

Palestinian experience with enhanced pre-treatment of black wastewater from Birzeit University using a UASB septic tank system

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Keywords

Anaerobic treatment, domestic wastewater, UASB reactors, treatment

Abstract

Successful implementation of the UASB (Anaerobic upflow sludge blanket) at pilot and full scale has produced very encouraging results that show its feasibility as a pre-treatment for black and domestic wastewaters. The economic advantages it offers, further encourages developing countries to become self-sufficient in this respect. In this contribution, the start-up of the UASB-septic tank system and its monitoring during this period was the main objective. A pilot scale UASB reactor with a liquid volume of about 400 L ($h=1.88\text{m}$ and $\phi=0.265\text{m}$) was fed with the black wastewater collected from the Faculty of Commerce at Birzeit University. During the start-up phase, the reactor was operated in a batch mode for six months and only shortly operated in a continuous flow mode. The results obtained demonstrated that the system is quite effective in removing organic pollutants. The removal rate of the organic pollutants was mainly due to bio-physical process, which is sedimentation of the particles and its microbial degradation. Although, the microbial activity was yet slow it contributed to the total COD removal efficiency. The $\text{COD}_{\text{total}}$ removal attained was approximately 80% in which the removal of COD_{ss} , COD_{col} , and COD_{dis} was 68%, 23% and 52% respectively. The UASB effluent has a good transparency with an elimination rate of 80% and 85% for TSS, and VSS respectively. This would facilitate a natural post-treatment (waste stabilization ponds), where photosynthesis and pH might increase. Based on the results obtained from this research study, the UASB-septic tank system offered practical advantages compared to conventional septic tanks through its small size, biogas collection and utilization, and elimination of odour problems. Furthermore, its ease of operation encourages its application in poor rural areas of Palestine.

Introduction

Conventional septic tank systems are world wide used for the house on site treatment of domestic sewage. The removal efficiency of these systems is however limited, moreover large volumes are generally applied. As the flow through systems is mainly horizontal, the purification is mainly due to settling of solids. The UASB-septic-tank is a promising alternative for the conventional septic-tank (Bogte *et al.*, 1993 and Lettinga *et al.*, 1993). The most important difference with the traditional UASB system is that the UASB-septic-tank system is also designed for the accumulation and stabilization of sludge. It differs from the conventional septic tank system by the upflow mode in which the system is operated, resulting in both improved physical removal of suspended solids and improved biological conversion. So UASB-septic-tank is a continuous system with respect to the liquid, but a fed-batch or accumulation system, with respect to the solids. Application of these modified septic tank systems, was

studied under Dutch (low) and Indonesian (high) ambient temperatures. Zeeman and Lettinga (1999) recommend the use of modified UASB septic tanks for the improvement of the removal efficiencies especially for low temperature regions or regions with a period of short winter period, like Middle East. Therefore, this study will investigate the performance of UASB septic tank system. The black wastewater discharged from the Faculty of Commerce at Birzeit University will be tested.

The realization of the necessity to reconsider seriously the management of the existing water resources, either due to its scarcity or the concern of its pollution has motivated expertise in the water sector to search for alternatives. Consequently, the reuse of the domestic wastewater is a potential alternative for the semi arid country of Palestine, as well as many surrounding countries in the Middle East. The increasing urbanization and industrialization in Palestine have dramatically increased the amount of generated wastewater. With the very limited existing disposal systems throughout the country, Palestine is now threatened by this waste which may infiltrate and pollute its underground water resources unless measures are taken to alleviate this dilemma. Thus the new treatment process that offers a substantial promise is the Upflow Anaerobic Sludge Blanket (UASB) technology.

Complex wastewaters containing a high amount of suspended solids will limit the performance of a one phase anaerobic UASB system (Zeeman, 1999). The accumulation of these compounds in the sludge bed will reduce the sludge retention time (SRT) and the methanogenic activity of the sludge. This problem was perceived by Hulshoff Pol and Lettinga (1991) when they stated, 'For the treatment of partially soluble complex wastewater the required removal efficiency of the SS should be given attention'. Thus with the implementation of this pre-treatment method, it is necessary to consider the strength of the wastewater. The wastewater in the West Bank is classified as a strong domestic wastewater due to the high concentration of pollutants such as COD, TKN, phosphorous, sulphate, ammonia, SS and VSS.

Materials and methods

Experimental set-up (UASB-septic tank)

The set-up of the UASB reactor is shown in Figure 1. A holding tank, preceding the UASB reactor, will serve as a balance tank and as a primary sedimentation tank. The incorporation of the holding tank will provide a partial removal of the solids, which will be accumulated and experience further stabilization. The reactor was inoculated with 200 litres of anaerobic sewage sludge from pilot anaerobic ponds treating wastewater from Birzeit University. The specific methanogenic activity was 0.07 g COD/g VSS.d. The inoculum characteristics and the operational conditions are shown in Table 1.

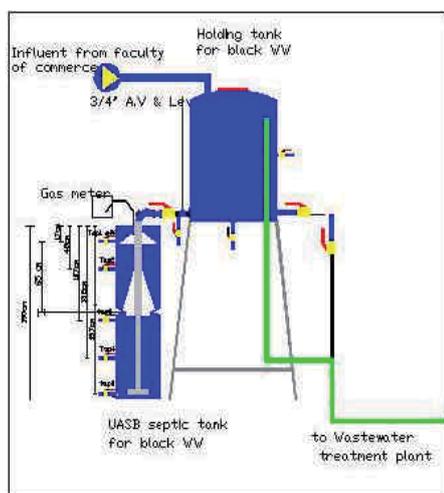


Figure 1: UASB septic tanks and holding tanks

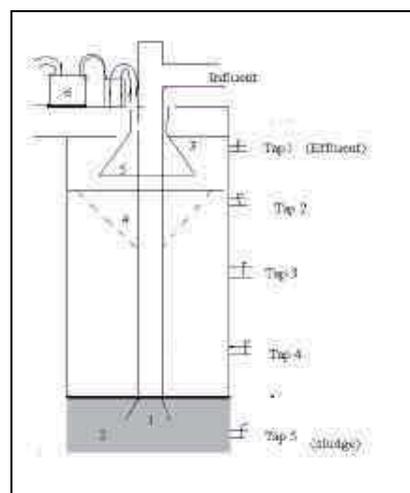


Figure 2: A schematic diagram of the 0.4 m³ UASB-pilot plant

Parameter	Unit	UASB septic tank-BZU
Hydraulic retention time	hr	16
Sludge concentration	kg VSS/m ³	13.9
Methanogenic activity	g COD/g VSS.d	0.07
Upward velocity	m/h	0.12

Table 1: Start-up conditions of the UASB septic tank at BZU

Results and discussion

Inoculation

According to the measured wastewater quality, the reactor needs to be started with a 1kg of inoculum. When inoculum of sludge of about 0.1-0.08 g COD/g VSS methanogenic activity is used (Lettinga et al., 1991). Although the seeding of the reactor was during the second week of April till the end of May, the actual monitoring period was during June and July were the ambient temperature range was from 22°C - 28°C. The influent sewage temperature was 24.54°C which was almost similar to the effluent temperature. The influent's pH was in the range of 8.0-8.3, and the effluent pH was about 7.5.

The COD_{tot} removal efficiency attained an average value of 76% considering the entire period of operation. The major contributor to the COD_{tot} was the removal of suspended solids. The average removal efficiencies for COD_{ss} was 91%, the COD_{col} was 71% and COD_{dis} was 43%.

With respect in the removal of the TSS and VSS efficiencies, the average removal efficiency was 58% and 53% for the TSS and VSS removal efficiency, respectively. Tap 5 contents a high concentration in Tss and Vss due to settling of suspended solids.

Parameters ⁺	Black Wastewater Characteristics		
	Sample no.	Average	STD
COD Total	20	1013	262
Suspended	5	784	162
	Colloidal	5	162
	Dissolved	5	155
BOD	6	458	109
NH ₄ ⁺ as N	10	21	2
Total P as P	6	11	3
PO ₄ ³⁻ as P	8	10	3
TSS	11	715	285
VSS	11	401	212
TKN	3	41	3
pH	19	8.02	0.37
T _{ww}	19	28.8	2.2
Colour	Grey (fresh) – Black (old)		

⁺All unit in mg/l

Table 2: Characteristics of wastewater generated from the faculty of Commerce/ Birzeit university

Conclusions and Recommendations

The UASB-septic tank system can efficiently perform as a pre-treatment unit during summer period. The average removal efficiencies for suspended COD (COD_{ss}), Colloidal the COD_{col} and dissolved COD (COD_{dis}) were respectively 91%, 71% and 43%.

More research is required to monitor the reactor performance over the whole year especially during the winter period; and consequently the system should be optimised, e.g. amount of inoculums, desludging period, etc.

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Specific quantification of pathogenic and indicator organisms in digester samples using quantitative real-time PCR (qPCR)

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Keywords

Anaerobic digesters, cattle manure, indicator organisms, hygiene, pathogens, qPCR

Abstract

Pathogenic (micro)organisms present in environmental samples can be quantified by cultivation techniques. However, techniques of molecular biology may be applicable more efficiently. Cattle manure and digester samples were analyzed for pathogens and indicator organisms by Quantitative Real-Time Polymerase Chain Reaction (qPCR). Similar quantities were obtained in comparison to cultivation techniques. However, analysis by qPCR required less time and in some cases indicated higher values for distinct organisms. This might be due to the presence of cells that can not be cultivated but detected with qPCR, or to different specificities.

Introduction

Anaerobic digestion of solid waste is considered as a profitable reuse technology that allows the recycling of end products. Biogas is produced and the digest may be used as fertilizer e.g. in agriculture. However an efficient hygienization step should be included in the process to prevent sanitary risks before applying the product as soil conditioner.

Pathogens and indicator microorganisms can be quantified by conventional cultivation techniques, but these exhibit serious disadvantages: they are frequently time and material consuming, cannot detect active but non-cultivable (ABNC) germs, and frequently lack adequate specificity. If indicator organisms are analyzed, results may not allow extrapolation for the behavior of recalcitrant pathogens.

Pathogenic (micro)organisms can be quantified by qPCR. This molecular technique offers a convenient rapid and specific alternative to conventional cultivation in various application areas, e.g. for hygiene monitoring of environmental samples, such as organic waste or wastewater.

The scope of a joint project of Bavarian research institutions and local water suppliers is to evaluate the potential of a three-stage anaerobic digestion process for the environmentally sustainable and economical control of pathogens. In the frame of this project, we develop and evaluate qPCR systems for the specific quantification of hygienically relevant microorganisms and viruses in cattle manure, digest, soil, and water samples.

Here we present selected preliminary results obtained from qPCR and parallel cultivation techniques.

Methods

Cattle manure and samples from anaerobic digesters connected in series (mesophilic, thermophilic, mesophilic) were analyzed and quantified for pathogens and indicator microorganisms using qPCR on DNA-extracts. An optimized protocol for nucleic acid extraction from reactor samples was applied using a standard spiking technique and modified kit-based protocols (Lebuhn et al., 2003). This protocol greatly reduces coextraction of PCR inhibitors, such as humic acids and allows to assess the method detection limit. Cultivation based analyses (selective plating, MPN-analyses) were performed in parallel.

Results and discussions

According to Table 1, the development of bacterial numbers from manure and digester samples assessed by qPCR is consistent with results from cultivation. For fecal enterococci, qPCR results exceeded those from cultivation by a factor of 10 to 100. This may be due to the presence of ABNC cells that cannot be cultivated, or to dead cells, or to different specificities of the systems used. As expected, bacteria with relatively low tenacity (*E. coli*, enterococci) efficiently decreased in the fermenter cascade, whereas the spore formers and thermophiles remained constant (Tab. 1). Quantities of *Campylobacter jejuni* were at or below the detection limit of the system. In comparison to cultivation techniques, detection by qPCR can be performed in a short time (only 6 hrs) and it is cost effective. It also provides high sample throughput (96 measurements simultaneously), high specificity and sensitivity; and it allows the determination and quantification of ABNC cells. Our results suggest, that qPCR may substitute conventional cultivation routines.

Bacterium Bacterial group	Cattle manure		Mesophilic digester 1		Thermophilic digester		Mesophilic digester 2	
	qPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)	qPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)	qPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)	qPCR (DNA equivalents per ml sample)	Cultivation (CFU or MPN per ml sample)
<i>E. coli</i>	1.0 - 1.3*10 ⁵	3.0 - 4.6*10 ⁵	3.19*10 ³		<1.0*10 ² - 1.96*10 ³		1.11*10 ²	
Fecal coliforms	4.0*10 ⁵	n.d.		1.1*10 ³		2.3*10 ¹		<3.0
<i>Enterococcus faecalis</i> , <i>E. faecium</i>	8.95*10 ⁴ 1.37*10 ⁶		1.4*10 ³		< 1.0*10 ² 5.8 - 15.4*10 ²		5.9*10 ² 1.17*10 ³	
Intestinal enterococci	3.5*10 ⁶	2.9*10 ⁵		1.3*10 ³		4.0*10 ²		1.0*10 ²
<i>Clostridium perfringens</i>	n.d.		<1.0*10 ² - 1.1*10 ³		<1.0*10 ² - 6.4*10 ²		1.42*10 ³	
<i>Clostridium perfringens</i>		5.5*10 ²		n.d.		n.d.		n.d.
<i>Bacillus cereus</i> group	7.0*10 ³		n.d.		5.1*10 ³		4.6*10 ²	
<i>Bacillus cereus</i>		2.0*10 ⁵		2.0*10 ³		<1		1.15*10 ³
<i>Campylobacter jejuni</i>	0.8 - 2.6*10 ¹		n.d.		< 1.0*10 ²		n.d.	

n.d.: not determined

CFU: colony forming units

MPN: most probably number

Table 1: Preliminary selected results from qPCR and cultivation analyses of different digestion stages of cattle manure

References

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Source separation of domestic sewage components and integrated management with organic fraction from MSW

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Keywords

Anaerobic co-digestion of food waste and domestic wastewater separated fractions, domestic wastewater fractions separation; greywater phytotreatment

Abstract

A pilot facility has been constructed at the University of Padua to investigate the scientific and technical aspects of a new approach to integrate wastewater and solid waste management. This paper presents the first results from a system that treats separated wastewater flows by the phytotreatment of greywater and the anaerobic co-digestion of food waste and faecal matter.

Introduction

The current discussion regarding the sustainable management of domestic wastewater and solid waste is based on concepts such as avoidance, source separation, recycling and reuse. On the one hand, a clear trend has been taken towards a systematic look at the different domestic wastewater fractions, foreseeing new strategies and potentialities for treatment and management of these fractions, and on the other hand, it is also recognised that there is a need to integrate the treatment of these fractions with the management of domestic solid waste, in the search for integrated sustainable solutions (Cossu et al, 2001). A pilot facility has been constructed in the IMAGE Department at the University of Padua with the purpose of studying the scientific and technical aspects of this approach. This paper looks at the first experimental results obtained and the further steps that are being taken in this direction.

Facilities description

The pilot facility consists of an experimental WC with a special source control device for the separation of urine (yellow water) and faecal matter (brown water), including individual flushing systems and a separate collection pipe for each fraction. Greywater (from the washbasin) is also kept separate from the other fractions. These three fractions flow to individual tanks that are equipped with mixers, level detectors and electrical automatic valves for periodic discharge. At the entrance of the toilet, a photocell system is installed to count the number of users. Thus, while greywater is conducted to a constructed wetland for phytotreatment, brown water is mixed with food waste and then treated in an anaerobic reactor at lab scale. In Figure 1 an scheme of the facilities is presented.