EFFECTS OF HIGH VOLATILE SOLIDS CONCENTRATION UPON THE TREATMENT EFFICIENCY AND GAS PRODUCTION IN THE ANAEROBIC TREATMENT OF ALCOHOL WASTEWATER

By

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Licenciado en Quimica

Universidad de Oriente

1982

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
Master of Science
December, 1985

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ACKNOWLEDGMENTS

I want to give special thanks to my sponsor, "Instituto Nacional de Obras Sanitarias," for providing the financial support needed to obtain this degree. I would also like to extend this acknowledgement to my major adviser, Dr. Enos L. Stover, for his teaching and assistance given when needed. Also, to Dr. Don F. Kincannon and Dr. Veenstra is this acknowledgment extended for their instruction and advise.

Very special thanks are given to my beloved wife, Nohelia, who with her confidence, understanding, and love knew how to encourage me when times got rough.

I would also like to thank my friend and fellow countryman, Reinaldo González, for his unconditional help given throughout my attendance at Oklahoma State University.

I wish to give thanks to my friends Kar and John of the Bioenvironmental Engineering Department.

I also wish to thank all of those who helped with the typing and editing of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

One of the areas which has received a second look as a means of producing energy, while reducing the pollutional effects of organic wastes, is that of anaerobic treatment. Anaerobic treatment has been used since the earliest part of this century in the stabilization of human wastes, as well as to some extent those wastes coming from livestock and fruit and vegetable waste production. A review of the literature of recent years shows that there has been a renewed interest in anaerobic treatment as an energy-conserving and waste treatment technique. This process may provide industries with two important things; (1) a potential source of energy from biomass, and (2) wastewater treatment (1, 2, 3).

The process of anaerobic digestion involves the multiplication of microorganisms by metabolizing organic matter in the absence of oxygen. End products of this conversion are methane, carbon dioxide and cell mass. The methane produced at this stage is used as a fuel gas. In some industries it is a means of supplementing energy supplies while disposing of the by-product and waste materials.

The decline in oil supplies and the increase in the price of these supplies in the mid 1970's have led to considerable interest in ethyl alcohol as an alternative fuel to petroleum and its derivatives, or as a supplement to hydrocarbon fuels. Ethanol is produced via fermentation of agricultural products such as sugarcane, sugar beets, and grains (milo and corn). Throughout this process, long-chain polysaccharides are enzymatically hydrolyzed to sugars, which in turn are converted to alcohol and carbon dioxide by yeast in an aqueous medium.

In order to obtain ethyl alcohol as the main product, distillation is needed. It has been established that during the production of alcohol from grains, the quantity of water spent is about 16 gallons per every gallon of alcohol produced (4). The wastewater coming out of this type of process is of high temperature, low pH and high organic strength. Before these wastewaters are discharged, grain solids are screened and the effluent results in what is referred to as the "thin stillage."

The characterization of these wastewaters has already been reported (5), as well as the biological treatment kinetics developed for an anaerobic suspended growth system (6). From those studies it was found that fuel alcohol wastewaters can be treated very effectively via the processes already mentioned and that the gas produced in such systems could be used as an energy source (7, 8).

The gas resulting from the anaerobic fermentation of the soluble part of the thin stillage typically has a composition of between 70 and 80% methane with carbon dioxide making up most of the remaining fraction (8). Methane is a clean burning fuel gas, transportable and storable, thus allowing the wastewater to serve as an energy saver instead of resulting in disposal costs.

The objective of this research was to investigate the effects of high influent volatile suspended solids concentrations upon the gas production and treatment efficiency of an anaerobic suspended growth reactor. If, as it is hypothesized, gas production increases in conjunction with increases in the influent solids content, then it would be of great importance, since small increases in gas yield may greatly improve the net energy balance of digestion.

In this investigation the wastewaters were obtained from the Oklahoma State University Agricultural Engineering's 200,000 gal/yr fuel alcohol plant. Once in the research facility, they were pumped into the bench scale, complete mix, continuous flow activated sludge suspended growth system.

CHAPTER II

LITERATURE REVIEW

Wastewaters From the Fuel Alcohol Industry

The basic process in producing alcohol as a fuel substitute is fermentation. Such an approach has the same basic steps that are followed in any other commercial industry for the production of ethanol, and almost the same waste by-product.

The fermentation of grains such as wheat, corn, and milo, as well as sugarcane and sugar beets, followed by hydrolysis of long chain polisaccharides to sugars, produces alcohol in an aqueous medium which is extracted via distillation. This process requires the use of large amounts of water. The grain solids and yeast solids remaining mixed with water is referred to as the "whole stillage." After centrifugation of the "whole stillage," a "thin stillage" is produced which contains a high concentration of soluble and colloidal matter (yeast solids).

The wastewater is high temperature, high organic strength and acidic, thereby making it amenable to anaerobic treatment (9). The disposal of these wastewaters has always been of concern to investigators, as well as to the industries producing them due to environmental laws and antipollution regulations. Studies regarding the treatability of such wastewaters have been performed extensively.

Sheehan and Greenfield (10) reviewed methods for handling distillery wastewaters. They observed that anaerobic treatment followed by aerobic polishing of the supernatant is attractive due to the production of energy in the form of methane, which can be used at the distillation stage. Badhakrishnan et al. (11), using cane molasses distillery wastes in anaerobic digestion, found that if the wastewater is diluted, digester loading can be much higher than when raw waste is used. Dahab and Young (12), investigated the composition of wastewater produced by small-sized stills used for the production of grain alcohol, as well as the operational characteristics of those stills and found that the stillage can be treated effectively with anaerobic filters. It should be mentioned that this wastewater was simulated and did not duplicate the waste one hundred percent.

Basu and LeClerc (13), using molasses distillery wastes digested at mesophilic and thermophilic temperatures, concluded that mesophilic digestion is preferred due to the high cost of running a digester at 55°C, although thermophilic digestion gave slightly better results. Stafford et al. (14), reported that anaerobic digestion produces better reduction of the pollution load, in a fermentation effluent than the following alternatives as shown below:

Treatment	BOD Reduction (%)
Chemical	10
Electrodialysis	28
Activated Sludge	30
Trickling Filters	72
Anaerobic Digestion	83

The high-organic strength wastewaters produced from the grain alcohol production process have been the subject of extensive characterization studies at the Bioenvironmental Engineering Laboratories of Oklahoma State University. These studies included both aerobic and anaerobic biological treatment of this waste, and they have provided very important information with regard to the capability of biological treatment to handle these high organic strength wastewaters. A review of the anaerobic treatment studies that have been performed at these laboratories during the last three years follows.

Stover and Gomathinayagam (5, 8), found in the anaerobic treatment of synthetic fuel (alcohol production) wastewater that in the recycle and reuse potential of both stillage solids and waste activated sludge (WAS), the protein and carbohydrate content of both were essentially the same; indicating that the mechanism of conversion of the soluble organics in this waste to biological solids, for use as cattle feed, to be an important asset of biological treatment. Stover (15), investigated the suspended growth anaerobic treatment of these same wastewaters and concluded that the methane produced during anaerobic digestion could be used as an energy source within the alcohol plant. The quality of the methane was determined to be a function of the food to microorganism ratio (F/M) or sludge retention time (SRT) operating condition of the system.

Stover et al. (16), in another investigation compared batch and continuous flow anaerobic suspended growth activated sludge systems and observed similar conclusions with regard to treatment capabilities; but with one difference: the reaction kinetics of the batch and continuous systems appeared to be different due to volatile acid accumulations in the batch system above a certain F/M ratio. These studies indicate that extreme caution should be used in designing batch anaerobic treatment experiments to develop data for future use in designing continuous flow systems. Also, Stover and coworkers (8, 19). compared suspended growth and fixed film anaerobic treatment digesters fed with grain alcohol production wastewaters and found that either type of anaerobic system is capable of achieving very high treatment efficiencies, as well as excellent methane production capabilities. In these studies removals of 99.4 and 97.5 percent (95.8 and 96.1), in terms of soluble BOD (COD), applied to the suspended growth and fixed film digesters, were obtained along with methane production rates of 19.1 and 13.9 $ft^3 CH_4$/lb sol. BOD removed (9.0 and 9.9 $ft^3 CH_4$/lb sol. COD removed) respectively. Stover et al. (18), developed biological kinetic constants for design and operation of anaerobic fixed-film biological treatment systems using the same substrate and found that the methane production and gas quality kinetics defined in terms of soluble BOD and COD, were a function of the total applied substrate loading rate. Gomathinayagam and Gonzalez (18), addressed start-up problems pertinent to suspended growth and fixed-film anaerobic digesters. Also, they developed a nomagraphic chart to size an actual reactor (for suspended growth) based upon the biological kinetics obtained from the anaerobic treatment of the grain alcohol production wastewater (soluble fraction).

In another important investigation Stover et al. (20), described a graphical method for comparing the substrate removal and gas production in terms of the food to microorganisms ratio (F/M) and substrate loading (FSi/A). This comparison was based upon kinetic modeling approaches in which the substrate utilization and gas production were expressed as a function of the mass substrate loading rate by monomolecular kinetics. Stover et al. (20), reported the successful operation of both anaerobic suspended growth and fixed film reactors fed with the grain alcohol production wastewater (soluble fraction), and concluded that the fixed film reactor has potential advantages over the conventional contact process such as:

1. smaller tankage required
2. larger inventory of immobilized biota
3. more stable systems operations
4. and even higher loading rates.

Keenan and Kormi (21), using brewery by-products as the substrate for an anaerobic reactor, investigated the energy recovery potential in the brewery industry via the production of methane gas through the fermentation of such by-products. They found that the waste is amenable to mesophilic anaerobic fermentation and that methane production declines as the loading rate increases, whereas it increases as the retention time increases. They reported gas productivities at standard conditions of temperature and pressure (STP) of approximately 0.30 liters per gram of volatile solids added with a methane percentage of 60 to 65% by volume. These investigations showed that the generation of methane can be used as a means of resource recovery from brewery industrial waste and proved the technical feasibility of such a process.

Solids Destruction and Anaerobic Digestion

Anaerobic treatment is widely used as a means of stabilizing waste organic sludges. This method of stabilizations is very attractive due to its ability to achieve a high degree of solids destruction at a low operating cost. This eliminates the costs and problems associated with aeration, along with the added benefit of methane production, making anaerobic digestion the method of choice for many treatment schemes. The biodegradable organic matter coming into an anaerobic reactor most of the time is made up of two fractions: (1) a soluble part which is assumed to be readily biodegradable, and (2) a second fraction that is particulate and assumed to be slowly biodegraded.

The degradation of the macromolecules depends on several factors such as shape, surface area, the presence of specific bacterial groups that can biodegradate those solids and chemical composition. It has been found that of the three major components: lipids, cellulose, and proteins, lipids biodegradation was slower than in the other two types of compounds. This fact suggested the existence of several different reactions catalyzed by different groups of bacteria.

Early works by Schulze (22), showed that by gradually adding dry solids to the anaerobic digester it was possible to obtain normal methane fermentation of solids concentration up to 37 percent of dry solids as long as the volatile acids stayed in a range of 1000 to 2000 mg/L. A unit operating under similar conditions at up to 39 percent solids produced only one half as much gas per day for corresponding feed rates when the average volatile acids concentration was greater than 4000 mg/L. Hawkes and Horton (23) performed a literature review and found a relationship suggesting that in the digestion of sewage sludge gas yield increased with increasing influent volatile solids.

In tests conducted by Mueller et al. (24), anaerobic digesters were loaded at different rates while the retention time was kept constant. It was found that at increased loading rates an increase in total volatile acids, alkalinity, suspended solids in the supernatant, and the proportion of CO_2 in the gas occurred. Also, the total gas production per unit of volatile matter added per unit of time, the volatile solids reduction, and the relative quantity of acetic acid increased.

Webb and Hawkes (25), studied the mesophilic anaerobic digestion of poultry litter and found that gas yield increased when the percent of volatile solids in the influent increased. The mean methane composition was 59%. However, Fisher et al. (26), found an opposite effect when working with swine manure as substrate. They found that as influent volatile solids increased less methane was produced per gram of volatile solids added to the digester. However, total methane production (liters of CH_4/day) increased up to an influent solids concentration of 70 g/L. These two investigations were performed using batch feedings to the reactors.

Using the gas production rate as a direct indicator of the condition of the gas producing bacteria, the diagnosis of an anaerobic digester can be monitored very effectively. This rate has been found to be dependent upon the substrate loading rate (23); in monitoring it a sudden change either in composition or methane production rate is of critical importance if the system's economics depends heavily on the recovery of usable energy.

Although some of the investigations reported here were done with volatile solids, other than those coming from grain alcohol production, the point that the author wants to make is that only limited research has been performed in this area of anaerobic digestion of high strength industrial wastewaters with high concentrations of volatile suspended solids.

CHAPTER III

MATERIALS AND METHODS

The wastewater used in this study came from the OSU Agricultural Engineering fuel alcohol plant which had a 200,000 gal/yr capacity. The stillage collected was stored at room temperature until its usage as substrate for the anaerobic treatment studies. The characteristics of this stillage feed is similar to those reported by Gomathinayagam, G. (7), and Stover, et al. (15, 16). Table I presents these characteristics.

BOD, COD, SS, VSS, and pH analyses were conducted immediately on the stillage samples upon arrival at the research facilities for the studies reported in this investigation.

Anaerobic Suspended Growth Treatment Unit

The bench scale plexiglass unit used in this investigation was completely sealed, but had openings in its top for influent flow, release of the gas produced, and control of the Mixed Liquor Suspended Solids.

The mixing tank volume was 7.5 liters and the settling tank had a volume of 3.5 liters. Figure 1 shows a graphic description of the system used.

The flow rate of the incoming substrate was kept around 2.88 L/day, which gave a hydraulic retention time of 2.60 days.

TABLE I

RAW WASTEWATER (THIN STILLAGE) CHARACTERISTICS **

Parameter*	Corn Feedstock		Milo Feedstock	
	Mean	Standard Deviation	Mean	Standard Deviation
TS	32,200	9,300	42,800	2,150
TDS	18,600	7,100	20,400	6,800
SS	11,800	3,700	22,500	5,100
VSS	11,800	3,500	19,500	2,600
Total COD	64,500	12,600	75,700	12,100
Soluble COD	30,800	6,200	40,700	9,100
Total BOD_5	26,900	800	34,900	2,000
Soluble BOD_5	19,000	2,100	21,700	1,360
Soluble TOC	9,850	2,200	14,900	2,600
Total P	1,170	100	1,280	100
Soluble P	1,065	75	1,075	150
Total TKN	755	115	--	--
Soluble TKN	480	95	--	--
Soluble NH_3-N	130	60	--	--
Total Protein	4,590	650	--	--
Soluble Protein	2,230	780	--	--
Total Carbohydrate	8,250	750	--	--
Soluble Carbohydrate	2,250	550	--	--
Soluble Glucose	1/4 750	--	--	--
pH (range)	3.3-4.0	--	--	--

* All units in mg/l except pH.

** From reference #7

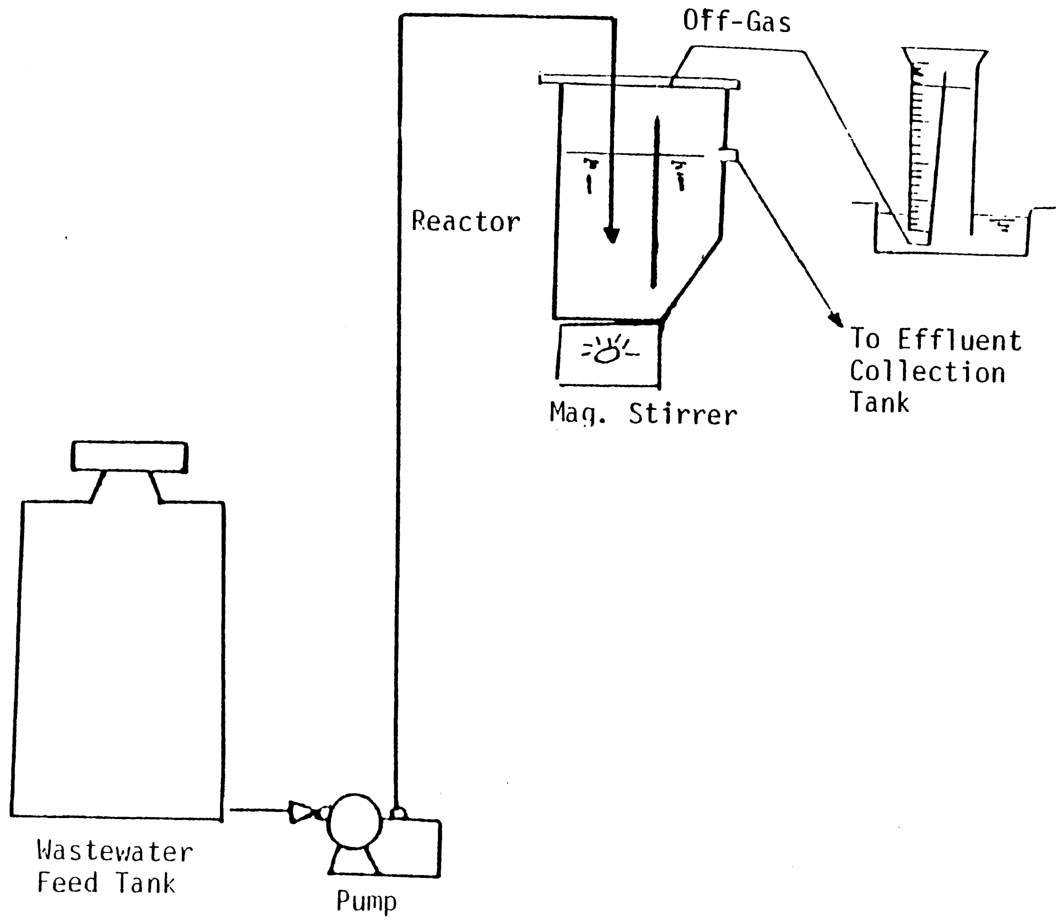

Figure 1. Schematic of the Complete Mix Anaerobic System

BOD, COD, gas production, pH, volatile acids, and alkalinity were the parameters used to monitor the performance of the biological system. Suspended solids concentration and volatile suspended solids concentration were the other parameters followed in operation of the system. Determination of volatile acids, alkalinity and their ratio (VA/ALK) were used as a fast and reliable method of evaluation of the anaerobic system. Sodium hydroxide was added to the feed in order to raise its pH to approximately 8.5.

The temperature of the reactor was maintained between 33°C and 38°C, which was a good range for the growth of the mesophilic bacteria inside the reactor. The gas released as a final product of the anaerobic process was collected and measured using a graduated glass column filled with water which was later displaced by the gas produced. The total gas production was measured in liters/hour and its quality determined by allowing the CO_2 content to dissolve in a KOH saturated solution. The difference in level measured represents the percent of CO_2 in the off-gas (27).

Analytical Procedures

Chemical Oxygen Demand, COD

The COD test was conducted on the samples following the Hach modified method (28).

Biochemical Oxygen Demand, BOD_5

The BOD_5 test on the samples was determined according to The Standard Methods for the Examination of Water and Wastewaters 15th Edition procedure, with a seed correction factor applied to the acclimated microorganisms. The dissolved oxygen in the sample was measured using an oxygen electrode by Orion Research, Model 97-08-00.

pH

The pH of the different samples was measured using a digital Ionalyzer by Orion Research, Model 601A and an Orion pH Combination Electrode, Model 91-05.

Suspended Solids and Volatile Suspended Solids (SS, VSS)

Suspended Solids were determined by filtering a sample using a glass microfibre filter (Whatman, 934-AH, 4.25 cms in diameter), drying the filtered sample in an oven at 103 ± 2°C for one hour fifteen minutes, and reweighing the sample. The volatile suspended solids were determined by combusting the filter with the suspended solids in a muffle furnace at 550°C for twenty minutes and reweighing the combusted filter.

Volatile Fatty Acids (as Acetic Acid)

Volatile fatty acids were determined by the procedure developed by Dilallo and Albertson (29). In this method a 100 ml sample is titrated to pH 4.0 with the appropriate sulfuric acid strength, the used volume is recorded and then the titration is continued to pH 3.5 to 3.3. The sample is boiled for 3 minutes to remove dissolved carbon dioxide, then cooled to original temperature, and back titrated from pH 4.0 to pH 7.0

with sodium hydroxide. For the calculation of the volatile acid alkalinity (as $CaCO_3$), the following equation is used:

$$\text{volatile acid alkalinity} = \frac{\text{mL of NaOH x Normality of NaOH x 50,000}}{\text{mL of sample}}$$

to convert from volatile acid alkalinity to volatile acid as acetic acid, a conversion factor should be used:

for volatile acid alkalinity > 180 mg/L,

volatile acid (as acetic acid) = volatile acid alkalinity x 1.5

for volatile acid alkalinity < 180 mg/L,

volatile acid (as acetic acid) = volatile acid alkalinity x 1.0

Methane Content of Gas

The methane content of the off-gas was measured indirectly by measuring the carbon dioxide and assuming 2% other gases.

$\%\ \text{Methane} = 100 - \%\ CO_2 - 2$

The carbon dioxide content of the gas was measured as described in the handbook "Operation of Wastewater Treatment Plants" (27). In this method, the carbon dioxide is adsorbed into KOH solution and by difference in volumes the percent of carbon dioxide in the off-gas is determined.

CHAPTER IV

RESULTS

The objective of the research project reported here was to evaluate the impact of total organic loading rate to a suspended growth anaerobic reactor treating fuel alcohol production wastewaters by increasing the volatile suspended solids concentration in the feed to the reactor. The anaerobic system was operated at approximately constant influent soluble COD concentration of around 10,000 mg/l. Two different operating conditions of average influent volatile suspended solids concentrations of 2,400 mg/l and 3,850 mg/l were investigated. The average values for each operating parameter during these two test conditions are presented in Table II.

The baseline operating condition presented in Talbe II is the data from tests performed by Gomathinayagam (7). Gomathinayagam (7) evaluated the use of anaerobic suspended growth treatment of fuel alcohol production wastewater after the majority of the wastewater suspended solids had been removed by gravity settling. The operating methodology used for his experiments was that these solids would be physically removed and mixed with the grain solids as by-product; whereas, the operating methodology used in the studies reported here was to allow these suspended solids to enter the anaerobic system with the intent of biodegradation and conversion to methane gas. Therefore, his data was used as the baseline data for comparison purposes of the two different oper-

TABLE II

AVERAGE CONTINUOUS FLOW ANAEROBIC SYSTEM OPERATING CHARACTERISTICS

DATA SOURCE	SRT Days	Influent				Mixed Liquor			Effluent				Total Gas Prod L/D	$\%CH_4$ in the gas
		HRT Days	FLOW L/D	BOD** (COD)	SS (SSS)	MLSS (MLVSS)	pH	T°c	BOD** (COD)	$CaCO_3$ alk.	VFA	SS (VSS)		
Baseline* Data	30	2.60	2.88	4100 (10100)	---- (225)	5980 (5380)	7.36	35	28 (380)	3200	50	---- (52)	21.5	71.0
Operating Condition No. 1	29	2.60	2.87	5546 (11534)	2811 (2403)	18459 (14250)	7.44	36	270 (566)	2984	299	715 (508)	27.4	67.5
Operating Condition No. 2	14	2.60	2.88	5542 (10333)	4355 (3851)	12013 (9850)	7.14	34	493 (1030)	5696	946	2273 (1981)	18.0	64.0
ALL UNITS OF CONCENTRATION EXPRESSED AS mg/L														

* From Reference 7

** In terms of soluble BOD (COD)

ating methodologies. The study objective was to match his operating condition (baseline data in Table II) as close as possible with the exception of increasing the feed volatile suspended solids concentration.

Table III shows the treatment efficiency at each operating condition and the amount of gas produced in terms of cubic feet of methane per pound of soluble BOD or COD removed. Tables II and III are presented in order to compare the treatment efficiency and methane production as the non-soluble COD (volatile suspended solids) if the feed was increased. The system operating objective at all three conditions was to maintain a 30 day SRT. The 30 day SRT was maintained when the influent VSS was increased to 2,400 mg/l. The system performed well at this condition as indicated in Tables II and III. However, the effluent BOD, COD, TSS, VSS, and VFS concentrations all increased above the baseline values. The total methane production also increased.

When the influent VSS concentration was increased to around 3,850 mg/l, operational problems were encountered. These operational problems, consisting of washout of the biological solids in the reactor, were never overcome during several months of operation. The effluent VFA concentrations increased significantly to around 950 mg/l along with deteriorated effluent quality in terms of BOD, COD, TSS, and VSS. During this operating period there was never a well defined zone of thickened solids and clarified supernatant in the clarifier. Gas bubbles were observed to constantly prevent sludge thickening with a net result of solids flotation and loss in the effluent. As a result the SRT could only be maintained at 14 days during this test period. At this test condition the methane gas production was less than that from the base-

TABLE III

AVERAGE TREATMENT SYSTEM PERFORMANCE IN TERMS OF SOLUBLE BOD (COD)

DATA SOURCE	SRT DAYS	F/M	INFLUENT mg/L	EFFLUENT mg/L	% REMOVAL	METHANE PERCENT	METHANE PRODUCTION Ft^3/lb BOD (COD) rem.
Baseline*	30	0.23 (0.56)	4100 (10100)	28 (380)	99.3 (96.2)	71.0	20.7 (8.8)
Operating Condition No. 1	29	0.15 (0.31)	5546 (11534)	270 (566)	95.0 (94.6)	67.5	22.1 (11.3)
Operating Condition No. 2	14	0.23 (0.44)	5542 (10333)	493 (1030)	90.5 (90.0)	64.0	15.5 (6.1)

* From Reference 7

line or control system.

Figure 2 is a graph in which the amount of methane produced in terms of the soluble BOD and COD removed during treatment is plotted against the concentration of VSS in the influent. Since gas production is expressed only in terms of soluble substrate in Figure 2, the methane production rate should increase if the VSS in the feed are being biodegraded and converted to methane. As can be seen this is the case with the first operating condition; however, during the second operating condition the methane production rate actually decreased.

In Figure 3, the volume of methane produced per pound of total BOD (COD) removed is plotted as a function of the volatile suspended solids in the influent. The solid line represents the $ft^3 CH_4$/lb total BOD removed and the broken line represents the $ft^3 CH_4$/lb total COD removed. The trend of these lines shows that the methane production rate decreased when the amount of volatile suspended solids in the substrate was increased.

Table IV presents a solids balance around the system. During the 3,800 mg/l influent VSS test condition, the effluent VSS concentration was approximately 50% of the influent value. Figure 4 is a plot of the methane content of the gas as a function of the VSS concentration in the influent. Table V shows the effect of the VSS on the quantity of methane produced.

Table V shows that during the baseline test condition 8.8 ft^3 CH_4/lb soluble COD removed was obtained. When this methane production rate is taken into account during the first test condition it can be estimated that 2.5 $ft^3 CH_4$/lb particulate COD removed was obtained. This methane gas production rate converts into 6.0 $ft^3 CH_4$/lb VSS removed during the first test condition. However, during the second test condition the total gas production in terms of only soluble COD removed was less than that of the baseline condition. At 6.1 ft^3 CH_4/lb soluble COD removed, the gas produced per pound of COD removed indicates that there is a problem with the system. Instead of being converted to methane gas, a portion of the soluble COD was only converted to VFA's. Undoubtedly the higher F/M and lower SRT (14 days) was a major factor during this test period. Both the low SRT and the high influent VSS concentrations were believed to be major contributors to the poor test results observed during the second test condition.

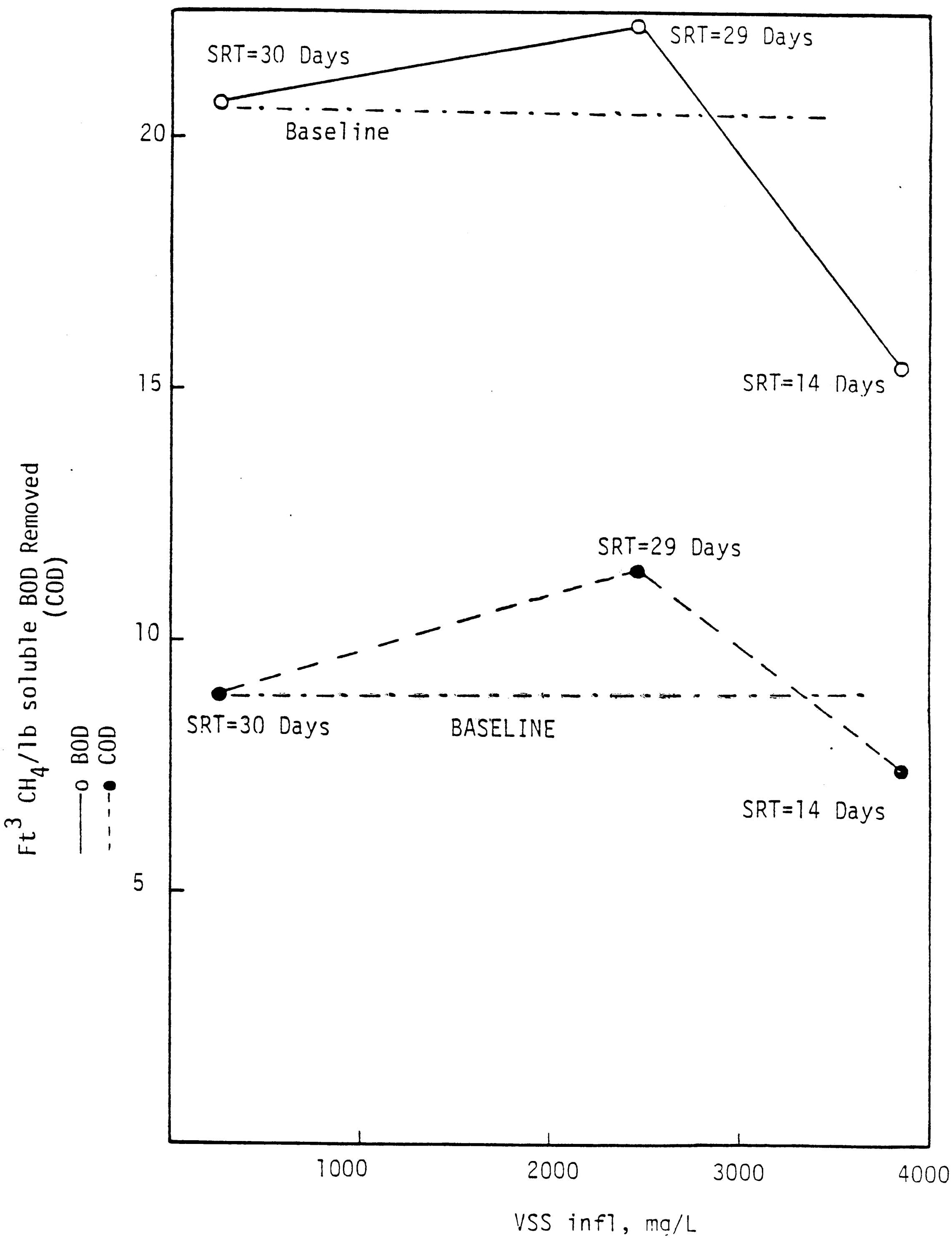

Figure 2. Methane Production as a Function of the Volatile Suspended Solids Applied to the Digester (Constant HRT - 2.6 days)

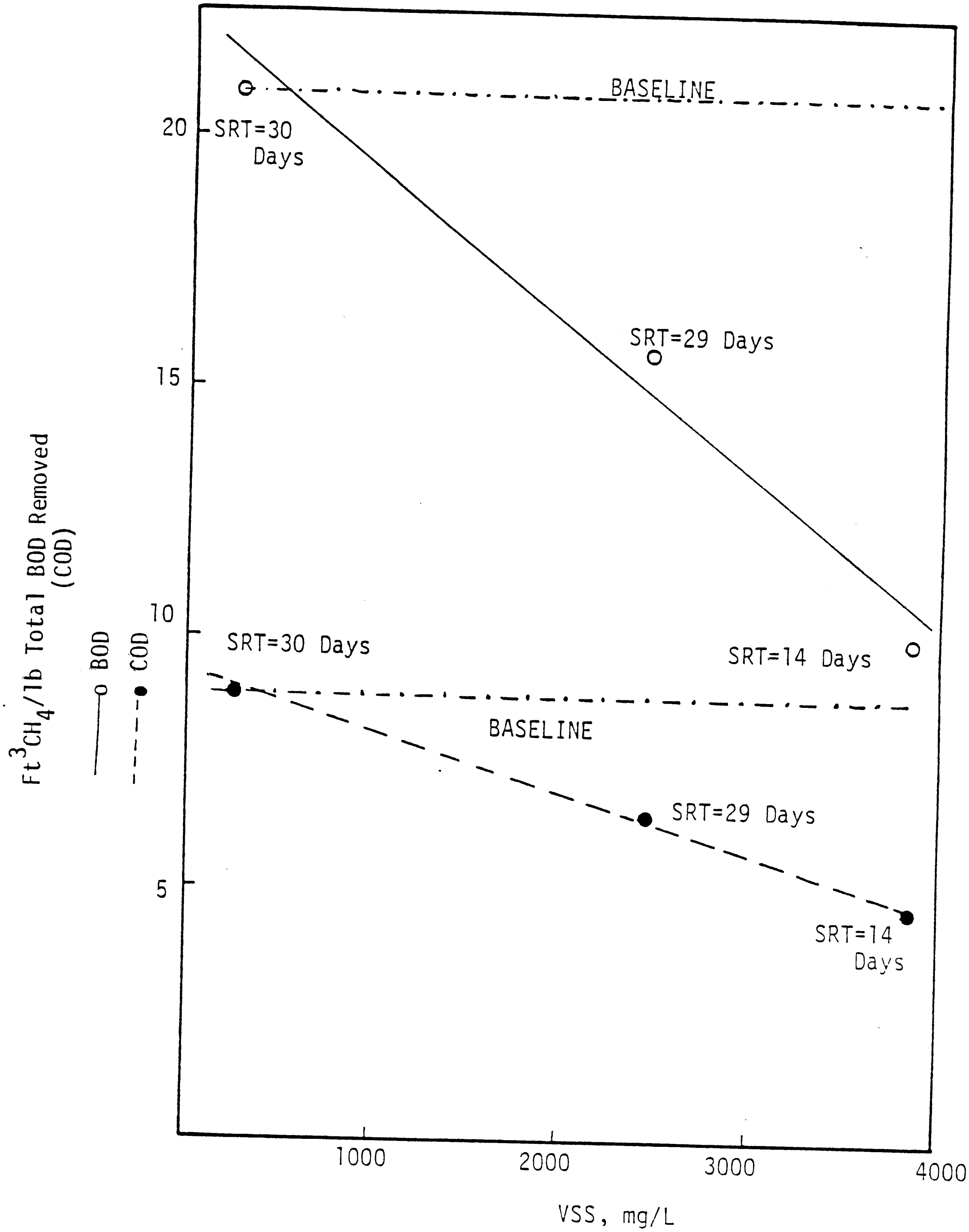

Figure 3. Methane Production in Terms of Total Pounds of BOD and COD Removed as a Function of the Volatile Suspended Solids Applied to the Digester

TABLE IV

SUSPENDED SOLIDS CONCENTRATION IN THE INFLUENT AND EFFLUENT

DATA SOURCE	INFLUENT SUSPENDED Solids (mg/L)		EFFLUENT SUSPENDED Solids (mg/L)		AMOUNT OF SUSPENDED Solids Removed (mg/L)		% REDUCTION	
	TSS	VSS	TSS	VSS	TSS	VSS	TSS	VSS
Baseline*	-	225	-	52	-	173	-	76.8
Operating Condition No. 1	2811	2403	715	508	2096	1895	74.5	78.8
Operating Condition No. 2	4355	3851	2273	1981	2082	1870	47.8	43.0

* From Reference 7

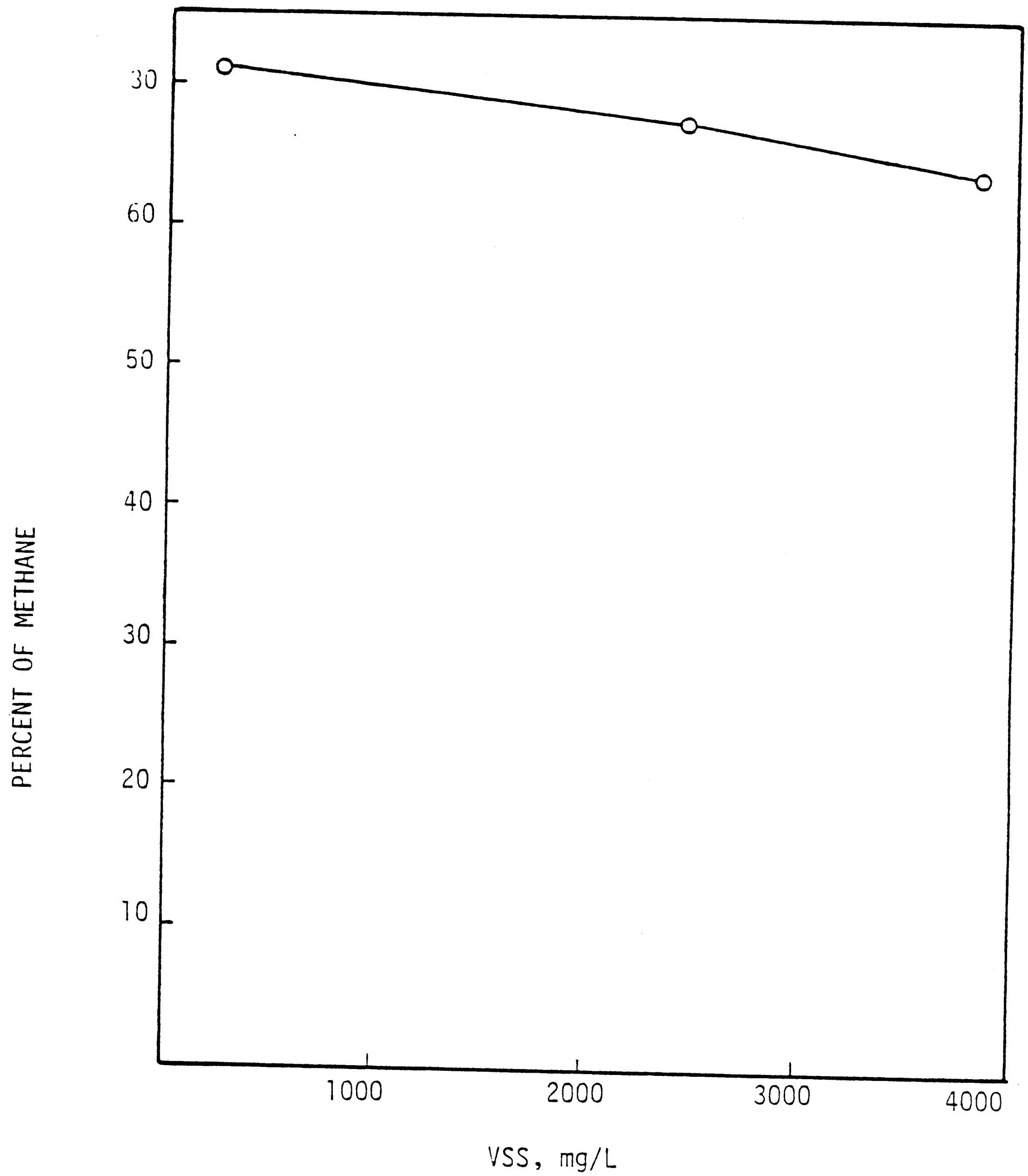

Figure 4. Percent of Methane as a Function of the Volatile Suspended Solids Applied to the Digester

TABLE V

VOLATILE SUSPENDED SOLIDS AND THEIR EFFECT UPON THE QUANTITY OF METHANE PRODUCED

DATA SOURCE	SRT	$Ft^3 CH_4$/lb rem COD (SOLUBLE)	$Ft^3 CH_4$ lb/rem COD (PARTICULATE)	$Ft^3 CH_4$/lb rem COD (TOTAL)	$Ft^3 CH_4$/lb VSS rem
Baseline*	30	8.8	--	8.8	---
Operating Condition No. 1	29	8.8	--	---	6.0
Operating Condition No. 2	14	6.1	--	4.7	---

* From Reference 7

CHAPTER V

DISCUSSION

As previously indicated the primary objective of this experimental program was to evaluate the impact of increasing the VSS content of the wastewater feed to an anaerobic suspended growth reactor treating fuel alcohol production wastewater. A baseline test condition using data developed by Gomathinayagam (7) where the majority of the influent solids had been removed was used as a control condition for comparison purposes. The operating conditions of 30 days SRT was established as the objective for all test conditions.

During the first test condition at 2,400 mg/l VSS in the feed, the system performed very well. The VSS in the feed was effectively handled and biodegraded at the rate of 2.5 ft^3 CH_4/lb particulate COD removed or 6.0 ft^3 CH_4/lb VSS removed. The 2.5 ft^3 CH_4/lb particulate COD removal rate was significantly lower than the 8.8 ft^3 CH_4/lb soluble COD removal rate. This would be expected due to the hydrolysis requirements and solubilization of the VSS in the feed before they could be used as substrate by the acid forming bacteria. Hydrolysis of the VSS is a necessary requirement for methane formation and would probably be the rate limiting step in the treatment of suspended matter.

During the second test condition the operating condition of the system could not be maintained at 30 days SRT due to solids washout, as previously explained. The SRT could only be maintained at 14 days. As a result the effluent quality and methane gas production rate during this test period was significantly worse than during the first test period. The total methane production rate in terms of soluble COD removed was lower than that of the baseline (control) test condition, even though the influent volatile suspended solids were increased to around 3,850 mg/l. It is postulated that both the lower SRT and higher VSS feed concentrations were both contributing factors to this condition.

The test results presented here indicate that the anaerobic suspended growth reactor can effectively handle wastewater with high VSS concentrations. However, due to operational problems encountered, the primary objective of determining a limiting influent VSS concentration at the set condition of SRT = 30 days and influent soluble COD = 10,000 mg/l could not be determined. The physical limitations of the small bench-scale reactor with an internal clarifier presented operational problems since the mixed liquor could not be de-gassed prior to settling.

Methane gas production rates were developed in terms of both soluble COD removal and particulate COD removal. These gas production rates could be used to evaluate the feasibility of removing the solids prior to biological treatment as by-product or treating the solids to produce methane gas. With proper design of an anaerobic reactor considering the F/M in terms of both soluble and particulate substrate and proper operations it is believed that a system could be designed to effectively handle all the solids in the thin stillage from the fuel alcohol production process.

CHAPTER VI

CONCLUSIONS

The following conclusions may be drawn from the results obtained in this investigation.

1. The wastewaters from a grain alcohol production plant are very amenable to mesophilic anaerobic digestion.

2. The volatile suspended solids added to the reactor in concentrations around 2400 mg/L resulted in increased gas production.

3. When a concentration of 3900 mg/L of volatile suspended solids was added to the influent substrate the treatment efficiency of the digester and the off-gas produced diminished along with the operational problems encountered.

4. The increase in gas production during the first solids loading rate demonstrates that the volatile suspended solids (VSS) can be broken down and converted to gas.

5. The maximum VSS loading rate was not defined due to the operational problems in the digester.

6. The methane production rate was 6.0 cubic feet per pound of volatile suspended solids removed during the first loading condition. This value is among the methane productions observed previously in the digestion of less complex organic matter, which indicates the high degree of biodegradability of this type of waste compared to municipal refuse and sewage solids.

CHAPTER VII

RECOMMENDATIONS

1. A complete analysis of the volatile suspended solids (VSS) in the thin stillage is desirable to evaluate possible forms of toxicity to the biomas.

2. Determination of the maximum loading rate is necessary in order to obtain the largest methane production rate that can be obtained without a drastic decrease in the treatment efficiency of the system.

3. A better design of the gas collecting system like vacuum degasification is recommended when gas volumes are measured by water displacement columns.

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