AlgaeBioGas

Algal treatment of biogas digestate and feedstock production

D4.1

Case study operation assessment

CONFIDENTIAL

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1 Summary

Set-up and operation of the demonstration centre is one of the central activities of the AlgaeBioGas project. This report documents Task 4.1 Data analysis of the demonstration centre operation. This activity followed the construction phase which was complete 15 months ago. Raw data collected during demonstration centre operation is presented in reports prepared every 6 months of operation. This report presents top level view of the collected data and operational experience. Operational modes are described and studied. Operation is categorized into different modes of operation and supporting data is presented.

Editorial note

Deliverables in AlgaeBioGas project necessary build on and refer to previous deliverables. Our aim is to make them self-contained readable documents which necessary involves some replication of contents of previous deliverables, either as verbatim or summarized quotes. We are aware that such text is annoying to someone reading deliverables in series, so we have decided to set such text in lighter colour.

Thus, if you are reading just this text, please find contextual and reference information in lightly set sections; if you are acquainted with the project context (like a reviewer), please ignore the text set in light typeface.

Previous deliverables (partially) quoted in this document:

- DoW Description of work (Annex I of the Grant Agreement)
- D2.1 Design of the Demonstration centre
- D2.2 Assembly and Startup Report
- D3.1 Report on the demonstration centre operation – datasets M1-6
- D3.2 Report on the demonstration centre operation – datasets M7-12

2 Project Abstract

AlgaeBioGas project is focused to market introduction of algal-bacterial treatment of biogas digestate. Using algae we can recycle CO_2 emissions and nutrients contained in the biogas digestate. Excess heat can also be productively used. Treated digestate is of such quality that it can be reused or released to the environment. Resulting biomass can be used as biogas substrate, possibly after extraction of specific components in biorefinery.

Classical biological (bacterial) waste water treatment successfully reduces the quantities of organic substances at the cost of significant CO2 emissions and significant energy consumption for aeration. Mineral nutrients, flushed with the liquid phase of digestate, are lost in the bacterial sludge which is frequently deposited, incinerated or discharged to the environment.

Algae hold a great potential because of their high growth rate, easy production, better utilization of sunlight compared to conventional plants, shorter lifecycles and independence from fertile agricultural land. Biogas plants are rich sources of mineral nutrients, CO2 and heat. By algal recycling we can close material cycles, provide feedstock for bio-refining various high value products and decrease competition between biogas and food use of agricultural crops.

The project aims to set-up the first application as a demonstration centre and prepare all prefabricated technology, organization and marketing tools to market replication projects. The technology demonstration centre is not only be able to demonstrate the technology in full size at a demanding customers site, but also provides on-site support for customer’s testing, analysis, evaluation, training and other activities required as part of a complex project.

3 Task Description and Objectives

AlgaeBioGas demonstration centre has been built in the first year of project execution. Demonstration centre is one of the pillars of the project, it is an installation of the technology at one of the project partners (KOTO) where we are able to demonstrate the technology in different working regimes, measure the operating characteristics of the system, measure environment impacts, provide the LCI data in a realistic set-up, and above all show the installation to the potential customers to enable repeated installations.

From DoW (task 4.1 Data analysis of the demonstration centre operation)

Data analysis on the basis of the created database will be made. Data will be analyzed using various software tools with the ultimate goal to prepare the data from the demonstration operation in a presentable and meaningful form that can be used as a sales tool. Such information is also the basis for performance and capacity planning for next customers.

There is a set of interesting questions that may be answered by data analysis, like influence of weather on the operation, influence of input digestate composition to process parameters, influence of various control parameters to composition of algae-bacterial community, and in general modelling the algae-bacterial process and determination of model parameters.

4 Overview of the demonstration centre

The demonstration centre consists of the following subsystems:

- a greenhouse,
- main pond with mixing,
- inoculation pond with mixing,
- digestate separation and supply subsystem,
- CO_2 (exhaust) cooling, dehumidification and supply subsystem,
- pond heating & cooling subsystem,
- sedimentation, harvesting and output water subsystem,
- control system with sensors.

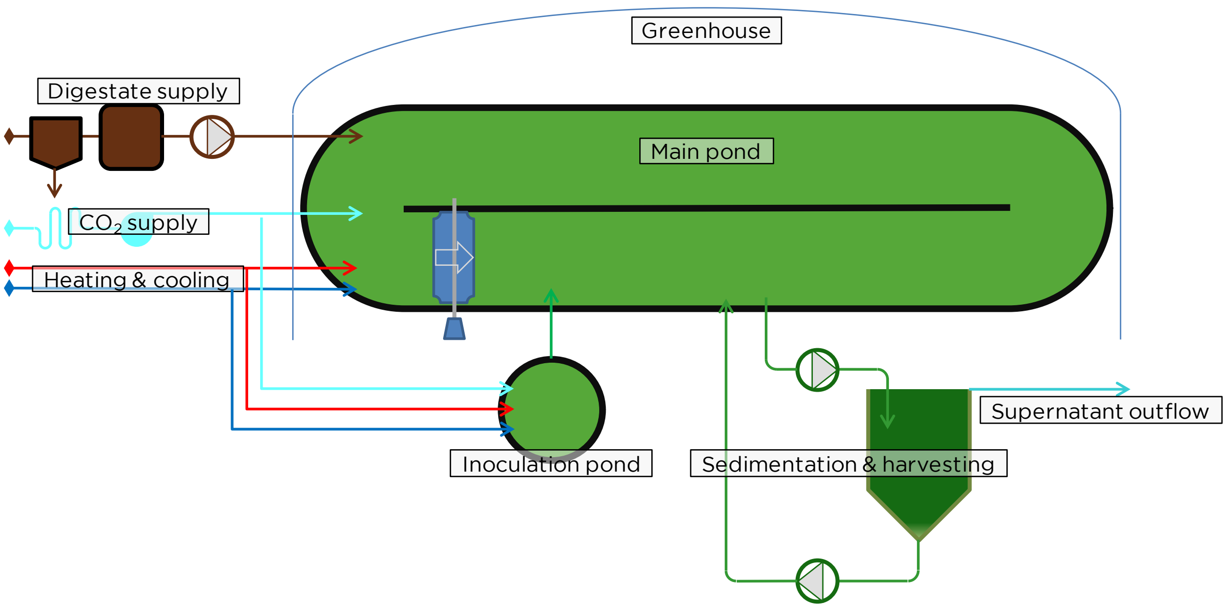

Figure 1 Demonstration centre subsystems

Details of the subsystems are described in *D2.2 Assembly and Startup Report*. We will concentrate here on functioning of the demonstration centre as a system.

4.1 AlgaeBioGas process

Algae bacterial treatment of digestat takes place in the main pond, where algal-bacterial community uses nutrients present in digestat which results in growth of algal-bacterial biomass. Mixed algae and bacterial culture is maintained in inoculation pond and added to the main pond when necessary. Both ponds are continuously mixed. Biomass from the main pond is recycled through the sedimenter and harvested. The supernatant outflow from sedimenter is discharged to the sewage system. To assure optimal conditions for system operation, water level, CO_2 addition, water and air temperature in greenhouse are controlled.

4.1.1 Inoculation

Inoculation procedure starts in a lab from a starter culture. Starter culture is cultivated from different algal strains selected from most perspective algal strains mentioned in scientific publications on one side, and strains collected from local environment on the other side. All microalgal strains are initially grown on selected microalgal growth medium (U, AlgEn, Slovenia) until cell concentration 10^6 cell/ml. In next phase algal cultures are mixed together and during selection process adapted for growth on biogas digestate. Small amount of algal inoculum is stored in AlgEn's algal bank.

Inoculum for inoculation pond (MB) has been prepared in AlgEn's laboratory by slowly increasing the volume. When volume of 150 L has been reached, inoculation pond has been inoculated. The full volume of MB pond has been reached in a week. After a week half of the main pond (VB) has been filled with water (15.000 L), and 1500 L of culture from MB has been added. After 7 days the full volume (30.000 L) of VB pond has been reached.

During operation process inoculum culture can be changed due to different factors. Most important are the physico-chemical conditions in the system (VB) such as concentration of mineral nutrients, organic matter, salinity, humic acids etc, all of which depends on the biogas digestate hydraulic retention time, algal biomass retention time and the daily properties of the biogas digestate entering the system. Another important factor is the weather, especially solar illumination, which importantly affects the biomass production, oxygen production and enhances the biogas digestate treatment process. Additionally new microalgal species are entering into the system constantly due to weather factors and with operators and visitors of the ABG demo centre. All mentioned factors can cause deviations of the mixed microalgal culture with establishing optimal conditions for some single microalgal species that are present in the system. This results in higher reproduction of the cells that have optimal conditions and inhibition of all the other microalgal species in the system.

For this reason inoculation pond is maintained with optimal conditions for inoculum containing initial microalgal species, which is periodically used as inoculum for the main pond (VB).

4.1.2 Digestate (nutrient) addition

Digestate is added from the digestate collection tank (output from anaerobic filter) by gravity flow. There is an electrically controlled valve with relatively long transition time, so we implemented digestate addition as a periodic process. Digestate addition is determined by the following settings:

- period length (in minutes)
- maximum amount per period (in litres)
- maximum amount per day as a safety measure (in litres)

- conductivity limit (in µS) – digestate is not added in the period if conductivity is above this limit,
- ORP limit (in mV) – digestate is not added in the period if ORP is below this limit,
- dissolved oxygen limit (in mg/L) – digestate is not added in the period if ORP is below this limit.

There are two modes of operation of the system:

- during inoculation procedure the total amount of added digestate is increased from 50, 100, 200 L/d to continuous mode in 4 weeks. The pulsed operation period is set to 120 and 60 min to spread the digestate pulses in a wider range of time.
- in continuous mode the pulsed operation period is set to minimal value (5 min) so the system can react as soon as possible to changing conditions.

Many settings of the limiting values have been tested and the following limit values are used now: period length is 5 minutes, 15 L of digestate is added per period. Limiting values for dissolved oxygen were tested between 2,2 mg/L and 3,5 mg/L. ORP is most of the time the main limiting factor and therefore limited to +200 mV; conductivity limit is set to 2000 µS.

4.1.2.1 Digestate composition

Digestate represents main source of nutrients such us nitrogen, phosphorus and microelements, needed for the growth of algae and bacteria in ALBA system. We conduct regular measurements of digestate composition and COD (chemical oxygen demand). During the first year of demo centre operation the COD of digestate varied between 7000 and 8000 mg O_2/L up until middle of September 2015, when quality of digestate changed due to the change at biogas plant operation. From September 2015 on, the COD values varied between 3000 and 4000 mg O_2/L.

4.1.3 Mixing (VB)

The paddle wheel is used for mixing. Continuous mixing is providing water flow speed in the range of 0,3 – 0,5 m/s.

4.1.4 Sedimentation

The biomass separation process is done by sedimentation in a 2000 L sedimenter. Biomass enters the sedimenter by pumping with a recirculation flow of cca. 400 L/h, so the retention time is approx. 5 hours. Water leaving the system is supernatant outflow. The outflow is determined by sedimenter water level.

Sedimenter has a shallow cone at the bottom. To detach the sedimented biomass from the bottom, a scrubber is installed. Biomass is collected in the bottom pit. Scrubber has a rotation speed of 1 rpm and it is switched on for 10 min in 30 min period. Scrubbing is turned off completely from 19:00 to 07:00 to collect denser biomass for harvesting.

4.1.5 Harvesting

The biomass is harvested every morning after overnight sedimentation (scrubber off). Harvesting decision is done manually by operator. Harvesting procedure consists of turning on the scrubber and output pump at the same time. Duration of harvesting operation is determined visually based on the density (colour) of the outflowing biomass. The general instruction to the operator is to perform harvesting for specified amount of time or until the colour becomes notably lighter. If operator is not available in time, morning scrubber operation is delayed manually by remote access. Experience has shown that colour change (density) is swift enough to determine the harvest end-time accurately enough when the biomass density in the pond is high; at time when biomass pond content was low the density change was slower.

4.1.6 Outflow

The supernatant outflow is determined by water level in sedimenter. Water level is measured by a pressure sensor and it is regulated by a proportional valve and duty cycle of the membrane pump. Both are controlled by PID feedback loop from the level sensor and the in-flow in sensor of the sedimenter. Output flow is highly unstable and non-linearly determined by the water level, so this control loop has been subject to many modifications and improvements. Due to high variability of the output flow a thermal flow meter has been designed and implemented in the output line which is still under customisation.

4.1.7 Pond water level

For mass balance preservation the volume of the digestate input is balanced with the harvesting volume and the outflow of supernatant (on average 200 L/day); in the hot period of the summer the evaporation of the water has to be considered. If the evaporation is greater than the digestate input, fresh water was added to adjust the pond level at the constant value. Pond level measurement is manual and done by the operator.

For most of the time the pond level was maintained at 35 cm; this has been reduced recently to 30 cm and will be further reduced in the future. The light intensity (PAR) at 5 cm underwater is very close to zero even at very strong sunlight.

4.1.8 CO_2 addition

For algal biomass production carbon source is needed. System for anorganic carbon introduction was installed in both ponds. Raceway pond is equipped with gas diffuser, a perforated pipe at the bottom of the pond covered by slanted plate of approx size 2 x 3 m that prolongs the bubble path in the water (counter flow). Inoculation pond has a perforated pipe installed on its bottom for introduction of CO_2.

Algae can use organic and inorganic sources of carbon, but whenever we introduced higher loads of digestate to the main pond, enough of carbon entered the system the system, making further addition of CO_2 unnecessary for the main pond.

4.1.9 Greenhouse side vent adjustments

Side ventilation of greenhouse is primary means of temperature control during the summer. It is controlled manually (motor control has been delayed to gain some experience with this control).

4.1.10 Greenhouse fan

Greenhouse fan has been installed relatively late (June 2015). It regulates airflow through the greenhouse (in combination with side vents) thus controlling the evaporation which is primary cooling process in high temperature season. During this season the control loop was based on water temperature, but this will be changed to the greenhouse air temperature.

During colder periods the fan is periodically turned on to reduce condensation in on the greenhouse walls. This can be set by a time loop, at present it is turned on for 10 min every hour between 10:00 and 14:00.

4.1.11 Heating and cooling

Heating and cooling is realized by built-in pile in the pond construction. A circulation pump is pumping water at set temperature. Temperature is limited on the high side to prevent local overheating. Temperature is controlled by a PID controller using diverter valve so that the recirculation flow gets through the heat exchanger at appropriate rate. When/if cooling is required a separate diverter valve is used to lead the flow through chiller heat exchanger.

Heating or cooling power is calculated from the flow and input and output water temperatures.

4.1.12 Control parameters

Temperature: winter temperatures are controlled in 20-24 ^{0}C range by waste heat and side vents regulation, summer temperatures are controlled in the range 26-32 ^{0}C with a greenhouse fan and side vent regulation. Exceptionally the chillier is activated (mainly as a safety measure).

ORP set value is 200 mV in order to assure the optimal conditions for the processes of nitrification and phosphate fixation.

Conductivity is maintained below 2000 µS (if possible) with harvesting and digestate addition regime. We observed conductivity drop after digestate addition and determined, to our surprise, that humic acids in digestate apparently work as chelators.

Dissolved Oxygen (DO) set values were tested in the range from 2,8 to 3,5 mg/L. DO is influenced by auto/heterotrophic metabolism, nitrification and mixing.

pH is influenced by auto/heterotrophic metabolism and digestate addition. The pH stabilises around the value of 6.0. We have a control loop implemented to add CO_2 when pH raise.

5 Data analysis of the demonstration centre operation:

In the following we will show operation of the demonstration centre in several operating modes:

- normal & optimal conditions,
- irregular events,
- unexplained events.

All modes will be explained based on a chart from the control system showing typical situation. On all charts time is on horizontal axis and values (at different scales) are on vertical axis. All charts have the same colour coding:

- red curve indicates pond water temperature
- black curve indicates pH,
- green curve indicates dissolved oxygen (in mg/L)
- blue curve indicates conductivity (in µS)
- yellow-greenish curve indicates solar irradiation (PAR – in µmol/m^2/s)
- orange indicates ORP (in mV),
- purple curve indicates cumulative digestate quantity added (in L) or CO_2 concentration in the green house (ppm),
- grey spikes indicate CO2 valve opening (0/1)
- dark purple spikes indicate digestate or water inflow rate (in L/h)

PAR curve gives good orientation of daily cycles.

5.1 Optimal system conditions and recurring events

The amount of processed digestate per day is considered as main indicator for optimal system operation. Based upon collected data we determined the summer months as prime time for optimal system operation, as expected. The highest amount of digestate was processed in June and July 2015.

We are operating two different processes: inoculation pond is a typical algal process. A typical chart is shown in Figure 2 for inoculation pond in three days. Solar irradiation is shown as yellow-greenish curve (a November pattern – short and weak daylight). During the day oxygen concentration (green curve) increases, during the night it slowly decreases. pH (black curve) tends to increase slowly and when it reaches a threshold value, we open CO_2 valve (grey spikes) to decrease it. Purple curve shows CO_2 concentration in greenhouse (it is evident that side vents are closed). Red curve shows water temperature which is kept reasonably stable. We only add minor amounts of digestate to the inoculation pond (manually, from time to time, e.g. once per week). Large amount of CO_2 in the greenhouse atmosphere show that our diffuser is not very effective (this is especially true for the inoculation pond, but we did not optimize diffuser operation as we have unlimited quantity of flue gas). Ripples in the oxygen curve show that CO_2 sparging also reduces CO_2 concentration – it stimulates gasification of oxygen to the bubbles.

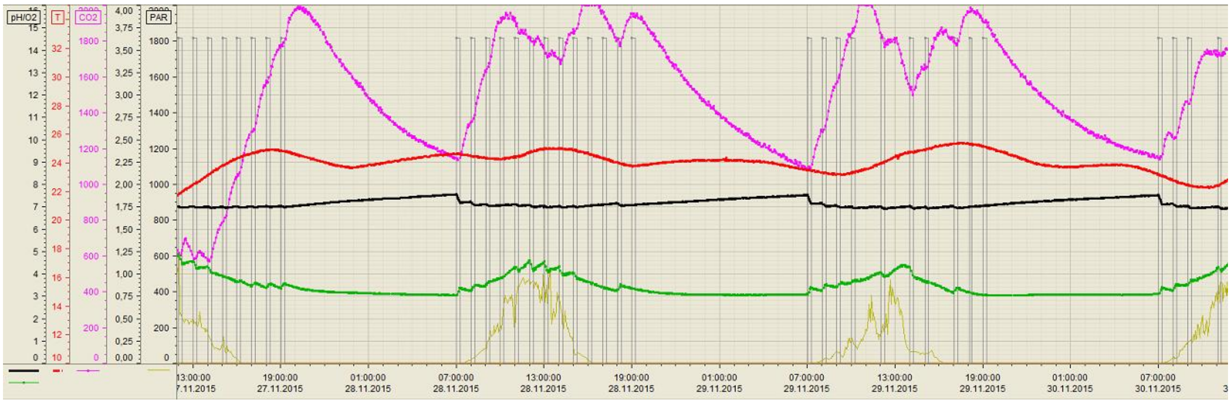

Figure 2 Typical algal process

The algal bacterial process in the main pond is different. It includes addition of relatively large quantity of digestate. Bacteria are also present in significant quantity and this includes ordinary bacteria that consume organic matter and oxygen, respiring it to CO_2 but also nitrificators (consuming NH_4^+ and O_2 and producing NO_x) and other bacterial processes to a lesser extent (denitrification and annamox are not very likely due to high oxygen values, but local conditions within flocs and biofilms may be very different). Added digestate has some interesting properties: its pH value is above 7, so it increases pH. It was expected that it contains a lot of inorganic ions so it would increase the conductivity, but in fact it turns out that it has mainly chelating properties: digestate addition reduces conductivity in short term.

When we add digestate to the system, pH increases. Algae in algal-bacterial community in the pond use nutrients from digestate, resulting in production of oxygen, which is used by aerobic bacteria. As seen on Figure 3 during optimal operation we can see decrease of pH (black curve) and ORP (orange curve), which indicates oxygen consumption by bacteria and mixotrophic algae. Increase in oxygen and ORP levels can be seen at night, when digestate is not added.

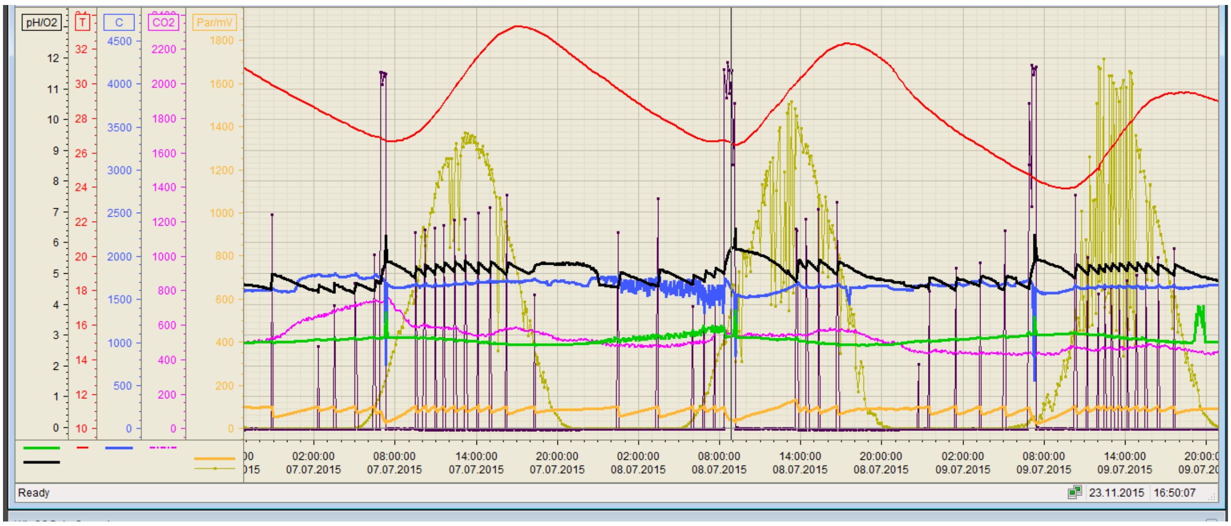

Figure 3 pH and ORP in optimal operation mode

Figure 4 shows decrease in oxygen (green curve) and simultaneously decrease of ORP (orange curve). This shows correlation between digestate addition and oxygen levels (independent from sun light and temperature). At the same time, pH (black curve) is rising, due to digestate addition.

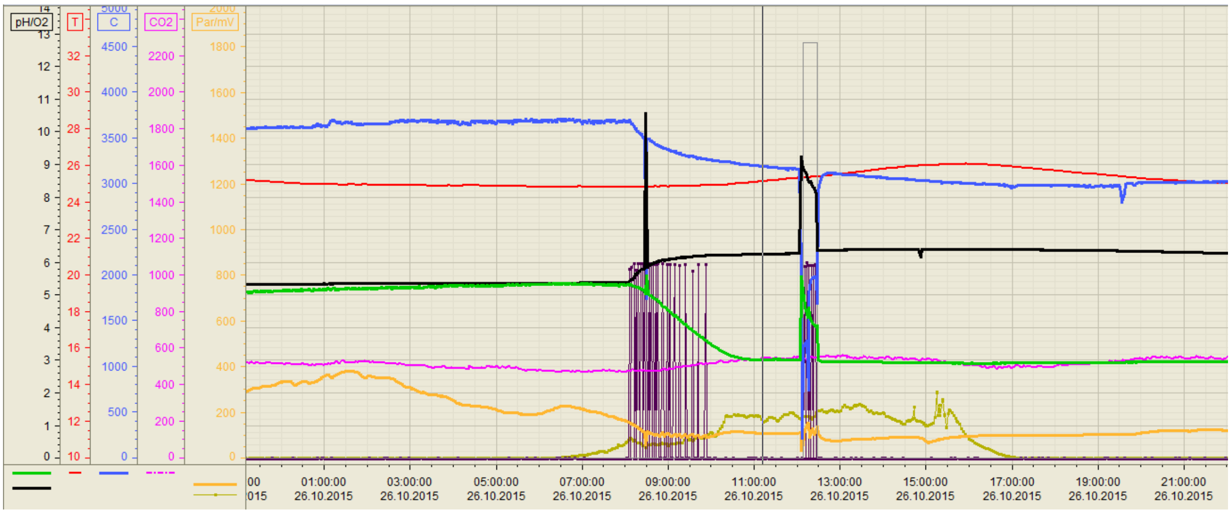

Figure 4 Decrease in oxygen and ORP after digestate addition

One of the interesting recurring events appears to be increase in conductivity when digestate is not added to the system and vice versa (Figure 5, blue curve). We assumed that possible explanation for this might be presence of humic acids in digestate. Humic acids are products of organic matter decomposition and can act as chelators for ions and therefore lower conductivity. We might further test our hypothesis by setting up some lab scale experiments involving humic acids and digestate.

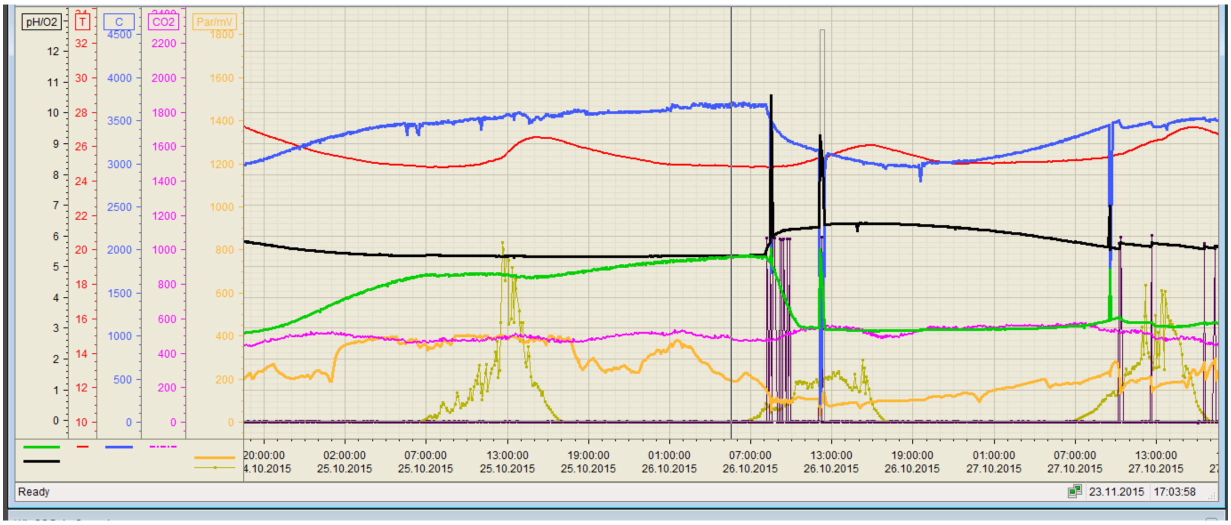

Figure 5 Conductivity and digestate dependency

5.2 Irregular events

One of the recurring events at the time of irregular system operations seems to be change of colour in the main pond. Digestate itself has strong brownish colour, which might affect ALBA community, by limiting light available for algae. For example, on 8th and 9th of November 2015 the main pond had strong brownish colour (Figure 7, middle bottle). Oxygen level was constant, digestate was added in the night time, which was unexpected, since we assumed digestate would be added during day, when algal community is most active. Due to the oxygen lock digestate (violet curve) was not added during day, following increase in ORP (orange curve) and bacterial activity, as seen from lowering pH (black curve). Therefore, one of the remaining questions is why there is lack of oxygen during day (when algal activity should be optimal and oxygen levels higher), but on the other hand, oxygen increases during night. This, in return, triggers addition of digestate at night, since oxygen is above set blocking value.

Events like the one described above, show, that we must be careful with settings for locks and rises questions which parameter would assure optimal control of the system and enable highest volume of processed digestate. We are expecting to be able to fully answer these questions by the end of the project.

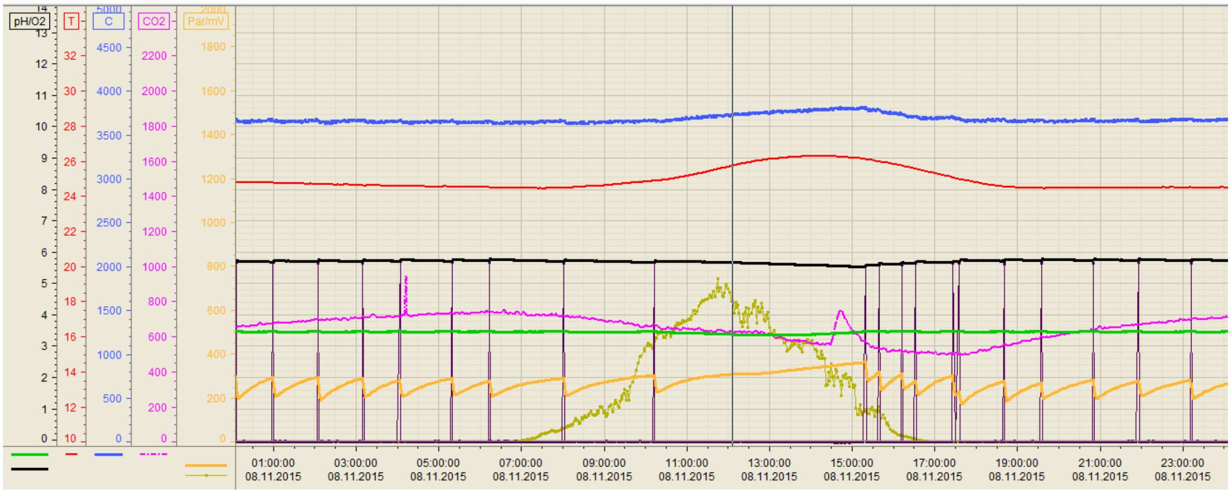

Figure 6 Irregular event: addition of digestate during night

Figure 7 Effect of digestate on colour

5.3 Unexplained events

Over the last half of the year we noticed several interesting events in the system operation, which shows complexity of algal-bacterial treatment of digestate.

One of such events appears to be lowering of oxygen levels at the time of highest PAR levels (Photosynthetically Active Radiation: the amount of light available for photosynthesis) while during night oxygen increases, contrary to what we would expect. Another interesting aspect of this event is the fact that this only happens every now and then. For example, we can see decrease of oxygen at high PAR at 9th and 10th of June 2015 (Figure 8), while there is increase of oxygen at high PAR on 7th, 8th June (Figure 9) and 15th of June 2015 (Figure 10). On the other hand, oxygen is not decreasing in inoculation pond, at the time of high PAR (Figure 11).

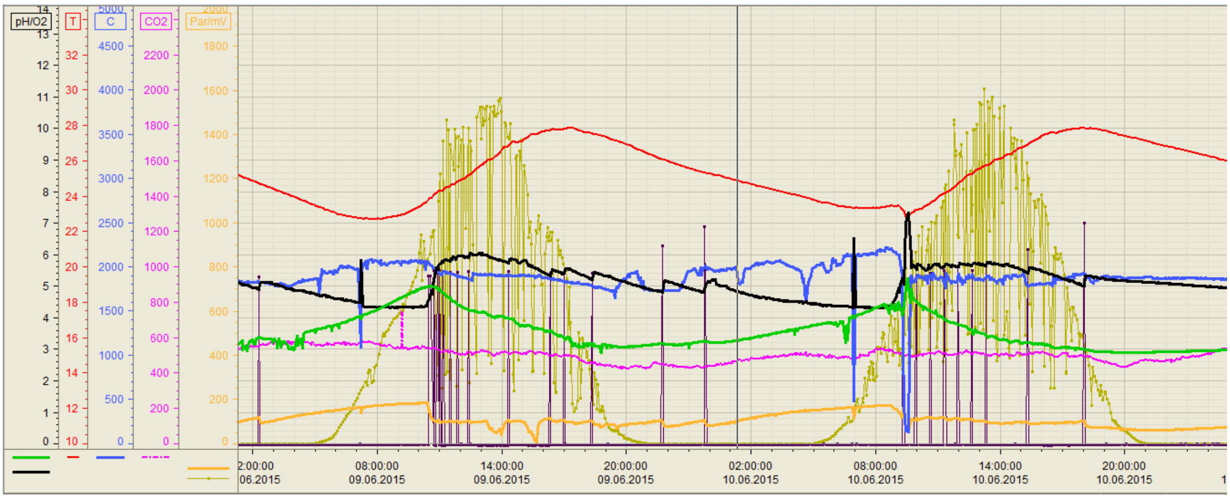

Figure 8 Decrease of oxygen during high PAR

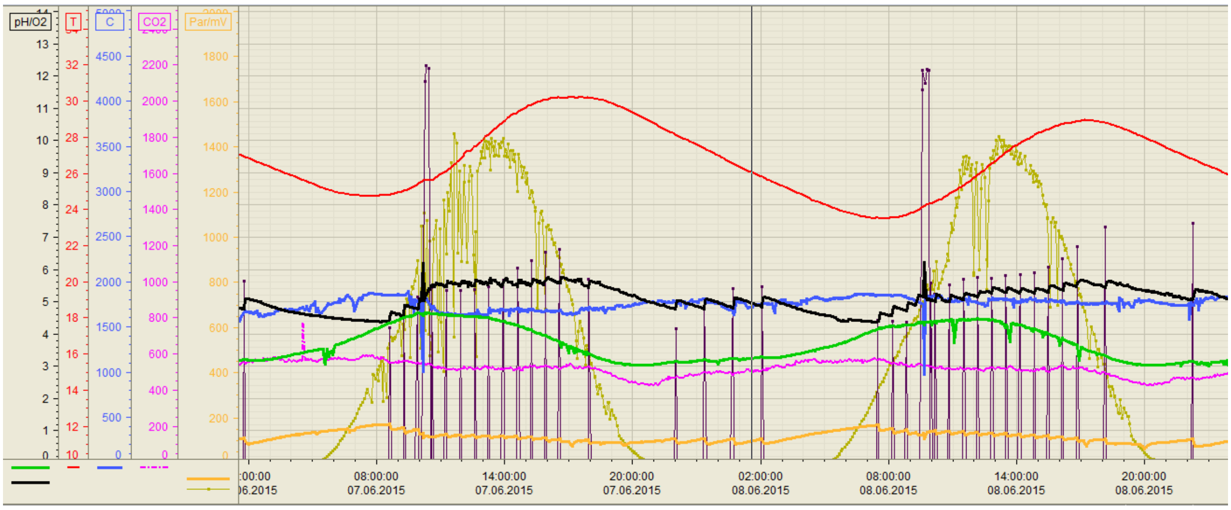

Figure 9 Increase of oxygen during PAR

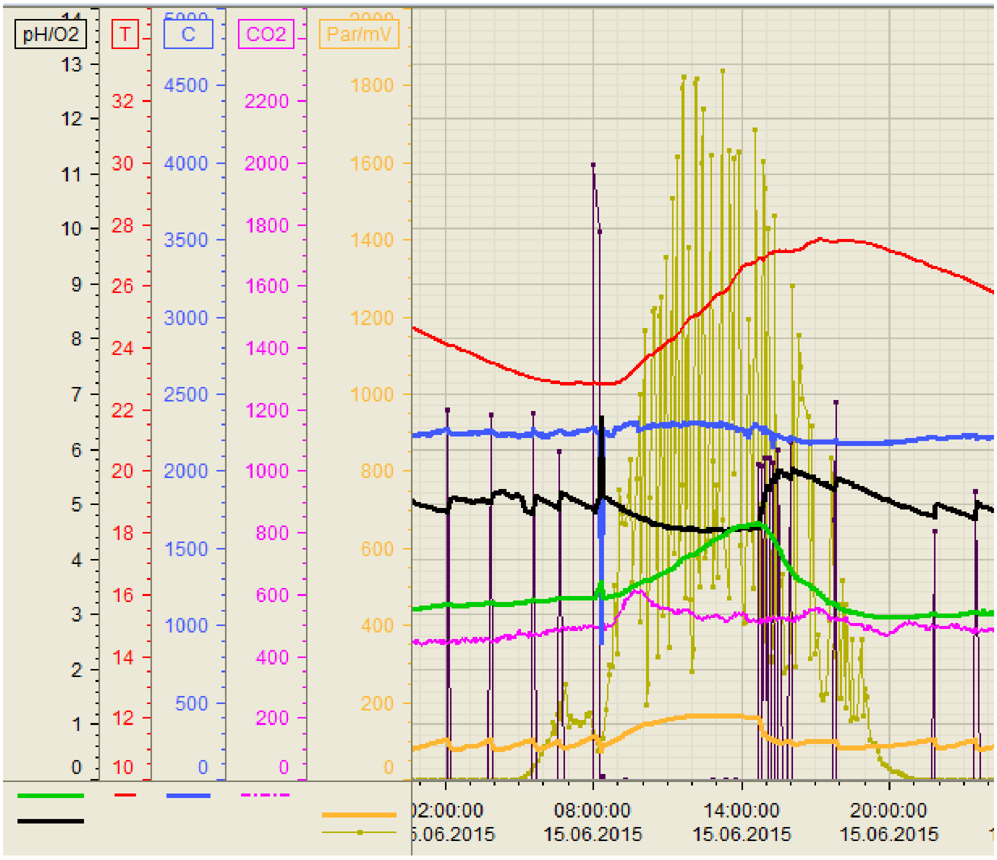

Figure 10 Increase of oxygen during PAR

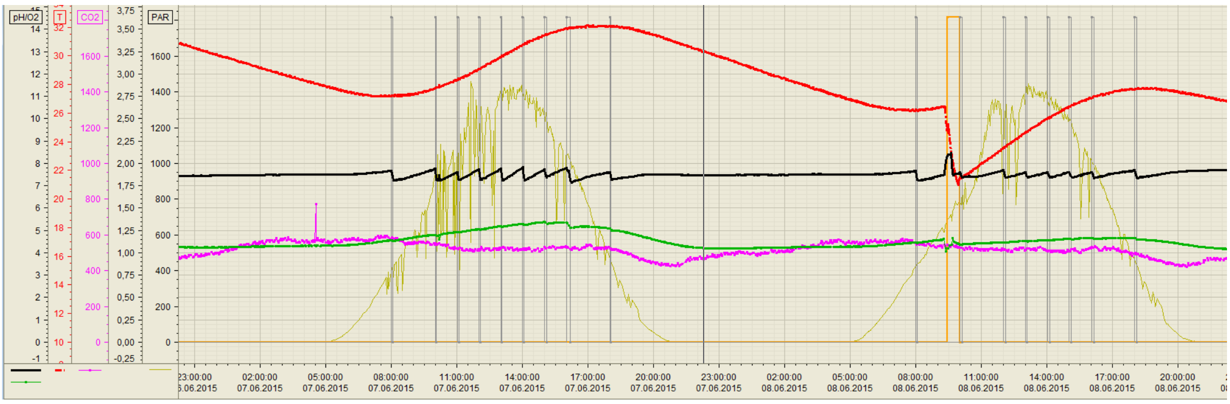

Figure 11 Oxygen levels at high PAR in inoculation pond

5.4 Mechanical errors and maintenance

During demonstration centre operation we also encountered some technical problems, such as various mechanical errors, for example electrodes malfunction, which, in this case, caused high inflow of digestate to the ponds. Since some maintenance work needs to be done from time to time, this is seen in data as well, supporting our need for special mode option during maintenance (as already expressed in report D3.5). To assure accurate measurements, electrodes in both ponds are cleaned daily, which in turn is seen on the SCADA logs.

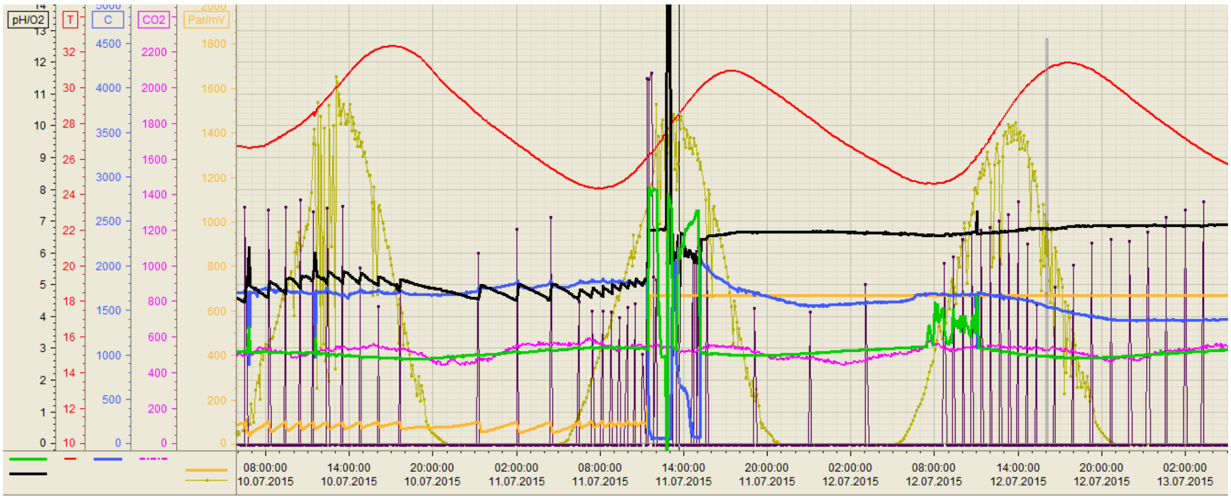

Figure 12 Electrodes malfunction

6 Changes in microbial community

We followed changes in microbial community with regular (once per week) microscopy of samples from main and inoculation ponds. At the start of the system (September 2014) *Scendesmus* sp. (Figure 13) appeared to be dominant species, up until the end February 2015, when we first noticed new species (Figure 15), which was not added at the start of operation. Possible reasons for changes in microbial community are explained in chapter 4.1.1. We identified the new species as *Monoraphidium* sp. In March, ratio between *Scenedesmus* sp. and *Monoraphidum* sp. was approximately 1:1 (Figure 17), while in May, *Monoraphidium* sp. became dominant (Figure 18). In May we also observed new species, which most likely is *Ankistrodesmus* sp. (a relative of *Monoraphidium*) Figure 19. *Monoraphidium* sp. and *Ankistrodesmus* sp. stayed dominant species up until November 2015 (Figure 20).

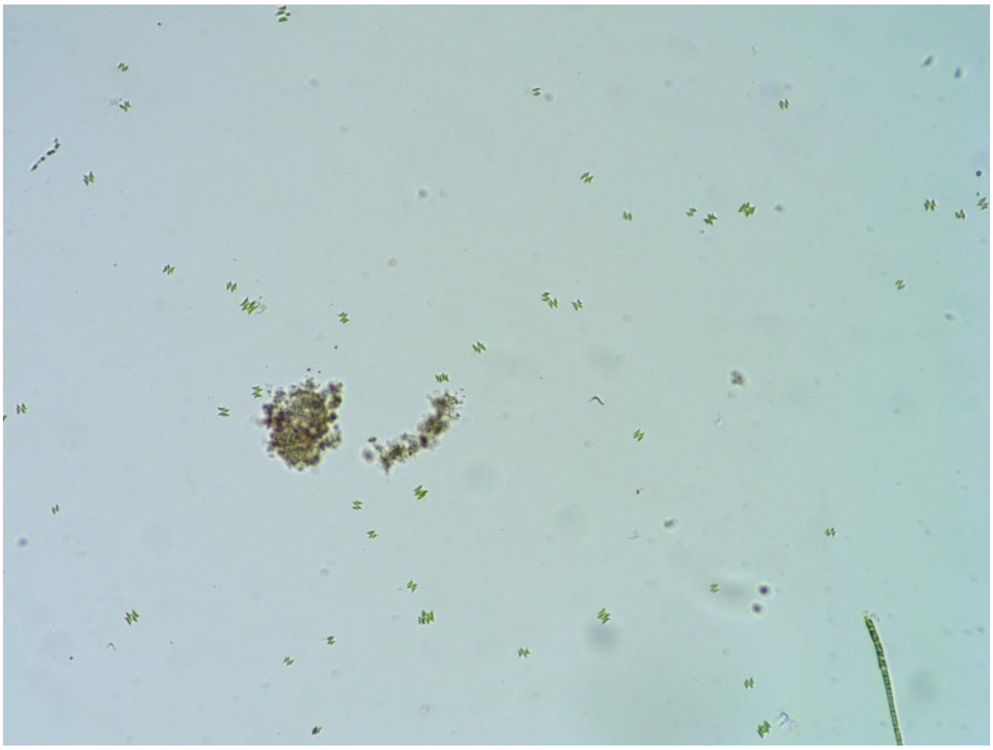

Figure 13 *Scenedesmus* sp. 100x, February 2015

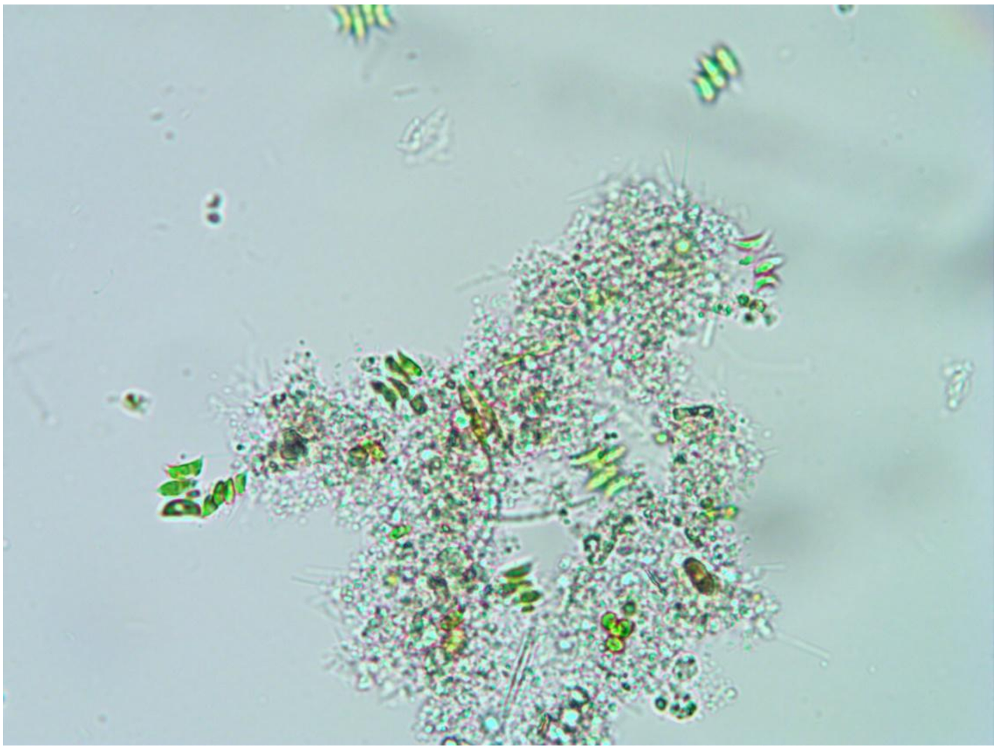

Figure 14 *Scenedesmus* sp. 400x, February 2015

Figure 15 *Monoraphidium* sp., 400x, March 2015

Figure 16 Microbial community 100x, March 2015

Figure 17 *Monoraphidium* sp. and *Scendesmus* sp. 400x, March 2015

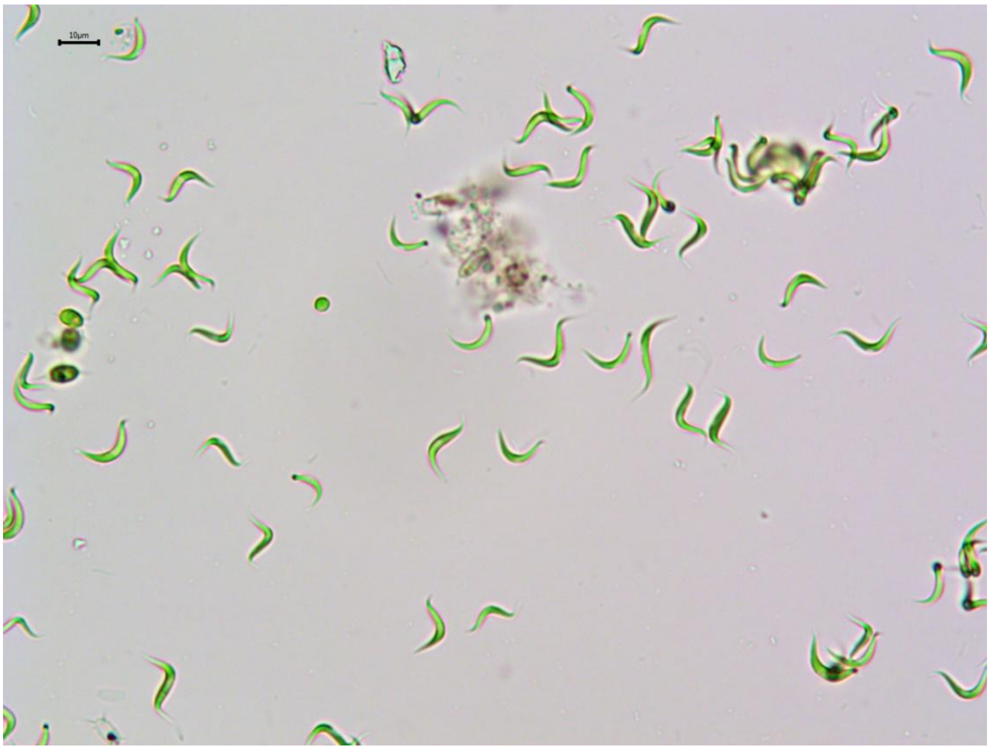

Figure 18 *Monoraphidium* sp. 400x, May 2015

Figure 19 New species *Ankistrodesmus* 400x, May 2015

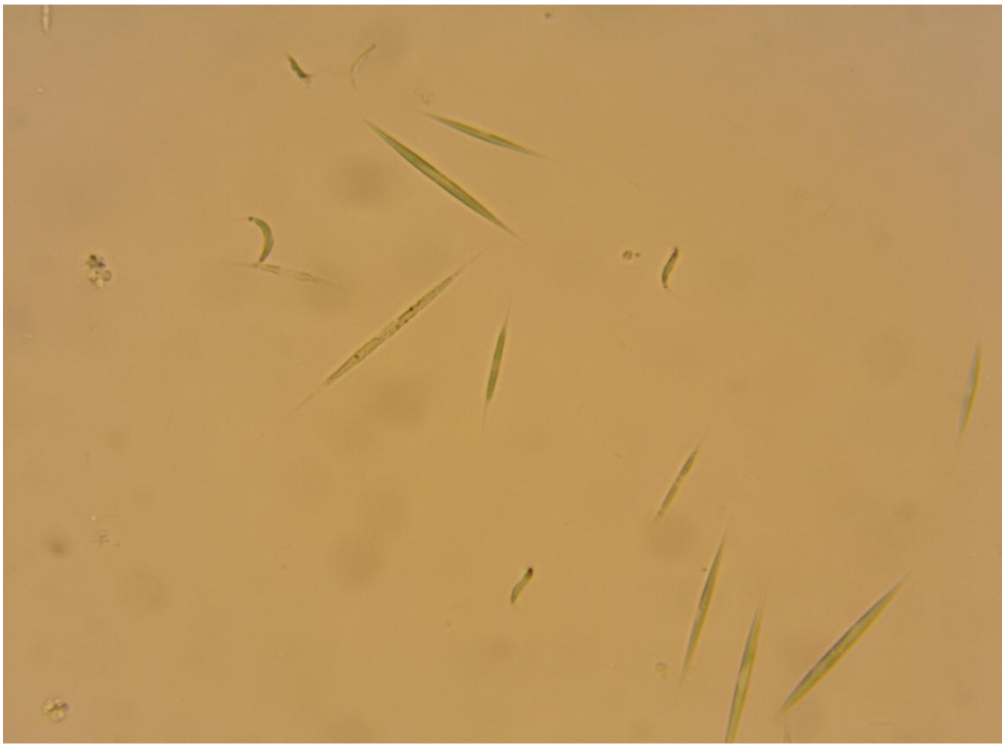

Figure 20 Microbial community 400x, November 2015

All the pictures above represent microbial community in the main pond of demonstration centre.

7 Conclusions

As described in DoW there is a set of interesting questions that might be answered by data analysis, like influence of weather on the operation, influence of input digestate composition to process parameters, influence of various control parameters to composition of algae-bacterial community, and in general modelling the algae-bacterial process and determination of model parameters.

Most of these questions remain open with just partial answers after the first year of operation. We can provide some synthetic, top level answers:

7.1 Weather influence

There are two main factors influencing pond operation under weather control: light and temperature. Light conditions definitely influence algal photosynthesis and consequently consumption of CO_2 and production of oxygen. Light conditions are not easy to overcome, but in general the tradeoffs should be moved more to the shallow solutions: a very shallow pond would perform better.

At higher temperatures all the metabolic processes, including photosynthesis, are faster. We found out that our heating system is under dimensioned and so we had problems keeping the temperature at set levels under worst weather condition. In general it can be seen from the charts that temperature control could be more efficient.

7.2 Influence of input digestate composition to process parameters

Composition of digestate varies depending on the type of substrate used in biogas plant and type of process (mezophilic or thermophilic). Most definitely digestate composition is important parameter, which affect process parameters in our system. We are conducting regular analysis of digestat, measuring COD (organic matter), essential nutrients for algal growth, such as NH_3, NO_2^-, NO_3^-, PO_4^{3-} and salt content (NaCl). During operation we conducted some other analysis as well, for example content of humic acids and heavy metals.

One of the important aspects of digestate composition is organic matter content. In our system we require lower content of organic matter, since this would require higher use of CO_2, added in the form of flue gases, which we would like to use as much as possible. Organic matter present in digestate switches system operation towards bacterial metabolism (bacteria use organic matter), making algae less effective.

Higher amounts of salt in digestate present additional challenge. Apart from chemical analysis we can also measure salt content through conductivity. In case of higher salt content, conductivity rises; salt represents osmotic disturbance, limiting cell's accessibility for water. Since NaCl is not used by algae or bacteria, it tends to accumulate in the system.

Digestate also contains ammonium, which can be toxic under certain conditions. If there is enough oxygen in the system, ammonium is converted to nitrate and nitrite by nitrifying bacteria. All mentioned forms of nitrogen sourc, ammonium, nitrate and nitrite can be used by algae. Our results show, that oxygen level is sufficient for bacteria to execute nitrification. Since oxygen is needed for the process, level of oxygen stays lower in the main pond, while oxygen level in inoculation pond rises during peak time for photosynthesis (daylight).

7.3 Influence of various control parameters to composition of algae-bacterial community

Over the course of demo centre operation we saw changes in microbial community, as described in chapter 6. From February to November 2015 we saw 3 distinguished changes in the community. At the start of the year the prevailing algae was *Scenedesmus* sp., which was later, towards the summer months, exchanged with *Monoraphidium* sp. Towards the end of the year, new species started to prevail. The later was not identified exactly, but it seems to be one of the *Monoraphidium* relatives, possible *Ankistrodesmus* sp. From this we conclude, that probably microbial community changes depending on the season. There are several factors influencing the change of microbial community, as already described in the chapter 4.1.1. Obviously parameters such as light availability, temperature and amount of digestate and therefore nutrients added affect microbial community. We can speculate, that *Monoraphidium* sp. grows better in conditions with more light and higher temperatures, compared to *Scendesmus* sp. Another factor influencing the structure of algae community might be salinity levels. Due to the complex system it is difficult to pin point exact reason for community change. We assume there is combination of factors involved in changes of microbial community. Since demo centre is operating for a year, we shouldn`t draw fast conclusions just yet, but we expect there might be option to grow different mixed cultures of algae in inoculation pond, depending on the season. We would like to be able to prepare several different mixes (according to what we saw in this year of operation), which would later be introduced to inoculation and main pond, depending on the season. For this, we need to have different culture mixes from different parts of the year and test it over at least 2 seasons to confirm whether certain community is established in certain part of the year. If we succeed at this, we will be able to improve digestate treatment process even further.

7.4 Demonstration centre performance data

After one year of operation we manged to collect data for different operation modes. Depending on the results we changed, adapted and optimised different parameters in order to achive optimal operation of the system. Now, we will have to test this optimal parameters for longer period of time, to collect performance data. With this we will be able to improve quality of disschared water, use of CO2 from fuel gases and use of waste heat.

We established that on average, 250 L of digestate per daywas added to the system, under not optimal conditions. Using the collected data and running system in optimum mode should ensure treating of 500 L of digestate per day. We have to keep in mind that level of system performance depends also on quality and composition of digestate.

7.5 Performance and capacity planning

Based on acquired date we anticipate that for treatment of 80m3 of digestate per day, 3-5ha of surface would be used. In our system, main pod has surface area of 100m2, which means there is higher share of side parameters which influence the system. For example, share of self shading is bigger in smaller system than in larger one. In larger ponds we should be able to treat 500L of digestate per day, or even more, depending on the size of the system. For optimal performance, separation of liquid and solid phase of digestate is needed, as well as efficient biogas process (methanogenesis), which influences quality digestate.

We harvested approx. 100L of wet biomass per day. Calculating from % of moisture we concluded that on 100m2 we produce 1kg of biomass per day. This would mean, roughly saying, 150kg of biomass produced per day on 1ha of surface. If we presume that system would operate in sufficient mode for 9 months, we would harvest 45 tons of biomass per year. Produced biomass can be further used for biogas production, bio plastic, fertilizer etc., depending on customer needs.

7.6 Improvements & modifications

Of course there is always space for improvements, and so this is also the case for our system. Majority of improvement and modifications has to do with technical part of the system. Possible improvements needed in pour case involve:

- Automatic side vent regulation,
- CO2 diffusor improvement,
- Pond geometry (specific problem only in this case, due to the problems at the time of construction),
- Flow vanes,
- Separated peristaltic pumps for digestate and culture,
- DAF for sedimenter,
- Sedimenter re-design: steeper slopes and DAF system for collection of biomas.