DEVELOPMENT OF OPERATION AND PERFORMANCE MONITORING GUIDELINES FOR ANAEROBIC INDUSTRIAL WASTEWATER TREATMENT PLANTS

Case Studies for Agro-based Industries in Germany and Egypt

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ABSTRACT

From past experiences of operation problems of anaerobic treatment plants, it is found that most of these problems may be due to insufficient design quality, resulted from using of incorrect or roughly assumed parameter values in the initial design. Then it was very obvious that the decision of design parameters must be considered as a part of the operation and monitoring of the process. The main subject of this paper is development and description of operation and plant's performance monitoring guidelines for the anaerobic treatment plants as a pre-treatment for industrial wastewater. The methodology of this paper comprised three phases of design, operation and performance monitoring guidelines: First, Pre-design phase, which in turns consisted of two types of experiments; a.) Triphenyltetrazoliumchloride TTC-tests were used for determination of biochemical activity of sludge as anaerobic inoculum and characterization of the effect of wastewater compounds on the dehydrogenase activity of sludge; b.) Anaerobic batch tests (ABT) were used for determination of anaerobic bio-degradability of wastewater. Second, start-up phase, in which the start-up procedure was discussed and defined; Third, operation/ Process performance monitoring phase, in which development and description of operation and plant's performance monitoring guidelines for the anaerobic treatment plants were illustrated. The paper also includes two case studies one from Germany and the other from Egypt for agro-based wastewater treatment by anaerobic process.

Keywords: industrial wastewater; food industries; anaerobic treatment; operation and monitoring; performance guidelines

INTRODUCTION

Anaerobic digestion has become the most frequently used method for the treatment of medium and high concentration wastewaters, due to the economy of the process, the low generation of surplus sludge, and winning of bio-energy by the biogas production (Van Haandel and Lettinga, 1994). Nowadays, the anaerobic technology has a very wide application in the field of anaerobic digestion whether for liquid or biosolid waste. High rate anaerobic treatment for industrial wastewater was first applied on commercial scale in the sugar industry in the mid 70's. Since that time the technology has developed into a standard method of wastewater treatment for a wide variety of industries. High rate anaerobic treatment for industrial wastewater was first applied on commercial scale in the sugar industry in the mid 70's. Since that time the technology has developed into a standard method of wastewater treatment for a wide variety of industries.

The technology is functional in over 65 countries and a total of approx. 1400 plants were built by the 16 leading vendors of such systems, 65% of the total number of these plants for industrial application. There are (in 1999) approx. 125 full scale anaerobic treatment plants in Germany for industrial wastewaters, 49 plants are working with a contact process, 38 with sludge blanket reactors UASB, 33 with fixed-film methane reactors, and the other 11 plants have completely stirred tank reactor, self-made construction, hybrid reactors, or the reactor type is not named (Haun, Meyer, Seyfried, and Rosenwinkel, 1999). ISAH institute has been involved in the research, design, or operation of 26 of these plants. The experiences were made with all types of reactor systems treating different types of industrial wastewaters. ISAH also is participating on several specialist groups of VDI (VDI-4630, 2003) and ATV (ATV-DVWK-IG 5.1, 2004) as well as publishing a lot of papers in that field last years. The main subject of this paper will be the development and description of operation and plant's performance monitoring guidelines for the anaerobic treatment plants as a pre-treatment for industrial wastewater. Also it includes the results of a case study of compliance and application of these guidelines in the food industry sector.

STATEMENT OF THE PROBLEM

Through the evaluation of operation and monitoring problems of anaerobic industrial wastewater plants in the past experience of ISAH and Cairo University whether in germany or in Egypt, it is found that most of these problems may be due to insufficient design quality, resulted from using of incorrect or roughly assumed parameter values in the initial design. Then, it was very obvious that the decision of design papmeters must be considered as a part of the operation and monitoring of the process. Therefore, a complete step by step operation and monitoring manuals including all of basic measurements and their frequencies must be implemented to gurantee the achievment of the plant peformance. ISAH, HBRC, and Cairo University have a lot of experiences in the agro-based industry by participating in solving of operation and monitoring problems in different factories in Germany as well as in Egypt, where the most popular problem was insufficent pollutants removal effeciencies by the anaerobic reactors, also in sometimes a complete failure in the process and non-compliance to the designed effeciencies and allowed regulations.

MATERIALS AND METHODS

The applied methodology was depending on discussing and defining the main phases controlling the anaerobic process, starting from design phase to the operation phase passes during start-up phase. Therefore the methodology could be summarized in the following main phases:

- ***Pre-design Phase***

This phase helped to give an expectation of the design parameters of the anaerobic UASB plants, two types of experiments were done: a) Triphenyltetrazoliumchloride TTC-test was used for determination of biochemical activity of sludge as anaerobic inoculum and characterization of the effect of wastewater compounds on the dehydrogenase activity of sludge; b) Anaerobic Batch Test (ABT) was used for determination of anaerobic bio-degradability of wastewater as well as determination of design parameters of sludge loading rate, hydraulic retention time, organic loading rate, temperature effect, as well as an expectation of treatment efficiency and biogas quantity and quality. The pre-design phase can be divided into:

TTC-Test:

The sludge is considered one of the most important issues governing the performance and efficiency of the anaerobic process in the reactor, therefore, the bio-activity of the sludge is very important to be measured as well as the inhibition effect of the wastewater on the sludge activity must be evaluated. Determination of the biochemical activity of sludge (granular and digested) by means of the dehydrogenase activity using 2, 3, 5-Triphenytetrazoliumchloride (TTC) had performed as a rapid pre-step test enables:

1) The determination of the biochemical activity (AS) of the sludge in terms of the µg triphenylformazane (TPF) per mg of the dry sludge mass.
2) The characterization of the effect of wastewater and wastewater compounds on sludge (stimulation or inhibition of the dehydrogenase activity DHA in percentage).

Anaerobic Batch Test (ABT):

In this study, the anaerobic batch tests are performed according to the guidelines of (VDI-4630, 2004), (DWA-IG 5.1, 2004) and (EN ISO 11734, 1998) and were used as a lab scale simple, low cost method to determine the biodegradation of industrial wastewater produced from agro-based food industry inoculated with granular sludge at different hydraulic retention times and different organic/volumetric and sludge loading rates, incubated at temperature 37°C as a potential to predict and decide: the applicable sludge loading rate; the best hydraulic retention time; sludge methanogenic activity; and the specific biogas production during the operation of the UASB reactor under the mesophilic temperature conditions. ABT was performed in 500 ml glass bottles sealed by silicon stoppers. Samples of raw and pre-settled wastewaters were inoculated with anaerobic granular sludge with different initial Sludge Loading Rates (SLR) of 0.2, 0.3, and 0.5 g COD substrate/g VS sludge.

Reference substrate: Sodium-acetate (CH3COONa) as a reference substrate (with good anaerobic biodegradation) was prepared in the laboratory with a COD-value near to those of the wastewaters to be used for the results' comparison.

Incubation: All samples were incubated at 37°C in shaking water bath provided with thermostat to control the temperature or in water bath provided with a magnetic stick connected to control device and stirrer had put inside the bottles for mixing between substrate and sludge to guarantee a good contact between them during the test time, Figure 1.

Figure 1: Incubation method used in the ABTs

Analyses and measurements:
Pressure inside bottles was measured during incubation according to the planed time intervals using digital pressure gauge provided by needle to penetrate through the silicon stopper of the bottles.
The analyses and measurements for the anaerobic batch tests can be classified as shown in Table 1.

Table 1: Analyses and measurements for the anaerobic batch test

			Wastewater	Acetate	Sludge	Substrate/sludge mixture	Biogas
Before the test (x) During the test (xx) At end of the test (xxx)	Analysis	Unit					
	COD_{total}	mg/l	x	x	x	x / xxx	
	$COD_{filtered}$	mg/l	x		x	x / xxx	
	COD_{ss}*	mg/l	x			x / xxx	
	VFA	mg/l	x	x	x	x / xxx	
	pH	—	x	x	x	x / xxx	
	TSS	mg/l	x				
	VSS	mg/l	x				
	TS	g/l			x	x / xxx	
	VS	g/l			x	x / xxx	
	Pressure	Bar					xx
	GC-test (CH_4, CO_2, H_2S)	%					xxx

* Calculated value = COD_{total} - $COD_{filtered}$

Start-up Phase

- *Preparation before start-up*

Before start-up phase of the anaerobic plant, the entire plant must be checked and inspected and all mechanical equipment should be tested and proven to be operational (dry run), also all instruments must be checked and calibrated.

- *Initial start-up*

The start-up procedure of the anaerobic plant "UASB reactor" is done using gradually increasing sludge loading rate by controlling the discharge of the inflow wastewater. At the beginning before the wastewater introduced to the bottom of the reactor, the required seed sludge volume is seeded to the reactor and whole reactor volume is filled with clean water and the temperature is adjusted to the norm temperature. The clean water was circulated for two days without any addition of wastewater to re-activate the seeding sludge as well as remove any residual COD in the sludge. Starting from the third day, 10% of design wastewater discharge is introduced daily to the bottom of reactor and all of the measurements for influent and effluent wastewaters and gas quantity and quality were done. The up-flow velocity during start-up is adjusted to 0.5-0.6 m/hr. Monitoring sheets were designed for recording the measurements as well as for the necessary calculation. Based on results stability of COD removal efficiencies and controlling the values of volatile fatty acids and pH in the reactor as an indication for good microbiological performance of the process, the start of steady state period is decided. Table 2 shows the recommended measured and calculated parameters during start-up phase.

Table 2: Recommended measured and calculated parameters during start-up phase

2-a) Measured parameters

Parameter	Influent wastewater parameters							
	pH	COD	TSS	VSS	VFA	TN	TP	T
Unit	–	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	°C
Fequency	daily	daily	daily	daily	daily	3/week	3/week	daily

Parameter	Effluent wastewater parameters							
	pH	COD	TSS	VSS	VFA	TN	TP	T
Unit	–	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	°C
Fequency	daily	daily	daily	daily	daily	3/week	3/week	daily

Parameter	Biogas		Sludge		
	Volume	GC	Volume	TS	VS
Unit	L	% CH_4/ CO_2	L	g/L	g/L
Fequency	daily	3/week	2/week	2/week	2/week

2-b) Calculated parameters

Parameter	For wastewater						For Biogas		For Sludge	
	Removal COD (COD_{rem})	Removal VFA	Removal TSS	Removal VSS	Removal N	Removal P	CH_4	Specific CH_4 production	Sludge Loading Rate (SLR)	Specific methanogenic activity (SMA)
Unit	%	%	%	%	%	%	L/d	L CH_4/g CODrem	g COD/g VS.d	g CH_4-COD/g VS.d
Fequency	daily	daily	daily	daily	daily	3/week	daily	daily	2/week	2/week

Operation/ Process performance monitoring phase

After the start-up period, when the reactor had a stable COD effluent characteristics and steady COD removal efficiencies within fixed range, it was considered as the "steady state" operation. The UASB reactor is run at steady state operation; the process performance parameters were measured, monitored and evaluated.

Sampling:
Wastewater sampling of the influent and effluent of the wastewater is made and collected the daily effluent from the reactor. Composite samples for 24 of the influent and effluent of the reactor are collected for analysis.
Sludge Composite samples of sludge in the reactor as well as samples along the reactor height are collected for analysis of volatile suspended solids as an indication of sludge bio-activity.

Analyses and measurements:
The analyses and measurements during the steady state operation of UASB plant can be classified as shown in Table 3, where Excel spreadsheets are prepared to record the measurements as well as automatic calculations of the process parameters such as COD, TSS, BOD, TP, TN removal efficiencies as well as gas quantity and quality inclusive the specific gas production, excess sludge volume and characteristics and specific methanogenic activity.

Table 3: Recommended measurements during operation phase of UASB plant and their frequency

Measured parameter	Abbreviation	unit	Calculation	Wastewater		Sludge		Biogas	Measurement Frequency
				Influent	Effluent	Initial seed	Excess		
Temperature	T	°C	direct	x	x	x	x	–	daily
pH	–	–	direct	x	x	x	x	–	daily
Total COD	COD_t	mg/L	direct	x	x	–	x	–	daily
Paper-Filtered[(1)] COD	COD_{pf}	mg/L	direct	x	x	–	x	–	daily
Membrane-Filtered[(2)] COD	COD_{mf} (COD_{sol})	mg/L	direct	x	x	–	–	–	3/week
Suspended COD	COD_{ss}	mg/L	COD_t-COD_{pf}	x	x	–	–	–	daily
Colloidal COD	COD_{col}	mg/L	COD_{pf}-COD_{mf}	x	x	–	–	–	3/week
Volatile Fatty Acids	VFA	mg/L	direct	x	x	–	–	–	daily
Volume of biogas	V_{biogas}	L	direct	–	–	–	–	x	daily
Total suspended Solids	TSS	mg/L	direct	x	x	–	–	–	3/week
Volatile Suspended Solids	VSS	mg/L	direct	x	x	–	–	–	3/week
BOD_5	BOD	mg/L	direct	x	x	–	–	–	2/week
Total Nitrogen	TN	mg/L	direct	x	x	–	–	–	3/week
Nitrogen- NO_3	NO3-N	mg/L	direct	x	x	–	–	–	3/week
Nitrogen-NH_4	NH4-N	mg/L	direct	x	x	–	–	–	3/week
Total Phosphor	TP	mg/L	direct	x	x	–	–	–	3/week
Sludge Volume	V_{slg}	L	direct	–	–	x	x	–	3/week
Sludge composition	VS, TS	g/L	direct	–	–	x	x	–	1/week
Gas Composition (CH_4, CO_2, H_2S)	GC	%	direct	–	–	–	–	x	1/week

[(1)] Folded paper filter 4.4 µm [(2)] Membrane filter 0.45 µm

For this study, two production facilities represent the agro-industry were selected one from Egypt and the other from Germany (Table 4). Composite samples from the different departments and the final effluents were collected. Physicochemical analyses were carried out according to the APHA (1998). Laboratory experiments have been carried out to assess wastewater characteristics in both.

Table 4: Basic Information about the Selected Factories

Item	Case Study 1 from Egypt	Case Study 2 from Germany
Main Products	Fructose 55% 75,000 t/y, Fructose 42% 25,000 t/y Glucose 30,000 t/y.	Milk-Snacks (Corn-flakes, Pop Corn,………etc)
Main Raw Materials	Maize 130,000 t/y, Acid, NaOH, Activated Carbon, Enzymes, Ion Exchange Resins, Ammonia, Sulfur.	Corn, Milk, fats, Chocolates, Ion Exchange resins, Acids, Enzymes.
No. of Employee	400	300
Working shifts	3	3
Wastewater discharge m^3/d	2400 -3000	240 - 400

Each facility has a wastewater treatment facility to comply with the environmental regulations. It is worth to mention that the main objective is to apply the proposed methodology for a successful start up for the anaerobic reactor aiming at standardization of the proposed procedure as a universal approach applicable in both developed and developing countries. The following paragraphs illustrate the wastewater characteristics and the main components of the existing wastewater treatment plant WWTP.

CASE 1: AGRO-INDUSTRY FROM EGYPT

Wastewater Characteristics

COD: 8000 g/m^3	BOD: 4800 g/m^3
TSS: 600 g/m^3	TDS: 7000 g/m^3
Organic DS: 4400 g/m^3	TKN: 120 g/m^3
NH3: 75 g/m^3	TP: 10 g/m^3

WWTP Description

The influent wastewater is directed to the equalization basins. The execution and operation of the equalization basin allows a very efficient pH buffering, pH-control and pre-acidification. Nutrients (N & P) are added in this equalization basin. In this basin a partly acidification of the carbohydrates takes place. At the same time the pH is controlled by a combined action of the effluent recycle flow, which recycles (bicarbonate)-buffering capacity on one hand. On the other hand, a further pH correction is possible with the addition of the NaOH or HCl if the pH value deviates too much from its set point. The conditioned and mixed flow is pumped to the anaerobic reactor.

The anaerobic reactor is an Up-flow Anaerobic Sludge Blanket reactor (UASB). In this UASB reactor, the influent is first distributed equally all over the bottom of the reactor, and then the wastewater rises through an expanded bed of anaerobic active sludge and a gas collection device at the top which results initially in a separation of the mixed liquor into biogas on one hand and a mixture of wastewater and sludge. On the other hand, the biogas is deflected and captured into the concrete gas domes. The effluent of the anaerobic reactor is partially recycled to the equalization basin. This is made to assure a minimum level in the equalization basin, to feed the UASB reactor at a constant flow rate, and to minimize consumption of chemicals. The effluent of the anaerobic treatment is then directed to the aerobic post treatment.

The aerobic post-treatment is provided with a selector. In the selector, the effluent from the anaerobic treatment is mixed with the recycled sludge from the clarifier. The aim of the selector is to generate a good quality of sludge. A high substrate concentration combined with a high substrate bio-sorption to the sludge improves the formation of heavy flocs and reduces the growth of filamentous organisms. The selector is highly aerated with a submerged aeration system to prevent that the redox potential wastewater would be too low before entering the aerobic post-treatment. The aeration basin is aerated with a surface aerator.

The effluent of the aeration basin flows by gravity to a clarifier, where the wastewater is separated in final effluent and a settling mixture of treated wastewater and sludge. The sludge is largely recirculated to the selector. The excess sludge is dewatered with a centrifuge. The dewatered sludge is then transported by trucks to the existing city dump-site; Figure 2 illustrates the process flow diagram.

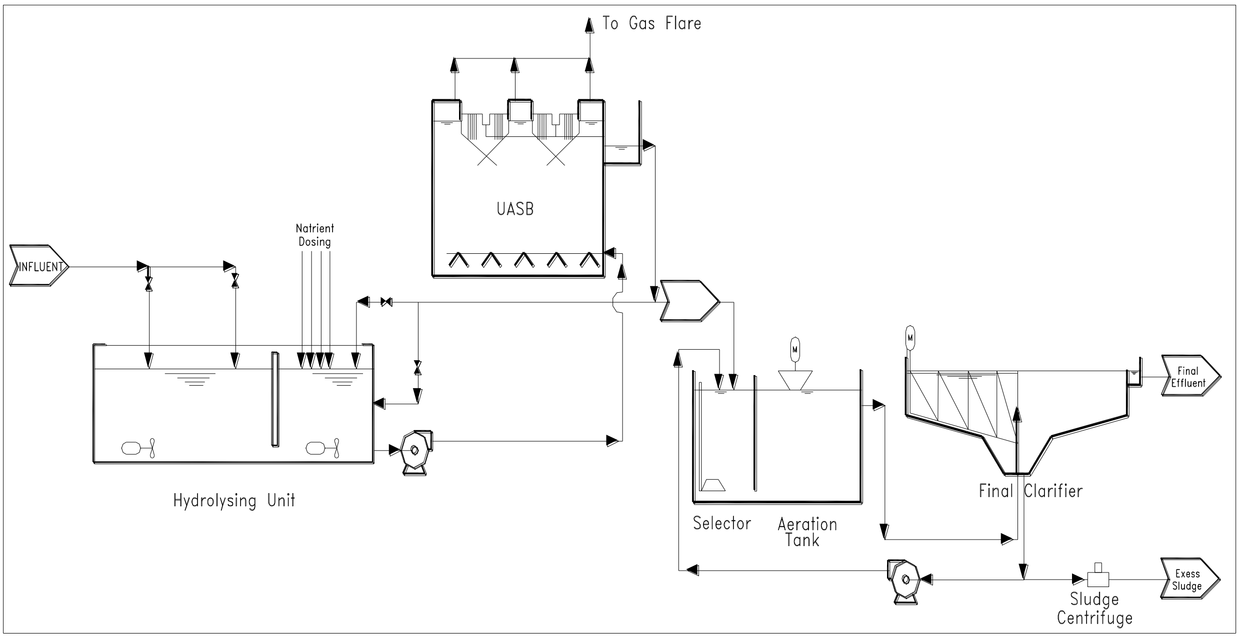


Figure 2: Process flow diagram *(Egyptian case study)*.

CASE 2: AGRO-INDUSTRY FROM GERMANY

Wastewater Characteristics

COD (hom): 9200	NO3-N: 6.5 g/m^3
COD (filt): 7843 g/m^3	TN: 22.5 g/m^3
BOD: 6305 g/m^3	SO4-S: 223 g/m^3
NH4-N: 17.9 g/m^3	TP: 10.7 g/m^3
Temp.: 25.3 °C	TP: 10.7 g/m^3

WWTP Description

The influent wastewater is directed to the hydrolysis tank (522 m^3) has retention time of 2 days the hydrolysis tank also plays as an equalizing tank. The execution and operation of the hydrolysis allows a very efficient pH buffering, pH-control and pre-acidification. In this tank a partly acidification of the carbohydrates takes place. pH correction is possible with the addition of the NaOH or HCl if the pH value deviates too much from its set point. The conditioned and mixed flow is pumped to the anaerobic reactor. Figure 3 illustrates the process flow diagram.

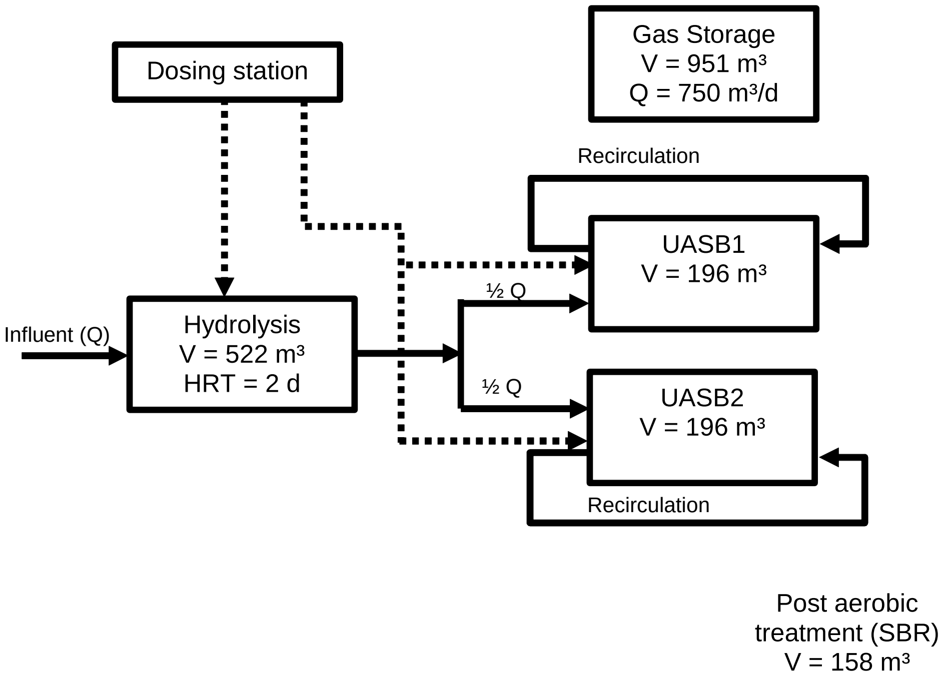


Figure 3: Process flow diagram *(German case study)*

The plant consists of two anaerobic reactors of UASB. In these UASB reactors, the influent is first distributed equally all over the bottom of the reactor, and then the wastewater rises through an expanded bed of anaerobic active pellets sludge initially collected from similar working reactor for seeding the plant; this sludge has a SMA of 0.8-1.3 g CH_4-COD/g VSS.d. Three phase separator is used to separate the biogas from treated wastewater and solids. The biogas is deflected and captured into the gas storage tank (950 m^3) as a potential to be used in energy generation. The effluent of the anaerobic UASB reactors is partially recycled again to the influent of the reactor to make a dilution for the incoming wastewater as well as to keep constant suitable up-flow velocity around 1 m/h for a good mixing between wastewater and the sludge blanket. Also this is made to assure to minimize consumption of chemicals. The effluent of the anaerobic treatment is then directed to the aerobic post treatment by means of SBR (158 m^3).

RESULTS AND DISCUSSION

Case Study 1: Agro-Industry from Egypt

During the study the quality and quantity of the sludge added to the UASB reactor as well as anaerobic biodegradability of wastewater was investigated. Several samples from wastewater and sludge were taken and sampled. The following paragraphs will explain the results obtained following the proposed methodology mentioned above.

Biodegradability of Influent Wastewater

The assessment of level of influent wastewater biodegradability based on the COD, a composite sample was taken and fed to anaerobic sludge having a Specific Methanogenic Activity SMA of 1 gm CH_4-COD/gm VSS.d The anaerobic sludge was obtained from a running full scale UASB reactor at a sugar factory. The mixture was incubated at 35°C and the produced biogas was collected measured. The composite wastewater sample has the following characteristics: COD total, 9400 mg/l; COD soluble, 9330 mg/l; and TKN, 144 mg/l. The measured accumulated biogas was 2400 ml with a CH_4 concentration of 63%. The batch test proved the anaerobic biodegradability of the influent wastewater. About 65% of the influent COD was transformed into biogas without acclimatized anaerobic sludge. No inhibitors were observed during the test.

Selection of source of the Anaerobic Sludge

Four sources of seeding sludge were investigated, two from the UASB it self; from the USAB bottom and 0.80 m above the bottom, one from digested municipal sludge DMS, and the fourth from UASB reactor in a sugar factory. The characteristics of the different anaerobic sludge samples from different sources are shown in Table (5).

Table 5: Sludge Characteristics of different Sources

Parameter	Units	Source of Sludge			
		USAB Bottom	USAB, 0.80m	DMS	UASB, SugarFactory
DS	%	6.30	0.86	4.83	1.79
VS	%	3.1	0.32	3.3	1.23
VS/DS	%	49.1	37.2	68.1	68.7
TSS	g/l		1.27		21.63
VSS	g/l		1.0		17.90
VSS/TSS	%		78.7		82.80

The SMA of different sludge was calculated the cumulated biogas production over 24 hours using the ethanol as a substrate. The SMA values expressed in g CH_4-COD/g VSS.d were as the following:

USAB Bottom	USAB, 0.80m	DMS	UASB, Sugar Factory
0.02	0.1	0.1	0.015

It is clear that all investigated sources of sludge have a poor SMA. However, the SVI of sludge from sugar factory will be checked to ensure the settlability of such sludge.

Sludge Volume Index SVI

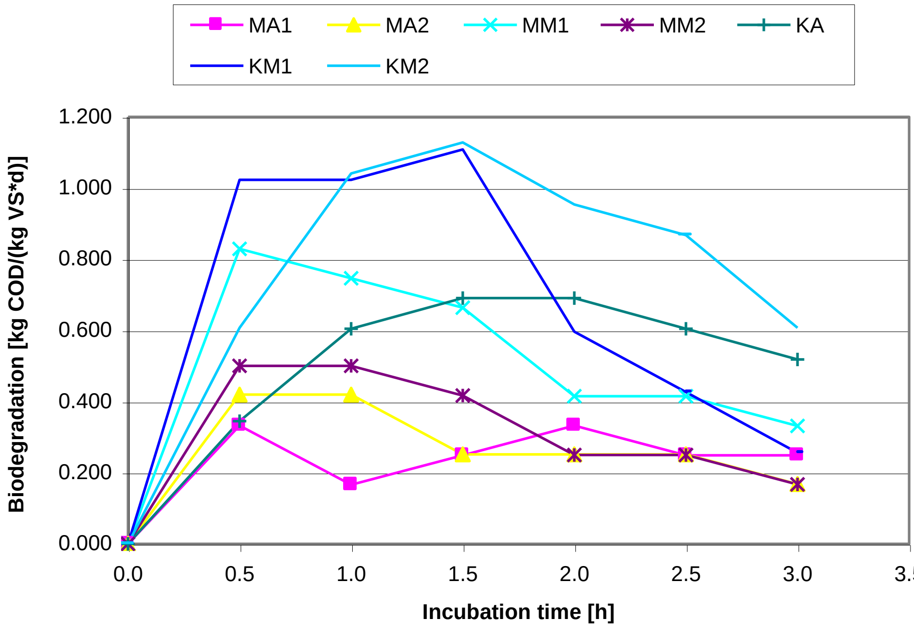
The pattern of SVI and SVI_{30} of the anaerobic sludge against time as well as the total anaerobic sludge in the reactor at 0.80 sampling point was investigated. It was observed that SVI is ranged from 57 to 150 ml/gm, while the amount of anaerobic sludge for the USAB was ranged between 2000 to 4000 kg VSS.

Case Study 2: Agro-Industry from Germany

During the study the characteristics of influent and effluent wastewater from of hydrolysis tank as well as of UASB reactors were observed. Also anaerobic biodegradability of wastewater was investigated as a pre-step to decide the most applicable sludge loading rate leads to best biodegradability. Several samples from sludge were taken for evaluation of sludge methanogenic activity. The following paragraphs will explain the results obtained following the proposed methodology mentioned above.

Biodegradability of Influent Wastewater (ABTs)

A composite sample was taken and fed to two different anaerobic sludges having a TS of 138 and VS of 113.2 (Pellets sludge S1) and TS 78 and VS of 57 g/L (Granulated sludge S2) with different sludge loading rates of 0.15 – 0.30 kg COD/kg VS.d The anaerobic sludge was obtained from a running full scale UASB reactor at Alcohol company. The mixture was incubated at 35°C± °C and the produced biogas volume was calculated by measuring the pressure. The composite wastewater sample has the following characteristics: COD filt, 7400 mg/l; pH 7.30. The ABTs proved the anaerobic biodegradability of the influent wastewater with 1.128 kg COD/kg VS.d during incubation duration of 3 hrs. Figure 4 shows the biodegradability results along incubation duration for different sludge loading rates (SLRs). No inhibitors were observed during the test.



KA: Acetate + S1 (SLR 0.299)
KM1: WW + S1 (SLR 0.299) KM2: WW + S1 (SLR 0.0.31)
MA1: Acetate + S2 (SLR 0.297) MA1: Acetate + S2 (SLR 0.15)
MM1: WW + S2 (SLR 0.295) MM2: WW + S2 (SLR 0.148)

Figure 4: Wastewater biodegradability along incubation time at different SLRs

Observed wastewater characteristics and treatment efficiencies among different stages:

Hydrolysis:
Figure 5 shows the influent flow rate and influent COD_{hom}, the hydrolysis and acidification rate was 40-60 % in the hydrolysis stage.

UASB reactors:
Also, Figure 6 shows the elimination and biodegradation COD in the UASB reactor where the elimination (degradation) rate was ranged between 85.4- 86.4 % of the total COD. The volumatric loading rate was with average value of 7.5 kg COD/m^3.d. the temperature inside UASB was kept at average of ca. 34°C and pH value was 7.2 in average. During the operation, the average hydraulic retention time was 40 h. the up-flow velocity was obseved as 0.8-1.0 m/h along operation period. The biomass bio-activity was average at 0.50 kg COD/ kg VS.d. The Methan content was 79 % of the total biogas concentration and specific gas production of 315 L/kg COD_{rem}.

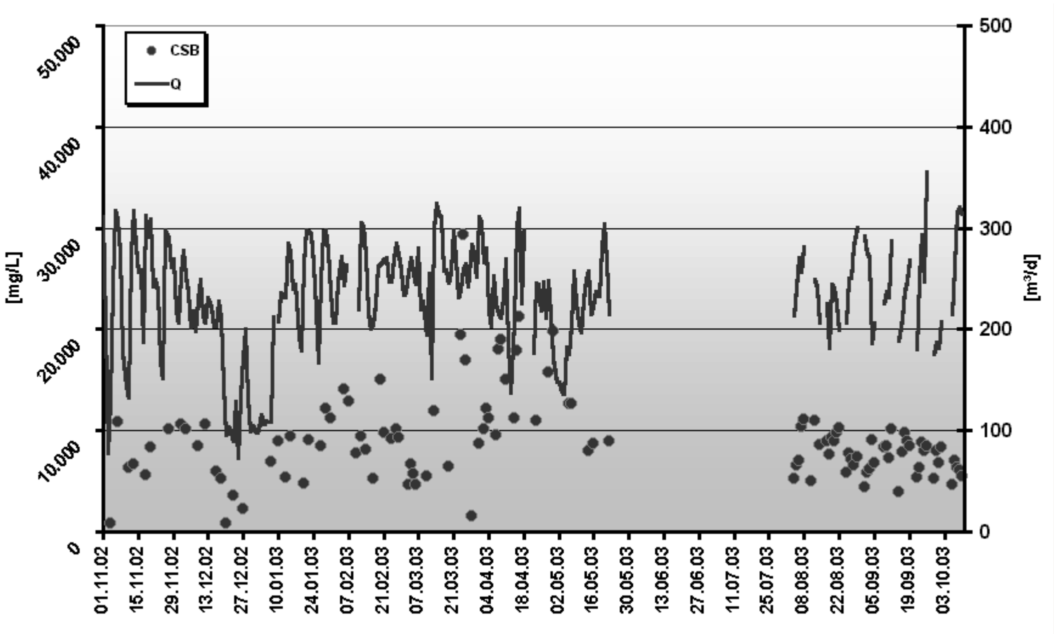


Figure 5: Influent flow rate and influent COD_{hom}

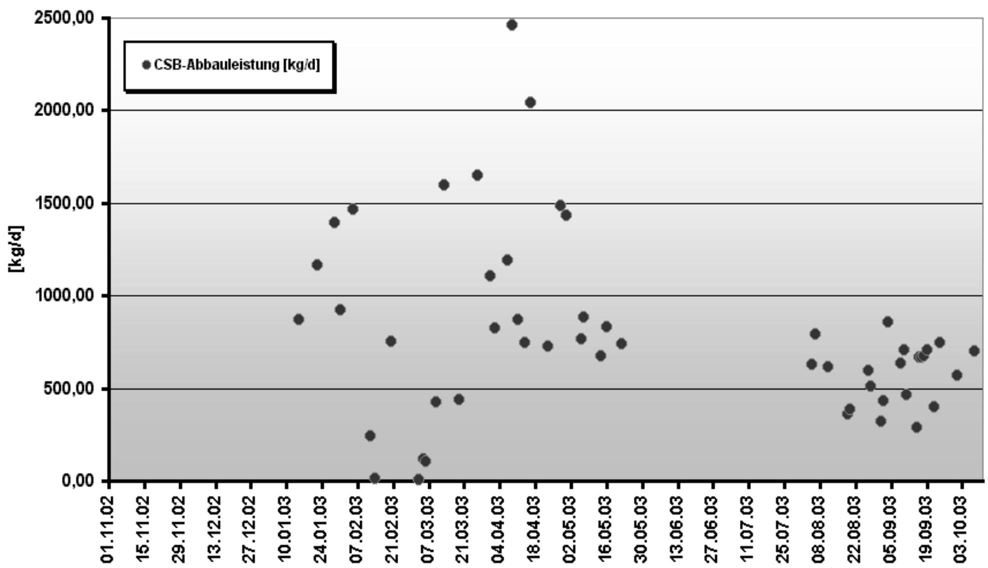


Figure 6: COD degradation in UASB reactor (Kg/d)

CONCLUSION AND RECOMMENDATIONS

For Case Study 1

Based on the implemented batch tests and the monitored performance of the UASB reactor it is recommended to follow the following actions to achieve successful start up:

1- Add more anaerobic sludge from the sugar reactor to achieve about 9000 kg VSS anaerobic sludge form up-flow reactor. Each sludge load should be monitored by sampling to calculate the organic fraction of the anaerobic sludge.
2- Add adequate amount of bio-available N and P in order to achieve the optimal ratio of COD/N/P of 100/1.25/0.25.
3- Based on the detailed influent wastewater analysis, it is concluded that some micro-nutrients are not available in adequate concentrations. These are Fe, Ca, Mo, and Co. It is therefore recommended to dose one of the chemicals to overcome this problem. As for the Fe, it is recommended to use FeSO4 at 2 mg/l influent.
4- To avoid the washout of poorly settling but active anaerobic sludge, it is recommended to control the up-flow velocity to 0.40 m/hr.

Plant Performance following taking the recommended Actions
The plant performance was observed after implementing the recommended start up procedures and actions. It is observed that the plant is able to achieve about 65-70% COD reduction in the USAB reactor. Then the aerobic reactor can achieve more than 90% COD removal complying with the environmental regulations.

For Case Study 2
Based on the implemented methodology and the monitored performance of the UASB, to keep effective anaerobic process in the UASB reactor the following steps must be taken into consideration and taking the following recommended actions:

1. The acidification rate must be kept min at 30-50 %
2. pH must be controlled and adjusted
3. Sludge blanket must be observed and protected against acidification and/or inhibition effect or organic load or temperature shocks.
4. Ammonium concentration (NH_4-N) must be controlled (> 500 mg/L)
5. Organic and volumetric loading rates must me kept at obtained applicable values as well as the sludge loading rate.
6. All analyses must be done periodically according to the mentioned procedure and frequency.

GENERAL CONCLUSION

In this study: it is proved that operation, monitoring and control of the anaerobic treatment plant should be integrated at the initial step of the design stage as well. Also, the study assisted to give comprehensive guidelines of operation and monitoring procedures for the anaerobic wastewater treatment plants using two anaerobic stages; Hydrolysis and methanogenic reactors. Also the anaerobic batch tests were successfully used as a simple technique for determination of wastewater biodegradability and initial determination of operating parameters as well.

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