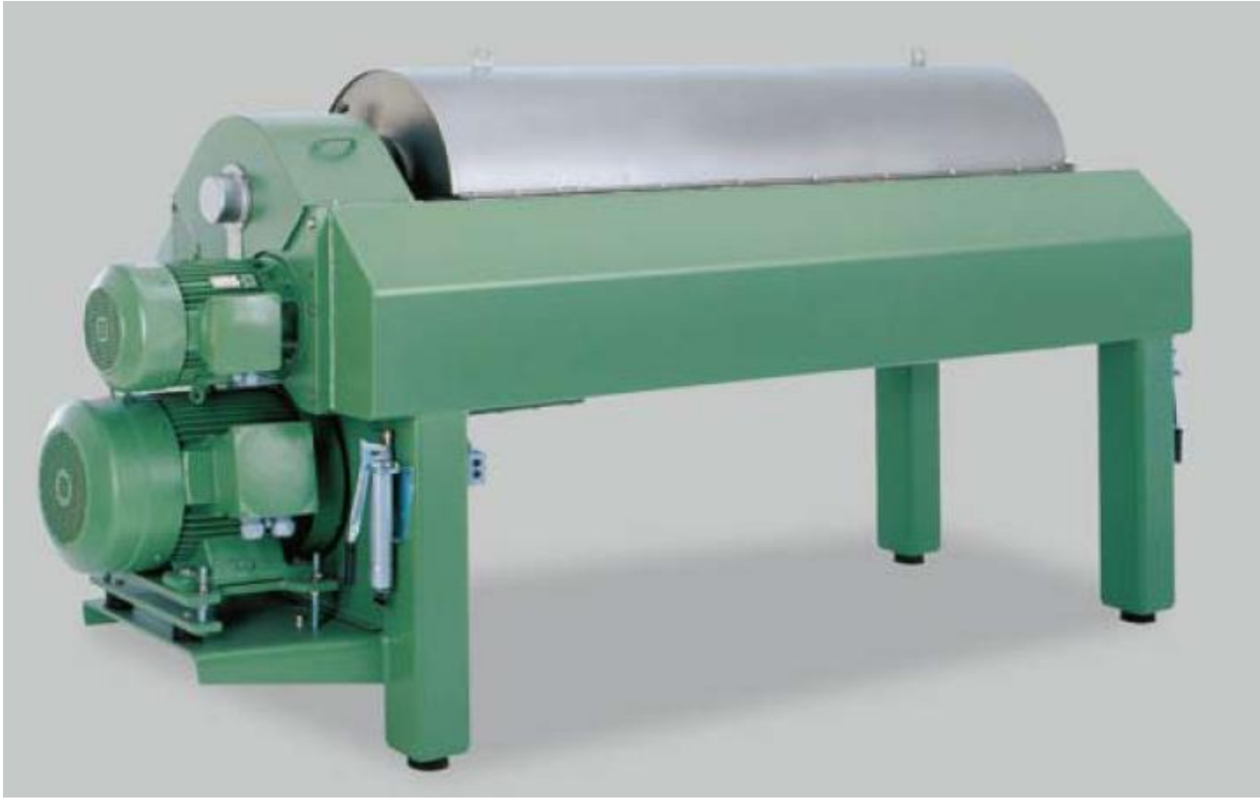
GEA Westfalia UCA 501-00-02
Post-treatment of digested biomass

Verification Report



Version 2-0

Document information

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1 TABLE OF CONTENTS

2 INTRODUCTION

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and quality assurance.

This document is the verification report resulting from the test and verification of a specific product, GEA Westfalia decanter centrifuge, used for post-treatment of digested biomass.

2.1 Name of product

The product for verification was GEA Westfalia UCA 501-00-02 decanter centrifuge.

2.2 Name and contact of vendor

UCA 501-00-02 is developed and produced by GEA Westfalia Separator, Werner-Habig-Strasse 1, 59302 Oelde, Germany. Website: www.westfalia-separator.com.

UCA 501-00-02 is marketed and sold in Denmark by GEA Westfalia Separator DK A/S, Noerskovvej 1b, 8660 Skanderborg, Denmark, phone +45 8794 1000. Contact person of GEA Westfalia Separator DK is Martin Rishøj. Email: martin.rishoj@geagroup.com. Phone: +45 4030 0266.

2.3 Name of centre and verification responsible

Verification centre: DANETV, Test Centre AgroTech, Udkaersvej 15, DK-8200 Aarhus N, Denmark.

Verification responsible: Thorkild Q Frandsen. Phone +45 8743 8468. E-mail: tqf@agrotech.dk.

2.4 Verification and test organization

The verification was conducted by Danish Centre for Verification of Climate and Environmental Technologies, DANETV, which performs independent tests of technologies and products for reduction of climate changes and pollution.

The verification was planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).

An internal and an external technical expert have provided independent review of the planning, conducting and reporting of the verification and tests.

An overview of the organisation associated with test and verification is given in figure 1.

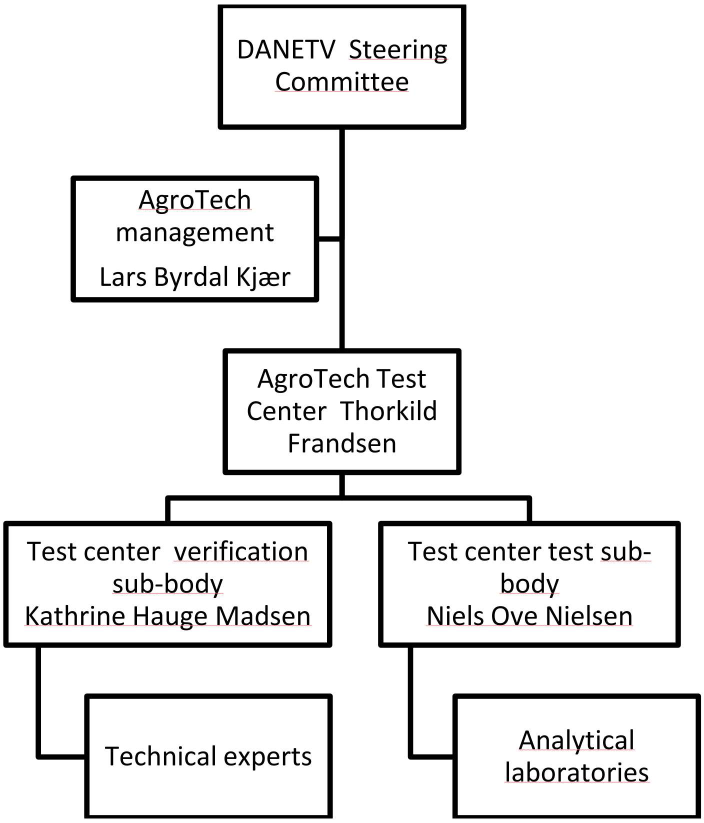

Figure 1. Organisation of test and verification

2.5 Expert group

The technical experts assigned to this verification and responsible for review of the verification plan and report documents include:

Bjørn Hjortshøj Andersen, AgroTech, Udkaersvej 15, DK-8200 Aarhus N, Denmark. Phone: +45 8743 8420, e-mail: bha@agrotech.dk.

Bjørn Malmgren-Hansen, Danish Technological Institute, Kongsvang Allé 29, DK-8000 Aarhus, Denmark. E-mail: bmh@teknologisk.dk.

2.6 Verification process

Verification and tests was conducted in two separate steps, as required by the EU ETV. The steps in the verification are shown in Figure 2.

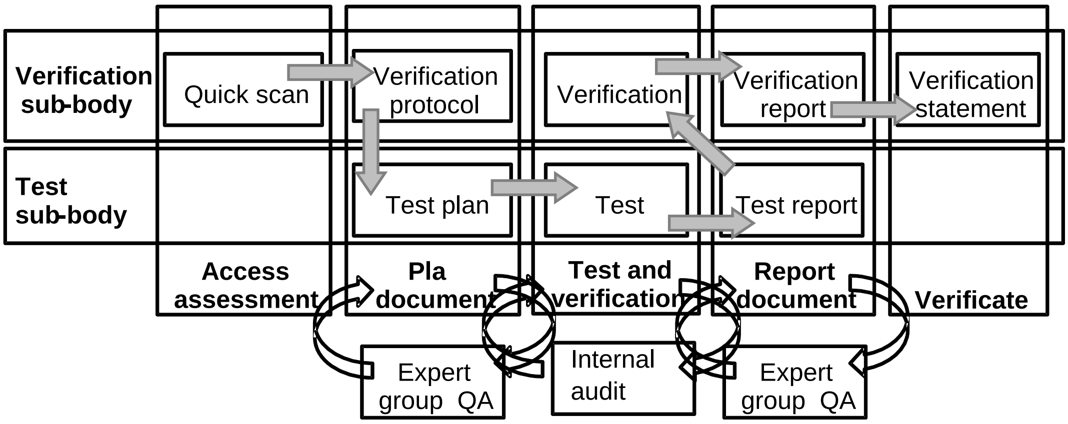

Figure 2. Verification steps.

The verification process is described in the AgroTech Test Centre Quality Manual [8].

This verification protocol, the test plan and the AgroTech Test Centre Quality Manual shall be seen as one consolidated verification description.

3 DESCRIPTION OF THE TECHNOLOGY

In this context post-treatment of digested biomass include technologies that are used for separation of solids and/or extraction of specific components of digested biomass from a biogas plant to produce output fractions that are better adapted for the intended end use.

Many different technology types can be used for post-treatment of digested biomass including decanter centrifuges, ultrafiltration, reverse osmosis, ammonia stripping, evaporation and treatment via chemical additives.

This verification report is the result of a test and verification of a decanter centrifuge producing a liquid output fraction and a solid output fraction.

4 DESCRIPTION OF THE PRODUCT

GEA Westfalia UCA 501-00-02 is a decanter centrifuge using the centrifugal force to separate solids from the digested biomass. The digested biomass is led into a closed horizontal cylinder with a continuous turning motion. Inside the cylinder solids and liquids are separated at the wall into an inner layer with a high dry matter concentration and an outer layer consisting of a liquid containing a suspension of colloids, organic components and salts.

The solid and liquid phases are transported to either end of the centrifuge by rotating the entire centrifuge at high speed and by simultaneously rotating the conveyor at a speed that differs slightly from the speed of the bowl [1], [2], [3].

5 APPLICATION AND PERFORMANCE PARAMETERS

The intended application of the GEA Westfalia UCA 501-00-02 is defined in terms of the matrix, the target and the effect of the decanter centrifuge.

The matrix is the type of material that the decanter is intended for. Targets are the measurable properties that are affected by the decanter. The effects describe how the targets are affected by the decanter.

A detailed description of the application is presented in Appendix 3 – Application and performance parameter definitions.

5.1 Matrix

The UCA 501-00-02 decanter is verified for post-treatment of digested biomass at a biogas plant using manure as the main substrate and operated within the mesophilic temperature regime. Typically, the total solids content of digested biomass at such biogas plants is within the range of 4,0 – 8,0 %.

5.2 Targets

In the case of GEA Westfalia UCA 501-00-02 the targets of the application are:

- Concentrations of total solids (TS), volatile solids (VS) and suspended solids (SS) in digested biomass, liquid output fraction and solid output fraction.
- Concentrations of total nitrogen, ammonium nitrogen, phosphorous (P), potassium (K) and sulphur (S) in digested biomass, liquid output fraction and solid output fraction.
- Weight of liquid output fraction and solid output fraction.
- Particle size distribution in liquid output fraction.

5.3 Effects

In the case of GEA Westfalia UCA 501-00-02 the effects are:

- Increased concentrations of total solids (TS) and volatile solids (VS) in solid fraction compared to input digested biomass.
- Increased concentrations of total nitrogen and phosphorous (P) in solid fraction compared to input digested biomass.
- Removal of the larger particles in liquid output fraction.

Based on measured masses of input digested biomass, liquid output fraction and solid output fraction and the measured concentrations of TS, VS, SS and nutrients in the input and output fractions mass balances are calculated.

5.4 Performance parameters for verification

The performance parameters provide the relevant information on the performance of the technology product. In the case of the GEA Westfalia UCA 501-00-02 decanter the performance parameters were:

- Separation efficiency with respect to total solids (TS), volatile solids (VS), suspended solids (SS), total nitrogen (N), phosphorous (P) and sulphur (S).
- Share of particle volume with a diameter below a certain level in liquid output fraction (%).

In this verification the *recovery factor* expresses the proportion of a given component in the input digested biomass that ends up in a specific output stream. The recovery factor is expressed as a percent.

Here the recovery factor is calculated this way:

$$RF_i^{S,L} = \frac{(M^{S,L} \times C_i^{S,L})}{(M^{input} \times C_i^{input})} \times 100$$

Where:

RF_i^S = Percent of component *i* in input digested biomass recovered in solid output fraction (S).

SE_i^L = Percent of component *i* in input digested biomass recovered in liquid output fraction (L).

$M^{input,S,L}$ = Mass of input digested biomass (input), solid (S) and liquid (L) output fraction respectively.

$C_i^{input,S,L}$ = Concentration of component *i* in input digested biomass (input), solid (S) and liquid (L) output fraction respectively.

In this verification task *separation efficiency* is defined as the recovery factor of a given component for the solid fraction. Thus, separation efficiency is a measure of the proportion of a given component in the input digested biomass that ends up in the solid fraction (expressed as a percent).

The claims put forward by the manufacturer, GEA Westfalia, are:

Table 1. Performance claims for this application of UCA 501-00-02 by the manufacturer, GEA Westfalia.

Performance parameter	**Claim**
Total nitrogen separation efficiency	Min. 20 %
Total phosphorous separation efficiency	Min. 70%
Total solids separation efficiency	Min. 60 %
Volatile solids separation efficiency	Min. 75 %
Suspended solids separation efficiency	Min. 80 %
Share of particle volume in liquid output fraction with a diameter below 40µm	Min. 90 %

In order to verify the performance claimed by the manufacturer a number of parameters have been measured during the test. In table 2 below the primary measurement parameters are presented. For each parameter it is noted how many samples that shall be taken, where to take samples and the measuring method.

Table 2. Primary measurement parameters.

Parameter [Unit]	Numbers of samples	Measured in	Measuring method
Total solids, TS [Kg/ton]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	EØF 103°C
Total volatile solids, VS [Kg/ton]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	DS 204
Suspended solids, SS [mg/l]	1 per day from liquid streams in 5 batches.	Digested biomass, liquid output fraction	DS 207
Total nitrogen [kg/ton]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	Kjeldahl/Dumas
Ammonium nitrogen [kg/ton]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	71/393/EØF
Mass flow [tons/hour)	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	Siemens flowmeter
Total phosphorus [kg/ton]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	ICP/OES DS1885,1998
Total potassium [kg/ton]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	ICP/OES DS11885,1998
Total sulphour [S]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	ICP-OES
pH [pH units]	1 per day from each stream in 5 batches.	Digested biomass, liquid and solid output fraction	Radiometer, GLP
Particle size distribution	1 per day from liquid output stream in 5 batches	Liquid output fraction	Laser diffraction (Mastersizer)

5.5 Additional parameters

Additional parameters are effects of the product that were described as part of the verification but are considered secondary compared to the primary performance parameters.

5.5.1 Operational parameters

In the case of GEA Westfalia UCA 501-00-02 electricity consumption (kWh/tons input digested biomass treated) was judged to be a relevant additional parameter.

During the planning of the test of the GEA Westfalia UCA 501-00-02 the test organisation assessed whether it was relevant to measure the emission of ammonia and hydrogen sulphide from the decanter in operation.

It was judged by the test organisation that these emissions are minimal in the case of UCA 501-00-02 and do not constitute any risk to neither occupational health nor environment and therefore it was decided not to include these parameters as part of the verification.

5.5.2 Occupational health and safety

In general, decanter centrifuges as all industrial machinery and equipment – must comply with the Machinery Directive (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)). They must be designed and constructed in such a way that they can be used, adjusted and maintained throughout all phases of their life without putting persons at risk.

In detail the installations must satisfy the essential safety requirements contained in Annex I of the Directive, a correct conformity assessment must be carried out and a “Declaration of Conformity” must be given.

It is the responsibility of the manufacturer, importer or end supplier of the equipment to ensure that equipment supplied is in conformity with the Directive. In addition, Council Directive 89/655/EEC of 30 November 1989 concerns the minimum safety and health requirements for the use of work equipment by workers at work (amended 2007/30/EC) and places obligations on businesses and employers to take into account potential dangers to operators and other persons using or affected by machines and equipment.

In general terms, the directive requires that all equipment provided for use at work is: Suitable for the intended use; safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case; used only by people who have received adequate information, instruction and training; and accompanied by suitable safety measures, e.g. protective devices, markings, warnings.

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.

The safety instructions must be documented for example in a safety data sheet and must be observed carefully.

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. may be required. Moreover, one must make sure that protective installations, such as eye wash and shower units, are available and work properly.

5.5.3 User manual

An evaluation of the user manual for the GEA Westfalia UCA 501-00-02 decanter centrifuge was undertaken as part of this verification task.

6 EXISTING DATA

6.1 Summary of existing data

A number of tests of decanter centrifuges have previously been undertaken to evaluate the performance, e.g. [5], [6], [7].

6.2 Quality of existing data

The previous tests were undertaken for other decanter centrifuges than UCA 501-00-02 and/or for other matrices. Thus, none of the previous tests are carried out for separation of digested biomass with GEA Westfalia UCA 501-00-02. In addition, the previous tests are based on methods that differ significantly from the DANETV verification protocol in a number of aspects.

6.3 Accepted existing data

No data from previous tests have been included in this verification of the GEA Westfalia UCA 501-00-02 decanter centrifuge.

7 TEST PLAN REQUIREMENTS

Based on the application and performance parameter identification above the requirements for the test design have been set. A detailed test plan was prepared by the test organisation based upon the specification of the test requirements presented below.

7.1 Test design

The test should be designed so that mass balances of total solids, volatile solids, suspended solids, total nitrogen, ammonium nitrogen, phosphorous, sulphur and potassium could be calculated. This was done by following the decanter centrifuge in batches with a fixed start time and end time.

For each batch the weight of input digested biomass, liquid output fraction and solid output fraction should be determined as part of the test. In addition, during the batch representative sampling of input digested biomass, liquid output fraction and solid output fraction should be done to determine concentrations of solids and nutrients.

7.1.1 Requirements for the test site

The test could be carried out at a commercial anaerobic digestion plant or at an anaerobic digestion test plant. The test should be carried out under normal conditions that reflect how the decanter centrifuge would be used at an anaerobic digestion plant in full scale. The test site proposed by the test unit should be approved by the verification responsible.

7.1.2 Sampling strategy

The test should consist of minimum 5 batches. Each batch should last at least 4 hours and the minimum amount of digested biomass to be treated in one batch was 20 tons. The test could be performed throughout the year.

The performance of the decanter centrifuge should be determined by sampling, measuring and analyzing the input and output flows. The sampling and measurements had to be carried out while the decanter was in normal operation without any disturbances or malfunctions.

During the period of sampling and measuring a logbook had to be used. All matters concerning the sampling and measurements had to be recorded in the logbook. It means all relevant information including functional problems that occurred had to be recorded in the logbook.

The test staff should strive to take samples that are representative of the flow at that moment. This means that the sample should have the same composition as the sampled flow. The test plan should describe the sampling method and equipment used.

In addition, the mass flow to and from the separator (measured in tons or cubic metres) should be determined.

The test report should describe the methods used for measuring mass flow.

7.2 Reference analysis

All measurements and analytical methods had to be documented satisfactory.

7.2.1 Mass balances and separation efficiencies

If it is assumed that no losses would occur during the separation process the mass of each parameter led into the GEA Westfalia UCA 501-00-02 should equal the mass of that parameter leaving the decanter as part of either the solid output or liquid output.

To evaluate the validity of the mass balance calculations were made demonstrating to what extent the mass led into the separator was recovered in the solid and liquid output fractions (expressed as a percent).

$$\mathrm{R_i} = \frac{\mathrm{M_i^I} - (\ \mathrm{M_i^L} + \mathrm{M_i^S})}{\mathrm{M_i^I}} \times 100$$

Where:

$\mathrm{R_i} =$ Percent of component *i* not recovered in liquid and solid output fraction

$M_i^{I,L,S} =$ Mass of component *i* in input slurry (I), liquid (L) or solid output fraction (S)

In each batch for every parameter:

- R_i (per batch) has to be less than +/- 25%

In cases where R_i (per batch) was larger than +/- 25% the result had to be omitted from the calculation of separation efficiency. If possible the batch should be repeated. Verification of the separation efficiency of a given component shall be based on results from minimum 4 batches.

All batches together for every parameter:

- R_i (all batches) had to be less than +/- 15%.

In cases where R_i (all batches) was larger than +/- 15% the result had to be omitted from the calculation of separation efficiency. If possible the test should have been repeated. If it was not possible to repeat the whole test the test responsible should assess whether some of the samples should be re-analyzed.

7.3 Data management

Data storage, transfer and control had to be done in accordance with the requirements described in the AgroTech Test Centre Quality Manual. Similarly, filing and archiving requirements are described in the AgroTech Test Centre Quality Manual.

7.4 Quality assurance

The test plan and test report had to be reviewed by an internal and an external expert.

The quality assurance of the tests should include control of the test system and control of the data quality and integrity.

7.5 Test report

The test report should be based on the template included in the AgroTech Test Centre Quality Manual.

8 EVALUATION

8.1 Calculation of performance parameters

For each individual batch and for all batches together mass balances and separation efficiencies with respect to nutrients and solids have been calculated. The calculations are based on the measured concentrations of the nutrients and solids and the masses of input digested biomass and the two output fractions.

The measured concentrations of solids and nutrients are presented in table 3 and table 4 below. Data from all batches are presented in the test report, which is attached as Appendix 4 to this verification report.

Table 3. Average content of total solids, ashes, volatile solids, suspended solids and pH over 5 batches.

Fraction	Total solids (%)	Ash content (%)	Volatile solids* (%)	Suspended solids (mg/L)	pH (ph units)
Input digested bio-mass	4,85	1,46	3,39	35.000	7,64
Liquid output fraction	2,31	0,82	1,49	8.400	7,94
Solid output fraction	27,66	6,46	21,20	---**	8,12

*Note: Values for volatile solids are not measured but calculated as the difference between total solids and ash content.

**Note: It does not make sense to measure suspended solids in the solid output fraction.

Table 4. Average concentrations of nutrients over 5 batches.

Fraction	Total Nitrogen (Kg/ton)	Ammonium Nitrogen (Kg/ton)	Organic Nitrogen* (Kg/ton)	Total phosphorous (Kg/ton)	Total potassium (Kg/ton)	Total sulphur (kg/ton)
Input digested biomass	4,08	2,87	1,21	0,94	2,24	0,42
Liquid output fraction	3,49	2,63	0,86	0,31	2,31	0,29
Solid output fraction	8,15	4,50	3,65	6,52	2,28	1,56

*Note: Values for organic nitrogen are not measured but calculated as the difference between total-N and ammonium-N.

During the test the volume of the input digested biomass and the weight of solid output fraction has been measured. In converting the measured volume of input digested biomass to weight, the density of the treated biomass is approximated to 1 ton/m^3. The weight of the input output fraction has been calculated this way:

$$M^{L} = M^{input} - M^{S}$$

Where:

M^{L} = Mass of liquid output fraction
M^{input} = Mass of input digested biomass
M^{S} = Mass of solid output fraction

The verified recovery factors as defined in section 5.4 above are presented in table 5 and table 6.

Table 5. Recovery factors for total solids, volatile solids and suspended solids.*

Batch 1 - 5	Fraction	Total solids %	Volatile Solids** %	Suspended solids*** %	Treated input digested biomass %
Average	Solid output	63	68	82	12
	Liquid output	37	32	18	88
	Control	100	100	100	100

*Note: Results are adjusted to make masses of the solids sum up to 100 %. See test report (Appendix 4).
** Note: Results for volatile solids are based on 4 batches only since one batch did not meet quality requirements.
*** Note: Results for suspended solids are based on 3 batches only due to lacking data for batch no. 4 and 5.

Table 6. Recovery factors for nutrients.*

Batch 1 - 5	Fraction	Total nitrogen %	Ammonium nitrogen %	Organic nitrogen %	Total phosphorous** %	Total potassium %	Total Sulphur*** %
Average	Solid output	25	20	38	72	12	45
	Liquid output	75	80	62	28	88	55
	Control	100	100	100	100	100	100

*Note: Results are adjusted to make masses of the nutrients sum up to 100 %. See test report (Appendix 4).
** Note: Results for total phosphorous are based on 4 batches only since one batch did not meet quality requirements.
***Note: Results for sulphur are based on 3 batches only due to lacking data for batch no. 4 and 5.

It is seen from table 6 that the performance of the GEA Westfalia decanter centrifuge with respect to total nitrogen and total phosphorous corresponds well to the state-of-the-art performance described in Appendix 3.

In table 7 the results of the particle size analysis is presented. It is seen that in average over 5 batches 92 % of the total particle volume are particles with diameters less than 40 µm.

Table 7. Particle size distribution in liquid output fraction from GEA Westfalia UCA 501-00-02.

Batch No. 1 - 5	Share of particle volume with increasing particle diameters						
	<1 µm	< 5 µm	< 10 µm	< 15 µm	< 20 µm	< 40 µm	< 65 µm
Average	***14 %***	***41 %***	***60 %***	***71 %***	***78 %***	***92 %***	***97 %***

8.2 Performance parameter summary

In table 8 the verified performance is compared with the performance claimed by the technology producer.

Table 8. Evaluation of performance parameters.

Performance parameter	Claimed performance	Verified performance
Total nitrogen separation efficiency	Min. 20 %	25
Total phosphorous separation efficiency	Min. 70%	72
Total solids separation efficiency	Min. 60 %	63
Volatile solids separation efficiency	Min. 75 %	68
Suspended solids separation efficiency	Min. 80 %	Not sufficient data to verify performance
Share of particle volume in liquid output fraction with a diameter below 40µm	Min. 90 %	92

On the basis of this test the technology producer´s claims on the performance parameters total nitrogen, total phosphorous, total solids and particle size distribution have been confirmed. For volatile solids the technology producer´s claim could not be confirmed on the basis of this test.

The results from evaluation of suspended solids separation efficiency are presented in section 8.1. However, since the quality requirements as defined in section 7.2.1 was not met for this parameter the performance cannot be verified on the basis of this test.

8.3 Evaluation of test quality

8.3.1 Control data

The R_i (per batch) values and R_i (all batches) values are presented in table 9 below (see definition of R_i values in section 7.2.1).

Table 9. Percent of components not recovered in liquid and solid output fraction (R_i values).

Batch no.	Total Nitrogen	Ammonium-Nitrogen	Organic Nitrogen	Total phosphorous	Total potassium	Total sulphur	Total solids	Volatile Solids
1	-3,00	-2,05	-5,29	-7,93	-2,44	-4,56	-3,90	-3,42
2	-4,48	-0,96	-13,19	-10,96	0,58	-6,47	-14,73	-15,88
3	-5,90	-6,85	-3,74	-31,01	-8,41	-13,45	-21,57	-23,25
4	11,85	9,73	16,46	-14,00	16,24	---	-7,28	-10,55
5	4,76	2,83	9,92	-16,41	-20,30	---	-21,72	-42,38
1-5	**0,65**	**0,54**	**0,83**	**-16,06**	**-2,87**	***-8,16***	***-13,84***	***-19,10***

According to the analytical performance requirements defined in section 7.2.1:

- R_i (per batch): No values must be greater than +/- 25%
- R_i (all batches): No values must be greater than +/- 15%

It is seen in table 9 that:

- $R_{phosphorous}$ (batch 3) = - 31,01
- $R_{Volatile\ solids}$ (batch 5) = - 42,38

Consequently, in calculation of the average separation efficiency for phosphorous the result from batch 3 has been omitted. In calculation of the separation efficiency for volatile solids the result from batch 5 has been omitted.

8.3.2 Audits

No external or internal audits were undertaken for this specific verification task.

8.3.3 Deviations

According to the original test schedule batch 4 and batch 5 were planned to end of December 2009. However, since the biogas plant used as test site was not in normal operation the original schedule for the test could not be followed. Instead batch 4 and batch 5 were postponed to 21.01.2010. The operational problems at the biogas plant were not related to the GEA Westfalia UCA 501-00-02.

8.4 Additional parameter summary

8.4.1 User manual

The user manual for GEA Westfalia UCA 501-00-02 [3] has been evaluated as part of this verification using the template described in the AgroTech Test Centre Manual. Based on this evaluation it is concluded that the description of the following topics was sufficient:

- Operation of the GEA Westfalia decanter centrifuge
- Prevention of and dealing with incidents
- Occupational health and safety measures
- Service and maintenance
- Surveillance of the installation

8.4.2 Occupational health and wastes

The safety instructions in the user manual [3] regarding operation of the UCA 5001-00-02 decanter centrifuge were regarded as sufficient.

8.5 Operational parameters

In table 10 the measured capacity of the decanter centrifuge during test is presented together with the results of the electricity consumption measurements.

Table 10. Capacity and electricity consumption.

Batch no. 1 - 5	Capacity Tons of input digested biomass treated per hour	Electricity consumption* kWh / ton input digested biomass treated
Average	13,72	1,67

* Note: Results on electricity consumption are based on data logged electronically by GEA Westfalia during test period.

8.6 Recommendations for verification statement

It is recommended to issue a verification statement based on the verified performance described in section 8.1, 8.2, 8.3 and 8.5.

8.7 Liability exclusion

DANETV verifications are based on test and evaluation of technology performance under specific, predetermined operational conditions and parameters and the appropriate quality assurance procedures. AgroTech makes no expressed or implied warranties as to the performance of the technology and do not certify that the technology will always operate as verified. The end user is solely responsible for complying with any applicable regulatory requirements.

9 VERIFICATION SCHEDULE

The verification was planned and carried out in 2009-2010. The overall schedule is presented in table 11.

Table 11. Schedule for verification of GEA Westfalia UCA 501-00-02 decanter centrifuge.

Task	Timing
Quick scan and contract negotiation	August - September 2009
Verification protocol and test plan	September - November 2009
Test and analyses	December 2009 - February 2010
Test reporting	March 2010
Verification report	March 2010
Report document review	April 2010
Verification statement	April 2010

10 QUALITY ASSURANCE

The quality assurance of the verification is described in table below and in figure 2. The quality assurance of the test is described in the test plan.

Table12. Quality assurance plan for the verification of GEA Westfalia UCA 501-00-02 decanter centrifuge.

Task	AgroTech	Technical experts
Plan document including verification protocol and test plan	BHA	Bjørn Malmgren-Hansen, Danish Technological Institute
Report document including test report and verification reports	BHA	Bjørn Malmgren-Hansen, Danish Technological Institute

Internal review of verification protocol, verification report, test plan and test report was done by Bjørn Hjortshøj Andersen (BHA). No test system audit is planned for this verification task.

A P P E N D I X 1

Terms and definitions used in the verification protocol

Word	DANETV
Analytical labo-ratory	Independent analytical laboratory used to analyse test samples
Application	The use of a product specified with respect to matrix, target, effect and limitations
DANETV	Danish center for verification of environmental technologies
(DANETV) test center	Preliminary name for the verification bodies in DANETV with a verification and a test sub-body
Effect	The way the target is affected
(Environmental) product	Ready to market or prototype stage product, process, system or service based upon an environmental technology
Environmental technology	The practical application of knowledge in the environmental area
Evaluation	Evaluation of test data for a technology product for performance and data quality
Experts	Independent persons qualified on a technology in verification
Matrix	The type of material that the product is intended for
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis
Liquid fraction	Liquid or thin fraction derived from the separation of slurry.
Performance claim	The effects foreseen by the vendor on the target (s) in the matrix of in-tended use
Performance parameters	Parameters that can be documented quantitatively in tests and that pro-vide the relevant information on the performance of an environmental technology product
Procedure	Detailed description of the use of a standard or a method within one body
Producer	The party producing the product
Recovery factor	Expresses the proportion of a given component in the input slurry that end up in a specific output stream. The recovery factor is expressed as a percent.
Separation effi-ciency	In this verification separation efficiency is defined as the recovery factor for the solid fraction. Thus separation efficiency is a measure of the pro-portion of a given component in the input slurry that ends up in the solid

Word	DANETV
	fraction (expressed as a percent).
Slurry	Faeces and urine produced by housed livestock, usually mixed with some bedding material and some water during management to give a liquid manure with a dry matter content in the range from about 1 – 10%. A slurry is a mixture of liquid and solid materials, where typically the solid materials are not dissolved in the liquid phase, and will precipitate out of the slurry under a prolonged period of storage.
Slurry additive	Manufactured or naturally occurring products or substances that are added to manures to modify their biological, chemical or physical properties. Many additives are commercially available but most have not been subjected to independent testing so their effectiveness has not been assessed.
Slurry separator	Slurry separators (separation technologies) are here defined as technologies that divide liquid livestock manure (slurry) into one or more solid fractions and one or more liquid fractions.
Solid fraction	A fraction from separation with a higher content of solids (e.g. dry matter or phosphorus) than the input material. Normally the solid fraction is stackable.
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis
Target	The property that is affected by the product
Test center, test sub-body	Sub-body of the test center that plans and performs test
Test center, verification sub-body	Sub-body of the test center that plans and performs the verification
Test/testing	Determination of the performance of a product for parameters defined for the application
Vendor	The party delivering the product to the customer
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance

A P P E N D I X   2

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A P P E N D I X 3

Application and performance parameter definitions

This appendix defines the application and the relevant performance parameters as input for the verification and test of GEA Westfalia UCA 501-00-02 decanter centrifuge following the DANETV method.

1. Applications

The intended application of the UCA 501-00-02 is defined in terms of the matrix, the target and the effect of the slurry separator.

1.1 Matrix

The matrix is the type of material that the product is intended for. In the case of GEA Westfalia UCA 501-00-02 the matrix of the application is digested biomass at a biogas plant based on manure running within the mesophilic temperature regime.

Typically, the total solids content of such digested biomass is in the range of 5,0 – 8,0 %. The digested biomass shall be regularly stirred to avoid sedimentation in the tank from which the biomass is led into the decanter centrifuge. Stirring secures that the decanter centrifuge is fed with relatively homogenous input biomass.

1.2 Targets

Targets are the measurable properties that are affected by the technology product. In the case of GEA Westfalia UCA 501-00-02 the targets of the application are:

- Concentrations of total solids (TS), volatile solids (VS) and suspended solids (SS) in digested biomass, liquid output fraction and solid output fraction.
- Concentrations of total nitrogen, ammonium nitrogen, phosphorous (P), potassium (K) and sulphur (S) in digested biomass, liquid output fraction and solid output fraction.
- Weight of liquid output fraction and solid output fraction.
- Particle size distribution in liquid output fraction.

1.3 Effects

The effects describe how the targets are affected by the technology product.

In the case of GEA Westfalia UCA 501-00-02 the effects are:

- Increased concentrations of total solids (TS) and volatile solids (VS) in solid fraction compared to input digested biomass.
- Increased concentrations of total nitrogen and phosphorous (P) in solid fraction compared to input digested biomass.
- Removal of the larger particles in liquid output fraction.

Based on measured masses of input digested biomass, liquid output fraction and solid output fraction and the measured concentrations of TS, VS, SS and nutrients in the input and output fractions mass balances are calculated.

1.4 Exclusions

GEA Westfalia UCA 501-00-02 decanter centrifuge can be used for separation of other biomasses like pig slurry, cattle slurry and waste water. However, these matrices differ from digested biomass at a biogas plant in a number of aspects.

Consequently, the results of the verification of GEA Westfalia decanter centrifuge for separation of digested biomass are not necessarily valid for separation of pig slurry or cattle slurry. Additional tests are necessary to verify the performance of UCA 501-00-02 for separation of such matrices.

2. General performance requirements

2.1 Regulatory requirements

If the digested biomass is separated at the biogas plant and the solid fraction is used for other applications than for spreading on land the farmer who receive the digested biomass can achieve a reduction in the area that shall be available for application of the digested biomass ("harmony area").

The size of the reduction in harmony area depends on the separation efficiency with respect to total nitrogen. Thus, the larger the share of total nitrogen from the digested biomass that is recovered in the solid fraction, the larger the reduction in harmony area.

In some areas phosphorous are lost to vulnerable surface waters leading to Eutrophication. In such areas the farmers receiving the digested biomass are sometimes met by restrictions on the application of phosphorous on their fields. In this case separation of the digested biomass can be a tool to reduce phosphorous content in the liquid output fraction compare to untreated digested biomass and thereby balancing the amount of phosphorous applied to the needs of the crops.

2.2 Application based needs

Typically, biogas plants considering investing in a technology for post-treatment of digested biomass prefer separators with high separation efficiency with respect to total nitrogen. But biogas plant owners also prioritise separators with low initial investment costs, low operational costs (electricity, man power, etc.) and high operational stability.

3. State of the art performance

A draft version of a technology description for decanter centrifuges used for separation of slurry has been published on the internet by the Danish Environmental Protection Agency in 2009. This technology description will be used for evaluation of decanter centrifuge as best available technologies for intensive livestock production.

According to this technology description the expected performance of decanter centrifuges used for separation of pig slurry is:

- Total nitrogen separation efficiency: 25 % with variations from 18 % to 28 %
- Total phosphorous separation efficiency: 65 % with variations from 60 % to 70 %

Probably, separation efficiencies within the same range will result when decanter centrifuges are used for separation of digested biomass instead of pig slurry.

4. Performance parameter definitions

The performance parameters are defined in section 5.4 above.

APPENDIX 4

Test report

The test report is attached to this verification report as a separate file.

A P P E N D I X 5

Review reports

Comments, questions and proposals for improvements of plan documents and report documents have been communicated from internal and external reviewers both by e-mail and by telephone and at meetings.

These comments, questions and proposals for improvements are stored according to the archiving procedures described in the AgroTech Test Centre Quality Manual.

A P P E N D I X 6

Amendment and deviation report for verification

During the test the following deviations from the test report were registered:

According to the original test schedule batch 4 and batch 5 were planned to end of December 2009. However, since the biogas plant used as test site was not in normal operation the original schedule for the test could not be followed. Instead batch 4 and batch 5 were postponed to 21.01.2010. The operational problems at the biogas plant were not related to the GEA Westfalia UCA 501-00-02.

Since the analytical performance requirements were not met the pooled samples of liquid output fraction from batch 4 and batch 5 were re-analyzed at analytical laboratory.

In calculation of the average mass balances the following batches have been omitted because the analytical performance requirements have not been met:

- Phosphorous, batch 3.
- Suspended solids, batch 4 and batch 5.
- Volatile solids, batch 5
- Sulphur, batch 4 and batch 5.

Consequently, separation efficiencies for phosphorous and volatile solids are based on results from 4 batched only. Calculation of separation efficiencies for suspended solids and sulphur are based on results from 3 batches only.