Test Protocol

for

Slurry Separation Technologies

VERA

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Foreword

To meet the environmental challenges within livestock production, new technologies are being developed within the EU member states and elsewhere. These so-called environmental technologies are designed for different stages of the livestock production chain and may potentially enhance the eco-efficiency of livestock production by reducing material inputs, emission of pollutants and energy consumption, recovering valuable by-products and minimising waste disposal problems.

However, central stakeholders, such as farmers and authorities, only have limited information about the performance of the environmental technologies, which hampers the diffusion of these technologies in the livestock production sector. The Dutch Ministry of Infrastructure and Environment, the German Federal Ministry of Food, Agriculture and Consumer Protection, and the Danish Ministry of Environment, in cooperation with experts from Wageningen University & Research Centre in the Netherlands, the German Association for Technology and Structures in Agriculture (KTBL), the German Federal Research Institute for Rural Areas, Forestry and Fisheries, the German Agricultural Society DLG, the University of Hohenheim and Kiel University in Germany, the University of Aarhus in Denmark, the Danish Institute for Agro Technology and Food Innovation (AgroTech) and the Danish Pig Research Centre, have therefore decided to develop joint test protocols for testing and verification of a number of these environmental technologies for livestock production. The development of test protocols was initiated in October 2008 and the first version of this protocol was finalised in December 2009. The VERA test protocols are designed to test the environmental performance and operational stability of a range of environmental technologies for livestock production. Basically, the test protocols can be used to provide reliable and comparable information about the performance of new technologies to farmers, authorities and other stakeholders. The ground can thereby be prepared for these technologies to be used to a higher extent in meeting the environmental challenges of livestock production within the EU.

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Summary

This test protocol for slurry separation technologies was developed within VERA – Verification of Environmental Technologies for Agricultural Production. The protocol is a joint initiative between environmental authorities and experts from Denmark, the Netherlands and Germany with the purpose of providing a framework for independent verification of the environmental efficiency and operational stability of slurry separation technologies. This test protocol is also intended to help promote an international market for environmental technologies for agricultural production.

A slurry separation technology is defined in this protocol as a unit that separates liquid livestock manure (slurry) into one or more solid fractions and one or more liquid fractions. Examples are: screw presses, mechanical screen separators, gravity sedimentation techniques, decanting centrifuges, chemical treatment and reverse osmosis.

This protocol outlines the conditions for testing primary and conditional test parameters related to the environmental efficiency and operational stability of slurry separation technologies. The test focuses on verifying the efficiency of separating dry matter and nutrients from the raw manure into the solid and liquid fractions.

A VERA test of a slurry separation technology must be carried out by an independent test organisation. This test protocol outlines detailed requirements for the actors involved: applicant/manufacturer, test organisation and the farmer hosting the test facility. The test should be carried out on three similar manures representing the type of manure for which the environmental efficiency is to be verified. The technology should be operated on 3 consecutive days for each slurry and samples for measurement should be collected on each of these 3 days.

On completion of a VERA test, the test organisation must produce a test report containing a description of the technology tested, the test design and methods used. The test report must also include a presentation of the results obtained and an evaluation of the environmental efficiency and operational stability of the system.

1. Introduction

The environmental footprint of livestock production can be reduced by stimulating the use of environmental technologies designed for improving the eco-efficient performance. The eco-efficiency of livestock production is enhanced by reducing material inputs, emissions of pollutants and energy consumption, recovering valuable by-products and minimising waste disposal problems. Environmental technologies can be introduced into different stages of the livestock production chain, for example techniques for application in animal houses or techniques for reducing the emissions from manure storage, processing or land application.

In order to facilitate the diffusion of environmental technologies for agricultural production it is crucial that the environmental performance and operational stability of the technologies are thoroughly tested. These tests should be based on test protocols comprised of descriptions of common standard methods for measuring the environmental efficiency and operational stability of an environmental technology.

In a joint initiative between Denmark, the Netherlands and Germany, protocols have therefore been developed to test and verify different types of environmental technologies for agricultural production. This initiative is organised within VERA – Verification of Environmental Technologies for Agricultural Production. VERA was established in 2009 to promote an international market for environmental technologies for agricultural production. The overall purpose of VERA is to fill the information gap for central stakeholders by offering independent verification of the environmental performance and operational stability of environmental technologies by applying specific VERA test protocols.

This paper outlines the test protocol for slurry separation technologies. This includes definitions, requirements and conditions for the parties involved in the test, measurement and sampling methods, processing and interpretation of measurement results, and reporting.

A slurry separation technology is defined in this protocol as a unit with the primary function of separating livestock slurry into one or more solid and liquid fractions in order to concentrate the slurry fertiliser value in one of more of these fractions. The protocol presented here outlines the methods and demands in testing a technology for its separation efficiency of total solids, nitrogen, phosphorus and potassium.

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

However, for reasons of costs and time, test protocols have restrictions on the number of parameters that can be evaluated and the applicable methods are limited. The starting point in the design of the present test protocol was therefore to create an optimal balance between reliable information that meets the demands of the different users, and costs in terms of time and expense in carrying out tests.

This protocol describes the requirements for testing slurry separation technologies during a defined test period. The test period and the number of sampling days are determined by the requirements for a statistically adequate evaluation of the separation performance. During the testing period, the operational stability and any deviations from normal operational function must be observed and recorded, and reported in the test and evaluation report. However, specific test parameters for the assessment of long-term operational reliability and durability are not included in this protocol.

While it is recommended that separation technologies are re-evaluated 3-5 years after market introduction in order to assess the long-term effects and the durability of the separators, the present test protocol does not include specifications on such re-evaluation.

2. Scope

This protocol specifies the information needed for carrying out testing of slurry separation technologies.

The information specified includes:

- A comprehensive system description including user manual
- Technical performance of the separation technology based on data collected during the test period (requirements for test parameters, measurement methods, sampling strategy, data collection and handling, calculation methods and reporting are specified in the protocol)
- Evaluation parameters to assess the environmental performance and operational stability of the technology

In-house separation is not included in this test protocol.

After a test has been completed, verification of the environmental efficiency based on the test results can be carried out in accordance with this protocol. The test does not lead to a verification of the technology itself, but only its environmental efficiency and operational performance. VERA does not endorse, certify or approve technologies.

3. Terms and definitions

Additive (directly added to the slurry)

A product or substance that is manufactured or naturally occurring, which is added to manures with the purpose of modifying their biological, chemical or physical properties. Many additives are commercially available but most have not been subjected to independent testing and their effectiveness has therefore not been assessed.

Types of additives include:

- Bacterial enzyme preparations
- Plant extracts
- Oxidising agents
- Disinfectants
- Urease inhibitors
- Masking agents
- Acids, acidifying compounds
- Adsorbents

Downtime

The period when the system tested is not operating as a result of malfunction.

Enrichment factor

The ratio of the concentration of a compound in a specific output fraction to its concentration in the input fraction.

Liquid fraction

Liquid or thin fraction derived from the separation of slurry.

Manure

A general term denoting any organic material that supplies organic matter to soils together with plant nutrients, usually in lower concentrations than inorganic fertilisers.

Odour

Pleasant or unpleasant smell caused by different odorants with very different chemical, physical and biological properties. The odour concentration is given in European Odour Units per cubic metre air (OUE m^{-3}) and the concentration is measured by olfactometric analyses in accordance with European CEN standard EN 13725.

Particulate Matter (PM) – also referred to as dust. Airborne, finely distributed solid particles

Total dust = all particles emitted from a source with an aerodynamic diameter of 500 micrometres or less. PM10 = particles with an aerodynamic diameter of 10 micrometres, corresponding to 50% sampling efficiency. PM2.5 = particles with an aerodynamic diameter of 2.5 micrometres, corresponding to 50% sampling efficiency.

Processing

Treatment.

Recovery factor

See separation efficiency.

Separation efficiency

A measure of the efficiency (recovery factor) of a separation process. Several expressions exist, e.g. enrichment factor:

$$SepEf_P = (M_{output1} \cdot C_{P\_output1}) / (M_{input} \cdot C_{P\_input})$$

where M is mass flow and C is the concentration of a specific compound P. The separation efficiency specifies the proportion of a compound that ends up in a specific output stream (recovery factor).

Separation technologies

Technologies that divide liquid livestock manure (slurry) into one or more solid fractions and one or more liquid fractions. Examples are: screw presses, mechanical screen separators, gravity sedimentation techniques, decanting centrifuges, chemical treatment and reverse osmosis.

Slurry

Faeces and urine produced by housed livestock, usually mixed with bedding material and water during management. The dry matter content of slurry is usually in the range 1-10%. Slurry is a mixture of liquid and solid materials, where the majority of the solid materials are typically undissolved in the liquid phase and therefore precipitate from the liquid during longer periods of storage.

Solid fraction

A fraction from separation with a higher content of solid material (e.g. dry matter or phosphorus) than the input material. The solid fraction is normally stackable.

Uptime of the system

The period of time when the system tested is functioning.

4. System description

The manufacturer/applicant is responsible for providing a precise and full description of the technology before initiation of a VERA test. This information should be provided as essential data for the test institute, users of the system, verification authorities, etc. and to some extent also forms part of the final test report. The system description must include all relevant and essential information that is needed to:

- Organise and design the test
- Enable the farmer to operate, maintain and monitor the system properly
- On-line monitor the system including the key parameters needed for the determination of uptime/downtime of the system (only where relevant)
- Allow the verification authorities to check the system after a test has been carried out
- Provide insights into the working mechanisms of the system.

The **detailed description of the technology** to be tested must include:

- A list of the (technical) components needed for application, including type (e.g. material and characteristics), technical and functional descriptions and design
- Description of the technique applied, and if relevant, type and composition of additives used, their complete chemical name, concentrations and provisions including the accuracy of application
- Illustrations and/or diagrams of the system (top and sectional views, details if necessary)
- Technical description (capacity, dimensions, weight, power requirements)
- Installation (fixed or mobile installation)
- Description of the slurry input (recommendations/requirements on the types of slurry that can be used in the separator. For instance pig slurry and cattle slurries with dry matter contents between 2% and 10%).
- Recommendations from the manufacturer of the separator regarding capacity for storage of liquid and solid fractions
- A list of the essential design and operational parameters (ranges) that are specific for the system to be tested and are decisive for proper function, and should therefore be monitored during the test.

See example in Annex A.

In addition, the description must include detailed instructions on operation, maintenance and monitoring.

The manufacturer/applicant must provide general information about:

- Environmental and occupational safety of the technology applied
- Essential parameters for the calculation of the uptime/downtime of the system (although the test institute is responsible for a professional evaluation of whether this information is reliable and sufficient)
- Predicted durability of the system and its components

- Warranty provisions
- A list of demonstration units already working (animal category and type of housing system) if available.

User manual

The user manual for the technology must be available in the local language. It must be written in consideration of EN 62079:2003 *Preparation of instructions – Structuring, content and presentation,* which provides general principles and detailed requirements for the design and formulation of all types of instructions, and Machinery Directive 2006/42/EC, which provides the regulatory basis for the harmonisation of essential health and safety requirements for machinery.

The user manual must include the information provided with the system description according to the descriptions above in this chapter and should in particular include instructions for:

- The operation of the system and technical installations
- The prevention and handling of incidents (environmental safety)
- Operational health and safety measures
- Service and maintenance
- Monitoring of the installations.

5. Requirements

This chapter describes the requirements related to the testing of slurry separation technologies. The requirements described apply to the planning of test activities, test facilities and test organisation, as well as requirements for the framework and contents of the test plan.

In addition, the chapter describes the measurement parameters to be included in the test and a specification of the methods to be used and of the persons/organisations responsible for providing the specified information. Finally, the chapter describes the requirements related to the impact of the system on occupational health and safety, as well as animal health and welfare.

5.1 Pre-testing or full testing of a technology

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

It is strongly recommended that pre-testing of a new technology be carried out before a full VERA test is initiated. It is also recommended that a full test only be initiated when the system/technology has been proven to be stable and functional.

During pre-testing of a technology, parts of the test protocol can be used in order to clarify and optimise the performance and stability of a new technology. The manufacturer may visit the test facility at any time during pre-testing.

However, during a full test of a technology with the aim of VERA verification, all the requirements mentioned in the following sections have to be fulfilled.

This means that the results from pre-testing can only be used as part of the results from a full test if all the specific requirements listed below (5.2 - 5.5) are fulfilled, which includes requirements on quality-related issues and restrictions on farm visits and modifications of the technology.

5.2 Requirements on organisation of the test activities

The testing of a new slurry separation technology involves various actors:

1. The applicant/manufacturer, wishing to have a technology system tested.
2. The test institute that carries out the required test.
3. The farmer(s) who owns the facilities where the tests are carried out.

Certain requirements are related to each of these three categories of actors, as described in the following sub-sections.

Test plan

It is required that the applicant or test institute writes (in the local language) the test plan based on the template in Annex B, and that all questions included in the template are answered. To reduce the risk of test results being rejected by the verification authority due to inconsistencies between the test results and the protocol requirements, it is advisable to consult the relevant verification authorities in the event of uncertainties about the preparation of the test plan.

The applicant or the test institute can decide whether the test plan should be treated as confidential.

Full system description of the technology tested

The applicant/manufacturer is responsible for providing a full description of the system of the technology to be tested prior to the start of a full VERA test, cf. Chapter 4. The description must include detailed instructions for operation, service, maintenance and monitoring.

Requirements and restrictions during the test period

During operation of the separator system, the applicant/manufacturer is responsible for electronic or manual logging of a number of key parameters to check the operation of the system. This logging must include those parameters essential for the calculation of the uptime/downtime of the system, cf. chapter 4.

The applicant/manufacturer of the technology is not allowed to visit the farm during the test period unless contacted by the farm owner concerning operational problems. In such cases, the operational problems must be dated and described in the test logbook by the farmer or the test institute. In addition, a dated record must be made of when and how the problem was solved, to be signed by the farmer and the applicant/manufacturer when repairs have been completed.

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

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

The logbook must be made available to the farmer and the test institute at any time during the test period.

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

5.3 Requirements on the test facility

The separation technology must be tested under farm conditions that are representative of the standard practices for which the technology is intended for use. This means that requirements need to be defined to ensure that both the design of the test facility and the management conditions during the test period are representative of the farm characteristics concerned. Test facilities must possess farm characteristics that can be considered representative of standard practices in the country in question.

5.4 Requirements on the test institute

General requirements on the test institute to ensure adequate quality of all activities related to the test measurements and reporting are specified in this section.

The test institute and laboratories involved must fulfil the following requirements:

1. Sampling and measuring of all test parameters listed in Table 3 must be carried out by laboratories accredited according to ISO/IEC 17025 *General requirements for the competence of testing and calibration laboratories.* In addition, it is recommended that the test institute fulfil the general requirements of ISO 9001 *Quality management.*

2. For specific measurement parameters, as defined in section 5.6, laboratories must fulfil the specific requirements of the quality standard indicated.

3. The test institute and laboratories involved must demonstrate relevant experience and expertise to the International Verification Committee (IVC). Relevant experience should include measurement experience in livestock production in general. The technicians and researchers involved should have a thorough understanding of livestock production systems and their management. The test institute must demonstrate its ability to combine measurement experience and livestock production expertise into data collection, handling, analysis, interpretation and reporting to meet the standards of sound research.

4. The test institute must demonstrate its independence from the other actors involved.

5.5 Test design and sampling strategy

5.5.1 Test design

The test must be designed so as to allow the mass balances of total dry matter, organic matter, total nitrogen, ammonium nitrogen, phosphorus, potassium etc. to be calculated.

Figure 1 shows a simplified model of a slurry separator where the rectangular box is a symbol for the system boundaries. The separation unit includes only one process operation in some systems. In more advanced systems the separation unit consists of two or more process operations, e.g. one process operation for addition of polymers followed by a screw press.

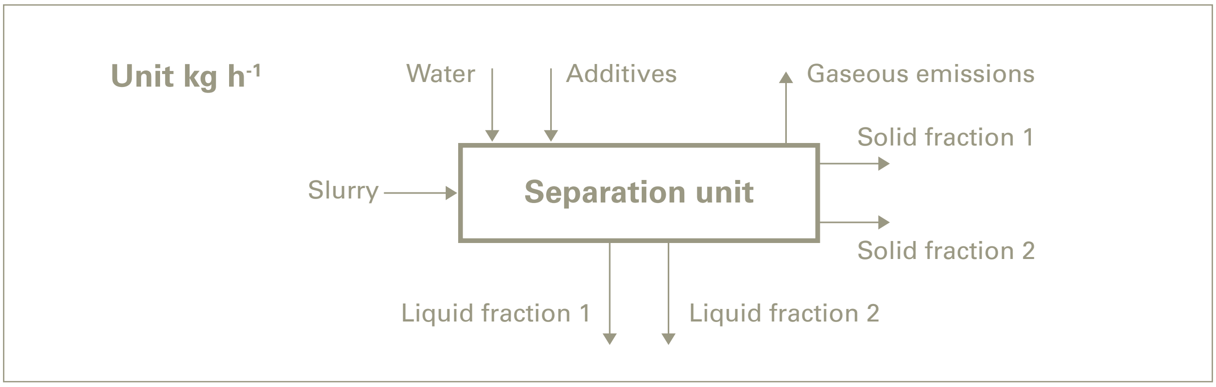

Figure 1. Simplified model showing input and output streams in a slurry separation unit.

During planning of the test it should be decided jointly by the test institute and the verification authorities whether it is relevant to measure emissions of ammonia, hydrogen sulphide, nitrous oxide or other gaseous substances from application of this particular technology. Based on the design and the function of the separation unit, an assessment should be made on whether there is a potential risk of such emissions.

Before starting the test, a sampling schedule must be drawn up by the test institute and accepted by the partners involved in the test. Requirements for the test design are described in Table 1.

Table 1. Sampling strategy for test of slurry separation technologies

Parameter	Requirement
Test location	The test can be carried out at a commercial farm or at a test farm. The test has to be carried out under normal conditions that reflect how the separator is used by the farmer at farm level. The test location should be approved by the test institute.
Slurry	The separation technology should be tested on a minimum of three (3) slurries originating from three (3) different sites. However, the slurries should be comparable with respect to animal type.
Test period	For each of the slurries tested a minimum test period of three (3) working days of operation is required. Prior to testing a new slurry, one day should be allowed for adjustment of the separator. The test can be performed throughout the year. Samples for chemical and physical analyses should be collected every day for three of the five days of operation.
Running hours	During the test period, the separator must be run for at least five (5) hours per day.

Slurries from the following animal type categories can be tested:

- Piglets
- Lactating sows
- Pregnant sows
- Finishing pigs
- Dairy cattle (incl. calves)
- Beef cattle
- Mink
- Others

The tested slurries must be described with respect to animal type, bulk density, total solids etc. and the tested slurries must be comparable with respect to animal type and slurry origin.

Sampling

The performance of a slurry separator is determined by sampling, measuring and analysing the input and output flows. The sampling and measurements must be carried out while the system is in normal operation (without any disturbances or malfunctions).

Only a general description of the methods for sampling and measurement can be given, since storage facilities, type and configuration of manure treatment systems vary significantly. A specific sampling and measurement protocol must be written for each performance test of a slurry separator.

Recording

During the period of sampling and measurement, all matters concerning sampling and measurements must be recorded in a logbook. This means that all relevant information and problems occurring during the test must be recorded in the logbook.

5.5.2 Sampling of liquid and solid streams

The technician carrying out the sampling must endeavour to take samples that are representative of the flow at the moment of sampling. Below, some examples are given as an indication of how representative samples can be collected. During sampling sufficient action should be taken to collect representative samples from several flows.

The sampling method applied and the equipment used must be recorded in the logbook.

Sampling from a pit

The contents of the pit should be thoroughly mixed with a mixer (or a pump) before sampling. Everything in the slurry should be 'in solution' while the samples are being collected. Consequently, while the mixer is still in operation the sample should be collected from the pit, for example with a bucket. Afterwards, the contents of the bucket should be well stirred and a sampling jar filled from the bucket.

Sampling from a pipe

If there is a tap (or a valve) on the pipe, the tap should be opened. The preferred position of the tap is at the bottom of the pipe. When the tap is located at the top of the pipe, it is possible that sedimentation may occur in the pipe and that only a relatively thin fluid is sampled. If possible, the whole flow should be carried away through the tap and not only a part of the flow. This ensures that the fluid from the tap has the same composition as the flow that normally enters the installation. The first fluid that comes from the tap must be discarded. All stagnant fluid from the pipe and tap must be flushed away before a sample is collected. Subsequently a bucket should be filled with the fluid from the tap. Afterwards, the contents of the bucket should be well stirred and a sampling jar filled from the bucket.

Sampling from solid material in a heap

When a large heap is sampled, careful attention must be paid to obtaining a sample that is representative of the whole heap. A minimum of four (4) sub-samples should be collected from different parts of the heap (left, right, several depths, etc.). These sub-samples should be mixed thoroughly. Afterwards, a sample from this mixture should be collected in a sampling jar.

Storage of samples

Samples must be collected in airtight, lockable jars. Immediately after sampling the jar must be closed and stored in a cold storage unit (refrigerator or freezer). This prevents the continuation of conversion processes in the sample or the disappearance of volatile substances (e.g. ammonia). The samples may be stored for a maximum of 48 hours in a refrigerator prior to analysis. If a longer storage time is required, the samples must be stored in a freezer.

5.5.3 Measurement of liquid and solid mass flow

When the samples have been analysed, the concentration of various substances in the different flows can be determined. Besides the concentration, it is also important to determine the amount (tonnes or cubic metres) of each flow in the system. A system balance can be made based on knowledge of the total flow and compound concentrations and possible emissions can be quantified. Therefore the mass/volume flow (e.g. kg $hour^{-1}$, litres $hour^{-1}$, kg day^{-1}) of all flows must be determined. These flows must be measured as accurately as possible. Some examples are presented below as an indication of how flow can be measured.

When it is not possible to measure the flow in a specific situation according to one of the possibilities outlined above, efforts should made to measure the flow as accurately as possible while bearing in mind the information presented below. Sufficient action must be taken to measure representative flows.

The method and equipment used for flow measurement must be recorded in the logbook.

Flow meter ('Water meter')

If a flow meter is present in a pipe, the flow is determined by reading the meter. If the volume (amount of litres or cubic metres) is displayed, then the flow can be determined by measuring volume of flow through the pipe per minute with a stopwatch. The measuring period must be long enough to allow a considerable amount of fluid to flow through the pipe. Ordinary flow meters (paddle wheel meters) have problems with contaminated fluids such as slurry. Therefore reliable flow measurement can only be carried out with magnetic-inductive flow meters.

Bucket – stopwatch method

If a fluid streams freely from a pipe, a bucket can be held at the end of the pipe and the time taken to fill the bucket can be measured with a stopwatch. For reliable measurement it is necessary that the measurement takes at least 20 seconds. If necessary, a larger bucket or container must be used for the measurement to ensure a minimum measuring period of at least 20 seconds. In the same way, the mass flow of a solid material can be determined by collecting the material in a bucket or other container and weighing the bucket/container afterwards.

1. If a fluid is drained from a tap (or valve) which is opened during measurement but in normal operation is closed, an inadequate measurement is made. This is because as a result of the open tap the pressure in the system is lower than in normal operation, which results smaller flow than during normal operation.

2. For liquid flows it is sufficient to determine the amount of litres or cubic metres per hour (1 litre weighs 1 kg). Solid flows must be weighed in order to determine the amount of kg per hour (1 litre weighs less than 1 kg).

Level measurement

If slurry or fluid is pumped from a pool, tank or silo (hereafter called tank) the height of the liquid level can be measured in order to estimate the volume change. For reliable measurement it is necessary to have a difference in level of at least 2-3 centimetres. The surface area of the tank (m^2) must be measured accurately in order to calculate the amount of fluid that has been pumped from the tank. No slurry or fluid (e.g. rain) may enter the tank during measurement of the levels. In the same way, the volume of fluid which is pumped into a tank can be determined [1].

5.5.4 Other measurements

All activities that are carried out in the daily operation of the system and especially deviations from the daily routines, disturbances or malfunctions must be recorded in the logbook in order to provide full background information about the system during the sampling and measurement period.

5.5.5 Gaseous emissions

No harmonised methods are currently available for measuring emissions from a slurry separator. Therefore measurement of emissions of odour, ammonia and greenhouse gases is not mandatory in this test protocol. However, if the technology has an expected efficiency in reducing gaseous emis-

[1] This calculation is only valid for a tank with perpendicular side walls. If the side walls are inclined, the slope of the side walls must be determined before the amount of the fluid that has been pumped can be calculated. If the tank/silo is cylindrical, the diameter must be determined before the amount of pumped fluid can be calculated.

sions it is recommended that other standard methods for measuring gaseous emissions be applied, as outlined in Table 2.

5.5.6 Statistical treatment

Description of test design:

- Three comparable slurries should be tested. The separator can be moved to different locations, or the slurries can be transported to the separator.
- One (1) sample per day consisting of minimum five (sub-samples) from each stream of the separator should be collected simultaneously from each of the three slurries tested after a specified running-in period.
- Samples should be collected every day for 3 days.

By collecting the samples simultaneously (or with as small a time lag as is practically possible) and assuming that the amount of slurry inside the separator is small compared with the slurry flow, fluctuations in slurry flow and composition during the period of one sampling can be minimised.

For each sampling, all the parameters of interest (see Tables 2 and 3) must be analysed and separation efficiencies calculated. Thereafter the mean values for the three sampling days of the same slurry are calculated. Finally, the mean, standard deviation and 95 per cent confidence limits of all the performance parameters of the three slurries are calculated.

5.6 Measurement parameters

Two lists of measurement parameters are shown in the tables below: a list of primary measurement parameters (Table 2) and a list of conditional measurement parameters (Table 3).

Some of the conditional parameters are mandatory, while others are optional. In Table 3, the mandatory and optional measurement parameters are marked ‘M’ or ‘O’, respectively. Both tables mainly present the principles of measurement.

Sampling from the slurry, liquid and solid fractions should be carried out during the 5 hours of operation at each of the 3 days of operation. A minimum of 5 sub-samples must be collected from each stream equally distributed during the 5 hours of operation. The 5 sub-samples must be mixed into one sample that constitutes a representative sample from the stream.

Table 2. Primary measurement parameters

Parameter	Units	Numbers of samples per slurry	Measured in	Suggested measuring methods [1]
Total solids, TS	kg t^{-1}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	2540 B [2]
Total volatile solids (VS)	kg t^{-1}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	2540 E [2]
Total nitrogen	kg t^{-1}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	Kjeldahl/Dumas
Ammonium nitrogen	kg t^{-1}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	71/393/EØF
Bulk density	kg m^{-3}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	GLP
Mass flow	t h^{-1}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	
Emissions of ammonia (only if relevant)		Minimum 4 samples. Sampling time: 24 hours	Air	Photo-acoustic monitor (NDIR), FTIR spectrometer, NOx-chemoluminescence monitor, impinger system (impingers can only be used when the ventilation rate is fixed)
Total phosphorus	kg t^{-1}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	3030H/3030I/3030J [2]
ICP: ISO/DS 11885,1998				
Total potassium	kg t^{-1}	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	3030H/3030I/3030J [2]
ICP: ISO/DS 11885,1998				
pH	pH units	1 per day from each stream for 3 days.	Slurry, liquid and solid fractions	GLP

1 In cases where measuring methods other than those suggested above are applied, the method should be described in detail.

2 Greenberg, A.E., Clesceri, L.S., Eaton, A.D. (Eds.). Standard methods for the examination of water and wastewater, 18th edition 1992. American public health association, Washington.

Table 3. Conditional measurement parameters

Parameter (M)=Mandatory (O)=Optional	**Units**	**Sampling conditions** (where, how and how often)	**Measured in**	**Measuring method** (reference to the method)
Capacity of separator (M)	t slurry h^{-1}			
Electricity consumption (M)	kWh t^{-1}			
Consumption of water (M)	m^3 t $slurry^{-1}$			
Consumption of additives: e.g. polymer (all additives must be listed) (M)	kg t $slurry^{-1}$			
Time consumption for start-up procedure (M)	hours			
System running hours (M)	hours			
External temperature (M)	˚C	Continuous measuring methods: based on hourly values (24 samples).		
Noise (indoor and noise emission) (M if relevant)	dB (A)	Outdoor 1-2 m from ventilation outlet	Air	Noise level meter ISO 3746
Emissions of odour (M if relevant)	OUE s^{-1}	Measured in ventilation outlet if possible	Air	EN 13725:2003 Olfactometry
Emissions of hydrogen sulphide (H_2S) (O)	mg s^{-1}	Combine with odour sampling	Air	Jerome (Measurement principle)
Emission of nitrous oxide (N_2O) (O)	mg^{-1}	Combine with odour sampling	Air	GC-ECD, Photo-acoustic infrared monitor
Methane (CH_4) (O)	mg s^{-1}	cf. Table 2 'Ammonia' and 'General recommendations' above, or combine with odour sampling		
COD (O)	kg t^{-1}		Slurry and liquid fraction	ISO 15705
Slurry temperature (O)	˚C		Slurry	
Total copper (O)	kg t^{-1}		Solid and liquid	Oplukning: SM 3030(J) ICP: ISO/DS 11885,1998
Total zinc (O)	kg t^{-1}		Solid and liquid	Oplukning: SM 3030(J) ICP: ISO/DS 11885,1998

5.7 Occupational health and safety requirements

Technical installations in the slurry separation technology must comply with:

- Machinery Directive 2006/42/EC and Amending Directive 95/16/EC, which refer to safe design and construction of machinery and proper installations and maintenance without putting persons at risk. It is the responsibility of the manufacturer, importer or end supplier of the equipment to ensure that the equipment supplied is in compliance with these Directives.

- Council Directive 89/655/EEC of 30 November 1989 and Amendment 2007/30/EC concerning the minimum health and safety requirements for the use of work equipment by workers at work. The safety instructions must be documented, for example in a safety data sheet, and must be observed carefully.

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

Before the beginning of any work, the installation must always be shut down. In addition, good ventilation and appropriate protective equipment, such as acid-resistant protective clothing, eye protection, etc. are required. Moreover, protective installations such as eye wash and shower units must be made available and kept in good working order.

5.8 Animal welfare

Since only external treatment of the slurry is within the scope of this test protocol the operations will not have any influence on animal welfare.

6. Test report and evaluation

This paragraph describes the requirements on the test report, including formalities for system and test description, data handling, statistical analysis, etc.

The test report must be written in English and, if necessary, in the local language. The report must include chapters with the subheadings listed below. The following text gives a description of the contents that must be included in the chapters and the contents of the individual sections.

Foreword

The foreword should include:

- A description of the three parties that have been involved in the test – the applicant, the test institute and the farmer(s) – and their respective roles during the test period.
- Specification of the test period, including dates
- Date and signatures of the person(s) responsible for the test
- Name and address of the test organisation.

Introduction

The introduction must include a description of the background regarding the environmental need for implementation of the technology in question, include a description of the manufacturer involved in the test, and give a general description of the slurry separator to be tested. The introduction should include an explanatory description of how the system/technology tested can meet these environmental challenges by decreasing emissions of environmental pollutants and thereby reducing the overall environmental effect of the agricultural production system in question.

In addition, the introduction must include a description of the applicant/manufacturer involved in the test and give a general description of the separation technology. If the applicant/manufacturer has carried out previous tests, these must be described and references provided.

Materials and Methods

The materials and methods section must include a description of the:

- Slurry involved in the test
- Slurry separation technology, including photos and any drawings
- The measurement method applied and its measuring uncertainty. If the method applied deviates from those described in this protocol, the method should be thoroughly described.
- Sampling procedure ´where, when and how´
- Description of calculation and statistical methods used.

The test design must be described, including dimensioning of the test and measurement methods, with a specification of the measurement instrument used, the measurement points and the measurement frequency and calibration procedures

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

Results

The description of the results must start with specification of the separation efficiencies of total solids, nitrogen and phosphorus, which is the primary target of the test. The individual raw data must be shown in graphs and subsequently the processed data must be presented in tables together with median, mean and 95 percentiles.

Raw data of the total solid content in each raw slurry must be presented together with the separation efficiencies of nitrogen and phosphorus on each slurry.

A mass balance for nitrogen must be presented.

The mean and standard deviation of the conditional measurement parameters must be shown in tables and commented upon in the text.

An evaluation of the operating stability of the system must be given. This evaluation must be based on observations made during the entire test period and must include all recorded data describing the stability of the slurry separation technology.

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

- Occupational health and safety;
- The overall environment.

These evaluations must cover situations with normal operation of the slurry separation technology system and any unforeseen use and problems.

The test report must include advice to the authorities on how to inspect the system.

In cases where the verification body deems it necessary, the raw data should be made available by the applicant or the test institute for interpretation of the results and conclusions presented.

Discussion and Conclusions

The results must be discussed in relation to aspects of the working principle of the system, the plausibility of the results and findings in related research reports.

The conclusions must sum up the major results and validate the slurry separation technology in general. The conclusions section should only include aspects that have been verified in the results section in the test report.

References
Relevant references to be specified.

Annexes
Annexes can be added if relevant.

Bibliography

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

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

ISO/IEC 17025:2006 General requirements for the competence of testing and calibration laboratories

ISO 12100-2:2003 Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles

Annexes

Annex A (informative) Template for system description

System description

1	**Manufacturer**	Name of company
2	**Model**	Model name and number
3	**Dimensions**	Weight (kg) Height (m) Width (m)
4	**Power requirements**	
5	**Additives used in process**	Type and amount of the different additives (including water)
6	**Mobile or fixed installation**	
7	**Separator type**	Screw press, decanting centrifuge, mechanical screen separator, combination of several techniques, etc.
8	**Capacity**	Amount of input slurry treated per hour.
9	**Specification of input slurry the separator is capable of treating**	Slurry from which animal category. Minimum and maximum of dry matter % of input slurry. Recommendations regarding age of input slurry. Recommendations regarding pretreatment (e.g. mixing).
10	**Short description of the function of the separator in 'running' text**	

Annex B (informative) Template for a test plan

Name of test organisation

Test plan for [name of slurry separation technology]
[Name of technology/system] **delivered from** [name of manufacturer/applicant]

Contact data etc.:

Farmer:	
Address of housing unit (if different from address of the herd owner):	
Health status:	
Visiting rules:	
Start of test of test (dd/mm/yy):	
End of test (dd/mm/yy):	
Technician responsible:	
Technician(s):	
Consultant(s) from the test organisation:	
Local advisor/veterinarian:	
Contact person from the company financing the test: Service technician(s) from the supplier of the technology/system:	
File:	

Name of test institute

Test plan for [name of slurry separation technology]
[name of the slurry separation technology] **from** [name of manufacturer/applicant]

Contact data etc.:

Farmer:	
Address of the test location (or the address to which the slurry is delivered):	
Start date of test (dd/mm/yy):	
End date of test (dd/mm/yy):	
Technician responsible from the test institution:	
Technician(s):	
Consultant(s) from the test institute:	
Service technician(s) from the applicant:	
File no:	

Background and aim [maximum of one page]

A short description of the system and a reference to where details can be found should be included. The development process of the system and any previous tests must be specified (all references must be included in the reference list at the end of the test plan).

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

Test procedure

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

- Description of the slurry separation technology where the test was carried out. (Previous descriptions of the individual components in the system/technology must be specified in an appendix to the test plan. The verification authorities can then check that the system/technology applied is identical to the system/technology tested).
- Specification of the primary measurement parameters (Table 2).
- Specification of the conditional measurement parameters (Table 3).
- Description of the location of measurement points, instruments and how they are calibrated.
- Timetable for the entire test period.
- Logbook. Location of logbook and description of parameters to be recorded.

Data recording
The tables provided for recording data must be presented.

Allocation of responsibility
The allocation of responsibility must cover all working processes in the system/technology, so that the technician can use the list when instructing the stockmen.

A list must be drawn up for each section and system/technology.

What needs to be done	When	By whom

Processing of results
Raw data must be presented in tables, which must be included as appendices to the final test report. The raw data must also be presented in graphs, which must be included in the results section in the final test report.

The primary measurement parameters must then be analysed in accordance with the specifications given in the test protocol to determine whether the concentration after treatment in the slurry separation technology system is statistically significantly different from the concentration before treatment. For the primary parameters, the mean must be calculated instead of the median. The mean and the standard deviation must be calculated for the secondary parameters.

Appendices
The appendices must include all data recording tables, e.g. tables of:

- Odour recordings
- Ammonia recordings
- Dunging behaviour
- The calculated separation efficiency.

Compensation
Any arrangements made about providing the farmer with financial compensation in connection with the test must be described, e.g. farmer paid DKK/Euro XXX per hour for any extra work.

Updates to the test plan

The test plan must be updated every time changes are made. It is not sufficient to list the changes in the logbook. For each update, the date for the changes must be noted and the test plan must be assigned a new version number.

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

It is recommended to have the test plan verified by the verification authority prior to initiation of a VERA test.

Annex C (informative) Examples of the contents of the user manual

Operating instructions include e.g. the:

- Relevant parameters to be periodically checked by the operator (daily/weekly etc.)
- Adjustment of the parameters
- Position and access to the relevant components of the installation
- Operation during service times of the separation system
- Documentation of the operation (data and maintenance work).

Service and maintenance instructions include e.g.:

- A maintenance schedule determining single and repeat tasks and their frequency, such as cleaning of the system components and replacement of components
- The position and access to the maintenance points
- Tools, protective devices and auxiliary materials needed.

The majority of the maintenance and repair work necessary can be carried out by the operator of the installation. In addition, a maintenance contract should be agreed with the manufacturer.

Instructions for the prevention and handling of incidents (environmental safety) include e.g.:

- Type of possible incidents (e.g. water spills, power failure, breakdown of ventilation), prevention and measures to be taken
- Waste management, i.e. production, amount, composition and handling of wastes
- Manufacturer's hotline.

Monitoring instructions depending on the type of system being tested.

VERA

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