresh air takes place via the door.

2.2.3 Stall system of D. van de Brandhof in Ede

The stall has a half grid feed with a traditional manure disposal. Up to 576 pigs are housed here, divided over six units with a maximum of 96 pigs per unit. Each unit has eight pens; four on each side of the feed aisle. The drinking water supply is unlimited. Per unit, there is one ventilator available that is controlled by temperature in the stall. The intake of fresh air takes place via the floor.

2.3 Ammonia-reducing principle

The manure-processing installation reduces ammonia emissions by means of spraying an amount of natural mineral mixture on the slurry every day. By repeating this daily, the process in the manure changes. As a result, the formation of gas in the manure stops and the emissions, including ammonia, are reduced. The nitrogen remains in the manure and later becomes available for plants. The dry matter content of the manure and the organic matter content decrease through the addition of the mineral mixture.
The natural mineral mixture consists of natural minerals, mineral oxygen and a number of specific bacteria.
The natural mineral mixture strongly inhibits the methanogenic phase (gas production). By stopping the anaerobic process in the manure and starting an aerobic process, a reduction of ammonia emissions takes place.

2.4. Operational management

2.4.1 Zootechnics

Appendices D.1 and D.2 contain data about the operational management of the two farms on all production rounds wherein measuring took place.

2.4.2 Conditions

The measurement locations had to meet the following conditions:

- the units that are measured have to have been in use for at least two months;
- the fattening pigs are kept in accordance with the applicable welfare standards;
- the number of pigs in a pen is between 10 and 40;
- drinking water is limitlessly available
- the growth of the pigs from 25-115 kg is at least 750 g/day;
- the dropout rate does not exceed 5%;
- the minimum number of pigs per unit is 50.

Both measurement locations satisfy all these requirements.

2.5. Measurements

2.5.1 Quality assurance

Taking effect from 28 July 2004, the Dutch Accreditation Council has granted Buro Blauw B.V. the accreditation for the implementation of various operations by the metering service in accordance with NEN-EN-ISO/IEC 17025 (nl) (2005), *Algemene eisen voor de competentie van beproevings- en kalibratielaboratoria* (General requirements for the competence of testing and calibration laboratories). Buro Blauw is registered under number L400. The accredited operations relate only to the implementation of measurements and their analysis.

Buro Blauw B.V. is member of the Vereniging Kwaliteit Lucht (Association of Air Quality). This association is committed to the continuous development and assurance of high-quality air measurements and consists of leading measurement and inspection bodies in the Netherlands.

Buro Blue has successfully completed the flow rate and ammonia sections of the third-line control organised by the VKL at the Flemish Institute for Technological Research in Belgium.

Table 2.1 gives an overview of the measurement methods applied in this investigation.

Table 2.1 The measurement methods employed in the investigation

Determination	Activity	Standard	Accreditation[1]	Appendix
Waste gas flow rate	Waste gas speed, temperature, pressure and moisture content	ISO 10780	Q	B
NH_3 determination	Sampling on gas wash bottles with absorption liquid	NEN 2826	Q[2]	C
Methane + nitrous oxide	Sampling with lung method			

1: The operations marked with Q are accredited by the Dutch Accreditation Council
2. The measurements are carried out in accordance with the measurement plan approved by TAC-RAV. As a result some points of NEN 2826 are deviated from.

The NH_3 analyses were outsourced to AL-West, an accredited external laboratory. The nitrous oxide and methane analyses were carried out by the Environment Laboratory of the Agrotechnology & Food Sciences Group from Wageningen University and Research Centre.

2.5.2. Ammonia concentration measurements

The ammonia measurements were carried out for 24 hours by means of the absorption method and wet chemical analysis. A detailed description of the measurement method is given in appendix C. The concentration measurements have been made in the exhaust duct. One ventilation duct per unit was involved at both locations.

2.5.3 Ventilation flow rate

At Van de Brandhof in Ede the ventilation flow rates were continuously measured by the control software made by Hotraco. A value was registered per ventilator per minute. The operation of the ventilators is controlled with flow rate measurements in accordance with ISO 10780 (1994), *Stationary source emissions –Measurement of velocity and volume flow rate of gas streams in ducts.* A detailed description of this measuring method is given in appendix B. A measuring duct was positioned in order to carry out flow rate measurements. The relationship between the ventilation conditions and the flow rate under operating conditions of unit 23 is shown in a graph in figure 2.3.

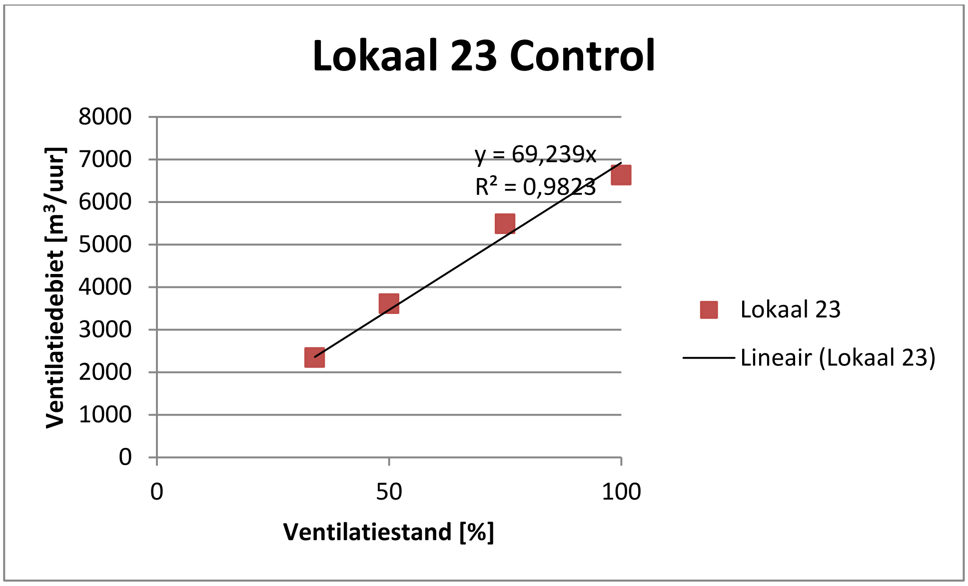


Figure 2.3 Relationship between ventilation and flow rate of unit 23

Lokaal 23 Control = Unit 23 Control
Ventulatiedebiet [m3/uur]= Ventilation flow rate [m3/h]
Ventilatiestand [%] = Ventilation rate [%]
Lokaal23 = Unit 23
Lineair (Lokaal23) = Linear (Unit 23)

The relationship between the ventilation rate and the flow rate under operating conditions of unit 21 is shown in a graph in figure 2.4.

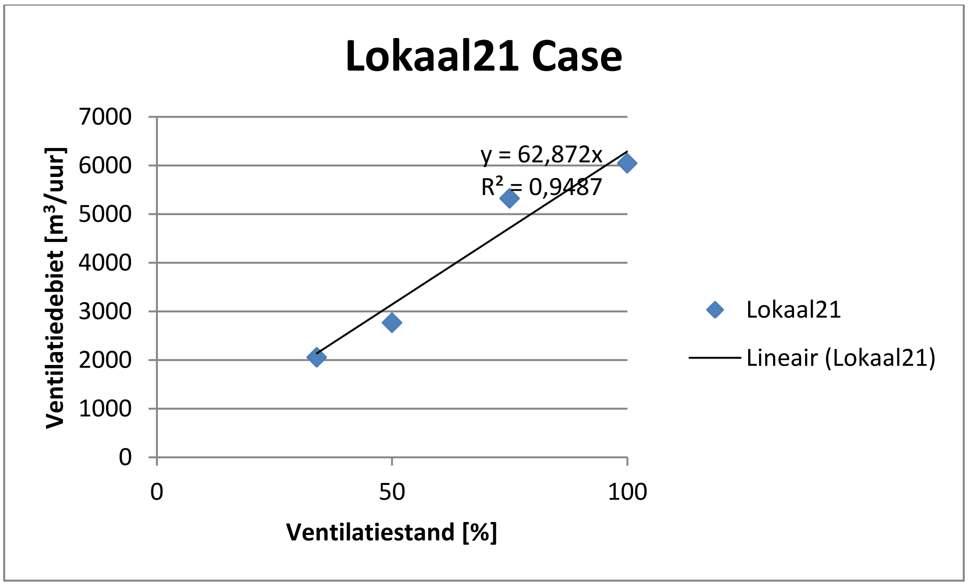


Figure 2.4 Relationship between ventilation rate and flow rate of unit 21

Lokaal21 Case = Unit 21 Case
Ventulatiedebiet [m3/uur]= Ventilation flow rate [m3/h]
Ventilatiestand [%] = Ventilation rate [%]
Lokaal21 = Unit 21
Lineair (Lokaal21) = Linear (Unit 21)

The flow rate was determined in the existing ventilation duct at Van de Beek in Putten. The mean velocity of air was logged at the ventilators over a unit of time using an anemometer. A measuring surface assessment was first conducted on the ventilators before measuring. This determined where the velocity of air in the measuring duct is equal to the mean air velocity in the measurement plane. The anemometer was positioned at that spot in order to record the velocity of air during the 24-hour measurement.

2.5.5 Nitrous oxide and methane measurement method

The nitrous oxide and methane measurements were carried out by means of the lung method over 24 hours. The nitrous oxide and methane analyses were carried out by the Environment Laboratory of the Agrotechnology & Food Sciences Group from Wageningen University and Research Centre.

2.5.6 Measurement set-up

The measurements were carried out according to the case–control methodology. This means that per farm, two equivalent sections were measured wherein one unit was equipped with a manure-processing installation and the other one not. At Van de Beek in Putten it concerned unit 3 (control) and unit 5 (case). At Van de Brandhof in Ede it concerned unit 23 (control) and 21 (case). In addition to ammonia measurements, nitrous oxide and methane components were also included. A round production of fattening pigs in the relevant section at Van de Beek takes approximately 12 weeks and at Van de Brandhof in Ede about 17 weeks. The measurements are divided over the growth cycle and are conducted divided across the season, with spring and autumn being considered as equivalent seasons. The first measurement was carried out on 26 July 2011 and the last measurement was carried out on 5 March 2012. Manure samples were also taken on the measurement days and these were submitted for analysis to the BLGG laboratory at Wageningen. The results of the manure sample analyses are given in appendix E.

3. RESULTS

3.1 PRODUCTION RESULTS

The average data of the farms during the period of the six measurements is given in table 3.1. The production data per production round and per farm is given in appendices D.1. to D.2.

Table 3.1 The average data of the two farms during the measurement period

	Van de Beek, Putten		Van de Brandhof, Ede	
	Control Unit 3	Case Unit 5	Control Unit 23	Case Unit 21
Number of Pigs per section	80	80	96	96
Number of pens per stall	8	8	8	8
Number of animals per pen	10	10	12	12
Stocking weight (kg)	22.2	23.2	24.2	24.7
Drop-out rate (%)	2.5	1.7	2.5	2.0
Delivery weight (kg)	116	116	91.4	92.1
Health problems before measurement period (%)	18.1	15.0	n/k	n/k
Health problems during measurement period (%)	9.2	3.8	n/k	n/k
Occupancy (/m^2)	0.9	0.9	0.8	0.8
Growth per day (g)	772	789	824	804
Total amount of feed provided (kg)	26,468	25,449	21,197	22,143
Amount of water provided (l)	n/k[1]	n/k	55,960	58,457
Water-feed ratio (-)	n/k	n/k	25% ds	25% ds

1. (n/k = not known)

It is noted that at Van de Beek in Putten when stocked, the pigs first stay in two different units before they go to units 3 and 5. The pigs remain for approximately 12 weeks in units 3 and 5 per production round. The medication use at litter/herd level is given in appendices D.1 and D.2.

From the table and appendices D.1 and D.2 it follows that at both farms there are slight differences in agricultural conditions between the case and control section. The number of pigs per section, the pen occupancy, the drinking water consumption, the feed provided and the veterinary treatment were alike for the case and control. The length of the production round, the growth per day, the delivery weight, the amount of feed provided and the percentage drop-out differ less than 5% between case and control at both farms. From this it is concluded that at both farms for the case and control section as far as the agricultural conditions are concerned, they are equal.

3.2. Measurement spread

The measurements were carried out, spread across the seasons and the growth cycle of the animals. Figure 3.1 shows the measurement data of the measurements and the distribution over the measurement period

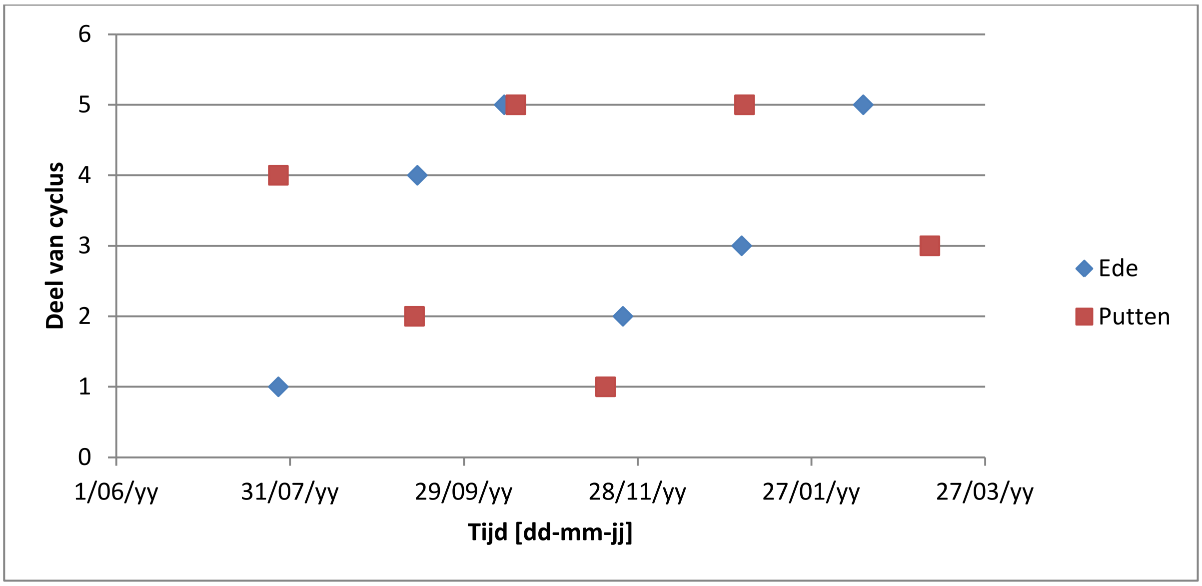


Figure 3.1 Spread of the measurements over the measurement period

Deel van cyclus = Part of cycle
Tijd [dd-mm-jj] = Time [DD-MM-YY]

At both farms, no measurements were made in the sixth part of the growth cycle because the head is then already out of the stall and an uneven number of pigs are present in both pens. Because of this, an incomparable situation arises.
Per farm, measuring was done twice in the fifth part of the growth phase. At Van de Brandhof in Ede, where the pigs remained in units 17 and 23 for an average of 17 weeks, the growth cycle was divided into parts of three weeks. At Van de Beek in Putten, because the pigs first stay in two other units after stocking and then later go to units 3 and 5, the holding time in units 3 and 5 amounts to approximately 12 weeks. The growth phase is split into parts of two weeks.
There are a total of four measurements carried out in the summer, four measurements in the winter, and four measurements in the spring or autumn.

In respect of the growth stage, it follows from the figures that the measurements on both farms are reasonably distributed across the seasons. This fulfilled the organisational requirements for conducting the investigation. With the first measurement at Van de Beek the head was already out of unit 3 (control) The changed number of animals is included in the emission factor calculation.

3.3 Results of the ventilation flow rate measurements

The results of the ventilation flow rates are shown in table 3.3.

Table 3.3 Results of the measurements of the ventilation flow rate and the stall temperature.

Date	Location	Part in cycle	Control		Case	
			Flow rate	Temperature	Flow rate	Temperature
[dd-mm-yy]		[-]	[m_0^3/hr.]	[^oC]	[m_0^3/hr.]	[^oC]
26-07-11	Van de Beek	4	2833	26.4	1876	28.7
12-09-11	Van de Beek	2	2049	27.6	1760	27.6
17-10-11	Van de Beek	5	2251	25.9	1936	25.4
23-11-11	Van de Beek	1	2184	25.0	1937	24.0
03-01-12	Van de Beek	5	1792	24.1	1768	23.9
05-03-12	Van de Beek	3	2275	21.5	2139	21.2
	Mean		**2231**	**25.1**	**1903**	**25.1**
27-07-11	Van de Brandhof	1	1571	27.1	1191	27.4
14-09-11	Van de Brandhof	4	2639	25.4	2063	25.9
13-10-11	Van de Brandhof	5	2587	24.0	2308	23.4
07-12-11	Van de Brandhof	2	1257	24.4	875	24.8
05-01-12	Van de Brandhof	3	1791	24.4	1322	23.7
10-02-12	Van de Brandhof	5	1200	21.6	1097	21.4
	Mean		**1841**	**24.5**	**1476**	**24.4**

From the table it follows that there is a positive correlation (R=0.3) between the growth phase of the animal and the ventilation flow rate of the stalls. This is consistent with the expectations.
There is also a positive correlation (R=0,3) between the season and the ventilation flow rate of the stalls. The flow rate is at its lowest in winter and highest in summer. This is also consistent with the expectations.

It also follows from the table that at both Van de Beek in Putten and Van de Brandhof, the ventilation flow rate in the control section is greater than in the case section. The temperature in the case and control sections in Putten and in Ede is, however, equal.

3.4 Ammonia emission results

The results of the ammonia emission measurements at Van de Beek in Putten are shown in table 3.4.

Table 3.4 Results of the ammonia emission measurements at Van de Beek in Putten

Annual emission [kg/animal*y] Van de Beek, Putten			
Part of cycle	Unit 3 Control	Unit 5 Case	Efficiency [%]
4	11.3	6.2	45
2	5.5	3.5	35
5	7.2	4.3	39
1	5.8	4.2	26
5	6.2	4.7	25
3	4.8	2.9	38
Mean	**6.8**	**4.3**	**35**

The results of the ammonia emission measurements at Van de Brandhof in Ede are shown in table 3.5.

Table 3.5 Results of the ammonia emission measurements at Van de Brandhof in Ede

Annual emission [kg/animal*y] Van de Brandhof, Ede			
Part of cycle	Unit 23 Control	Unit 21 Case	Efficiency [%]
4	1.4	1.0	27
2	1.9	1.5	21
5	3.0	2.3	25
1	1.1	1.0	7
5	1.4	1.2	10
3	2.1	1.8	11
Mean	**1.8**	**1.5**	**17**

From table 3.4 it follows that the mean ammonia emission reduction at Van de Beek in Putten is equal to 35% through use of the manure-processing installation. From table 3.5 it follows that the mean ammonia emission reduction at Van de Brandhof in Ede is equal to 17% through use of the manure-processing installation. The mean measured ammonia reduction of both farms amounts to 26%.

During the lack of occupancy during two cycles, ammonia concentration measurements were conducted by Dijkstra Agrimarketing at different places in the units, using an electrochemical hand device. The mean value of these measurements is shown in table 3.6. The detailed data are given in appendix F.

Table 3.6 Results of the electrochemical ammonia concentration measurements.

Farm	Date [dd-mm-jj]	Ammonia concentrations [ppm] Case	Control	Efficiency [%]
Van de Beek	25-08-11	44	20	54
Van de Beek	15-11-11	21	10	52
Van de Beek	01-02-12	33	14	58
Mean				**54**
Van de Brandhof	01-11-12	26	24	11

These measurements also appear to show a difference in ammonia removal efficiency between the two farms. The measured efficiency using the ammonia meter at Van de Beek in Putten is higher than with the official measurements. This can be explained by the total ammonia emission being composed of the drain emission and the pen emission. During the lack of occupancy, the share of the drain emission is higher in relation to the pen emission. The manure-processing installation only has an ammonia emission-reducing effect on the drain emission.

3.5 Methane and nitrous oxide emission results

The results of the methane emission measurements at Van de Beek in Putten are shown in table 3.7.

Table 3.7 Results of the methane emission measurements at Van de Beek in Putten

	Annual emission [kg/animal*y] Van de Beek, Putten		
Part of cycle	Unit 3 Control	Unit 5 Case	Efficiency [%]
4	21	23	-14
2	21	21	3
5	25	19	22
1	14	18	-29
5	24	18	25
3	23	19	19
Mean	**22**	**19**	**4**

The results of the methane emission measurements at Van de Brandhof in Ede are shown in table 3.8.

Table 3.8 Results of the methane emission measurements at Van de Brandhof in Ede

Annual emission [kg/animal*y] Van de Brandhof, Ede			
Part of cycle	Unit 23 Control	Unit 21 Case	Efficiency [%]
4	1.6	1.0	37
2	2.5	1.9	25
5	3.3	3.4	-3
1	3.9	1.9	51
5	3.3	1.6	50
3	4.3	2.1	52
Mean	**3.1**	**2.0**	**35**

From table 3.7 it follows that the mean methane emission reduction at Van de Beek in Putten is equal to 4% through use of the manure-processing installation. From table 3.8 it follows that the mean methane emission reduction at Van de Brandhof in Ede in Putten is equal to 35% through use of the manure-processing installation. The mean measured methane reduction of both farms amounts to 20%.

The results of the nitrous oxide measurements at Van de Beek in Putten are shown in table 3.9.

Table 3.9 Results of the nitrous oxide emission measurements at Van de Beek in Putten

Annual emission [kg/animal*y] Van de Beek, Putten			
Part of cycle	Unit 3 Control	Unit 5 Case	Efficiency [%]
4	0.17	0.16	5
2	0.14	0.14	-2
5	0.21	0.20	4
1	0.18	0.20	13
5	0.16	0.18	-11
3	0.16	0.17	-4
Mean	**0.17**	**0.18**	**-4**

The results of the nitrous oxide emission measurements at Van de Brandhof in Ede are shown in table 3.10.

Table 3.10 Results of the nitrous oxide emission measurements at Van de Brandhof in Ede.

Annual emission [kg/animal*y] Van de Brandhof, Ede			
	Unit 23	Unit 21	Efficiency
Part of cycle	Control	Case	[%]
4	0.10	0.08	23
2	0.15	0.12	24
5	0.19	0.18	8
1	0.11	0.07	38
5	0.15	0.11	23
3	0.08	0.08	7
Mean	**0.13**	**0.10**	**20**

From table 3.9 it follows that the mean nitrous oxide emission reduction at Van de Beek in Putten is equal to -4% through use of the manure-processing installation. From table 3.10 it follows that the mean nitrous oxide emission reduction at Van de Brandhof in Ede in Putten is equal to 20% through use of the manure-processing installation. The mean measured nitrous oxide reduction of both farms amounts to 8%.

4. DISCUSSION

In this chapter the effects on the measured ammonia emission reduction from differences in agronomic conditions between the case and control sections in both farms are discussed. Below we examine the effects of:

1. the difference in weight of the animals between the case and control unit;
2. the difference in ventilation flow rate of the case and control unit;
3. the difference in manure composition between the case and control unit;
4. differences in ammonia emission reduction between both farms;
5. the relationship of ammonia emission reduction and working mechanism;
6. the reduction of methane and nitrous oxide emission.

Recommendations for further investigation are made based on the above discussion points.

sub 1. Difference in weight

The weights of the animals in both sections at both farms are compared with each other in table 4.1.

Table 4.1 Comparison of number of animals and animal weights in the control and case section.

Measurement	Section	Number of pigs	Date: Stocking	Date: Measurement	Weight [kg]: Stocking	Weight [kg]: Measurement	Difference [%]
	Van de Beek						
1	Control	78	8-7-2011	26-07-2011	16.0	109	-11
	Case	78	29-6-2011	26-07-2011	15.2	97	
2	Control	79	8-7-2011	12-09-2011	16.0	67	-11
	Case	79	29-6-2011	12-09-2011	15.2	75	
3	Control	79	14-9-2011	17-10-2011	25.6	96	-7
	Case	79	29-9-2011	17-10-2011	31.8	102	
4	Control	79	14-9-2011	23-11-2011	25.6	81	7
	Case	80	29-9-2011	23-11-2011	31.8	75	
5	Control	79	21-12-2011	3-01-2012	25.9	109	2
	Case	79	7-12-2011	3-01-2012	24.9	106	
6	Control	79	21-12-2011	5-03-2012	16.0	82	-14
	Case	80	7-12-2011	5-03-2012	15.2	94	
	Mean						**-6**
	Van de Brandhof						
1	Control	96	5-7-2011	27-07-2011	22	40	13
	Case	96	13-7-2011	27-07-2011	23	35	
2	Control	96	5-7-2011	14-09-2011	22	80	6
	Case	96	13-7-2011	14-09-2011	23	76	
3	Control	96	5-7-2011	13-10-2011	22	105	4
	Case	96	13-7-2011	13-10-2011	23	100	
4	Control	96	2-11-2011	7-12-2011	25	52	9
	Case	96	9-11-2011	7-12-2011	25	48	
5	Control	96	2-11-2011	5-1-2012	25	73	5
	Case	96	9-11-2011	5-1-2012	25	70	
6	Control	96	2-11-2011	10-02-2012	25	103	2
	Case	96	9-11-2011	10-02-2012	25	101	
	Mean						**5**

It follows from the table that the number of animals in the case and control section of both farms was the same with all measurements. There was also a small weight difference between the animals of both sections. At Van de Beek the weight of the animals in the control section was on average 6% higher than in the case section. As a result, the measured ammonia emission reduction at Van de Beek is somewhat overestimated.
At Van de Brandhof, to all intents and purposes the effect is the opposite. Here, the mean weight of the pigs in the case section is 5% greater than in the control section. As a result, the measured ammonia emission reduction at Van de Brandhof is somewhat underestimated.

Overall, the difference in weight of the animals in the control and case department hardly affects the measured ammonia emission reduction.

sub 2. Difference in ventilation flow rate

In paragraph 3.3 the ventilation flow rate in the control department is observed to be larger than in the case department. The temperature in the case and control sections in Putten and in Ede is equal. Figure 4.1 graphically shows the effect on the ammonia emission reduction of the difference in ventilation flow rate between the control and case department.

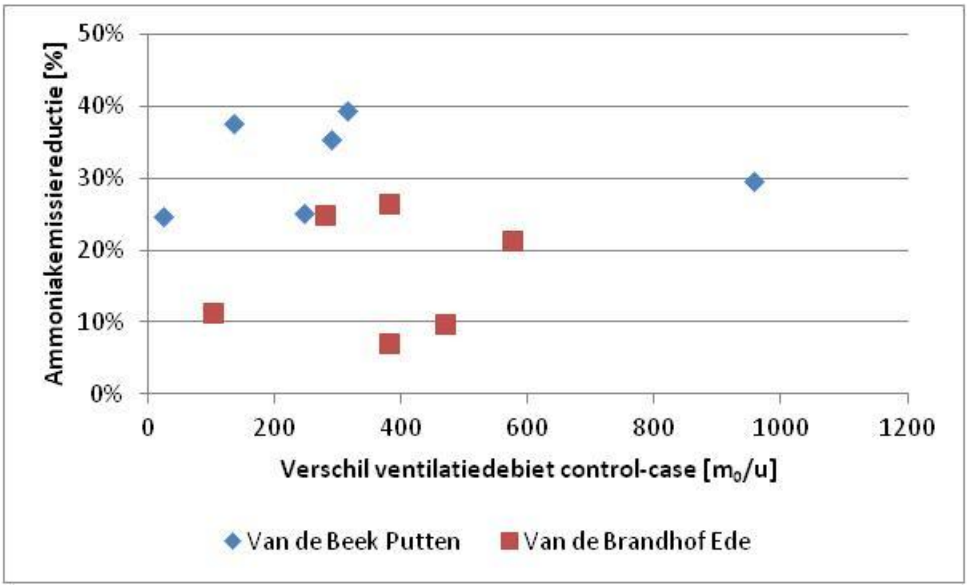


Figure 4.1 Relation between the difference in ventilation flow rate between the control and case section and the ammonia emission reduction.

Ammoniakemmessuereductie [%] = Ammonia emission reduction [%]
Verschil ventilatiedebiet control-case [m0/h] = Control-case ventilation flow rate difference [m0/h]

From the figure it appears clear that no systematic effect is found of the difference in ventilation flow rate on the ammonia emission reduction. The correlation coefficient between both quantities is equal to -0.03.

It is concluded that the difference in ventilation flow rate does not have an influence on the measured ammonia emission reduction. This is in line with the fact that no difference in stall temperature occurred between the case and control section.

sub 3. Difference in manure composition

In table 4.2 the composition of the manures at Van de Beek and Van de Brandhof are compared with each other. Also looked at is the difference in manure composition between the control and case section per farm. Finally, the 'average' compound of the manure is also shown. It should be noted that in the freely accessible literature, there are hardly any publications available about the composition of untreated manure. No information about the composition of the manure is included in any of the reports found about the ammonia emission reduction of other systems. There is also no information found about the spread in composition of untreated fattening pig manure.

Table 4.2 Comparison of the composition of the manure in the control and case section and the average composition of thin fattening pig manure [(1)].

Manure composition		Van der Beek		Van de Brandhof		Average
		control	case	control	case	composition
Dry matter	[g DM/kg]	121	94	132	132	93
Raw ash	[g RAS/kg]	32	23	27	28	
Organic matter	[g OM/kg]	90	71	105	104	43
Nitrogen	[g N/kg]	9	8	9	9	7
C/N ratio	[-]	4	4	5	5	
Nitrogen-ammonia	[g N-NH_3/kg]	5	4	5	5	
Organic nitrogen	[g org-N/kg]	4	3	4	4	3
Phosphorous	[g P/kg]	3	2	2	2	
Phosphate	[g P_2O_5/kg]	7	5	5	5	5
Potassium	[g K/kg]	6	5	5	5	
Potassium oxide	[g K_2O/kg]	7	5	6	7	6
Magnesium	[g Mg/kg]	2	1	1	1	
Magnesia	[g MgO/kg]	3	2	2	2	2
Sodium	[g Na/kg]	1	1	1	1	
Natron	[g Na_2O/kg]	2	1	2	2	1

The following conclusions are drawn from the table:

- The dry matter content and the content of organic matter are lower at Van de Beek than at Van de Brandhof for both the control and case section.
- The dry matter content and the content of organic matter are lower at Van de Beek in the control section than at Van de Brandhof, while these are the same in both sections at Van de Brandhof.
- All manure parameters, with the exception of the C/N ratio and the nitrogen-ammonia, are 15-25% higher in the control section at Van de Beek than in the case section. At Van de Brandhof the value of all manure parameters are equal in both sections, including the C/N ratio.
- Due to the low ammonia emission at Van de Brandhof there are small differences in absolute amounts in the manure and differences are difficult to demonstrate.

The causes of the above differences are discussed below. The effect of the differences observed on the measured ammonia emission reduction is also discussed.

<u>Manure dry matter content</u>

The higher dry matter content of the manure at Van de Brandhof may be caused by the effect of the newness of the stall at Van de Brandhof. New concrete has a hygroscopic effect and sucks moisture out of the manure. The measurements are carried out after the manure round in the stall. It is unknown how long the hygroscopic effect of new concrete persists.

Differences between dry matter content between case and control

At Van de Beek a clear reduction of the dry matter and organic matter content is found in the case section in relation to the control section. At Van de Brandhof no differences are found.
It has been previously reported that the agronomic conditions at Van de Beek are the same for the case and control section. The difference in dry matter cannot be explained by a difference in drinking water supplies. The reduction in the dry matter content and organic matter content in the case section at Van de Beek is in line with the operating mechanism described in paragraph 2.3.
This raises the question as to why this reduction does not occur at Van de Brandhof. A possible explanation is the above-mentioned hygroscopic effect of the new concrete at Van de Brandhof. From table 4.2 it appears that the dry matter content at Van de Brandhof and to a much lesser extent, at Van de Beek, has clearly increased in relation to the mean. Owing to the moisture suction effect of the concrete, the dry matter content reduction effect of the manure treatment installation may have perished at Van de Brandhof.

Differences in other manure parameters

The other manure parameters differ little, with the exception of the C/N ratio and the nitrogen-ammonia. This applies both to the average composition and for differences between the control and case per farm and differences between the farms.
This is consistent with the operating mechanism described in paragraph 2.3. Due to the addition of the mineral mixture, dry matter and organic matter are broken down and the ammonia-nitrogen is bound in the manure. In other words, the C/N Ratio in the treated manure decreases compared with the untreated manure. This is what can be seen from the data in Table 4.2.

The differences in the manure composition between the control and case section at Van de Beek are not the same for all manure parameters. With magnesium and sodium, the difference is not statistically significant. This means that the differences could not have been caused by diluting the manure, because then all of the parameters in the case section should decrease equally relative to the control section. Also, given the fluctuating dry matter content, there can be no question of a structural leakage of drinking water at Van de Beek.

In summary, it is concluded that the differences in the composition of the manure at Van de Beek correspond to the described operating mechanism of the installation for manure treatment. At Van de Brandhof, the hygroscopic effect of the relatively new concrete has a large influence on the dry matter content of the manure. This is a possible explanation that the composition of the manure in the case and control section at Van de Brandhof does not differ from each other.

sub 4. Difference in ammonia reduction between the farms

A clear difference in the ammonia emission reduction at both farms emerged from the measurements. A mean reduction of 35% was measured at Van de Beek in Putten and 17% at Van de Brandhof in Ede. From the foregoing it may be concluded that the difference in effect can be attributed to the influence of the new concrete on the manure composition at Van de Brandhof in Ede. In the reference section at Van de Brandhof, an average ammonia emission factor was measured of 1.8 kg N per animal place per year, while for this type of stall in the RAV list, there is an emission factor of 3 kg N per animal place per year. The ammonia emission occurs in the stall and in the drain. The manure-processing installation particularly influences the drain emission. If, as is the case at Van de Brandhof, the overall ammonia emission is significantly lowered, lowering the drain emission by means of the manure-processing installation only has a limited impact on the total emissions from the stall.

sub 5. Relationship of ammonia reduction and operating mechanism

In addition to the manure-processing installation, the measured emission reduction may be caused by other factors such as the measurement set-up. However, above it is shown that the measured ammonia emission reduction is not caused by systematic differences between case and control section.

Differences in the manure composition between the control and case section may also explain part of the emission reduction. At Van de Brandhof no differences in manure composition occurred. Nevertheless an ammonia emission reduction of 17% was measured at this farm.
It is possible that the emission reduction may be explained purely by dilution of the manure. At Van de Beek there is a clear difference in dry matter between control and case found as well as an ammonia emission reduction of 35%. Dilution of manure is a method included on the stoppers list for ammonia emission reduction(2). By diluting the manure an ammonia emission reduction of 45% may be achieved. Using the manure-processing installation, minute quantities of moisture are added to the manure, i.e. 15.3 ml per day or rather 0.07 litres per animal place per year. According to the Infomil publication(3) at least 1000 litres of water per animal place per year must be added to the manure. Moreover the dry material content may not exceed 70 g/Kg. Both at Van de Beek and at Van de Brandhof this content is significantly higher for the untreated and treated manure. The measured ammonia emission reduction also cannot be ascribed to the dilution of the manure.

From the results of the analysis it appears that the installation changes the composition of the manure. According to the operating mechanism described (paragraph 2.3) the gas formation in the manure is reduced, which in line is with the reduced methane emission. At Van de Beek nitrogen is mainly bound in NH_3 and this has not resulted in reduced nitrous oxide emissions. At Van de Brandhof the ammonia emission reduction is smaller than at Van de Beek, but a greater nitrous oxide emission reduction of 20% is measured there.

sub 6. Reduction of other gases

The results of the methane and nitrous oxide measurements are listed in paragraph 3.5 and in appendix E. This shows that at Van de Beek, across the measurements on average there is no difference measured in methane and nitrous oxide emissions through use of the manure-processing installation. However, it can be noted that in four of the six measurements, a methane emission reduction by the manure-processing installation was measured. Measurement 4, wherein a large negative methane emission reduction is demonstrated due to the manure-processing installation, may be statistically considered as an outlier. If this measurement is disregarded, a methane emission reduction of 16% is measured at Van de Beek.

At Van de Brandhof, in the stall with the manure-processing installation, a 35% reduction in methane emissions and a 20% lower nitrous oxide emission was measured with respect to the reference unit.

A mean methane emission reduction of 20% and a nitrous oxide emission reduction of 8% were measured at both farms.

sub 7. Recommendations

From the foregoing it follows that the measured emission reduction of ammonia, methane and nitrous oxide must be attributed to the influence of the manure-processing installation. The manner in which the manure-processing installation changes the composition of the manure and the factors that are of influence are not known at this time. Further investigation should scientifically substantiate the operating mechanism, for example by means of mapping out the mass balance of the treated manure. This can be done by carrying out laboratory tests.

5. CONCLUSIONS

1. At the two farms, two measurements were carried out in the summer, two in spring/autumn and two in the winter. In respect of the growth stage, the measurements conducted at the two locations were reasonably distributed across the seasons. There was also a small acceptable difference in weight of the animals in the case and control section of both farms. This fulfilled the organisational requirements for conducting the investigation.

2. A clear difference in the ammonia emission reduction at both farms emerged from the measurements. A mean reduction of 35% was measured at Van de Beek in Putten and 17% at Van de Brandhof in Ede. With this, a mean ammonia emission reduction of 26% was demonstrated.

3. The difference in the measured reduction in ammonia emission at Van de Beek and Van de Brandhof can be attributed to the influence of the new concrete on the manure composition at Van de Brandhof in Ede. Moreover, a low ammonia emission factor was involved at Van de Brandhof. As a result, lowering the drain emission by means of the installation of manure processing only had a limited impact on the total emissions from the stall.

4. In the study various factors which may have affected the measured ammonia emission reduction were investigated. This concerns:
   - the difference in weight of the animals between the case and control unit;
   - the difference in ventilation flow rate of the case and control unit;
   - the difference in manure composition between the case and control unit;
   - the dilution of the manure due to the installation for processing.

   Analysis of the measurement results shows that the measured ammonia emission reduction cannot be ascribed to the above-mentioned factors.

5. At Van de Beek a methane emission reduction of 16% was measured. No nitrous oxide (laughing gas) emission reduction was measured. At Van de Brandhof, in the stall with the manure-processing installation, a 35% reduction in methane emissions and a 20% lower nitrous oxide emission was measured with respect to the reference unit. A mean methane emission reduction of 20% and a nitrous oxide emission reduction of 8% were measured at both farms.

6. The measured emission reduction of ammonia, methane and nitrous oxide must be attributed to the influence of the manure-processing installation. The manner in which the manure-processing installation changes the composition of the manure and which factors are of influence here are not completely known at this time. Further investigation should scientifically substantiate the operating mechanism, for example by means of mapping out the mass balance of the treated manure. This can be done by carrying out laboratory tests.

6. LITERATURE

1. **voedergewassen, Commissie bemesting grasland en.** *Mestsamenstelling in Adviesbasis Bemesting Grasland en Voedergewassen.* 2012. Rapport 1.
2. **Ministerie van Infrastructuur en milieu.** *Lijst alternatieve maatregelen voor stoppende bedrijven, Actieplan ammoniak veehouderij.* 19 december 2012.
3. **Infomil.** Ammoniak en agrarische bedrijven - Tabel met maatregelen. *Infomil.* [Online] [Citaat van:] http://www.infomil.nl/onderwerpen/landbouw-tuinbouw/ammoniak-en/actieplan-ammoniak/stoppersmaatregelen/tabel-maatregelen/. AAV 2012.07.

Translation of above:

1. **Commission on grassland fertilisation and feed crops.** *Manure composition in Basic Advice on Fertilising Grassland and Feed Crops.* 2012. Report 1.
2. **Ministry of Infrastructure and Environment.** *List of alternative measures for farms stopping, Ammonia action plan for livestock farms.* 19 December 2012)
3. **Infomil.** Ammonia and agricultural companies – Table with measures. *Infomil.* [Online] [Quote from:] http://www.infomil.nl/onderwerpen/landbouw-tuinbouw/ammoniak-en/actieplan-ammoniak/stoppersmaatregelen/tabel-maatregelen/. = www.infomil.nl/subjects/arable farming-horticulture/ammonia and/ammonia action plan/stoppers measures/table of measures/. AAV 2012.07.

APPENDICES

A. Manure treatment installation

Operating principle

The manure-processing installation reduces ammonia emission by means of spraying an amount of natural mineral mixture on the slurry every day. By repeating this daily, the process in the manure changes. As a result, the formation of gas in the manure stops and the emissions, including ammonia, are significantly reduced. The nitrogen remains in the manure and later becomes available for plants.
The natural mineral mixture consists of natural minerals, mineral oxygen and a number of specific bacteria.
The natural mineral mixture strongly inhibits the methanogenic phase (gas production). By stopping the anaerobic process in the manure and starting an aerobic process, a reduction of ammonia emissions takes place.

The technical design of the system

Control
The control ensures the time of administration and the duration of the administration of the AgriMestMix. Both the magnetic valves and the volume pump are controlled for this.

Magnetic valves
The valve is opened and closed based on an electric signal. One section is connected per magnetic valve.

Volume pump
The volume pump takes care of adding the AgriMestMix to the air current. The volume pump is adjustable from 0% to 100%.

Air compressor
The air compressor provides a continuous pressure of at least 3 bar on the system.

AgriMestMix storage vessel.
The AgriMestMix is sucked up from the storage vessel.

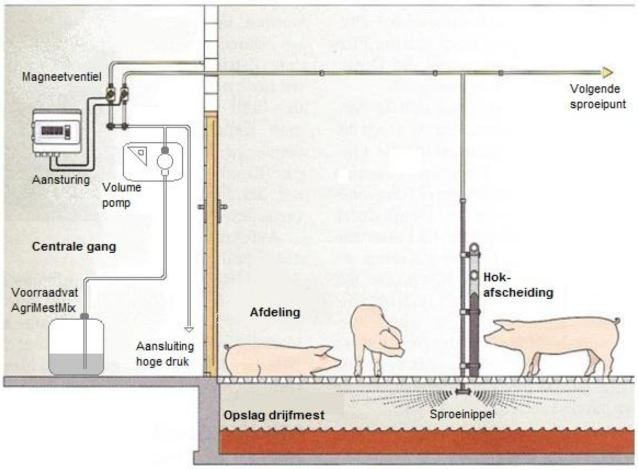
Spray nipples
The spray nipples at the front and the back of the stall should be constructed unilaterally. The spray nipple in the middle of the section is constructed bilaterally.

Control
Every week the control display screen should be checked for error messages.
Each year the installation is checked for operation by the supplier/expert party.

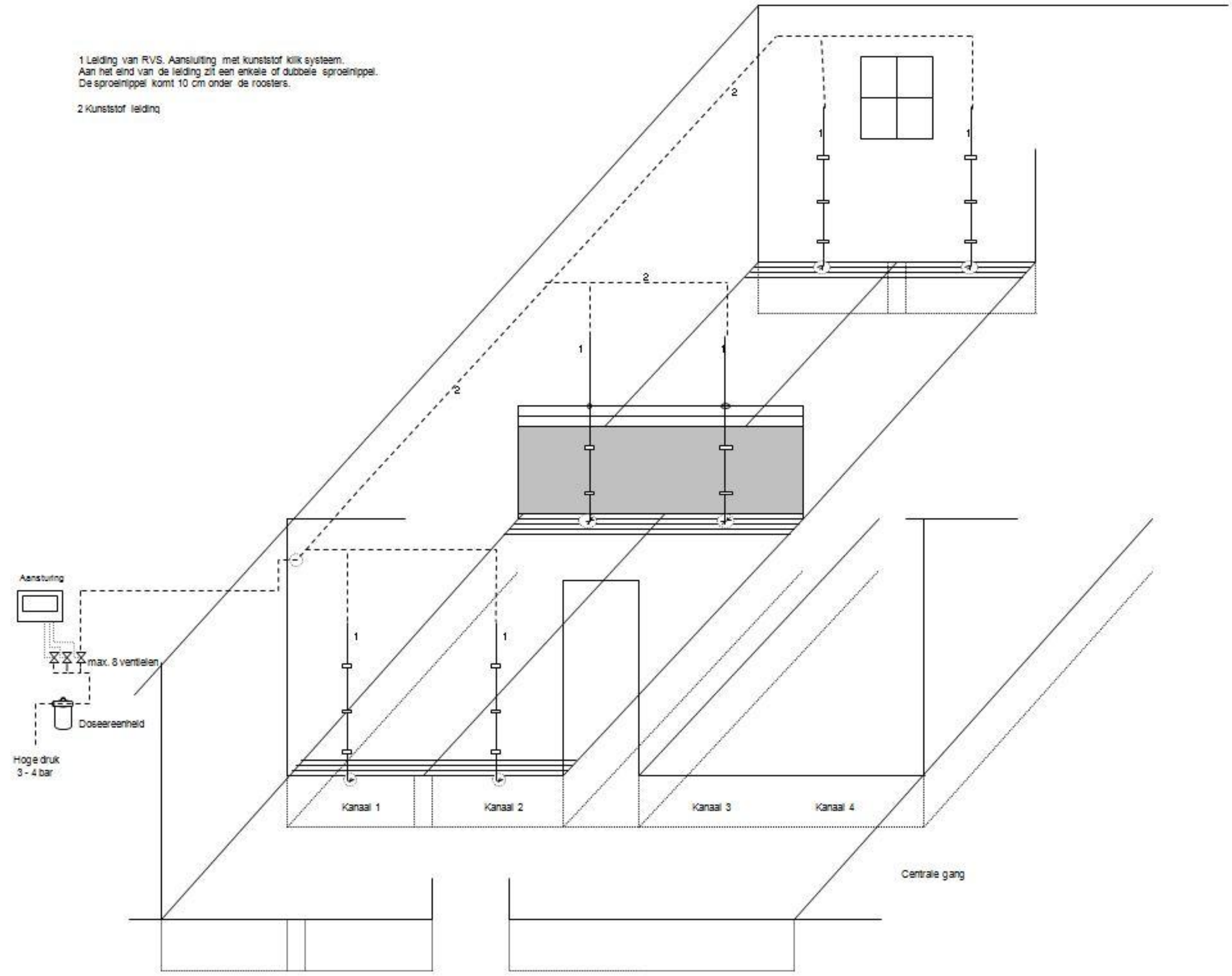
Maintenance
The system is maintenance-free.

Registration
The registration is determined in consultation with the Ministry.
The read-out of the amount of AgriMestMix used is relevant for the system. This can be done via:

a. the recording of the amount by the volumenometer;
b. the recording of the amount that is sucked up from the volume vessel;
c. the certifying of the manure by the supplier/expert party. For this, the installation is regularly checked by the supplier/expert party and the AgriMestMix stock is replenished. In this method the manure is also certified and offered to the market as special fertiliser. Tests show that the treated manure is beneficial to soil life, gives a better utilisation of the nitrogen, and provides better development of the root system. The latter gives a higher organic matter content in the soil.



Magneetventiel = Magnetic valve
Aansturing = Control
Volume pomp = Volume pump
Centrale gang = Central aisle
Voorraadvat AgriMestMix = AgriMestMix storage vessel
Aansluiting hoge druk = High-pressure connection
Volgende sproeipunt = Following spraying point
Afdeling = Section
Opslag Drijfmest = Manure slurry storage
Hokafscheiding = Pen partition
Sproeinippel = Spray nipple



1 leiding van RVS. Aansluiting met kunststof Kliksysteem.
Aan het eind van de leiding zit een enkele of dubbele sproeinippel.
De sproeinippel komt 10 cm onder de roosters.
=
1 Stainless steel piping. Connections with plastic click system.
At the end of the pipe there is a single or double spray nipple.
The spray nipple is 10 cm below the grids.

2 Kunststof leiding = 2 Plastic piping

Aansturing = Control
Max. 8 ventielen = maximum of 8 valves
Doseereenheid = Dosing unit
Hoge druk 3-4 bar = High pressure 3-4 bar

Kanaal 1 = Duct 1
Kanaal 2 = Duct 2
Kanaal 3 = Duct 3
Kanaal 4 = Duct 4

Centrale gang = Central aisle

Manure-processing installation at the Van de Beek farm in Putten.
Test set-up

The diagram below gives an overview of the stall of Van de Beek in Putten

Unit 1	Unit 2	Unit 3	Unit 4	Unit 5

The manure-processing installation is installed in section 5. Sections 3 and 5 are compared with each other.

Eighty pigs are held per section. When entering the stall the pigs weigh approximately 40 kg. Upon leaving the stall the pigs weigh an estimated 110 kg. Four spray valves are mounted in a section, two on each grid floor. A spray valve that sprays in one direction has been placed on the wall side at the entrance. A spray valve that sprays in two directions has been placed on the third pen partition.

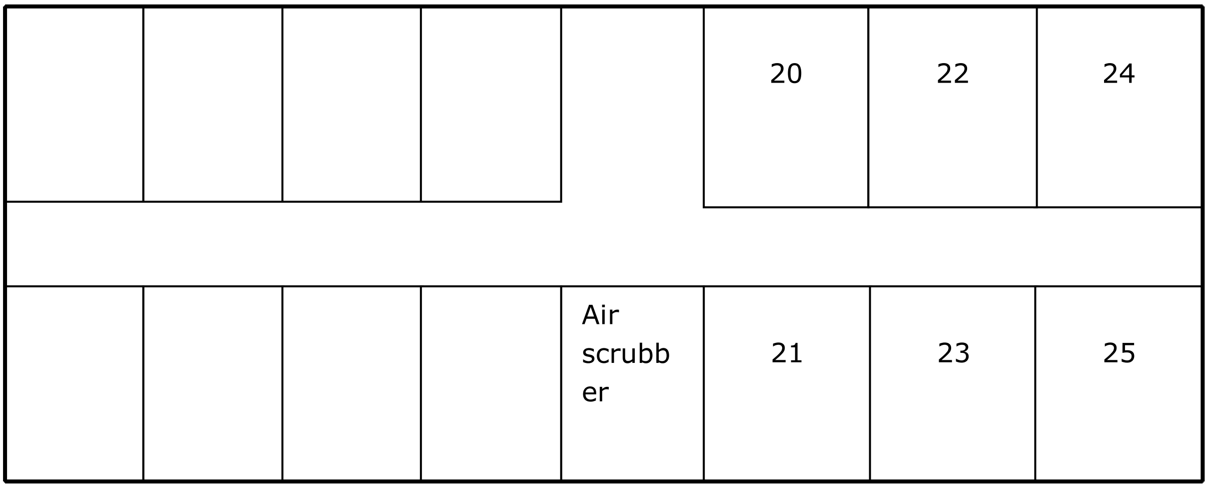
From 27 June 77 ml (one part of AgriMestMix en four parts of water) is dosed every day.

On 17 August 2011 the administering of diluted AgriMestMix was switched over to undiluted AgriMestMix. The dosing amounted to 15.3 ml AgriMestMix per day.

On the measurement days, Buro Blauw checked whether the manure-processing installation was operating.

Manure-processing installation at the van den Brandhof farm in Ede.
Test set-up

The diagram below gives an overview of the stall of Van de Brandhof in Ede.



The manure-processing installation is installed in sections 20 and 21. Sections 21 and 23 are compared with each other.

Ninety-six pigs are held per section. When entering the stall the pigs weigh approximately 25 kg. Upon leaving the stall the pigs weigh an estimated 110 kg. Four spray valves are mounted in a section, two on each grid floor. A spray valve that sprays in one direction has been placed on the wall side at the entrance. A spray valve that sprays in two directions has been placed on the third pen partition.

From 11 June 80 ml (one part of AgriMestMix en four parts of water) is dosed every day.

On 17 August 2011 the administering of diluted AgriMestMix was switched over to undiluted AgriMestMix. The dosing amounted to 15.3 ml AgriMestMix per day.

On the measurement days, Buro Blauw checked whether the manure-processing installation was operating.

B. Flow rate measurement method according to ISO 10780

The flow rate measurements of the forced emissions are carried as described in the ISO 10780 (1994) standard, *Stationary source emissions – Measurement of velocity and volume flow rate of gas streams in ducts.* The air velocity is measured with a pitot tube or vane anemometer, the temperature with a K-type sensor, the differential pressure with a pressure sensor, moisture with a capacitive sensor or with the wet bulb/dry bulb method, and the pressure method with a precision barometer. Table C.1 gives an overview of the flow rate measurement devices used.

Table B.1. Measuring devices for the measurement of the exhaust gas characteristics.

Quantity	Dimension	Device	Measurement range	Accuracy
Air velocity	hPa	L or S type pitot tube with pressure sensor	0-10 hPa	± 0.03 hPa
Moisture content	% g/m^3	Capacitive sensor K-type thermocouples	0…100% RV -40…260 ^oC	± 2% RV (2…98% RV) ± 1.1 ^oC
Temperature	^oC	K-type thermocouple	-40…260 ^oC	± 1.1 ^oC
Pressure difference	hPa	Pressure sensor	± 100 hPa	± 0.1 hPa (0…20 hPa)
Absolute pressure	hPa	Precision barometer	908…1062 hPa	± 0.8 hPa

According to the ISO 10780 standard, a measurement uncertainty of less than 5% can be achieved if all conditions in the standard are met. In practice, the most ideal conditions are often lacking whereby a measurement uncertainty of 10% - 20% is applied.

In order to determine whether the measurement surface meets the conditions laid down in ISO 10780 for flow rate measurements, temperature and air velocity are measurements are conducted prior to the measurements. The criteria for an undisturbed profile are given in table B.2.

Table B.2 Criteria for measurement surface assessment of flow rate measurements

Parameter	Criterion
Gas velocity	> 3 m/s
Gas stream direction of duct	< 15^o w.r.t. longitudinal axis of duct
Pressure difference fluctuations per measuring point	≤ 24 Pa
Dynamic and static pressure	P > 0,5 mm H_2O (P > 5 Pa)
Gas velocity distribution	Deviation of mean velocity per axis < 5% of total mean
Direction	No ‘negative’ air velocities
Temperature deviations	≤ 5% of the mean

C. Ammonia measuring method

The concentration of ammonia (calculated as ammonia) in the exhaust gases is measured in accordance with NEN 2826, 1999*: Air quality. Discharge from stationary point sources. Sampling and determination of the content of gaseous ammonia.*

A heated sampling pipe is used with hot exhaust gasses for the sampling of ammonia. The sample of air is isokinetically sucked in and first passed through a filter holder and then, via the sampling pipe to three cooled washing bottles, filled with 0.05 M H_2SO_4 and by being passed through a drying column filled with silica gel. A sampling pump sucks the sampled air through the washing bottles and the drying column at approximately 1 litre per minute. After this the air is passed through a calibrated dry gas meter. Figure C.1 shows an schematic overview of the measuring set-up. After completion of the measurements, the sampling pipes are rinsed out with 0,05 M H_2SO_4 and the rinsing sample is added to the first washing bottle.

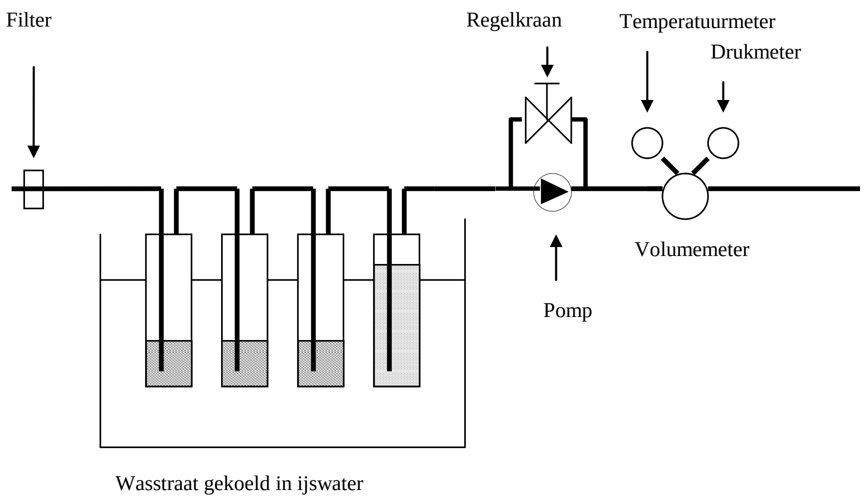


Figure C.1 shows a schematic overview of the measuring set-up for ammonia

Filter = Filter
Regelkraan = Regulating valve
Temperatuurmeter = Thermometer
Drukmeter = Pressure meter
Pomp = Pump
Volumemeter = Volumenometer
Wasstraat gekoeld in ijswater = Washing system cooled in ice water

After completion of the measurement the contents of the first and the second washing bottle are added together. The contents of the third washing bottles are submitted separately to the laboratory for analysis. If the concentration in this sample is higher than 5% of the concentration in the first two washing bottles, then a breakthrough is involved and the measurement is rejected.

The impinger liquids are analysed by the accredited AL-West laboratory in Deventer.

2.2.2 Technical data of Van de Beek in Putten

A photo of the measurement situation at Van de Beek in Putten is shown in figure D1.1.

Figure D.1.1 Photo of the Van de Beek stall in Putten

Stall dimensions
The stall of Van de Beek consists of five sections. Each section is 6.55 metres wide and 12.60 metres deep. Each section consists of 2*4 pens with a centre aisle. The entire stall is 35 metres long and 14.7 metres wide.

Manure area in the manure pit
The emitting manure area is 35 m2 per section.
The pit under the fattening berths is closed off.

Ventilation setting
Based on one temperature thermostat per section.

Temperature setting
The temperature is set to 22 degrees Celsius on the thermostat.

Heating
Ventilation system sucks out hot air between roofing sheets and insulation sheets.

Feeding system and feed types
Dry feed troughs that are filled daily using the feed cart.
Feed types are growth and fattening chunks

Feed supply, feeding times
The animals receive a daily dose once per day.

Drinking system
One drinking nipple in each dry feed trough.

Lighting regime
The lights are on for 9.5 hours per day.

The technical data of unit 3 are given in table D.1.1.

Measured round	**1**	**2**	**3**	**4**
Date of stocking	8-4-2011	8-7-2011	14-9-2011	21-12-2011
Number of pigs in	80	80	80	80
Length of production round (days)	139	130	139	113
Delivery weight (kg)	113	114	121	117
Number of animals dropped out	4	1	1	0
Degree of occupancy (/m^2/animal)	0.9	0.9	0.9	0.9
Number of animals per pen	10	10	10	10
Growth per day (g)	779	788	749	796
Feed composition g RE/EW	160/105	160/105	160/105	160/105
Drop-out rate (%)	5	1.25	1.25	0%
Water-feed ratio	?	?	?	?
Total amount of feed provided	23,962	26,185	29,257	19,851
Total amount of water used	Ad lib	Ad lib	Ad lib	Ad lib
veterinary treatment at herd/litter level	OTC	OTC	OTC	OTC
estimate of the amount of cleaning water used including the residue in the manure drain.	?	?	?	?
times of removal of manure (slurry) from the manure drain	None	None	None	None

The technical data of unit 5 are given in table D.1.2.

Measured round	**1**	**2**	**3**	**4**

Date of stocking	22-4-2011	29-6-2011	29-9-2011	7-12-2011
Number of pigs in	80	80	80	80
Length of production round (days)	125	139	124	118
Delivery weight (kg)	111	117	120	113
Number of animals dropped out	2	1	1	0
Degree of occupancy (/m^2/animal)	0.9	0.9	0.9	0.9
Number of animals per pen	10	10	10	10
Growth per day (g)	797	792	777	726
Feed composition g RE/EW	160/105	160/105	160/105	160/105
Drop-out rate (%)	2.5	1.25	1.25	0
Water-feed ratio	?	?	?	?
Total amount of feed provided	24,721	27,391	24,235	19,079
Total amount of water used	Ad lib	Ad lib	Ad lib	Ad lib
veterinary treatment at herd/litter level	OTC	OTC	OTC	OTC
estimate of the amount of cleaning water used including the residue in the manure drain.	?	?	?	?
times of removal of manure (slurry) from the manure drain	None	None	None	None

D.2 Technical data of Van de Brandhof in Ede

Dimensions
Section dimension 9 by 10 metres, four pens on both sides with a feeding aisle in the centre; pens 2.5 wide and 4 metres deep.

Manure area
Grid surface 2 * 10 times 2 is 40 square metres per section; is also manure area

Ventilation

	Temperature	minimum Ventilation	,maximum ventilation
Day 0	25	5 %	35%
Day 7	24	5%	50%
Day 50	23	5%	75%
Day 99	21	5%	85%

Floor heating
Turns on when the temperature drops below the setting

Feed system
Pulp/mash is fed three times daily

Feeding type
Two phases: Starting and fattening pigs feed

Feed supply
The pigs are limitedly fed at 6 a.m., 1 p.m. and 6 p.m. according to feeding schedule

Drinking system
Drinking nipple

Light
Via the windows, 40 lux. Natural lighting.

The technical data of unit 23 are given in table D.2.1.

Measured round	**1**	**2**
Date of stocking	5-7-2011	2-11-2011
Number of pigs in	96	96
Length of production round (days)	118	124
Delivery weight (slaughtered kg)	92.06	92.1
Number of animals dropped out	1	3
Degree of occupancy (/m^2/animal)	0.8	0.8
Number of animals per pen	12	12
Growth per day (g)	830	777
Feed composition g RE/EW	170/115	170/115
Drop-out rate (%)	1	3
Water-feed ratio	25% ds	25% ds
Total amount of feed provided	21,601	22,684
Total amount of water used	57,027	59,886
veterinary treatment at herd/litter level	-	-
estimate of the amount of cleaning water used including the residue in the manure drain.	0	0
times of removal of manure (slurry) from the manure drain	Aug.	April

The technical data of unit 21 are given in table D.2.2.

Measured round	**1**	**2**
Date of stocking	13-7-2011	9-11-2011
Number of pigs in	96	96
Length of production round (days)	118	112
Delivery weight (slaughtered kg)	93.7	89.1
Number of animals dropped out	1	4
Degree of occupancy (/m^2/animal)	0.8	0.8
Number of animals per pen	12	12
Growth per day (g)	834	813
Feed composition g RE/EW	170/115	170/115
Drop-out rate (%)	1	4
Water-feed ratio	25% ds	25% ds
Total amount of feed provided	21,659	20,735
Total amount of water used	57,180	54,740
veterinary treatment at herd/litter level	-	-
estimate of the amount of cleaning water used including the residue in the manure drain.	0	0
times of removal of manure (slurry) from the manure drain	Aug.	Feb.

E.1 Detailed measurement data Van de Beek, Putten

Meting		1	1	2	2	3	3
		Onbehandeld	Behandeld	Onbehandeld	Behandeld	Onbehandeld	Behandeld
		Lokaal 3	Lokaal 5	Lokaal 3	Lokaal 5	Lokaal 3	Lokaal 5
Ammoniak							
Concentratie	[mg/m$_o^3$]	30,7	32,7	26,7	20,1	31,9	22,5
Debiet	[m$_o^3$/uur]	2833	1876	2049	1760	2251	1936
Datum	[dd-mm-jjj]	26-07-11	26-07-11	12-09-11	12-09-11	17-10-11	17-10-11
Deel van cyclus	[-]	4	4	2	2	5	5
Emissie	[g/uur]	87	61	55	35	72	43
Aantal dieren	[-]	80	80	80	80	80	80
Emissie per dier	[g/dier/uur]	1,09	0,77	0,68	0,44	0,90	0,54
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	8597	6051	5398	3483	7087	4290
Emissie per dier per jaar	[kg/dier/jaar]	8,6	6,1	5,4	3,5	7,1	4,3
Rendement	**[%]**		**30%**		**35%**		**39%**
Temperatuur afgas	[°C]	26,4	28,7	27,6	27,6	25,9	25,4
Relatieve luchtvochtigheid afgas	[%]	65,3	71,2	69,4	67,6	73,4	64,0
Droge stof	[g DS/kg]	123	95	133	98	123	70
Ruwe as	[g RAS/kg]	31	20	34	23	33	21
Organische stof	[g OS/kg]	92	75	99	75	90	49
Stikstof	[g N/kg]	8,7	7,6	9,1	7,4	9,0	7,0
C/N ratio	[-]	5	4	5	5	4	3
Stikstof-ammoniak	[g N-NH_3/kg]	4,9	4,2	4,6	4,1	5,1	4,7
Stikstof-organisch	[g N-org/kg]	3,8	3,4	4,5	3,3	3,9	2,3
Fosfor	[g P/kg]	2,9	2,3	3,3	2,1	3,0	1,7
Fosfaat	[g P_2O_5/kg]	6,6	5,4	7,6	4,7	6,9	3,9
Kalium	[g K/kg]	6,0	4,7	6,2	4,8	6,1	4,6
Kali	[g K_2O/kg]	7,2	5,7	7,5	5,8	7,3	5,5
Magnesium	[g Mg/kg]	1,1	1,3	2,0	1,3	2,0	1,1
Magnesia	[g MgO/kg]	1,8	2,2	3,3	2,2	3,3	1,8
Natrium	[g Na/kg]	0,7	0,9	1,4	1,1	1,4	1,2
Natron	[g Na_2O/kg]	0,9	1,2	1,9	1,5	1,9	1,6
pH		8,0	7,8	8,0	7,8	8,1	7,8
Methaan	[ppm]	103	177	147	166	155	141
Concentratie	[mg/m$_0^3$]	74	127	105	119	111	101
Debiet	[m$_o^3$/uur]	2833	1876	2049	1760	2251	1936
Emissie	[g/uur]	209	238	216	209	250	195
Aantal dieren	[-]	80	80	80	80	80	80
Emissie per dier	[g/dier/uur]	3	3	3	3	3	2
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	20624	23471	21290	20649	24660	19293
Emissie per dier per jaar	**[kg/dier/jaar]**	**21**	**23**	**21**	**21**	**25**	**19**
Lachgas	[ppm]	0,311	0,448	0,345	0,408	0,482	0,540
Concentratie	[mg/m$_0^3$]	0,61	0,88	0,68	0,80	0,95	1,06
Debiet	[m$_o^3$/uur]	2833	1876	2049	1760	2251	1936
Emissie	[g/uur]	1,73	1,65	1,39	1,41	2,13	2,05
Aantal dieren	[-]	80	80	80	80	80	80
Emissie per dier	[g/dier/uur]	0,0216	0,0206	0,0174	0,0176	0,0266	0,0257
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	170,86	163,00	137,10	139,25	210,40	202,73
Emissie per dier per jaar	**[kg/dier/jaar]**	**0,171**	**0,163**	**0,137**	**0,139**	**0,210**	**0,203**

Measurement	1 Untreated Unit 3	1 Treated Unit 5	2 Untreated Unit 3	2 Treated Unit 5	3 Untreated Unit 3	3 Treated Unit 5
Ammonia						
Concentration [mg/ m_0^3]	30.7	32.7	26.7	20.1	31.9	22.5
Flow rate [m_0^3/hr]	2833	1876	2049	1760	2251	1936
Date [dd-mm-yyyy]	26-07-11	26-07-11	12-09-11	12-09-11	17-10-11	17-10-11
Part of cycle [-]	4	4	2	2	5	5
Emission [g/hr]	87	61	55	35	72	43
No. of animals [-]	80	80	80	80	80	80
Emission per animal [g/animal/hr]	1.09	0.77	0.68	0.44	0.90	0.54
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	8597	6051	5398	3483	7087	4290
Emission per animal per year [kg/animal/year]	8.6	6.1	5.4	3.5	7.1	4.3
Efficiency [%]		**30%**		**35%**		**39%**
Exhaust gas temp. [°C]	26.4	28.7	27.6	27.6	25.9	25.4
Relative air humidity exhaust gas [%]	65.3	71.2	69.4	67.6	73.4	64.0
Dry matter [g DM/kg]	123	95	133	98	123	70
Raw ash [g RAS/kg]	31	20	34	23	33	21
Organic matter [g OM/kg]	92	75	99	75	90	49
Nitrogen [g N/kg]	8.7	7.6	9.1	7.4	9.0	7.0
C/N ratio [-]	5	4	5	5	4	3
Nitrogen-ammonia [g N-NH_3/kg]	4.9	4.2	4.6	4.1	5.1	4.7
Organic nitrogen [g N-org/kg]	3.8	3.4	4.5	3.3	3.9	2.3
Phosphorus [g P/kg]	2.9	2.3	3.3	2.1	3.0	1.7
Phosphate [g P_2O_5kg]	6.6	5.4	7.6	4.7	6.9	3.9
Potassium [g K/kg]	6.0	4.7	6.2	4.8	6.1	4.6
Potassium oxide [g K_2O/kg]	7.2	5.7	7.5	5.8	7.3	5.5
Magnesium [g Mg/kg]	1.1	1.3	2.0	1.3	2.0	1.1
Magnesia [g MgO/kg]	1.8	2.2	3.3	2.2	3.3	1.8
Sodium [g Na/kg]	0.7	0.9	1.4	1.1	1.4	1.2
Natron [g Na_2O/kg]	0.9	1.2	1.9	1.5	1.9	1.6
pH	8.0	7.8	8.0	7.8	8.1	7.8
Methane [ppm]	103	177	147	166	155	141
Concentration [mg/ m_0^3]	74	127	105	119	111	101
Flow rate [m_0^3/hr]	2833	1876	2049	1760	2251	1936
Emission [g/hr]	209	238	216	209	250	195
No. of animals [-]	80	80	80	80	80	80

Emission per animal [g/animal/hr]	3	3	3	3	3	2
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	20624	23471	21290	20649	24660	19293
Emission per animal per year [kg/animal/year]	**21**	**23**	**21**	**21**	**25**	**19**
Nitrous oxide [ppm]	0.311	0.448	0.345	0.408	0.482	0.540
Concentration [mg/ m_0^3]	0.61	0.88	0.68	0.80	0.95	1.06
Flow rate [m_0^3/hr]	2833	1876	2049	1760	2251	1936
Emission [g/hr]	1.73	1.65	1.39	1.41	2.13	2.05
No. of animals [-]	80	80	80	80	80	80
Emission per animal [g/animal/hr]	0.0216	0.0206	0.0174	0.0176	0.0266	0.0257
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	170.86	163.00	137.10	139.25	210.40	202.73
Emission per animal per year [kg/animal/year]	0.171	0.163	0.137	0.139	0.210	0.203

E.1 Continuation of detailed measurement data Van de Beek, Putten

Meting		4	4	5	5	6	6
		Onbehandeld	Behandeld	Onbehandeld	Behandeld	Onbehandeld	Behandeld
		Lokaal 3	Lokaal 5	Lokaal 3	Lokaal 5	Lokaal 3	Lokaal 5
Ammoniak							
Concentratie	[mg/m$_o^3$]	26,3	22,2	34,6	26,4	21,0	13,9
Debiet	[m$_o^3$/uur]	2184	1937	1792	1768	2275	2139
Datum	[dd-mm-jjj]	23-11-11	23-11-11	3-01-12	3-01-12	5-03-12	5-03-12
Deel van cyclus	[-]	1	1	5	5	3	3
Emissie	[g/uur]	58	43	62	47	48	30
Aantal dieren	[-]	80	80	80	80	80	80
Emissie per dier	[g/dier/uur]	0,72	0,54	0,77	0,58	0,60	0,37
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	5678	4245	6113	4598	4713	2940
Emissie per dier per jaar	[kg/dier/jaar]	5,7	4,2	6,1	4,6	4,7	2,9
Rendement	**[%]**		**25%**		**25%**		**38%**
Temperatuur afgas	[°C]	25,0	24,0	24,1	23,9	21,5	21,2
Relatieve luchtvochtigheid afgas	[%]	65,6	62,5	79,0	78,4	57,2	53,6
Droge stof	[g DS/kg]	112	111	116	105	119	86
Ruwe as	[g RAS/kg]	30	27	31	25	30	22
Organische stof	[g OS/kg]	82	84	85	80	89	64
Stikstof	[g N/kg]	8,7	8,2	9,3	8,2	9,5	7,1
C/N ratio	[-]	4	5	4	4	4	4
Stikstof-ammoniak	[g N-NH_3/kg]	5,0	4,5	5,4	4,5	5,4	4,2
Stikstof-organisch	[g N-org/kg]	3,7	3,7	3,9	3,7	4,1	2,9
Fosfor	[g P/kg]	2,8	2,7	2,9	2,6	2,9	2,2
Fosfaat	[g P_2O_5/kg]	6,3	6,1	6,5	5,9	6,6	5,1
Kalium	[g K/kg]	5,7	4,7	5,6	4,4	5,6	3,8
Kali	[g K_2O/kg]	6,9	5,7	6,7	5,3	6,7	4,6
Magnesium	[g Mg/kg]	1,8	1,8	1,9	1,7	1,8	1,5
Magnesia	[g MgO/kg]	3,0	3,0	3,2	2,8	3,0	2,5
Natrium	[g Na/kg]	1,3	1,1	1,4	1,1	1,3	0,9
Natron	[g Na_2O/kg]	1,8	1,5	1,9	1,5	1,8	1,2
pH		8,0	7,8	7,8	7,7	7,9	7,7
Methaan	[ppm]	92	134	189	144	146	126
Concentratie	[mg/m$_0^3$]	66	96	135	103	105	90
Debiet	[m$_o^3$/uur]	2184	1937	1792	1768	2275	2139
Emissie	[g/uur]	144	186	242	182	238	193
Aantal dieren	[-]	80	80	80	80	80	80
Emissie per dier	[g/dier/uur]	2	2	3	2	3	2
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	14203	18341	23932	17992	23479	19049
Emissie per dier per jaar	**[kg/dier/jaar]**	**14**	**18**	**24**	**18**	**23**	**19**
Lachgas	[ppm]	0,419	0,534	0,459	0,516	0,360	0,398
Concentratie	[mg/m$_0^3$]	0,82	1,05	0,90	1,01	0,71	0,78
Debiet	[m$_o^3$/uur]	2184	1937	1792	1768	2275	2139
Emissie	[g/uur]	1,80	2,03	1,62	1,79	1,61	1,67
Aantal dieren	[-]	80	80	80	80	80	80
Emissie per dier	[g/dier/uur]	0,0225	0,0254	0,0202	0,0224	0,0201	0,0209
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	177,48	200,54	159,47	176,89	158,85	165,09
Emissie per dier per jaar	**[kg/dier/jaar]**	**0,177**	**0,201**	**0,159**	**0,177**	**0,159**	**0,165**

Measurement	4 Untreated Unit 3	4 Treated Unit 5	5 Untreated Unit 3	5 Treated Unit 5	6 Untreated Unit 3	6 Treated Unit 5
Ammonia						
Concentration [mg/ m_0^3]	26.3	22.2	34.6	26.4	21.0	13.9
Flow rate [m_0^3/hr]	2184	1937	1792	1768	2275	2139
Date [dd-mm-yyyy]	23-11-11	23-11-11	3-01-12	3-01-11	5-03-12	6-03-12
Part of cycle [-]	1	1	5	5	3	3
Emission [g/hr]	58	43	62	47	48	30
No. of animals [-]	80	80	80	80	80	80
Emission per animal [g/animal/hr]	0.72	0.54	0.77	0.58	0.60	0.37
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	5678	4245	6113	4598	4713	2940
Emission per animal per year [kg/animal/year]	5.7	4.2	6.1	4.6	4.7	2.9
Efficiency [%]		**25%**		**25%**		**38%**
Exhaust gas temp. [°C]	25.0	24.0	24.1	23.9	21.5	21.2
Exhaust gas relative air humidity [%]	65.6	62.5	79.0	78.4	57.2	53.6
Dry matter [g DM/kg]	112	111	116	105	119	86
Raw ash [g RAS/kg]	30	27	31	25	30	22
Organic matter [g OM/kg]	82	84	85	80	89	64
Nitrogen [g N/kg]	8.7	8.2	9.3	8.2	9.5	7.1
C/N ratio [-]	4	5	4	4	4	4
Nitrogen-ammonia [g N-NH_3/kg]	5.0	4.5	5.4	4.5	5.4	4.2
Organic nitrogen [g N-org/kg]	3.7	3.7	3.9	3.7	4.1	2.9
Phosphorus [g P/kg]	2.8	2.7	2.9	2.6	2.9	2.2
Phosphate [g P_2O_5kg]	6.3	6.1	6.5	5.9	6.6	5.1
Potassium [g K/kg]	5.7	4.7	5.6	4.4	5.6	3.8
Potassium oxide [g K_2O/kg]	6.9	5.7	6.7	5.3	6.7	4.6
Magnesium [g Mg/kg]	1.8	1.8	1.9	1.7	1.8	1.5
Magnesia [g MgO/kg]	3.0	3.0	3.2	2.8	3.0	2.5
Sodium [g Na/kg]	1.3	1.1	1.4	1.1	1.3	0.9
Natron [g Na_2O/kg]	1.8	1.5	1.9	1.5	1.8	1.2
pH	8.0	7.8	7.8	7.7	7.9	7.7
Methane [ppm]	92	134	189	144	146	126
Concentration [mg/ m_0^3]	66	96	135	103	105	90

Flow rate [m_0^3/hr]	2184	1937	1792	1768	2275	2139
Emission [g/hr]	144	186	242	182	238	193
No. of animals [-]	80	80	80	80	80	80
Emission per animal [g/animal/hr]	2	2	3	2	3	2
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	14203	18341	23932	17992	23479	19049
Emission per animal per year [kg/animal/year]	**14**	**18**	**24**	**18**	**23**	**19**
Nitrous oxide [ppm]	0.419	0.534	0.459	0.516	0.360	0.398
Concentration [mg/ m_0^3]	0.82	1.05	0.90	1.01	0.71	0.78
Flow rate [m_0^3/hr]	2184	1937	1792	1768	2275	2193
Emission [g/hr]	1.80	2.03	1.62	1.79	1.61	1.67
No. of animals [-]	80	80	80	80	80	80
Emission per animal [g/animal/hr]	0.0225	0.0254	0.0202	0.0224	0.0201	0.0209
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	177.48	200.54	159.47	176.89	158.85	165.09
Emission per animal per year [kg/animal/year]	**0.177**	**0.201**	**0.159**	**0.177**	**0.159**	**0.165**

E.2 Detailed measurement data Van de Brandhof, Ede

Meting		1	1	2	2	3	3
		Onbehandeld	Behandeld	Onbehandeld	Behandeld	Onbehandeld	Behandeld
		Lokaal 23	Lokaal 21	Lokaal 23	Lokaal 21	Lokaal 23	Lokaal 21
Datum	[dd-mm-jjj]	27-07-11	27-07-11	14-09-11	14-09-11	13-10-11	13-10-11
Ammoniak							
Concentratie	[mg/m_o^3]	11,0	10,6	8,9	8,9	14,2	11,9
Debiet	[m_o^3/uur]	1571	1191	2639	2063	2587	2308
Emissie	[g/uur]	17,3	12,7	23,4	18,4	36,7	27,5
Aantal dieren	[-]	96	96	96	96	96	96
Emissie per dier	[g/dier/uur]	0,18	0,13	0,24	0,19	0,38	0,29
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	1420	1043	1925	1512	3020	2266
Emissie per dier per jaar	[kg/dier/jaar]	1,4	1,0	1,9	1,5	3,0	2,3
Rendement	**[%]**		**27%**		**21%**		**25%**
Temperatuur afgas	[°C]	27,1	27,4	25,4	25,9	24,0	23,4
Relatieve luchtvochtigheid afgas	[%]	72,6	76,4	61,4	62,6	67,6	65,1
Droge stof	[g DS/kg]	125	139	136	130	130	124
Ruwe as	[g RAS/kg]	26	30	26	26	26	26
Organische stof	[g OS/kg]	99	109	110	104	104	98
Stikstof	[g N/kg]	8,1	9,0	8,8	8,5	8,6	9,6
C/N ratio	[-]	5	5	6	6	5	5
Stikstof-ammoniak	[g N-NH_3/kg]	4,7	5,0	4,6	4,3	4,8	4,9
Stikstof-organisch	[g N-org/kg]	3,4	4,0	4,2	4,2	3,8	3,7
Fosfor	[g P/kg]	2,0	2,2	1,9	2,1	2,1	2,1
Fosfaat	[g P_2O_5/kg]	4,7	5,0	4,4	4,8	4,9	4,8
Kalium	[g K/kg]	4,8	5,1	5,0	5,1	5,1	5,5
Kali	[g K_2O/kg]	5,8	6,1	6,0	6,1	6,1	6,6
Magnesium	[g Mg/kg]	1,4	1,4	1,2	1,5	1,5	1,5
Magnesia	[g MgO/kg]	2,3	2,3	2,0	2,5	2,5	2,5
Natrium	[g Na/kg]	1,0	0,9	1,2	1,1	1,2	1,2
Natron	[g Na_2O/kg]	1,3	1,2	1,6	1,5	1,6	1,6
pH		7,5	7,2	7,3	7,4	7,1	7,2
Methaan	[ppm]	17,8	14,8	15,9	15,3	21,5	24,8
Concentratie	[mg/m_o^3]	13	11	11	11	15	18
Debiet	[m_o^3/uur]	1571	1191	2639	2063	2587	2308
Emissie	[g/uur]	20	13	30	23	40	41
Aantal dieren	[-]	96	96	96	96	96	96
Emissie per dier	[g/dier/uur]	0	0	0	0	0	0
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	1647	1038	2471	1859	3276	3371
Emissie per dier per jaar	[kg/dier/jaar]	1,6	1,0	2,5	1,9	3,3	3,4
Lachgas	[ppm]	0,393	0,400	0,354	0,346	0,459	0,474
Concentratie	[mg/m_0^3]	0,77	0,79	0,70	0,68	0,90	0,93
Debiet	[m_o^3/uur]	1571	1191	2639	2063	2587	2308
Emissie	[g/uur]	1,21	0,94	1,84	1,40	2,33	2,15
Aantal dieren	[-]	96	96	96	96	96	96
Emissie per dier	[g/dier/uur]	0,0126	0,0097	0,0191	0,0146	0,0243	0,0224
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	99,79	76,96	150,97	115,33	191,92	176,78
Emissie per dier per jaar	[kg/dier/jaar]	0,100	0,077	0,151	0,115	0,192	0,177

Measurement	1 Untreated Unit 23	1 Treated Unit 21	2 Untreated Unit 23	2 Treated Unit 21	3 Untreated Unit 23	3 Treated Unit 21
Date [dd-mm-yy]	27-07-11	27-07-11	14-09-11	14-09-11	13-10-11	13-10-11
Ammonia						
Concentration [mg/ m_0^3]	11.0	10.6	8.9	8.9	14.2	11.9
Flow rate [m_0^3/hr]	1571	1191	2639	2063	2587	2308
Emission [g/hr]	17.3	12.7	23.4	18.4	36.7	27.5
No. of animals [-]	96	96	96	96	96	96
Emission per animal [g/animal/hr]	0.18	0.13	0.24	0.19	0.38	0.29
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	1420	1043	1925	1512	3020	2266
Emission per animal per year [kg/animal/year]	1.4	1.0	1.9	1.5	3.0	2.3
Efficiency [%]		**27%**		**21%**		**25%**
Exhaust gas temp. [°C]	27.1	27.4	25.4	25.9	24.0	23.4
Exhaust gas relative air humidity [%]	72.6	76.4	61.4	62.6	67.6	65.1
Dry matter [g DM/kg]	125	139	136	130	130	124
Raw ash [g RAS/kg]	26	30	26	26	26	26
Organic matter [g OM/kg]	99	109	110	104	104	98
Nitrogen [g N/kg]	8.1	9.0	8.8	8.5	8.6	9.6
C/N ratio [-]	5	5	6	6	5	5
Nitrogen-ammonia [g N-NH_3/kg]	4.7	5.0	4.6	4.3	4.8	4.9
Organic nitrogen [g N-org/kg]	3.4	4.0	4.2	4.2	3.8	3.7
Phosphorus [g P/kg]	2.0	2.2	1.9	2.1	2.1	2.1
Phosphate [g P_2O_5kg]	4.7	5.0	4.4	4.8	4.9	4.8
Potassium [g K/kg]	4.8	5.1	5.0	5.1	5.1	5.5
Potassium oxide [g K_2O/kg]	5.8	6.1	6.0	6.1	6.1	6.6
Magnesium [g Mg/kg]	1.4	1.4	1.2	1.5	1.5	1.5
Magnesia [g MgO/kg]	2.3	2.3	2.0	2.5	2.5	2.5
Sodium [g Na/kg]	1.0	0.9	1.2	1.1	1.2	1.2
Natron [g Na_2O/kg]	1.3	1.2	1.6	1.5	1.6	1.6
pH	7.5	7.2	7.3	7.4	7.1	7.2
Methane [ppm]	17.8	14.8	15.9	15.3	21.5	24.8
Concentration [mg/ m_0^3]	13	11	11	11	15	18
Flow rate [m_0^3/hr]	1571	1191	2639	2063	2587	2308
Emission [g/hr]	20	13	30	23	40	41
No. of animals [-]	96	96	96	96	96	96

Emission per animal [g/animal/hr]	0	0	0	0	0	0
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	1647	1038	2471	1859	3276	3371
Emission per animal per year [kg/animal/year]	1.6	1.0	2.5	1.9	3.3	3.4
Nitrous oxide [ppm]	0.393	0.400	0.354	0.346	0.459	0.474
Concentration [mg/ m_0^3]	0.77	0.79	0.70	0.68	0.90	0.93
Flow rate [m_0^3/hr]	1571	1191	2639	2063	2587	2308
Emission [g/hr]	1.21	0.94	1.84	1.40	2.33	2.15
No. of animals [-]	96	96	96	96	96	96
Emission per animal [g/animal/hr]	0.0126	0.0097	0.0191	0.0146	0.0243	0.0224
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	99.79	76.96	150.97	115.33	191.92	176.78
Emission per animal per year [kg/animal/year]	0.100	0.077	0.151	0.115	0.192	0.177

E.2 Continuation of detailed measurement data Van de Brandhof, Ede

Meting		4	4	5	5	6	6
		Onbehandeld	Behandeld	Onbehandeld	Behandeld	Onbehandeld	Behandeld
		Lokaal 23	Lokaal 21	Lokaal 23	Lokaal 21	Lokaal 23	Lokaal 21
Datum	[dd-mm-jjj]	7-12-11	7-12-11	5-01-12	5-01-12	10-02-12	10-02-12
Ammoniak							
Concentratie	[mg/m$_o^3$]	10,9	14,5	9,3	11,4	20,9	20,2
Debiet	[m$_o^3$/uur]	1257	875	1791	1322	1200	1097
Emissie	[g/uur]	13,7	12,7	16,7	15,1	25,0	22,2
Aantal dieren	[-]	96	96	96	96	96	96
Emissie per dier	[g/dier/uur]	0,14	0,13	0,17	0,16	0,26	0,23
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	1124	1043	1375	1240	2059	1826
Emissie per dier per jaar	[kg/dier/jaar]	1,1	1,0	1,4	1,2	2,1	1,8
Rendement	**[%]**		**7%**		**10%**		**11%**
Temperatuur afgas	[°C]	24,4	24,8	24,4	23,7	21,6	21,4
Relatieve luchtvochtigheid afgas	[%]	70,3	63,1	70,4	55,6	57,8	57,7
Droge stof	[g DS/kg]	144	127	129	130	125	141
Ruwe as	[g RAS/kg]	30	26	27	30	27	28
Organische stof	[g OS/kg]	114	101	102	100	98	113
Stikstof	[g N/kg]	8,7	8,9	8,6	8,7	9,0	9,0
C/N ratio	[-]	6	5	5	5	5	6
Stikstof-ammoniak	[g N-NH_3/kg]	4,8	5,1	4,8	4,9	4,9	4,9
Stikstof-organisch	[g N-org/kg]	3,9	3,8	3,8	3,8	4,1	4,1
Fosfor	[g P/kg]	2,4	2,2	2,3	2,3	2,4	2,5
Fosfaat	[g P_2O_5/kg]	5,5	5,1	5,2	5,3	5,6	5,7
Kalium	[g K/kg]	5,3	5,5	5,5	5,5	6,0	6,1
Kali	[g K_2O/kg]	6,4	6,6	6,6	6,6	7,2	7,3
Magnesium	[g Mg/kg]	1,6	1,4	1,5	1,6	1,3	1,4
Magnesia	[g MgO/kg]	2,7	2,3	2,5	2,7	2,2	2,3
Natrium	[g Na/kg]	1,3	1,2	1,4	1,3	1,2	1,1
Natron	[g Na_2O/kg]	1,8	1,6	1,9	1,8	1,6	1,5
pH		7,3	7,4	7,2	7,4	7,3	7,2
Methaan	[ppm]	52,6	37,0	31,1	20,9	60,6	32,0
Concentratie	[mg/m$_0^3$]	38	26	22	15	43	23
Debiet	[m$_o^3$/uur]	1257	875	1791	1322	1200	1097
Emissie	[g/uur]	47	23	40	20	52	25
Aantal dieren	[-]	96	96	96	96	96	96
Emissie per dier	[g/dier/uur]	0	0	0	0	1	0
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	3893	1908	3280	1628	4283	2068
Emissie per dier per jaar	[kg/dier/jaar]	3,9	1,9	3,3	1,6	4,3	2,1
Lachgas	[ppm]	0,536	0,480	0,507	0,532	0,416	0,424
Concentratie	[mg/m$_0^3$]	1,05	0,94	1,00	1,05	0,82	0,83
Debiet	[m$_o^3$/uur]	1257	875	1791	1322	1200	1097
Emissie	[g/uur]	1,32	0,83	1,78	1,38	0,98	0,91
Aantal dieren	[-]	96	96	96	96	96	96
Emissie per dier	[g/dier/uur]	0,0138	0,0086	0,0186	0,0144	0,0102	0,0095
Aantal dagen per jaar	[-]	329	329	329	329	329	329
Emissie per dier per jaar	[g/dier/jaar]	108,86	67,90	146,71	113,68	80,67	75,18
Emissie per dier per jaar	[kg/dier/jaar]	0,109	0,068	0,147	0,114	0,081	0,075

Measurement	4 Untreated Unit 23	4 Treated Unit 21	5 Untreated Unit 23	5 Treated Unit 21	6 Untreated Unit 23	6 Treated Unit 21
Date [dd-mm-yy]	07-12-11	07-12-11	5-01-12	5-01-12	10-02-12	10-02-12
Ammonia						
Concentration [mg/ m_0^3]	10.9	14.5	9.3	11.4	20.9	20.2
Flow rate [m_0^3/hr]	1257	875	1791	1322	1200	1097
Emission [g/hr]	13.7	12.7	16.7	15.1	25.0	22.2
No. of animals [-]	96	96	96	96	96	96
Emission per animal [g/animal/hr]	0.14	0.13	0.17	0.16	0.26	0.23
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	1124	1043	1375	1240	2059	1826
Emission per animal per year [kg/animal/year]	1.1	1.0	1.4	1.2	2.1	1.8
Efficiency [%]		**7%**		**10%**		**11%**
Exhaust gas temp. [°C]	24.4	24.8	24.4	23.7	21.6	21.4
Exhaust gas relative air humidity [%]	70.3	63.1	70.4	55.6	57.8	57.7
Dry matter [g DM/kg]	144	127	129	130	125	141
Raw ash [g RAS/kg]	30	26	27	30	27	28
Organic matter [g OM/kg]	114	101	102	100	98	113
Nitrogen [g N/kg]	8.7	8.9	8.6	8.7	9.0	9.0
C/N ratio [-]	6	5	5	5	5	6
Nitrogen-ammonia [g N-NH_3/kg]	4.8	5.1	4.8	4.9	4.9	4.9
Organic nitrogen [g N-org/kg]	3.9	3.8	3.8	3.8	4.1	4.1
Phosphorus [g P/kg]	2.4	2.2	2.3	2.3	2.4	2.5
Phosphate [g P_2O_5kg]	5.5	5.1	5.2	5.3	5.6	5.7
Potassium [g K/kg]	5.3	5.5	5.5	5.5	6.0	6
Potassium oxide [g K_2O/kg]	6.4	6.6	6.6	6.6	7.2	7.3
Magnesium [g Mg/kg]	1.6	1.4	1.5	1.6	1.3	1.4
Magnesia [g MgO/kg]	2.7	2.3	2.5	2.7	2.2	2.3
Sodium [g Na/kg]	1.3	1.2	1.4	1.3	1.2	1.1
Natron [g Na_2O/kg]	1.8	1.6	1.9	1.8	1.6	1.5
pH	7.3	7.4	7.2	7.4	7.3	7.2
Methane [ppm]	52.6	37.0	31.1	20.9	60.6	32.0
Concentration [mg/ m_0^3]	38	26	22	15	43	23
Flow rate [m_0^3/hr]	1257	875	1791	1322	1200	1097
Emission [g/hr]	47	23	40	20	52	25
No. of animals [-]	96	96	96	96	96	96

Emission per animal [g/animal/hr]	0	0	0	0	1	0
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/year]	3893	1908	3280	1628	4283	2068
Emission per animal per year [kg/animal/year]	3.9	1.9	3.3	1.6	4.3	2.1
Nitrous oxide [ppm]	0.536	0.480	0.507	0.532	0.416	0.424
Concentration [mg/ m_0^3]	1.05	0.94	1.00	1.05	0.82	0.83
Flow rate [m_0^3/hr]	1257	875	1791	1322	1200	1097
Emission [g/hr]	1.32	0.83	1.78	1.38	0.98	0.91
No. of animals [-]	96	96	96	96	96	96
Emission per animal [g/animal/hr]	0.0138	0.0086	0.0186	0.0144	0.0102	0.0095
No. days per year [-]	329	329	329	329	329	329
Emission per animal per year [g/animal/hr]	108.86	67.90	146.71	113.68	80.67	75.18
Emission per animal per year [kg/animal/year]	0.109	0.068	0.147	0.114	0.081	0.075

F Results of ammonia concentration measurements with an ammonia meter

v d Beek, Putten

	25-aug		15-nov		1-feb	
	Afd 3	Afd. 5	Afd 3	Afd 5	Afd 3	Afd 5
Hok 1 (voor tegen muur)	66	49	45	16	48	12
Hok 1 (tegen de muur)			28	23	39	9
Hok 2 (tegen de muur)	39	19	18	14	35	17
Hok 3 (tegen de muur)			16	7	20	20
Hok 4 (tegen de muur)	20	8	11	3	15	15
Hok 4 (achter tegen de muur)			3	2	13	10
Hok 5 (tegen de voormuur)	100	31	51	15	33	22
Hok 5 (tegen de zijmuur)			29	16	59	18
Hok 6 (tegen de muur)	43	17	20	11	34	15
Hok 7 (tegen de muur)			18	7	24	11
Hok 8 (tegen de muur)	13	7	12	4	25	13
Hok 8 (achter tegen de muur)			8	3	55	9
Middenpad (1,5 meter)	25	11	17	12	33	11
Gemiddeld	44	20	21	10	33	14
Reductie		**54%**		**52%**		**58%**

Van de Beek, Putten

	25-Aug		15-Nov		1-Feb	
	Section 3	Section 5	Section 3	Section 5	Section 3	Section 5
Pen 1 (front against wall)	66	49	45	16	43	12
Pen 1 (against the wall)			28	23	39	9
Pen 2 (against the wall)	39	19	18	14	35	17
Pen 3 (against the wall)			16	7	20	20
Pen 3 (against the wall)	20	8	11	3	15	15
Pen 4 (back against the wall)			3	2	13	10
Pen 5 (against the front wall)	100	31	51	15	33	22
Pen 5 (against the side wall)			29	16	59	18
Pen 6 (against the wall)	43	17	20	11	34	15
Pen 7 (against the wall)			18	7	24	11
Pen 8 (against the wall)	13	7	12	4	25	13
Pen 8 (back against the wall)			8	3	55	9
Centre aisle (1.5 metres)	25	11	17	12	33	11
Mean	44	20	21	10	33	11
Reduction		**54%**		**52%**		**58%**

v d Brandhof, Ede

	1-nov	
	Afd 23	Afd. 21
Hok 1 (voor tegen muur)	32	30
Hok 2 (tegen de muur)	31	35
Hok 3 (in het midden)	14	12
Hok 4 (achter tegen de muur)	31	30
Hok 5 (tegen de voormuur)	40	39
Hok 6 (tegen de muur)	33	23
Hok 7 (tegen de muur)	14	17
Hok 8 (achter tegen de muur)	18	20
Middenpad (1,5 meter)	25	6
Gemiddeld	26	24
Reductie		**11%**
Middenpad (1,5 meter)	25	6
Reductie middenpad		76%

	1-Nov	
	Section 23	Section 21
Pen 1 (front against wall)	32	30
Pen 2 (against the wall)	31	35
Pen 3 (in the centre)	14	12
Pen 4 (back against the wall)	31	30
Pen 5 (against the front wall)	40	39
Pen 6 (against the wall)	33	23
Pen 7 (against the wall)	14	17
Pen 8 (back against the wall)	18	20
Centre aisle (1.5 metres)	25	6
Mean	26	24
Reduction		**11%**
Centre aisle (1.5 metres)	25	6
Reduction centre aisle		76%

ACCOUNTABILITY

Report title	INVESTIGATION INTO AMMONIA EMISSION REDUCTION BY MANURE-PROCESSING INSTALLATION
Subtitle	Case control measurements at two farms
Report number:	BL2012.5216.02-V04
	This version replaces any previously released versions in its entirety
Document name	BL2012_5216_02_V04.docx
Keywords	Ammonia, emission, efficiency, fattening pigs, manure-processing installation; RAV
Client	Rinagro Piaam
Contact person	Mr A. Dijkstra
Implementers	Raoul van Onzenoort, K. van Setten, Peter Gerritzen, J.W. Winters
Controller	F.B.H. de Bree
Date	27 March 2013

blauw
luchthygiëne
onderzoek en advies

Nude 54 – 6702 DN Wageningen
telephone +31 (0)317 466699 – fax +31 (0)317 426111
email info@buroblauw.nl – internet www.buroblauw.nl