Quantification of odour emission from mink housing units

Test report

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Test report

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Document information

Document titel	Test report VERA mink odour KF
Project	VERA-mink-odour
Responsible	Martin Nørregaard Hansen
Date	10-10-2016
Version	1-4
Status	Final

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Content

FOREWORD

This test was conducted to quantify the odour emission from mink housing units. The test was executed in accordance to the prescriptions of the VERA test protocol for Livestock Housing and Management Systems version 2 (2011-29-08) taking into account the specific conditions related to mink production.

The test was initiated, planned and organized in cooperation between the applicant, the involved farmers, and the test institute.

The applicant

The applicant of the project was Kopenhagen Fur, which is cooperatively owned by the members of the Danish Fur Breeders Association. The Contact person was Henrik Bækgaard, phone: +45 8740 5232, mobile: +45 4186 1307, e-mail: hbk@copenhagenfur.com.

Farmers

The test took place at the following four mink farms:

FARM ID	FARM 1	FARM 2	FARM 3	FARM 4
Farm owner	Per Henriksen	Herman Jensen	Ulrik Jensen	John Papsø
Address	Nørrealle 3, 9530 Støvring, dk	Nibevej 206, 9530 Støvring, dk	Nør-skovsmindevej 25, 8882 Fårvang, dk	Duelundvej 9, 8620 Kjellerup, dk
Contact Info	Per Henriksen (22 17 36 53)	Herman Jensen (24 45 19 86)	Ulrik Jensen (86 87 23 24)	Alex Olesen (28 19 15 65)

Test institute

The test was carried out by AgroTech, Agro Food Park 15, DK-8200 Aarhus N. AgroTech is an authorised technological service institute which offers impartial consultancy and provides technological services.

Test responsible:

Martin N. Hansen, Agro Food Park 15, DK-8200 Aarhus N, e-mail: mno@agrotech.dk, phone: +45 3092 1784.

Technical experts

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

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Test period:

The test was initiated the 12th of August 2014 and ended the 21th of July 2015.

Signature and date (name, title, and name of institution in capital letters)

____ date_______________

Senior Consultant Martin Nørregaard Hansen

AgroTech A/S, Institute of Agri Technology and Food Innovation, Agro Food Park 15, DK-8200 Aarhus N.

INTRODUCTION

Denmark is the world biggest producer of mink fur. The high production is justified by cold summers and mild winters, available relevant foodstuff, and a considerable knowhow regarding production, breeding, organization, and marketing of mink products. The yearly production is about 17 million mink produced at about 1500 farms situated mainly in the peninsula Jutland. The high national production of mink and the high number of mink produced at individual farms cause regional and local odour emission, which may cause odour nuisance when farms are situated close to neighbors and villages.

Mink production is like other Danish husbandry production systems holding more than 75 livestock units regulated by an Environmental Approval Act for Livestock Holdings. The approval act gives the frame for approval of projects for livestock holdings and has a national minimum requirement for environmental protection for odour, ammonia, nitrates and phosphorus surplus. The odour impact of mink production is therefore part of the environmental approval act involved in planning of new or enlarged production systems. However, to estimate the odour impact of mink production facilities the actual odour emission from mink production needs to be known. The Danish Environmental Protection Agency (EPA) has therefore asked the Danish Fur breeder organization to initiate an impartial study to quantify the odour emission from mink housing units. This odour study was planned and performed by the GTS institute AgroTech.

The odour emission from mink housing units is expected to be influenced by temperature and the density and mass of mink. A Swedish study found that the odour emission from laying hens increased significantly with temperature (Nimmermark and Gustafsson, 2005). A high odour emission can therefore be expected when temperatures are high during the summer period. Contrary, the manure production is at the highest just before the mink offspring are taken out of production (pelted) in the period of November and December. A high odour emission may therefore take place in autumn. Therefore, as the periodic odour emissions pattern is unknown, it was decided that the odour emission should be quantified repeatedly from spring to autumn.

It is well established that odour emissions varies between farms (Zhou and Zhang, 2003). To obtain the average odour emission it was decided to measure the odour emission repeatedly at several farms.

To ensure a sufficient test level, the odour emission measurement was executed in accordance to the prescriptions of the VERA test protocol for Livestock Housing and Management Systems version 2 (2011-29-08). However, due low temperatures and low number of housed mink in the period between December and May, odour emission measurement during this period was omitted.

The majority of the odour emission is considered to be related to the manure produced by the mink. In Denmark mink manure has to be collected in slurry pits situated underneath the mink cages (Figure 2)Figure 2. Picture of the slurry pits situated below the mink cages. Mink allocate their urine and faeces in a restricted area as far away from their nest as possible, which means that the majority of the excreted manure can be collected in the slurry pits. The slurry pits were 0.34 m wide. The slurry pits were emptied mechanically twice weekly.

The majority of produced manure is collected by the slurry pits, while a minor fraction is excreted outside the area of the slurry pits. This fraction is collected in a straw layer below the mink cages. The manure collected in the slurry pits has, depending on the environmental approval of the specific production system, to be removed daily or once or twice weekly, while the manure collected below mink cages has to be removed once monthly. In order to generate odour emission from an average manure handling system, manure sampled in the slurry pit was cleaned out twice weekly, while manure collected below mink cages were removed on monthly basis.

This test report is therefor based on a study developed for quantification of odour emission from mink housing units. The study has been conducted in accordance to the prescriptions of the VERA test protocol for Livestock Housing and Management Systems version 2 (2011-29-08), and a developed test plan accepted by the Danish VERA Secretary (ETA Denmark) prior to the initiation of the test.

MATERIALS AND METHODS

The farms involved in the test

The odour emission was quantified at four commercial mink farms during a 12 months period covering summer, and autumn conditions. The odour samplings took place during summer and autumn when temperature and number of mink were high.

Characterization of test farms

The test took place at four commercial mink farms (Figure 1). All farms had conventional mink production in housing systems typical for Danish mink production system. At each farm one housing unit was chosen as test unit. Test sections were chosen to represent the different types of housing systems used for housing mink in Denmark. The specification of the test units can be seen in Table 1.

The number and weight of mink in test sections varied considerably between the measuring periods. The actual number and weight of mink were therefore measured and reported for each test farm and measuring period (Appendix 2a. Number, age and weight of mink in the different test periods).

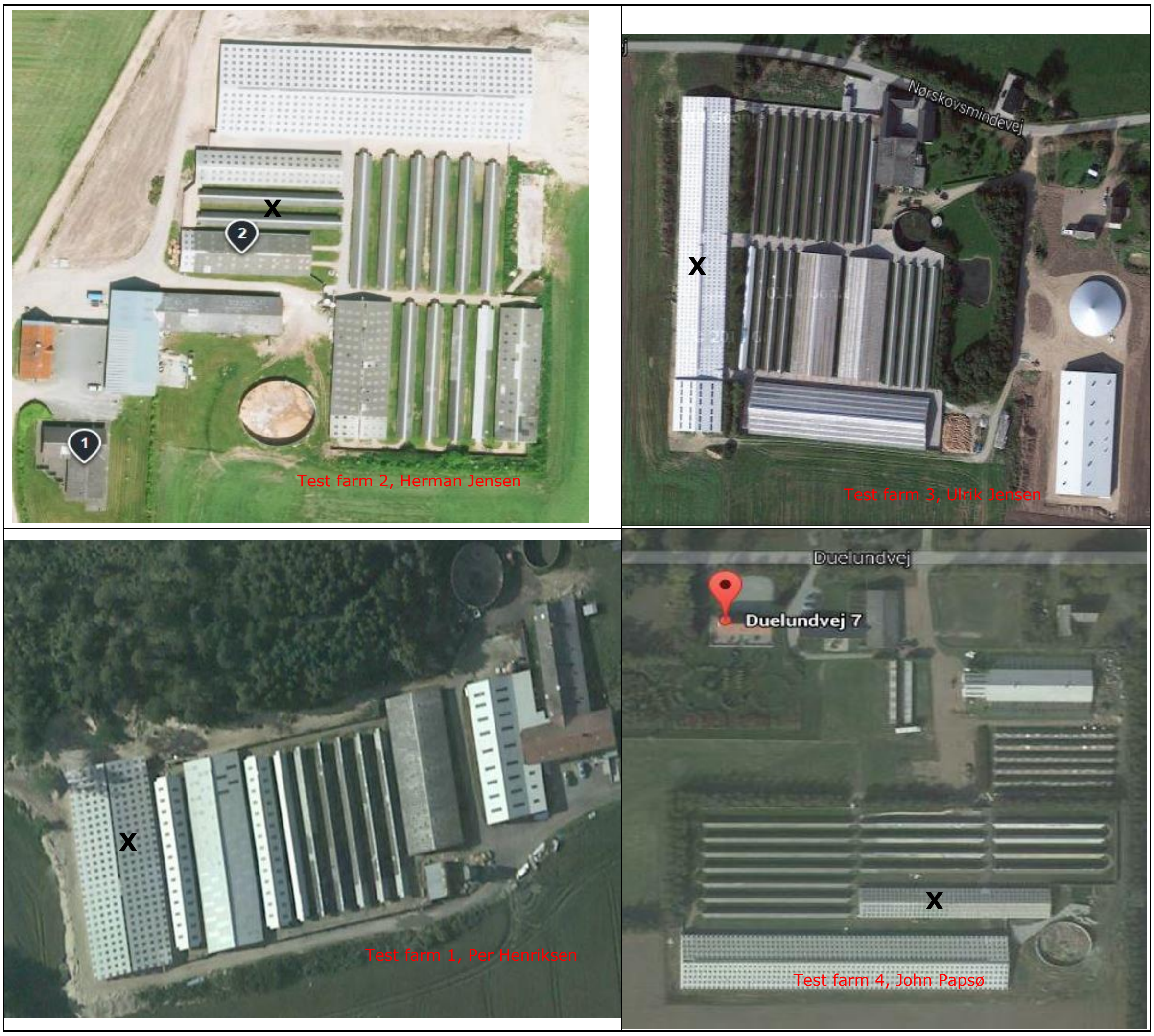

Figure 1. Overview of the four test farms. Test sections are marked by X.

All test farms were running typical mink production system in natural ventilated housing system.

The mink at all test farms produced offspring in the beginning of May. These grow up during summer and autumn. The majority of offspring are taken out of production (pelted) in November and December. So during winter and early spring the test units were only holding adult females and males requested for breeding. The number and weight of mink at each measurement period are listed in Appendix 2. Number, age and weight of mink in the different test periods).

Bedding material in form of straw was supplied to the mink nests. The mink were fed once daily with a mix of hen, fish and slaughter residues, balanced with soybean meal, wheat and essential amino acids and vitamins. All mink had access to a watering system via water nipple drinkers. Water spilled from the water nipples was collected in the slurry pits.

At each test farm one test unit was chosen before the test was initiated. The selection of test unit was done according to specific test requirement and to represent the different types of housing systems used in the Danish mink production.

Housing and management system

The odour emission was measured from mink housing units that best possible represent typical Danish mink management practice. This included

- All mink were held in cages. See details in Table 1
- The mink manure were collected by slurry pits situated below mink cages (Figure 2)
- Manure collected in slurry pits was cleaned out twice weekly
- Manure excreted outside the slurry pits were collected in a straw layer below mink cages. This layer was removed once monthly
- Feeding of mink according to normal feeding practice. See details in Table 1
- Management of mink according to normal management practice. See details in Table 1.

Figure 2. Picture of the slurry pits situated below the mink cages. Mink allocate their urine and faeces in a restricted area as far away from their nest as possible, which means that the majority of the excreted manure can be collected in the slurry pits. The slurry pits were 0.34 m wide. The slurry pits were emptied mechanically twice weekly.

Odour sampling related to manure management

The odour emission from mink houses can be expected to increase in the period from the mink manure is removed from slurry pits and below mink cages. To obtain the worst case scenario the odour sampling took place when half a week production of mink slurry were accumulated in the slurry pits and half a month production of straw/manure were accumulated below the mink cages.

Characteristics of the test units

The characteristics of the test farms and test units can be seen in Table 1.

Table 1. Key characteristics of test farms and test units.

Parameter	Farm 1	Farm 2	Farm 3	Farm 4
Farm owner	Per Henriksen	Herman Jensen	Ulrik Jensen	John Papsø
Address	Nørrealle 3, 9530 Støvring	Nibevej 206, 9530 Støvring	Nørskovsmindevej 25, 8882 Fårvang	Duelundvej 9, 8620 Kjellerup
Contact Info	Per Henriksen (22 17 36 53)	Herman Jensen (24 45 19 86)	Ulrik Jensen (86 87 23 24)	Alex Olesen (28 19 15 65)
CVR No.	60507317	76279314	15897872	38683357
Number of adult females per farm	2650	3300	6300	5000
Number of mink per test unit	1428 – 5712	412 – 1648	2376 – 9504	630 – 2520
Weight range (g) adult males	3300 – 3700	3300 – 3700	3300 – 3700	3300 – 3700
Weight range (g) adult females	1250 – 1450	1250 – 1450	1250 – 1450	1250 – 1450
Weight range (g) male offspring	10 – 4000	10 – 4000	10 – 4000	10 – 4000
Weight range (g) female offspring	10 – 2000	10 – 2000	10 – 2000	10 – 2000
Bedding material	Straw	Straw	Straw	Straw
Dimensions of test unit, (w, l)	28 x 84 m	14 x 36 m	27.5 x 154 m	16 x 94 m
Dimensions of cages (w, l, h)	0.3 m, 0.9 m, 0.45 m	0.3 m, 0.9 m, 0.45 m +0.3m, 0.6m, 0.45m[1]	0.3 m, 0.9 m, 0.45 m	0.3 m, 0.9 m, 0.45 m
Floor system	Solid floor	Solid floor	Solid floor	Solid floor
Manure system	Manure gutter system	Manure gutter system	Manure gutter system	Manure gutter system
Manure removal system	Mechanical scrapping system	Mechanical scrapping system	Mechanical scrapping system	Mechanical scrapping system
Feed composition	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat, vitamins, and essential amino acids	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat, vitamins, and essential amino acids	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat, vitamins, and essential amino acids	Mix of poultry, fish and slaughter residues, balanced with soybean, wheat, vitamins, and essential amino acids
Feeding system	Daily manual food delivering system	Daily manual food delivering system	Daily manual food delivering system	Daily manual food delivering system
Feed analysis	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276 – Limfjorden feeding central	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276 – Limfjorden feeding central	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276 – Bording feeding central	http://www.danskpelsdyrfoder.dk/Default.aspx?ID=276 – Bording feeding central
Ventilation	Natural ventilation	Natural ventilation	Natural ventilation	Natural ventilation
Heating system	No	No	No	No

[1] Double cage on top

Drawings of the test sections can be seen in Appendix 3. Technical drawings of test sections). The test sections, each holding between 4 and 12 lines of mink cages, had a max capacity between 1650 and 9500 mature mink. All mink were held in mink cages 0.9 m long, 0.3 m wide and 0.45 m high. A nest was attached to all cages.

The weight of adult females was estimated to be 1250 g when lactating and 1450 g outside the lactating season, and the weight of adult males was estimated to be 3466 g per animal (Bækgaard H. 2012 pers. com).

The weight of offspring was calculated by a weight model based on previous weekly weight measurement performed at test farms, and previous studies of offspring weight development performed by Kopenhagen Fur (Bækgaard H. 2012 pers. com.). The models used for calculation of weight of male and female offspring were:

$$Weight\ male\ offspring = -0.0013X^3 + 0.3596X^2 - 2.1232X + 10$$

$$Weight\ female\ offspring = -0.0006X^3 + 0.1433X^2 + 4.929X + 10$$

Where weight is in gram per animal, and X is the age of the offspring in days.

Test procedure

Test parameters

Odour was the only primary performance test parameter. In addition, a number of operational parameters were measured throughout the test periods. A list of the test parameters can be seen in Table 2.

Table 2. Test parameters, involved analytic methods and detection limits

Parameter	Analytical method	Limit of detection	Uncertainty
CO_2	Photo acoustic multigas analyzer	2.5 mg/m^3	15 % RSD[1]
Odour	Olfactometric analyses, EN 13725/AC:2003	100 OU_E/m^3	±2 x RSD
NH_3	Photo acoustic multigas analyser/Kitagawa gas detection tubes	0.2 ppm/0.1 ppm	15 % RSD/5% RSD
H_2S	Jerome 631-X™	3 ppb	0.003-2 ppm[2]
Air Temperature	Testo 174H/	0.1 °C	±0.5 °C (-20 to +70 °C)
Relative air humidity	Testo 174H	0.1 %	±3 %RH (2 to 98 %RH)

1. RSD: Relative standard deviation
2. Depending on concentration

Test design and sampling methods

The overall principle for quantification of odour emission is to quantify the concentration of odour in air leaving the test unit and the air exchange (ventilation) of the test unit. The emission of odour (E_g) was calculated on basis of the odour concentration (C_g) in out flowing air, and measured air exchange (Ventilation (V)).

Determination of air exchange

The air exchange is given as the volume of air leaving the housing system. As the air exchange cannot be measured directly in naturally ventilated housing systems, the air exchange was measured indirectly by a tracer gas method (Demmers et al., 2001). The determination of air exchange was quantified by a CO_2 tracer gas method. The method and its preconditions are described in detail by Laussmann and Helm (2011), but a brief description will be given in the following.

Carbon dioxide (CO_2) is a gaseous compound always detectable in animal housing systems. Since mink exhale metabolic CO_2, its concentration in mink housing units is considerably higher than in ambient air.

The calculation of the air exchange by the tracer gas method is based on the release of a tracer gas inside a housing system and its dilution. The weight specific emission of the tracer gas CO_2

(E_S) from the housed mink was calculated on basis of CO_2 emission measurements conducted at the University of Copenhagen (Data provided by Elnif J, 2012, pers. com) (Figure 3).

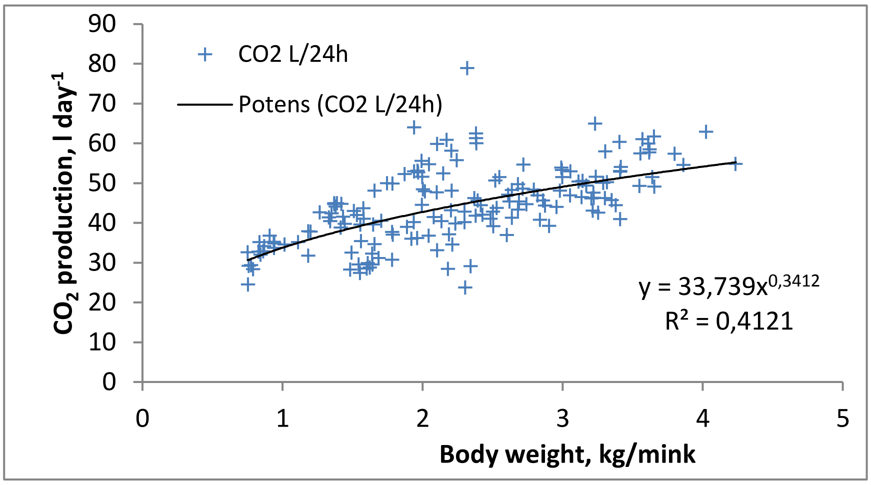

Figure 3. Correlation between mink body weight and CO_2 production (Data provided by Elif J, Copenhagen University, 2012)

Based on the correlation between mink weight and CO_2 production the weight specific CO_2 production was calculated by Eq. 1

$$E_{CO_{2p}} = \sum_{j=1}^{4} N_{jp} * (33.7 \times W_{jp}{}^{0.34}) \qquad \text{Eq 1.}$$

Where

$E_{CO2_{sp}}$ = total CO_2 production in l day^{-1}

W = Average weight of type j mink in kg

N = Number of mink

j = type of mink (adult male, adult female, female offspring, male offspring)

p = measuring period.

The air exchange (V) of the housing units was calculated by eq. 2:

$$V_i = \frac{10^6 \cdot E_{sp}}{\rho_s(t)(C_{si} - C_{so})} \quad \text{Eq. 2:}$$

Where

V_i = the air exchange in m^3 h^{-1} in test period i

E_{sp} = the CO_2 tracer gas emission in l CO_2 h^{-1} in period p

$\rho_s(t)$ = density of tracer gas in kg m^{-3} at a given temperature t

C_{si} og C_{su} = measured concentrations of tracer gas in mg m^{-3} in indoor (i) and outdoor (o) air.

Based on the measured difference of indoor and outdoor concentrations of the tracer gas (CO_2) the air exchange in the specific measuring period was determined simultaneously with the odour sampling period.

Air sampling system

The concentration of tracer gas was quantified by continuously sampling and analyses of air drawn from the test sections air outlets (indoor air) and air sampled from outside the test section (outdoor air). The indoor air was during the sampling periods drawn to the sampling equipment through Teflon air tubes connected to three 20 m long perforated Teflon tubes situated along the sides and below the ridge of the test section (Figure 4). Outdoor air was drawn through Teflon air tubes from two outdoor sampling tubes situated one m above ground level and two m away from the test sections (Figure 4).

Prior the start of the odour sampling the tracer gas concentration of all sampling points was quantified. Based on measured tracer gas concentrations, the odour sampling took place from the indoor sampling tube having the highest tracer gas concentration.

The tracer gas concentration measured in air sampled by this sampling tube was included as indoor air concentration (C_{si}) in the calculation of the air exchange rate, while the tracer gas concentration in the outdoor sampling point with the lowest measured tracer gas concentrations was included as outdoor tracer gas level (C_{so}). These values were used for calculation of the air exchange during the odour sampling period (Eq 2.)

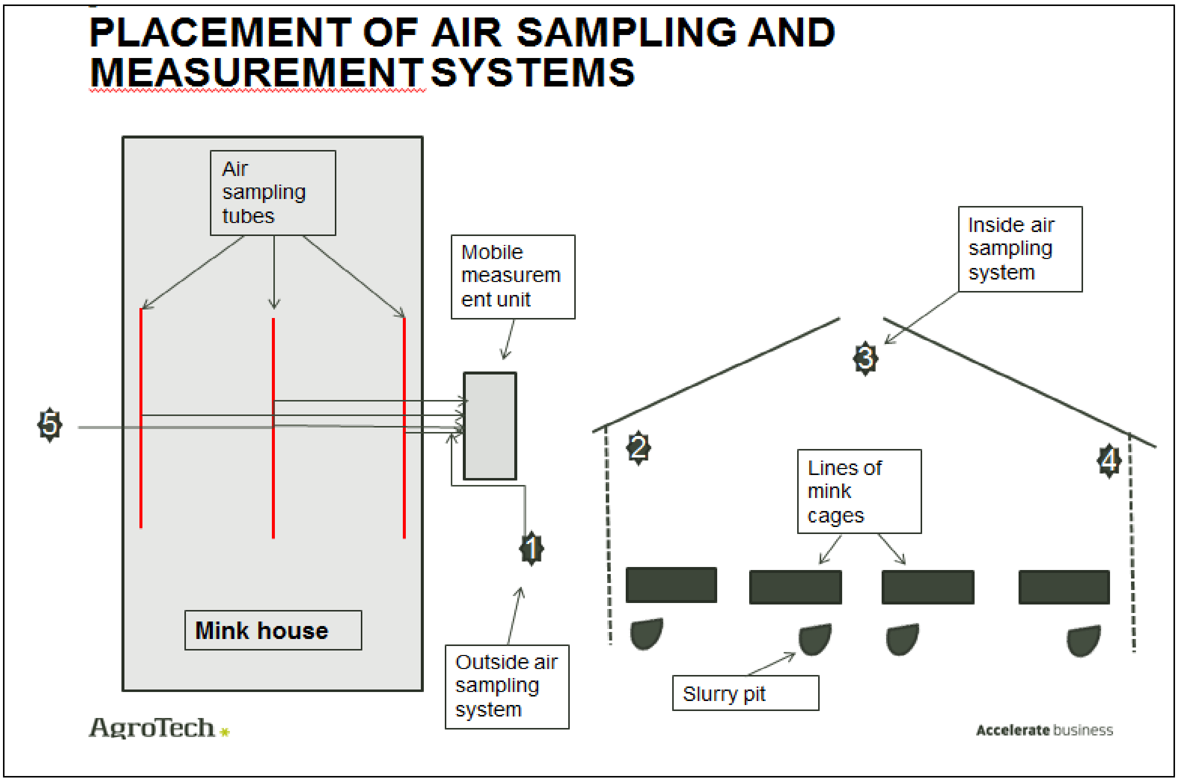

Figure 4. Schematic drawing of the placement of sampling tubes and measurement equipment. Perforated air sampling tubes (20 m long) were situated along the ventilations openings in sides and ridge of the mink house. During sampling, air was drawn by pumps through Teflon tubes from the indoor and outdoor sampling systems to the mobile measurement unit holding the tracer gas measurement system.

Determination of odour emission

The principle for determination of odour emission is sampling and odour analyses of odorous air leaving the housing system. The odorous air was sampled in 30 l nalophan bags. The odour bags were filled by use of vacuum containers. The odour concentrations of the sampled air were subsequently quantified by dilution olfactometric analyses within 24 hours after sampling in accordance with the European standard En 13725 (CEN 2003).

Sampling procedure

The odour samplings were done by a mobile sampling system consisting of vacuum containers and diaphragm pumps. Once at the site, the vacuum containers were prepared and connected to diaphragm pumps that allow a controlled airflow evacuating the vacuum containers. The vacuum was regulated so that the odour sampling time was 30 minutes per sample. Marked odour bags were inserted into the vacuum containers, and the inlet of the odour bag was connected to the sampling point by Teflon tubes.

Before test sampling, the odour bags were conditioned by filling the bags with indoor air and afterwards emptying the bags. Then three air samples per test section were simultaneous sampled into marked odour bags. After test sampling the odour samples were stored and transported in black plastic bags or closed cardboard boxes to the odour analytic institute where the odour concentrations were quantified by dynamic dilution olfactometric analyses within 24 hours after sampling. The climatic and environmental condition that may influence the odour emission was recorded in prepared log books (Appendix 1. Example Logbook: External parameters related to the odour sampling periods).

The odour emission was calculated by the following equation:

$$\boldsymbol{E_{OU_E j}} = \frac{\mathbf{1}}{\boldsymbol{N_j * 3600}} * \overline{\boldsymbol{OU_{Ej}}} * (\boldsymbol{V_j}) \quad \text{Eq 3.}$$

Where

$\boldsymbol{E_{OU_E}}$ = *Odour emission per animal per second, Odour Units (OU_E) head^{-1} s^{-1}*

$\overline{\boldsymbol{OU_E}}$ = *Average measured odour concentration, OU_E m^{-3} air*

V_j = Air exchange in test section, *m^3 air h^{-1}*

N = Total number of animals in test section

j = Actual measurement event.

Test schedule

Deviation to test protocol.

Number of test periods

According to the VERA test requirement, the specific odour sampling requirement for Denmark is that six of the odour sampling periods shall take place during summer period, while three shall be evenly distributed outside the summer period. Due the very low number and mass of housed mink between December and May, and a low number of odour complains in this period, one sampling period in the winter period and one sampling period in the early spring period were omitted. The odour sampling was therefore performed when the number and mass of housed animals and temperatures were high.

Analytical parameters

The primary analytical parameter is presented inTable 3. Odour is the only primary measurement parameters as ammonia emission from mink houses has been quantified in a previous VERA tests (Hansen MN., 2013), and dust is not considered an environmental problem related to mink production.

Primary analytical parameters

The primary analytic parameter and corresponding analytical methods are listed in Table 3.

Table 3. Primary analytical parameter and corresponding analytical methods.

Parameter	Analytical method	Number of measuring periods	No. of samples/ measuring period/test section	Sampling time
Odour	Olfactometric analyses, EN 13725/AC:2003	7 measuring periods	3	30 minutes

Conditional parameters

Table 4 gives the conditional parameters, which may influence the emission level of the primary environmental pollutant. In addition, the table includes additional secondary environmental pollutants.

Table 4. Conditional parameters and corresponding analytical methods.

Parameter	**Analytical method**	**Measuring periods**	**Sampling time/period**
CO_2	Photoacoustic multigas analyzer, Innova 1412	7	Continuous measurements in situ.
H_2S	Jerome 631-X™	7	10 minutes
NH_3	Kitagawa gas detection tubes	7	2 minutes
Temperature on site	Testo 174H	7	Continuous during sampling
Relative air humidity on site	Testo 174H	7	Continuous during sampling
Noise	Not relevant		
Electricity consumption of tested technology	Not relevant		
Manure parameters • pH • DM [%] • Organic DM [%] • Total N [g/kg] • TAN [%] [g/kg]	Not relevant		
Climatic conditions • wind direction [°] • wind speed [m/s] • Air humidity [% RH]	UTM based climatic data service developed by the Danish Meteorological Institute (DMI)	7	Continuous during sampling

Test schedule

The test schedule is presented in Table 5.

Table 5. Test schedule for 2014 and 2015. The specific activities are marked by X.

Year	2014								2015										
Month	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11
Test plan	X	X																	
Acceptance of test plan		X	X																
Installation and pre-testing			X																
Start test period				X															
Odour sampling periods				XX	X	X	X							X	X				
End of test period															X				
Test report draft																X			
Test report quality assurance																X	X		

Test report final version																	X	X	

The specific planning of measurements depended on practical management conditions like periods of fluctuating number of animals due mating, birth, relocation and pelting of mink. Due the birth, handling, and relocation of mink in May, early July, late November and December odour sampling was not performed during these periods.

Table 6. List of measuring dates.

Sampling period	**Farm 1**	**Farm 2**	**Farm 3**	**Farm 4**
Period 1	12.08-2014	12.08-2014	14.08-2014	14.08-2014
Period 2	26.08-2014	26.08-2014	28.08-2014	28.08-2014
Period 3	16.09-2014	16.09-2014	18.09-2014	18.09-2014
Period 4	14.10-2014	14.10-2014	16.10-2014	16.10-2014
Period 5	04.11-2014	04.11-2014	05.10-2014	05.10-2014
Period 6	15.06-2015	15.06-2015	17.06-2015	17.06-2015
Period 7	20.07-2015	20.07-2015	21.07-2015	21.07-2015

Management of production system

The farm owners were responsible for housing and production systems. The farmers reported at each measurement day the number, sex and age of adult mink and offspring in the test section, and problems regarding the housing and manure management system in a log book prepared by the test institute (Appendix 4. Example of log book for registration of no of mink and problem related to housing and management).

Analytic analyses

Analytical laboratory

Odour samples were analysed by dynamic dilution olfactometric analyses by external accredited odour analytic institute (EuroFins Danmark. Address: Smedeskovvej 38, DK-8464 Galten, Denmark. Phone: +45 7022 4266. E-mail: info@eurofins.dk).

Preservation and storage of samples

Ammonia

When kitagawa gas detection tubes were used for measurement of ammonia concentration in odour samples, the samples were analysed as soon as possible after sampling.

Odour samples

Odour samples were sampled and stored during transport according to the description given by Miljøstyrelsen (Danish EPA) (2006) regarding sampling and analyses of odour samples from livestock production units.

Analytical methods

The analytical methods of the primary parameter are presented in Table 3. The analytical methods of the operational parameters are presented in Table 4.

Ammonia analysis

The ammonia concentration in sampled animal house air was measured by Kitagawa gas detection tubes.

Odour analyses

The odour concentration in sampled animal house air will be determined by dilution olfactometric analyses by an external odour analytic institute (EuroFins, Galten) according to the standard EN 13725/AC:2003.

Data management

Data management including filling and archiving procedures are described in the AgroTech Management Manual (AgroTech, 2014)

Data storage, transfer and control

Some data were collected and reported at the test site. These data were stored as hard copy according to the archiving procedures described in the AgroTech Management Manual (AgroTech, 2014). These data are listed in appendix Appendix 2a. Number, age and weight of mink in the different test periods).

Other data collected by electronic means at the test site were sent from an external server to a PC at AgroTech main office.

Results from external laboratories were sent electronically by email or in paper version by mail. A list of data compilation and storage can be seen in Table 7.

Table 7. Data compilation and storage summary.

Data type	Data media	Data recorder	Recording of data	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	Test staff at test site	During collection	Files and archives at AgroTech
Calculations	Excel files	Test responsible, AgroTech	After conclusion of data sampling	Files and archives at AgroTech
Analytical reports	Paper / pdf-files	Test responsible, AgroTech	When received	Files and archives at AgroTech

Quality assurance

The test was performed in accordance to the AgroTech ISO 9001 certified Management System Manual (AgroTech, 2014).

Test plan review

The test plan was prior to the initiation of the test external reviewed by the Danish VERA National Technical Advisory Committee (NTAC) assigned to this verification task (MELT), and accepted by ETA-Danmark, the Danish verification body for Environmental Technology Verification

Test system control

The stability of the test equipment was ensured by use of annually calibrated measuring systems and by supervision during recording of data. Before start of the sampling procedure the gas analyser was controlled by simultaneously sampling of gas concentration by Kitagawa gas detection tubes. Procedures ensuring that test facilities and equipment were calibrated and fit for the purposes are described in the AgroTech Management System Manual (AgroTech, 2014). These procedures are subject to internal audits from the AgroTech Management.

Data integrity check procedures

All data transfer from printed media to digital form and between digital media was checked by spot check undertaken by the test responsible. If errors were found by the spot check, all data transfers from the specific data collection were checked.

Test system audits

Internal audits were done following the procedure described in the AgroTech Management System Manual (AgroTech 2014).

Test report review

The test report was reviewed by the appointed technical expert.

Statistical data processing method

The mean and the median odour emission were calculated for the individual test locations and averaged for all farm locations. Differences between emissions at test locations were analysed by variance analyses (ANOVA) (Microsoft analysis Toolpack). When significant differences were found ($p<0.05$) test for equal variance of data was performed by F test. Significant difference between data with equal variance was identified by pairwise t-test ($p<0.05$). Data with unequal variance were ln transformed to obtain equal variance before statistical analysed.

The mean and the median odour emission were calculated for the individual sampling periods, before averaged for all sampling periods. Significant difference between sampling periods were analysed by variance analyses (ANOVA) ($p=0.05$).

RESULTS

Results regarding the conditional parameters (concentrations of CO_2, NH_3, air humidity, odour, hydrogen sulphide and climatic data) can be seen in Appendix 5a. Concentration of tracer gas, odour, ammonia, and hydrogen sulphide, air exchange, and climatic condition during the sampling periods.

The odour emission was quantified by seven test periods at each of the four test farms involved in the study. The results obtained at the individual test periods can be seen in Table 8.

Table 8. Overview of samplings dates, average air temperature and measured odour emission for the individual test periods at the four test farms. Values shown in parentheses are standard deviations.

Farm	Test period	Month	Start of measure-ments	Total No of mink	Air tempera-ture, °C	Measurement start	Median odour emission $OU_E\ s^{-1}\ mink^{-1}$	Mean odour emission $OU_E\ s^{-1}\ mink^{-1}$
Farm 1	1	Aug	12-08-2014 10:42	5689	23.8	12-08-2014 10:42	0,86	0.9 (0.1)
Farm 1	2	Aug	26-08-2014 09:50	5689	16.3	26-08-2014 09:50	1,28	1,3 (0.2)
Farm 1	3	Sep	16-09-2014 12:17	5684	20.9	16-09-2014 12:17	0,90	0.9 (0.07)
Farm 1	4	Oct	14-10-2014 10:00	5677	9.0	14-10-2014 10:00	1,09	1.1 (0.1)
Farm 1	5	Nov	04-11-2014 10:15	5650	12.0	04-11-2014 10:15	0,78	0.7 (0.2)
Farm 1	6	June	17-06-2015 13:45	8287	11.6	17-06-2015 13:45	0,66	0.8 (0.4)
Farm 1	7	July	22-07-2015 12:07	5708	28.1	22-07-2015 12:07	1,37	1.3 (0.2)
Mean farm 1							**0,99**	**1.0 (0.2)**
Farm 2	1	Aug	12-08-2014 10:42	1474	24.1	12-08-2014 10:42	1,36	1.4 (0.2)
Farm 2	2	Aug	26-08-2014 09:50	1481	23.3	26-08-2014 09:50	0,70	0.7 (0.02)
Farm 2	3	Sep	16-09-2014 12:17	1483	18.0	16-09-2014 12:17	0,68	0.7 (0.03)
Farm 2	4	Oct	14-10-2014 10:00	1487	16.0	14-10-2014 10:00	1,72	1.5 (0.3)
Farm 2	5	Nov	04-11-2014 10:15	1499	12.8	04-11-2014 10:15	1,10	1.1 (0.0)
Farm 2	6	June	17-06-2015 13:45	1235	11.1	17-06-2015 13:45	1,53	1.5 (0.08)
Farm 2	7	July	22-07-2015 12:07	1620	23.1	22-07-2015 12:07	1,09	1.1 (0.3)
Mean farm 2							**1,17**	**1.1 (0.1)**
Farm 3	1	Aug	14-08-2014 10:35	9494	20.2	14-08-2014 10:35	0,73	0.7 (0.1)
Farm 3	2	Aug	28-08-2014 10:27	9490	17.6	28-08-2014 10:27	0,26	0.3 (0.04)
Farm 3	3	Sep	18-09-2014 09:55	9490	16.4	18-09-2014 09:55	0,71	0.6 (0.2)
Farm 3	4	Oct	16-10-2014 13:33	9483	13.7	16-10-2014 13:33	0,86	0.9 (0.2)
Farm 3	5	Nov	05-11-2014 09:55	9474	9.5	05-11-2014 09:55	0,69	0.7 (0.09)
Farm 3	6	June	18-06-2015 09:35	15584	12.1	18-06-2015 09:35	0,51	0.5 (0.07)
Farm 3	7	July	23-07-2015 12:56	15584	17.0	23-07-2015 12:56	0,86	0.8 (0.08)
Mean farm 3							**0,66**	**0.7 (0.2)**
Farm 4	1	Aug	14-08-2014 12:56	2409	21.4	14-08-2014 12:56	1,35	1.2 (0.2)
Farm 4	2	Aug	28-08-2014 13:06	2407	20.1	28-08-2014 13:06	0,77	0.7 (0.03)
Farm 4	3	Sep	18-09-2014 12:50	2406	20.8	18-09-2014 12:50	1,65	1.8 (0.2)
Farm 4	4	Oct	16-10-2014 10:48	2399	12.9	16-10-2014 10:48	0,77	0.8 (0.06)
Farm 4	5	Nov	05-11-2014 12:42	2399	10.0	05-11-2014 12:42	0,91	0.9 (0.1)
Farm 4	6	June	18-06-2015 13:15	4284	14.4	18-06-2015 13:15	1,92	1.8 (0.9)
Farm 4	7	July	23-07-2015 09:42	2512	16.9	23-07-2015 09:42	1,29	1.5 (0.5)
Mean farm 4							**1,24**	**1.2 (0.4)**

The odour emission varied between the individual sampling periods and farms (Figure 5). The difference is considered to be caused by differences in climatic conditions, farm management, age of offspring, and manure production.

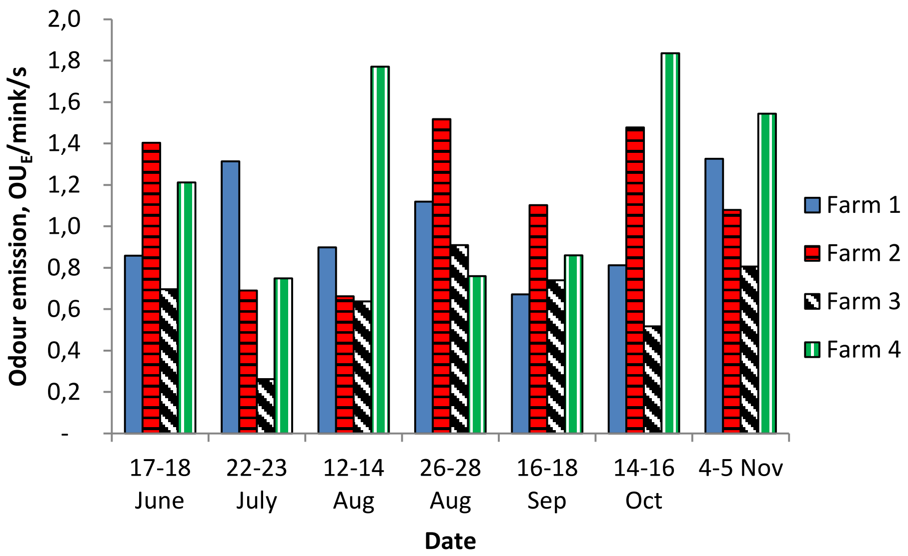

Figure 5. Mean odour emission at the seven odour measurements periods performed at the four test farms.

Differences between test farms

The average measured odour emissions varied significantly between farms (p=0.02). Farm 3 was found to have significantly lower average odour emission (p=0.002) than farm 1, farm 2 and 4. Farm 1, 2, and 4 were found to have similar average odour emission levels (p=0.37) (

Table 9).

Table 9. Measured average odour emission at the four participating test farms. Results are shown as median and mean values±95 per cent confidence intervals. Values in same row followed by different characters are significantly different (p<0.05).

	Odour emission, OU_E mink^{-1} s^{-1}				
	Farm 1	Farm 2	Farm 3	Farm 4	Mean
Median	0.99^{a}±0.24	1.17^{a}±0.36	0.66^{b}±0.19	1.23^{a}±0.41	1.0±0.4
Mean	1.0^{a}±0.24	1.13^{a}±0.33	0.65^{b}±0.20	1.25^{a}±0.44	1.0±0.4

Differences between measurement periods

The odour emission was at each test farm quantified by seven measurement periods taking place in the period between the middle of June and the start of November. The average odour emission at the different measurement periods did not vary significantly between sampling periods (p=0.72) (Table 10).

Table 10. Average odour emission at the seven measurement periods. Results are shown as median and mean values±95 per cent confidence intervals. Values are given in Odour Units (OU_E) per second per Livestock Unit (LU) (one LU is equal to 500 kg mink) and per housed mink. Values in same column followed by different characters are significantly different ($p<0.05$).

Test period (sampling dates)	Odour emission/LU	Odour emission/mink	
	Mean OU_E LU^{-1} s^{-1}	Median OU_E $mink^{-1}$ s^{-1}	Mean OU_E $mink^{-1}$ s^{-1}
6. (17-18 June 2015)	813^a ± 663	1.15^a±1.08	1.16^a±0.96
7. (22-23 July 2015)	439^b ± 189	1.20^a±0.36	1.19^a±0.51
1. (12-14 Aug 2014.)	299^b ± 188	1.04^a±0.52	1.04^a±0.51
2. (26-28 Aug 2014.)	184^b ± 161	0.72^a±0.66	0.75^a±0.69
3. (16-18 Sep 2014.)	204^b ± 159	0.78^a±0.72	0.99^a±0.85
4. (17-18 Oct 2014.)	208^b ± 144	1.01^a±0.68	1.08^a±0.52
5. (04-05 Nov 2014.)	162^b ± 92	0.80^a±0.29	0.84^a±0.30
Mean periods	**330^b ± 215**	**0.96±0.18**	**1.01±0.15**

Influence of temperature

The odour emission was not found to vary significantly between measurement periods; however differences were observed (Figure 6). The odour emission was observed to be relatively high in June, despite low temperatures and low manure production. The relative high odour emission is expected to be due the fact that the mink feed in this period has to be situated above the nests and that the young offspring are not yet fully capable to excrete their urine and faeces into the slurry gutter.

The odour emission was found to decrease during August, probably due the decrease in temperature at the sampling periods. The odour emission was found to increase in September and October despite decreasing temperatures. The increase is expected to be due the increase in manure production during this period.

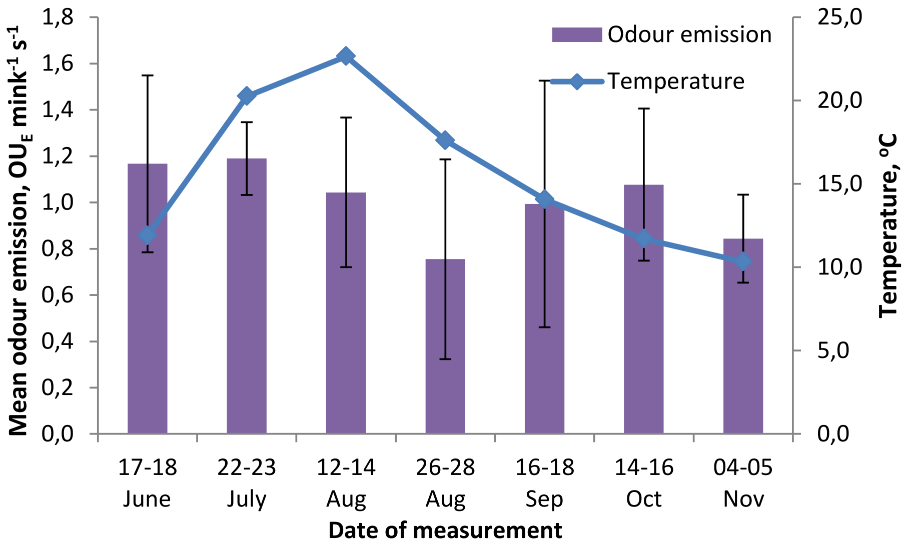

Figure 6. Mean odour emission and out-door temperature for the seven measurements periods performed at the four test farms.

Impact of ambient temperature and humidity on odour emission

The odour emission from mink was found to be influenced by the ambient temperature (Figure 7a). Higher odour emission was observed at higher air temperatures; however air temperature only explained a minor fraction of the observed variation.

The test protocol defines that that six of the odour measurement periods should be taken at summer condition, which is defined to be at temperature higher than 16°C. In this study only four odour sampling periods per test farm took place at temperature higher than 16°C, while the remaining three sampling periods took place at lower temperatures in June, October and November. The reason for this deviation was that it was expected that the odour emission in October and November, despite the lower temperatures, would be high due the high animal density and slurry production. A week correlation between temperature and odour emission was observed by the study (Figure 7a), but the odour emission was not found to differ significantly between sampling periods with temperature higher than 16°C and periods with temperature below (Table 10). This indicates that other factors like higher slurry production late in the production period counteracts the effects of lower air temperature.

Air humidity is another parameter that potentially may influence air emission. However, air humidity was not found to influence odour emission in the study performed (Figure 7b).

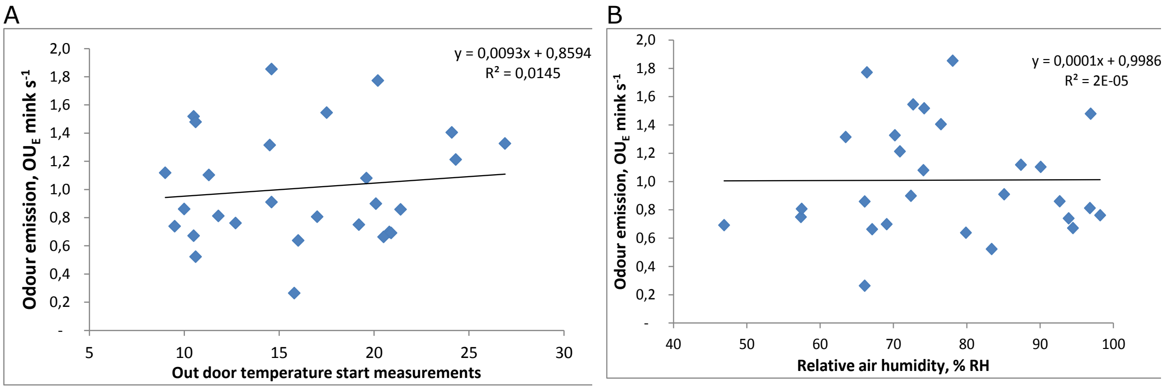

Figure 7. Impact of outdoor air temperature and humidity on measured odour emission. The correlation between odour emission and air temperature is shown in figure a. The correlation between odour emission and air humidity is shown in figure b.

Odour emission per adult female

The number of mink varies considerable during periods. Numbers of mink are high following the birth of offspring in the beginning of May and numbers are low in winter and early spring when only adult females and males requested for mating are housed. The numbers of mink are therefore often given as number of adult females (one female + her offspring) and this term is normally used in connection to environmental approval of mink production facilities.

The number of offspring per female mink depends on breed, farm and management system; however, average number of offspring per female is estimated annually based on the number of mink pelted. In 2014 the average number of pelted offspring per female mink was 5.45 (Poulsen H.D, 2015). One adult female in 2014 is therefore equal to 1 + 5.45 = 6.45 mink.

The mean odour emission per adult female is given in Table 11.

Table 11. Mean odour emission per adult female at the seven measurement periods. Values are given in Odour Units (OU_E) per second per adult female (equal to one adult female + 5.45 off-spring). Results are shown as mean values±95 per cent confidence intervals. Values in same column followed by different characters are significantly different ($p<0.05$).

Test period (sampling dates)	Odour emission per adult female Median OU_E adult female^{-1} s^{-1}	Odour emission per adult female Mean OU_E adult female^{-1} s^{-1}
6. (17-18 June 2015)	7.39	7.49^{a} ±6.2
7. (22-23 July 2015)	7.76	7.67^{a} ±3.3
1. (12-14 Aug 2014.)	6.68	6.73^{a} ±3.3
2. (26-28 Aug 2014.)	4.65	4.87^{a} ±4.4
3. (16-18 Sep 2014.)	5.04	6.40^{a} ±5.5
4. (17-18 Oct 2014.)	6.54	6.94^{a} ±3.4
5. (04-05 Nov 2014.)	5.16	5.44^{a} ±1.9
Mean periods	**6.17**	**6.51 ±0.95**

Summary

Mink production cause, like other husbandry systems, odour emission, however the odour emission rate is not known. An odour study was therefore put up to quantify the odour emission from mink houses. The study measured the odour emission from four typical Danish mink farms when the odour emission was assumed to be at the highest level due a combination of high temperatures and high animal density. At each of the farms the odour emission was quantified by seven measurement periods taking place following the birth of offspring in May and the pelting of mink in November. The odour emission was quantified by use of olfactometric dilution analyses. The mean odour emission per housed mink was found to be 1.0±0.15 OU_E s^{-1}.The odour emission was found to be positively correlated to air temperature. The odour emission was not found to differ significantly between the individual measurement periods.

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APPENDIXES

Appendix 1. Example Logbook: External parameters related to the odour sampling periods

Appendix 2. Number, age and weight of mink in the different test periods

Appendix 3. Technical drawings of test sections

Appendix 4. Example of log book for registration of no of mink and problem related to housing and management

Appendix 5. Concentration of tracer gas, odour, ammonia, and hydrogen sulphide, and climatic condition during the sampling periods

Appendix 1. Example Logbook: External parameters related to the odour sampling periods

Dokumenttitel	LOG BOOK Odour sampling
Dokumentansvarlig	Tina Thora Hansen (TIH)
Dokumentnummer	03-06-XX
Dato for aktuel version	18-05-2015
Gældende version	03-06-2015

ISO 17025

LOG BOOK Odour sampling

Tider, temperatur og H_2S og NH_3 koncentrationer ved lugt målinger
Udarbejdelse af skema: MNO
Prøveudtager: SGR
Bedrift id: John Papsø og Ulrik Jensen Mink 7
Dato: 23.07 2015

Udstyrs id

Kit pumpe id	Kitagawa NH3	Kitagawa H2S	Jerome	Temperatur

Sample ID	Målestald	Målested (VM, Kip, MM)	Ude temp ved start sampling	Vacuum kasse id	Start af olfac sampling (tt:mm)	Slut af olfac sampling (tt:mm)	NH_3 Kit-konc. ppm	H2S konc. Ppm	Udetemp ved slut sampling	Stald-temp. ved slut sampling	Bemærkninger (eksempelvis sol, skygge, kraftig vind, fejl på udstyr/opsamling).
10443_MNO_JP-7-a-5165	John P										
10443_MNO_JP-7-b-5166	John P										
10443_MNO_JP-7-c-5167	John P										
10443_MNO_UJ-7-a-5168	Ulrik J										
10443_MNO_UJ-7-b-5169	Ulrik J										
10443_MNO_UJ-7-c-5170	Ulrik J										

Husk

- Lugtposer, vacuumkasser, pumper, etiketter, temperaturmåler til stald og udetemperatur, kitagawaudstyr og jerome
- at få kopi eller billede af produktionslogs med antal dyr (evt. opdelt på dyretype, antal døde etc.)
- at gemme/hjemtage/sende Veng/Innnova data for den aktuelle måleperiode

Husk at registrere luftskiftet i løbet af lugtindsamlingen, hvis mekanisk ventilering

Behandling	Stald id	Tidspunkt	Luftskifte per kip vent, m3/h	Luftskifte veksler, m3/h	Bemærkning
Kontrol	IR	**IR**	**IR**	**IR**	**IR**
Teknologi	IR	**IR**	**IR**	**IR**	**IR**

Appendix 2a. Number, age and weight of mink in the different test periods

Farm id. 1 and 2

Farm id	**Unit**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**2**	**2**	**2**	**2**	**2**	**2**	**2**
Study day	dd-mm-aaaa	12-08-2014	26-08-2014	16-09-2014	14-10-2014	04-11-2014	17-06-2015	22-07-2015		12-08-2014	26-08-2014	16-09-2014	14-10-2014	04-11-2014	17-06-2015	22-07-2015
Section id		12-12 rk	12-12 rk	12-12 rk	12-12 rk	12-12 rk	12-12 rk	12-12 rk		16-4 rk	16-4 rk	16-4 rk	16-4 rk	16-4 rk	16-4 rk	16-4 rk
Number of cage lines		12	12	12	12	12	12	12		4 (double)	4 (double)	4 (double)	4 (double)	4 (double)	4 (double)	4 (double)
Period id		period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7		period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
Study id		PH_1	PH_2	PH_3	PH_4	PH_1	PH_6	PH_7		HJ_1	HJ_2	HJ_3	HJ_4	HJ_5	HJ_6	HJ_7
Number of mink																
Number of female kits	animals/section	2495	2495	2493	2490	2480	3550	2854		1150	1175	1175	1175	1175	520	810
Number of male kits	animals/section	2838	2838	2835	2832	2820	3550	2854		216	204	204	208	216	520	810
Number of adult females	animals/section	356	356	356	355	350	1178	0		108	102	104	104	108	195	0
Number of adult males	animals/section	0	0	0	0	0	0	0		0	0	0	0	0	0	0
Total number of mink	animals/section	5689	5689	5684	5677	5650	8278	5708		1474	1481	1483	1487	1499	1235	1620
Offspring																
Date of birth	dd-mm-aaaa	29-04-2014	29-04-2014	29-04-2014	29-04-2014	29-04-2014	29-04-2015	29-04-2015		29-04-2014	29-04-2014	29-04-2014	29-04-2014	29-04-2014	29-04-2015	29-04-2015
Age of offspring	days	105	119	140	168	189	49	84		105	119	140	168	189	49	84
Weight of mink																
Weight of female kits	kg/animal	1.41	1.61	1.86	2.04	2.01	0.53	1.08		1.41	1.61	1.86	2.04	2.01	0.53	1.08
Weight of male kits	kg/animal	2.25	2.66	3.19	3.64	3.68	0.62	1.60		2.25	2.66	3.19	3.64	3.68	0.62	1.60
Weight of adult fe-males	kg/animal	1.5	1.6	1.7	1.8	1.8	1.5	1.5		1.5	1.6	1.7	1.8	1.8	1.5	1.5
Weight of adult ma-les	kg/animal	3.6	3.6	3.6	3.6	3.6	3.6	3.6		3.6	3.6	3.6	3.6	3.6	3.6	3.6

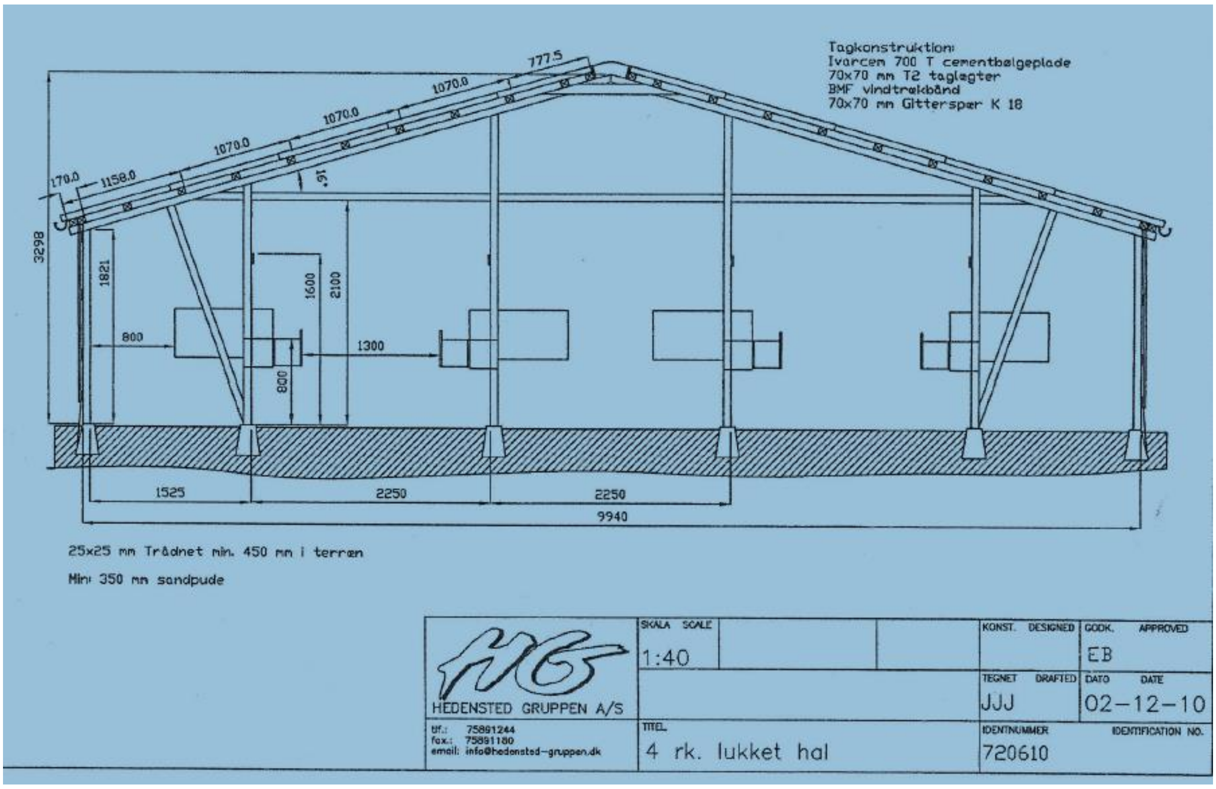
Appendix 2b. Number, age and weight of mink in the different test periods

Farm id. 3 and 4.

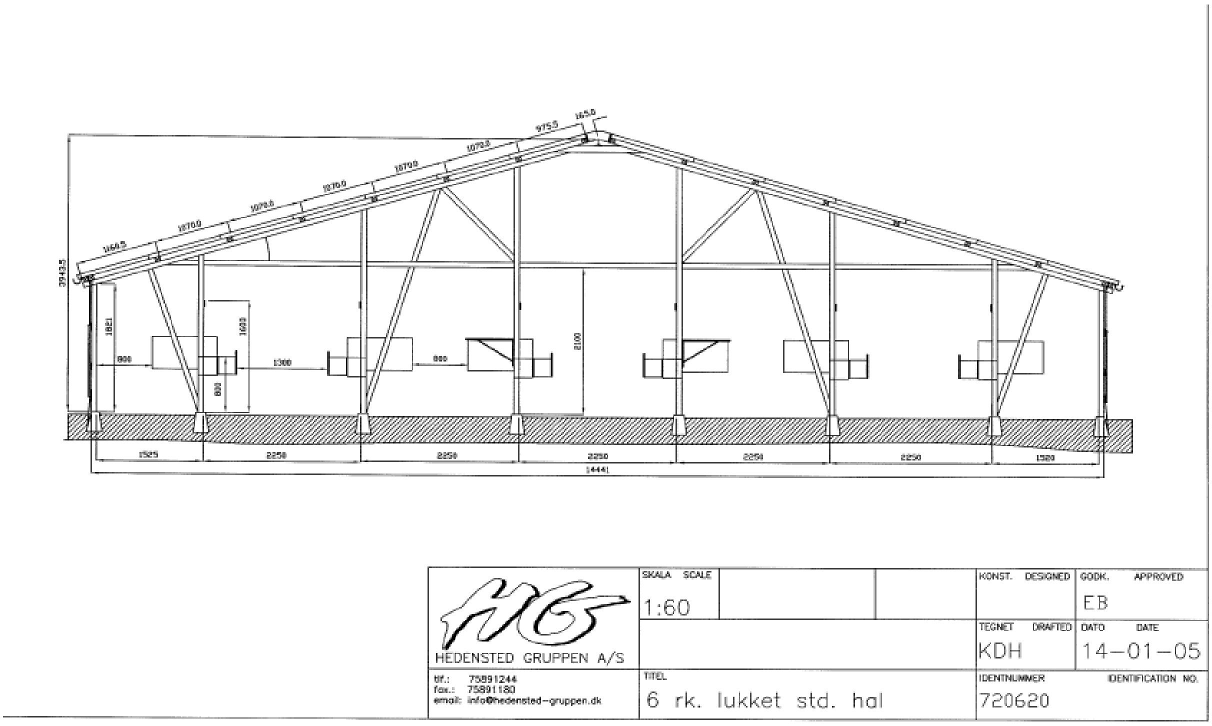
Farm id	Unit	3	3	3	3	3	3	3		4	4	4	4	4	4	4
Study day	dd-mm-aaaa	14-08-2014	28-08-2014	18-09-2014	16-10-2014	05-11-2014	18-06-2015	23-07-2015		14-08-2014	28-08-2014	18-09-2014	16-10-2014	05-11-2014	18-06-2015	23-07-2015
Section id		33-44, 12 rk	33-44, 12 rk	33-44, 12 rk	33-44, 12 rk	33-44, 12 rk	33-44, 12 rk	33-44, 12 rk		6 rk	6 rk	6 rk	6 rk	6 rk	6 rk	6 rk
Number of cage lines		12	12	12	12	12	12	12		6	6	6	6	6	6	6
Period id		period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7		period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7
Study id		UJ_1	UJ_2	UJ_3	UJ_4	UJ_5	UJ_6	UJ_7		JP_1	JP_2	JP_3	JP_4	JP_5	JP_6	JP_7
No. mink																
No. female kits	animals/section	3939	3937	3937	3935	3930	6700	6700		793	793	790	790	790	1827	1256
No. male kits	animals/section	4745	4743	4743	4740	4737	6700	6700		1204	1202	1204	1199	1199	1827	1256
No. adult fema-les	animals/section	810	810	810	808	807	2184	2184		412	412	412	410	410	630	0
No. adult males	animals/section	0	0	0	0	0	0	0		0	0	0	0	0	0	0
Total no. mink	animals/section	9494	9490	9490	9483	9474	15584	15584		2409	2407	2406	2399	2399	4284	2512
Age of offspring	Days	107	121	142	170	190	50	85		107	121	142	170	190	50	85
Weight of mink																
Weight of female kits	kg/animal	1.44	1.64	1.88	2.04	2.00	0.54	1.10		1.44	1.64	1.88	2.04	2.00	0.54	1.10
Weight of male kits	kg/animal	2.31	2.71	3.24	3.65	3.67	0.64	1.63		2.31	2.71	3.24	3.65	3.67	0.64	1.63
Weight of adult females	kg/animal	1.5	1.6	1.7	1.8	1.8	1.5	1.5		1.5	1.6	1.7	1.8	1.8	1.5	1.5
Weight of adult males	kg/animal	3.6	3.6	3.6	3.6	3.6	3.6	3.6		3.6	3.6	3.6	3.6	3.6	3.6	3.6

Appendix 3. Technical drawings of the test section

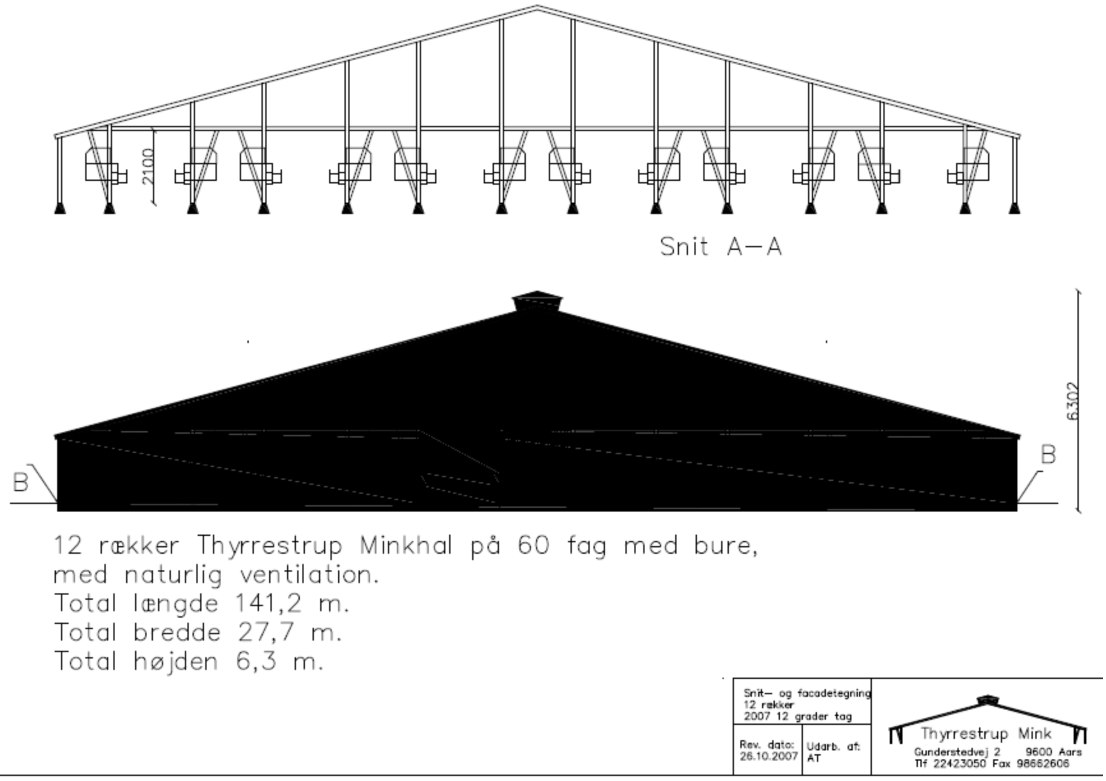
Test section farm id 2



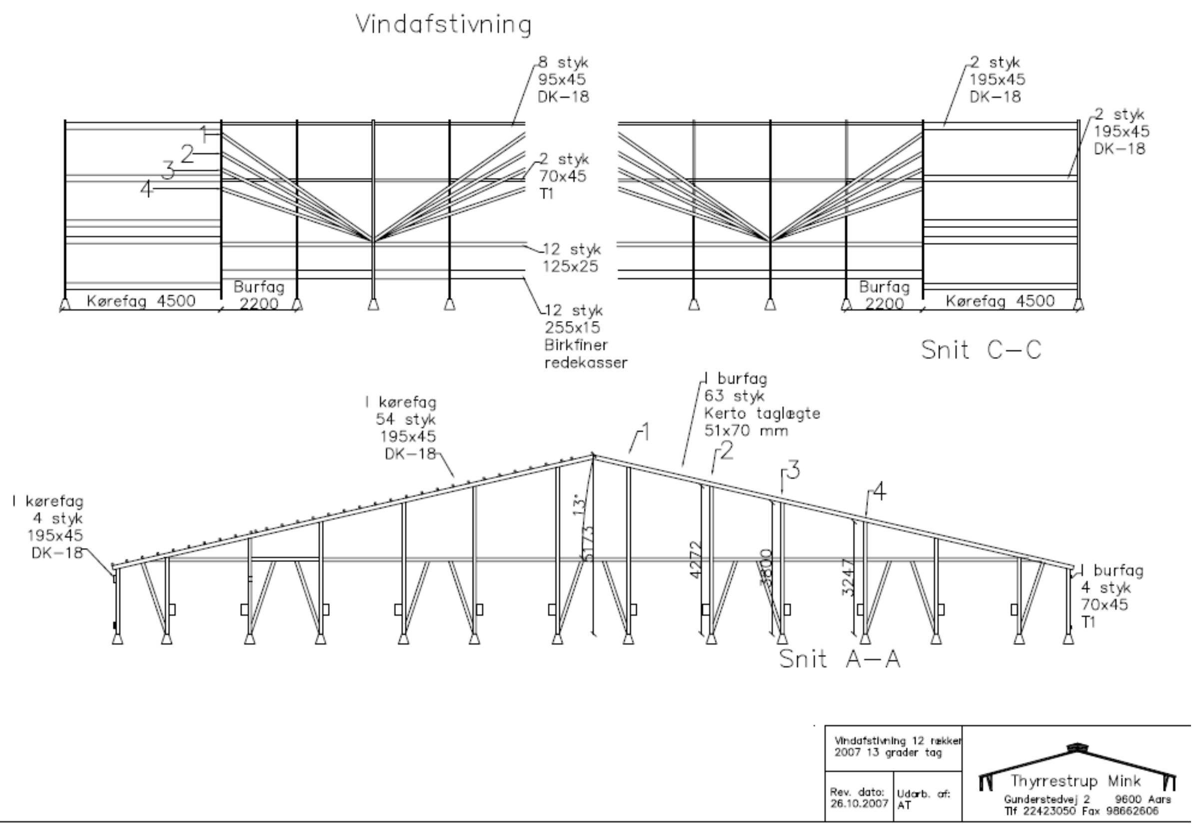
Test section farm id 4



Test section farm id 1



Test section farm id 3



Appendix 4. Example of log book for registration of no of mink and technical problems related to housing and management

Registrering af antal mink i målestalden i forbindelse med lugtmåling

I forbindelse med bestemmelse af lugt fra minkhaller, har vi behov for at kende antallet af mink i den hal vi måler på så præcist som muligt. I bedes derfor registrere antallet af voksne tæver og eventuelle voksne hanner, samt antallet af tæve og hanhvalpe i testhallen og indføre disse antal i skemaet herunder.

Skemaet udleveres eller sendes til os på adressen:

Att: Martin Nørregaard Hansen, AgroTech, Agro Food park 15, 8200 Aarhus N, eller på mail: mno@agrotech.dk

Bedrift: 3 Ulrik Jensen, Nørskovsmindevej 25, 8882 Fårvang. Tlf: 8687 1289, 8687 2324, 8687 2478

7 måledag 23. juli 2015

Tvilum Minkfarm	**7. måledag**
Hal	
Dato måledag	**23. juli 2015**
Dato optællingsdag	
Antal voksne tæver	
Antal voksne hanner	
Antal tævehvalpe	
Antal hanhvalpe	
ID af foderblanding	
Fejl eller problemer I forbindelse med udmugning (type, årsag, dato og tid)	
Fejl eller problemer I forbindelse med staldsystemet (eksempelvis huller i tag eller sider (type og årsag)	
Bemærkninger til produktionsforhold (eksempelvis flytning af dyr, sygdom etc.), eller gyllehåndtering som kan påvirke udledningen af lugt.	
Andet	

Appendix 5a. Concentration of tracer gas, odour, ammonia, and hydrogen sulphide, air exchange, and climatic condition during the sampling periods.

Farm id. 1 and 2

Test farm id	**Unit**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Test period		1	2	3	4	5	6	7	1	2	3	4	5	6	7
Date of measurement	dd-mm-yy	12-08-14	26-08-14	16-09-14	14-10-14	04-11-14	17-06-15	22-07-15	12-08-14	26-08-14	16-09-14	14-10-14	04-11-14	17-06-15	22-07-15
Start odour sampling	hh:mm	10:42	9:50	12:17	10:00	10:15	13:45	12:07	13:57	12:53	14:02	12:10	13:10	10:50	9:56
End odour sampling	hh:mm	11:17	10:20	12:47	10:30	10:45	14:15	12:37	14:30	13:30	14:32	12:40	13:40	10:45	10:26
Air volumen/mink	m^3/mink	1.72	1.72	1.72	1.72	1.73	1.18	1.71	0.88	0.87	0.87	0.87	0.86	1.04	0.80
Area below cages	m^2/mink	0.137	0.137	0.137	0.137	0.138	0.094	0.136	0.084	0.083	0.083	0.083	0.082	0.100	0.076
Measured tracer conc															
CO2 conc, inhouse	mg CO2/m3	922	1027	809	852	1309	940	969	848	1024	904	809	798	764	879
CO2 conc, background	mg CO2/m3	762	726	681	748	725	748	739	742	786	751	740	714	721	697
C_{tracer} CO2 conc netto	mg CO2/m3	161	301	128	104	583	192	230	106	238	153	69	84	43	182
Air exchange															
V air exchange	m3/h/section	109.928	61.645	153.268	195.958	34.693	95.564	69.300	40.658	19.055	31.208	71.697	59.495	63.617	24.872
V air exchange	m3/h/mink	19.3	10.8	27.0	34.5	6.1	11.5	12.1	27.6	12.9	21.0	48.2	39.7	51.5	15.4
Odour concentration															
A	OUE/m3	150	450	110	Bd	520	100	460	200	190	110	100	100	110	280
B	OUE/m3	170	350	120	120	340	310	380	190	190	110	140	bd	100	230
C	OUE/m3	160	510	130	130	320	350	340	160	200	120	bd	100	100	250
Mean	OUE/m3	160	437	120	117	393	253	393	183	193	113	113	100	103	253
STD (odour conc)		10.0	80.8	10.0	15.3	110.2	134.3	61.1	20.8	5.8	5.8	23.1	0.0	5.8	25.2
Median	OUE/m3	160	450	120	120	340	310	380	190	190	110	100	100	100	250
Sensitivity factor		1.06	1.05	1.02	1.05	0.99	1.10	1.10	1.06	1.05	1.02	1.05	0.99	1.10	1.10
Odour emission															
Emission/test section	OUE/s/hal	4.886	7.477	5.109	6.350	3.791	6.725	7.572	2.071	1.023	982	2.257	1.653	1.826	1.750
Emission/1000kg animal	OUE/s/1000 kg dyr	468	616	357	396	237	1.156	991	911	393	326	676	493	2.061	807
Emission/head	OU_E/s/mink	0.86	1.31	0.90	1.12	0.67	0.81	1.33	1.40	0.69	0.66	1.52	1.10	1.48	1.08
Climatic data															
Indoor temperature	˚C	24.9	18.9	18.3	14.0	15.3	14.0	27.8	21.2	25.1	18.0	16.0	12.8	11.1	23.0
Outdoor temperature	˚C	23.8	16.3	20.9	9.0	12.0	11.6	28.0	24.1	23.3	21	10.5	10.7	10.7	20.6
Ambient temperature	˚C	18.0	17.0	18.0	10.4	9.9	12.0	18.9	16.7	19.5	18.5	11.1	9.7	10.7	18.4
Air humidity	RH %	66.1	63.5	72.4	87.4	94.5	96.8	70.2	76.5	46.9	67.1	74.2	90.1	96.9	74.1
Precipitation	mm/h	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.5	0.1	0.0	0.0	0.0	2.2	0.0
Wind speed	m/s	7.2	2.9	6.3	5.2	2.53	7.8	5.3	5.1	2.5	6.6	4.1	3.8	6.3	5.9
Wind direction		S	SV	E	NE	S	S	SW	S	NE	E	NE	SW	SW	SW
Global radiation	MJ/m^2	603	592.7	574.1	200.7	89	68.8	431.3	328.0	598.2	465.9	141.8	106.8	97.7	531.6
Mean NH3 conc.	Ppm	3.0	3.5	1.0	1.0	2.0	ND	7.8	3.0	1.0	2.0	0.7	0.2	2.5	4.3
Mean H_2S conc.	Ppm	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 5b. Concentration of tracer gas, odour, ammonia, and hydrogen sulphide, air exchange, and climatic condition during the sampling periods

Farm id. 3 and 4.

Test farm id	Unit	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Date of measurement	dd-mm-yy	14-08-2014	28-08-2014	18-09-2014	16-10-2014	05-11-2014	18-06-2015	23-07-2015	14-08-2014	28-08-2014	18-09-2014	16-10-2014	05-11-2014	18-06-2015	23-07-2015
Start odour sampling	hh:mm	10:35	10:27	9:55	13:33	9:55	9:35	12:23	12:56	13:06	12:50	10:48	12:42	13:15	9:42
End odour sampling	hh:mm	11:10	10:58	10:25	14:03	10:25	10:05	12:53	13:30	13:38	13:20	11:13	13:12	13:45	10:12
Air-volumen/mink	m^3/mink	1.59	1.59	1.59	1.59	1.59	0.97	0.97	1.80	1.80	1.80	1.81	1.81	1.01	1.72
Area below cages	m^2/mink	0.135	0.135	0.135	0.135	0.135	0.082	0.135	0.137	0.137	0.137	0.138	0.138	0.077	0.132
Measured tracer conc															
CO2 conc, inhouse	mg CO2/m3	910	1453	1031	1185	1417	912	978	845	926	861	1095	873	843	751
CO2 conc, background	mg CO2/m3	727	761	745	762	789	703	709	749	752	785	830	727	718	709
C_{tracer} CO2 conc netto	mg CO2/m3	183	692	286	423	627	209	269	96	174	76	265	146	125	42
Air exchange															
V air exchange	m3/h/section	162.563	45.031	114.757	80.310	54.035	166.039	163.492	78.873	45.316	109.632	32.311	58.685	76.574	167.657
V air exchange	m3/h/mink	17.1	4.7	12.1	8.5	5.7	10.7	10.5	32.7	18.8	45.6	13.5	24.5	17.9	66.7
Odour concentration															
A	OUE/m3	120	230	170	300	500	200	260	120	140	120	190	110	360	50
B	OUE/m3	180	170	140	410	400	150	310	160	150	150	200	120	560	100
C	OUE/m3	140	200	260	450	500	180	260	120	140	150	220	150	200	100
Mean	OUE/m3	147	200	190	387	467	177	277	133	143	140	203	127	373	83
STD (odour conc)		30.6	30.0	62.4	77.7	57.7	25.2	28.9	23.1	5.8	17.3	15.3	20.8	180.4	28.9
Median	OUE/m3	140	200	170	410	500	180	260	120	140	150	200	120	360	100
Sensitivity factor		1.05	1.04	1.00	1.01	1.02	1.14	1.09	1.05	1.04	1.00	1.01	1.02	1.14	1.09
Emission															
Emission/test section	OUE/s/hal	6.623	2.502	6.057	8.626	7.004	8.148	12.565	2.921	1.804	4.263	1.825	2.065	7.941	3.881
Emission/1000kg animal	OUE/s/1000 kg dyr	371	121	251	322	262	729	583	643	345	701	271	307	2.561	1.134
Emission/head	OU_E/s/mink	0.70	0.26	0.64	0.91	0.74	0.52	0.81	1.21	0.75	1.77	0.76	0.86	1.85	1.54
Climatic data															
Inhouse temperature	˚C	20.1	21.4	18.6	17.4	12.8	14.5	17.5	23.5	29.7	22.9	14.8	12.3	16.6	17.5
Outdoor temperature	˚C	20.2	17.6	16.4	13.7	9.5	12.12	17.0	21.4	20.1	20.8	12.9	10.0	14.4	16.9
Ambient temperature	˚C	18.0	16.7	17.6	13.3	7.9	11.6	16.6	18.3	18.8	20.7	12.1	8.8	12.6	14.8
Air humidity	RH, %	69.1	66.1	79.9	85.1	93.9	83.4	57.5	70.9	57.4	66.4	98.2	92.7	78.1	72.7
Precipitation	mm/h	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Wind speed	m/s	6.0	2.0	4.4	2.1	2.0	6.0	6.4	6.8	2.2	5.2	2.2	1.8	8.0	5.8
Wind direction		SW	W	E	S	NE	W	W	SW	W	E	S	NE	W	W
Global radiation	MJ/m^2	545.0	451.4	468.1	203.4	50.3	358.0	663.1	489.0	634.0	499.5	195.7	94.0	427.7	533.3
Mean NH3 conc	Ppm	6.0	11.8	1.7	3.3	3.7	ND	1.7	4.0	5.0	0.8	1.7	1.2	ND	6.7
Mean H_2S conc	Ppm	0	0	0	0	0	0	0	0	0	0	0	0	0	0