VERA TEST PROTOCOL

for
Slurry Separation Technologies

Version 3:2018-07

VERA

Verification of Environmental Technologies for Agricultural Production

Foreword

To meet the environmental challenges in livestock production, new technologies are being developed within EU member states and elsewhere. These so-called environmental technologies are designed to potentially enhance the eco-efficiency of livestock production by reducing material inputs, emissions of pollutants, and energy consumption, in addition to recovering valuable by-products and minimising waste disposal problems. Environmental technologies in agriculture can be introduced in different stages of the production chain, e.g. techniques applied in animal houses or techniques for manure storage, processing, or land application.

However, central stakeholders, such as farmers and authorities, only have limited information about the performance of these technologies, which hampers their diffusion in the agricultural sector.
The Danish Ministry of Environment, the Dutch Ministry of Infastructure and Environment, the German Federal Ministry of Food and Agriculture and the German Federal Environment Agency, in cooperation with international technical experts, have therefore begun the development of common test protocols for the testing and verification of such environmental technologies for agricultural production. The VERA test protocols are designed to investigate the environmental performance and operational stability of a technology, thus providing reliable and comparable information about the performance of technologies to farmers, authorities, and other stakeholders.

This initiative is organised by VERA - Verification of Environmental Technologies for Agricultural Production. The VERA cooperation was established in 2008 to promote an international market for environmental technologies for agricultural production. The overall purpose of VERA is to fill the information gap for main stakeholders by offering independent verification of the environmental performance and operational stability of environmental technologies determined by applying specific VERA test protocols.

The first version of the protocol for slurry separation technologies was finalised in December 2009, with Version 2 being completed in July 2013. The present Version 3 was published in July 2018.

Questions and comments on the VERA test protocols should be sent to

International VERA Secretariat
www.vera-verification.eu
info@vera-verification.eu

Amendments

This edition of the VERA test protocol has been thoroughly revised to reflect the latest-state-of-the-art, and differs from the earlier Version 2:2013 as follows:

a. In order to obtain more reliable information about the system and its function, **mass balances for all mandatory parameters** are required, not only for nitrogen.

b. Apart from livestock slurry, biogas slurry (digestate) is also now within the scope of this test protocol.

c. The parameters are grouped into categories by describing characteristics of the slurry or biomass, the technology itself, and the emission parameters. This should make its structure clearer.

d. Requirements and recommendations are more precisely indicated, especially for the description of sampling and testing of certain parameters, such as mass flow and emission measurements.

e. With the simultaneous revision of other VERA test protocols, the general format and structure of the documents have been harmonised by means of a new **'high level structure'** for VERA test protocols. This should help the user to navigate the documents, in addition to being closer to the format of an international standard.

f. Instead of listing suitable measurement methods for the test parameters, this new version of the VERA test protocol introduces the **'standard reference method'**, according to EN 14793. A standard reference system is now defined for the key measurement parameters. This method has been validated, has proven its suitability for such use, and, as such, is commonly recognised. The equivalence of any other measurement method must be demonstrated, e.g. as described by EN 14793.

Previous editions

VERA Test Protocol for Slurry Separation Technologies Version 2:2013-07

VERA Test Protocol for Slurry Separation Technologies Version 1:2009-12

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1. Introduction

The objective of this test protocol is to specify the test procedures for the environmental efficiency of slurry separation technologies. This includes definitions, specific requirements and conditions for testing, measurement and sampling methods, processing and interpretation of measurement results, and reporting specifications. More general requirements for the parties involved in the test and the individual process steps for testing and verification are laid down in the "General VERA Guidelines", which were approved by the International VERA Board.

This document was drawn up by nominated international experts on the "International VERA Committee" (IVC) for slurry separation technologies.

The aim of the VERA Verification Statements is for their information to be used optimally by different stakeholders in the member states. This means that the test protocol should provide a broad array of reliable information that can be analysed and summarised during verification in such a way as to be directly or indirectly used as widely as possible by different national users.

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

2. Scope

This protocol specifies the information needed for testing and verifying the environmental performance of slurry separation technologies.

2.1. Definition of slurry separation technologies

In this protocol, a slurry separation technology is defined as a unit with the primary function of separating livestock slurry or digestate from biogas plants into one or more solid fraction(s) and one or more liquid fraction(s). The protocol presented here outlines the methods and demands in testing a technology with regard to its separation efficiency of total solids, nitrogen, phosphorus, and potassium.

2.2. Targeted results and information

The information specified includes:

- A comprehensive system description, including a 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.

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 the normal operational function must be observed, recorded, and then 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. Due to the fact that a separation technology is not operated and used in a continuous way, long-term operational stability cannot be verified.

Since only technologies that separate slurry after it is taken from the animal housing system are within the scope of this test protocol, the operations will not have any influence on animal health and welfare, as long as the liquid and solid fractions are not stored inside the animal house.

2.3. Use of results for verification

After a test has been completed, verification of the performance based on the test results can be carried out in accordance with this protocol and the General VERA Guidelines.

VERA does not endorse, certify, or approve technologies!

VERA verifications are based on an evaluation of the technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. VERA makes no expressed or implied warranties as to the performance of the technology and does not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Further, the end user must be aware that the countries involved in VERA have different legal requirements, which will influence the status and use of this verification statement in each country.

3. Normative references

The referenced standards in the following text and in the bibliography are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

4. List of abbreviations

a	Annus (Latin for year)
A	Animal
AP	Animal place
C	Carbon
CH_4	Methane
CO_2	Carbon dioxide
COD	Chemical oxygen demand
DM	Dry matter
GC	Gas chromatography
GHG	Greenhouse gases
IVB	International VERA Board
IVC	International VERA Committee
K	Potassium
N	Nitrogen
NH_3	Ammonia
N_2O	Nitrous oxide
NO_x	Refers to NO (nitric oxide) and NO_2 (nitrogen dioxide)
OU_E	European odour units
P	Phosphorus
PO_4^{3-}	Phosphate
ppmv	Parts per million by volume
TS	Total solids = Total dry matter
VERA	Verification of Environmental Technologies for Agricultural Production
VS	Volatile solids = Organic dry matter

5. 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.

Types of additives include:
- Acids and acidifying compounds
- Adsorbents
- Bacterial enzyme preparations
- Disinfectants
- Masking agents
- Oxidising agents
- Plant extracts
- Polymers
- Urease inhibitors
- Water

Downtime
The period when the tested system is not operating, e.g. 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
The liquid or thin fraction derived from the separation of slurry.

Manure
A general term denoting any organic material excreted from the digestive system of animals, which supplies organic matter to soils together with plant nutrients.

Odour
A 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 of air (OU_E m^{-3}), and the concentration is measured by olfactometric analyses in accordance with European CEN standard EN 13725.

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:

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

$SepEf_P$ = separation efficiency for a specific compound P [%]
M = mass flow [kg h^{-1}]
C_P = concentration of a specific compound P [g kg^{-1}]

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 slurry or digestate from biogas plants into one or more solid fractions and one or more liquid fractions, examples of which 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 water during management, or digested slurry from biogas plants.
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 or float (depending on weight) in the liquid during longer periods of storage. The water content of slurry is usually higher than 85%.

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

Uptime of the system
The period of time when the tested system is in operation.

6. 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. To some extent, it also forms part of the final test report. The system description must include all relevant and essential information needed to:

- Organise and design the test
- Enable the farmer/biogas plant owner to operate, maintain, and monitor the system properly
- Monitor the system online, including the key parameters needed for the determination of uptime/downtime of the system (if applicable)
- 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, and details if necessary)
- Technical description (capacity, dimensions, weight, and power requirements)
- Installation (fixed or mobile installation)
- Description of the slurry input (recommendations/requirements for the types of slurry that can be used in the separator, e.g. pig slurry and cattle slurries with dry matter contents between 2% and 10%)
- Recommendations from the manufacturer of the separator regarding capacity
- 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 which therefore should be monitored during the test.

Annex A of this document provides a template for a system description.

In addition, the description must include detailed instructions on:

- Operation
- Maintenance
- Monitoring.

The manufacturer/applicant must provide general information about:

- Environmental and occupational safety of the technology applied
- Predicted durability of the system and its components
- Warranty provisions
- A list of demonstration units already working, 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 82079 Preparation of instructions for use – 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.

7. Requirements

This chapter specifies the requirements related to the testing of slurry separation technologies.

In addition, the chapter describes the measurement parameters to be included in the test and a specification of the methods to be used and the people/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.

All more general requirements for testing and verification procedures, including the qualification of test partners, are specified in the **General VERA Guidelines** (GVG), which are publicly available on the VERA website: www.vera-verification.eu.

7.1 Pre-testing or preparation for a full test 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 a VERA verification.

It is strongly recommended that pre-testing of a new technology is carried out before a full VERA test is initiated, and a full test should only be started when it has shown 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 operational 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 a VERA verification, all the requirements mentioned in the following sections have to be fulfilled, including any general requirements stated in the General VERA Guidelines (GVG), requirements/restrictions on farm visits, and modifications of the technology.

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

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

A detailed test plan is to be elaborated by the test institute according to the template in Annex C, including all relevant parameters.

The applicant/manufacturer is responsible for providing a full description of the technology to be tested prior to the start of a full VERA test, cf. chapter 6. The description must include detailed instructions for operation, service, maintenance, and monitoring.

7.2 Responsibilities 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 6.

The applicant/manufacturer of the technology is only allowed to visit the farm/company during the test period together with the test institute. Operational problems must be dated and described in the test logbook by the test institute. A logbook must be made available to the farmer and the test institute at any time during the test period. The test institute must also record the time spent on operational problems and maintenance of the separation technology system. In addition, a dated record must be made of when and how the problem was solved, and it should be signed by the test institute and the applicant/manufacturer when repairs have been completed.

The test institute is responsible for coordinating 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 tested system.

7.3 Test design and sampling strategy

The separation technology must be tested under 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.

7.3.1 Test design

Figure 1 shows a flow diagram of a slurry separator, where the rectangular box is a symbol for the separation system. 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 the addition of polymers followed by a screw press.

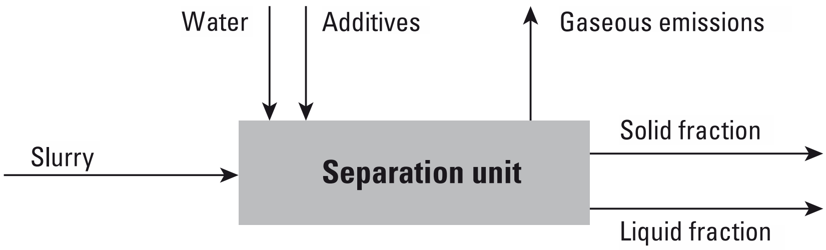


Figure 1: Flow diagram showing input and output streams in a slurry separation unit.

The performance of a slurry separator is determined by 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). The test must be designed to allow the calculation of mass balances for all mandatory parameters, e.g. total dry matter, organic matter, total nitrogen, ammonium nitrogen, phosphorus, and potassium (see Table 2).

Based on the design and the functionality of the separation unit, an assessment should be made as to whether there is a potential risk of specific emissions of gaseous substances, such as ammonia, hydrogen sulphide, and nitrous oxide.

Requirements for the test design are described in Table 1.

Table 1: Test design for slurry separation technologies

Parameter	Requirement
Test location	• Can be carried out at a commercial farm/biogas plant or at a test farm/biogas plant • Has to reflect the standard conditions for the use of the separator • The separator may be moved to different locations, or the slurries can be transported to the separator
Slurry	• The separation technology shall be tested for at least three slurry types – each originating from three different sites • Ideally, they represent slurries with high and low dry matter content
Slurry types	• Pig slurry • Cattle slurry • Mink slurry • Digested manure (biogas slurry) • Others
Test period	• At least three days of operation for each slurry type, with one day for each slurry from the different sites • Prior to testing a new slurry, one day should be allowed for adjustment of the separator. • The test can be performed throughout the year (temperature needs to be recorded) • Samples for chemical and physical analyses are to be collected every measurement day

Annex B provides an example for a possible test design.

Recording
All matters concerning sampling and measurements, as well as all relevant information and problems occurring during the test, must be recorded in a logbook. This also applies to all activities carried out in the daily operation of the system and especially to deviations from daily routines, disturbances, or malfunctions. The aim of the logbook is to provide full background information about the system during the sampling and measurement period.

7.3.2 Sampling strategy

- At least one sample shall be collected every day for three days for each input and output stream.
- Per sampling, a minimum of five subsamples are to be simultaneously collected from each stream of the separator. Variations in slurry flow and composition during one sampling period must be minimised by taking subsamples over a minimum of 2.5 hours per sampling (one sample every half hour) so as to balance variations.
- In order to ensure comparable measurements, mass balances for fresh and dry matter, as well as for all measured slurry concentrations (nitrogen, potassium, phosphorus, etc.), have to be calculated on each measurement day.

7.3.2.1 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 is to 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 shall be thoroughly mixed with a mixer (or a pump) before sampling in order to gain a solution of the slurry fractions. While the mixer is still in operation, the sample is to be collected from the pit, e.g. with a bucket. Afterwards, the contents of the bucket must be well stirred and a sampling jar filled from the bucket.

Sampling from a pipe
The preferred way is to sample directly from the tap. The position of the tap (or valve) is at the bottom of the pipe. Sedimented material and blocking by crystallisation must be avoided. A tap located at the top of the pipe may lead to sedimentation in the pipe, thus resulting in only having a relatively thin fluid sampled. Ideally, the whole flow, and not only part of it, should run through the tap so as to ensure 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.

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 12 subsamples shall be collected from different parts of the heap (left, right, several depths, etc.). These subsamples must be mixed thoroughly. Afterwards, the sample from this mixture is 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 (i.e. a 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.

7.3.2.2 Gaseous emissions

If the technology has an expected efficiency in reducing gaseous emissions, or if it is expected to result in considerably higher emissions, as outlined in Table 4, emission measurements are to be applied.

- The gas samples shall be taken from a ventilation outlet so as to be able to refer the emissions to a defined air volume.
- Sampling time must be 24 hours per sample.
- Per parameter: a minimum of four samples is required.
- The gas flow rate has to be measured continuously during the testing phase.

7.4 Measurements

7.4.1 Calibration, verification, and validation

For some measurement parameters, more than one measurement technique is listed in this VERA test protocol. These can be considered as approved for use in a VERA verification. Some techniques are explicitly referred to as a **'reference method'**, which shall be used to verify measurement data and validate other methods.

Each configuration of measurement equipment has to be validated according to the reference method specified in this protocol. The validation can be performed according to EN 14793.

The calibration of measurement instruments is an essential part of the definition of the configuration. This relates to calibration procedures that are only performed perennially or annually, as well as for those that need to be done before each use. The calibration must also take into account possible cross-interference from other gases in the test house, in addition to temperature, relative humidity, etc.

Verification, within the meaning of on-site control, of the measurement technique/equipment used has to be performed on the test site, in combination with a more precise measurement technique than the one used.

Any calibration and verification procedures and estimates of the measurement uncertainty for the relevant parameters must fulfil the requirements of ISO 17025 and be documented and reported.

7.4.2 Measurement parameters

The measurement parameters are shown in Tables 2, 3, and 4 below. They are divided into three groups of parameters characterising:

1. The livestock slurry/digestate and fractions produced
2. The technology
3. Emissions

Some of the parameters are mandatory while others are optional; in this regard, they are marked as either 'M' or 'O' respectively.

Slurry characteristics

Table 2: Measurement parameters - characteristics of livestock slurry/digestate and fractions produced

Parameter (M) = Mandatory (O) = Optional	Units	Numbers of samples per slurry	Measured in	Reference method
Total solids TS (M)	kg t^{-1}	1 per day from each stream for 3 days	Slurry, liquid, and solid fractions	2540 B2
Total volatile solids VS (M)	kg t^{-1}	1 per day from each stream for 3 days	Slurry, liquid, and solid fractions	2540 E2
Total nitrogen (M)	kg t^{-1}	1 per day from each stream for 3 days	Slurry, liquid, and solid fractions	Kjeldahl/Dumas
Ammonium nitrogen (M)	kg t^{-1}	1 per day from each stream for 3 days	Slurry, liquid, and solid fractions	71/393/EØF
Total phosphorus (M)	kg t^{-1}	1 per day from each stream for 3 days	Slurry, liquid, and solid fractions	3030H/3030I/3030J2 ICP: EN ISO 11885
Total potassium (M)	kg t^{-1}	1 per day from each stream for 3 days	Slurry, liquid, and solid fractions	3030H/3030I/3030J2 ICP: EN ISO 11885
Total copper (O)	kg t^{-1}	1 per day from each stream for 3 days	Solid and liquid fractions	SM 3030(J) ICP: EN ISO 11885
Total cadmium (O)	kg t^{-1}	1 per day from each stream for 3 days	Solid and liquid fractions	
Total zinc (O)	g t^{-1}	1 per day from each stream for 3 days	Solid and liquid fractions	SM 3030(J) ICP: EN ISO 11885
pH (M)	pH units	1 per day from each stream for 3 days.	Slurry (input) and liquid fractions	Calibrated pH meter
Mass flow (M)	t h^{-1}	1 per day from each stream for 3 days	Slurry (input), liquid, and solid fractions	Gravimetric "container method" or level measurement Magnetic-inductive flow meter, including measurement of bulk density (see description below)
Substrate temperature (M)	˚C	Continuous measurements based on hourly values (= 24 per day)	Slurry (input), liquid, and solid fractions	Thermocouples or other calibrated temperature sensors with adequate measuring range, sensitivity, and detection limit. Consider: undesired effects on measuring device by e.g. contamination, wind, or direct sunshine
Ambient temperature (M)	°C	Continuous measurements based on hourly values (= 24 per day)	Test environment	See substrate temperature
COD (O)	mg l^{-1}	1 per day from each stream for 3 days	Liquid fraction	ISO 15705

[2]Greenberg, A.E., Clesceri, L.S., and Eaton, A.D. (Eds.). Standard methods for the examination of water and wastewater, 18th edition (1992). American Public Health Association: Washington.

Measurement of liquid and solid mass flow

A system balance is to be made based on the knowledge of the total flow and compound concentrations. Possible emissions are to be quantified. Therefore, the mass /volume flow (e.g. kg $hour^{-1}$, litres $hour^{-1}$, and kg day^{-1}) of all flows must be determined. These flows must be measured as accurately as possible. Sufficient action must be taken to measure representative flows. The method and equipment used for flow measurement must be clearly described in the test report.

Flow meter and bulk density

The flow measurement for liquids can be carried out with magnetic-inductive flow meters. If the flow meter is used, the bulk density (kg m^{-3}) must be measured so as to be able to calculate the corresponding mass flow.

Gravimetry ("container method")

This method is applicable for both liquids and solids.
The mass flow of a solid or liquid material can be determined by collecting the material in a bucket or container, which is weighed afterwards. The time to fill the container will be measured with a stopwatch.
For liquids, it is sufficient to determine the amount of litres or cubic metres per hour, if density is 1 kg per 1 litre. Solids and other liquids must be weighed in order to determine the amount of kg per hour. For reliable measurements of liquids, at least 20 seconds and up to 20 hours, depending on the volume flow, is necessary. Be aware that opening taps or valves only for sampling may influence the volume flow due to other pressure conditions in the pipes than those in a normal operation.

Level measurement

If slurry or fluid is pumped from a pool, tank, or silo (hereafter 'tank'), the height of the liquid level can be measured in order to estimate the volume change. For a reliable measurement, it is necessary to have a difference in level of at least 30 cm. 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 that is pumped into a tank can be determined. 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 pumped fluid can be calculated. If the tank/silo is cylindrical, the diameter must be determined before the amount of pumped fluid can be calculated. A level measurement cannot be used if the substrate forms a foaming layer.

Technology characteristics

Table 3 lists the relevant parameters for characterising the specific technology for verification. Not all the listed parameters are relevant for all technologies, e.g. consumption of additives. An agreement between the applicant and the VERA Verification Body shall be made if parameters are not to be measured for the verification of each specific technology.

Table 3: Measurement parameters - technology characteristics

Parameter	Units	Sampling conditions	Reference method
Capacity of separator	t slurry h^{-1}		Recording
Energy consumption	kWh t^{-1}	Continuous measurement	Recording
Consumption of water	m^3 t $slurry^{-1}$	Continuous/cumulative measurement	Recording
Consumption of all additives	kg t $slurry^{-1}$	Continuous/cumulative measurement	Recording
Time consumption for start-up procedure	hours		Logbook
Operating hours	hours		Logbook
Operational function and stability		Continuous observation	Documentation through recording

Emission measurements

Emission measurements are to be defined by the applicant and the VERA Verification Body, based on their relevance to the technology.

If it is known that the type of environmental technology tested does not reduce a specific parameter or only has a marginal effect on it, the manufacturer/applicant can decide to specify the pollution reduction for this specific parameter as zero without carrying out the prescribed measurements.
However, the test report must justify that, based on previous research, theories, or test results, the environmental technology does not have any negative effect on the specific parameter.

Table 4: Measurement parameters – gaseous emissions and noise

Parameter	Units	Sampling conditions (where, how, and how often)	Reference method (To validate the measurement method see section 7.4.1)
Air flow (mandatory in all cases)	$m^3\ h^{-1}$	Measured in ventilation outlet Continuous measurements and simultaneous to gas measurements	Anemometer
Ammonia (NH_3) emission	$mg\ s^{-1}$	Cumulative sampling up to 24 hours Continuous measuring methods: based on hourly values (24 samples) Minimum: 4 x 24h Measured in ventilation outlet	Impinger system (impingers can only be used when the ventilation rate is fixed)
Methane (CH_4) emission	$mg\ s^{-1}$	Continuous measuring methods: based on hourly values (24 samples) Minimum: 4 x 24h Measured in ventilation outlet	GC-FID
Hydrogen sulphide (H_2S) emission	$mg\ s^{-1}$	Continuous measuring methods: based on hourly values (24 samples) Minimum: 4 x 24h Measured in ventilation outlet	Jerome (Measurement principle)
Nitrous oxide (N_2O) emission	$mg\ s^{-1}$	Continuous measuring methods: based on hourly values (24 samples) Minimum: 4 x 24h Measured in ventilation outlet	GC-ECD
Odour emission	$OU_E\ s^{-1}$	Minimum: four sampling days Minimum three samples per sampling day Measured in ventilation outlet, if possible	Olfactometry (EN 13725)
Noise (indoor and noise emission)	dB (A)	Outdoor, 1-2 m from ventilation outlet	Noise level meter (ISO 3746)

7.5 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 the safe design and construction of machinery and proper installation and maintenance without putting people 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 equipment by workers at work. The safety instructions must be documented, e.g. in a safety data sheet, and described in the user manual.

In addition, ISO 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction defines technical principles to help designers achieve safety in the design of machinery.

8. Test reporting and evaluation

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

The test report must be written in English. The report must include chapters, with the subheadings listed below. The following text provides 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 parties involved in the test 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 institute.

Introduction
The introduction must include a description of:
- The background regarding the environmental need for the implementation of the technology in question
- The manufacturer/applicant involved in the test
- A general description of the slurry separator
- How the tested system/technology can meet the environmental challenges
- Previous tests, including references, if applicable.

Materials and Methods
The materials and methods section must include a description of:
- The slurry or digestate involved in the test (detailed description with respect to animal type, bulk density, total solids, etc.)
- The slurry separation technology, including photographs and drawings
- The measuring methods used and their measuring uncertainty, including an explanation of why they were used and a validation report, if other than the reference method.
- The test design, 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
- Sampling procedure, including any deviations from the test plan
- Description of calculation and statistical methods used, including models and the statistical software package

Results
The individual raw data for all parameters characterising each stream (slurry and produced solid and liquid fractions) must be shown in tables and graphs. The processed data must be presented in tables, together with medians, means, and 95th percentiles.

All mandatory parameters on slurry characteristics (see Table 2) must be analysed and separation efficiencies calculated for each sampling day individually and as a mean of all three sampling days of the same slurry. They are to be calculated as follows:

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

$SepEf_P$ = separation efficiency for a specific compound P [%]
M = mass flow [kg h^{-1}]
C_P = concentration of a specific compound P [g kg^{-1}]

The upper limit of uncertainty must not exceed +/- 15%.

The mean and standard deviation of the parameters characterising the technology and the emissions must be shown in tables or graphs and commented upon in the text. Any equations used to calculate any parameter must be reported in a reproducible way.

An evaluation of the operating stability of the system must be given. This evaluation must be based on observations carried out 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 that may be related to the use of the system, including the potential impact on occupational health and safety and on the environment.

These evaluations must cover situations with normal operation of the slurry separation technology system.

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 has to 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 and 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 of the test report.

References

Relevant references to be specified.

Annexes

Annexes can be added if relevant.

9. Bibliography

- **Directive 2006/42/EC** of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast).
- **Council Directive 89/655/EEC** of 30 November 1989 (amended 2007/30/EC) on minimum safety and health requirements for the use of work equipment by workers at work.
- **ISO 12100** Safety of machinery – General principles for design – Risk assessment and risk reduction.
- **EN 82079** Preparation of instructions for use - Structuring, content and presentation.
- **ISO 3746** Acoustics - Determination of sound power levels of noise sources - Survey method.
- **ISO/IEC 17025** General requirements for the competence of testing and calibration laboratories.
- **EN 13725** Air quality – Determination of odour concentration by dynamic olfactometry.
- **EN ISO 11885** Water quality - Determination of selected elements by inductively coupled plasma optical emission spectrometry (ICP-OES).
- **ISO 15705** Water quality - Determination of the chemical oxygen demand index (ST-COD) - Small-scale sealed-tube method.
- **Greenberg, A.E., Clesceri, L.S., and Eaton, A.D. (Eds.).** *Standard methods for the examination of water and wastewater,* 18th edition (1992). American Public Health Association: Washington.

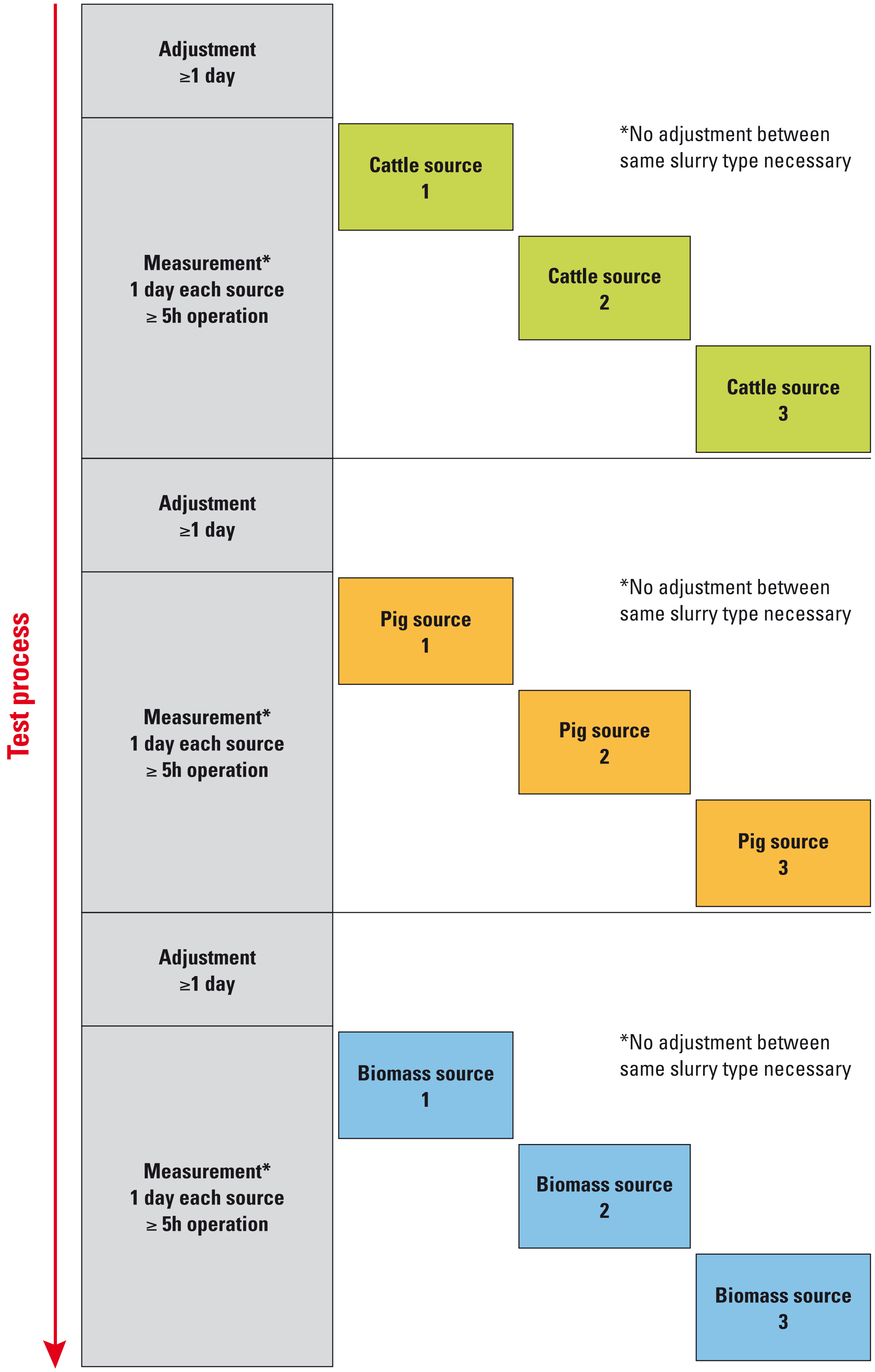
Annexes

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 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 able to treat**	Slurry from which animal category Minimum and maximum of dry matter as % of input slurry/digestate Recommendations regarding age of input slurry/digestate Recommendations regarding pre-treatment (e.g. mixing)
10	**Short description of the function of the separator in running text**	

Annex B (informative): Example of a possible test design



Annex C (informative): Template for a test plan

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.:

Owner of test location:	
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 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 body can then check that the system/technology applied is identical to the system/technology tested).
- Specification of the measurement parameters listed in Table 2.
- Specification of the measurement parameters listed in Table 3.
- Description of the location of measurement points, instruments, and how they are calibrated.
- Timetable for the entire test period.
- Logbook. Location of the 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 owner of the facility.
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 in order to determine whether the concentration after treatment in the slurry separation technology system is statistically significantly different from the concentration before the treatment. For the primary parameters, means must be calculated instead of medians. Means and standard deviations 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 efficiencies for all parameters.

Compensation
Any arrangements made in relation to providing the owner of the test location 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 approved by the verification body prior to the initiation of a VERA test.