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EFFECT ON ANAEROBIC DEGRADATION OF ORGANIC MATTER AFTER THICKENING PROCESS

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ABSTRACT

The objective of this research work presented in this paper is to study the effect of thickening on anaerobic degradation of organic matter. The stability is illustrated in terms of the performance of the methanogenic activity along the experimental period as well as the maximum reduction of organics pollutants inherent in the experimented sludge samples.

The experimental work was conducted in a batch processing system under temperatures (40, 45, 50 °C) to stimulate the optimum conditions of the degradation process. The experiments have continued until the gas production has ceased. The results show a reduction efficiency of 79.8% of COD, 95.5% of BOD and 85.9% of TS within about 58 days at 40 °C. Measured increase of reduction was obtained with the increase of operating temperature up to 50 °C. In addition, the study approved the independency of complete digestion period on the operating temperature. The study assures that the COD/BOD ratio has increased strongly indicating production of high quality digested sludge. Also, the specific methanogenic activity, SMA, is increasing with temperature. The experiments measured the parameter of M factor which presents the percentage of the removed COD that is converted into methane gas, accordingly, the M factor express the actual digestion performance of organic matter. The experimental results revealed that the M factor was almost the same for all temperature range explaining the main obstacle of anaerobic digestion of domestic sludge.

KEYWORDS: Sludge Stabilization; Thickening Effect; COD Balance; Sludge Stability; Anaerobic Digestion; Methane Production; Organic Matter; Complete Treatment

INTRODUCTION

The main sources of sludge at municipal wastewater treatment plants are primary sedimentation tanks and secondary clarifiers. In normal cases, primary sludge and secondary sludge are mixed together to perform combined raw sludge that is handled up commonly in the sludge treatment units. In some cases, the excess secondary sludge may be returned to the primary sedimentation tanks to give ultimately a single sludge stream consisting of combined sludge. Raw sludge may contain large volumes of water. Thus, more problems with handling and disposal of this sludge exist particularly with anaerobic sludge digestion. In accordance, it is a common practice to reduce the water content of raw sludge to decrease the problems with handling and disposal.

The most popular method used for reduction of water content before anaerobic digestion is thickening. Thickening of sludge is used to concentrate solids and reduce the original volume so as thickened sludge requires less digester capacity and smaller piping and pumping equipment for transport. In other hand, the activity of anaerobic bacteria can enhance due to reduction of the dilution ratio of solids inside the anaerobic digesters. At medium and large sized municipal plants, sludge thickening and anaerobic digestion are by far the most widely selected treatment scheme.

The products of anaerobic digestion of organic matter are methane, ex-organics, and relatively small amounts of cellular protoplasm. The process progress is limited by the availability of hydrogen acceptors. The process can be divided into three phases: hydrolysis, acidification, and methanogenization. The digestion process can be influenced strongly by the interference of the intermediate hydrolysis and acidification that may occur during thickening process due to retention in thickeners. This is depending mainly on the physical and chemical structure of organic matter. The partial hydrolysis and/or acidification during thickening may enhance the anaerobic destruction extend (conversion into methane) which is leading in accordance to enhance the specific methanogenic activity (SMA) of methane anaerobes.

Study Objective

The purpose of the present experimental work is to assess the validity of thickening process effect on the anaerobic degradation extend of organic matter of domestic sludge under thermophilic conditions in a batch digestion system and determine the relationship between the specific methanogenic activity and the operating temperature of the digestion process.

Experimental Setup

The present experimental work has been conducted in batch reacting system at temperatures of 40, 45 & 50 ^{o}C to cover the range of the thermophilic conditions. Each temperature has been investigated in two identical one-liter reactors and provided also with another similar reactor filled with tap water as a blank to justify the experimental results according to the operating conditions. Figure 1. shows the details of the experimental setup of the prevailing study. The six reactors have been filled with the same sludge and the same volume so as the only parameter can be varied is temperature (per each two reactors). The experimental setup is facilitated to measure the gas production as well as taking up sludge samples for analysis. The analysis of samples includes chemical oxygen demand (COD), biological oxygen demand (BOD_5), solids (including all fractions), and all physical parameters. The gas production has been measured using Marriot flask system (liquid-displacement) as shown in Figure 1. The gas has been flowed before measuring through sodium hydroxide solution for moisture absorption.

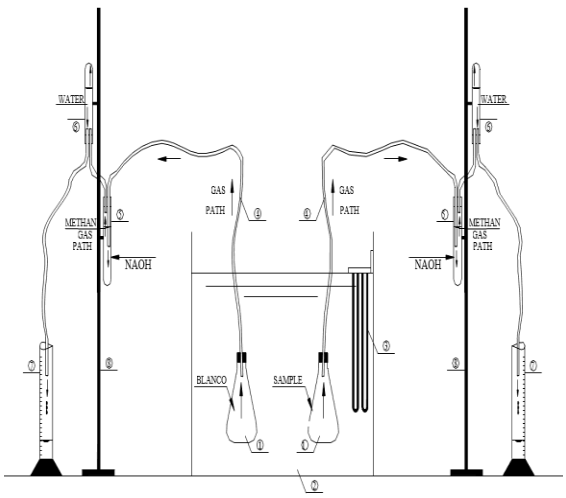


Figure 1: The Details of the Experimental Setup of the Prevailing Study.

Seed Sludge

The experimented seed sludge has been collected at El-Berkah WWTP where all the experimental work has been conducted. The seed sludge was thickened sludge (mix of primary sludge and waste activated sludge) and taken at the sump of sludge pumping station feeding the anaerobic digesters. Table 1. shows the physico-chemical characteristics of the experimented seed sludge.

Table 1: The Physico-Chemical Characteristics of Expermintal Seed Sludge

Parameter	Symbol	Unit	Value
Hydrogen Ion Concentration	pH-value	--	5.90
Total chemical oxygen demand	COD	mg/l	7810
Biological Oxygen Demand	BOD	mg/l	2180
Total solids	TS	mg/l	25760
Total Suspended Solids	TSS	mg/l	24332
Volatile Suspended Solids	VSS	mg/l	19317
Fixed Suspended Solids	FSS	mg/l	5015
Total Dissolved Solids	TDS	mg/l	1429
Volatile Dissolved Solids	VDS	mg/l	6130
Fixed Dissolved Solids	FDS	mg/l	816
Density	δ	kg/l	1.80

Sampling & Analysis

Small sludge samples were collected periodically every two or three days from each flask for analysis. At the same time of collecting samples, gas production was also measured via the water displaced in the collecting jar.

Before analysis, sludge samples were diluted five times or ten times according to sample strength to suite, the gauge range of the analytical devices. Chemical Oxygen Demand (COD) was analysed using spectrophotometer while Biological Oxygen Demand (BOD_5) was analysed using Oxymeter. All fractions of solids have been also determined by separating the coarse solids fraction, the colloidal fraction, and the soluble fraction. For each fraction, both organic and inorganic portion is determined by drying the filtrate at 105˚C then igniting at 600˚C. All analysis was according to Standard Methods.

RESULTS

Table 2 summarizes the performance of anaerobic degradation of thickened sludge at different temperatures with respect to COD, BOD, solids reduction and all other parameters shown in the table. Table 2 shows also, the average specific methanogenic activity (SMA) along with the total experimental period. It shows also M-Factors values at different temperatures. M-Factor refers to the percentage of the removed COD ($COD_{removed}$) that is converted into methane gas ($COD_{converted\ into\ methane}$). Hence, M-Factors express the actual digestion performance of organic matter.

Parameter	Temperature		
	40 ºC	**45 ºC**	**50 ºC**
Total BOD Reduction (%)	95.5	96.3	96.7
Total COD Reduction (%)	79.8	82.2	84.9
pH-value at Start	5.9	5.9	5.9
pH-value at End	6.63	6.65	6.66
Total TSS Reduction (%)	85.9	85.7	84.4
Total VSS Reduction (%)	85.1	85.3	84.7
Total FSS Reduction (%)	89.2	87.1	83.4
SMA (gCOD-CH_4/gVSS/day)	0.007707	0.009166	0.012037
Exp. Period (days)	58 (70)*	62 (70)*	58 (70)*
M-Factor	0.265	0.261	0.260
Density (δ) at Start	1.80	1.80	1.80
Density (δ) at End	2.20	2.20	2.20
Period between parentheses was the real experimental period.			

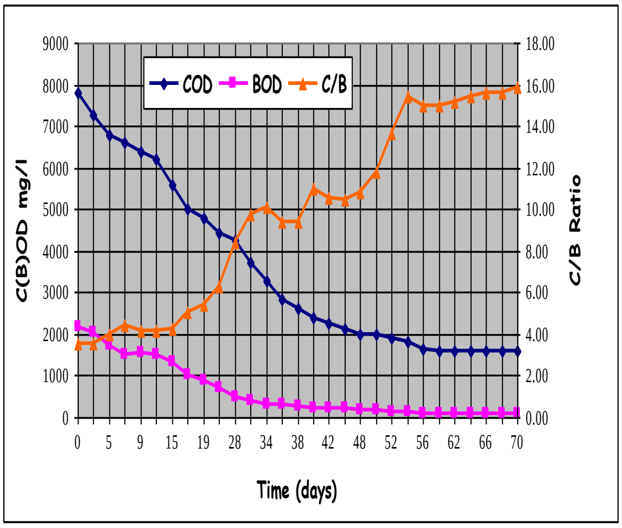
Table 2: The Anaerobic Degradation Performance of Thickened Sludge

Figure (2), Figure (3) & Figure (4). show the reduction of COD and BOD_5 (mg/l) versus time in combination with C/B (COD/BOD) ratio at all operating temperatures 40, 45 & 50°C. The C/B ratio indicates the biodegradable organic matter content of the total organics quantity.

The specific methanogenic activity of sludge is illustrated by the progress of the incremental specific methanogenic activity with experimental time. The incremental specific methanogenic activity (SMA gCOD-CH4/gVSS/day) is the rate of methane gas production (g COD-CH_4) during the time increment period between samples collection (T_i day) from the biomass bulk (g VSS_i), hence:

$$SMA = \frac{\mathrm{g\ COD\text{-}CH_4}}{\mathrm{T_i}\ day \times \mathrm{g\ VSS_i}}$$

The experiments ran until the gas production was vanished whereas the remaining organics are considered as slowly biodegradable or non-biodegradable fraction. Fig.(5), Fig.(6) & Fig.(7) present the progress of sludge activity (SMA) with experimental time for all experimented temperatures. The figures are provided with plotting the cumulative removed COD (Cumulative COD_{rem}) as well as cumulative methane gas production (Cumulative COD-CH_4) to assess the retained removed COD (Cumulative COD_{ret}). Curves plotted in Fig.(5), Fig.(6) & Fig.(7) are also provided trend lines (dashed lines) regressed to the suitable power to try to formulate the relationship between each parameter with digestion time. The regression of specific methanogenic activity (SMA) curve shows a corrupted coincidence with the original points ($R^2 \leq 0.777$). The fluctuation of gas production is apparent and is always leading to complicate prediction of uniform analytical relationship.



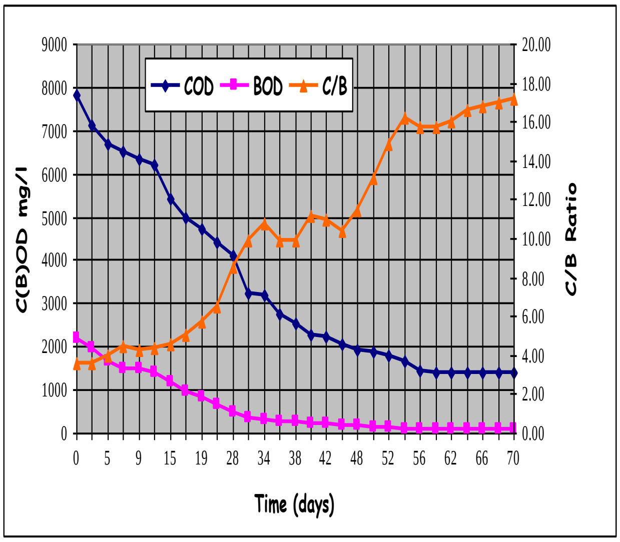


Figure 2: COD & BOD Reduction of Thickened Domestic Sludge at 40°C.
Figure 3: COD & BOD Reduction of Thickened Domestic Sludge at 45°C.

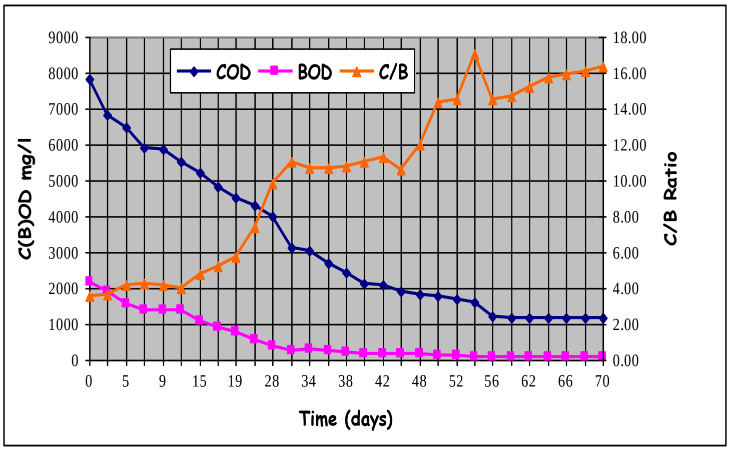
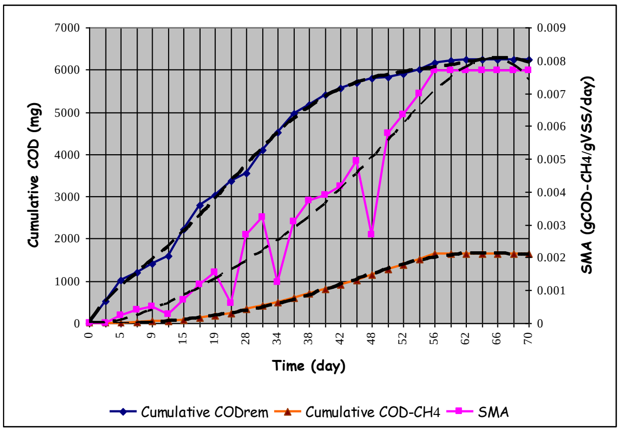


Figure 4: COD & BOD Reduction of Thickened Domestic Sludge at 50°C.

The experimental period considered for plotting curves is the total time elapsed until the end of the experiment that was longer than the time of gas production vanishes. Actually, the removal (adsorption) of organic matter does not stop completely although gas production vanishes. It seems in Figure (5), Figure (6) & Figure (7) that gas production vanished after about 56 days but the removal of COD continued slightly till the day 70th from the beginning of the experiment.



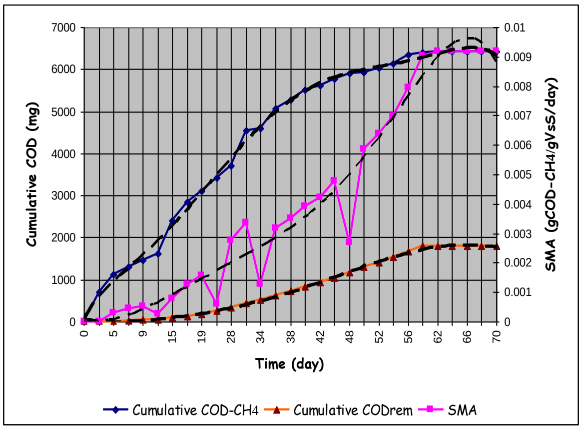


Figure 5: SMA Performance during Digestion of Thickened Domestic.
Figure 6: SMA Performance during Digestion of Thickened Domestic Sludge at 40°C Sludge at 45°C.

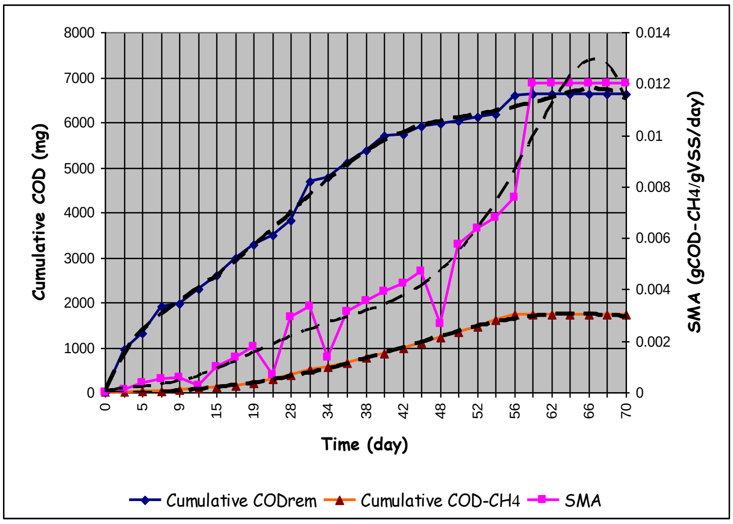


Figure 7: SMA Performance During Digestion of Thickened Domestic Sludge at 50 °C.

To elaborate the direct relationship between the specific methanogenic activity (SMA) of the experimented thickened sludge and temperature, the inherent specific activity is plotted against the experimented temperature as shown in Figure(8).The dashed line – shown in Figure (8) - represents the trend of the plotted curve of the relationship, confirms a very powerful regression of the intended relation (R^2 = 1.0). The sludge activity below 40°C does not match the same trend which is laying in methophilic digestion range, hence the point (0,0) doesn't represent any analytical effect of the derived formula.

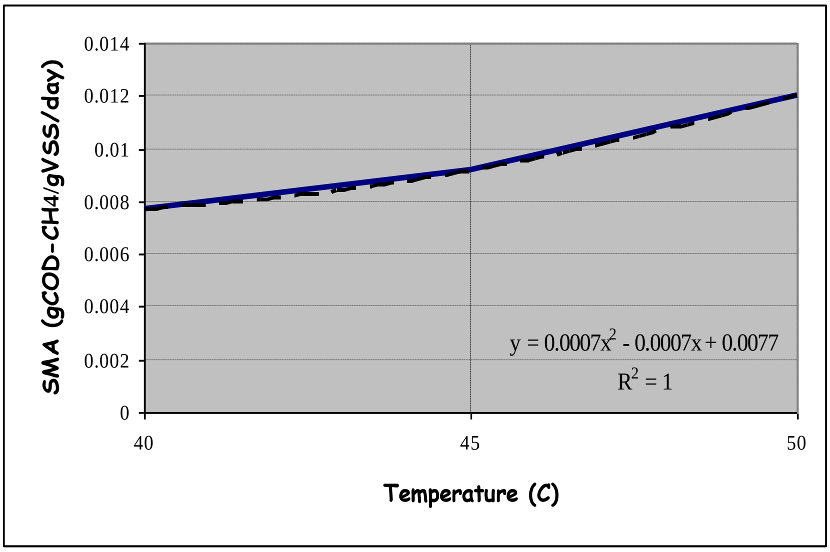


Figure 8: Relation of SMA & Temperature During Digestion of Thickened Sludge.

DISCUSSIONS

The destination of thickened sludge digestion is normal practice for sludge treatment particularly in big size plants. The prevailing study assures that thickening has a great effect on the digestion performance with respect to organics reduction or organics converted into methane. The results shown in Fig.(2), Fig.(3) & Fig.(4) reveal that more than 95% of biodegradable organic matter (BOD) have been removed completely. The COD/BOD (C/B) ratio has increased strongly indicating production of high quality digested sludge.

On other hand, the results shown in Table (2) indicate that the M-Factor is almost the same for all the experimented temperature but a considerable increase of COD reduction with higher experimented temperature is prevailing. The specific methanogenic activity (SMA) is also increasing with temperature. It is the fact that more operating temperature, more sludge activity is drawn. The constancy of M-Factor whatever the operating temperature explains the under loading condition which is always performs the main obstacle of anaerobic digestion of domestic sludge. This trend is always apparent whatever type of digestion is; methophilic or thermophilic.

The performance of removal of organic matter or gas production scheme did not alter greatly with operating temperature as shown in Fig.(5), Fig.(6) & Fig.(7). The trend regression lines are almost coincidence with the actual curves. However, the activity performance along the experimental period corrupts with its regression greatly. The uniformity of organics removal rate as well as cumulative gas production rate along with the interruption of methanogenic activity reveals the all the bacterial consortiums were suffering sharp lack of food. This means that anaerobic digestion of low-strength complex sludges induces serious technical and operating problems to the powerful anaerobic bacterial consortiums.

The effect of temperature is apparent in Fig.(8) which reveals the high increase of specific methanogenic activity with temperature. In spite of the scientific rule of this concept which is assessed herewith, the process performance is gone according to the main operating parameter of food (biodegradable organics) availability with respect to content and complexity. Also the values of the recorded specific methanogenic activities are still low with respect to the high operating temperatures.

CONCLUSIONS

The following conclusions can be apparently drawn regarding the stability of anaerobic degradation of organic matter under thermophilic conditions:

- Thickening has a great effect on the digestion performance with respect to organics reduction or organic converted into methane.
- Complete digestion of domestic organics under thermophilic conditions can reduce more than 95% of BOD and 80% of COD and 85% of the TS of the inlet load.
- The COD/BOD ratio has increased strongly indicating production of high quality digested sludge.
- The maximum efficiency was recorded after a period of 58 days, where the complete digestion has taken place, independent on the operating temperature.
- Small portion of organic was converted to methane. M-Factor (COD removed into methane/COD removed) was recorded to be about 0.26 in all operational temperatures (40, 45 and 50 ºC).
- The methanogenic activity of anaerobic sludge increases with digestion time until all biodegradable organic is completely digested.
- The anaerobic degradation process should be designed according to the required digestion time (days) and the corresponding maximum methanogenic activity (gCOD-CH4/gVSS/day) complying with the processed sludge characteristics and composition and the operating temperature.

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