Final Report

Releasing the full potential of
AIKAN©
- a dry anaerobic digestion biogas technology

Solum Gruppen
Aalborg University
Thursday, 11 July 2013

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Preface

This final project report contains a summary of the findings and documentation which have been carried out as a part of the EUDP-supported project "Documentation and Energy Yield Optimisation of AIKAN© - a dry anaerobic digestion biogas technology". The aim was to improve documentation of the AIKAN© technology, improve performance of the AIKAN© technology and thus remove important barriers for market entry on principal export markets caused by the lack of performance documentation. The final report also contains a description of the subsequent process and technology improvements which have been carried out in order to improve and optimize the production process at the full scale AIKAN© biogas plant, Biovækst, in Audebo, Denmark. The relevant analyses carried out as part of the different work packages are attached as appendixes to the report. It is the intention that the final report and the attached appendices should function as a work of reference for the employees involved in the day to day running and optimization of the AIKAN© technology.

The final project report – which follows the outlay of the original application to the EUDP – also constitutes the final evaluation report to the EUDP.

Bjarne Jørnsgård, Solum
Hinrich Uellendahl, AAU
Morten Brøgger Kristensen, Solum
Martin Wittrup Hansen, Solum

Vadsby, Thursday, 11 July 2013

WP1: progress, results and management

The relevant tasks and deliverables in connection to each work package are described in the Gant diagram shown below. The relevant analyses and tests carried out as part of the different work packages are attached as appendixes to the report.

AIKAN - dry AD biogas production	2010										2011-					
	m	a	m	j	j	a	s	o	n	d	j	f	m	a	m	j
WP1																
t11 project management																
d11 annual report										x						
d12 expert committee meeting															x	
WP2																
t21 state of the art																
t22 benchmark preproject																
d21 state of the art report						x										
d22 process instrumentation report								x								
d23 operation and maintenance report								x								
t23 energy yield model																
t24 releasing the full energy potential																
t25 benchmark postproject																
d24 energy and mass balance										x						
WP3																
t31 optimal plant design and layout																
d31 optimal design and layout													x			
t32 flexibility study wrt energy output																
d32 windows of operation															x	

t - task
d - deliverables

Process

In order to speed up the process and secure the development of the project according to the best interest of the targets and goals setup by EUDP an expert committee including all relevant stakeholders active in the business model was established.

The expert committee consisted of Lene Lange (AAU), Martin Wittrup Hansen (Solum), Hinrich W. Uellendahl (AAU), Bjarne Jørnsgård (Solum) and Morten Brøgger Kristensen (Solum).

It has primarily been Hinrich W. Uellendahl (AAU), Bo Pilgaard (AAU), Bjarne Jørnsgård (Solum), Carsten Mikkelsen (Solum) and Morten Brøgger Kristensen (Solum), who have been carrying out the research and experimental work.

There have been five physical meetings (26/-10, 13/9-10, 28/10 -10, 7/1 – 11, 10/1 – 11, 3/2- 11) during the project period.

Since there where only two partners in the project, the day to day contact and agreements has been through e-mail and phone. Decisions on sample taking, operation regimes and measurement points, analysis etc. have been taken according to the project plan on a day to day basis. Due to the closeness of the cooperation decisions have been recorded by means of email correspondence rather than minutes from meetings (An example on the e-mail cooperation is included in app. 1.2)

Novozymes has been delivering enzymes based on information/knowledge from the project partners on the composition of waste and intermediate fraction. From Novozymes it has primarily been Preben Nielsen and Hans Sejr Olsen, who have been involved. There have been two physical meetings and frequent contact by e-mail.

The cooperation has been working seamlessly and effective with well defined roles for the partners and a good understanding of the exploitation of results. The project was concluded by the 1. of august.

Deliverables/appendixes according to the application

- WP 1.1. All required and requested and needed status reports for EUDP – see appendix 1.1
- WP 1.2. Summaries from meetings in the expert committee – see appendix 1.2

WP2: AIKAN© due diligence

WP2 consisted of a status for AIKAN© - performance yields based on operation. AIKAN was benchmarked towards other commercial organic waste energy plants (e.g. incineration, gasification) and a plan for realising the full AIKAN© energy potential was conducted. This chapter is organized according to the deliverables mentioned in the EUDP application:

- Task 2.1: Performance of BioVækst and Hera Vekst from 2005 to 2009.
- Task 2.2: Benchmarking of other technologies for handling organic waste and biomass.
- Task 2.3: Optimal technical and economical capacity.
- Task 2.4: Releasing the full energy potential
- Task 2.5: Engineering and planning of future plants.

Task 2.1: Performance of BioVækst and Hera Vekst from 2005 to 2009

Subchapter 2.1 covers AIKAN© state of the art based on operation since 2003 and 2005 of the two AIKAN© plants in Audebo and Elverum has been described as regards performance.

BioVækst has been operating since 2003 whereas Hera Vekst has been operating since medio 2005. The plants have been producing compost and an increasing amount of biogas. At Hera Vekst in Norway the only use of biogas has been for internal heat the remaining biogas has been flared.

At BioVækst the biogas has been used for electricity production, but in the first years a very unreliable landfill biogas motor setup was used thus for longer periods a year the motor failed. Since 2010 a stable new motor and flaring equipment has given the right conditions for evaluating the system.

In table 1 and table 2 the overall performance data of the two plants are shown. As it shows compost has been produced continuously fairly stabile whereas there has been a slow rise in energy production. The energy production has been low even the potential of the waste as seen in the next section are quiet high. The main reason in Norway has been that focus has been only on compost production. Thus biogas phases has been skipped or only running for one week. In Denmark the reasons has been the unreliable biogas motor but also the fact that the plant has been exploited to over its full capacity, since sewage sludge has been composted too. That means that biogas phases in some periods have been cut to one week only here too.

BioVækst - Essence of Performance 2006-2009					
	2006	2007	2008	2009	
Massbalance (fresh weighed)					
Input					
BMSW	7400	8700	6700	12000	Ton
Structure	1233	1450	1117	2000	Ton
Output					
Residual waste	1400	2900	2200	3800	Ton
Compost	1500	2600	1650	3500	Ton
Process (including biogas and evaporation)	4500	3200	2850	6700	Ton
Energybalance					
Consumption					
Heat	300	300	300	300	MWh
Electricity	155	140	134	125	MWh
Diesel (for frontloaders, screens, shredders)	153	134	134	213	MWh
Production					
Energy content Biogas	900	1000	1200	2900	MWh

Table 1

Hera Vekst - Essence of Performance 2006-2009					
	2006	2007	2008	2009	
Massbalance (fresh weighed)					
Input					
BMSW	25000	23000	23000	23000	Ton
Structure	6250	5750	5750	5750	Ton
Output					
Residual waste	8750	8050	8050	8050	Ton
Compost	6250	5750	5750	5750	Ton
Process (including biogas and evaporation)	16250	14950	14950	14950	
Energybalance					
Consumption					
Heat	500	500	500	500	MWh
Electricity	150	150	150	150	MWh
Diesel (for frontloaders, screens, shredders)	1200	1200	1200	1200	MWh
Production					
Energy content Biogas	1950	2691	3140	3588	MWh
Data from Hera Vekst is very scarce and the focus has been on compost production - biogas has used internal for heating and otherwise been flared					

Table 2

In table 1 and 2 it must be emphasized that the energy content in the residual waste has not been shown. This would be relevant in a LCA context, where the amount of Energy would be subscribed to the system. In the tables it is only energy used and produced physically at the plant, which has been accounted for.

Task 2.2: Benchmarking of other technologies for handling organic waste and biomass.
Subchapter 2.2 deals with the correlation between other competing technologies able to handle organic waste and biomass and the state of the art description in subchapter 2.1

As part of the project an extensive collection of process data and test results has been carried out in order to establish a mass and energy balance for AIKAN©. The mass and energy balance constitutes – a part from being an important tool in its own right and an indispensable part of a LCA for the complete AIKAN© plant - the parameters for a benchmark analysis between the AIKAN© technology and similar technologies.

It has, though, proven more difficult than anticipated to get access to the relevant process data from partners and competitors in order to establish the necessary preconditions for the correlation and benchmarking of AIKAN© and other competing technologies able to handle organic waste and biomass. This means that the elaboration of a benchmark system that permits a comparison between the AIKAN© technology and similar technologies is carried on as part of the ongoing surveillance of competitors, competing technologies and applications for patents that Solum Gruppen performs on a regular basis.

The elaboration of a mass and energy balance has proven a valuable contribution in order to document how the AIKAN© technology separates municipal household waste in different fractions and the relation/ratios between the different fractions – compost, water, gas energy etc. – which are produced. See appendix 2.1 for the analysis on mass and energy for the AIKAN© technology.

Task 2.3: Optimal technical and economical capacity.
In order to establish relevant parameter variations and optimize performance as regards energy yield and essential technology components involved in the process flow various computer models have been developed.

The Aikan plant in Holbæk, BioVækst, has been thoroughly analyzed for its operation, efficiency and emissions. This has resulted in a series of tests, calculations and simulations concerning performance and efficiency of the ventilation systems in the process modules, compost maturation boxes and biofilters, concerning the leachate pumping and valve system, sprinkler and nozzle system and regarding gas production. The gas engine has been evaluated for greenhouse gas emissions and energy balances have been parameterized during composting and sanitation in the process modules.

This has led to improvements in nozzle size and position in the process modules, choice of valves for the leachate system. Changing the air tubes in the bio-filters, has significantly reduced the air flow resistance and change of pipe dimensions in the maturation boxes has also led to considerably more energy efficient ventilation. The analysis have also lead to new monitoring of pressures in liquids and gasses on key positions providing online information of process status.

Mass balances leachate flow and analysis of leachate biogas potential (COD), pH, etc. in several full-scale and pilot plant test have been used to identify bottlenecks for gas production and capacity. This has led to new experiments with percolate flooding and gas measurements in the process modules and a significant increase in gas yield. Clarification of these matters has opened important new improvements and development opportunities already being acted upon.

Furthermore measurements of the atmosphere (oxygen, carbon dioxide, methane and temperature) in the process modules during composting have enabled optimization of the composting and sanitation processes. Documentation of the conducted tests and analyses and the developed computer models - see appendix 2.3.1 – 2.3.5.

On the basis of the results emanating from the simulations conducted with the computer models as documented in app. 2.3.1 – 2.3.5 a key instrument has been developed as regards the launching and market penetration of the AIKAN-technology: A standard model which allows for technical and economical scalability of the AIKAN© technology. The model makes it possible to adapt the AIKAN© technology to local conditions and customer needs whether a small, medium sized or large AIKAN© plant is required.
See appendix 2.3.6 for an extract of the standard model for scalability of the AIKAN© technology. (Due to the confidential nature of the data in the standard model as regards competition app. 2.3.6 contains an abstract of the model.)

Task 2.4: Releasing the full energy potential
In order to release the full energy potential of the AIKAN© technology a detailed plan for optimizing the operational plant, Biovækst in Audebo, as regards energy yield has been produced. Individual action plans has been developed in order to get more energy output and reduce energy consumption and various gas usages have been described.

A detailed plan for optimizing the operational plan a series of tests were conducted at the AIKAN® plant in Audebo, Denmark. The efficiency of the AIKAN© two-stage biogas process for the source-sorted organic fraction of municipal solid waste (OFMSW) was investigated by methane potential analysis of the waste input and monitoring the hydrolytic and the methanogenic activity in the two stages of the process. To determine the potential of the AIKAN© plant performance the methane yield of the different waste materials used in the process was analysed in batch experiments. To evaluate the capability of the different stages of the AIKAN© process, VFA released from the processing module were measured and inoculum from the biogas reactor tank was compared to standard inoculum from a manure-based biogas process.

The analyses revealed that the bottleneck of the whole degradation process can be rather found in the hydrolytic first stage while the methanogenic second stage revealed high efficiency. Consequently, in order to increase the energy yield of the whole process measures have been taken to improve the hydrolysis process in the first stage. See appendix 2.4.1 and 2.4.2 for a complete overview of the test results and methane yields from different process setups as published in an article by Kristensen, Jørnsgård and Uellendahl.

As regards the individual actions plans covering the performance of specific technology components from the overall flow these were carried out as part of the elaboration of the computer models mentioned under task 2.3. (See appendix 2.3.1 – 2.3.5).

Task 2.5: Engineering and planning of future plants.
The tasks included in task 2.1 – 2.4 has been incorporated in the engineering and planning of future plants. In this respect attention is drawn to appendix 2.3.6 and work package 3, notably appendix 3.1. as regards planning and design of future plants. The above mentioned tasks carried out in order to improve and optimize the procesflow of the AIKAN© technology and the task mentioned in work package 3 has been the foundation for the elaboration of a full AIKAN Standard Operational Manual – see appendix 2.3.

Deliverables according to the application
WP 2.1. Report on AIKAN© technology state of the art - Operation parameters, compositions, and other relevant data. **This final report with appendixes constitutes the state of art on the process flow and technology of the AIKAN© technology**.
WP 2.2. A full Process Instrumentation Design (FID). The full content of the FID will obviously not be enclosed due to confidentiality and competition but examples of standard-layout and design have been enclosed under section 3.1 – see appendix ask 2+3
WP 2.3. A full O&M report. See appendix 2.3
WP 2.4. A comprehensive energy and mass balance. See appendix 2.3

WP3: Realising the AIKAN© potential

The main aim of WP3 has been to conduct design, layout and engineering of AIKAN© technology which includes implementing design and operation changes to release the full energy potential. This chapter is organized according to the deliverables mentioned in the EUDP application:

- Task 3.1: design and layout under optimal conditions
- Task 3.2: Determine windows of operation wrt. energy output – potentials and cost

Task 3.1: AIKAN© optimal plant design and layout
The optimal AIKAN© plant has been designed, engineered and standard lay-out has been developed. In collaboration with Alectia A/S the BioVækst plant ind Audebo has been modified and improvements has been implemented in the design. Operation parameters have been changed in order to test, demonstrate and verify the identified potential for improvements. In order to optimize and standardize – and thus develop a prototype physical layout of the AIKAN © technology – various operations have been carried out, notably: Development of criteria for optimal localisation of plants, combining architectural and engineering drawings, standardization of layout of buildings, standardisation of tender material and tender contract etc.
The full content of the various tasks in order to develop a prototype AIKAN© layout will obviously not be enclosed due to confidentiality and competition but examples of the tasks performed have been enclosed as appendix 3.1.

Task 3.2: Determine windows of operation as regards energy output – potentials and cost
Based on the testing and demonstration future estimates for AIKAN© applications have been performed. It has been the aim to collect and systematize relevant and sufficient data allowing Solum Gruppen to be able to provide commercial guaranties – performance and specifications – for all relevant biogas uses, thus opening new markets for the AIKAN© technology. An example of the wide range of technical specifications which have been elaborated is enclosed as appendix 3.2. The full content of the various drawings and standard specifications will obviously not be enclosed due to confidentiality and competition.

Deliverables according to the application
D.2.1. Plant design and layout under optimal conditions – see appendix 3.1
D.2.2. Determine windows of operation as regards energy output – potentials and cost – see appendix 3.2

Project cost

[Her skal være et skema som modsvarer budget men med regnskabstal, hvortil der kan genfindes alle bilag]

Appendices –

Releasing the full potential of
AIKAN©
- a dry anaerobic digestion biogas technology

App. 1.1 All required and requested and needed status reports for EUDP

EUDP-sekretariatet
EFP
Amaliegade 44
1256 København K
CVR-nr.: 59-77-87-14

Årsrapportskema for år __2010___.

Projektidentifikation

EFP-10 (angiv år) Journalnr.: 64010-0006

Vedr.: Demonstration and documentation of AIKAN

Titel: EFP-10 (angiv år) 2010

Tilsagnshaver (projektansvarlig)

Firma: Solum A/S Telefon: 43 99 50 20

Adresse: Vadsby Stræde 6 E-mail: mwh@solum.com

Projektleder: Martin Wittrup Hansen Telefon: 27 22 29 42

Totale udgifter (forbrug) (1000 kr.)

	Budget (tilsagn)	Afholdte udg.
År 1	1.200.000	500.000
År 2	800.000	0
År 3		
I alt	2000000	500000

Tidsplan (Se regler for modtagelse af tilskud)

Godkendt projektperiode (åååå/mm): 2010/01-2011/06

- ○ Projektet følger den godkendte tidsplan.
- ○ Projektet følger ikke den godkendte tidsplan (beskrives i vedlagte års-rapport).

Tilsagnshaver (projektansvarlig)

......26.08.2010................................. Martin Wittrup Hansen ....

Dato	Navn og underskrift

Forbeholdt Energistyrelsen

Sagsbehandling:

1. Projektets faglige fremdrift (hvilke faser eller hovedaktiviteter, der er afsluttet, opfyldelsen af de faglige delmål, hvilke resultater, der er opnået) Der er i projektet gennemført en omfattende ombygning af anlægget i Holbæk. Der er etableret måleudstyr og procedurer, således at energiproduktionen kan logges. Der er gennemført test af vores sprinklersystem, som er essentielt ved udvaskning af næringsstofferne. Ligeledes er anlægget gennemtestet for tryktab, med henblik på at optimere blæserydelsen. Den nye motor er i drift og der produceres tilfredsstillende el og varme. Gassens kvalitet er overraskende god - højt (70%+) methanindhold og lave indhold af svovl og sporstoffer. Samarbejdet med AAU er godt i gang - de laver en grundig analyse og evaluering af potentialet i vores perkolat og i vores væskestrømme. Ligeledes evalueres potentialet i vores modtagne affaldsstrøm. Optimeringsmæssigt har vi valgt at ombygge to af de ti driftsmoduler til forsøgsmoduler. Her er det muligt tæt at følge hydrolysen og komposteringen af affaldet, med henblik på at identificere optimeringspotentialer og besparelsesmuligheder. Disse er i drift i løbet af september. Endeligt er etableret to forsøgsanlæg - mindre enheder (3m3 moduler) og tilhørende reaktorer, hvori vi kan gennemføre forsøgsrækker, med forskellige parametervariationer og forskellige affaldstyper.
2. Tidsplan: følges tidsplanen? Hvis ikke, oplyses årsag og konsekvenser for realisering af projektmålene og resultatudnyttelsen. Det angives endvidere hvilke foranstaltninger, der tænkes foretaget for at indhente forsinkelsen. Såfremt projektet indgår i sammenhæng med andre projekter angives, om forsinkelsen vil have konsekvenser herfor. Såfremt projektet er bagud i forhold til tidsplanen, skal der indsendes en revideret tidsplan EUDP-sekretariatet til godkendelse. Projektet er forud for tidsplanen.
3. Eventuelle kommentarer til videre forløb Projektet bliver udvidet en del, da vi sammen med Kara/Noveren og Vestforbrænding har valgt at investere i at "opgradere" Aikan anlægget i Holbæk til et demonstrationsanlæg. Hertil er igangsat et projekt til belysning af ydelsen, hvor DTU er involveret i en LCA af Aikan.

4. Eventuelle publikationer mv. (offentliggjorte publikationer, artikler mv. og afholdte workshops mv. *eventuelle supplerende oplysninger (fx kommentarer til samarbejdet med eventuelle projektpartnere, ændringer i projektets aktualitet)* Der har ikke været publiceret. Der er afholdt en intern workshop mellem projekts partnere.
5. Eventuelle supplerende oplysninger Vi ville gerne foretage en budgetændring, hvor de 75.000 kr til rejser flyttes over til timer.
Der er vedlagt revisorerklæring for følgende projektdeltagere (deltagere, der fået tilsagn om tilskud på 10 mio. kr. eller derover):

App. 1.2 Summaries from meetings in the expert committee

Hej Morten,
Det er fint med at recirkulere væsken over procestanken lidt længere for at opretholde den lave pH – bare husk at det skal alligevel ikke være alt for længe. Og især er VFA'erne en vigtig parameter for at se om hydrolysen er godt i gang. Mht. temperatur så vil jeg hæve det i både PM og RT.
Bo (vores tekniker) har ingen planer om at holde ferie i oktobermåned, derfor kan i sagtens sende prøverne i uge 42. Jeg kan lige meddele at jeg er på en konference i uge 44.
Jeg kan godt se på udviklingsplanen for Aikan.

Mange hilsner,

Hinrich
(Header removed)
Kære Hinrich
Tak for dette – lige hvad jeg håbede.
Ja vi laver selv COD løbende.
Pt. er vi gået igang med at teste ideen med at holde pH lav i Procestanken så længe som muligt, ved at recirkulerer væske over modulet i længere tid. Dels for som du forslog at forlænge hydrolysen i PM og dels undgå gasdannelse ti PT. Vi har ikke resultater endnu men håber jo at vi vil kunne se direkte effekt på metandannelsen, subsidiært i COD concentrationen.
Ville du hæve tempraturen i RT eller i PM?
Mht hvornår I skal regne med at udfører praktisk arbejde:

1. affaldssammensætningen er relevant medio oktober (er der noget med efterårsferien uge 42 er dårlig?).
2. VFA er jo egentligt relevant netop det næste stykke tid af hensyn til forsuringsforsøgene – det skal jeg lige diskuterer med Bjarne i morgen.

Jeg vender tilbage med tidsplan for Jer.
TOC kan vi undvære eller finde nogen andre til.

Jeg har et håb, at du måske på et tidspunkt kan have tid at læse og kommenterer en udviklingsplan for Aikan på lidt længere sigt. Det er noget jeg sider og nørkler med og egentligt et internt dokument, men jeg tror dit input ville være værdifuldt – og det kunne måske også afstedkomme nogle projektideer sammen?

Med venlig hilsen / Best regards

Morten Brøgger Kristensen
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Fax: +45 4399 5231
E-mail: mb@solum.com

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Hej Morten,
Tak for det tilsendte forsøgsplan. Jeg vil gerne præcisere den lidt. Som jeg husker fra vores samtale vil vi lave følgende analyser:

- Biogaspotentiale på det tilførte husholdningsaffald (med og/eller uden strukturmateriale)
- Sammensætningsanalyse (cellulose/hemicellulose/lignin, COD) af det tilførte husholdningsaffald (med og/eller uden strukturmateriale)
- Løbende analyser af VFA under forsøget (prøvetagningssted og hyppighed skal aftales)
- TOC kan vi ikke lave hos os

Jeg går ud fra at i selv laver løbende COD målinger under forsøget, både opløst og partikulær som vi talte om til mødet. Jeg vil gerne være behjælpelig med at evaluere målingerne løbende for at bedømme effektiviteten af processen
Jeg mener stadig at pumperegimet mellem procesmodul og reaktortank er den umiddelbart mest interessante parameter for at optimere processen uden de store ændringer på anlægget. Den samlede opholdstid i hele systemet vil også komme med hvid der måles den samlede producerede biogasmængde over tiden. En anden parameter er selvfølgelig temperatur, hvor jeg vil klart anbefale 52 grader, men det gik jeg ud fra er ikke lige så nemt at ændre på. Men hvis det kunne lade sig gøre på det lille forsøgsanlæg, vil jeg mene i skulle prøve det.

Med venlig hilsen,

Hinrich

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Kære Hinrich
Vores overbliksplan er her.
Vi har ikke som først tænkt skrevet ….der tages xxx antal prøver da dette afhænger af formålet.
Status nu er at vi (næsten) har et fuldt kørende forsøgsanlæg. Der er nogle få tekniske udfordringer som løses inden for det næste par uger, men anlægget producere gas nu.
Lad mig i første omgang vide om du har andre optimeringsforslag….samt om det er de rigtige parametre der er sat op til jer om biogaspotentialet.
Jeg har talt med Novozymes i dag de kommer forbi i næste uge så vi kan aftale lidt om forsøgsplanen her også.

Med venlig hilsen / Best regards

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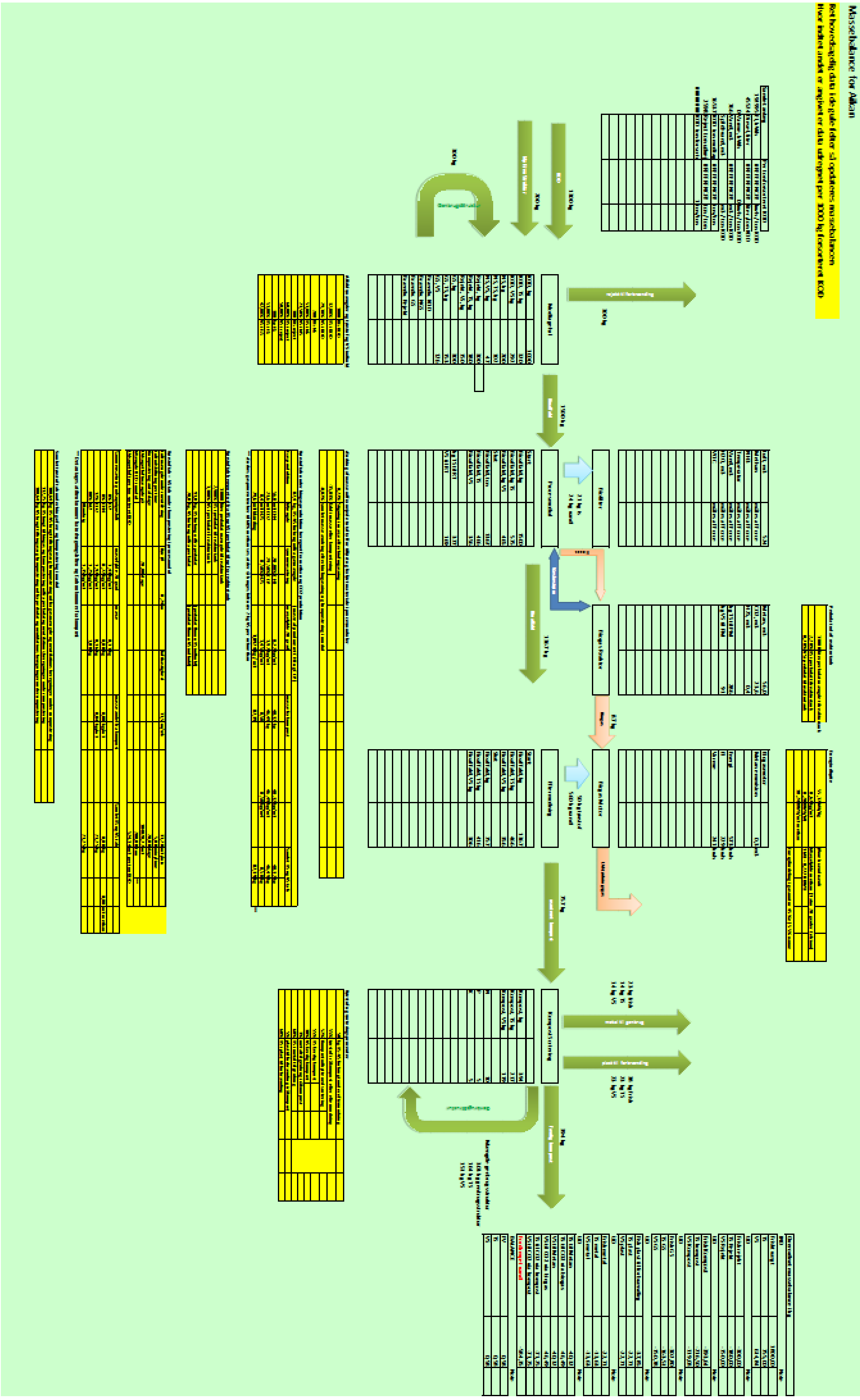
App. 2.1. Analysis on mass and energy balance.



App. 2.3.1 Perkolat- og gasanalyser, titreringer og gassimulering - BioVækst

Modul 11 er fyldt 1 og 2. februar 2011

I modulet er der indlagt: 147 ton forbehandlet knust KOD, 47 ton HPO, 25,5 ton genbrugsstruktur

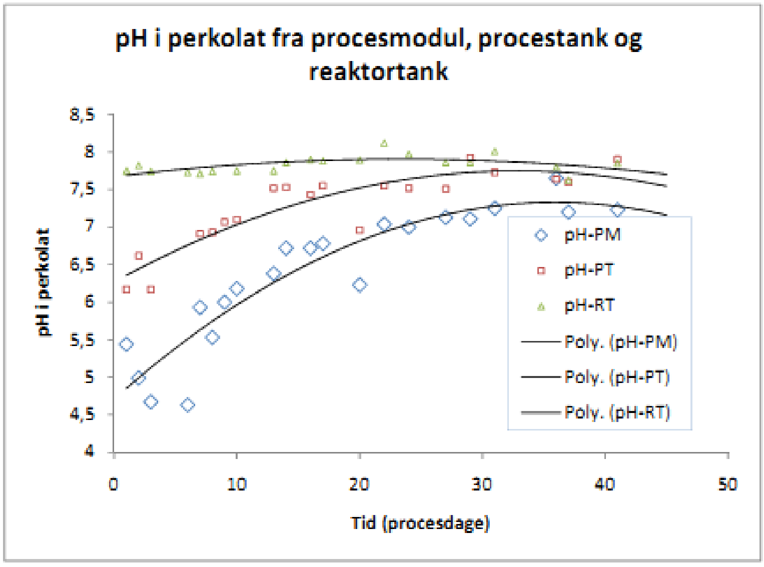
Sigterest-frasorteret affald, der sendes til forbrænding har ud af 1327 ton udgjort 307 tons, svarende til 23,13%.

Det er det der sorteres fra før affaldet blandes med strukturmateriale i foderblanderen og indlægges i modulerne.

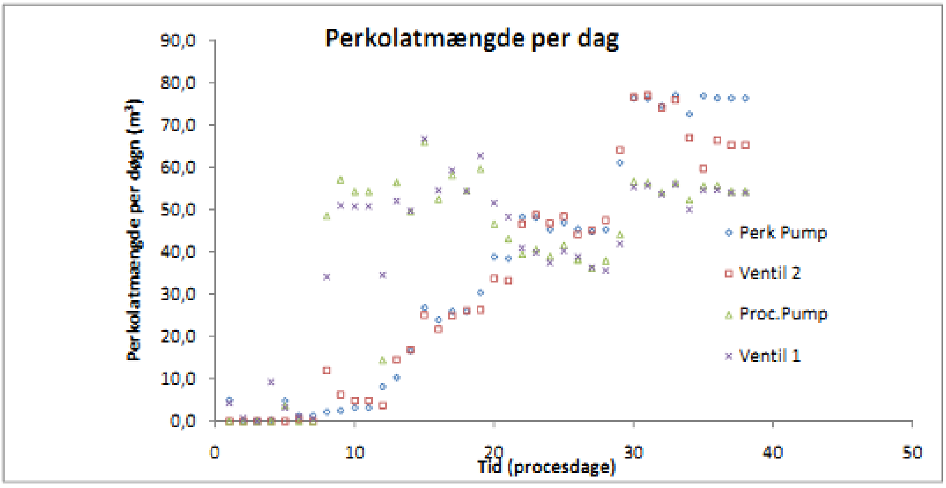
Gas Volumen korrigeret =(GasVol *(0,83221-(0,0086*(Meth%-60))))/0,83221

basis er 60% methan med en K værdi på 0,83221 lagt ind i PLC ved gasmåler

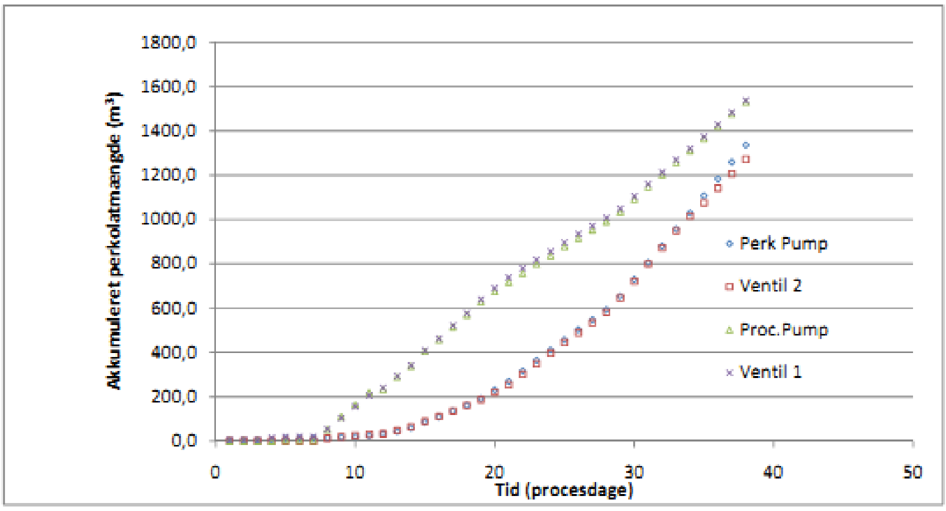
		Analyse	Analyse	Analyse	Aflæst	Aflæst	Aflæst	Aflæst	Aflæst	Aflæst
		pH	pH	pH	Gas	Gas	Gas	Perk m3	Perk m3	Perk m3
Dato	Procesdage	pH-PM	pH-PT	pH-RT	CH4 %	CO2 %	H2S ppm	PT-RT	RT-PT	PT-PM
02.02	1	5,44	6,17	7,75	69	27	642	0,0	0,0	0,0
03.02	2	4,99	6,62	7,82	60	35	769	22,5	17,5	27,7
04.02	3	4,67	6,17	7,74	59	36	707	29,4	22,0	81,0
05.02	4									
06.02	5									
07.02	6	4,63		7,73	60	35	690	46,9	31,3	228,9
08.02	7	5,93	6,91	7,71	61	34	621	65,6	42,5	267,0
09.02	8	5,53	6,93	7,74	63	32	567	86,9	53,9	305,4
10.02	9	6	7,07		64	32	760	114,9	64,9	338,6
11.02	10	6,18	7,1	7,75	65	31	644	145,0	76,0	360,0
12.02	11									
13.02	12									
14.02	13	6,38	7,52	7,75	70	27	621	227,0	101,0	421,0
15.02	14	6,72	7,53	7,86	71	26	612	280,0	122,0	464,0
16.02	15									
17.02	16	6,72	7,43	7,9	71	25	624	369,0	168,0	535,0
18.02	17	6,78	7,55	7,88	72	25	614	409,0	215,0	572,0
19.02	18									
20.02	19									
21.02	20	6,23	6,96	7,89						
22.02	21									
23.02	22	7,04	7,55	8,12						
24.02	23									
25.02	24	7	7,52	7,97						
26.02	25									
27.02	26									
28.02	27	7,13	7,51	7,86						
01.03	28									
02.03	29	7,11	7,92	7,86	73	23	506	801,0	683,0	982,0
03.03	30									
04.03	31	7,25	7,73	8,01	73	23	500	886,0	785,0	1071,0
05.03	32									
06.03	33									
07.03	34									
08.03	35									
09.03	36	7,65	7,64	7,8	72	25	414	1114,0	1059,0	1314,0
10.03	37	7,2	7,6	7,63	72	25	401	1149,0	1101,0	1354,0
11.03	38							1215,0	1186,0	1423,0
12.03	39									
13.03	40									
14.03	41	7,23	7,9	7,85	73	23	352	1772,0	1708,0	1437,0
15.03	42									
16.03	43									
17.03	44									
18.03	45									


pH i perkolat fra procesmodul, procestank og reaktortank
pH i perkolat
8,5
8
7,5
7
6,5
6
5,5
5
4,5
4
0
10
20
30
40
50
Tid (procesdage)
pH-PM
pH-PT
pH-RT
Poly. (pH-PM)
Poly. (pH-PT)
Poly. (pH-RT)

Aflæst	LogData	LogData	LogData	LogData	LogData	LogData	LogData	LogData	Aflæst	Aflæst
Perk m3	Perk m3/døgn	Perk accumuleret m3	Perk m3/døgn	Perk accumuleret m3	Perk m3/døgn	Perk accumuleret m3	Perk m3/døgn	Perk accumuleret m3	GAS	Gas korr for CH4 indhold
PM-PT	Perk Pump	Perk Pump	Ventil 2	Ventil 2	Proc.Pump	Proc.Pump	Ventil 1	Ventil 1	m3	m3
0,0	4,9	4,9	0,0	0,0	0,0	0,0	4,2	4,2	17031	15447,0
22,8	0,0	4,9	0,0	0,0	0,0	0,0	0,7	4,9	17323	17323,0
71,6	0,0	4,9	0,0	0,0	0,0	0,0	0,0	4,9	17648	17830,4
	0,3	5,2	0,0	0,0	0,0	0,0	9,2	14,1		0,0
	4,8	10,1	0,0	0,0	3,6	3,6	3,1	17,3		0,0
193,1	1,3	11,4	0,4	0,4	0,0	3,6	1,1	18,4	18388	18388,0
222,0	1,3	12,7	0,0	0,4	0,0	3,6	0,5	18,9	18777	18583,0
250,5	2,1	14,8	11,9	12,4	48,5	52,1	34,1	53,0	19181	18586,4
276,4	2,5	17,3	6,2	18,6	57,1	109,1	50,9	103,9	19579	18769,7
294,0	3,1	20,4	4,8	23,4	54,3	163,4	50,8	154,7	20004	18970,4
	3,1	23,5	4,8	28,2	54,3	217,7	50,8	205,4		0,0
	8,2	31,7	3,7	31,9	14,4	232,1	34,6	240,0		0,0
343,0	10,3	42,0	14,5	46,4	56,4	288,5	52,0	292,0	21253	19056,7
373,0	16,6	58,7	16,9	63,3	49,5	338,0	49,7	341,7	2877	2550,0
	26,8	85,5	25,1	88,3	66,0	404,0	66,7	408,3		0,0
425,0	23,9	109,4	21,7	110,0	52,5	456,5	54,6	462,9	22137	19620,6
451,0	26,0	135,4	24,8	134,9	58,1	514,5	59,2	522,1		0,0
	25,9	161,3	26,1	161,0	54,4	568,9	54,3	576,5		0,0
	30,3	191,7	26,3	187,3	59,6	628,5	62,7	639,1		0,0
	38,8	230,5	33,7	221,0	46,6	675,1	51,5	690,7		0,0
	38,4	268,9	33,2	254,2	43,2	718,3	48,2	738,9		0,0
	48,2	317,1	46,6	300,8	39,4	757,7	40,9	779,8		0,0
	48,1	365,2	48,7	349,5	40,6	798,4	39,8	819,6		0,0
	45,3	410,4	46,8	396,2	38,9	837,3	37,5	857,1		0,0
	46,9	457,3	48,4	444,6	41,6	878,9	40,2	897,2		0,0
	45,4	502,7	44,1	488,7	38,1	917,0	38,8	936,0		0,0
	44,8	547,5	45,2	533,9	36,1	953,1	36,3	972,3		0,0
	45,3	592,7	47,4	581,4	37,9	990,9	35,6	1007,9		0,0
761,0	61,0	653,8	64,1	645,5	44,1	1035,1	41,9	1049,8	24132	20890,1
	76,3	730,1	76,6	722,0	56,6	1091,7	55,3	1105,2		0,0
828,0	76,2	806,3	77,0	799,0	56,4	1148,1	55,7	1160,9	24315	21048,5
	74,5	880,8	74,1	873,1	54,1	1202,2	53,6	1214,6		0,0
	77,1	957,8	76,0	949,0	56,3	1258,5	55,9	1270,5		0,0
	72,6	1030,4	66,9	1015,9	52,3	1310,8	50,0	1320,5		0,0
	76,8	1107,2	59,7	1075,6	55,6	1366,4	54,6	1375,1		0,0
1006,0	76,3	1183,6	66,4	1142,0	55,7	1422,2	54,7	1429,8	24817	21739,5
1035,0	76,3	1259,9	65,2	1207,2	54,3	1476,5	54,0	1483,8	24900	21812,2
1079,0	76,3	1336,2	65,2	1272,5	54,3	1530,8	54,0	1537,8	24997	40496,0
1100,0										
										0,0

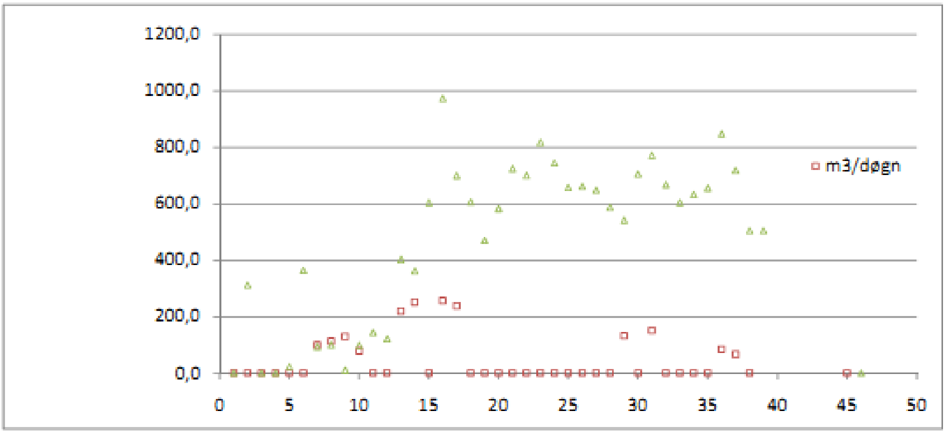


Perkolatmængde per dag
Perkolatmængde per døgn (m³)
Tid (procesdage)
Perk Pump
Ventil 2
Proc.Pump
Ventil 1



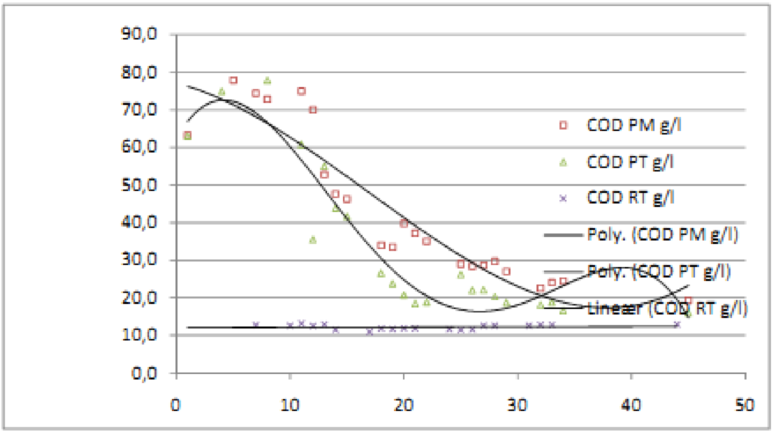
Akkumuleret perkolatmængde (m³)
Tid (procesdage)
Perk Pump
Ventil 2
Proc.Pump
Ventil 1

LogData	LogData	LogData	LogData	LogData	LogData	Methan pro	Korrigeret	LogData	Aflæst	
Gas	Dags prod gas uden tab	Mistet gas	Dagsprod gas	Acc gasproduktion gas	gas corr + tabt	corr	acc, korr for CH4	Temperatur-RT	Temperatur-PT	Temp procesmod midt
m3	m3	m3	m3	m3	m3	m3/døgn				
0,0				0,0	0,0	0,0	0,0	37,5	9	
0,0	0,0		0,0	0,0	0,0	0,0	0,0	37,7		
0,0	0,0		0,0	0,0	0,0	0,0	0,0	38	22	
0,0	0,0		0,0		0,0	0,0	0,0			
0,0	0,0		0,0		0,0	0,0	0,0			
0,0	0,0		0,0		0,0	0,0	0,0	37,5	22	
165,0	165,0		165,0	165,0	163,3	99,6	163,3	37,2	26	
351,1	186,1		186,1	351,1	180,3	113,6	343,6	36,2	28	
562,6	211,5		211,5	562,6	202,8	129,8	546,4	35,5	30	
690,4	127,8		127,8	690,4	121,2	78,8	667,6	36,9	31	
818,2	127,8		127,8	818,2	207,0	0,0	874,6			
945,2	127,0		127,0	945,2	205,7	0,0	1080,4			
1295,5	350,3		350,3	1295,5	314,1	219,9	1394,5	38,3	32	
1696,1	400,6		400,6	1696,1	355,0	252,1	1749,5	37,6	32	
2096,6	400,6		400,6	2096,6	648,9	0,0	2398,4	37,1	32	
2504,6	408,0		408,0	2504,6	361,6	256,8	2760,0	37,2	32	
2883,6	379,0		379,0	2883,6	332,0	239,0	3092,0	37,2	32	
3240,3	356,7		356,7	3240,3	577,9	0,0	3669,9			
3535,4	295,1		295,1	3535,4	478,1	0,0	4148,0			
3849,5	314,1		314,1	3849,5	508,9	0,0	4656,8			
4121,1	271,6		271,6	4121,1	440,0	0,0	5096,8			
4409,5	288,4		288,4	4409,5	467,2	0,0	5564,0			
4687,3	277,8		277,8	4687,3	450,0	0,0	6014,1			
4922,8	235,5		235,5	4922,8	381,5	0,0	6395,6			
5132,9	210,1		210,1	5132,9	340,4	0,0	6736,0			
5341,1	208,2		208,2	5341,1	337,3	0,0	7073,2			
5536,1	195,0		195,0	5536,1	315,9	0,0	7389,2			
5723,2	187,1		187,1	5723,2	303,1	0,0	7692,3			
5932,4	209,2		209,2	5932,4	181,1	132,2	7873,4	36	35	
6184,8	252,4		252,4	6184,8	408,9	0,0	8282,3			
6423,4	238,6		238,6	6423,4	206,5	150,8	8488,8	34,3	27	
6610,1	186,7		186,7	6610,1	302,5	0,0	8791,3			
6672,0	61,9	110,0	171,9	6782,0	278,5	0,0	9069,7			
6723,0	51,0	105,0	156,0	6938,0	252,7	0,0	9322,5			
6868,4	145,4		145,4	7083,4	235,6	0,0	9558,0			
7003,4	135,0		135,0	7218,4	118,3	85,1	9676,3	32,7	28	
7109,3	105,9		105,9	7324,3	92,8	66,8	9769,1	32,6	28	
7215,2	105,9		105,9	7430,2	171,6	0,0	9940,6	31,2	29	
								32	31	
7291,5	76,3		76,3	7506,5	123,6	0,0	10064,2			



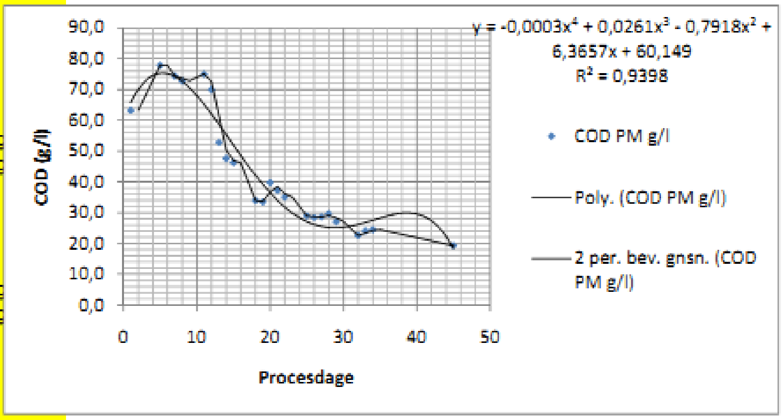
1200,0
1000,0
800,0
600,0
400,0
200,0
0,0
0
5
10
15
20
25
30
35
40
45
50
m3/døgn

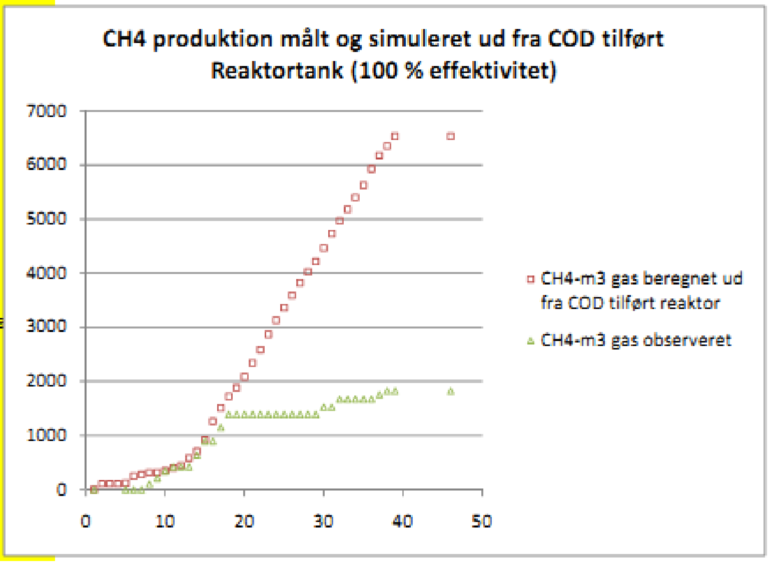
LogData	LogData	Analyse	Analyse	Analyse	Analyse	Analyse	Analyse	Analyse	Bereg	Beregning
Tryk Vent	COD PM	Prediktion	Prediktion	COD PT		COD RT		COD til RT netto (kg/døgn)	Effe ktivit et	Potentiel gas prod
	COD PM g/l	Prediktion average	Prediktion polynomial	COD PT g/l	Prediktion average	COD RT g/l	Prediktion average	AJ el AM		m3 methan
	63,2	63,2	64,5	63,0	63,0			312,0	1,00	109,2
		63,2	69,7		69,0			0,0	1,00	0,0
		70,5	73,3		69,0			0,0	1,00	0,0
		77,9	75,5	75,0	75,0			22,4	1,00	7,8
	77,9	76,1	76,4		75,0			364,1	1,00	127,5
		75,0	76,4		76,5		12,7	93,0	1,00	32,6
	74,4	75,0	75,4		77,9		12,7	99,3	1,00	34,8
	72,8	73,6	73,6	77,9	77,9	12,7	12,7	9,7	1,00	3,4
		74,1	71,3		69,3		12,7	98,1	1,00	34,3
		72,6	68,5		58,1		12,8	143,4	1,00	50,2
	75,0	65,9	65,3	60,8	50,4	12,6	12,8	121,2	1,00	42,4
	70,0	61,4	61,8	35,5	48,8	13,2	12,8	402,6	1,00	140,9
	52,8	58,3	58,3	55,0	47,4	12,6	12,6	362,9	1,00	127,0
	47,6	54,2	54,6	43,8	44,0	13,0	12,6	604,3	1,00	211,5
	46,3	48,9	51,0	41,6	46,8	11,5	12,4	973,6	1,00	340,8
		42,6	47,4		37,3		11,8	700,0	1,00	245,0
		37,9	44,0		30,7		11,4	606,6	1,00	212,3
	34,0	35,8	40,8	26,6	23,7	11,0	11,5	470,2	1,00	164,6
	33,5	36,1	37,9	23,8	22,4	11,9	11,6	582,8	1,00	204,0
	39,8	35,9	35,2	20,7	21,7	11,7	11,7	724,5	1,00	253,6
	37,2	36,4	32,9	18,5	20,5	11,9	11,8	700,2	1,00	245,1
	35,1	37,3	30,8	18,9	19,4	11,8	11,8	817,6	1,00	286,2
		33,7	29,1		21,2		11,8	745,3	1,00	260,8
		30,8	27,7		22,4		11,7	658,1	1,00	230,3
	29,0	28,7	26,6	26,2	23,4	11,7	11,6	662,4	1,00	231,8
	28,5	28,9	25,7	22,0	22,7	11,5	11,8	648,5	1,00	227,0
	28,7	28,6	25,2	22,1	21,9	11,6	12,0	587,7	1,00	205,7
	29,7	28,5	24,8	20,3	20,8	12,6	12,1	541,9	1,00	189,7
	27,1	28,5	24,5	18,8	20,4	12,6	12,3	705,0	1,00	246,8
		26,4	24,3		19,1		12,6	772,0	1,00	270,2
		24,6	24,2		18,6		12,7	668,4	1,00	233,9
	22,6	23,7	24,0	18,2	17,9	12,6	12,7	604,3	1,00	211,5
	24,1	23,7	23,6	18,8	17,9	12,8	12,7	633,4	1,00	221,7
	24,5	23,7	22,9	16,6	17,9	12,8	12,7	656,1	1,00	229,6
		24,3	21,9		17,7		12,8	847,7	1,00	296,7
		24,5	20,3		16,6		12,8	718,4	1,00	251,4
		19,4	18,2		16,0		13,0	505,0	1,00	176,8
		19,4	15,2		16,0		13,0	505,0	1,00	176,8
	19,4	19,4	-40,6	16,0	16,0	13,0	13,0	0,0	1,00	0,0



90,0
80,0
70,0
60,0
50,0
40,0
30,0
20,0
10,0
0,0
0
10
20
30
40
50
COD PM g/l
COD PT g/l
COD RT g/l
Poly. (COD PM g/l)
Poly. (COD PT g/l)
Lineær (COD RT g/l)

Beregning	Beregning	Beregning	Beregning
gas prod acc m3 meth	Obser methan prod.	Obs acc methan m3	Noter
gas beregnet	m3 / dag	gas observere	
109,2	0,0		Afdræning
109,2	0,0		
109,2	0,0		
117,1	0,0	0,0	
244,5	0,0	0,0	
277,1	0,0	0,0	
311,8	99,6	99,6	Biog
315,2	113,6	213,2	Biog
349,6	129,8	343,0	
399,8	78,8	421,8	
442,2	0,0	421,8	
583,1	0,0	421,8	
710,1	219,9	641,6	Biog
921,6	252,1	893,7	Biog
1262,4	0,0	893,7	
1507,4	256,8	1150,4	
1719,7	239,0	1389,5	
1884,3	0,0	1389,5	
2088,3	0,0	1389,5	Biogas 75,65,96,10,10-50,75,90
2341,8	0,0	1389,5	
2586,9	0,0	1389,5	Biogas 75,65,120,10,10-50,75,90
2873,1	0,0	1389,5	
3133,9	0,0	1389,5	
3364,2	0,0	1389,5	
3596,1	0,0	1389,5	
3823,0	0,0	1389,5	
4028,7	0,0	1389,5	
4218,4	0,0	1389,5	
4465,1	132,2	1521,7	
4735,4	0,0	1521,7	
4969,3	150,8	1672,5	
5180,8	0,0	1672,5	
5402,5	0,0	1672,5	
5632,1	0,0	1672,5	
5928,8	0,0	1672,5	
6180,2	85,1	1757,6	Bioga
6357,0	66,8	1824,4	
6533,7	0,0	1824,4	
6533,7	0,0	1824,4	





Hej Bjarne,

Du har helt ret i din udredning og det glæder mig at du er kommet godt i gang.

Lars Gjedde
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lg@cke.dk
www.cke.dk

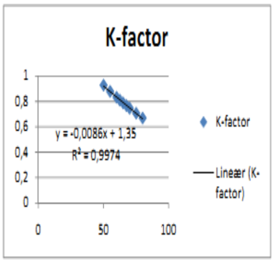
Fra: Bjarne Jørnsgård [mailto:bjo@solum.com]
Sendt: 16. november 2010 08:06
Til: Lars Gjedde
Cc: Karsten Graversen; Morten Brøgger Kristensen
Emne: SV: Flowmåling

Hej Lars,

Vi har nu en velfungerende flowmåler, der forhåbentlig måler rigtigt.
Jeg har et par spørgsmål nedenfor som jeg gerne vil diskutere – jeg prøvet at ringe senere i dag.
Vores Methan indhold ligger for tiden på 70-75%, den K værdi du oplyser 0,83221 nedenfor er den til 60% methan?
Er det rigtigt at når methanindholdet er højere bliver K værdien mindre og dermed skal det målte flow korrigeres ned?
Når vi har lagt K værdien 0,83221 ind i flowmåleren skal vi så for at opnå det korrekte flow ved et methanindhold på f.eks 75% dividere det målte flow med 0,83221 og gange det med 0,70708 for at lave korrektionen - der så betyder at vi korrigerer flowet ned ved et højere methan indhold?
Med venlig hilsen / Best regards
Fra: Lars Gjedde [mailto:LG@CKE.dk]
Sendt: 20. oktober 2010 11:30
Til: Bjarne Jørnsgård
Emne: Flowmåling

Hej Bjarne
Den oprindelige opsætning:
60/40 biogas K: 0,7723 Ø 110mm
Iout 1 0-100NMCH
Iout 2 0-100dgC
Biogas sammensætning 60/40 = K = 0,7723 den skulle have været 0,83221. Altså skal måleren vise 7,8 % mere end den gør nu.
Jeg er ikke klar over om det er en fejl i denne størrelsesorden vi leder efter, men det er et faktum, at vi har sat en forkert værdi ind. Beklager ☹
Det tager kun et øjeblik at rette fejlen med konfiguratoren. Ring evt. når i er klar til lave ændringerne, så skal jeg bistå....
Jeg delleverer FC88 konfiguratoren til dig i dag.
Jeg forsøgte at finde kurset hos Force, men forgæves indtil nu. Jeg har spurgt omkring og vender tilbage når jeg hører noget.
Korrektionerne for CH4/CO2 fremgår af nedenstående liste. Kombinationen af ST50 eller ST51, SSM6000 Pronova gasmåleren og listen sat ind som tabelopslag i en PLC eller lignende, giver den samme funktionalitet som systemet fra Geopal, men til en meget lavere pris, som vi talte om.

% CH4	*K-factor*
50	*0,92746*
55	0,87855
60	*0,83221*
62,5	0,80995
65	*0,78827*
67,5	0,76716
70	*0,7466*
75	0,70708
80	*0,66958*
	0

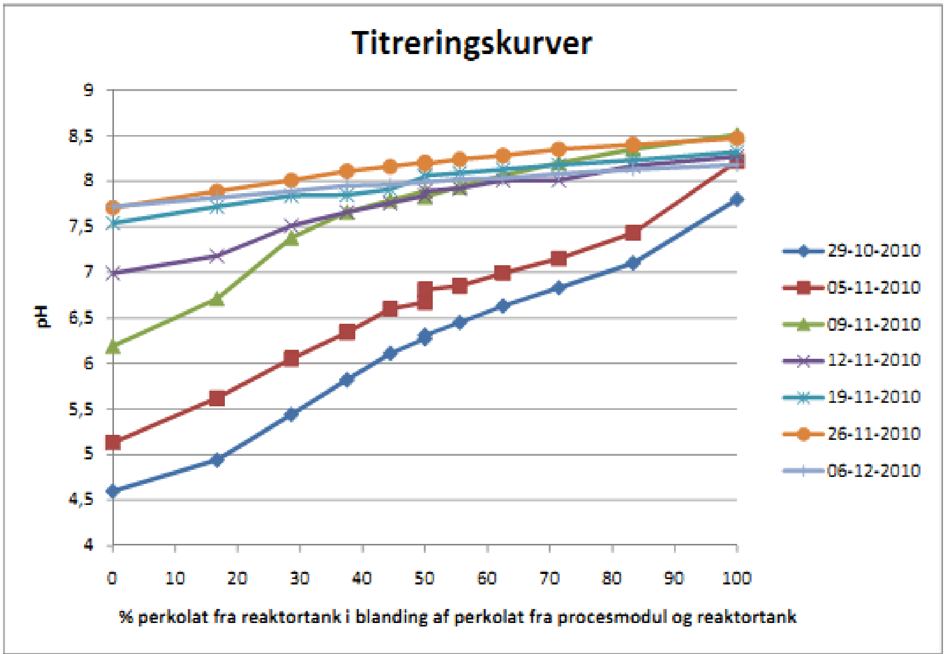


Titrering af perkolat fra reaktortank med perkolat fra procesmodul og omvendt

på forskellige tidspunkter i biogasfasen

Perkolat er taget fra procesmodul 11 og den lille reaktor i perioden okt til december 2010

PM11 ml perkolat	RT11 ml perkolat	forhold RT / PM	dato 29-10-2010	dato 05-11-2010	dato 09-11-2010	dato 12-11-2010	dato 19-11-2010	dato 26-11-2010	dato 06-12-2010
5	0	0	4,6	5,13	6,19	6,99	7,54	7,71	7,72
5	1	17	4,94	5,62	6,71	7,18	7,72	7,89	7,82
5	2	29	5,44	6,05	7,38	7,51	7,84	8,01	7,89
5	3	38	5,82	6,34	7,66	7,66	7,85	8,11	7,95
5	4	44	6,11	6,6	7,79	7,76	7,91	8,16	7,96
5	5	50	6,27	6,67	7,89	7,84	8,05	8,21	7,99
5	5	50	6,31	6,81	7,83	7,89	8,06	8,19	7,99
4	5	56	6,45	6,85	7,94	7,92	8,09	8,24	8,02
3	5	63	6,63	6,99	8,06	8,01	8,13	8,28	8,03
2	5	71	6,83	7,15	8,2	8,01	8,18	8,35	8,08
1	5	83	7,1	7,43	8,35	8,17	8,23	8,4	8,13
0	5	100	7,8	8,22	8,51	8,27	8,32	8,47	8,18



Dataloggere placere ca midt i affaldsmassen i modul 11 i Februar og marts 2011

Logger		Logger	
Type	TK-0014	Type	Tinytalk -40/85°C
Property	Temperatu	Property	Temperature °C
Reading capacit	1800	Reading capacity	1800
Serial number	342464	Serial number	305137
Logging run		Logging run	
Title	logger 15	Title	logger 16
Run ID	99ze rfje fg	Run ID	9psj psik ett2
Interval	30 Mins	Interval	30 Mins
Reading type	Normal	Reading type	Normal
Start mode	Delayed (3	Start mode	Delayed (3 Days 10 Hrs 15 Mins)
Logging started	23. Januar	Logging started	24. January 2011 00:00
Stop mode	Stop when	Stop mode	Stop when full
Offload		Offload	
Date	18. March :	Date	18. March 2011 14:09
Logger state	Stopped	Logger state	Stopped
Total readings	1800	Total readings	1800
User name		User name	
Statistics for full range of da		Statistics for full range of data	
First reading tim	23. Januar	First reading time	24. January 2011 00:00:21
Last reading tim	2. March 2	Last reading time	2. March 2011 11:30:21
Readings	1800	Readings	1800
Minimum readin	5,6 °C	Minimum reading	5,8 °C
Maximum readir	27,5 °C	Maximum reading	31,1 °C
Average reading	20.9268 °C	Average reading	21.452 °C
Area above zero	18834.2 °C	Area above zero	19306.8 °C x Hrs
Area below zero	0 °C x Hrs	Area below zero	0 °C x Hrs

				average
23-01-11 23:59	26	24-01-11 00:00	26,3	26,15
24-01-11 00:29	26	24-01-11 00:30	26,6	26,3
24-01-11 00:59	26,4	24-01-11 01:00	26,6	26,5
24-01-11 01:29	26,4	24-01-11 01:30	26,6	26,5
24-01-11 01:59	26,4	24-01-11 02:00	27	26,7
24-01-11 02:29	26,8	24-01-11 02:30	27	26,9
24-01-11 02:59	26,8	24-01-11 03:00	27	26,9
24-01-11 03:29	26,8	24-01-11 03:30	27,4	27,1
24-01-11 03:59	26,8	24-01-11 04:00	27,4	27,1
24-01-11 04:29	27,1	24-01-11 04:30	27,4	27,25
24-01-11 04:59	27,1	24-01-11 05:00	27,4	27,25
24-01-11 05:29	27,1	24-01-11 05:30	27,4	27,25
24-01-11 05:59	27,1	24-01-11 06:00	27,4	27,25
24-01-11 06:29	27,5	24-01-11 06:30	27,7	27,6
24-01-11 06:59	27,5	24-01-11 07:00	27,7	27,6
24-01-11 07:29	27,1	24-01-11 07:30	27,4	27,25
24-01-11 07:59	26,8	24-01-11 08:00	27	26,9
24-01-11 08:29	26,4	24-01-11 08:30	26,6	26,5
24-01-11 08:59	25,7	24-01-11 09:00	26,3	26
24-01-11 09:29	25,7	24-01-11 09:30	25,9	25,8
24-01-11 09:59	25,7	24-01-11 10:00	26,3	26
24-01-11 10:29	26	24-01-11 10:30	26,3	26,15

App. 2.3.2 Model til beregning af potentielt methantab ved tilførsel af atmosfærisk luft – BioVækst

Potentielt methantab ved tilførsel af atmosfærisk luft til procesmodulerne under bioforgasning

Nedenstående beregninger og vurderinger skal verificeres

Konklusion:

1 m3 atmosfærisk luft giver et potentielt tab på 0,15 m3 methan ved kompostering,
hvis alt ilten omsættes ved kompostering i stedet for at anvendes til methan produktion

Potentielt methan tab ved kompostering pga. ilt i procesmodul ved opstart
og ved volumen ændring ved perkolering er under 1 m3 methan per ton KOD

Andre utætheder for luft i systemet vil nok kunne give et betydeligt større tab, hvis luften siver konstant

Forudsætninger		
Massefylde atmosfærisk luft 1,29 kg/m3 (1 atm. 20 grader celcius, 20,9% O2)	1,29	kg/m3
iltindhold i atmosfærisk luft	0,21	
Massefylde methan 0,774 kg/m3, (1 atm 20 grader celsius)	0,77	kg/m3
Massefylde ilt	1,43	kg/m3
Massefylde CO2	1,98	kg/m3
Molvægt il O2	16,00	g/mol
C	12,00	g/mol
CH4	16,00	g/mol
CO2	44,00	g/mol
Det antages at ilten i tilført atmosfærisk luft omsættes fuldstændigt ved kompostering		
Iltmængde i 1 m3 atmosfærisk luft	0,270	kg O2
Kulstof forbrug ved kompostering (02 + C → CO2) med 1 m3 atmosfærisk luft	0,101	kg C
Alternativ biogasproduktion (70% CH4 og 25% CO2) med kulstoffet		
Methan indhold i biogas	0,700	
CO2 indhold i biogas	0,250	
Kulstofmængde i methan	0,089	kg C i methan
Methan mængde	0,119	kg methan
Methan volumen	0,154	m3 methan
1 m3 tilført anmosfærisk luft, hvor ilten omsættes ved kompostering vil give		
et potentielt methan tab på	0,15	m3 methan
Luftmængde i procesmodul	300,00	m3
Tabt methan produktion pga. ilt i procesmodul ved opstart	46,24	m3 methan
Perkolering		
Gange per døgn	120,00	
Volumen per gang	0,50	m3
Udskiftning af luftmængde per døgn	60,00	m3
Potentielt methan tab per døgn	9,25	m3 methan
Antal døgn med perkolering	14,00	dage
Samlet methantab ved perkolering	129,48	m3 methan
Affaldsmængde i procesmodul	200,00	ton KOD
Methan tab per ton KOD	0,88	m3 CH4 / ton KOD

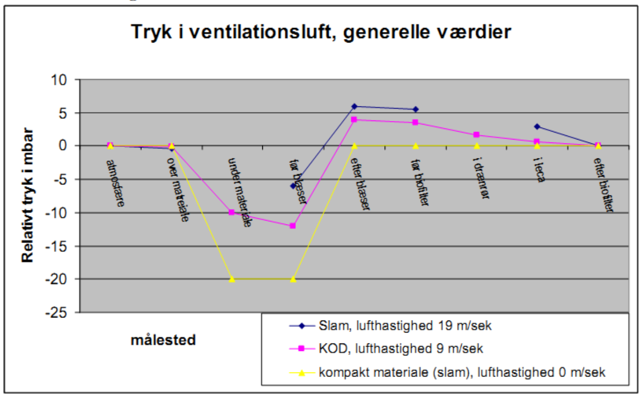
App. 2.3.3 Analyse og optimering af ventilationsanlæg på BioVækst

Noter fra tryk og flow målinger på ventilation på BioVækst

2010/2011

Ventilationssystemet i procesmoduler, biofiltre og modningsbokse på Biovækst's Aikan anlæg i Audebo er målt igennem. Der er målt tryk og lufthastighed på udvalgte positioner. Der er målt med variabelt antal blæsere i drift samtidig, således, at der opnås varierende belastning af biofiltrene.

Procesmodul 1-5 og 11-15



Sammenfatning

Procesmoduler

1. KOD yder større modstand mod gennemluftning end slam og giver derfor et større tryktab over materialet. Tryktabet over KOD er ca. 12-16 mbar mod 6-7 mbar over slammodulerne.
2. Tryktabet på indsugningen til procesmodulerne er lille, max målt til 0,44 bar over materialet i procesmodulerne med slam, hvor der var størst luftgennemstrømning.
3. Samlet giver det en mindre luftgennemstrømning i KOD og derved et relativt mindre tryktab over biofiltret efter KOD end efter slam.
4. Tryktabet fra bunden af procesmodulerne i laget af strukturmaterialet til udsugningsrøret før blæser er målet til ca. 2 mbar og udgør kun ca. 15-20 % af hele tryktabet fra over materialet i proces modulet frem til blæser. (usikkert da det kun er målt i et procesmodul med KOD) i slam modulerne vil tryktabet i udsugningen nok udgøre en større del af det samlede tryktab målt fra over materiale i PM til blæser, da slam giver mindre luftmodstand end KOD.
5. Det er vigtigt, at der i kortest muligt tid kører flere blæsere ad gange, da det øger modtrykket før biofilteret og dermed mindsker luftgennemstrømningen i det enkelte modul.
6. Programmeringen kunne laves med en prioritering således at anden blæser kun starter, hvis der er 2 blæsere, der venter på at starte. Er der kun en blæser i venteposition starter anden blæser først når første blæser slukker. Tredje blæser starter først hvis 2 yderligere blæsere venter på at starte osv.
7. Placering af tryksensorer for kontinuerlig måling af ventilations systemets funktion vil i prioriteret rækkefølge være 1) måling af undertryk før hver blæser, 2) hovedkanal før biofilter, 3) i leca under biofilter, 4) i dræn-ventilationsrør.

Biofiltre

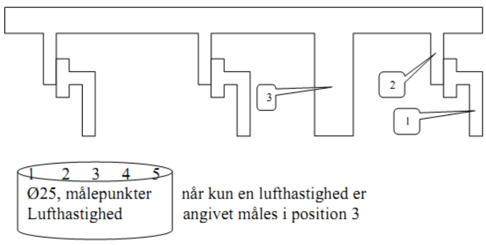
1. Det største tryktab sker over materialet i procesmodulerne, men jo flere blæsere der er i drift samtidig, des større del af tryktabet forekommer i biofiltrets rørsystem og bio-materiale. Er to blæsere i slammoduler i 11-15 i drift samtidig er 50% af det samlede tryktab i Biofiltret.
2. Tryktabet i hovedrør fra de enkelte udsugninger i proces modulerne over blæserne til hovedkanal før Biofilter er små (ubetydelige) sammenlignet med tryktab i biofiltre og procesmoduler.
3. I biofilttret ved procesmodul 1-5 sker der næsten en halvering af tryk fra hoved kanal til drænslanger, og yderligere mere end en halvering fra drænslanger til leca. Der er er intet målbart tryktab gennem lecaen. Samlet udgør tryktabet i bio-materialet i bio filtret fra hovedkanal til fri luft kun ca 25% af det samlede tryktab.
4. Da tryktabet op gennem biomaterialet i biofiltret ved procesmodul 1-5 er relativt lille kan højden af biofiltret eventuelt øges.
5. Luften skal fordeles under biofiltret således, at et område i biomaterialet med lille luftmodstand ikke lader uforholdsmæssigt meget luft passere. Det sikres p.t. ved at luften fordeles under hele biofiltrets areal med perforerede plastic slanger.

6. Biofiltret ved slammodulerne virker kompakt og vådt, giver relativ højt tryktab (luftmodstand) og det virker som om luften trænger igennem i spalter / koncentrerede områder. Biomaterialet giver her godt halvdelen af det samlede tryktab fra hovedkanal til udeluft.
7. Mindre lufthastighed i biofiltret kunne tænkes at øge dets effektivitet og mindske lugtgener.
8. Tværsnitsareal i hovedkanal under biofilter er 0.28m2 (Ø60cm), tværsnitsareal på drænslangerne er 0.010 m2 (Ø113mm indvendig- dette skal verificeres!). Med 18 overgange giver det et samlet tværsnitsareal på 0.18 m2. Tryktabet fra hovedkanal til drænslanger er optil 50% af trykket i hovedkanalen og dette tryktab bør kunne reduceres til næsten 0 ved at øge dimensionerne af drænslangerne til Ø160 eller Ø200, eller ved at montere flere slanger. Flere drænslanger er dog ikke hensigtsmæssigt, da lecaen giver den nødvendige luftfordeling. Anvendes Ø160 slanger med indvendig diameter på 145 mm eller 200 slanger med en indvendig diameter på 185 mm, bliver det samlede tværsnitsareal på slangerne henholdsvis 0,297m2 eller 0.48m2.
9. Almindelig drænslange har en hulstørrelse på 1,5 x 5 mm og et samlet hulareal på 22,5 cm2 per løbende meter, er slangerne 5,5 m lange giver det et samlet hulareal på 0.0124m2 per slange og 0,22m2 samlet for alle slangerne. Ved inspektion sad der fugt og snavs i kanten at de små huller i drænslangerne i biofiltret ved PM 1-5, der kan begrænse hularealet yderligere. Tryktabet fra inde i drænslangerne og til lecaen omkring er over 50% for biofiltret for modul 1-5, dette tab bør kunne reduceres betydeligt ved større samlet hulareal.
10. Der eksisterer plastslanger til plantørrerier, der ligner drænslanger, men de er specielt fremstillet med med henblik på optimeret luftgennemstrømning ved flere og større huller. www.nyrupplast.dk leverer disse slanger i dimentionerne Ø128, Ø160/145 og Ø200/185mm udvendig/invendig mål. Hulstørrelsen i slangerne er 2,4 x 7 mm og det samlede hulareal er 95cm2 per løbende meter, 4,4 gange mere en i drænslanger.
11. Afdræning af væske i biofilter skal sikres i bunden af lecaen til hovedkanal, evt. med drænslange i bunden af lecaen specielt til formålet. Det gøres for at sikre at der ikke står væske i luftslangerne, der forhindrer fri luftpassage.
12. Der er stor usikkerhed på lufthastighedsmålingerne i fugtig varm luft fra procesmodulerne, da der dannes kondens på måleudstyret, det blokerer de små lufthuller og dermed har tendens til at underestimere lufthastigheden.

Modningsbokse

1. Gennemluftningen i modningsboksene karakteriseres som effektiv for modning og tørring af kompost.
2. I modningsboksene udgør tryktabet fra blæser til fordelingsrør 74% af det samlede tryktab i systemet, det er en ineffektiv udnyttelse af blæserkapaciteten.
3. Trykket ved blæserafgang er 5,1 mbar, trykket ved fordelingsrør er 1,3 mbar. Det opnås ved et tryk på kun 1.3 mbar ved fordelingsrør. En blæser med en anden ydelseskurve kunne eventuelt opnå dette ved en mere hensigtsmæssig rørføring og et mindre strømforbrug.

Proces modul	Fyldt	Motor / blæser type	Noter
1	5 maj	?	
2	3 maj	?	
3	21 april	?	
4	16 april	?	
5	9 april	?	
11	27 april	?	
12	18 marts	?	Materialet faldet sammen, ingen gennemluftning
13	29 marts	?	
14	9 april	?	
15	15 april	?	



Målinger 5. maj. Lufthastighed er målt i Ø25 rør i 5 positioner diagonalt i røret, position1 er ved yderkant længst fra proces modul, pos.3 Er i centrum af rør og pos 5 er ved yderkant tættest ved procesmodul. (1mbar=10 mm vandsøjle

Modul	Tryk i PM over	Undertryk før blæser	Lufthastighed Pos. 1	Lufthastighed Pos. 2	Lufthastighed Pos. 3	Lufthastighed Pos. 4	Lufthastighed Pos. 5

	materiale blæser tændt		Længst væk fra Procesmodul				Tættest ved procesmoduk
	mbar	Mbar)	m/sek	m/sek	m/sek	m/sek	m/sek
1							
2							
3	-0,03	-14,5	7,5	8,3	7,5	9	9
4	-0,05	-16,8	10	10	9	8	7
4 (2 eller 3 blæsere tændt)			5	5	4	4	3
5	-0,11	-14,6	10,5	12	9,5	7,3	7,3

Den 11. maj blev der foretaget en ekstra måling af tryk i bunden af PM 3, sandsynligvis i strukturmaterialet i bunden (-10,80 mbar, målt med spyd gennem bagvæg i modul) samt i udsugningsrør lige før blæser (-12,75 mbar)

Målinger 6. maj. Lufthastighed målt i Ø25 rør i 5 positioner diagonalt i røret, position1 er ved yderkant længst fra proces modul, pos.3 Er i centrum af rør og pos 5 er ved yderkant tættest ved procesmodul.

Modul	Undertryk før blæser. En blæsere tændt	Undertryk før blæser. To blæsere tændt	Undertryk før blæser. Tre blæsere tændt	Differenstryk over blæser. En blæsere tændt	Differenstryk over blæser. To blæsere tændt	Differenstryk over blæser. Tre blæsere tændt	Lufthastighed før biofilter
		Mbar					m/sek
1							
2	-14,9		-12,0	15,1		15,8	
3		-12,9	-12,0			15,8	9
4	-17,8			17,2	16,7		7
5							7,3

Overtryk og lufthastighed i stort samlerør Ø60 før biofilter, relativt til atmosfære tryk.
Målt 5 og 11 maj. Der er god overensstemmelse mellem tryk i leca målt med spyd og slange.

	Tryk i samlerør før biofilter	Tryk i drænrør	Tryk i leca	Lufthastighed i samlerør
Process modul 1-5	mbar	mbar	Mbar	m/sek
Ingen blæsere, 5 maj	0	0	0	0
En blæser tændt, 11 maj	1,0	0,65	0,27 (slange)	
En blæser tændt, 5 maj	2,27			2
To blæsere tændt, 11 maj	1,55	0,78	0,35 (slange)	
To blæsere tændt, 11 maj	2,34	1,14	0,47 (slange)	
To blæsere tændt, 5 maj	3,25			5
3 blæsere tændt, 11 maj	3,80	2,05	0,72 (slange)	
3 blæsere tændt, 5 maj	6,15			
4 blæsere tændt, 5 maj	8,4			
Proces Modul 11-15				
1 blæser tændt	2,6		1,5 (spyd)	
2 blæsere tændt, (ikke mod 12, der er blokeret)	5,6		3,5 (spyd)	

Trykmålinger i ventilationen i modul 11-15

Modul	Tryk i PM over materiale blæser tændt	Lufthastighed i indsugnings rør over PM	Undertryk før blæser. En blæser tændt	Undertryk før blæser. To blæsere tændt	Overtryk efter blæser. En blæser tændt	Overtryk efter blæser. To blæsere tændt	Lufthastighed efter blæser. 1 blæser tændt	Lufthastighed efter blæser. 2 blæsere tændt
	mbar	m/sek	Mbar	mbar	mbar	mbar	m/sek	m/sek
11	-0,44	8,8		-7,4		9,4	17,9	
12	0	0	-19,5	<-23	3,5	7,2	0	0
13	-	-						

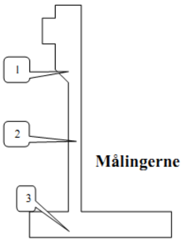
14	-0,1	5	-6,2	-6,0	5,3	5,4		19,5
15	-0,40	6	-6,4	-5,5		7,2		18,6

Målinger i ventilationen i modul 11-15

Mo dul	Differens tryk over blæser. En blæser tændt	Differenstryk over blæser. 2 blæsere tændt		
	mbar	mbar		
11		16,8		
12		22,4		
13				
14	10,4	11,5		
15	8	12		

Overtryk i samlerør før biofilter modul 11-15.
En blæser tændt 2,5 mbar
To blæsere tændt 7,5 mbar

Trykmålinger på ventilation i modningsbokse



Målingerne foretages med tændt blæser

Modningsboks	**Metode**	**Tryk position 1. mbar**	**Tryk position 2. mbar**	**Tryk position 3. mbar**	**Lufthastighed position 2. m/sek**
1 - ½ fyldt – defekt	**Ombøjet slange**	**-**	**-**	**-**	**-**
2 – 2/3 fyldt	**Ombøjet slange**	**5,0**	**3,9**	**1,4**	**21,4**
3 – fyldt	**Ombøjet slange**	**5,2**	**3,5**	**1,2**	**24,4**
4 – fyldt	**Ombøjet slange**	**5,2**	**3,8**	**1,4**	**24,0**
5 – fyldt	**Ombøjet slange**	**5,2**	**3,9**	**1,6**	**23,8**
6 – fyldt	**Ombøjet slange**	**5,1**	**3,5**	**1,0**	**23,1**
6 - fyldt	**Hængende slange**	**4,9**	**1,2**	**0,2**	**-**

Aikan A/S

Test og forbedringer af sprinklere og pumpe system i procesmodulerne

Document number: xx

Part of Aikan Internal Documentation

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Description of latest change to document:

Number of pages including front page: 15

Test og forbedringer af sprinklere og pumpe system i procesmodulerne

Formålet er at:

- Vurdere aktuel væskefordeling med det eksisterende setup.
- Foreslå ændringer vedr. valg af dyser, dyse placeringer og evt. filter og pumper for at opnå en fordeling, der sikrer en effektiv udvaskning af næringsstoffer af materialet i procesmodulerne.

Resume:
Med den nuværende dyse placering og størrelse (2 x 4 dyser af Ø12-13mm) er ydelsen ca 200 liter per minut perkolat og trykket ved dyserne ca 0,07 til 0.1 bar. Ved blokerede dyser (nul ydelse) er trykket 1,6 bar ved dyserne, ved 50 liter/minut ca 1.3 bar, ved 100 liter/min ca 1,05 bar og ved 150 liter/min ca 0.55 bar.
Ved 0.1 bar falder væsken i en koncentreret kejle fra dysen med en diameter på ca 1 meter 1 meter under dysen og nedbørsintensiteten er op til 100 mm per time. Med øget tryk øges spredediameteren og nedslags intensiteten bliver mere ensartet i forskellige afstande fra dysen og maksimum falder flere gange.
Dyse antal, størrelse og placering kan ændres for at opnå et højere tryk og en bedre fordeling af perkolat.

Baggrund:
Når procesmodulerne fyldes er afstanden under sprinklerne ca 50 cm, denne afstand stiger i løbet af udvaskningen til ca 100-125 cm. Det er vigtigt at perkolaten fordeles over materialet således, at der ikke er lommer, der ikke vaskes ud. Hellere "for meget" i nogle områder end for lidt i andre.

Sprinkleranlægget skal have kapacitet til at overrisle med den nødvendige mængde perkolat, vurderet udfra transport af COD samt være tilstrækkelig til at udføre ønskede forsøg.
Volumen perkolat, der skal vaskes gennem procesmodulerne for at producere 100m3 methan på hver af 300 ton KOD i et batch i et procesmodul når ét gram COD giver 3.5 liter methan og COD indholdet i perkolat fra procesmodulet er 30 g/liter og COD indhold i perkolat, der sprinkles over KOD er 15 g/liter er beregnet i tabel 1.

Tabel 1. Beregning af perkolatmængde til udvaskning af et batch KOD i procesmodul

Perkolatmængde =	[(100 m3 methan/ton KOD x 300 ton KOD x 1.000 liter/m3) / (3.5 liter methan / g COD)] / (30 g COD per liter – 15 g COD / liter)	
Forudsætninger		
KOD	Tons	300,00
Methan udbytte / KOD	m3 / ton	100,00
Methan / COD	liter / gram	3,50
COD perkolat ind	g/liter	30,00

COD perkolat ud	g/ liter	15,00
Beregnet perkolat-mængde		
Perkolat til udvaskning	liter	571.428,57
Perkolat til udvaskning	m3	571,43
Beregnet pumpe drift tid		
Pumpeydelse	m3 / time	12,00
Effektiv pumpe drifttid	% af tid	50,00
Drifttimer	Timer	95,23
Driftdøgn	Døgn	4,00

Konklusion: Dyser samt øvrigt anlæg må ikke dimensioneres således at pumpeydelsen falder markant under 12 m3 per time. Da en ændring på 1.0 cm i perkolat niveau i proces tanken svarer til 41,56 liter, kan pumpekapaciteten kontrolleres ved at dividere sænkning i væskestand målt i cm gange 41,56 liter per cm med tiden i sekunder det tager, at lave den pågældende væskesænkning. Med den eksisterende dysemontering er ydelsen 200 liter per minut svarende til

Proces Modul	Tid for at sænke væske-standen 10 cm	Pumpeydelse Liter / sekund Y= 415,6 / tid	Pumpeydelse m3 / time	Max tryk bar blokeret rør ved +135cm	Tryk bar før 4 mm filter +135 cm	Tryk efter 4 mm filter	Tryk efter 10 mm filter	Beregnet t ryk i højde + 460 cm	Tryk ved dyse 1 +460 cm	Tryk ved dyse 4 + 460 cm
1		3,5 ??		1,67	0,94	0,78	0,82	0,36	0,11	0,10
2										
3										
4	122 sek	3,4	12,24							0,08
5										
11										
12										
13										
14										
15										

Trykmålinger i sprinklersystem i Procesmodul 1

- Pumpen giver et max tryk målt 135 cm over væskestanden i pumpebrønden på 1,67 bar, tillagt væskesøjlen giver det et max tryk på 1,81 bar. Ifølge ydelseskurven for pumpen skulle max tryk være 21 mm vandsøjle svarende til 2,07 bar, 8,7% under forventet.
- Ved normal pumpefunktion med 4 mm filter og 8 dyser boret op til ca 12 mm er ydelsen 3,5 liter per sekund og trykket før filteret 0.94 bar, efter filteret 0,78 bar og ved dyserne ca 0,1 bar. Ved montering af 10 mm hulfilter, var trykket efter filteret 0,82 bar.

- Tryktabet over filteret er lille set i forhold til det samlede tryktab i systemet. Det kan dog nok være en fordel at have en hulstørrelse i filteret, der kun er et par millimeter mindre end dysestørrelsen.
    - Trykket ved dyserne er uforklarligt lavt – tryktab i rør – målefejl ------
    - Max opnåeligt tryk ved dyserne med blokerede dyser bør være 1,23 bar ved 0 ydelse
    - Mindre dyser vil giver markant mindre ydelse. En reduktion i ydelse på 50% skulle give et øget pumpetryk på op til 0,5 bar. Det kan ikke bregnes og bør verificeres ved målinger.
- Næste skridt er at ændre antallet af dyser og størrelse af dyser og se hvordan det ændrer tryk ved dyser og nedslagsfordeling.
- Alternativt laves en tryk/ydelses kurve ved sprinkler røret i loftet. Alle dyse udtag proppes til og der monteres en kugle hane for enden af et af rørene. Trykket i røret måles ved forskellig ydelse (åbning af kugleventilen). Ydelsen bestemmes ved tiden det tager at sænke væskestanden 10 cm (415 liter).

Gentagne registreringer i Procesmodul 4 gav en middeltid på ca 120 sek for at sænke væskestanden 10 cm. Det svarer til en pumpeydelse på 3,4 liter per sekund. Ifølge ydelseskurven for pumpen DL50-15, (http://www.flygt.dk/1282306.pdf) modsvarer en ydelse på 3.4 liter per sekund en løftehøjde på 16 m eller 1,58 bar. Væsken løftes ca 5,6 m fra procestanken til sprinkler, det giver et tryktab på 0,7 bar. Trykket ved dyserne er målt til 0.1 bar. Forskellen fra det forventede pumpetryk (1,58 – 0,7 – 0,1 bar) på 0,8 bar må forklares ved tryktab i rør og filter og nedsat pumpeydelse. Ønskes højere tryk ved dyserne for at opnå en bedre væske spredning, kan det opnås ved mindre ydelse (mindre dyser) og eller begrænsning af tryktab i rør og filter.

Perkolat i rørsystemet til dyserne løber tilbage i procestanken når pumpen slukkes, derved renses filteret. Fra den 1 dyse sprinkler til den 4 dyse sprinkler går der ca 7 sek. I forhold til en pumpetid på 120 sek, sprinkler dyse et i 6% længere tid end dyse 4.

Metode:

- Nedslagsprofiler (ydelseskurver) for forskellige dyser bestemmes i en testopstilling afhængig af dysehøjde og tryk.
- Forskellige modeller for dyseplacering, type og tryk overvejes udfra det nedbørskort det vil give i procesmodulerne i forskellig højde under dyserne.
- Ydelseskurverne fra testopstillingen kontrolleres i praksis i procesmodulerne målt 50cm og 100 cm under dyserne.

Procesmoduler:

Trykket ved sprinklerne er 0.10-0.11 bar. Der er praktiske taget ikke tryktab fra fra 1 dyse ved bagvæggen til sidste dyse ved portåbningen. Dyse 1-3 målt fra bagvæggen er boret op til Ø12-13 mm, dyse 4 er boret op til Ø11mm og dyse 5 er lukket.

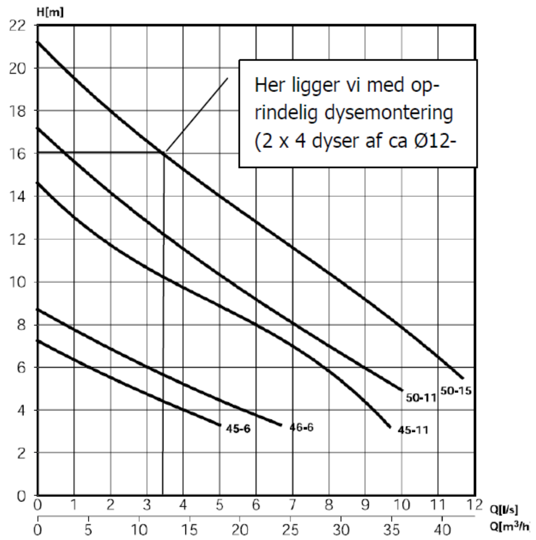
Dyse placering målt fra bagvæg og side

Dyse nr	Afstand fra bag-væg	Afstand fra sidevæg	Afstand mellem dyser, f.eks dyse 1 til dyse 1
1	2	1,5	4
2	6,3		4
3	10,6	1,5	4
4	14,9	1,5	4
5	19,2	1,5	4

Der er lavet en opstilling, der kan måle nedslagsfordelingen 50 cm og 100 cm under dyserne i procesmodulerne. Målingerne kunne ikke gennemføres da pumpen gik i stykker. Målingerne foretages i uge 23.

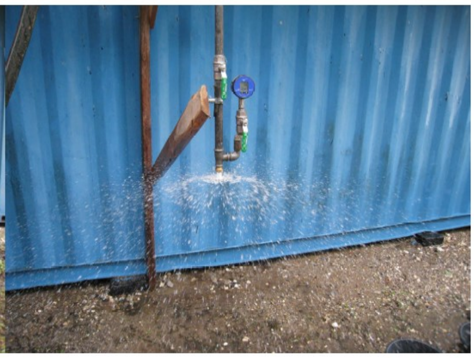
Pumper Flygt DL50.15. (http://www.flygt.dk/1282306.pdf)

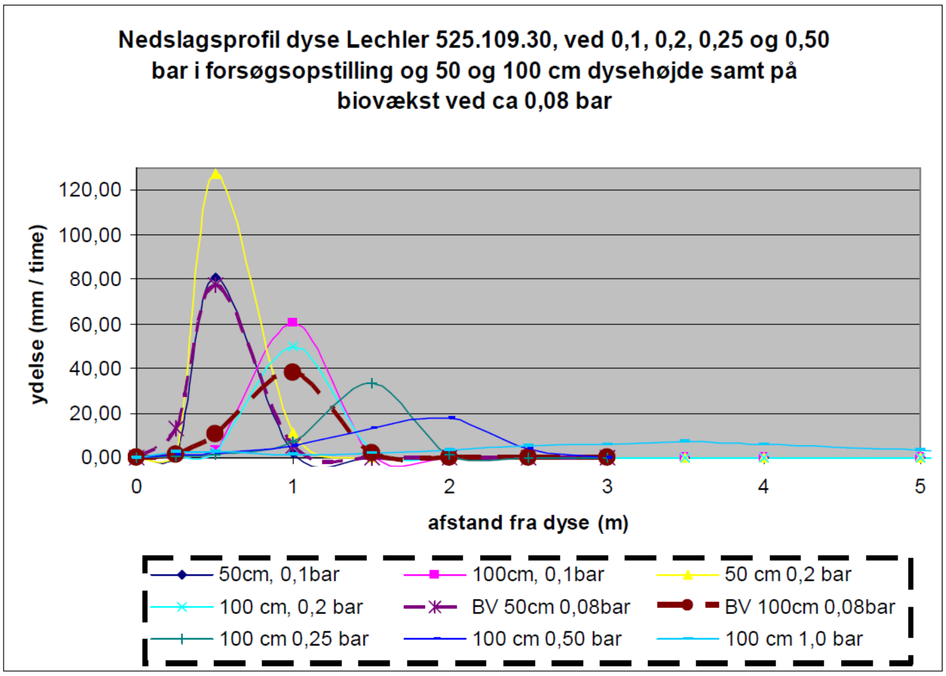
- Pumpe type Flygt dykpumpe DL50-15 har en maksimal løftehøjde på 21m, her går ydelsen ned til 0.
- Finde ydelsen i liter per sekund eller m3 per time udfra væskemængde og pumpetid, gå ind på ydelseskurven og se hvilket modtryk det svarer til for pumpen DL50-15.
- Mål tryk før filter og evt. efter filter



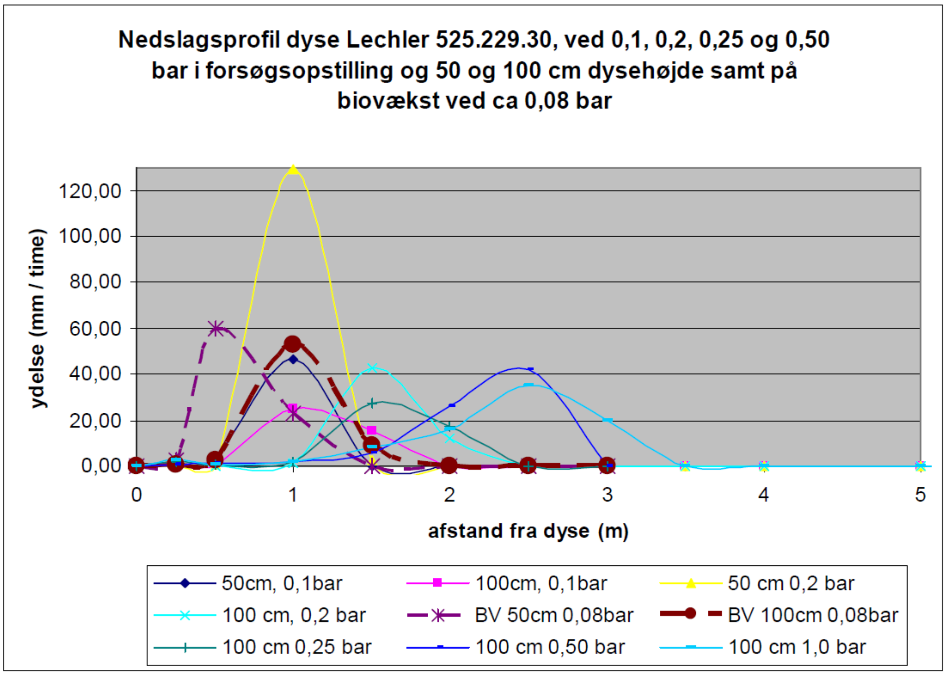
Forsøgsopstilling til måling af dysekarakteristik

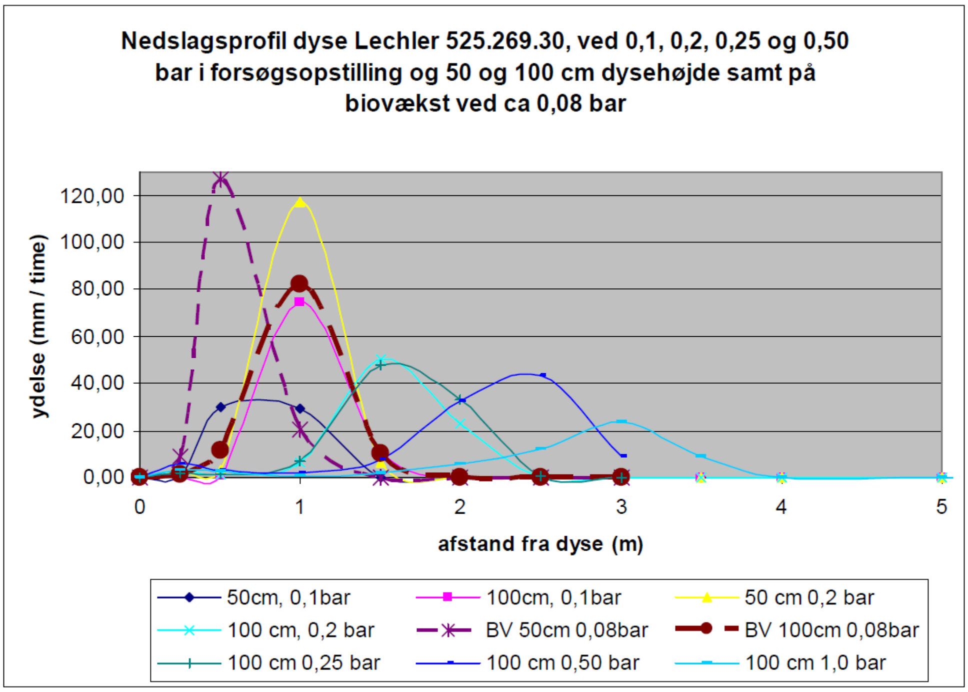
Forsøgsopstillling til måling af nedslagsprofil for de enkelte dyser afhængig af tryk og dysehøjde er udført ved dysehøjde 50, 100 og 150 cm og tryk 0.25 0.50 og 1.0 bar. Der er lavet nedslagsprofiler for dyserne Lechler525.109.30, Lechler525.229.30 og Lechler525.269.30, der har en hul diameter på henholdsvis 9.2 mm, 12.2 og 12.3 mm og en ydelsen ved 0.5 bar på 28 liter/min, 56 liter/min og 70 liter / min. Den sidstnævnte dyse med højeste ydelse har konisk udboring, hvorimod de to andre har skarp overgang fra ca. 15 mm og ned til den pågældende størrelse.



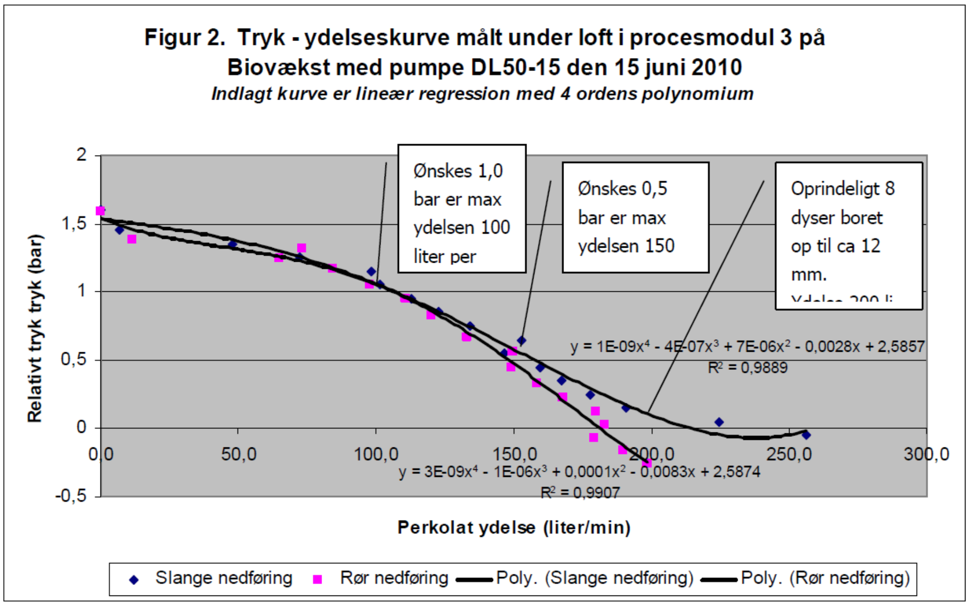


Figur 1. Eksempel på nedslagsprofil for en dyse ved et tryk og variabel dysehøjde.


Nedslagsprofil dyse Lechler 525.229.30, ved 0,1, 0,2, 0,25 og 0,50 bar i forsøgsopstilling og 50 og 100 cm dysehøjde samt på biovækst ved ca 0,08 bar
ydelse (mm / time)
120,00
100,00
80,00
60,00
40,00
20,00
0,00
0
1
2
3
4
5
afstand fra dyse (m)
50cm, 0,1bar
100cm, 0,1bar
50 cm 0,2 bar
100 cm, 0,2 bar
BV 50cm 0,08bar
BV 100cm 0,08bar
100 cm 0,25 bar
100 cm 0,50 bar
100 cm 1,0 bar



Pladens udformning / overflade kan sandsynligvis løse problemet med manglende væske under og i lille afstand fra dyssen. Pladens udformning vil ikke kunne øge spredediameteren.



Figur 2. Tryk - ydelseskurve målt under loft i procesmodul 3 med pumpe DL50-15 den 15 juni 2010

tryk	Samlet ydelse l/min	ydelse per dyse l/min 4 dyser	14 dyser
1,25	75	18,8	5,4
1	100	25,0	7,1
0,75	125	31,3	8,9
0,5	150	37,5	10,7
0,25	175	43,8	12,5

Afsluttende opgaver:

1. Ydelseskurver for standarddyser og udborede dyser måles ved 0.1 og 0.2 bar i højderne 50cm 100cm og evt 150cm.
2. Måle tryk før og evt. efter filter, og max tryk ved blokering af afgangsrør.
3. Måle fordelingsprofil 50 og 100 cm under sprinklere i procesmodul for standarddyser og egne udborede dyser.
4. Er der mulighed for at øge trykket ved dyserne ved at ændre dyseantal, hulstørrelse i dyser, filter eller pumpe?
5. Vurder nuværende ydelse på pumpen ydelse/tryk kurve, lav forsøgopstilling i Proces Modul med kuglehane, trykmåler og beholder til måling af ydelse.
6. Udfra ovenstående foreslå evt. ændringer i dysevalg, antal og placeringer.

LECHLER

Pralldüse

Deflector type nozzle
Pulvérisateur à disque déflecteur
Tobera con placa de rebotamiento Lechler

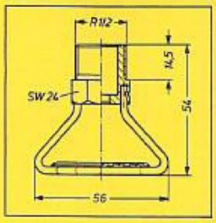
◆ Deutsch
● English
▬ Français
✕ Español

AVT / P 2
524.809

◆ Hohlkegelzersträubung, Verstopfungsunempfindliche Düse ohne Dralleinsätze
● hollow cone distribution. Non-clogging nozzle without inserts.
▬ Pulvérisation en cône creux. Pulvérisateur sans spirale intérieure, ne se bouchant pas.
✕ Pulverización de cono hueco. Tobera sin hélice interior, de obstrucción difícil.

◆ Verwendung: Brandschutz + zur Berieselung großer Flächen
● Application: Fire fighting + for spraying of large surfaces
▬ Application: Protection contre l'incendie + arrosage de grandes surface.
✕ Aplicación: Protección contra incendios + riego de grandes superficies

Abmessungen
Dimensions
Dimensiones



Volumenstrom $\dot{V}$
Volume of flow
Volume de débit
Volumen de caudal

◆ B = Bohrungs-Ø
● bore diameter
▬ Alésage Ø
✕ Ø del taladro

Material : 16
Gehäuse : 1.4305
Bügel : 1.4310
Prallteller: 1.4300

Material : 17
Gehäuse : 1.4571
Bügel : 1.4571
Prallteller: 1.4571

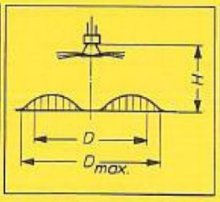
Material : 30
Gehäuse : Ms
Bügel : 1.4310
Prallteller: 1.4300

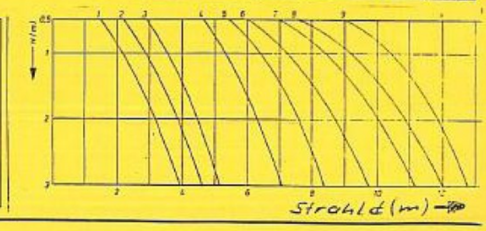
∢	Düsen-Nr. / nozzle No / pulv.-No / tobera No — Type/type/type/tipo, Größe/size/taille/tamaño	B Ø mm	$\dot{V}$ [l/min], p_{max} = 10 bar, p [bar] 0,5	1	2	3	5	10	Strahl-Ø, spray-Ø, strale-Ø D, bar 1	3	5	D_{max}, bar 1	3	5	Material-Nr. matériau No		
									Kurven-Nr./graph No/No de courbe No de curva								
180°	524.809	4,0	4,9	7,1	10,0	12,2	15,8	22,4	1	2	3	2	3	4	-	16	17
	524.939	6,0	10,59	14,98	21,19	25,95	33,5	47,38	2	4	5	3	5	6	-	16	17
	524.989	6,5	14,0	19,8	28,0	34,3	44,3	62,6	2	4	5	3	5	6	-	16	17
	525.029	7,7	17,8	25,1	35,5	43,5	56,1	79,4	3	5	6	4	6	7	30	-	17
	525.049	8,0	19,7	27,8	39,3	48,1	62,1	87,9	3	5	6	4	6	7	30	-	17
	525.059	8,3	21,3	30,1	42,5	52,1	67,2	95,0	3	5	6	4	6	7	30	-	17
	525.109	9,3	28,0	40,0	56,0	69,0	89,0	125,0	4	7	8	5	8	9	30	-	17
	525.149	10,6	36,0	50,0	71,0	87,0	112,0	159,0	4	8	8	5	9	9	30	-	17
	525.169	10,9	40,0	57,0	80,0	98,0	126,0	179,0	4	7	8	5	8	9	30	-	17
	525.229	12,2	56,0	79,0	112,0	137,0	177,0	250,0	5	6	7	6	7	8	30	-	17
	525.269	12,3	70,0	99,0	140,0	171,0	221,0	313,0	5	7	7	6	8	8	30	-	17

Gewicht/weight/poids/peso 65 g

AVT 1980-Okt.-10

Strahldiagram
Diagram of spray
Diagramme du jet
Diagrama del chorro





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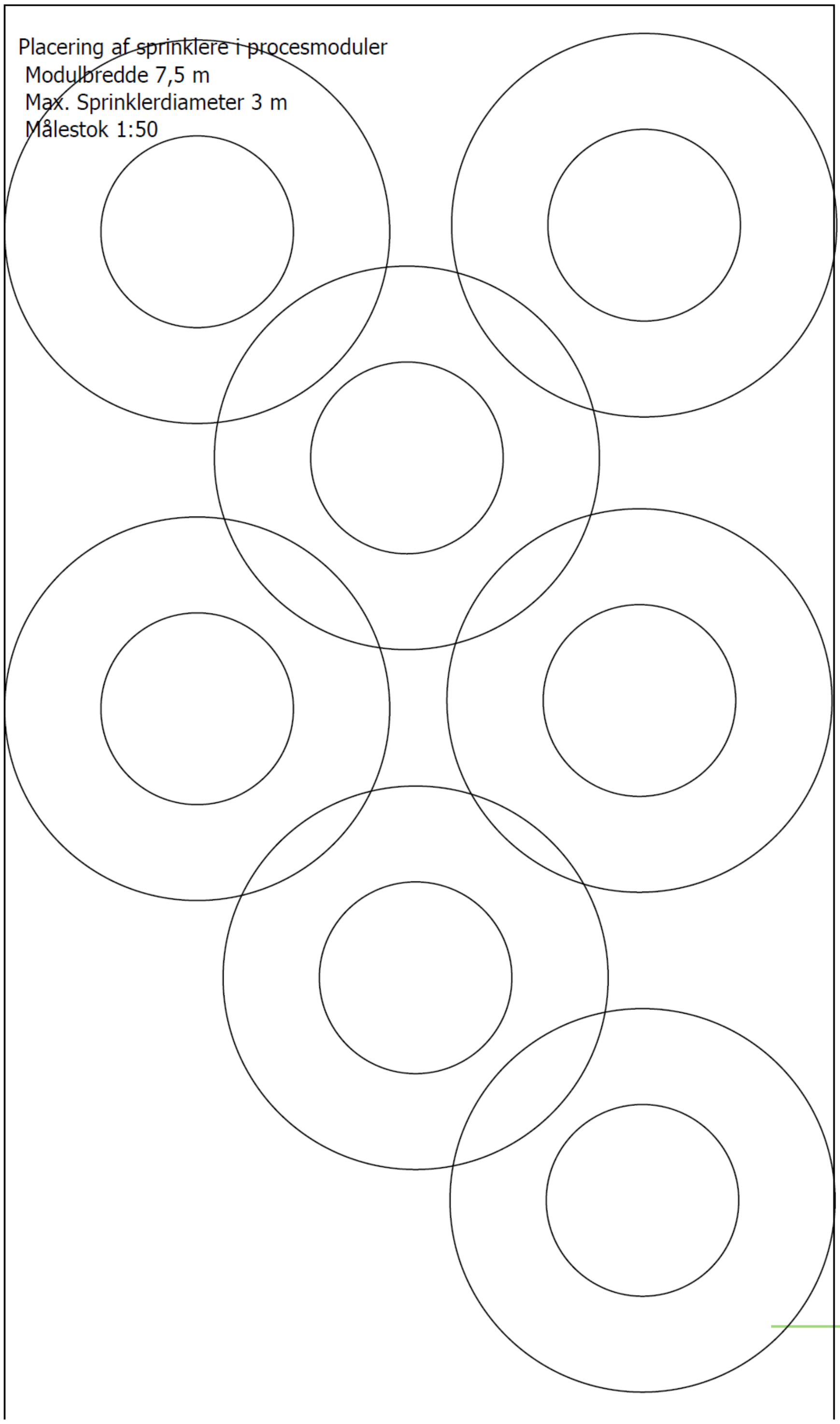
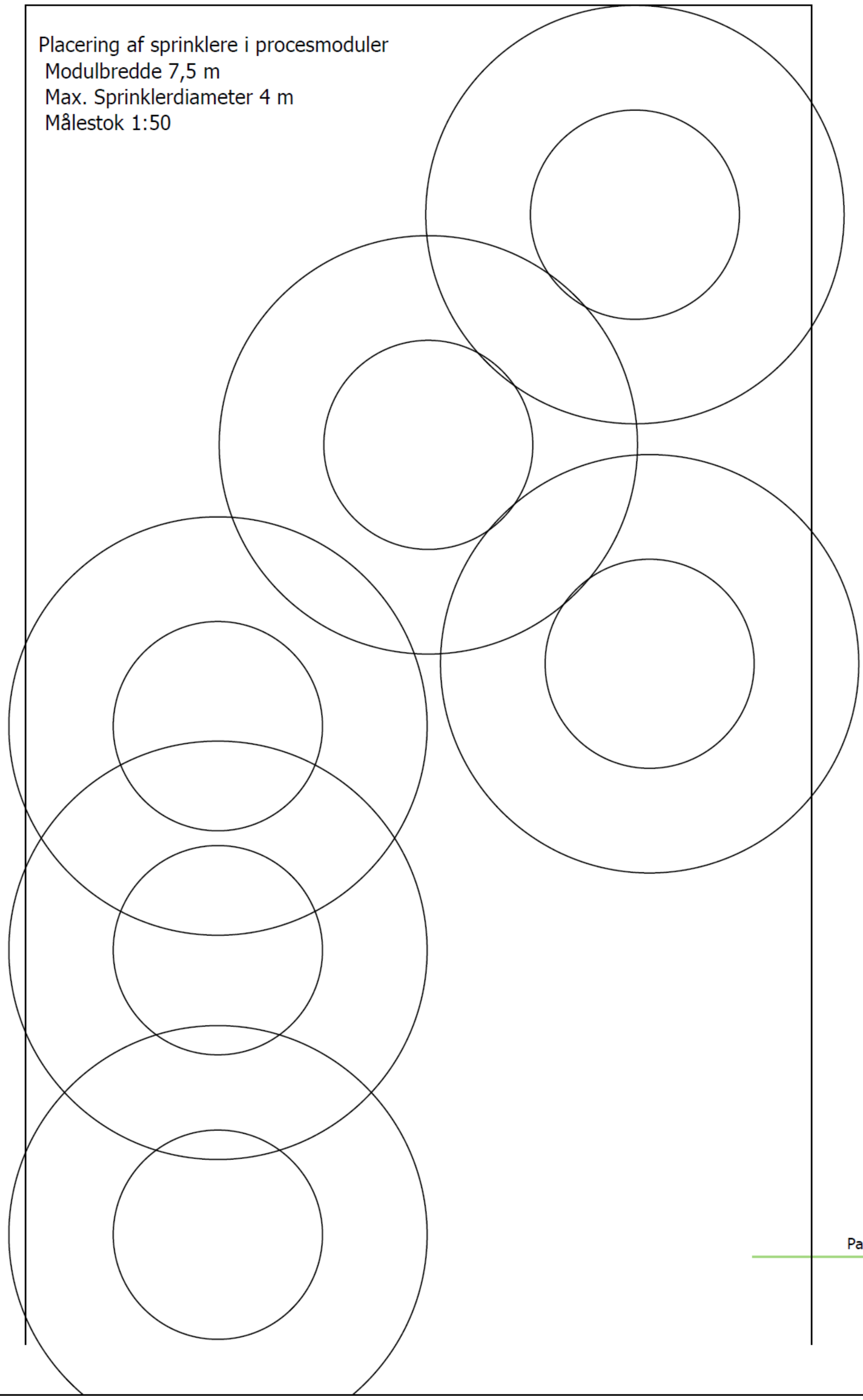
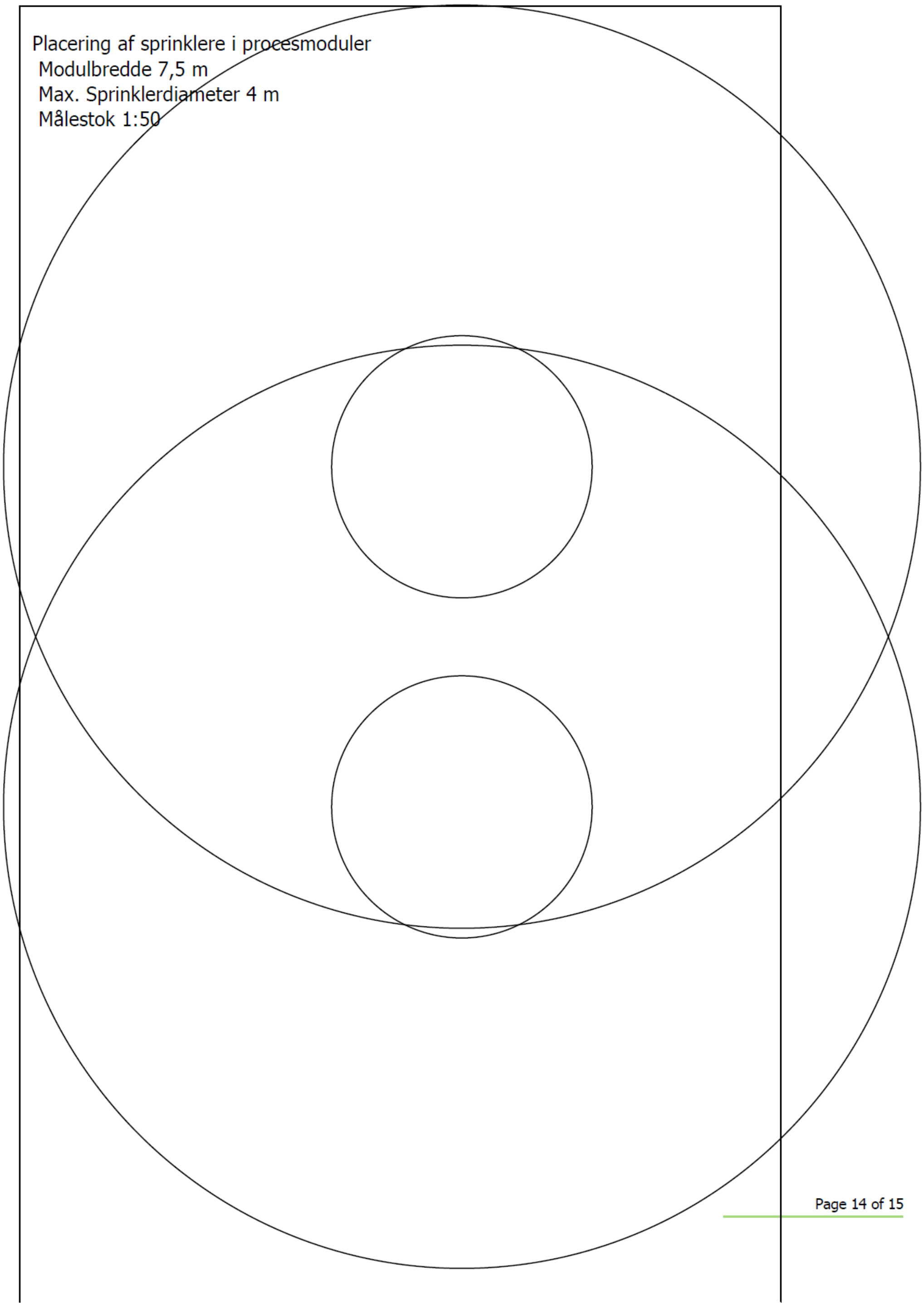
TM 5.7.4


Placering af sprinklere i procesmoduler
Modulbredde 7,5 m
Max. Sprinklerdiameter 3 m
Målestok 1:50


Placering af sprinklere i procesmoduler
Modulbredde 7,5 m
Max. Sprinklerdiameter 4 m
Målestok 1:50

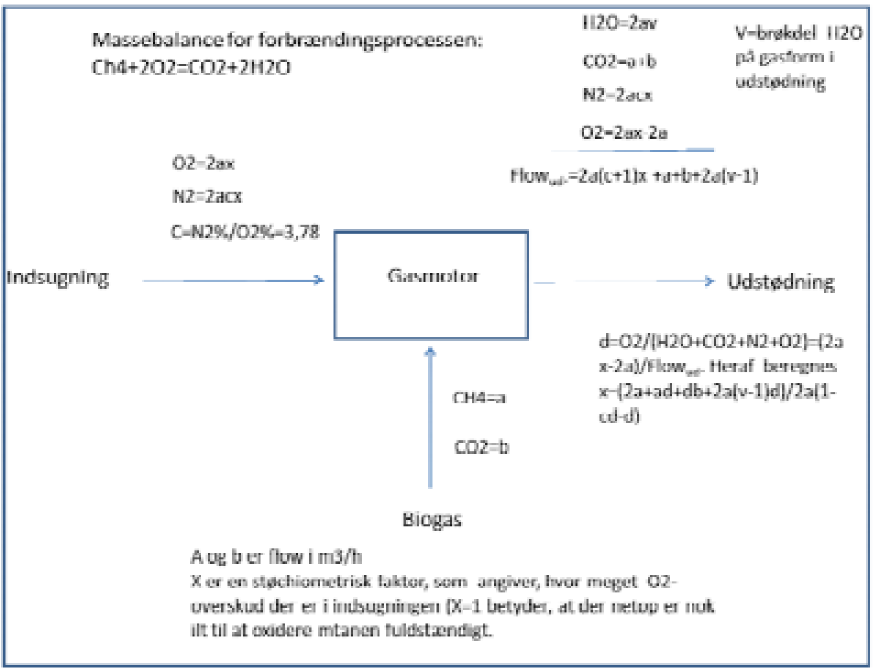

Placering af sprinklere i procesmoduler
Modulbredde 7,5 m
Max. Sprinklerdiameter 4 m
Målestok 1:50
Page 14 of 15

App. 2.3.5 Model: Gas engine emissions of CH4 & CO2

Beregning af metan-tab som funktion af methan og O2 indhold udstødning.
Felter med gul skal udfyldes.

metan i udstødning (ppm)		500,00	ppm
biogasflow (m3/h)		68,00	m3/hour
CH4 i biogas (%)		70,00	%
CO2 i biogas (%)		26,00	%
*brøkdel H2O som gas i udstødning	v	0,00	
brøkdel O2 i udstødning	d	0,05	
CH4 flow (m3/h)	a	47,60	m3/hour
CO2 flow (m3/h)	b	25,26	m3/hour
N2/O2 i luft	c	3,78	
støchiometrisk faktor	x	1,30	
udstødningsflow (m3/h)		569,37	m3/hour
metanforbrug (kg/h)		34,00	kg/hour
tab af metan (g/h)		203,35	g/hour
Tab af metan (%)		0,60	%

*Hvis der måles i varm luft er v=1, i kold luft er V=0



Beregning af CO2 udslip gennem motor (forbrænding og biogas CO2 indhold)

biogasforbrug (m3)		44114	m3
metan i udstødning (ppm)		500,00	ppm
biogasforbrug (m3)		47,00	m3
CH4 i biogas (%)		70,00	%
CO2 i biogas (%)		25,00	%
*brøkdel H2O som gas i udstø	v	0,00	
brøkdel O2 i udstødning	d	0,05	
CH4 flow (m3/h)	a	32,90	m3/hour
CO2 flow (m3/h)	b	16,79	m3/hour
N2/O2 i luft	c	3,78	
støchiometrisk faktor	x	1,30	
udstødningsflow (m3/h)		392,65	m3/hour
metanforbrug (kg/h)		23,50	kg/hour
tab af metan (g/h)		140,23	g/hour
Tab af metan (%)		0,60	%

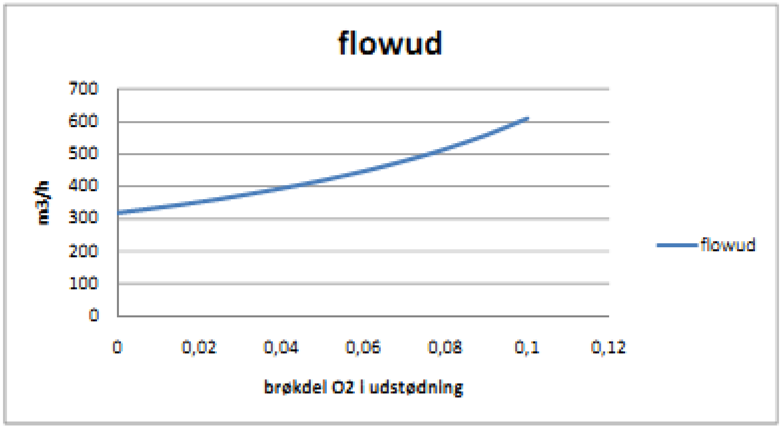
*Hvis der måles i varm luft er v=1, i kold luft er V=0

Methan forbrug	30879,80	m3
methan tab	184,27	m3
Forbrændt methan	30695,53	m3
Forbrændt methan	21925,38	kg
CO2 mængde ved forbrænding	60120,61	kg
CO2 mængde i biogas	11028,50	m3
CO2 mængde i biogas	7877,50	kg
Udledning af CO2 gennem motor	67998,11	kg
Udledning af CO2 gennem motor	68,00	ton

2010	CO2 motor	CH4 udslip motor
	ton	%
1.kvt	68	
2.kvt	105	
3.kvt	62,88	
4.kvt	47	0,6
ATD	283	

biogasflow	47	
CH4 i bioga	75	
CO2 i bioga	26	
CH4 flow (r a		35,25
CO2 flow (r b		16,29333
N2/O2 i luf c		3,784689
*brøkdel H v		0
brøkdel O2 d		0,05

*Hvis der måles i varm luft er v=1,



støchiometx	1,296793		udstødning	418,4783
metan i udstødning (p	291		metanforb	25,17857
			tab af meta	86,98371
i kold luft er V=0			Tab af met	0,345467

d	v	x	flowud
0	0	1	318,3639
0,01	0	1,047427	334,3621
0,02	0	1,099873	352,0532
0,03	0	1,158179	371,721
0,04	0	1,223385	393,7163
0,05	0	1,296793	418,4783
0,06	0	1,380055	446,5641
0,07	0	1,475296	478,6911
0,08	0	1,585304	515,7989
0,09	0	1,7138	559,1433
0,1	0	1,865874	610,4409
0,11	0	2,048669	672,1016
0,12	0	2,272542	747,6186
0,13	0	2,553092	842,2539
0,14	0	2,914961	964,3197
0,15	0	3,399497	1127,764
0,16	0	4,081803	1357,92
0,17	0	5,11401	1706,104
0,18	0	6,858083	2294,416
0,19	0	10,43802	3502,003
0,2	0	21,97338	7393,117
0,2089	0	1972,603	665380,6
0,22	0	-17,876	-6048,91
0,23	0	-9,33688	-3168,48
0,24	0	-6,30686	-2146,39
0,25	0	-4,75489	-1622,88
0,26	0	-3,81154	-1304,67
0,27	0	-3,17749	-1090,79
0,28	0	-2,72204	-937,156
0,29	0	-2,37904	-821,457
0,3	0	-2,11144	-731,187
0,31	0	-1,89682	-658,793
0,32	0	-1,72087	-599,442
0,33	0	-1,57401	-549,901
0,34	0	-1,44956	-507,924
0,35	0	-1,34277	-471,901
0,36	0	-1,25012	-440,649

App. 2.3.6 Abstract: Standard model financial and technical scalability of AI-KAN©

Turning Earth Triple Play™
powered by Aikan Technology™

Project Madison

Technical and Financial Estimate
version 8.4

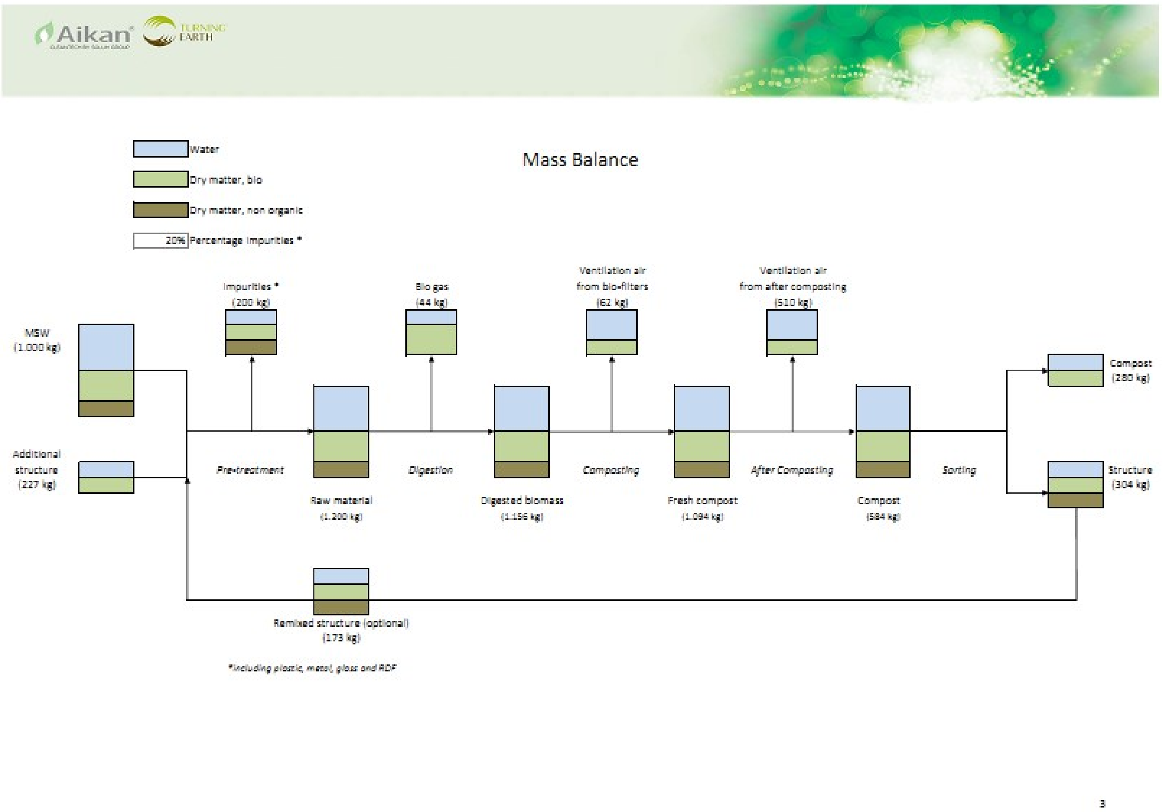
Project to be developed in MA, USA.

August 16, 2011

Table of Contents

This financial model is based on a series of assumptions, both financial and market-related. In addition, the historical operational experiences of the AIKAN plants have been used as a building block for this forecast. AIKAN A/S assumes no liability for the abidance of the key data in the project.

Print date: *August 23, 2011*



Aikan
TURNING EARTH
Mass Balance
Water
Dry matter, bio
Dry matter, non organic
20% Percentage impurities *
Impurities * (200 kg)
Bio gas (44 kg)
Ventilation air from bio-filters (62 kg)
Ventilation air from after composting (510 kg)
MSW (1.000 kg)
Additional structure (227 kg)
Pre-treatment
Raw material (1.200 kg)
Digestion
Digested biomass (1.156 kg)
Composting
Fresh compost (1.094 kg)
After Composting
Compost (584 kg)
Sorting
Compost (280 kg)
Structure (304 kg)
Remixed structure (optional) (173 kg)
*including plastic, metal, glass and RDF
3

Technical Overview

Design

Total Waste Capacity incl. structure	27.000	Metric tonnes per year
Industrial, Commercial and Institutional (ICI)	22.000	Metric tonnes per year
Organic Fraction	17.600	Metric tonnes per year
Biogas Yield (70% methane)	80	m^3 per metric tonne of organic fraction
Biogas Yield (70% methane)	1.408.000	m^3 per year
Methane Yield	985.600	m^3 per year
Installed MW Capacity	0,48	MW

Production for offtakers

Electricity Production	4.221	MWh per year
Thermal Heat Production - GJ	53.688	GJ per year
Biogas Production	-	m^3 per year
Compost production	6.160	Metric tonnes per year
Recycled Plastic	-	Metric tonnes per year
Recycled Metal	-	Metric tonnes per year
Recycled Glass	-	Metric tonnes per year
RDF	-	Metric tonnes per year
Liquid fertiliser	-	Metric tonnes per year
Carbon Credits	8.800	Metric tonnes per year

Plant Size

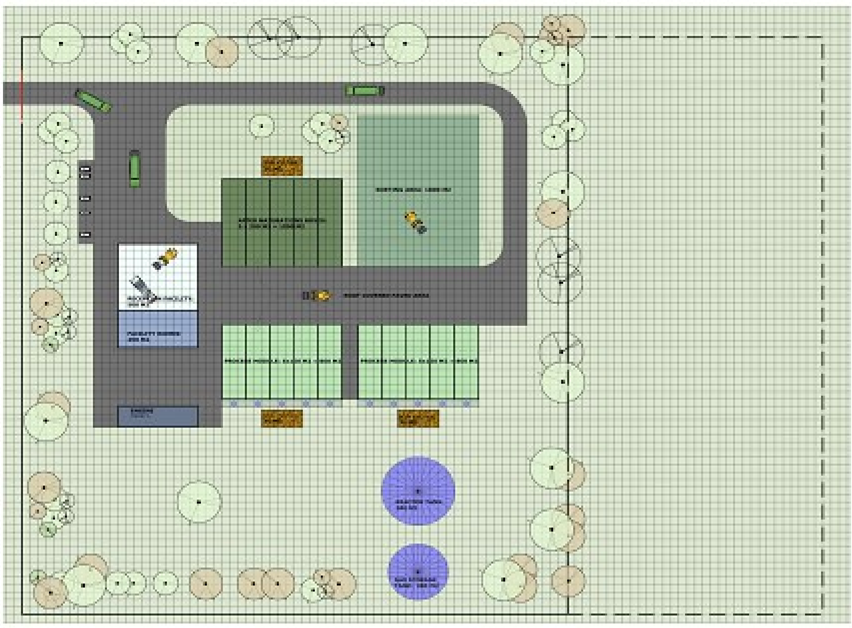
Process Modules (600 m3)	10	pcs
Process Tanks	10	pcs
Reactor Tanks (total volume 3000 m3)	1	pcs
Reception Facility	1	pcs
Process Area for tanks, pumps and fans	2	pcs
Bio Filters	3	pcs
Gas Engine	1	pcs
Gas Storage	-	pcs
Facility Rooms	1	pcs
After Maturation Boxes	5	pcs
Product Storage Area	1	pcs

Technical Overview

Plant Area

	per unit		total area	
Process Modules	160	m^2	1.598	m^2
Reactor Tanks	380	m^2	380	m^2
Reception Facility	750	m^2	750	m^2
Process Area for tanks, pumps and fans	259	m^2	518	m^2
Bio Filters	70	m^2	175	m^2
Gas Engine	24	m^2	24	m^2
Gas Storage	250	m^2	-	m^2
Facility rooms	290	m^2	290	m^2
After Maturation Boxes	200	m^2	1.000	m^2
Product Storage Area	1.800	m^2	1.800	m^2
Total Area for Construction			6.535	m^2
Land Required			2	hectare
			2	acres per hectare
Land Required			5	acres

Example of the Plant Layout



Documentation and energy yield optimisation of AIKAN® - a two-stage biogas technology for the organic fraction of municipal solid waste – biogas potential and efficiency

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Abstract
The efficiency of the AIKAN® two-stage biogas process for the source-sorted organic fraction of municipal solid waste (OFMSW) was investigated by methane potential analysis of the waste input and monitoring the hydrolytic and the methanogenic activity in the two stages of the process. The analyses revealed that the bottleneck of the whole degradation process can be rather found in the hydrolytic first stage while the methanogenic second stage revealed high efficiency. Consequently, in order to increase the energy yield of the whole process measures should be taken to improve the hydrolysis process in the first stage.

Keywords
Anaerobic digestion; biogas; compost; two-stage, flexible process; source-sorted, organic fraction of municipal solid waste; processing module; percolate

INTRODUCTION

The Danish company Solum A/S has developed a two-stage dry anaerobe digestion process labeled AIKAN®, which is able to convert organic household waste, garden waste, sewage sludge, leftovers from food production, and other organic waste into biogas and compost material. The treatment of solid waste at AIKAN® involves pre-sorting of the waste and mixing with woody structure material before loading the waste into the airtight process modules where anaerobic digestion followed by composting transforms these into biogas and sanitized compost. The process lasts for 7 weeks; 2-3 weeks of anaerobic digestion and 4-5 weeks of composting. After this fully enclosed process the compost is matured and screened and sold as fertilizer to farmers. The reject from the last screening is reused as structure material after removing metals and plastic.

The AIKAN® process is a feed-flexible process and organic waste of different purity and structure can be processed due to a robust screening process prior to the loading of the process modules. The two-stage design of the AIKAN® process enables pump-free filling of the screened waste into the 1st stage (processing module), eliminates the risk for blocking of pumps and pipes by pumping only the percolate from the 1st stage into the 2nd stage (biogas reactor tank) and finally makes the change to composting conditions possible without additional moving of the waste. Furthermore, the innovative two-stage technology combines different microbiological processes in a sequence of different process phases and solves the traditional conflict between the wish for high loading and inhibition of the process steps (figure 1). This makes the AIKAN® technology superior to other waste treatment processes for organic waste (Hartmann and Ahring 2006).

So far, Solum A/S has built two versions of the AIKAN® plant that are able to treat the organic fraction of municipal solid waste (OFMSW) with the recovery of energy and nutrients that is more beneficial than by incineration as the widespread solution applied for municipal solid waste in Denmark (Hartmann and Ahring 2006). The operation has proven robust and viable; however, the technology is only partially documented and still holds significant potential for improving the overall energy yield. The objective of the current project was to document a fully functional and operational plant and to identify measures for optimising the energy production. This was done by a series of tests performed at the AIKAN® plant close to Holbæk, Denmark. This plant converts 18,000 tons source-separated household waste, 5,500 tons garden waste collected in 8-10 municipalities and 4,000 tons sewage sludge into more than 1 million cubic meters of methane, and more than 6,000 tons of compost per year (Aikan Solum 2011). To determine the potential of the AIKAN® plant performance the methane yield of the different waste materials used in the process was analysed in batch experiments. To evaluate the capability of the different stages of the AIKAN® process, VFA released from the processing module were measured and inoculum from the biogas reactor tank was compared to standard inoculum from a manure-based biogas process.

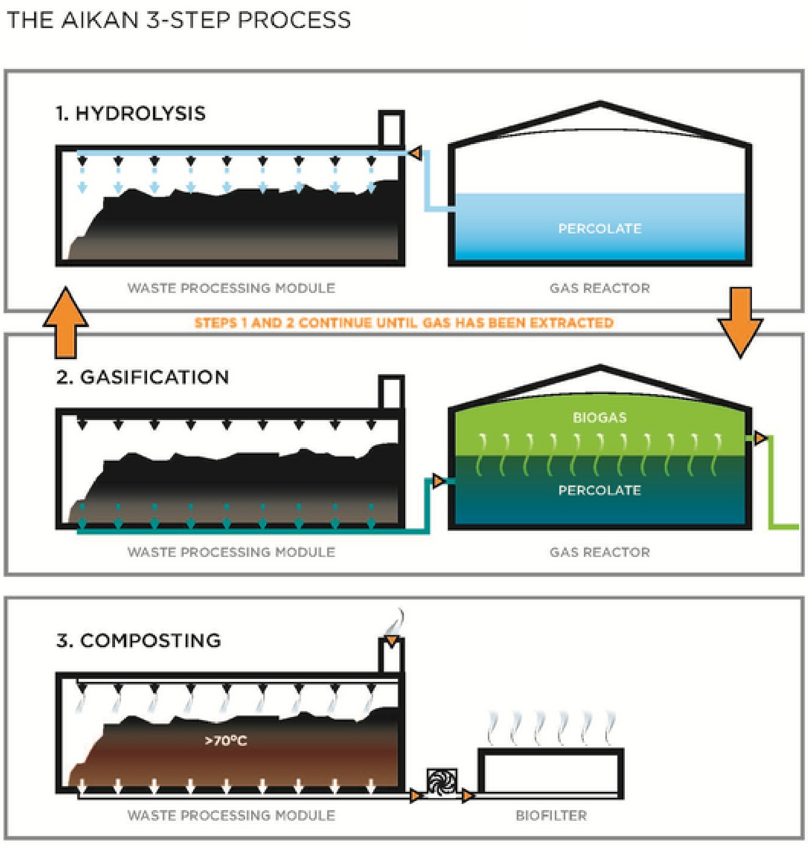

Figure 1. The 3 steps of the two-stage AIKAN® process

MATERIAL AND METHODS

Input characterization

The input to the AIKAN® process consists of the organic fraction of municipal solid waste (OFMSW) mixed with woody structure material. The AIKAN® process is dependent on the structure materials to secure the percolation during the AD phase and the airflow during the following composting phase. The received OFMSW is screened in a drum sieve with a hole size of 80 mm to remove plastic bags prior to the mixing with the structure material. 23% of the received OFMSW is typically found in the rejected oversize fraction from the screening process. The remaining screened waste is referred to as OFMSW. The structure material is a mixture of newly shredded woody green waste structure (WG structure) and recycled woody structure (RW structure) of the same origin. Coarse structure material of crushed wood (CW structure) from stems and roots is distributed on the floor of the processing module before loading to secure the function of drain and later ventilation during the composting step. The mixing ratio for one batch of the AIKAN® plant is typically 1000 kg OFMSW: 300 kg RW structure : 200 kg WG structure : 50 kg CW structure. The composition of the received OF-MSW was characterized by manual separation of impurity fractions (plastic, paper, wood, in-ert material). The screened OFMSW and the different structure materials were characterized by their TS and VS value.

Sampling. Samples of the different waste fractions where taken according to the guidelines given by the Swedish Waste Management Association, RVF /Avfall Sverige, (Vukicevic et al., 2005).

Waste composition. Characterization of the waste fractions was performed by analysis of TS, VS and pH according to standard methods (APHA et al., 1992). The composition of the OF-MSW was characterized by manual separation of impurity fractions (plastic, paper, wood, in-ert material).

Batch experiments. The methane yield of the different waste fractions was determined in an-aerobic batch tests at mesophilic conditions (38±0.5 ºC). Batch experiments were performed in triplicates in 117 mL vials for all samples, filled with 0.8 – 1.4 g-VS of biomass and 30 mL inoculum. To account for the lower homogeneity of the OFMSW samples their methane yield was also determined in 1000 mL vials, filled with 7.7 g-VS of biomass and 250 mL inoculum. Two different inocula were tested for degradation of OFMSW, one originating from lab-scale reactors at Aalborg University Copenhagen (Inoc AAU) treating manure fibers (Biswas et al. 2010) and the other from the reactor tank of the AIKAN® plant (Inoc AIKAN). Both inocula were preincubated at 38±0.5ºC for 3 days prior to the batch set-up. After adding the respective biomass and inoculum the vials were flushed with a gas mixture of 80% N_2 and 20% CO_2 be-fore closing the vials. Each set-up was performed in triplicates and for each inoculum a tripli-cate of vials was filled with inoculum and water only to determine the residual methane pro-duction of the inoculum. Methane production was monitored every 3–4 days by analysis of CH_4 concentration in the headspace using gas chromatography with flame ionization detec-tion (SRI-GC-310). The methane production was standardized by sampling the same volume (0.2 mL) from the batch vials under pressure as from a 30% methane standard under standard conditions (1 bar, 20ºC). At a pressure higher than 2 bar in the vials, the pressure was released and the amount of methane released was determined by the difference of the amount of me-thane in the vials before and after release. The methane production in the controls filled with inoculum only was subtracted to calculate the methane yield (mL/g-VS). The methane poten-tial was determined after 42 days of incubation, when no significant increase in methane pro-duction was observed.

Process monitoring. The hydrolytic and the methanogenic activity of the first and the second stage, respectively, of the AIKAN® process was determined by measuring the volatile fatty acids (VFAs) concentration in the effluent from the processing module and from the reactor tank, respectively. The VFAs acetate, propionate, iso-butyrate, butyrate, iso-valerate and valerate were analyzed by gas chromatography as described by Sørensen et al. (1991).

RESULTS AND DISCUSSION

Composition of the waste input to the AIKAN® process

Manual separation of different fractions of the OFMSW after screening revealed 11.5% plastic impurities while inert material (mainly glass and stones) accounted for only 0.3% of the waste mass (table 1). The paper fraction, which presumably can also be degraded throughout the AIKAN® process was contributing to almost 11% while only 0.3% of wood with a presumably low degradation was found. The TS and VS analyses of the different waste fractions entering the AIKAN® process revealed a TS value of about 32% for OFMSW while the structure material showed values of about 50% TS (table 2). The OFMSW showed furthermore a relatively high ash content of almost 21% and the low VS/TS ratio of the coarse wooden structure revealed a high content of inert material (glass and stones) in this structure material.

Table 1. Composition of OFMSW due to manual separation

Fraction	(% m/m)
Food waste fraction	77.2%
Plastic	11.5%
Paper	10.7%
Wood	0.3%
Inert material	0.3%

Table 2. TS, VS analyses of the input fractions to the AIKAN® process

Sample	%TS	%VS	%VS/TS
OFMSW	32.3%	25.6%	79.2%
WG structure	51.0%	48.7%	95.6%
CW structure	49.0%	27.4%	56.0%
RW structure	51.0%	43.8%	86.0%

Biogas potential of input fractions

The methane production in the batch experiments reveals both the conversion kinetics and the final methane yield for the different waste fractions. The course of the methane yield (figure 2) showed a lag phase of about 8 days when using the AAU inoculum from a process running on manure fibers while no lag phase was detected when using inoculum from the reactor tank of the AIKAN® process. This reveals that the anaerobic microorganisms in the reactor tank of the AIKAN® process are well adapted to the OFMSW leading to a rapid and robust degradation of the waste. The final methane yield of the OFMSW of 425 – 482 mL-CH_4/g-VS shows a high degradability of the waste assuming that most of the organic matter of the waste are carbohydrates with a theoretical value of 420 mL-CH_4/g-VS. The batch test also shows that the set-up in 117 mL vials leads to lower deviation and low variation compared to the 1 L set-up. The methane yield of the structure materials was significantly lower, for the woody green

waste structure and coarse wooden structure 50 – 60 mL-CH_4/g-VS and for the recycled woody structure below 10 mL-CH_4/g-VS. Together with the respective VS concentration of the different waste fractions (table 2) this results in methane potentials per ton of material of 113.7 m^3-CH_4/t in average for OFMSW and between 2.5 and 29 m^3-CH_4/t for the other fractions (table 3).
The results indicate that most of the methane potential stems from OFMSW while the contribution of methane production from the structure material is only small. The percentage of methane from OFMSW will be even higher in daily operation due to the fact that easily degradable organic matter is only found in the OFMSW and process time is the limiting factor. The structure material will mainly be degraded during the following composting phase. In order to identify the key points of the process for boosting the energy yield of the AIKAN® plant the efficiency of the different process stages was monitored.

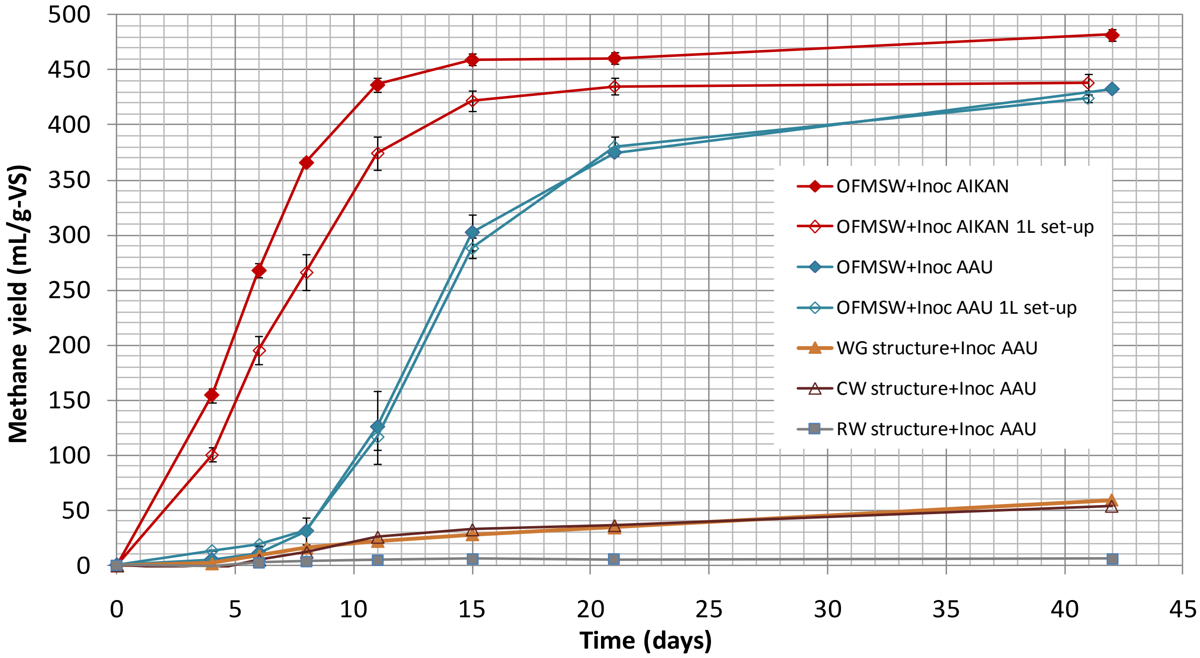

Figure 2. Cumulative methane yield of OFMSW (with AAU and AIKAN inoculum in both 117 mL and 1L set-up) and the different structure materials with AAU inoculum in 117 mL set-up; error bars indicate standard deviation

Table 3. Fraction distribution and methane yield for the input to the AIKAN® process

Sample	Mass in input	Methane potential	
	kg	mL-CH_4/g-VS	m^3-CH_4/t
OFMSW	1000	444.5	113.7
WG structure	200	59.5	29.0
CW structure	50	53.9	14.8
RW structure	300	5.7	2.5

Hydrolytic activity of the AIKAN® process

The hydrolytic activity during the start-up of the process was monitored by VFA analysis in the outlet of the processing module. The results in table 4 show that acid production started during 24 hours after percolation of the processing module, producing acetate, propionate and butyrate in significant amounts. The peak production of these acids was found on days 12 and 15 and declining to low acid production 39 days after start-up. The peak production for iso-butyrate was found on day 22. During the first days of process start the effluent from the percolating module was mainly drained and only small amounts of the effluent from the reactor tank were percolated over the waste in the processing module (figure 3). Accordingly the pH of the effluent from the first stage is low in the beginning and increases significantly after day 15 when higher amounts of the effluent from the reactor tank are percolated.

Methanogenic activity of the AIKAN® process

The conversion of the acids into methane by methanogenesis in the reactor tank was monitored by VFA analysis in the effluent from reactor tank. The results in table 5 show generally low levels of all VFAs, indicating rapid conversion of all VFAs from the processing module in the reactor tank. The acetate concentration showed a peak of 23 mM 8 days after process start-up, and was lower than 16 mM on day 15, when the acid production from the processing module was still high. This indicates high activity of VFA degrading and methanogenic microorganisms in the reactor tank.

Table 4. Concentration of acetate, propionate, butyrate and valerate and pH in the effluent of the processing module

Day after process start	Acetate mM	Propionate mM	Iso-butyrate mM	Butyrate mM	Iso-Valerate mM	Valerate mM	pH
1	114.74	32.12	0.31	20.73	0.39	3.68	4.6
8	152.01	37.23	0.93	33.78	1.12	6.55	5.3
12	196.36	40.09	5.21	71.34	6.45	24.37	6.4
15	176.68	41.68	6.08	56.88	6.32	18.92	7.6
22	152.79	31.64	15.56	26.71	4.91	9.91	8.1
29	128.20	29.46	7.02	10.45	3.41	4.14	8.4
39	86.38	27.52	3.26	2.94	2.73	1.86	8.6

Table 5. Concentration of acetate, propionate, butyrate and valerate and pH in the reactor tank

Day after process start	Acetate mM	Propionate mM	Iso-butyrate mM	Butyrate mM	Iso-Valerate mM	Valerate mM	pH
8	20.73	1.90	0.15	0.52	0.15	0.30	8.4
12	21.63	1.82	0.78	1.84	0.32	1.16	8.6
15	23.27	1.06	0.09	0.30	0.08	0.17	8.4
22	15.76	0.39	0.02	0.13	0.03	0.05	8.4
29	14.06	0.45	0.04	0.12	0.06	0.05	8.4
39	0.18	0.00	0.00	0.00	0.00	0.00	8.3

The total flow of VFAs released from the processing module and from the reactor tank after start-up (figure 3) is calculated as sum of the measured VFAs, converted as g-acetate/L, and multiplied with the flow of the effluent from the respective stage. This also reveals that the hydrolytic activity was highest between day 8 and day 15 and declined after this period (figure 3). The persisting low VFA flow from the reactor module also when the feed from the processing module is high reveals that the AIKAN® process is very robust in terms of conversion of the acids from the hydrolytic stage in the methanogenic stage in the reactor tank.
Together with the results of the batch experiments with the inoculum from the reactor tank it can be concluded that the methanogenic step of the AIKAN® process is highly efficient. Therefore, the bottleneck of the whole process leading to lower practical yields than the potential is rather in the hydrolytic step in the processing module.

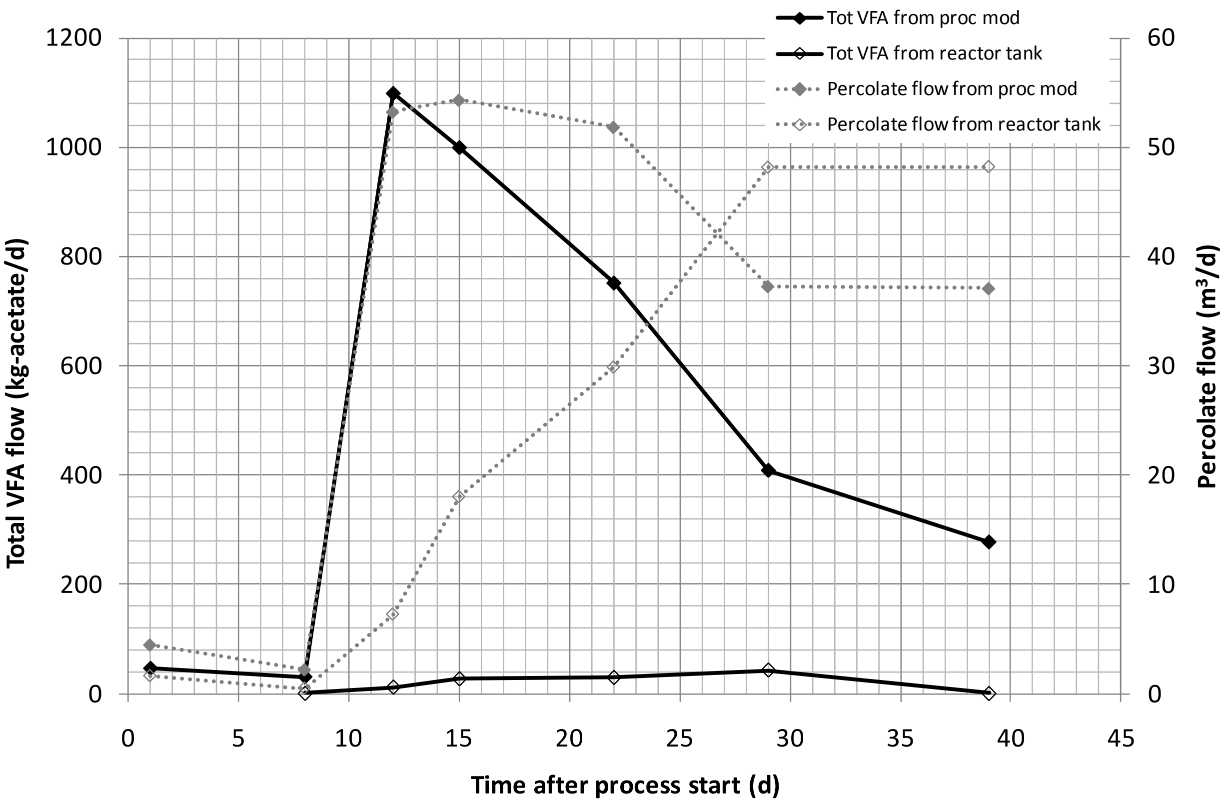

Figure 3. Percolate flow and flow of total VFA released from the processing module and in the effluent from the reactor tank after start-up of the process

CONCLUSION

The batch experiments reveal that the OFMSW delivered to the AIKAN® plant has a high methane potential and is relatively easily degradable. The added structure material only contributes to a minor percentage of the final methane yield. Comparing the methane potential of the OFMSW with the average methane yield achieved at the AIKAN® plant reveals that the energy potential of the waste is not fully exploited in the current process operation. The rapid conversion of the waste by using inoculum from the AIKAN® reactor tank together with low VFA concentrations in the reactor tank indicate that the methanogenic process is highly efficient. Further optimization of the AIKAN® process should therefore target on a higher conversion of the organic matter of the waste into VFAs and other easily degradable compounds in the hydrolytic stage in the process module. One measure could be to improve the contact of hydrolytic microorganisms in the percolate with the waste in the first stage processing module.

ACKNOWLEDGEMENTS

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App. 2.4.2 Documentation and energy yield optimization of AIKAN© - a dry anaerobic digestion technology

AALBORG UNIVERSITY COPENHAGEN

AIKAN© projekt

Documentation and energy yield optimisation of AIKAN© - a dry anaerobic digestion biogas technology

Analyseresultater

23. marts 2011

Aalborg University Copenhagen
Section for Sustainable Biotechnology

Hinrich Uellendahl

Resultater TS, VS, pH, VFA, biogaspotentiale

Tørstof (TS) og glødetab (VS)
Tabel 1 viser analyser af TS og VS i de forskellige råmaterialer modtaget af Solum.

Tabel 1: TS, VS analyser i affaldsfraktioner

Prøve	%TS	%VS	%VS/TS
KOD	32.30%	25.59%	79.24%
Bundflis	97.86%	54.80%	56.00%
HPO	97.21%	92.91%	95.58%
Genbrug	97.14%	83.49%	85.95%

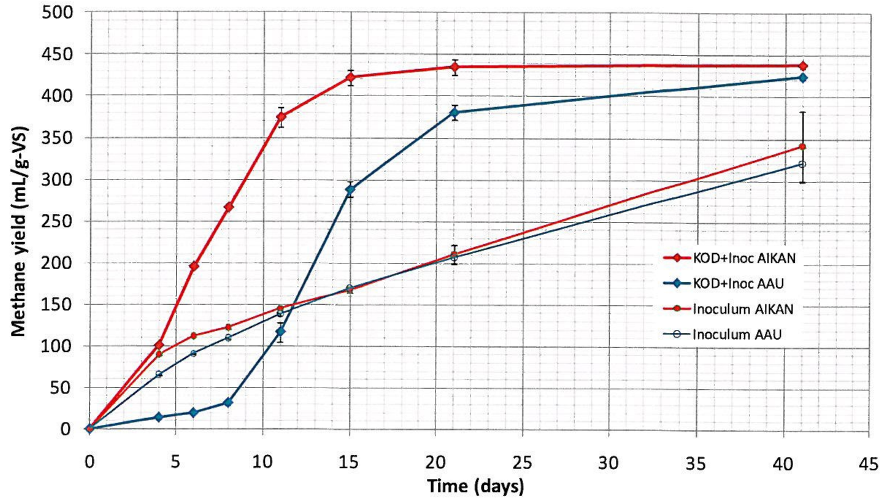
Flygtige fedtsyrer (VFA) og pH
Tabel 2 viser analyser af flygtige fedtsyrer i de forskellige prøver modtaget af Solum.

Tabel 2: Koncentration af acetat, propionat, butyrat og valerat og pH i prøver fra AIKAN© processen

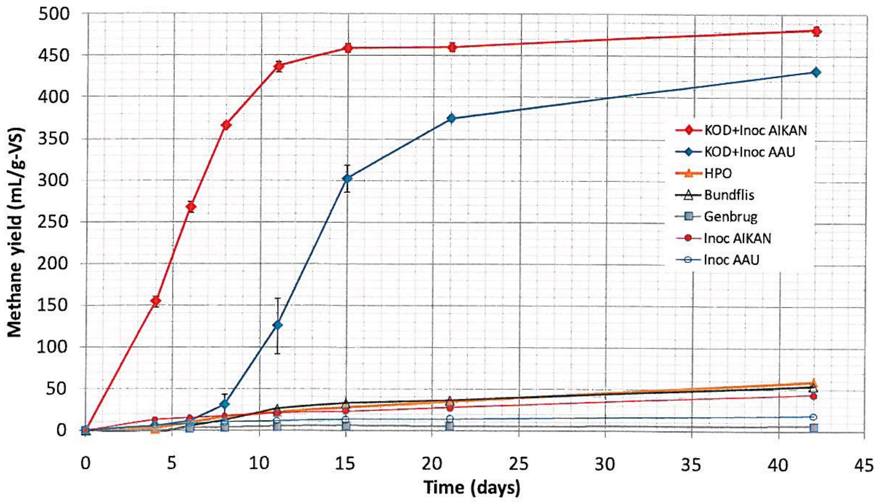
Prøve	Acetat	Propionat	Iso-butyrat	Butyrat	Iso-Valerat	Valerat	pH
#	mM	mM	mM	mM	mM	mM	
1	114.742	32.124	0.307	20.734	0.389	3.684	4.6
2	152.008	37.234	0.931	33.784	1.120	6.553	5.3
3	196.360	40.089	5.213	71.343	6.451	24.367	6.4
4	176.677	41.684	6.076	56.884	6.320	18.918	7.6
5	152.789	31.636	15.559	26.706	4.907	9.914	8.1
6	128.200	29.464	7.019	10.454	3.412	4.142	8.4
7	86.376	27.516	3.258	2.942	2.734	1.864	8.6
8	20.733	1.900	0.152	0.522	0.151	0.302	8.4
9	21.628	1.825	0.778	1.843	0.319	1.160	8.6
10	23.268	1.057	0.094	0.304	0.084	0.169	8.4
11	15.764	0.387	0.022	0.131	0.030	0.052	8.4
12	14.063	0.445	0.037	0.119	0.065	0.049	8.4
13	0.176	0.000	0.000	0.000	0.000	0.000	8.3
14	135.220	29.954	3.269	52.090	4.780	23.727	5.2
15	133.603	24.499	2.513	37.812	3.718	16.543	4.8
16	221.772	5.482	0.885	15.183	2.457	3.720	5.1
17	245.258	2.718	0.895	16.940	2.744	2.464	5.5
18	237.915	6.409	1.302	34.375	3.356	3.313	5.9
19	233.927	11.134	5.554	44.461	6.839	4.513	5.8
20	158.160	38.327	3.579	109.608	3.804	28.098	5.7
21	144.431	9.264	1.049	25.197	1.365	6.431	4.7
22	139.967	7.986	3.572	32.047	4.853	4.249	5.8
23	102.830	10.963	2.520	24.004	3.688	4.670	5.4
24	96.303	13.637	2.928	23.359	3.889	5.219	5.3
25	112.051	27.225	4.059	40.048	5.401	8.559	5.2

Biogaspotentiale

Figur 1 og 2 viser forløbet af metanudbyttet i batch forsøg i hhv. 1000 ml flaske og 117 ml flasker. Tabel 3 viser det endelige metanudbytte i de forskellige forsøg.



Figur 1: Forløb af metanudbyttet af KOD med forskellige inokulum i batch forsøg i 1000 ml flasker



Figur 2: Forløb af metanudbyttet af KOD (med forskellige inokulum), HPO, bundflis og genbrugsstrukturmateriale (med AAU inokulum) i batch forsøg i 117 ml flasker

Tabel 2: Endelig metanudbyttet af de forskellige råmaterialer i de forskellige forsøg

Prøve	Inokulum	Set-up	Endelig metanudbytte
			mL-CH_4/g-VS
KOD	AAU	1000 mL	424.57
KOD	AAU	117 mL	432.73
KOD	AIKAN	1000 mL	438.47
KOD	AIKAN	117 mL	482.03
Bundflis	AAU	118 mL	53.93
HPO	AAU	119 mL	59.46
Genbrug	AAU	120 mL	5.66

App. 2.5.1 A full AIKAN Standard Operation Manual

Aikan Standard Operational Manual

Indhold

3

1 Preamble

The present operational manual addresses four main issues:

- Health and Safety
- Service and maintenance
- Waste treatment
- Eco-efficiency

The content of this manual will be taught to new owners of an Aikan facility and the staff chosen to operate the plant.

The present version is a non exclusive standard version that has to be prepared with information for the concrete site

Since staff members might change over time. It is strongly recommended that new staff members are educated in a similar manner in the manual and reads the instructions thorough.

The Aikan team will be available and ready to answer questions that might arise from the reading of this manual as well as to answer questions arising from the day to day operation of the Aikan plant.

The manual is a document that relates to the Aikan plant:

[Contact Info]

The manual has been created on June 2010 by Aikan LtD

Revision protocol	Date of revision	Responsible for the changes
Version number 3	Sept 2010	Aikan LtD.

2 The Aikan plant

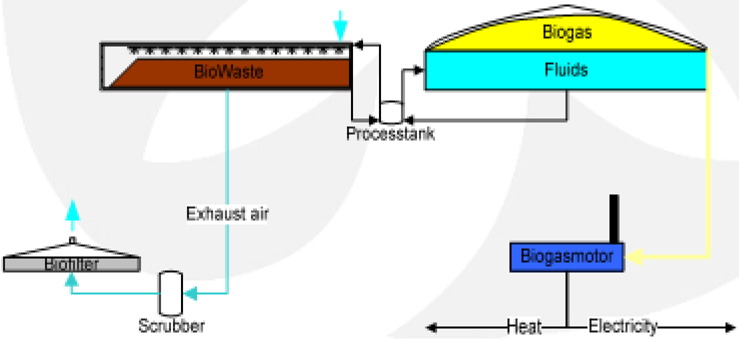
The Aikan plant is designed to produce biogas and compost out of municipal solid waste, green waste, sewage sludge, agriculture residues and a variety of other resources.

The output and quality of energy and compost from the Aikan plant is depending on waste types and amounts. Thus a firm waste characterisation has to be carried out involving fractions and amounts. The characterisation has to be done before detailed planning of the facility but it is also recommended that it is carried out once a year to register major changes.

Waste treatment is based on a good understanding among the operators for the technology they use. It is the scope of this manual to authorize operators to use the mobile equipment and the Aikan technology as complete as possible

The organic waste is a source of food for a multitude of different species of microorganism. The organic wastes consist of cells, forming tissue that act together via biochemical molecules. During biological waste treatment the tissue and cells are broken down and the biochemical molecules are transformed while "being eaten" by microorganisms.

The Aikan technology is based on two-phases and two processes. The solid waste is kept solid and fluids are treated as fluids. The fluid phase is being degraded by anaerobic microorganisms (without oxygen), whereas the solid fraction is mainly being degraded by aerobic microorganisms (with oxygen).



The solid Biowaste is placed in process modules. In the process modules the waste is washed out by percolation. The percolate is used to produce biogas in the reactor tank, where anaerobe microorganisms use volatile fatty acids and others organic chemical compounds. The anaerobe microorganisms' grow faster in temperatures around 38°C- 45°C. Lower temperatures slow down the growth rate and thus the biogas formation. Higher temperature will increase growth rates and biogas formation up to 55 °C, but then completely stop. The risk at higher temperatures is though that the high growth rate is sensitive to changes.

5

The non-soluble heavier degradable solid fraction is degraded by sucking oxygen containing air through the materials and keeping the waste moist. A great variety of aerobe microorganisms are involved in this degradation which is most effective at temperature from 45° C to 55° C. However in the end of the composting process the temperature is raised to 70° C. This is done to kill harmful microorganism.

6

3 Health and Safety

Health and safety is the backbone of operation at the Aikan facility.

No one should be ill, sick or injured by going to work! Working with waste implies risks of diseases stemming from degraded organic matter. Moving mechanical equipment can injure you if not handled proper and gasses can cause explosions or health risks if inhaled. Therefore we start this manual with issues that will keep everyone safe.

Prior to the specific instructions a Hazard Analysis of Critical Control Points (HACCP) has to be carried out for the concrete plant. Specific instructions need be merged into the present document

3.1 Basic rules of health and safety

Ten basic rules of health and safety apply for any facility.

1. Everybody working at waste facilities must be vaccinated against known nationally occurring diseases (see vaccination program)
2. Wear personal protective equipment as required for the specific task (described in each practical procedure in chapter 2 and 3)
3. No smoking except in designated areas
4. No open fire, welding or other spark creating activity near any gas installation or explosive liquids (gasoline, diesel etc). The plant is zone levelled according to explosion risks (see map xx)
5. Always read instructions before starting a new machinery or technical installation.
6. Do not bring dirty cloth, shoes or tools etc to the dinning hall
7. Always wash hands before eating
8. When working in wells always be 2 – one working, one to call for assistance if needed
9. For new unknown operations always consider, what could go wrong and how do I avoid or minimize a risk
10. Tell the management of any health and safety risk or accident, that occurs during operation – these experience help to prevent future accidents

The best way to avoid accidents and health injury is to be precautious and plan activities thoroughly based on knowledge. Thus if a new task is difficult and complex always ask for advice and discuss it with your colleagues.

3.2 HACCP

The conclusions of the concrete HACCP

3.3 Reporting deviations

The basic of safety is to learn from experience and rearrange operations every time a potential new risk is acknowledged. New preventive procedures are implemented, when such risk is acknowledged.

To acknowledge risks it is crucial that the staff report on all deviations from normal operation these deviations are:

1. Occurred accidents
2. Situations, where a risk for health and safety has arisen
3. Occurred environmental spills, emissions or other pollution of the environment
4. Situations, that has created risk of pollution of the environment

The reports are given immediately to the management team, who must evaluate the report, acknowledge the risk and create new preventive procedures.

3.4 Preventive procedures

According to the concrete HACCP

New preventive procedures have to be implemented and understanding among staff has to be reached.

4 Service and maintenance

To keep the plant well functioning and prolong the life of all equipment it is important to comply with service and maintenance intervals given for each component, mobile machinery or other equipment. It is also important due to the fact that guaranties for a lot of technical equipment no longer apply in case of missing service and maintenance.

This chapter describes service and maintenance in the day-to-day operation. Service and maintenance has to be taken care of by the staff.

In Appendix 1 all supplier documents are attached. When new equipment, machinery or equipment is purchased it is important that this manual is kept updated with these new materials.

The text below is not exclusive it needs to be adopted to the concrete plant

4.1 Test of functionality

Every time a process module has been emptied and cleaned it has to be tested for functionality prior to refilling and closing of the gate. The plant is not in any way complicated and tests are run quit easily

Four elements have to be tested:

1. The irrigation system
2. The draining system
3. The ventilation system
4. General inspections (Any other damage registered)

The testing can be done quit simply using the tablet computer to start and stop equipment one by one by following these instructions:

To test the irrigation and draining system

1. Sprinklers are inspected visually
2. Drain/ventilation holes in channels are inspected visually
3. Stand in front of the open process module and log on to operating system
4. Fill the process tank to level 100 cm by opening FT[XX]-MV02
5. Control that temperature off liquid are similar to temperature in RT
6. FT[XX]- MV02 is closed
7. Open FT[XX]-MV02

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8. While operator stands outside the open process module start PT[XX]-PU01
9. The spreading is visually inspected
10. Stop PT[XX]-PU01
11. Control that level recover to 100 mm
12. Set all in automatic mode

To test the ventilation system.

1. Go to the process area and log on to the system at the computer
2. Close FT[XX]-MVO1
3. Open PM[XX]-DA01
4. Start van
5. Inspect that the van is running and at the Pressure Transmitter (PM[XX]-PT[XX] not yet tagged) shows less than xx pressure
6. Close PM[XX]-DA01 test that pressure readings rise
7. Test that PM[XX]-TT01 shows expected outdoor temperature
8. Set all equipment back to automatic mode.

General inspections

Every time that a module is emptied and filled it is visually inspected for function or construction important failures or damages.

The need for repairing is evaluated

If urgent the repairing is executed immediately.

If not urgent the item is registered in a damage and failure log that is used for repairing and maintenance planning. The repairing and maintenance planning should typically be discussed on monthly meetings. Where actions are decided.

4.2 Maintenance

The equipment is chosen by Aikan to work in the aggressive environment that active biological process produce. However the life of instruments and equipment is prolonged by proper regular maintenance and thus securing that functionality is maintained.

When any equipment fails to function properly it has to be repaired or changed immediately therefore it is recommendable that a store of spare parts kept.

The main procedure is removal of scale from pumps, transmitters and tubes etc. This is done by use of citric acid. The plant is designed so that Citric acid can be cycled through all tubes and tanks. Tanks have to be emptied however for process liquid.

The citric acid concentration is 100 kg citric acid pr m^3. Citric acid is heated to 50°C to speed up de-scaling.

To keep track of maintenance the maintenance and service records has to be kept; see Appendix 2.

<u>How to remove scale from process tanks and heating modules</u>

For removal of scale inside the process tank a special spraying head is used, to distribute the acid even inside the tank volume.

1. The tank is emptied for process liquid, by closing the FT[XX]-MV01 and FT[XX]-MV02, opening PT[[XX]-SHV02 and starting pump PT[XX]-PU02 pumping liquid to reactor tank.

2. All valves and pumps are closed.

3. The spraying head is mounted on either PT[XX]-CIV01 PT] or PT[XX]-CIV02.

4. The process tank is filled with 2 m^3 of citric acid concentration and while heating by setting minimum temperature to 50°C. The process pump (PT[XX]-PU01 or PT][XX]-PU02) mounted on the spraying head is started.

5. The pump runs until heating coils and tank are cleaned.

The pump and tubes which is not used for the spraying head is cleaned by connecting PT[XX]-CIV01 PT] and PT[XX]-CIV02 and starting one of the pumps PT[XX]-PU01 or PT[XX]-PU02. Thus citric acid is recycled through the 2 pumps in the tank.

This procedure normally has to be carried out 2 times a year.

The maintenance record is kept to keep track of cleaning.

<u>How to remove slurry and scale from tubes and RT</u>

Every second year the reactor tank has to be cleaned. The RT has to be emptied to remove sludge from the bottom. At the same time the tubes inside the tank should be cleaned for scale.

To do so the following procedure has to be run:

1. The feeding of the RT is stopped one week in advance to slow down methane production.

2. All batches attached to the RT are restarted in maintenance compost batch program.

3. One of the PT is emptied for process liquid, by closing the FT[XX]-MV01 and FT[XX]-MV02, opening PT[[XX]-SHV02 and starting pump PT[XX]-PU02 pumping liquid to reactor tank.
4. The RT is emptied for biogas and liquid is pumped to the temporary storage in the gas storage tank.
5. The metal plate lid on the RT is removed and fresh air ventilation is started running for at least 5 times volume removing time.
6. The slurry in the tank is removed by a vacuum tanker with a sufficiently long hose. Staff working in the tank has to wear fresh air equipment
7. The input and output tubes are connected with the de-scale hose.
8. The PT (see bullet point 3) is filled with 4 m^3 of citric acid that are heated to 50° C.
9. PT[[XX]-SHV02 is opened and pump PT[XX]-PU02 is started by which mean citric acid is circulated through the tubes inside the RT
10. The RT is remounted and refilled with process liquid

The maintenance record is kept to keep track of cleaning.

<u>How to remove scale from tubes between PT and RT</u>

Every 6 month it is recommended that scales are removed from tubes between RT and PT. The following procedure is followed:

The process tank in the end of the line (further away from the RT) is emptied for percolate.

1. The tank is emptied for process liquid, by closing the FT[XX]-MV01 and FT[XX]-MV02, opening PT[[XX]-SHV02 and starting pump PT[XX]-PU02 pumping liquid to reactor tank.
2. All valves and pumps are closed.
3. The PT is filled with 4 m^3 of citric acid

The maintenance record is kept to keep track of cleaning.

4.3 Lists of equipment

The complete plant involves mobile machinery, pumps, vans etc.

The complete list of components with tag numbers is found in Appendix 3.

The schematic technical process is shown in the P&I diagrams Appendix 4.

The mobile equipment of the following types and producers are chosen:

5 Waste treatment

The Aikan plant is designed to produce biogas and compost out of municipal solid waste, green waste, sewage sludge, agriculture residues and a variety of other resources. Different wastes have to be treated differently due to structure and content. Therefore 5 different programs for the most common standard wastes are preinstalled. However waste is differing greatly from area to area, thus the option exist to re-program for special demands. It is recommended to consult the Aikan team prior to reprogramming to avoid wastes to be treated wrong.

Waste treatment is based on a good understanding among the operators for the technology they use. It is the scope of this manual to authorize operators to use the mobile equipment and the Aikan technology as complete as possible.

5.1 Reception and registration

All wastes, residues and structure materials entering the plant, and all compost, recyclable materials and residual wastes has to be registered at the weight. Remember to have the weight calibrated once a year for accuracy.

It is important prior to the acceptance of waste fractions to have proper waste characteristics, to decide which program is most suitable. This has to be given by the waste supplier. The aim is to decide the biogas potential, the degradability and the needed pre-treatment.

Trucks leaving and entering the plant has to drive through the wheel disinfection area. This is a request from veterinarian authority and has to be respected. Thus reception area is considered dirty zone on inner site of the disinfection area. The trucks only move in the dirty zone while being on the plant.

Once registered the trucks unload the waste in the waste pit designed for the specific type of waste. The pit has to be kept sufficiently empty to allow new waste to be offloaded. And all waste pits should be empty at the end of each working day.

5.2 Pre-sorting

The waste pits are emptied for waste by the front loader, which is moving in the unclean zone only. Waste that has to be pre-sorted (BMSW/MSW) is filled into the bag-opener (brand), which is mowing in the dirty zone only too.

The feed mixer parks in the wheel disinfection ditch, when loaded with waste by the front loader (for waste). The structure material is loaded by the front loader in the dirty zone too.

5.3 Blending of waste

The feed mixer is running while loaded with waste every shovel of waste and structure is noted so that the total weight of structure and the total weight of waste are known.

The present scheme gives the typical blends for BMSW and Sewage Sludge.

Waste type	**Waste** Mass (kg)	**New structure** Mass (kg)	**Recycle structure** Mass (kg)
Biodegradable Municipal Solid Waste	1000	200	300
Sewage Sludge (for composting)	1000	300	700

It is recommended that local experience with other waste types are written in the scheme to make it easy for any new operator to blend.

Vi kunne godt indarbejde et data modul således at vægten registreres direkte på det enkelte modul. Dette ville helt afgjort sikre en bedre registrering. Det betinger dog trådløs kommunikation i maskinerne.

The feed mixer drives to the process module while mixing. No waste must be spilled on the way since the process area after the disinfection ditch is clean zone. Only the inner side of the feed mixer jar is dirty zone.

5.4 Loading of process modules

It is necessary to register the total amount of waste, recycled structure and new structure loaded to the process module. Thus this is registered for each filling of the feed mixer (mentioned above) and the amount is summed up for the whole module.

The process modules are clean zone since they have been sanitized during the composting of the last module and cleaned thoroughly. The modules are filled with waste from the inner of the module by the conveyer belt on the feed mixer. Thus only the inner part of the module is being re-contaminated with waste, while filling up.

The module is filled up with waste 50 cm from the roof. When the module is filled approximately 3 meters from the gate the flooding barrier is lifted and the remaining part is filled.

5.5 Starting the process

The gate is closed and bolted tight. On the computer control system it is confirmed that the gate is closed, the amount of waste and structure is registered (the program will not start if not registered) the correct program is chosen and the plant is started.

5.6 Process surveillance

The program runs through the complete biogas and compost program without operator interference.

If process hardware failures occur an alarm is shown on the computer screen for the concrete component. The cause of failure must be identified and the broken/not functioning component must be replaced or repaired.

On a daily basis, it is recommended that the batch report for every process module is checked to see that ventilation and percolation has been functioning properly.

On a daily basis the biogas reactor data: pH, temperature, inlet and outlet percolate and biogas production and methane content is checked to see if the reactor performance is within range.

Standard ranges for the process is given in Appendix 5.

5.7 Emptying the process modules

The process modules are emptied by the front loader for sanitized compost. It is important not to lift the shovel up to high into the irrigation tubes. The compost is transported in the shovel to the maturation boxes. The compost is stabled in 4 meters height.

The trenches between the aeration channels are emptied with the bobcat mounted special cleaning shovel.

5.8 Preparing the process module and maturation boxes

After emptying the process module and maturation boxes they have to be hosed and ventilation holes must be cleaned.

All sprinklers in the process modules are checked (as described in 4.1)

Twice a year the metal plates on the drain channels are removed to remove dirt from the ventilation/drain channels.

5.9 Maturation

Sanitized compost is placed in the maturation boxes, where the ventilation is started for the concrete box.

Maturation can be run as long as wanted to fit in the compost screening routines, but it is recommended that maturation is at least 3 weeks to make compost mature.

5.10 Screening of compost

Compost is screened on a 10 mm drum screen.

The coarse fraction is screened on the wind sifter with magnetic separation and stone separation.

Mature 10 mm compost has to be declared according to the quality assurance system.

6 Eco-efficiency

The plant must perform in respect of environment and climate within an economically sound frame. The way the operation is carried out, is crucial to achieve these targets.

Everybody should be proud working at a facility that: recycle organic materials and produce environmental friendly energy without causing harm or nuisance to the environment.

To make sure that this is the case quality and performance has to be in top. This state can be reach by simple quality measures described below.

6.1 Compost quality assurance

The compost quality assurance scheme in generally involves control of input matrials, process and compost sampling an analysis. On the basis of these data a compost declaration sheet has to be worked out.

All compost customers have to be given the declaration to secure proper use of the product.

An example of compost declaration is given in Appendix 6.

6.2 Biogas output control

The yield (Nm^3) biogas and the quality (% of: CH_4, CO_2, H_2S) is measured continuously. Everyday these readings should be checked to see, that they are within the expected range (Appendix 5).

6.3 Environmental performance

Environmental performance is traditionally linked to 5 main themes:

1. Emissions to air
2. Emissions to water
3. Emissions to soil
4. Use of energy (electricity, diesel, heat etc)
5. Use of materials

The plant is designed to give as little emissions as possible – the description of environmental evaluation is done in the environmental application and environmental permission found in Appendix 7.

The environmental performance should be followed by one central data registration system. The Aikan team can assist in setting this system up if requested.

6.4 Economic key account

The plant economy depends on how well the operators understand the plant technology and the economy of the business. The figure below illustrates how input waste and output compost, energy and other recyclables influence the economy.

Concrete illustration on how input and output affects the overall economic performance – this figure is normally very helpful to give workers a good understanding of priorities.

The more waste and the higher yield of valuable products the better the economy at the facility.

To produce a good result:

1. Always treat waste
2. Always have the plant running to produce quality compost and biogas
3. Avoid pollution and emissions of runoff water
4. Maintain the facility so that major break downs does not close the production
5. Minimize the use of fuel, electricity and spill in generally

A good result gives a backbone for any improvement you will need on the plant.

App. 3.1. Plant design and layout under optimal conditions

ALECTIA

1 DREJEBOG

1.1 Lokalisering af egnet grund

1.1.1 Opsøge lokalområdet og vurdere egnede lokationer

- Opsøge lokalområdet
- Registrere mulige sites
- Undersøge lokal og overordnet planlægning
- Undersøge infrastruktur-muligheder
- Opsøge tilgængelige statistiske data i samfundet
- Affaldsmængder
- Tale med lokale myndigheder (dette kan gøres i ALECTIA's navn, uden at det afsløres, hvem den egentlige opdragsgiver er!)

1.1.2 Undersøge og vurdere infrastruktur

- Udarbejde en rapport over iagttagelser og anbefalinger vedr. lokalisering på basis af indsamlede oplysninger
- Udregne prognoser for fremtidig vækst
- Beregning af lokalsamfundets behov for et anlæg.

1.1.3 Udarbejde indstilling og evt. udarbejde businesscase til/for endelig ejer til brug for beslutning om køb

- Med de indsamlede informationer udarbejdes en business case, som kan anvendes i salgsarbejde.
- Business casen kan senere bruges som dokumentation til den fremtidige ejers brug i ansøgninger om bevillinger fra offentlige kasser og støtteordninger for at etablere anlægget.
- Her kunne man samtidig screene muligheden for at opnå finansiel støtte fra pågældende lands regering eller internationale fonde og organisationer.

1.1.4 Forhandle og evt. købe grund

Når beslutning er taget:

- Gå i markedet for at købe nødvendige arealer
- Undersøge lokale priser på jord
- Forhandle og udarbejde kontrakter

- Etablere kontakt til det lokale juridiske system (advokat)

1.2 Information om grund/projektgrundlag

1.2.1 Besigtigelse, iværksætte geoteknik

- Registrere grunden med fakta og nivellement
- Undersøge hvad der er tilgængeligt i form af forsyninger og afløb
- Opsøge lokale myndigheder for at få deres evt. krav udskrevet/notat.
- Er der lavspænding/højspænding?
- Har ledningsnet kapacitet til dette?
- Geoteknik, boringer kabes og sættes i gang. Prøver vurderes lokalt
- Geotekniske prøver sendes ligeledes til Danmark for kvalitetssikring og endelig beslutning

1.2.2 Endelig placering af anlæg

- Endelig placering af anlæg
- Analyse af grundens geometri
- Fastlæggelse af den endelige placering i h.t. geotekniske resultater
- Der tages hensyn til fremtidig udvidelse
- Byggepladsplacering bestemmes

1.2.3 Udarbejde layout over forsyninger/afløb

- Udarbejdelse af layout for nødvendige forsyninger på baggrund af oplysninger fra pkt. 1.2.1.
- Overordnet projektering fra kontoret i Virum
- Forhandling og godkendelse af endeligt layout sker lokalt

1.2.4 Tilslutning til offentlige systemer

- Tilslutning til offentlige systemer aftales med lokale myndigheder/forsyninger
- Kontrakt på etablering udarbejdes
- Vejadgang til site etableres

1.2.5 Samarbejde med lokal rådgiver aftales

- Området screenes for mulige samarbejdspartnere
- Interviews og udvælgelse af samarbejdspartner(e) og afgrænsning af samarbejdets indhold og udstrækning
- Kontrakt forhandles og indgås

1.3 Bygningslayout/projekt

1.3.1 ALECTIA's industrielle designere udarbejder layout – arkitekttegninger og beskrivelser

- ALECTIA optimerer det foreliggende layout fra Aikan
- Udarbejdelse af arkitekttegninger og beskrivelser frem til detailprojekt-niveau
- Fokus på optimering og forenkling af konstruktioner
- Udarbejdelse af foreløbig beskrivelse, som kan justeres efter layout og landets materialetradition

1.3.2 Arkitekt og ingeniør layout tegnes sammen

- Layout fra ALECTIA tegnes sammen med proces layout
- Udførelse af kvalitetssikring
- Indarbejdelse af justeringer
- Fælles optimering og forenkling

1.3.3 Hovedprojekt fra arkitekt og ingeniør samt hovedprojekt vedr. proces

Hovedprojekt - det detaljerede projekt udarbejdes.

Hovedprojektet udarbejdes i en større detaljegrad end normalt, da alle spørgsmål i princippet skal være løst i projekteringen. Der kombineres mellem de 3 fag – arkitekt, konstruktionsfag og proces.

Ved fælles indsats fra rådgivergruppen skal grænseflader defineres med følgende entrepriseskel:

- Jordarbejder, stik, kloak, belægning og ekstra fundering
- Betonarbejder
- Stål og lukning
- Indvendig finish tømrer/snedker/maler
- El i bygning
- El i produktion
- Procesudstyr
- Landskab

1.3.4 Arbejdsmiljøhensyn

- Sikre at anlæg og arbejdsgange lever op til relevante love om arbejds-miljø

- Sikre optimale biologiske, fysiske, kemiske og ergonomiske forhold

1.3.5 Udbudsmateriale

Udarbejdelse af udbudsmateriale med tilbudslister, tidsplaner, beskrivelser, sikkerhed og sundhed i byggefasen, Fællesbetingelser, Arbejds- og Bygningsdelsbeskrivelser.

1.3.6 Udarbejde budget

På basis af hovedprojektet udarbejdes budget, som tager udgangspunkt i danske priser, der så justeres til lokale priser for det pågældende land.

1.4 Forhandling/tender og kontrakt

1.4.1 Udvælgelse af lokale entreprenører

Invitation af områdets lokale entreprenører (fagentreprenører) med henblik på indledende udvælgelse af 5-8 firmaer inden for hvert fag. 3-5 firmaer pr. fag udvælges endeligt til afgivelse af tender.

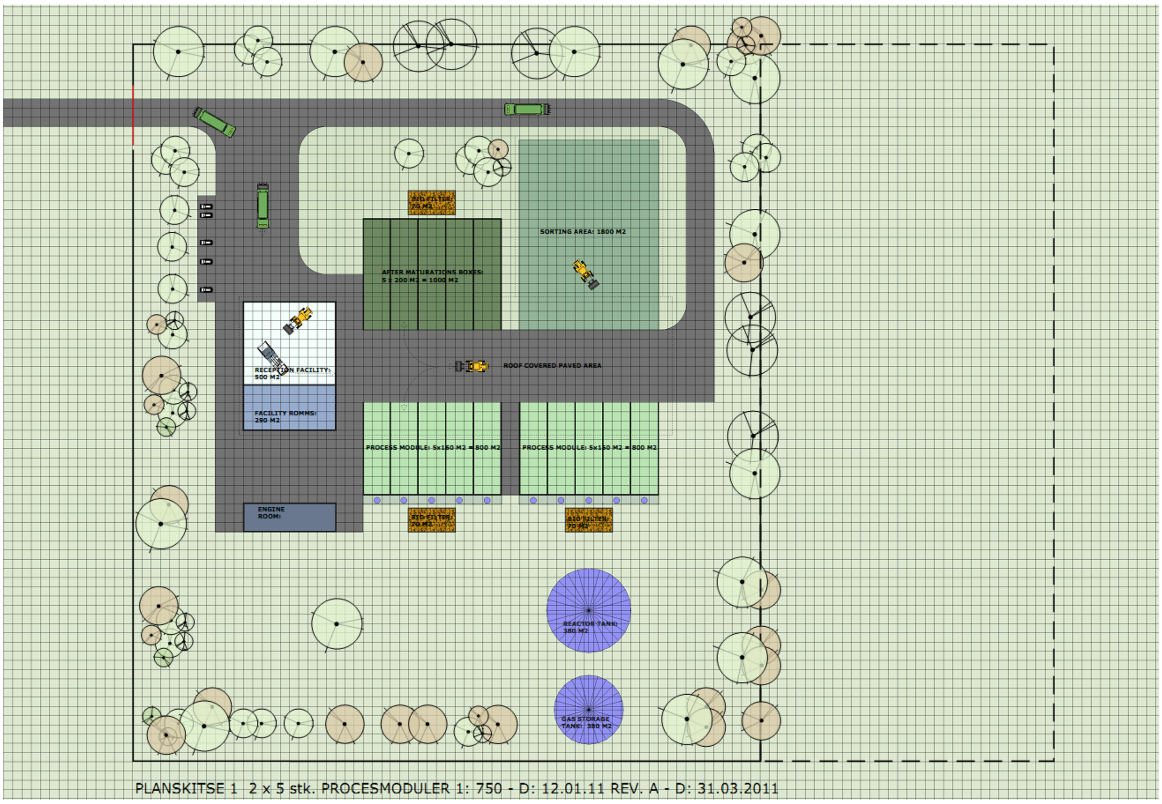
Udvælgelsen af entreprenørerne omfatter bl.a.

- Besøg hos mulige entreprenører
- Interview af mulige entreprenører
- Besigtige referencebyggerier
- Tale med tidligere bygherrer
- Analyse af entreprenørers regnskaber
- Projektgennemgang med fokus på entreprenørernes forudsætninger for at byde
- Gennemgang af FIDIC kontraktbetingelser

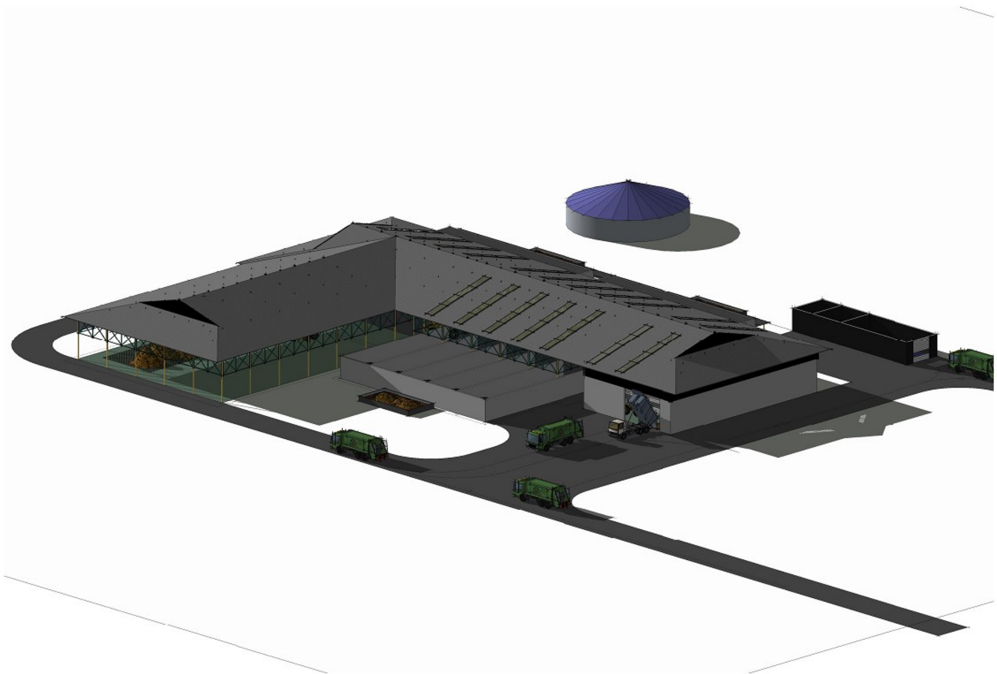
Hvis Solum Gruppen har eksisterende kontakter, vil disse blive screenet på samme måde.

1.4.2 Udsende tender

- Udarbejde dokumenter til brug for tender
- Fremsende til tender materiale til entreprenørerne
- Indsamle spørgsmål og svare på disse
- Eventuelt foretage vurdering, om dele skal udtages som bygherreleverancer
- Gennemgå tender materiale med entreprenører


BIO FILTER:
70 M2
SORTING AREA: 1800 M2
AFTER MATURATIONS BOXES:
5 x 200 M2 = 1000 M2
RECEPTION FACILITY:
500 M2
ROOF COVERED PAVED AREA
FACILITY ROMMS:
290 M2
PROCESS MODULE: 5x160 M2 = 800 M2
PROCESS MODULE: 5x160 M2 = 800 M2
ENGINE
ROOM:
BIO FILTER:
70 M2
BIO FILTER:
70 M2
REACTOR TANK:
380 M2
GAS STORAGE
TANK: 380 M2
PLANSKITSE 1 2 x 5 stk. PROCESMODULER 1: 750 - D: 12.01.11 REV. A - D: 31.03.2011

ALECTIA



App. 3.2. Determine windows of operation as regards energy output – potentials and cost