Statement of Verification

EU Environmental Technology
Verification pilot programme

Technology:	BioKube Summerhouses Wastewater System
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Signed, 14. december 2016

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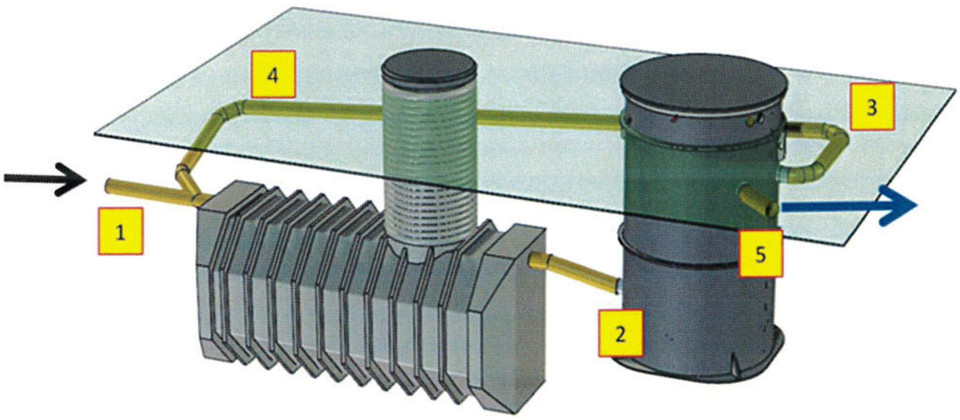
1 Technology description

1.1 The description of the technology is based on information from BioKube A/S.

The BioKube Summerhouses Wastewater System (hereafter: energy-saving treatment system) is based on a BioKube Venus 1850 wastewater treatment system (hereafter: ordinary treatment system), designed for 5 person-equivalents (PE). The treatment system includes recirculation of treated wastewater to the septic tank, at regular intervals, a feature that should ensure that the wastewater treatment system is functional even after prolonged periods without wastewater inflow. In the version for summer cottages, the Venus 1850 sy4.stem is furthermore equipped with an energy-saving control system, which is reducing aeration and pumping in times without incoming flow. The conceptual design is illustrated in Figure 1.



1. The sedimentation tank is fully integrated in the treatment process
Particles are removed in the septic tank upstream of the biological treatment zones. The large volume of water and the timed backwash of purified oxygen-rich wastewater from the last treatment chamber increase the efficiency of the sedimentation tank and evens out varying loads.
2. Timed inflow from the buffer tank ensures continuous nourishment to the biology (BioKube patent)
Wastewater is pumped into the first treatment chamber in the BioKube every 15 minutes for the full 24 hours day cycle. Biological nourishment is thereby fed continuously to the bacteria and not just in bursts as the wastewater is produced in the house. This also equalizes fluctuations in incoming detergents and other chemicals in the wastewater.
3. Timed backwash to the settling tank removes odours (BioKube patent)
During the treatment process, small air blowers supply oxygen to the bacteria. When the oxygen-rich treated wastewater is recycled to the settling tank every fifteen minutes, this prevents odour from toxic hydrogen sulfide in the settling tank. It provides better living conditions for the bacteria that cleans the wastewater by eliminating toxic hydrogen sulfide from developing in the settling tank.
4. Timed backwash ensures equal input of nutrition for the biology (BioKube patent)
By continuous backwash to the settling tank, it is ensured that nourishment from the settling tank is fed to the bacteria also during holiday periods. BioKube systems are therefore uniquely suitable for holiday homes and vacation hotels with large seasonal fluctuations in the incoming water.

Figure 1 Conceptual design of the BioKube Summerhouses Wastewater System: Venus 1850 with energy-saving control system (Provided by BioKube).

2 Application

2.1 Matrix

The technology is intended for treatment of household wastewater from summer cottages.

2.2 Purpose

The purpose is to treat wastewater from summer cottages, reducing in particular Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammonium (NH_4) and total phosphorous (P) to below the required values.

2.3 Conditions of operation and use

BioKube stated that the Summerhouses Wastewater System is functioning also in winter conditions, because the treatment systems is located under ground. No limits are mentioned as for the temperature range in which the system can be used. Operation of a BioKube Wastewater system requires the user to behave responsibly. Only easily biodrgradable detergents should be used (products with eco-label recommended), and no hazardous chemicals should be poured into the toilet and drains. Hydraulic and pollutant loads that exceed the dimensioned loads (750 litres/day for a 5-PE system) or addition of non-biodegradable chemicals may overload the treatment system and deteriorate the effluent quality. The system requires a yearly service check to ensure maintenance of mechanical parts and filling of coagulant, where applicable. Emptying the sedimentation tank is normally done once a year.

2.4 Verification parameter definition summary

The first claim is the treatment result for the following parameters. It is claimed that the ordinary treatment system (*i.e.* ordinary Venus 1850) and the energy-saving treatment system (*i.e.* the BioKube Summerhouses Wastewater System) comply with the current Danish effluent quality standards[1] immediately, on receiving incoming wastewater again, after a period (of up to 6 months) without influent wastewater:

- Biochemical Oxygen Demand (BOD) < 10 mg/l,
- Chemical Oxygen Demand (COD) < 70 mg/l,
- Ammonium (NH_4) < 5 mg/l,

and for systems having the P precipitation system installed:

- Total phosphorous (P) < 1.5 mg/l.

The second claim is that the use of a flow-switch will enable the energy-saving treatment system to power down parts of the system during periods without influent wastewater (up to 6 months), reducing the electric power consumption for use at summer cottages by at least 50%, compared to the ordinary treatment system.

The legal requirements for small wastewater treatment plants in Denmark are in a transition phase. The national type-approval regulations were withdrawn, effective June 1, 2015. While new regulations are developed, municipalities still refer to the effluent quality demanded in the in the national type-approval.

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3 Test and analysis design

Two separate tests were carried out: Flow controlled tests with municipal wastewater at a Wastewater treatment plant (WWTP), and field tests at eight existing summer cottage installations.

3.1 Existing and new data

BioKube had the performance of the phosphourous precipitation unit tested as part of the EN12566-6+A2 type-test for certification. The average concentration of total phosphorous in the raw wastewater during the test period was 10.9 mg/l P. The concentration of total phosphorous in the treated wastewater was 0.50 mg/l P, as an average of 20 samples. The data is stated in the certification report (Appendix 9 in verification report). All of the 20 effluent samples had P concentrations below the Danish guideline limit of 1.5 mg/l.

3.2 Laboratory or field conditions

At Tappernøje WWTP (Denmark), two treatment systems with phosphorous precipitation (one ordinary, the other energy-saving) were operated with a 6-months interruption of inflow during winter season. When the inflow of wastewater to the treatment systems was resumed, the inflow was adjusted to about 750 l/d of raw wastewater (after having passed the coarse screen). Spot samples from the inlet and effluent were taken within two weeks after restart.

At the existing summer cottage installations, the flow and composition of wastewater was not manipulated. Occupation of summer cottages varies a lot, which was also seen in the test. Some of the houses were not occupied at all during the whole test period, others were rented out more or less regularly, while one was occupied continuously. According to the self-reporting schemes, peak loads occurred during Easter holidays. On some of the days, the houses were occupied by more people than the treatment system was designed for.

3.3 Matrix compositions

The raw wastewater at Tappernøje WWTP was relatively diluted. The average inlet concentration of COD, BOD and ammonia components were below the concentrations recommended in EN 12466. Due to the relatively high flow during the test period (above the targeted 750 l/d), the pollutant load to the test plants corresponded to the recommended load for some of the sampling occasions.

3.4 Test and analysis parameters

The following tests parameters were investigated table 1.

Table 1 Test and analysis parameters overview

<table>
<tr><th>Wastewater parameters</th><th>Operational parameters</th></tr>
<tr><td rowspan="3">BOD
COD
NH3-N + NH4-N
Total P</td><td>Flow of raw wastewater to the BioKube treatment systems at the WWTP</td></tr>
<tr><th>Environmental parameters</th></tr>
<tr><td>Power consumption</td></tr>
</table>

3.5 Test and analysis methods summary

Analyses were performed at the external laboratory. The choice of methods for each parameter is summarised in the section below.

3.6 Parameters measured

Table 2 gives an overview of the parameters analysed by an external laboratory. The two BioKube plants siturated at the WWTP received the the same wastewater.

Table 2 Overview of parameters analysed and sampling points

Parameter	Method	WWTP BioKube Inlet	WWTP BioKube Outlet	Field Bio-Kube Outlet
Biochemical Oxygen Demand (BOD)	Reflab method 2:2002	One sampling point	Two plants	Eight plants
Chemical Oxygen Demand (COD)	DS/ISO 15705:2006	One sampling point	Two plants	Eight plants
NH3-N + NH4-N	EN/ISO 11732, modified	One sampling point	Two plants	Eight plants
Total P	DS/EN ISO 6878:2004	-	-	One plant

4 Verification results

4.1 Performance parameters

Flow-controlled tests at WWTP - Compliance with effluent standards

When the treatment systems received wastewater again after 6 months without inflow, both systems (ordinary and energy-saving) complied with the Danish effluent standard from day one: BOD<10 mg/l, COD<70 mg/l, and ammonia-N <5 mg/l. Claim no. 1 regarding the effluent quality was therefore verified by the flow-controlled tests at the WWTP.

The inlet concentrations are presented in Figure 1, effluent concentrations of COD in Figure 2, COD in Figure 3 and ammonia-N in Figure 4.

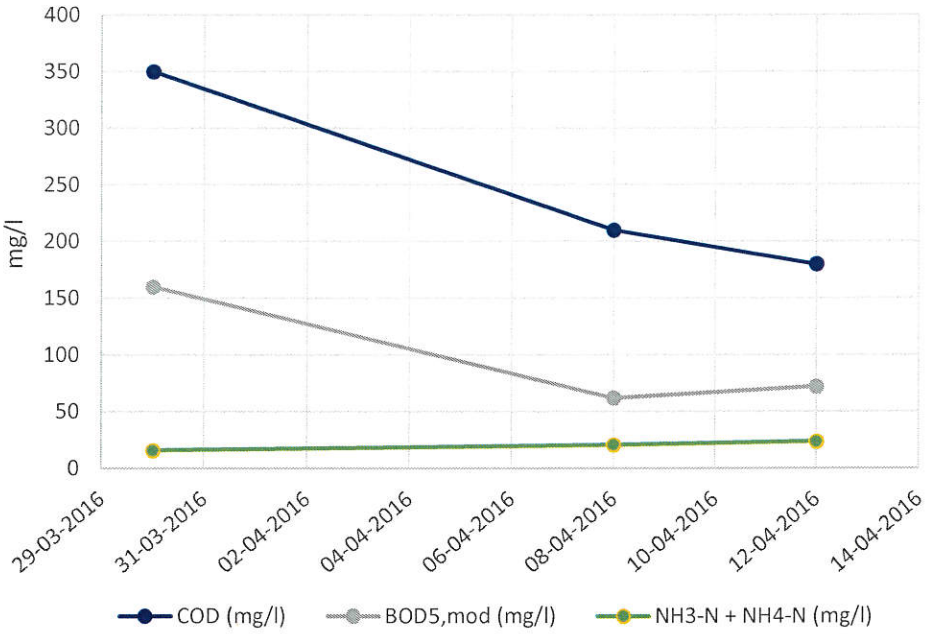

Figure 1: Development of inlet concentrations to test systems at Tappernøje WWTP.

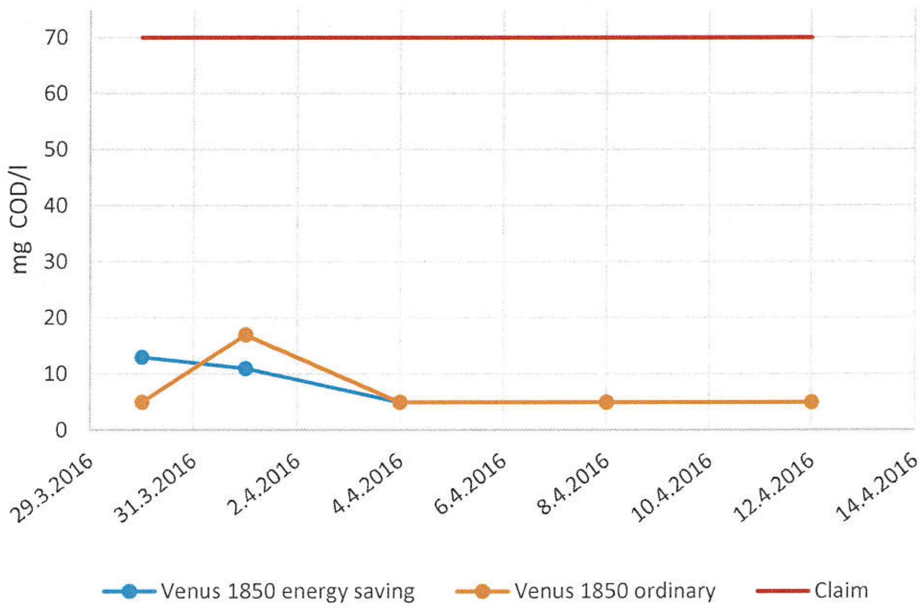

Figure 2: Development of effluent COD concentration after restarting the inflow to two BioKube systems (ordinary and energy-saving).

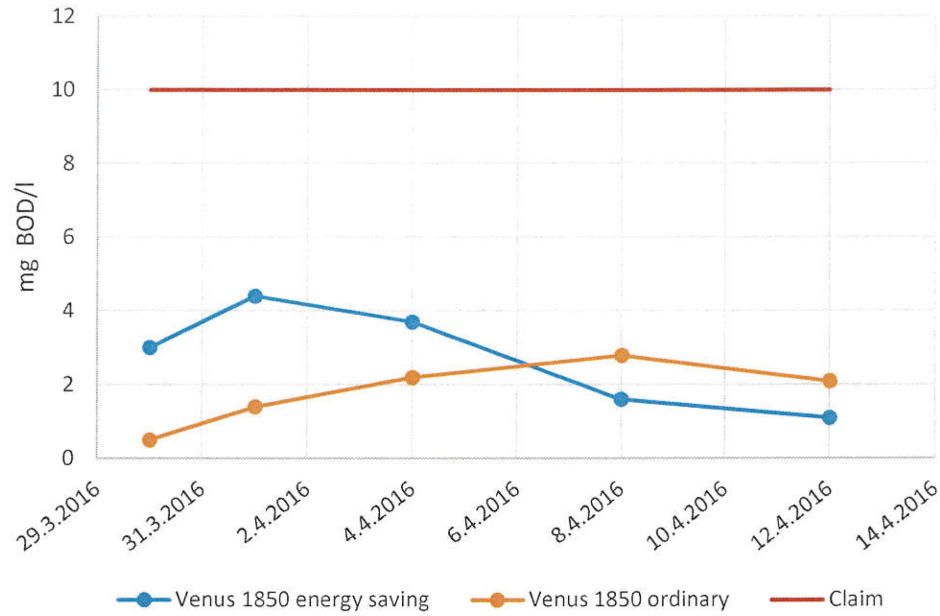

Figure 3: Development of effluent BOD concentration after restarting the inflow to two BioKube systems (ordinary and energy-saving).

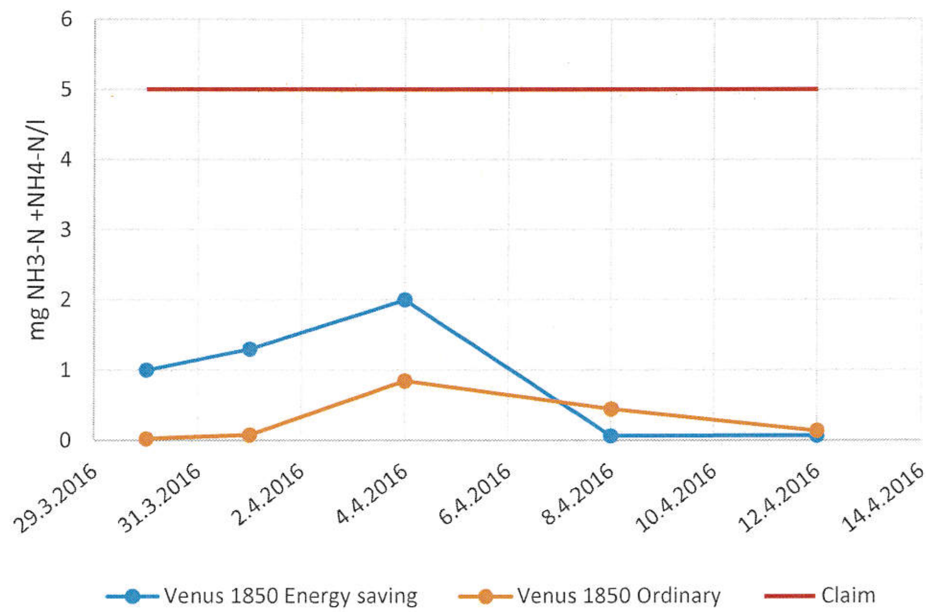

Figure 4: Development of effluent NH_3-N + NH_4-N concentration after restarting two BioKube systems (ordinary and energy-saving at Tappernøje WWTP.

The analytical results are for raw wastewater and effluent are presented in Table 3.

Table 3 Inlet and effluent quality from two treatment systems (ordinary and energy-saving) at Tappernøje WWTP.

Parameter	30-03-2016	30-03-2016	01-04-2016	04-04-2016	08-04-2016	08-04-2016	12-04-2016	12-04-2016
Energy-saving with P removal	**inlet**	**outlet**	**outlet**	**outlet**	**inlet**	**outlet**	**inlet**	**outlet**
COD (mg/l)	350	13	11	<10	210	<10	180	<10
BOD (mg/l)	160	3	4.4	3.7	62	1.6	72	1.1
NH_3-N + NH_4-N (mg/l)	16	1.0	1.3	2	21	0.065	24	0.071
Ordinary with P removal	**inlet**	**outlet**	**outlet**	**outlet**	**inlet**	**outlet**	**inlet**	**outlet**
COD (mg/l)	350	<10	17	<10	210	<10	180	<10
BOD (mg/l)	160	<1	1.4	2.2	62	2.8	72	2.1
NH_3-N + NH_4-N (mg/l)	16	0.024	0.079	0.85	21	0.45	24	0.14

Flow-controlled tests at WWTP - Energy consumption

During the dormant period without inflow of wastewater, the ordinary treatment system consumed 1.83 kWh/d, while the energy-saving treatment system consumed 0.76 kWh/d. **This corresponds to a 59% reduction of electricity consumption. Claim no. 2 regarding the energy-saving was therefore verified by the flow-controlled tests at the WWTP.** When the plants received wastewater again, their electricity consumption was similar Table 4.

Table 4 Energy consumption (kWh) by the energy-saving and ordinary treatment systems at Tappernøje WWTP during the dormant and active phases of the test period.

Treatment system	Dormant period (181 days)	Active period (13 days)
Energy-saving	0.76 kWh/d	1.79 kWh/d
Ordinary	1.83 kWh/d	1.70 kWh/d

Field tests at eight summer cottage installations - Compliance with effluent standards

Based on the samples and parameters (77 data points) included in the evaluation, the existing plants complied with the standards for 87% of the data points. The number of compliant data points and the total number of data points are shown in Table 5. The average concentrations and standard deviation of COD, BOD and NH3-N+NH4-N are presented. Only one of the eight existing plants at summer cottages had phosphorous precipitation installed.

Table 5 Compliance of existing plants with effluent standards

Parameter	Claim mg/l	Average mg/l	Std.dev. mg/l	Compliant / no data points	Data points when 5 PE design load exceeded / no. data points
COD	<70	46	32.3	22 / 24	2 / 24
BOD	<10	3.4	6.2	21 / 24	2 / 24
NH3-N + NH4-N	<5	5.5	13.9	21 / 25	2 / 25
Total P	<1.5	0.84	0.62	3 / 4	1 / 4

At two summer cottages, the design load of 5 PE was exceeded during Easter, according to the selv-reported usage data. This coincided with five of the ten non-compliant data points. Both of these houses had the energy-saving treatment system installed. For the remaining five non-compliant results, the energy-saving versions were not overrepresented. There were 3 non-compliant data points from the ordinary treatment systems, and 2 non-compliant data points from the energy-saving treatment systems. Further details are explained in the Verification Report. The complete dataset with the results for individual treatment systems is presented in the Test Report.

Field tests at eight summer cottage installations - Energy consumption

During the test period, the four ordinary treatment systems consumed 325 kWh on average (1.81 kWh/d, std.dev. 0.09 kWh/d), while systems with energy-saving technology consumed 113 kWh (0.62 kWh/d, std.dev. 0.17 kWh/d). **This corresponds to a 65% reduction of reduction of electricity consumption. Claim no. 2 regarding the energy-saving was therefore verified by the field tests.**

4.2 Operational parameters

Operational conditions during the tests are reported in the Test Report.

4.3 Environmental parameters

The main environmental parameters are effluent quality and energy consumption. These are reported as performance parameters.

4.4 Additional parameters

The user manual and the installation guide for sewer contractors were considered sufficient. No critical issues were identified with regard to use of resources.

5 Additional information

The treatment system depends on the function of electrical and mechanical parts and therefore requires yearly maintenance. The sedimentation tanks needs to be emptied, usually once a year.

5.1 Quality assurance and deviations

The verification was carried out according to the Quality Assurance Plan described in the verification protocol. During testing, internal and external audits were carried out by DHI and ETA Danmark, respectively. There were two deviations to the specific verification protocol and test plan:

1. The specific verification protocol postulated logging of the points in time, when the flow-switch was activated in the existing treatment systems used for the field test. This was not possible, since there was no logging capability in BioKube's treatment systems. Therefore, the successful operation of the energy-saving function was evaluated based on the measured energy consumption, combined with the users' self-reporting forms.

2. The specific verification protocol expected measurement of total phosphorous (total P) in the effluent from all BioKube plants with phosphorous precipitation. Due to an oversight made by the test body, phosphorous in the influent and effluent to/from the systems situated at the WWTP plants was not analysed by the external laboratory. Data from an identical phosphorous precipitation unit for the type-approval test (certification) of a BioKube plant was accepted for the verification.

None of two deviations were considered to have significant impact on the verification.