ORGANIC WASTE MANAGEMENT BY A SMALL-SCALE INNOVATIVE AUTOMATED SYSTEM OF ANAEROBIC DIGESTION

USER GUIDELINES

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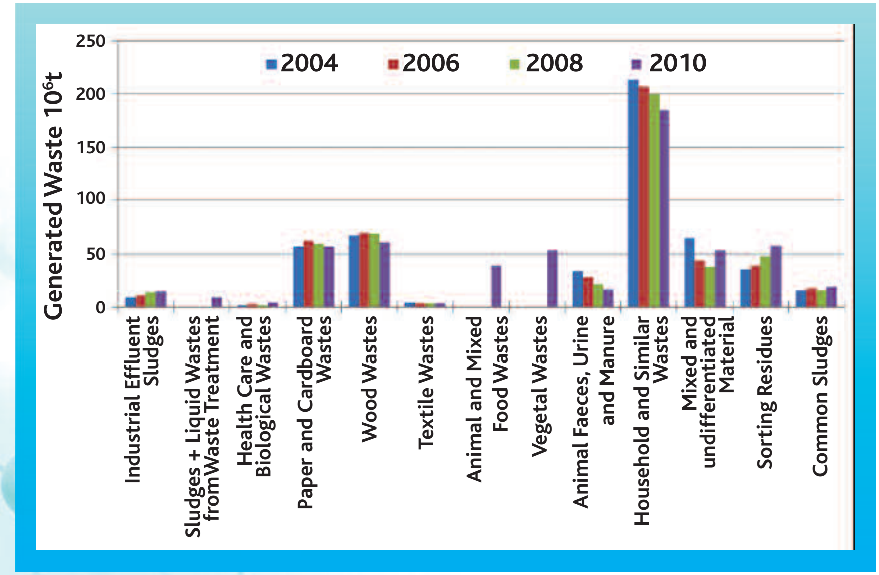
OVERVIEW

Millions of tonnes of organic waste are produced by agro-food industries every year. Figures based on EUROSTAT data from 2006 (the most recent figures at time of printing) estimates approximately 89Mt of food waste is produced annually and includes manufacturing and household sectors. At present there are anaerobic digestion (AD) systems in place for large enterprises producing 5,000 – 50,000 tonnes of organic waste per year. For small-to medium-enterprises (SMES) that may only produce 100 – 3,000 tonnes annually, the only solution for organic waste treatment is incineration or landfill. These treatments are both costly and harmful to the environment. The development of an innovative anaerobic digestion system for smaller quantities means that SMEs will be able to manage their own organic waste.

AD equipment consists of a waste conditioning system, a thermo-regulated digestion tank, a gas holder to store the biogas and a gas burning engine/generator set if electricity is to be produced. The organic waste is broken down in the tank and 40-90% of the waste is converted into biogas. Apart from biogas the process also produces a digestate which may be separated into liquid and solid components. The liquid element can be used as a fertilizer and the solid component may be used as a soil conditioner or further processed to produce higher value organic compost. ORION focused on several agro-food industries including biomass, agro-food (fisheries, vegetable oil producers, dairy and beef) and markets.

WASTE GENERATION BY SOURCE



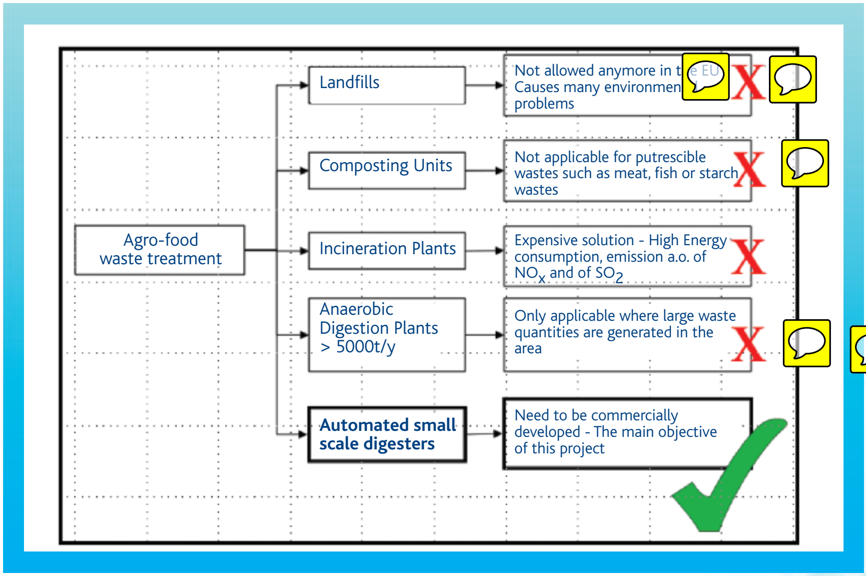
European Biomass Industry Association

EU POLICY ENVIRONMENT

Landfill Directive (1999/31/EC)

- Landfill diversion targets for biodegradable waste, compared to 1995: **35% by 2016 (for s countries by 2020)**
- Municipal waste: **50% minimum recycling by 2020**
- Member States shall take measures to encourage (art. 22):
  - separate collection of bio-waste with a view to the composting and digestion;
  - use of environmentally safe materials produced from bio-waste;
  - environmental friendly treatment of bio-waste

TREATMENT OPTIONS



ANAEROBIC DIGESTION

- Anaerobic digestion is a multi step process (including hydrolysis, acidogenic, acetogenic and methanogenic phases) by which different bacteria and archaea can break down a biodegradable substrate in the absence of oxygen.

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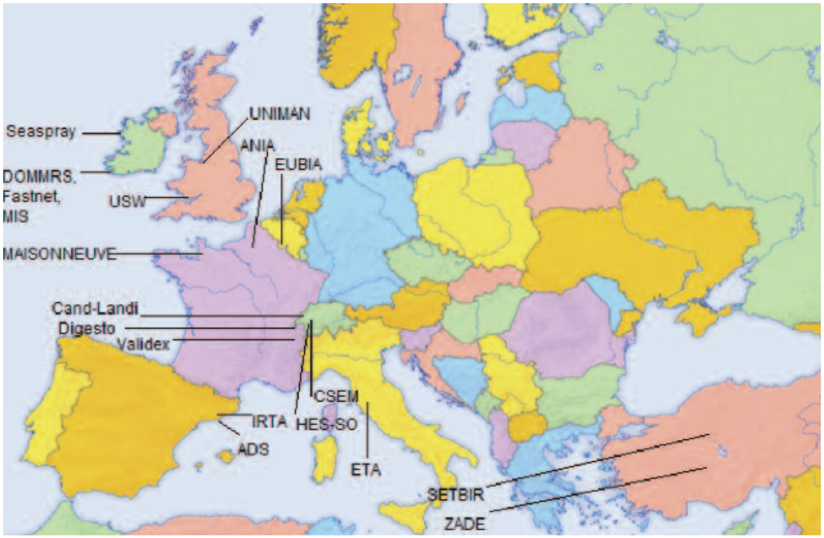
- This process produces:
  - A **"biogas"** which can be used as fuel thanks to its high methane content (60 to 80%). This biogas also includes carbon dioxide and traces of hydrogen sulphide, ammonia, water vapour, other organic volatiles and nitrogen gas;
  - A nutrient-rich **digestate** which can be used as fertilizer.

- It occurs in multiple environments including digestive systems, marshes, rubbish dumps, septic tanks etc. Humans have managed to transfer the activity occurring in the environment to engineered sealed controlled vessels of various designs called digesters.

OBJECTIVES

1. Developing AD machines at the SME scale that will combine effectiveness for a wide range of organic wastes and reduced capital and operating costs;
2. Developing advanced control tools and sensors to reach an optimum reliability;
3. Increasing know-how on the impact of nanostructured surfaces on bacterial growth and increase waste throughput in the digester;
4. Developing a training strategy in order to address a vast community of SMEs and offer them a personalised service;
5. To contribute to the implementation of EU policies on waste management and renewable energies production.

PROJECT PARTNERS



WORK PROGRAMME

WORKING PACKAGE NUMBER	TITLE
1	Technological evaluation of SME needs to manage their organic waste
2	Digestion module development/test
3	Combustion module development/test
4	Supervision and control module development/test
5	Active surfaces for bacterial control
6	Integration
7	Validation tests
8	Validation and pre-normalisation activities, economic and environmental risk assessment
9	Dissemination, training and exploitation
10	Project management

WASTE MATERIALS - ORION SOLUTION – FEEDING

SUITABLE INPUTS / ORGANIC WASTE FROM:	WASTES – EXAMPLES	
Agri-food	Cheese whey	297 NLCH4/kgVS
Aquaculture	Salmon waste	408-525 NLCH4/kgVS
	Seaweed	149 NLCH4/kgVS
HORECA	Restaurant waste	560 NLCH4/kgVS
	Food & vegetable	399 NLCH4/kgVS

Orion can process 25–250 kg/day of dry matter, corresponding more or less to 80 – 1000 kg/day of fresh waste (depending on digester dimension, composition and water content of the waste).

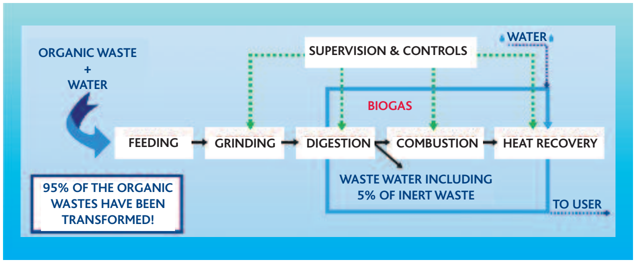
Waste streams≤ 5,000 t/y.

The composition and characteristics of biogas are highly dependent on the different organic waste sources(produced quantities, physico-chemical and biochemical parameters). Co-substrate may be necessary in order to optimize theAD process.

The control tools maximize the stability of the digester.

THE ORION SOLUTION

- Local treatment and valorisation on-site in a compact and isolated unit;
- Reduction of working hours and financial savings for the end-user;
- The development of a digester with a volume of 3m³;
- Organic load: 80-1000 kg/day ofhumid waste;
- Daily energy production of 1.5–7.5 Nm³ biogas/m³;
- Production of biogas containing 50-65 % methane;
- On-site direct use of biomethane or combined production of heat/power (hot water/electricity).

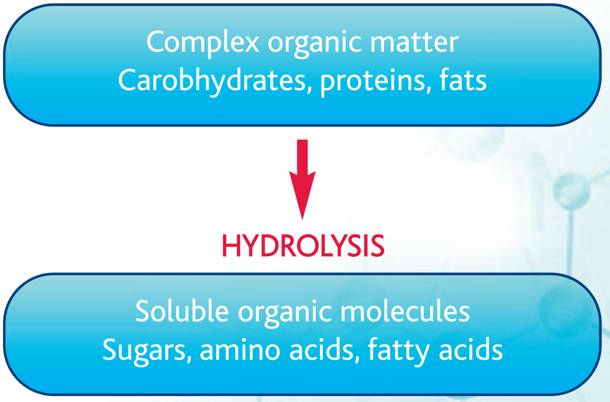


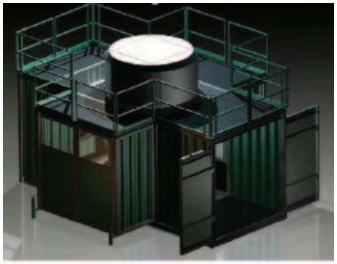
An overview of the components of the ORION solution.

THE DIGESTER

HYDROLYSIS

- The incoming substrate is built of carbohydrates, proteins and fats which are not water-soluble.
- These undissolved compounds are broken down into water-soluble fragments (monomers) by exoenzymes produced by bacteria.
- A large group of bacteria is needed for this process.
- The products of this stage are some simple sugars, fatty acids and amino acids





Deployed maritime ISO-20" container, used as a fully integrated digestion station at the end-user site.

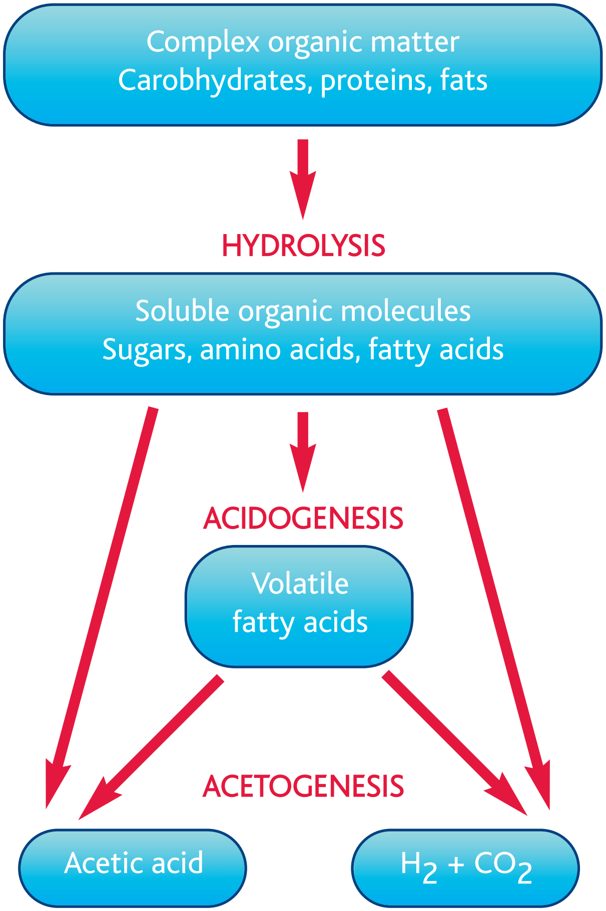
ANAEROBIC DIGESTION – STEP 2, 3

ACIDOGENESIS (ACID FORMATION)

- The monomers that were the products of the hydrolytic phase are taken up by the bacteria and further degraded into short-chain organic acids, alcohols, hydrogen and carbon dioxide.

ACETOGENESIS (ACETATE FORMATION)

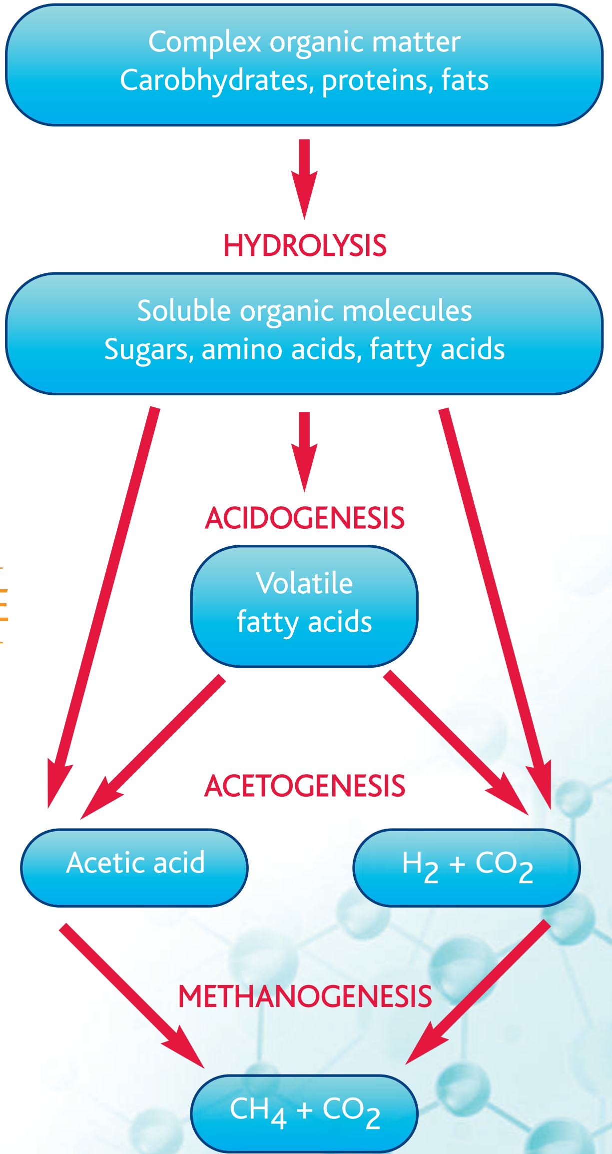
- These simpler molecules are utilised by "acetogenic" bacteria to produce acetic acid, with carbon dioxide as another product of the breakdown.
- The product of the acetogenic phase is acetate. Acetate is important because it is the primary substrate used by methanogenic bacteria.



ANAEROBIC DIGESTION – STEP 4

METHANOGENIC PHASE (METHANE FORMATION)

- A group of archaea(bacteria)is responsible for the methanogenic phase.
- These "methanogen" bacteriaare then able to use the acetic acid and produce methane.
- There is also another group of methanogens that convert hydrogen and carbon dioxide to methane. In this step the archaea methanogens form methane using mostly acetate, CO_2 and H_2.
- Methane can also be formed from some other organic compounds but all compounds that are not degraded by the methanogens will accumulate in the digester.



ANAEROBIC DIGESTION-TEMPERATURE

- There are also some bacteria that compete with the productive bacteria. One kind of such bacteria are sulphate-reducing bacteria that also use acetate, hydrogen and carbon dioxide (like the methanogens) but instead produce hydrogen sulphide. There are different temperatures that are optimal for different species and there are also some substances that are toxic/inhibitory for some species.
- The two conventional operational temperature levels for anaerobic digesters determine the species of methanogens in the digesters:
  - Mesophilic digestion takes place optimally around 30 to 38 °C, or at ambient temperatures between 20 and 45 °C, where mesophiles are the primary microorganism present.
  - Thermophilic digestion takes place optimally around 49 to 57 °C, or at elevated temperatures up to 70 °C, where thermophiles are the primary microorganisms present.

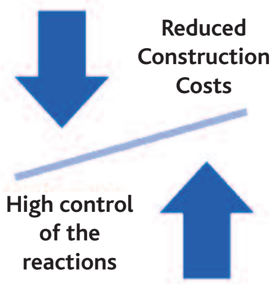
ANAEROBIC DIGESTION - COMPLEXITY

Single-stage digestion system (one-stage): all of the biological reactions occur within a single, sealed reactor or holding tank.

The biological reactions of the different species in a single-stage reactor can be in direct competition with each other!!

Two-stage digestion system (multistage): different digestion vessels are optimised to bring maximum control over the bacterial communities living within the digesters.

COMPETING NEEDS:



DIGESTION MODULE – GRINDING

- The user puts the organic matter in the feeding hopper of the grinder and presses the "grinding" button.
- Besides this operation the user manually triggers the grinding process.
- A grinding cycle can be started as soon as the feeding hopper is full (daily, twice a day).
- When functioning, the door of the grinder is blocked. In case of problem with the grinding (unwanted materials, mechanical problem, etc.), an alarm will warn the user/maintenance operator and stop the system to prevent further damage.
- The grinder reduces the organic matter to be digested into small particles (2-3 mm) and mixes it in order to facilitate the breakdown of the biodegradable substrate by microorganisms.
- The PLC (programmable logic controller) controls the moment to pump it to the jabot of the digestion module.
- An automatic periodic self-cleaning cycle is foreseen.
- The grinding unit can be located in the container (door towards the outside) or directly adjacent to where the waste is produced (i.e. kitchen). This second solution is the most convenient for the end-user but requires pipework to transport the ground material to the digestion module.

DIGESTION MODULE – COMPONENTS

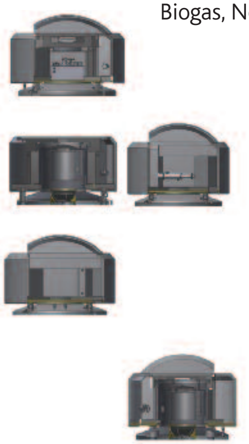
- Total digester volumes: between **3 and 30 m^3**
- The digestion module consists of a methanation tank, fitted with a central jabot and topped by a rotating, floating gasholder linked to the agitation system.

The head collects the biogas produced in a gasholder and contains operation and measurement equipment.
The body is where the biological process of biomethanation occurs.

Digesto concept (Patent demand PCT/IB2013/056263)

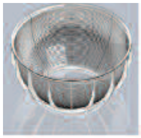
DIGESTION MODULE – HEAD

4 lateral covers of the head where connected devices can be placed.
The lateral compartments are dedicated to 4 sub-systems: Hydraulic, Biomass, Biogas, Nose & Tongue.



Central cover of the head
housing a mobile, floating and rotating gasholder, linked with the agitation system, responsible for collecting the biogas produced and connected to the gas utilization unit (peripheral). The central compartment gives access to: Tank, Mixing system of the tank, Jabot, Gasometer

DIGESTION MODULE - BODY

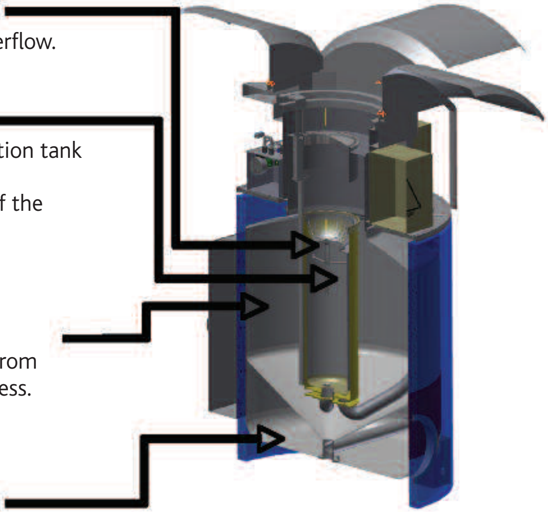


SIEVING GRID
- Filters the overflow.

JABOT
- Feeds the methanation tank regularly.
- Initiates first step of the digestion.

METHANATION TANK
- Biogas production from methanogenic process.

HOT WATER BATH



DIGESTION MODULE - FUNCTIONING

- The jabot receives the matter to be digested from the grinder and releases it into the methanation tank at short, regular intervals (which may be regulated, e.g. 10 – 30 min). It may also initiate the first steps of the digestion process.
- The sheath surrounding the jabot can collect the outflow of the liquid fraction of the digestate through the sieving grid before draining.
- The methanation tank, surrounding the jabot, is where the biological methanogenic process leading to biogas production occurs (infinitely stirred process with suspended biomass).
- The sieving grid filters the overflow from the methanogenic tank and retains particles of insoluble matter which cannot pass through the grid, thus allowing them to fall back to the jabot and returning to the beginning of the digestion process. The liquid fraction of the over flow going through the sieving grid is the liquid effluent, which is eliminated.
- The digester is heated and continuously kept at a constant temperature to ensure an optimal biomethanation process. It can be programmed for mesophilic or thermophilic process.

DIGESTION MODULE – CIRCULATION AND MIXING

- The circulation and mixing system is entirely internal to the digestion module.
- It is operated by a 4-way distributor coupled with a bi-directional volumetric pump, controlled by the PLC.
- The hydraulic system is responsible for substrate and co-substrate (optional) distribution and mixing.

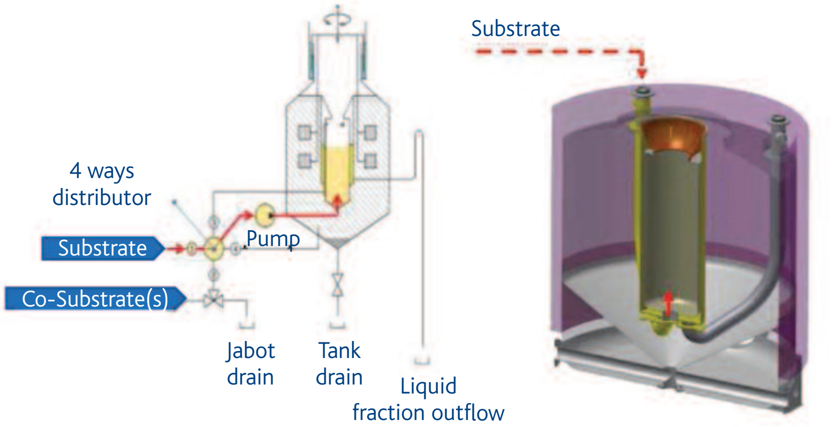
Mixing of the methanation tank content can be achieved by:

- Mechanical agitation (using ad justable rotary blades)
- Biogas re-circulation (through bubbling plate)
- Substrate re-circulation.

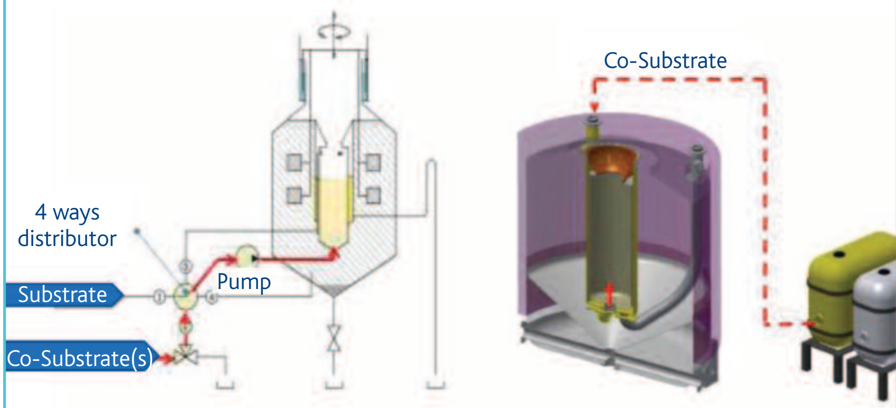
Mixing of the jabot content can be achieved by:

- Substrate re-circulation
- Biogas re-circulation (optional).

The 4-ways distributor defines a 4-position switch, corresponding to:
Position 1: Substrate loading from the grinder (or buffer tank) into the jabot

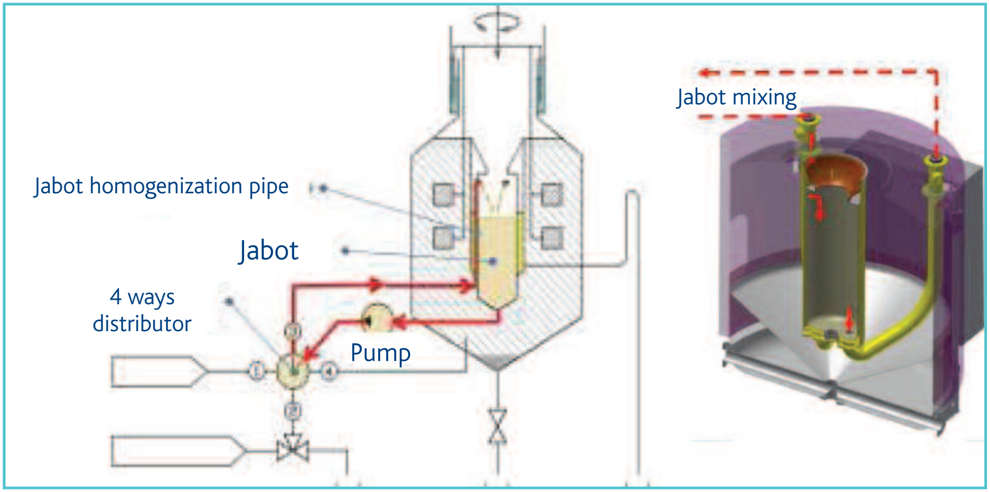


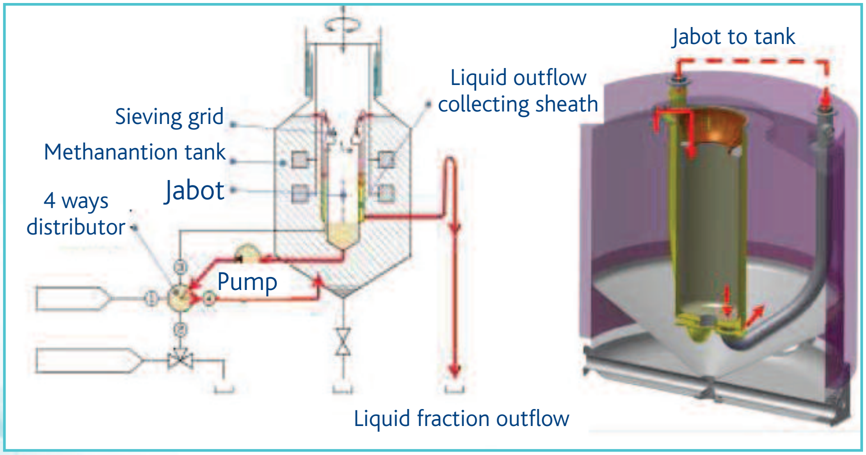
The 4-ways distributor defines a 4-position switch, corresponding to:
Position 2: co- substrate loading (optional) to the jabot



DIGESTION MODULE – CLEANING AND DRAINING

Different parts of the digestion module need to be regularly cleaned to ensure optimal function.
The self-cleaning device for the grinder uses hot water to clean the grinder after each grinding cycle. If necessary, soapy water can also be used, but in that case the effluent is sent to sewage.
The self-cleaning device for the sieving grid ensures that the grid does not get blocked as its role is to filter the methanation tank overflow into the jabot.
The sieving grid can also be easily changed when necessary.
The self-cleaning device for the gasholder is an access to ensure that the device can be easily cleaned if necessary.





DIGESTION MODULE – CLEANING AND DRAINING

When necessary, floating or sedimented materials that cannot be digested can be removed from the digestion module.
Floating inert materials accumulated in the methanation tank can be removed to the jabot by overflow. If these materials are not degraded and accumulate in the biological system, they can be pumped out the jabot through the 4-way distributor in position 2.
Inert and heavy materials (e.g. sand) sedimented in the bottom of the methanation tank are drained out through a drain (to sewage). The same path can be used to empty the whole methanation tank if necessary (e.g. if there is a process failure).

DIGESTION MODULE – CONNECTING NETWORKS

The connecting networks requirements are:
Electricity
Power requirement:
1 plug CEE, 400 V, 32 A.
Water
Water supply: connection to tap water.
Sewage connection: for digested liquid fraction going through the sieving grid.
Solids extraction: 1 tank > 3m^3 (also to empty the digester if needed).
Gas
Internet
Internet connection with a good bandwidth.
Through a delivered Internet switch, different components will be connected:
A PC with the development tool (giving access to the low level panels).
The PLC
A webcam

The digestion module is conceived as a machine that includes all connections to
devices necessary to its functioning, apart from some peripheral devices (grinding unit, combustion module, buffer tanks).

DIGESTION MODULE – INNOVATIVE ASPECTS

- The ORION process combines advantages of one-phase and of two-phase digesters, both vessels working under a common gas phase.
- Uncoupled solid and liquid retention times made possible by the use of an internal "jabot" and sieve.
- Intelligent selection of surface materials to promote or to inhibit biofilm growth.
- The microorganisms in the methanation tank combine H_2 (eventually produced in the jabot in significant amounts) with CO_2 to synthesize methane. In this way H_2 concentration is kept very low, avoiding explosion risks and losses.
- Liquid and gas phase sensors of conventional parameters including H_2 and Volatile Fatty Acids.

DIGESTION MODULE – PERFORMANCE

Conventional indicators of anaerobic digestion performance

Indicator	Units	Remark
Organic loading rate	Kg VS or COD.m^{-3} digester.day^{-1}	Determines tank volume
Hydraulic retention time	Days	Determines tank volume
Biogas yield	m3 Biogas.kg^{-1} VS or COD loaded	Effectiveness of the digester configuration and of the bacteria
Volumetric productivity	m3 biogas.m-3 digester.day^{-1}	Used to compare to other digesters
Methane content of biogas	% volume	Depends on substrate, digester configuration and microbiology
Volatile solids removal	% of loaded volatile solids	Effectiveness in removal of the biodegradable fraction of wastes
COD removal	% of loaded COD	Effectiveness in removal of the biodegradable fraction of wastes

Possible performance indicators from the end user's point of view

Indicator	Units	Remark
Waste treatment capacity	kg wet wastes.m^{-3} digester.day^{-1}	Including washing water
Space requirements	m2 floor space.kg^{-1} wet waste.day^{-1}	The grinder and the digester can be placed in separate locations
Availability	% of business hours with unrestricted use	The user must be able to eliminate wastes at any time during business hours
Methane yield	m3 CH4.kg^{-1} wet waste loaded	Needed to estimate the energy production
Thermal energy production	kW thermal power	Heat available to the user after satisfying the digester's requirements
Effluent total solids	g.l^{-1}	To be compared to local discharge limits
Effluent COD	g.l^{-1}	To be compared to local discharge limits
Effluent NH4+	mg.l^{-1}	To be compared to local discharge limits
Effluent PO43-	mg.l^{-1}	To be compared to local discharge limits
Effluent flow rate	l.day^{-1}	Needed to determine wastewater discharge fees
Gaseous emissions	ppm SO^2, ppm CO	To be compared to local emissions limits

DIGESTION MODULE – RESULTS

Results from bench-scale and pilot testing of restaurant wastes

Indicator	Units	Bench-scale (20 liters)	Pilot-scale (650 liters)
Organic loading rate	kg $VS.m^{-3}$ $digester.day^{-1}$	Up to 5,5 kg VS	1,3 to 3 kg VS
Hydraulic retention time	Days	17.5 to 30	20 to 38
Biogas yield	m3 $biogas.kg^{-1}$ VS loaded	0.5 to 1.3	0.6 to 1
Volumetric productivity	m3 $biogas.m^{-3}$ $digester.day^{-1}$	1 to 7	0.8 to 2.2
Methane content of biogas	% volume	52 to 72%	50 to 64%
Volatile solids removal	% of loaded volatile solids	Up to 75%	92%

Results from bench-scale and pilot testing of restaurant wastes

Indicator	Units	Bench-scale (20 liters)	Pilot-scale (650 liters)
Waste treatment capacity	kg wet $wastes.m^{-3}$ $digester.day^{-1}$	75	50
Space requirements	m2 floor space.100 kg^{-1} wet $waste.day^{-1}$	n.a.	5.2
Availability	% of business hours with unrestricted use	n.a.	90
Methane yield	m3 $CH4.kg^{-1}$ wet waste loaded	0.5	0.5
Thermal energy production	Watts thermal power equivalent	12	200
Effluent total solids	$g.l^{-1}$	30-100	3 to 12
Effluent COD	$g.l^{-1}$	Not measured	5 to 20
Effluent NH4+	$mg.l^{-1}$	800 to 2000	350 to 2200
Effluent PO43-	$mg.l^{-1}$	Not measured	Not measured
Effluent flow rate	$l.day^{-1}$	Up to 2	up to 30
Gaseous emissions	ppm SO2, ppm CO	Not measured	Not measured
Solid emissions	kg wet inorganics (sand) every 2 weeks	Not Measured	2

COMPLETE DESIGN - COMBUSTION MODULE

Taking into account the requirements of this project and a variety of biogas utilisation solutions, it is clear that the most cost effective solution would be one which involves making acceptable modification to an existing off-the-shelf boiler which should also reduce the cost of certification/approval for safe use down to an absolute minimum. Therefore the proposed design consists of a combination of a 12 kW natural gas boiler (for start up, providing top up heat during winter etc.), a 6 kW (approx.) thermal output modified natural gas boiler to burn biogas of a specified quality (approximately 60/40% volume of CH_4/ CO_2) and a small flare (for H&S and environmental reasons to reduce methane emissions in cases where low quality transient or intermittent biogas is produced). The design is to suit the 3 m3 demand unit. The system has been tested by using the simulated biogas, and the initial test results provide positive prospects down to CH_4/CO_2 mix of 55/45% by volume. The complete prototype system cost about €25,000 (at least 50% less than other solutions) and the unit cost will be reduced significantly if there is mass production of the unit.

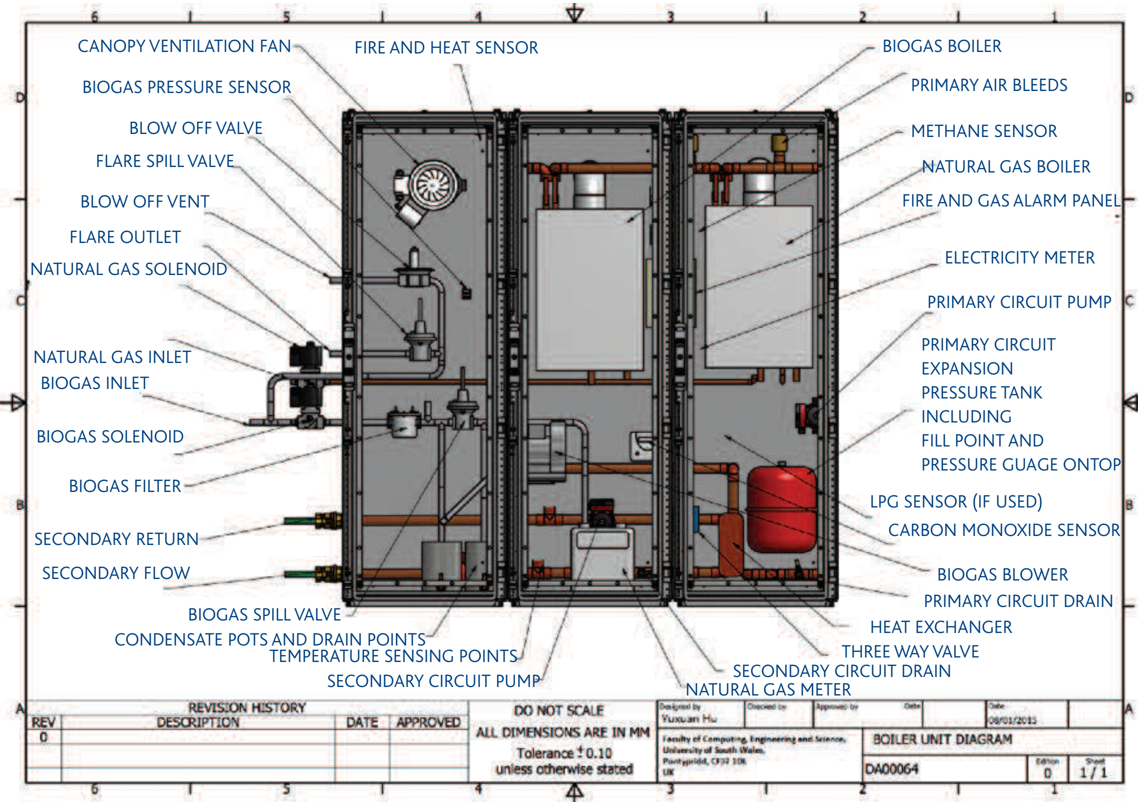
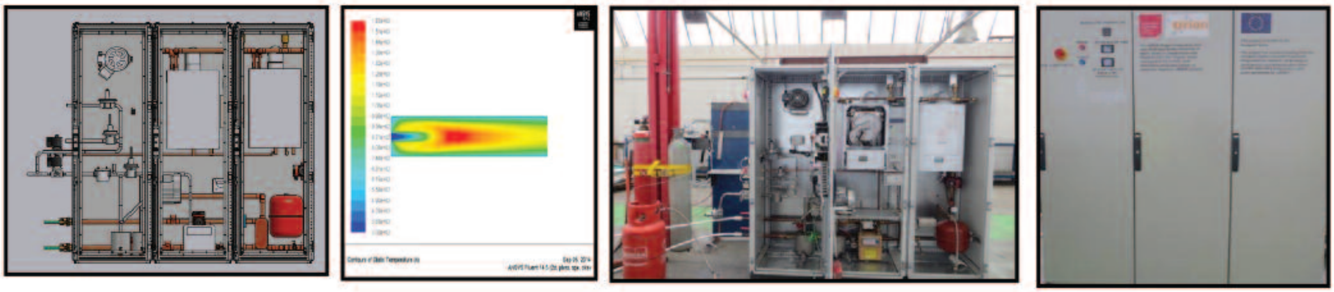


Figure: The system layout, inside story and main components

MICRO AND SMALL SCALE BIOGAS COMBUSTION SYSTEM

- ✔ Small scale biogas combustion module for heat delivery
- ✔ Fully automated with safety shut down via PLC
- ✔ Successfully burns biogas with methane content of 55% and above
- ✔ Integrates a conventional domestic boiler for start-up or reduced biogas production
- ✔ Comes with a flare for coping with low quality biogas and reduce methane emissions
- ✔ Automatic recording of process parameters



Development of a 6 kW biogas combustion

AUTOMATION MODULE

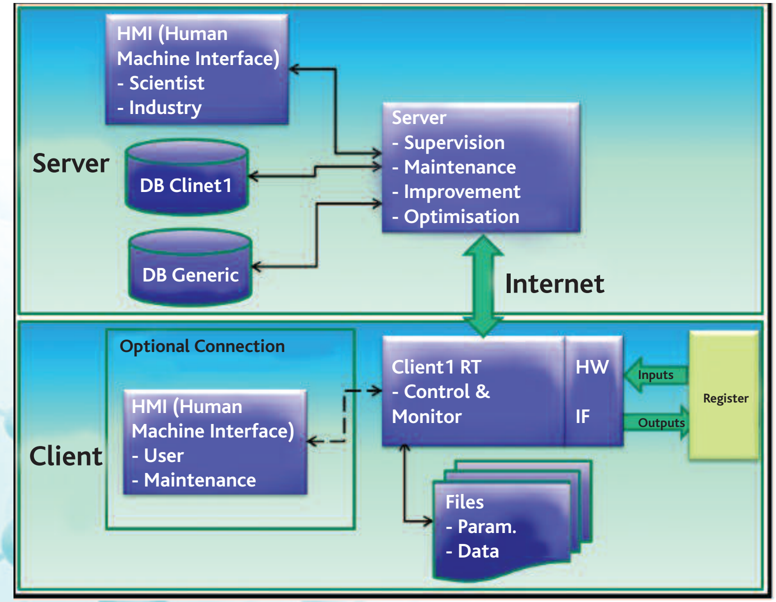
Simple for the user and sophisticated for the supervision, configuration and maintenance, the software controlling the ORION digesters are divided into 2 parts:

1. THE "CLIENT"

This program controls each digester as a standalone system and runs on an industrial PLC. It is responsible for the regulation of the digester. It continuously acquires the data of all sensors (temperatures, positions, liquids, gases, etc.) and regulates the digester depending on the values of these sensors. At a defined interval, the client sends all data to the server.

2. THE "SERVER"

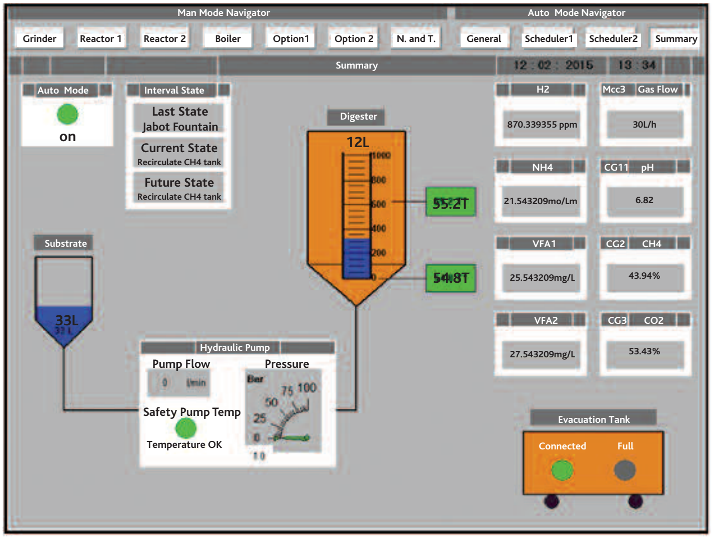
This program monitors and centralises the data from all the clients. It is a web application and runs on a Linux PC server. The received data are stored in a database and a User Interface (UI) allows scientists and maintenance people to visualise the data from each digester. The server is also able to detect values out of limits and report warnings.



Chemical sensors are used to monitor and control the operation of the digester. Gas sensors measure the composition of gas emitted from the digester. Liquid sensors are used to measure the composition of the effluent from the digester. These chemical sensors are located in a sophisticated sub-system called "smart nose + tongue". This sub-system communicates its data with the client through Ethernet.

The temperature of the digester is provided by two systems: an electric mantle and a combustion biogas sub-system. The client is also responsible for managing these systems.

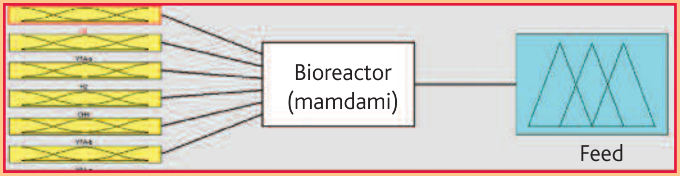
A connection with a terminal (notebook, notepad, etc. or internet remote control) allows technicians to perform maintenance and commissioning of each digester. A typical panel of this mode is:



The server has one internet connection allowing the exchange of data with all the digesters and to provide an interface to the world (biologists, technician, etc.).

FUZZY LOGIC CONTROLLER FOR AD SYSTEMS

- ✔ Automated control system for digester optimisation
- ✔ Controller based on multiple inputs and control conditions
- ✔ Inputs may include total or speciated volatile fatty acids, ammonia and other cations, solid content, hydrogen partial pressure, methane content and pH
- ✔ Control actions may be organic and hydraulic feedstock rate and alkalinity adjustments, co-substrate and trace element additions and ammonia removal
- ✔ Within the given operational limits, able to cope with non-linear plant behaviour using en capsulated operator knowledge
- ✔ A good degree of tolerance to sensor failure
- ✔ Tested under varied conditions using the ADM1



ELECTRONIC NOSE AND TONGUE GUIDELINES FOR USERS

The electronic nose and tongue (N&T) is the ORION AD subsystem that is in charge of measuring a number of the physical-chemical features of the digestion effluent, and of the biogas produced. Based on its outputs, the low level control system of the digester acts to maintain an optimal feeding rate and to maximise the efficiency of the digestion process.

The core of the N&T is built around three different sets of sensors. A first set of ion selective electrodes monitors the concentration of different ions in the digester effluent (ammonium, sodium, potassium and calcium), as well as the pH and ORP. A second set of gas sensors detects the composition of the produced biogas and provides the concentration of carbon dioxide, methane, hydrogen and hydrogen sulphide at user defined intervals. Finally, an innovative set of conductive polymer sensors responds to the content of volatile fatty acids in the digester effluent. Instead of pursuing classical titrimetric and gas chromatographic methods to detect the levels of volatile fatty acids, the N&T utilises a completely different and original approach. It samples a small aliquot of effluent and the volatile fatty acids dissociated in the effluent are transformed into their unionised form. In this way, they became volatile and they are transferred in the vapour phase. The conductive polymer sensor array senses this vapour and a calculation is done giving the amount of fatty acids in solution.

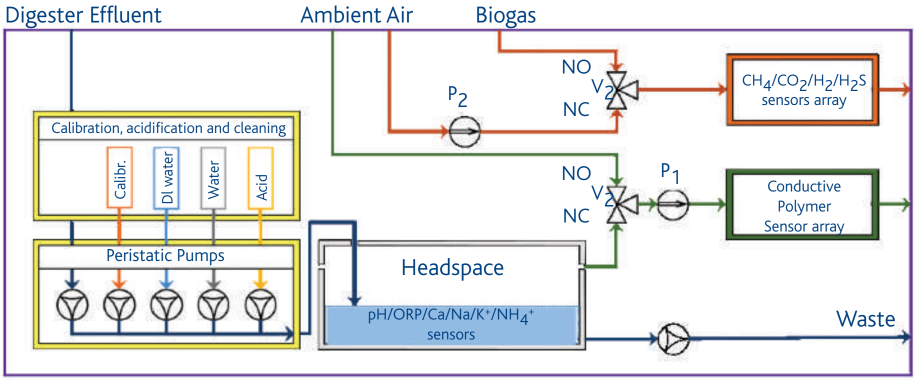
The following table summarises the analytes and the ranges of concentrations that the system can sense.

Biogas element				Effluent elements							
	Min.	Max.	Unit		Min.	Max.	Unit		Min.	Max.	Unit
CH_4	0	100	%	pH	0	14		K^+	10	10000	mg/L
CO_2	0	100	%	ORP	-2000	+2000	mV	NH_4^+	10	10000	mg/L
H_2	0	2000	ppm	Na^+	10	10000	mg/L	CH_3COOH	0	>5000	mg/L
H_2S	0	2000	ppm	Ca^{2+}	10	10000	mg/L	CH_3CH_2COOH	0	>1000	mg/L

The low level control system is responsible for starting a measurement cycle from the N&T subsystem without any intervention by the end user. The low level control system can independently start a measurement of the liquid effluent or of the biogas produced. The frequency of the measurements can be increased or decreased to better follow the needs of the algorithms that monitor the development of any faulty conditions in the AD integrated machine. The measurements of the N&T can be as frequent as every 2 hours for biogas analysis, and 4 times per day for the VFA and ionic concentration analysis.

The N&T subsystem operates utilising a few consumable chemical solutions. These consumables are needed in particular to automatically recalibrate the ion selective electrodes from time to time, to maintain a standard degree of accuracy of the sensors during their expected lifetime. This recalibration is started by the low level control system, without any intervention by the end user. The expected frequency of the recalibration is once every one or two weeks. Also, some of the consumables are used during the measurement of the effluent to increase the volatility of the volatile fatty acids. In the first prototype of the ORION AD integrated machine the amount of the consumables held in the reservoirs is enough to carry out around 100 measurements and 50 recalibrations. Nonetheless, the ORION AD integrated machine is designed to be able to accommodate much larger quantities of these consumables. Also, the sets of sensor arrays used in the N&T are to be considered as consumables as well. Their expected lifetime is at least one year of standard operation of the ORION AD integrated machine.

A simplified sketch of the N&T subsystem is depicted in the figure below.



The user would need to replace calibrant solutions on a yearly basis and acid solutions at 6 monthly intervals. Electrodes should be replaced on a yearly basis. The distilled water filter should be replaced every two years.

ACTIVE SURFACES

In the Orion system, some critical parts could suffer from biofilm formation. The critical parts are the sieving grid, some parts of the inside of the digester chamber and the sensors. These surfaces must be kept without the formation of biofilm. On the other side, it is interesting to have in the digester itself surfaces that will favor the growth of biofilms and methanogen archaea. Therefore active surfaces either to avoid or to promote the growth of biofilm can affect the behavior and the yield of the system.

The surfaces are made active either using a coating, (nano)structuration or both. Several commercial coatings were tested and gave interesting results to prevent biofilm formation. Hydrophilic brushless from SuSos, hydrophobic surface (Teflon based coating) and topographic surface (Sharklet from TactivexTM) have been tested. For the digester operation, the sieving grid was treated with Teflon like coating (Spray coating: Dry Lube-F from CRC).

For the improvement of the biofilm growth studies shows that nanostructures affect the attachment of cells on the surfaces. Different types of structured surfaces were tested in situ and the effect on the attachment of methanogenic archaea was observed. Current study on monophasic and biphasic small reactors does not show an improvement of the attachment of methanogenic archaea on the nanostructured surfaces. Therefore no recommendation can be given before a new experimental study shows evidence of the effect of nanostructured surfaces either on the attachment of the archaea, or on the digester methane production yield.

CASE STUDY: FASTNET MUSSELS LTD

The company was established in 1984, initially concentrating on growing and selling fresh mussels for export, by 1989 production had reached 150 tonnes. In 1990 the company built a depuration and holding facility which enabled Fastnet to process their harvested mussels and consequently increase margins and profitability. In 1996, having patented a process for the production of individual quick frozen (IQF) mussels, work commenced on a new state of the art 4,000m² facility which was approved by the Department of the Marine (EU Directive 91/492) and is HACCP and BRC approved. Currently the company farms 250 tonnes and processes 1400 tonnes of mussels (annual turnover €3.5 million) and employs 33 people. However, they have the capacity to farm 500 tonnes and process 2,000 tonnes. Since then through successful R&D the company has diversified into the production of value added products; pasteurised mussels in sauces (white wine, garlic butter), cooked crab claws, lobster tails, oysters and periwinkles. They have also worked on a number of nationally and EU funded research projects including an investigation of turbot and scallop farming and biofouling research. Due to their versatility they have the necessary attributes for transferring and receiving knowledge. Fastnet Mussels produces 500 tonnes of mussel waste per year costing €37,500 disposal. The company is located on a remote peninsula where other fish processing plants are also located. The AD system could potentially process the waste from all the companies located in the area.

ADVANTAGES OF THE ORION SYSTEM

- On-site treatment of wastes thereby avoiding costs of handling and transport
- Robust and compact design allows convenient installation and operation in utility rooms separated from the loading point
- All gas, liquid and solid outputs have useful applications in energy production or as high quality fertilisers and soil amendments
- Automation, advanced sensors, remote monitoring and proactive process control enable optimisation with minimal demands on the end-users

BENEFITS TO USERS

Benefits of anaerobic digestion compared to landfill or incineration include:

- Reduced cost for waste treatment;
- Local recovery and recycling of energy from organic wastes;
- Enclosed process with a low risk of air and water emissions;
- Removes risks related to hygiene in food waste logistics;
- Technology complies with European and National legislation;
- 70-80% diversion of waste from landfill;
- Reduction in greenhouse gases in comparison to uncontrolled landfill;
- Growing market for renewable energy;
- Large potential of compost market;
- Full integration into the local waste handling logistics (e.g. kitchen wastes);
- Potentially a mobile machine.

NOTES