PERFORMANCE OF FACTORY ANAEROBIC CONTACTORS OPERATED WITH AND WITHOUT PRE-ACIDIFICATION (PA) OF FEED TO THE CONTACTORS AND COMPARISON TO BENCH PA TRIALS

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ABSTRACT

American Crystal Sugar Company (ACS) has anaerobic wastewater treatment systems in operation at three factories: Moorhead (MHD), East Grand Forks (EGF) and Hillsboro (HLB). Performance differences were noted between the systems operated with a heated pre-acidification (PA) system (EGF), one operated with a covered pond with or without heat (MHD), and another with a lagoon system (HLB) for storage of high strength wastewater. A series of bench scale PA trials were carried out at different conditions (temperature, retention time, and pH) at the ACS Technical Services Center. These studies showed the optimum temperature, retention time, and COD level conditions for conversion of COD to volatile fatty acids (VFA) and lactic acids. Data from PA trials and operational data from ACS factories at EGF, MHD, and HLB (with or without PA) showed that a minimum of 20% VFA and % VFA + lactic acid of > 35% was required for continued processing of high strength wastewater at high treatment rates. The MHD factory added macro and micro nutrients and treated 133,000 lbs of COD /day from December 1 to May 31, 2010. The HLB factory treated 101,931 lbs of COD /day in 2010 and 146,063 lbs COD/day in the 2009 campaign. The EGF factory operating with PA of their wastewater was able to treat 184,538 lbs of COD /day during the same period with sustained treatment rates of >250,000 lbs of COD /day.

Introduction:

A series of pre-acidification (PA) trials were carried out at the American Crystal Sugar Technical Services Center from March to November 2009 (Series I) and August 2010 to January 2011 (Series II). These trials were carried out to determine the following: a) the necessary conditions and degree of PA required during periods of high loading to the anaerobic contactor at Moorhead (MHD) factory, b) the least cost operating strategies required in PA to attain the desired level of acidification. Different conditions of pH, temperature, retention time for treatment of high strength (52,000 mg/L COD) and moderate strength (32,000 mg/L COD) covered equalization (EQ) pond water and flume water from Moorhead (MHD) factory were evaluated. In trial Series I the bench bioreactor was batch fed with MHD EQ pond water or flume water of different strengths, while in trial Series II the bioreactor was fed semi-continuously with moderate strength flume water of ≈30,000 mg/L COD (see picture of set up of equipment). The flume water was pulse fed into the reactor on an hourly basis.

Materials and Methods:

1) <u>Bench Bioreactor</u>:
   a) The PA trials were carried out using a 7 liter autoclavable glass bioreactor (Applikon) with a stirrer motor, pH electrode and digital pH controller. The pH was maintained at the required levels with use of 2N NaOH which was pumped into the reactor with the use of a peristaltic pump. The required temperature in the reactor was maintained by placing it in an Isotemp large capacity refrigerated incubator (Fisher Scientific). The total volume of liquid in the reactor was maintained at 4 liters (trial Series I) by removing a liter of liquid each day (trial Series I - 1, 1A, 2, 2A, 3, 3A, 4, 4A) or by removing 1 L of liquid every 3-4 days (trial Series I - 5, 5A). This was followed by adding 1 L of frozen and thawed feed water or feed water mix (see Table 1). In trial Series II, the total volume of liquid in the bioreactor was maintained at 5L with a semi-continuous feed of flume water kept cold in an ice box.

2) Temperature Measurements:
   a) Temperature in the reactor was monitored daily by a temperature probe (Pt 100) within the thermometer pocket in the reactor. The probe was connected to a digital temperature controller. In trial Series I the temperatures studied were 22°C, 28°C, 32°C, and 35°C. In trial Series II the temperatures studied were 20°C, 32°C, and 35°C.
3) pH Measurements and Regulation:
   a) The pH in the reactor was monitored daily with an autoclavable glass pH electrode with a double reference reservoir inserted in the bioreactor. The pH electrode was connected to a digital pH and temperature controller. The pH's studied were 5, 7, and when unregulated. The pH was regulated using 2N NaOH and added to the reactor using a peristaltic pump. The volume of NaOH used was recorded during some of the batch fed PA trials.
4) Wastewater types used in reactor in trial Series I:
   a) MHD EQ pond water (3L) with 3% sugar solution and wastewater mix (1L) *
   b) MHD EQ pond water only (4L)
   c) MHD Flume water only (4L)
   d) MHD EQ pond water and Sucrose (50g or 26g) mix to obtain high and low COD concentrations (4L)

      * Note: The 1L daily feed material (trials 1, 1A, 2, 2A) consisted of a mix of 250 mL of MHD EQ pond water and a 3% sucrose solution (25g sucrose in 750 mL water).

   Wastewater type used in reaction in trial Series II:
   a) MHD flume water only (5L)
5) Sample Collection:
   Sample aliquots of solution in the reactor were taken intermittently as required in trial Series I and 3 times each week in trial Series II. These samples were evaluated for COD, volatile fatty acids (VFA's) and microbial counts (mesophiles and mesophilic anaerobes) as required.
6) Chemical Oxygen Demand (COD) by Reactor Digestion Method:
   Measurements were made using the Hach 8000 colorimetric method with the Hach DR/4000V spectrophotometer.
7) Organic Acid Measurements:
   Analyses were carried out for volatile fatty acids or VFA's (acetic, propionic, formic, butyric, and valeric acid) and total lactic acid using a Waters HPLC with a refractive index detector. The column used was an Aminex HPX-87H from BioRad. Results were reported as %VFA and %VFA+ (volatile fatty acids + lactic acid).
8) Microbial Counts:
   Microbial estimates for mesophiles and mesophilic anaerobes were carried out only in trial Series I.

   Mesophiles and Mesophilic Anaerobes:

   Appropriate serial dilutions were made and decimal dilutions of samples were spirally plated on sterile prepoured and dried media plates using a spiral plater (Spiral Biotech – Autoplate 4000). The media plates used were plate count agar (PCA) for mesophiles and Reinforced Clotridial Agar (RCA) for mesophilic anaerobes. The inverted PCA plates were incubated at 35°C for mesophiles per 48 h. The inverted RCA plates were placed in an anaerobic jar with an anaerobic gas generator sachet and anaerobic indicator pill. The closed jars with inoculated RCA plates were incubated at 30°C for 48-72 h. The mesophilic and mesophilic anaerobic counts were made using the Spiral Biotech Laser Colony Scanner Model 500A.

9) Length of Trials:
   This varied from 6 to 47 days. See Tables 1 and 2.

Results, Observations and Discussion:

The MHD factory starts off the campaign each year with a low influent COD (1,500 ppm) to the anaerobic tank in the Fall of the campaign and the COD then increases to about 50,000 – 60,000 ppm towards the end of campaign (spring of following year). In the past, problems with processing of wastewater began around January when temperatures decrease in the EQ pond, due to low or subzero ambient temperatures. These temperatures are not conducive to microbial growth. Therefore breakdown of COD dropped sharply in the EQ pond at MHD during this time. The low ambient temperature also coincides with high COD in the wastewater due to sugar leaching from the frozen beets. The high strength wastewater which had not been sufficiently acidified by the microbes was then carried over to the anaerobic digester causing an overloaded situation in it, due to the following reasons:

Overloaded conditions in the anaerobic tank at MHD occur due to insufficient break down or pre-acidification of high strength waste. Therefore, the kinetics of degradation are slow or the microbes are incapable of degrading the waste resulting in stressed conditions and die off.

Overloaded conditions would also cause the filamentous microbes to take advantage of the situation and utilize the nutrients available easily due to having a larger surface area than the methanogens and grow rapidly, causing filamentous sludge bulking. This was a problem during the 2008/2009 campaign at MHD (3). However, filamentous bulking was not a problem in the MHD digester during the 2009/2010 campaign. The stressed microbes did not settle in the tank or flocculate. This resulted in the sludge blanket increasing in height in the anaerobic clarifier causing carry-over of solids and anaerobic biomass into the aerobic basin.

The carry-over of solids into the aerobic basin then caused the dissolved oxygen (DO) in the activated sludge system to decrease leading to a stressed condition for the aerobic microbes as well. However, during the 2009/2010 campaign at MHD the DO did not decrease in the aerobic basin. This could be due to higher aeration capacity last year. Overloaded situations cause filamentous microbes to grow in the aerobic basin as well and was observed again this campaign. This was compounded by the flow of belt press wash water into the aerobic basin as well. The overloading of the aerobic basin then caused the aerobic microbes to not settle and the sludge blanket in the activated sludge system to increase in height. This caused further over flow of un-pretreated solids into the condenser pond. This could cause increase in fecal coliform counts and the inability to meet permit and regulatory requirements. The presence of high solids in the ponds could result in odor issues in the spring and delay discharge of wastewater to the river at the end of campaign due to high TSS values.

Therefore, due to the above annual sequence of events occurring in the wastewater treatment system at MHD, a series of pre-acidification trials were initiated at the ACS Technical Services Center from March 2009 through November 2009 (trial Series I) and again from August 2010 to January 2011 (trial Series II). These trials with comparison to wastewater operations at EGF were carried out to determine the following:

- The necessary conditions and degree of pre-acidification required during periods of high loading to the anaerobic digester at Moorhead (MHD) factory.
- The least cost operating strategies required in pre-acidification to attain the desired level of acidification.

In trial Series I different temperatures (22°C, 28°C, 32°C, and 35°C), pH variations (pH 5, pH 7, and unregulated pH) along with different COD loadings of feed water (30,990 to 52,117 mg/L) and varying feed water types (MHD EQ pond water, MHD flume, MHD EQ and 3% sucrose solution, MHD EQ (with 26 and 50 g sucrose) were evaluated. See Table 1. The main observations in these studies were as follows:

TABLE 1. <u>Results of Pre-acidification Trials</u> (February - November 2009)

Trial #	Temp (ºC)	pH	Feed Water Type	Avg COD (mg/L)	2N NaOH used/day (ml)	Reten-tion Time (Days)	Avg VFA %	Avg VFA + %	Trial Length	Dates of Trials
1	22ºC	7.0	MHD EQ & 3% sucrose soln.	33,983	Δ	4	9.5%	15.2%	6 days	Mar. 9-15, 2009
1A	32ºC	7.0	MHD EQ & 3% sucrose soln.	30,990	Δ	4	18%	46%	4 days	Feb. 9-13, 2009
2	22ºC	Not* regulated	MHD EQ & 3% sucrose soln.	35,506	Δ	4	7.3%	12.7%	9 days	Mar. 23 to Apr. 1, 2009
2A	32ºC	Not** regulated	MHD EQ & 3% sucrose soln.	35,493	Δ	4	11.7%	21.3%	6 days	Mar. 16-22, 2009
3	28ºC	5.0	MHD EQ	31,480	Δ	4	26.4%	44.4%	11 days	Apr. 6-17, 2009
3A	32ºC	5.0	MHD EQ	31,133	0 ml	4	45.2%	47.5%	14 days	Apr. 20 to May 4, 2009
4	28ºC	5.0	MHD Flume	49,050	45 ml	4	8.8%	24%	14 days	May 18 to June 1, 2009
4A	32ºC	5.0	MHD Flume	43,217	13.6 ml	4	15.2%	23.5%	14 days	May 4-18, 2009
5	35ºC	5.0	MHD EQ & 50 g sucrose	52,965	42.7 ml	8	11%	35.7%	39 days	Aug. 27 to Oct. 5, 2009
5A	35ºC	5.0	MHD EQ & 26 g sucrose	33,793	21 ml	8	50%	60.5%	47 days	Oct. 7 to Nov. 23, 2009

* = < pH 7 to 4.84; ** = < pH 7 to 4.68; Δ = 2N NaOH used but not recorded, VFA+% = Percent Volatile Fatty Acids & lactic acid

In trial Series I, a greater degree of PA was observed at higher temperatures both in the MHD EQ pond water and MHD flume water trials. This was observed in studies at 32°C versus 22°C, 32°C versus 28°C, 35°C versus 32°C and 28°C, with higher %VFA & %VFA+ values being observed at the higher temperatures. At a higher temperature (32ºC versus 28ºC) and pH of 5.0 a lower amount of caustic was required for pH control as less lactic acid was produced. This was due to the microbes using other fermentative pathways (butyrate, propionate, mixed acid fermentation, etc.) rather than the lactate fermentation pathway.

The flume water trials (4 and 4A – Table 1) showed a distinct difference from the EQ pond wastewater trials (3 and 3A – Table 1). Here a large amount of NaOH had to be added to maintain the pH at 5.0 at both 32ºC (13.6 mL/day) and 28ºC (45 mL/day) in the flume water trial. NOTE: More caustic was required at the lower temperatures than at the higher temperatures to maintain pH. In contrast during the MHD EQ wastewater trial (3A – Table 1) at 32ºC no caustic (0 mL) was required to maintain the pH for the duration of the trial. This could also be due to the MHD EQ pond water being initially more pre-acidifed than flume water at the start of the trial. In the flume water trial at 28ºC (Trial 4) the lactic acid produced showed a rapid increase to 10,168 ppm while at 32ºC the lactic acid increased to 7,494 ppm. The 32ºC flume water trial (VFA% = 15.2%) also gave better results than the 28ºC trial (VFA% = 8.8%) with higher average concentration of formic, acetic and butyric acids throughout the trial. Therefore the flume water PA trial similar to the EQ pond water trial showed that greater PA occurred at higher temperatures. In addition due to higher PA in the EQ pond, it is probably a better influent source to the anaerobic tank rather than flume water especially during times of high COD loading.

Trials with regulated pH showed a higher degree of PA than those without pH regulation. See trials IA and 2A in Table 1 at 32°C. Here trial 1A at pH 7.0 gave a %VFA+ = 46% while trial 2A without pH regulation gave %VFA+ = 21.3%. Zoetemeyer et al (6) in their studies also found that to operate an acidification reactor at maximum efficiency it was necessary to maintain a constant pH in addition to mixing. Also pH 5 gave better PA than pH 7. See Trial 3A (32°C, pH5) and Trial 1A (32°C, pH 7). Trial 3A giave 45.2% VFA and 47.5% VFA+ while Trial 1A gave 18% VFA and 46% VFA+.

In trials 5 and 5A (Table1) sucrose (50 g or 26 g) was added to the MHD EQ pond water at pH 5.0 and 35ºC to obtain the required high level of COD (52,965 mg/L) and moderate level COD (33,793 mg/L) loading respectively. In this case the moderate COD trial -5A (VFA+% = 60.5%) out performed the high COD trial -5 (VFA+ % = 35.7%) at PA. Trial 5A also showed that at moderate COD (33,793 mg/L) the lactic acid concentration decreased over the time frame of the trial of 47 days to zero. At the same time other volatile fatty acids (acetic acid and butyric acid) increased in concentration. See Fig.1. However in the trial 5 high COD trial (52,965 mg/L) the lactic acid concentration decreased only partially, and the butyric and acetic acid concentrations were also fairly low (see Fig. 2).

Fig. 1 Volatile Fatty Acids and Lactic Acid at Moderate COD (COD = 33,793, T = 35°C, pH = 5)

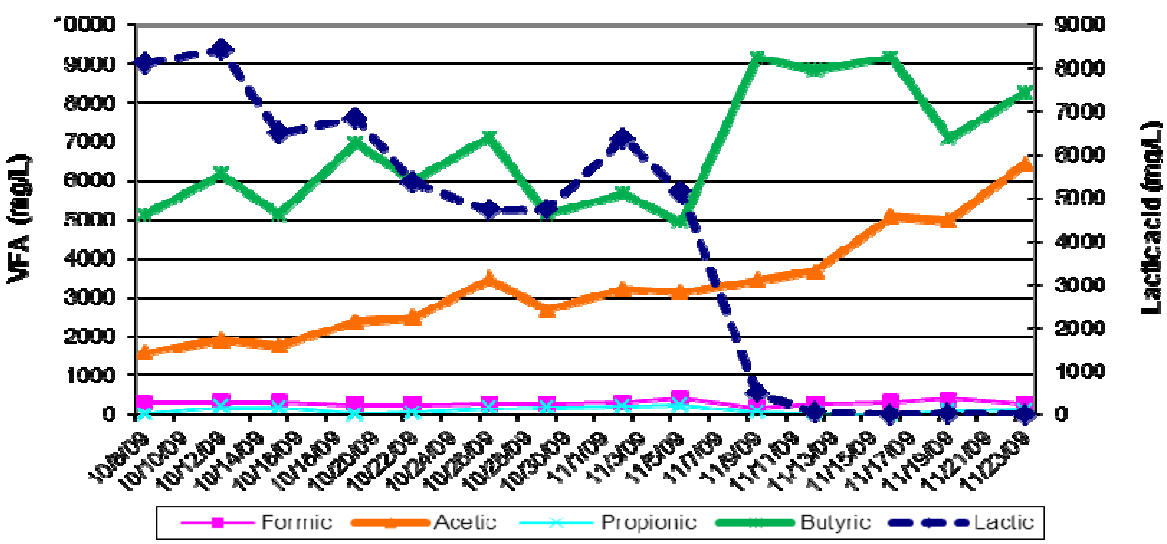

Fig. 2 Volatile Fatty Acids and Lactic Acids at High COD
(COD = 52,965 mg/L, T = 35°C, pH = 5)

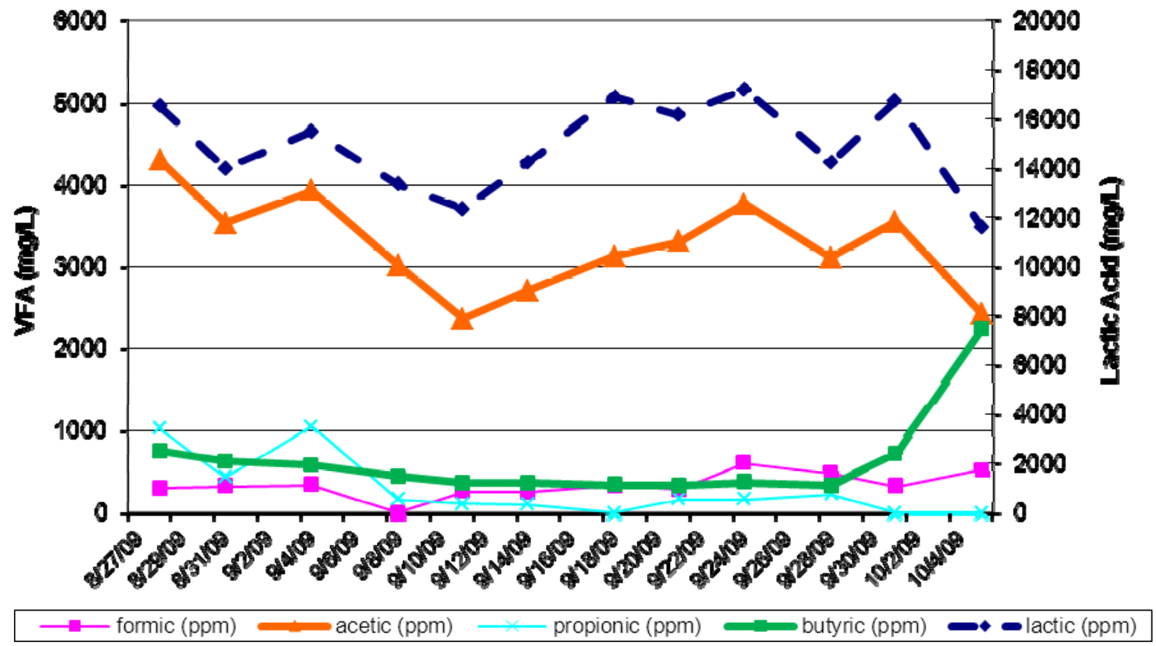

Fig. 3 Microbial Counts in High COD Trial
(COD = 52,965 mg/L, T = 35°C, pH = 5)

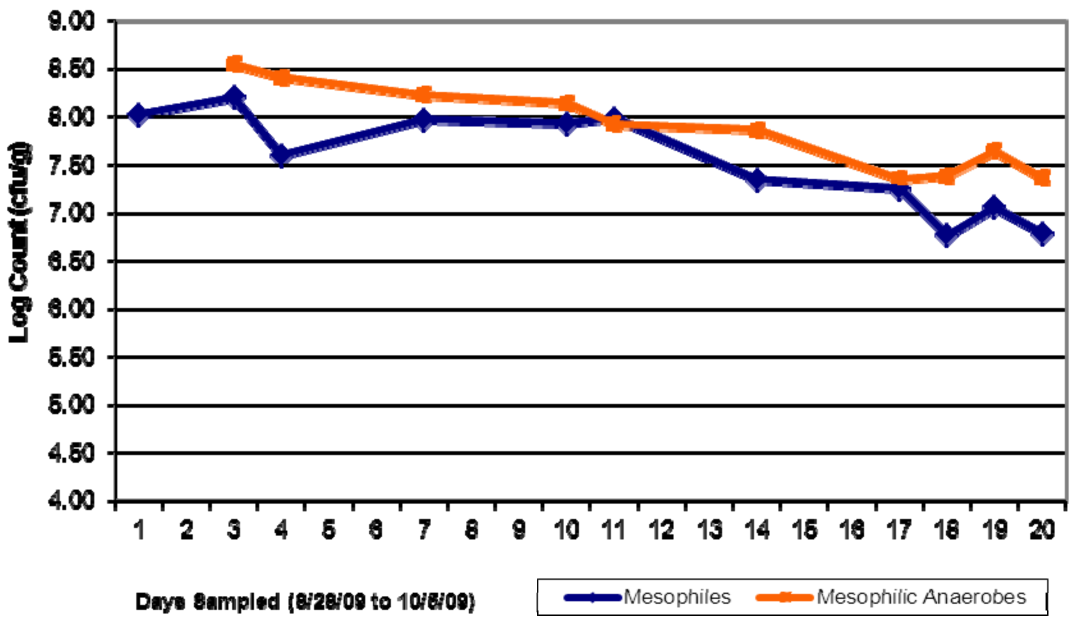

Fig. 3 gives the microbial counts (mesophiles and mesophilic anaerobes) in the high strength COD trial (52,965 mg/L). Here a decrease in microbial counts of greater than 1 log unit was observed. This shows the microbes are stressed at very high COD loading. The decrease in microbial counts corresponds to decrease in % VFA's during this trial.

Therefore the above series of trials showed that a pH of 5 and temperature of 35°C or higher was adequate for PA. Trials with very high strength COD levels of 50,000 – 60,000 mg/L led to a lower degree of PA and required more caustic to maintain a pH of 5. Therefore dilution of these high strength wastewater streams for sufficient treatment in the anaerobic reactor may still be required.

Comparison of the PA Bench Study (Series I) Data with MHD, EGF and HLB Wastewater Operation (F2010, 2009, and 2008):

See Tables 2A and 2B.

TABLE 2A. Comparison of MHD, EGF, HLB (F'2010) Wastewater Data, with and without Pre-acidification and Bench Studies

Tests & Conditions (Average Values)	**PA Trial (5) High Strength**	**PA Trials (5A) Moderate Strength**	*** MHD Factory An. Influent (3-15-10)**	*** MHD Factory An. Influent (1-4-10)**	**EGF EQ Pond (3-15-10)**	**EGF PA Tank (3-15-10)**	*** HLB An. Influent (3-11-10)**
COD	52,965 mg/L	33,793 mg/L	33,250 mg/L	15,480 mg/L	25,800 mg/L	25,100 mg/L	30,080 mg/L
VFA COD	6,457	17,900	5,165	6,518	13,754	14,670	5,246
Average VFA %	11%	50%	16%	42%	53%	58%	17%
Average VFA + %	35.7%	60.5%	36%	62%	69%	74%	41%
Conditions	pH 5.0, Temp 35ºC	pH 5.0, Temp 35ºC	pH 4.9	pH 5.0	pH 4.5, Temp 36ºC	pH 4.5, Temp 44ºC	pH 5.2
Retention Time	8 days	8 days					

TABLE 2B. Comparison of MHD, EGF, HLB (F'2009 & 2008) Wastewater Data, with and without Pre-acidification and Bench Studies

Tests & Conditions	**PA Trial (5) High Strength**	*** MHD Factory An. Influent (5-6-09)**	**PA Trials (5A) Moderate Strength**	*** MHD Factory An. Influent (3-17-09)**	**EGF EQ Pond (4-28-09)**	**EGF PA Tank (4-28-09)**	**** HLB An. Influent (5-31-08)**
COD	52,965 mg/L	54,300 mg/L	33,793 mg/L	34,350 mg/L	37,000 mg/L	36,600 mg/L	49,200 mg/L
VFA COD	6,457	1,031	17,900	3,433	13,793	15,280	17,971
VFA %	11%	2%	50%	10%	37%	42%	37%
VFA + %	35.7%	6%	60.5%	28%	56%	57%	66%
Conditions	pH 5.0, Temp 35ºC	pH 4.8	pH 5.0, Temp 35ºC	pH 4.3	pH 4.7, 35.8ºC	pH 4.8	pH 4.9
Retention Time	8 days		8 days				

* = No Pre-acidification (PA), no heating of influent
** = No heating of Influent but PA occurring in the influent Mud Pond #1 due to long storage

The moderate strength PA trial 5A at 33,793 mg/L COD (35ºC and pH 5.0) gave an average VFA +% = 60.5%. However the MHD anaerobic influent wastewater or EQ pond (without PA or heating) and similar COD and pH (33,250 mg/L, pH 4.9) to trial 5A on 3/15/10 gave a low VFA +% = 36% and had low settling with solids going over the weir of the MHD anaerobic clarifier (Table 2A). Likewise MHD factory influent on 1/4/10 gave VFA+% = 62% comparable to PA trial 5A. However the COD loading in the EQ pond at the time was low 15,480 mg/L (while PA trial COD was 33,793 mg/L) and no solids were going over the weir in the anaerobic clarifier at MHD at the time due to low loading.

On 3/15/10 the EQ at EGF which is heated to 36ºC (pH 4.5) and therefore has PA gave a VFA+% = 69% at 25,800 COD level. The EGF PA tank on 3/15/10 which is heated to 44ºC gave VFA+% = 74%. This again shows higher the temperature greater the PA similar to that observed in the PA trials at ACS Tech. Services.

The HLB anaerobic influent (without PA or heating) on 3/11/10 had a COD (30,080 mg/L) that was similar to the PA trial 5A and MHD An. influent on 3/15/10. However, the VFA +% = 41% was lower than was obtained in the PA trial 5A (VFA +% = 60.5%) due to absence of heat in the HLB pond for sufficient PA.

Table 2B showed the MHD anaerobic influent during campaign 2009 (without PA or adequate heating) on a similar day to above (3/17/09), was at comparable COD of 34,350 mg/L and pH 4.3 and gave a worse VFA +% = 28%. The high strength COD (52,965 mg/L) PA trial 5 did not readily PA and gave a VFA +% = 35.7%. However the MHD anaerobic influent during the 2009 campaign on 5/6/09 without PA and high COD (54,300 mg/L) similar to PA trial 5 did even worse with VFA +% = 6% at pH 4.8.

During campaign 2009 on 4/28/09 the EGF EQ pond (with PA) was at 37,000 COD and gave VFA +% = 56% and the EGF PA tank was at VFA +% = 57%. This was fairly similar to the Tech. services PA trial 5A at 33,793 COD with VFA +% = 60.5%. Therefore these trials compared very well to those at EGF.

HLB factory has the anaerobic influent to the digester coming from a mud pond which is not heated but had good PA. This can be seen from data obtained more than 2 years ago on 5/31/08 HLB anaerobic influent COD was 49,200 and the VFA +% = 66%. This is in comparison to MHD data for anaerobic influent on 5/6/09 with 54,300 COD and low VFA +% = 6%.

Therefore the above data from the respective factories and PA studies carried out at Tech. Services show that adequate VFA, in the anaerobic influent are required for continued processing of high strength wastewater. Also higher the temperature higher the degree of PA.

<u>Comparison of Moderate Strength Factory Wastewater Operations to PA trial – see Table 3</u>:

TABLE 3. <u>Comparison of MHD, EGF, & HLB (F'2010) Wastewater Data (moderate strength) To PA Trial 5A & COD Processed</u>

Tests, Flows, COD Processed & Conditions	**PA Trial (5A) Moderate Strength**	*** MHD Factory An. Influent (3-29-10)**	**EGF Factory Anaerobic Influent (EQ) (3-29-10)**	**** HLB Factory Anaerobic Influent (3-23-10)**
COD	33,793 mg/L	39,400 mg/L	28,700 mg/L	25,480 mg/L
VFA COD	17,900	7,204	10,235	4,558
VFA %	50%	18%	36%	18%
VFA + %	60.5%	40%	64%	42%
Flow to Digester	**-**	**0.36 MGD**	**1.22 MGD**	**0.64 MGD**
Pounds COD Processed per Day	**-**	**120,000 lbs**	**287,000 lbs**	**128,700 lbs**
Conditions	pH 5.0 Temp 35ºC	pH 4.8	pH 4.5 Temp 36ºC or less	pH 5.2
Pounds COD Processed Dec. 1 to May 31, 2010	-	133,000 lbs COD	184,538 lbs COD with sustained treatment rates of >250,000 lbs COD/day	101, 931 lbs COD in 2010 & 146,063 lbs COD in 2009

* = No Pre-acidification (PA), no heating of influent
** = No heating of Influent & no PA occurring in HLB Mud Pond during 2010 campaign

Table 3 compares the moderate strength PA trial (5A) with the An. influent from the three factories on specified days MHD (3/29/10), EGF (3/29/10), and HLB (3/23/10). On 3/29/10 MHD influent was at a COD of 39,400 mg/L very close to the PA trial (5A) of 33,793 mg/L and almost similar pH but without heating of the MHD EQ pond the PA was much less VFA +% = 40% as compared to 60.5% in the PA trial. In contrast the EQ pond at EGF (28,700 COD) was heated to 36ºC and gave very good PA with VFA +% = 64%. EGF was processing 287,000 lbs of COD at the time with a flow rate 1.22 MGD while MHD was able to process only 120,000 lbs COD on the same day with a flow rate of 0.36MGD and had solids going over the weir of the anaerobic clarifier. EGF had no solids going over the weir on 3/29/10 and processing a large amount of COD.

Likewise HLB An. influent on 3/23/10 had a COD of 25,480 mg/L and without pond heating at pH 5.2 gave a low PA of VFA +% = 42% (as compared to the PA trial VFA+% = 60.5% and EGF VFA+% = 64%). HLB was able to process only 128,700 lbs of COD that day at a flow rate of 0.64 MGD (and had solids going over the weir) as compared to EGF processing 287,000 lbs COD on 3/29/10 and had no problems with good solids settling in the anaerobic clarifier.

Therefore both the PA trial data (Series I) and the present operation of the EQ pond at EGF at 36ºC shows that heating of the anaerobic tank influent to 35 – 36ºC results in good PA enabling high wastewater flow and pounds of COD to be processed.

Trial Series I showed us the pH and temperature that was adequate for PA. Therefore in trial Series II all the different trials were carried out at a pH 5 with continuous flow of flume water of moderate COD (≈30,000 to 32,000 mg/L). Three different temperatures (32°C, 35°C, and 20°C) and 2 different retention times (5 days and 10 days) were studied. See Table 4. In this series of trials (Trial II) the focus was on semi-continuous flow of influent to the reactor to mimic the wastewater operations at the factories better and to study retention times of wastewater and temperature at moderate COD loading more closely.

TABLE 4. <u>Results of Pre-acidification Trials with Flume Water and Continuous Flow</u> (Aug. 2010 to Jan. 2011)

Trial #	Avg. Temp (ºC)	Avg. pH	Flume Water initial COD (mg/L)	Avg COD (mg/L)	Reten-tion Time (Days)	Avg VFA %	Avg VFA+ %	Change in VFA & VFA+	Trial Length (Days)	Dates of Trial
1	32°C	5.29	32,400	31,621	5 d	37%	41%	VFA↓ 45% to 35% VFA+↓ 47% to 41%	14 d	Aug. 6 – 20, 2010
2	32°C	5.14	32,400	29,813	10 d	51%	52%	VFA↑44 to 56% VFA+↑ 48-56%	15 d	Aug. 23 to Sept. 7, 2010
3	35°C	5.06	32,400	26,409	10 d	56%	59%	% VFA↑ 59 to 64% %VFA+↑ 59-64% *	35 d	Sept. 8 to Oct. 13, 2010
4	35°C	5.15	32,400	27,282	5 d	47%	47%	%VFA↓ 55 to 47% %VFA+↓ 56 to 47%	37 d	Oct. 15 to Nov. 22, 2010
5	20°C	5.07	27,700	26,778	5 d	39% **	42% **	%VFA↓ 45 to 39% %VFA+↓ 45 to 44% Δ	19 d	Nov. 24 to Dec. 13, 2010
6	20°C	5.17	30,350	25,515	10 d	52%	52%	%VFA↑ 42 to 56% %VFA+↑ 45 to 56%	28 d	Dec. 15, 2010 to Jan. 12, 2011

* When VFA high no lactic acid production

Δ Lactic acid ↑ up to 1408 ppm

Flume water from 5/3/10 of 64,800 mg/L COD was used, dil: 1:1 with distilled H_2O = 32,400 mg/L

** NB COD of flume water was less in this case to others.

The second series of trials with semi-continuous flow of influent (versus batch feeding of influent in trial Series I) further validated the results from the Series I trial. Here again a greater degree of PA was observed in the trials at higher temperatures. (See Table 4 - 1) Trial #3 at 35°C (%VFA+ = 59%) versus Trial #2 at 32°C (%VFA+ = 52%) and Trial #6 at 20°C (%VFA+ = 52%). There did not seem to be much difference in PA at 20°C and 32°C at the same retention time (RT).

For instance 20°C at 10 day RT gave %VFA+ = 52% and likewise 32°C at 10 day RT gave a %VFA+ = 52%. However, an increment of 3°C from 32°C to 35°C made a larger difference in VFA production (35°C, 10 d RT, %VFA+ = 59% while 32°C, 10 d RT % VFA+ = 52%). See Table 4 for more detail.

In addition the longer the RT (10 days versus 5 days) a greater degree of PA was observed. This was observed at each temperature (32°C, 35°C, and 20°C). At 32°C with 5 d RT VFA+ = 41% while at 32°C and 10 d RT VFA+ = 52%, likewise at 35°C 5 d VFA+ = 47% while at 10 d RT VFA+ = 59%. Gerardi (2) and Speece (4) state that the typical solids retention time for anaerobic digesters are >12 days, and Gerardi states further that <10 days was not recommended as significant wash out of methane forming bacteria occurred. Likewise our studies showed that about a 10 day RT was required for sufficient PA to occur in the bioreactor. However, this was in contrast to Zoetemeyer et al (6) findings of a couple of hours RT being sufficient for acidification.

The comparative data from the three factories (MHD, EGF, and HLB) with PA trials showed that the greatest PA occurred at EGF with a heated PA system. This corresponded to PA trial findings which showed that the degree of PA increased with increase in temperature. The influent to the MHD and HLB anaerobic digesters are from a covered pond and a lagoon system respectively. Both these systems are unheated or minimally heated and therefore the degree of PA was far less than that observed at EGF. However, HLB influent generally showed a higher degree of PA than that at MHD. This was probably due to a longer retention time of wastewater in the lagoon system than in the covered pond at MHD. This corresponds to findings in trial Series II which showed PA was greater with a 10 day retention time than with a 5 day retention time.

The results of the PA trial (Series II) with semi-continuous flow of influent validated the results of the PA trial (Series I) with batch flow of influent regarding temperature, pH, COD, and retention time for maximum PA. These trials showed that the most cost effective strategy for processing of wastewater of less than 40,000 mg/L COD was the use of a minimum temperature of 35°C, pH 5.0, and a retention time of about 10 days. Yu et al (5) found degradation of dairy wastewater increased with pH from pH 4.0 - 5.5 and further increase of pH increased degradation of carbohydrates, protein and lipids only slightly. These results corresponded to our findings as well as greater PA was observed at pH 5 rather than at pH 7 at the same temperature.

The MHD factory added macro and micro nutrients and treated 133,000 lbs of COD/day from December 1 to May 31, 2010. The HLB factory treated 101,931 lbs of COD/day in 2010 and 146,063 lbs COD/day in the 2009 campaign. The EGF factory operating with PA of their wastewater was able to treat 184,538 lbs of COD/day during the same period with sustained treatment rates of >250,000 lbs of COD/day. This showed the effectiveness of PA in the EQ pond at EGF in comparison to none or minimal PA in the MHD and HLB EQ ponds especially at high COD loading due to the absence of heat. Dinopoulou et al (1) assessed the performance of a two-phase anaerobic digestion system with a CSTR acidogenic reactor and a methanogenic fluidized bed reactor. Their studies showed the two-phase system was capable of COD removal superior or similar to a single stage system. This data is similar to what we have observed at the EGF factory.

Conclusions:

The series of pre-acidification (PA) trials carried out at Tech. Services have shown that the best conditions and the most cost effective strategy for pre-acidification of the EQ pond at MHD during periods of moderate to high loading to the anaerobic digester are as follows:

- Use of a minimum temperature of 35ºC and a pH of 5.0. This was due to less chemical usage at the higher temperature for pH control as less lactic acid was produced.
- High strength wastewater of 50,000 ppm - 60,000 ppm COD was not readily pre-acidified. Therefore dilution of the wastewater at these concentrations of loading may still be required for continued operation of the digester and treatment of wastewater. Our data shows that PA of wastewater of less than or equal to 40,000 ppm COD works best and is recommended.
- MHD EQ pond water gave much higher pre-acidification than the flume water at similar conditions and duration of the trials. Therefore MHD EQ pond water is a better influent source to the anaerobic digester than flume water at times of high loading.
- Data from PA trials and operational data from ACS factories at EGF, MHD, and HLB with and without pre-acidification have shown that a minimum %VFA (20% -35%) and %VFA+ (>35%) are required for continued processing of high strength waste with maximum flows.
- Longer retention times of wastewater in EQ pond or flume (10 days versus 5 days) showed a greater degree of PA of moderate (32,000 mg/L COD) and high strength (52,000 mg/L COD) wastewater.

Recommendations:

Run the EQ pond at MHD at 35ºC or higher at a pH of 5.0. (pH of 4.5 – 5.0 based on EGF experience)

- Rationale:
  a) Less chemical usage in the EQ pond for pH control at the higher temperature due to production of a desirable mix of acids, with less lactic acid for methane production. This is due to the microbes using other fermentative pathways (butyrate, propionate, mixed acid fermentation, etc.) rather than the lactate fermentation pathway for degrading of wastewater.
  b) Prevent overflow of solids from the anaerobic tank as the microbes are less stressed due to receiving partially treated waste from the EQ pond. This is due to complex substrates such as carbohydrates, proteins and lipids being broken down to simple subtrates (acids) that can be converted to methane easier. Higher the temperature > the enzyme activity and degradation of wastes by the microbes in the EQ pond resulting in better settling of sludge in the anaerobic clarifier.
  c) Fewer solids in the activated sludge system and therefore greater likelihood of meeting regulatory requirements for fecal coliforms even without chlorination of the sedimentation basin.

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