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APPENDICES

Appendix A Gas Chromatograph's Calibration Curves

Table A 1 Gas chromatograph's calibration curves for air

Amount of air (mL)	**Peak area**
0.1	4137115
0.2	9044634
0.3	13600000
0.4	18239458

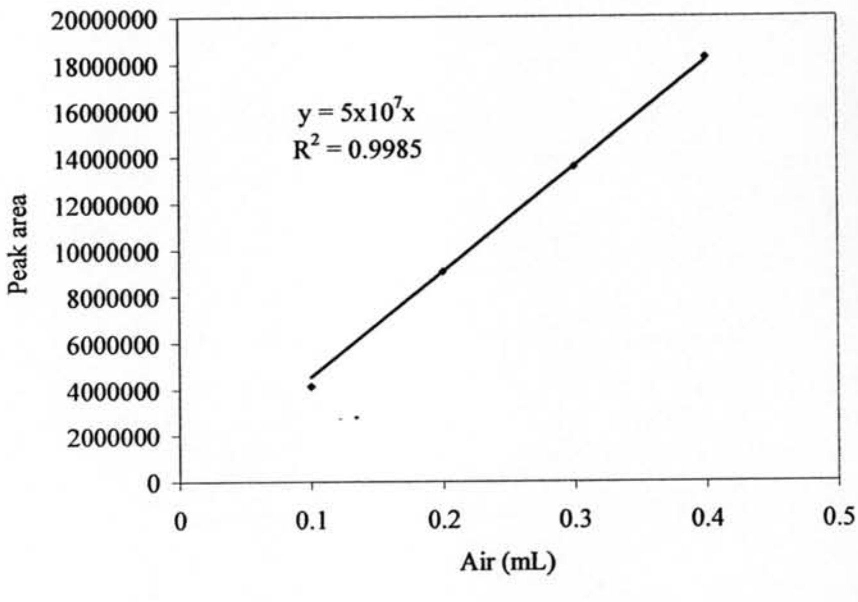


Figure A 1 The relationship between peak area and amount of air.

Relationship

$$\text{Peak area} = 5\text{x}10^7 \text{ x amount of air (mL)}$$

Table A 2 Gas chromatograph's calibration curves for hydrogen (H_2)

Amount of H_2 (mL)	Peak area
19.132	4109
18.805	5410
19.05	5104
58.66	23990
59.446	14260
59.588	18356
79.559	37565
79.784	35046

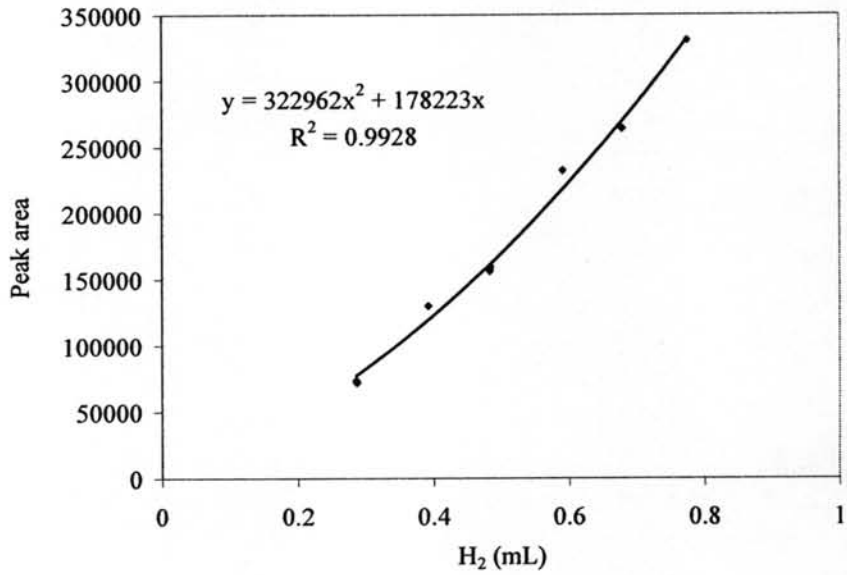


Figure A 2 The relationship between peak area and amount of hydrogen (H_2).

Relationship

$$\text{Peak area} = 322{,}962 \times (X)^2 + 178{,}223 \times X$$

where

X = amount of hydrogen (mL)

Table A 3 Gas chromatograph's calibration curves for carbon dioxide (CO_2)

Amount of CO_2 (mL)	**Peak area**
0.018	960193
0.0367	1993588
0.0554	3006185
0.074	4036503
0.093	5288153
0.112	6022949

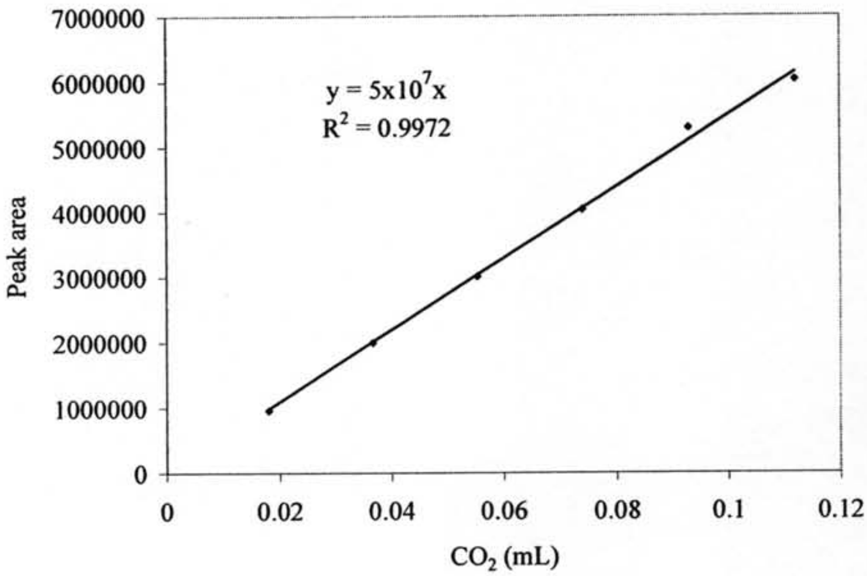


Figure A 3 The relationship between peak area and amount of carbon dioxide (CO_2).

Relationship

Peak area = 5×10^7 x amount of carbon dioxide (mL)

Table A 4 Gas chromatograph's calibration curves for methane (CH_4)

Amount of CH_4 (mL)	Peak area
0.094	3063075
0.19	7001020
0.287	10691500

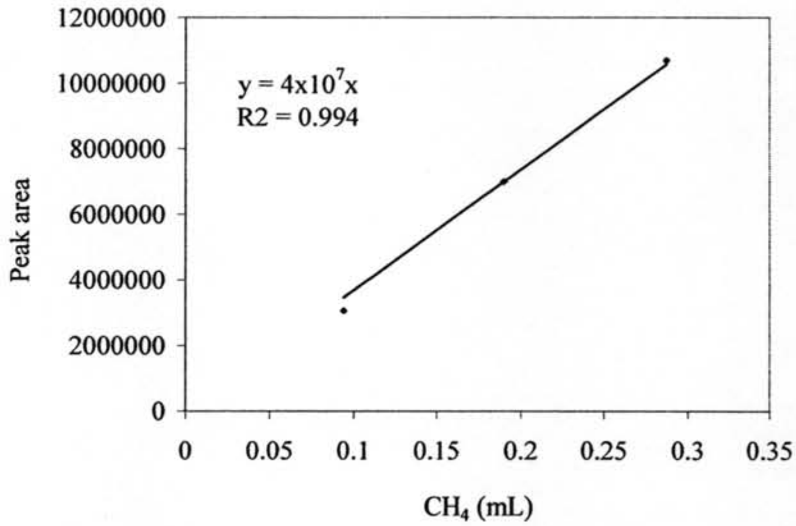


Figure A4 The relationship between peak area and amount of methane (CH_4).

Relationship

Peak area = $5x10^7$ x amount of methane (mL)

Appendix B Volatile Fatty Acids (VFA) Quantification by Distillation Method

B 1. Acetic Acids Stock Solution Preparation for Recovery Factor (f) Determination

Concentration of fresh acetic acid (liquid)	=	99.7%
Density of acetic acid	=	1.07 g mL^{-1}
Molecular weight of acetic acid	=	60

- Determination of fresh acetic acids concentration in term of molar

$$= \frac{0.997 \text{ L of acetic acid}}{\text{L of solution}} \text{x} \frac{1.07 \text{ g of acetic acid}}{\text{mL of acetic acid}} \text{x} \frac{1 \text{ mole of acetic acid}}{60 \text{ g of acetic acid}}$$

= 17.78 M

- Preparation of acetic acid at concentration of 2,000 mg L^{-1}

$$= 2{,}000 \frac{\text{mg of acetic acid}}{\text{L of solution}} \text{x} \frac{1 \text{ mole of acetic acid}}{60 \text{ g of acetic acid}}$$

= 0.0333 M

- Dilution of acetic acid

$$M_1V_1 = M_2V_2$$

$$V_1 = M_2V_2/M_1$$

$$= 0.0333 \text{x} 1/17.78$$

$$= 1.873 \text{x} 10^{-3} \quad \text{L}$$

B 2. Standard Sodium Hydroxide (0.1) Preparation

Concentration of fresh NaOH (solid) = 99%

Molecular weight of acetic acid = 40

- Preparation of acetic acid at concentration of 0.1 M

$$= \frac{0.1 \text{ mol}}{\text{L}} \text{x} \frac{40 \text{ g}}{\text{mol}} x \frac{100}{99}$$

= 4.04 g

B 3. Recovery Factor (f) Determination

- Distill 150 mL of 0.0333 M of acetic acid in distillation apparatus
- Calculate the recovery factor

$$f = \frac{a}{b}$$

where

a = volatile acid concentration recovered in distillate, mg L^{-1}

b = volatile acid concentration in standard solution used, mg L^{-1}

- Find volatile acid concentration recovered in distillate by titration with 0.1 M of NaOH (MW of acetic acid = 60.5)

1) Distillate 50 mL NaOH 11.7 mL

Used NaOH = $11.7 \times 10^{-3} \times 0.1$

= 1.17×10^{-3} mol

∴ Acetic acid in distillate = 1.17×10^{-3} mol

= $1.17 \times 10^{-3} \times 60.5$

= 0.07 g

∴ Concentration of acetic acid in distillate

= 0.07/50

= 1.405×10^{-3} g mL^{-1}

= 1,405 mg L^{-1}

2) Distillate 25 mL NaOH 5.7 mL

Used NaOH = $5.7 \times 10^{-3} \times 0.1$

= 5.7×10^{-4} mol

∴ Acetic acid in distillate = 5.7×10^{-4} mol

= $5.7 \times 10^{-4} \times 60.5$

= 0.034 g

∴ Concentration of acetic acid in distillate

= 0.034/25

= 1.368×10^{-3} g mL^{-1}

= 1,368 mg L^{-1}

Average = 1,387 mg L^{-1}

Recovery factor (f) = 1,387/2,000

= 0.6935

Appendix C Feed and Seed Sludge Preparation

C 1. Glucose Preparation (Example: COD = 20 g L^{-1})

	$C_6H_{12}O_6$	+	$6O_2$	$\rightarrow$	$6CO_2$	+	$6H_2O$
(MW)	180		6(32)				
(Mass)	180 g		192 g				
	180x20/192		192x20/192				
	18.75 g		20 g				

Desired COD = 20 g L^{-1} Desired Glucose = 18.75 g L^{-1}

For 4 L of reactor,

Amount of glucose used= 18.75x4 = 75 g

C 2. Suspended Solid (SS) of Seed Sludge Determination

(1) Weight of filter (B) = 114.5 mg

Weight of filter + dried residue at 100°C (A) = 761.8 mg

Sample volume = 20 mL

$$\frac{\text{mg (SS)}}{\text{L}} = \frac{(\text{A} - \text{B})\text{x}1{,}000}{\text{sample volume (mL)}}$$

$$\text{SS} = \frac{(761.8 - 114.5)\text{x}1{,}000}{20}$$

$$\text{SS} = 32{,}365 \text{ mg L}^{-1}$$

(2) Weight of filter (B) = 111.7 mg

Weight of filter + dried residue at 100°C (A) = 273.3 mg

Sample volume = 5 mL

$$\frac{mg\,(SS)}{L} = \frac{(A - B)x1{,}000}{\text{sample volume (mL)}}$$

$$SS = \frac{(273.3 - 111.7)x1{,}000}{5}$$

$$SS = 32{,}320 \;\; mg\, L^{-1}$$

Average $SS = 32{,}342.5\ mgL^{-1}$

C 3. Determination of 0.5% (W/V) of Seed Sludge

0.5% (W/V) = 0.5 g/100 mL

32,342 mgL^{-1} = 0.0323425 g L^{-1}

- Find volume of seed sludge for adding to 4 L of reactor

$M_1V_1 = M_2V_2$

$0.032345V_1 = (0.005)(4)$

$V_1 = 0.618$ L

Appendix D Sodium Hydroxide (NaOH) and Hydrocloric Acid (HCl) Preparation for pH Control System

D 1. 1 M of NaOH Preparation

Concentration of fresh NaOH (solid) = 99%

Molecular weight of acetic acid = 40

- Preparation of acetic acid at concentration of 1 M

$$= \frac{1\,mol}{L} x \frac{40\,g}{mol} x \frac{100}{99}$$

$$= 40.404\ g$$

D 2. 1 M of HCl Preparation

Concentration of fresh HCl (liquid) = 37%

Density of HCl = 1.19 g mL^{-1}

Molecular weight of HCl = 36.46

- Determination of fresh HCl concentration in term of molar

$$= \frac{0.37 \text{ L of HCl}}{\text{L of solution}} \times \frac{1.17 \text{ g of HCl}}{\text{mL of HCl}} \times \frac{1 \text{ mole of HCl}}{36.46 \text{ g of HCl}}$$

= 11.873 M

- Dilution of HCL

M_1V_1	=	M_2V_2	
V_1	=	M_2V_2/M_1	
	=	1x1/11.873	
	=	0.08422	L
	=	84.22	mL

Appendix E Experimental Data of The Effect of COD Loading

E 1. Volatile Suspended Solids (VSS) Determination

Set A *COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Volume of solution		=	40	mL
Weight of filter paper		=	0.1211	g
Weight of residue + filter paper (100°C)		=	0.1515	g
Weight of residue + filter paper (500°C)		=	0.1225	g
(VSS)				
VSS =	(0.1515-0.1225)/40	=	7.25×10^{-4}	g mL^{-1}
		=	725	mg L^{-1}

Set B *COD Loading Rate = 20 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Volume of solution	=	30	mL
Weight of filter paper	=	0.1209	g
Weight of residue + filter paper (100°C)	=	0.1483	g
Weight of residue + filter paper (500°C)	=	0.1251	g

(VSS)

VSS	=	(0.1483-0.1251)/30	=	7.73×10^{-4}	$g\ mL^{-1}$
			=	773	$mg\ L^{-1}$

***Set C** COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Volume of solution	=	30	mL
Weight of filter paper	=	0.1211	g
Weight of residue + filter paper (100°C)	=	0.1465	g
Weight of residue + filter paper (500°C)	=	0.1226	g

(VSS)

VSS	=	(0.1465-0.1226)/30	=	7.97×10^{-4}	$g\ mL^{-1}$
			=	797	$mg\ L^{-1}$

***Set D** COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Volume of solution	=	30	mL
Weight of filter paper	=	0.1211	g
Weight of residue + filter paper (100°C)	=	0.1453	g
Weight of residue + filter paper (500°C)	=	0.1219	g

(VSS)

VSS	=	(0.1453-0.1219)/30	=	7.80×10^{-4}	$g\ mL^{-1}$
			=	780	$mg\ L^{-1}$

E 2. Valatile Fatty Acids as Acetic Acid Determination by Distillation

Formula

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{\text{mL NaOH x N x 60,000}}{\text{mL sample x f}}$$

where

N	=	Normality of NaOH solution
f	=	recovery factor

***Set A** COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Distillate = 5 mL

NaOH 0.1 M = 4.4 mL

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{4.4 \times 0.1 \times 60{,}000}{5 \times 0.6935}$$

$$= 7{,}613.554 \quad \frac{\text{mg VFA as acetic acid}}{L}$$

***Set B** COD Loading Rate = 20 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Distillate = 5 mL

NaOH 0.1 M = 7.1 mL

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{7.1 \times 0.1 \times 60{,}000}{5 \times 0.6935}$$

$$= 1{,}2285.5083 \quad \frac{\text{mg VFA as acetic acid}}{L}$$

***Set C** COD Loading Rate = 30 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Distillate = 10 mL

NaOH 0.1 M = 38 mL

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{38 \times 0.1 \times 60{,}000}{10 \times 0.6935}$$

$$= 32{,}876.7123 \quad \frac{\text{mg VFA as acetic acid}}{L}$$

***Set D** COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Distillate = 10 mL

NaOH 0.1 M = 40 mL

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{40 \times 0.1 \times 60{,}000}{10 \times 0.6935}$$

$$= 34{,}607.0656 \quad \frac{\text{mg VFA as acetic acid}}{L}$$

E 3. Glucose Determination in Effluent using UV Spectrophotometer

Formula

$$\frac{\text{mg glucose}}{\text{mL}} = \frac{(\Delta A) \text{ x}(TV) \text{ x } (F) \text{ x } (0.029)}{SV}$$

***Set A** COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

A(sample blank) = 0.375

A(reagent blank) = 0.026

A(total blank) = 0.401

A(test) = 0.536

ΔA = A(test)-A(total blank) = 0.536-0.401 = 0.135

mg glucose/mL = (0.1351x2x10x0.029)/2

= 0.03919 g/L

%glucose removal = (9.375-0.03919)x100/9.375

= 99.582%

***Set B** COD Loading Rate = 20 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

A(sample blank) = 0.695

A(reagent blank) = 0.027

A(total blank) = 0.722

A(test) = 1.246

ΔA = A(test)-A(total blank) = 1.246-0.722 = 0.5024

mg glucose/mL = (0.5024x2x10x0.029)/2

= 0.146 g/L

%glucose removal = (18.75-0.1457)x100/18.75

= 99.233%

***Set C** COD Loading Rate = 30 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

A(sample blank) = 1.068

A(reagent blank) = 0.026

A(total blank) = 1.094

A(test) = 1.896

ΔA = A(test)-A(total blank) = 1.896-1.094 = 0.8020

mg glucose/mL = (0.8020x2x10x0.029)/2

= 0.2326 g/L

%glucose removal = (28.125-0.2326)x100/9.375

= 99.173%

***Set D** COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

A(sample blank) = 0.642

A(reagent blank) = 0.026

A(total blank) = 0.668

A(test) = 1.8486

ΔA = A(test)-A(total blank) = 1.8486-0.668 = 1.1806

mg glucose/mL = (1.1806x2x10x0.029)/2

= 0.3424 g/L

%glucose removal = (37.5-0.3424)x100/37.5

= 99.087%

E 4. Hydrogen Productivity (Yield of Hydrogen) Determination

***Set A** COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Amount of used glucose = 9.375-0.03919

= 9.3358 g L^{-1}

(1 day) Amount of used glucose = 9.3358x4

= 37.3432 g

Mole of used glucose = 37.3432/180

= 0.2075 mole

Volume of H_2 in 1 day = 0.2x0.274x24

= 1.3152 L

Mole of H_2 produce in 1 day

$$n = \frac{PV}{RT} \qquad ; R = 0.082 \ \frac{L \cdot atm}{mol \cdot K}$$

$$n = \frac{1x1.3152}{0.082x(273+25)}$$

$$= 0.0538 \text{ mole of } H_2$$

$$\text{Yield of hydrogen production} = \frac{0.0538}{0.2075} \ \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

$$= 0.2594 \ \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

Set B *COD Loading Rate = 20 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Amount of used glucose	=	18.75-0.1457
	=	18.6043 g L^{-1}
(1 day) Amount of used glucose	=	18.6043x4
	=	74.4172 g
Mole of used glucose	=	74.4172/180
	=	0.4134 mole
Volume of H_2 in 1 day	=	1.0908x0.32x24
	=	8.3773 L

Mole of H_2 produce in 1 day

$$n = \frac{PV}{RT} \qquad ; R = 0.082 \ \frac{L \cdot atm}{mol \cdot K}$$

$$n = \frac{1x8.3773}{0.082x(273+25)}$$

$$= 0.3428 \text{ mole of } H_2$$

$$\text{Yield of hydrogen production} = \frac{0.3428}{0.4134} \ \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

$$= 0.8292 \ \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

***Set C** COD Loading Rate = 30 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Amount of used glucose	=	28.125-0.2326
	=	27.8924 g L^{-1}
(1 day) Amount of used glucose	=	27.8924x4
	=	111.5696 g
Mole of used glucose	=	111.5696/180
	=	0.6198 mole
Volume of H_2 in 1 day	=	2.085x0.35x24
	=	17.514 L

Mole of H_2 produce in 1 day

$$n = \frac{PV}{RT} \quad ; R = 0.082 \frac{L \cdot atm}{mol \cdot K}$$

$$n = \frac{1x17.514}{0.082x(273+25)}$$

$$= 0.7167 \text{ mole of } H_2$$

$$\text{Yield of hydrogen production} = \frac{0.7167}{0.6198} \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

$$= 1.156 \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

***Set D** COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Amount of used glucose	=	37.5-0.3424
	=	37.1576 g L^{-1}
(1 day) Amount of used glucose	=	37.1576x4
	=	148.6304 g
Mole of used glucose	=	148.6304/180
	=	0.826 mole
Volume of H_2 in 1 day	=	2.1435x0.38x24
	=	19.5487 L

Mole of H_2 produce in 1 day

$$n = \frac{PV}{RT} \qquad ; R = 0.082 \ \frac{L \cdot atm}{mol \cdot K}$$

$$n = \frac{1x19.5487}{0.082x(273+25)}$$

$$= 0.7999 \text{ mole of } H_2$$

$$\text{Yield of hydrogen production} = \frac{0.7999}{0.826} \ \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

$$= 0.9684 \ \frac{\text{mole of } H_2}{\text{mole of glucose}}$$

E 5. COD Removal Determination

***Set A** COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Feed COD	=	16,000	mg L^{-1}
Product COD	=	7,300	mg L^{-1}
%COD removal	=	(16,000-7,300)/16,000	
	=	54.375%	

***Set B** COD Loading Rate = 20 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Feed COD	=	19,500	mg L^{-1}
Product COD	=	6,000	mg L^{-1}
%COD removal	=	(19,500-6,000)/19,500	
	=	69.231%	

***Set C** COD Loading Rate = 30 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

Feed COD	=	32,000	mg L^{-1}
Product COD	=	10,100	mg L^{-1}
%COD removal	=	(32,000-10,100)/32,000	
	=	68.438%	

***Set D** COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = Not Controlled,*

Temperature = 37°C

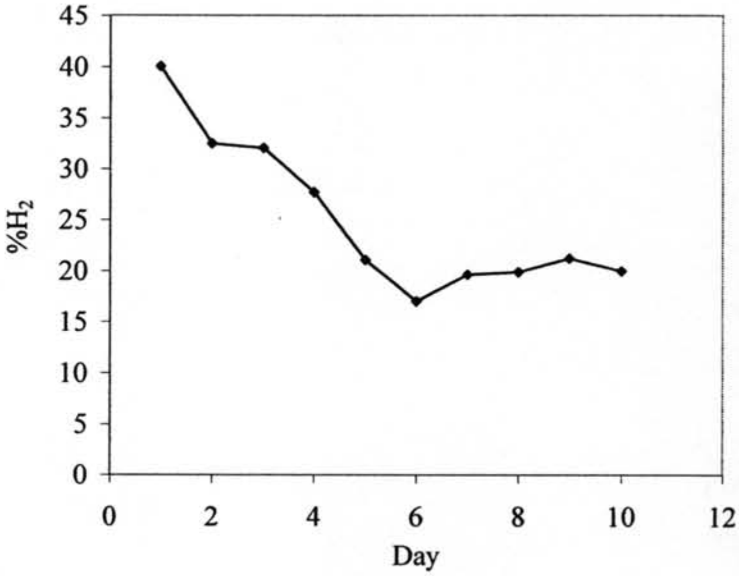
Feed COD	=	37,700	mg L^{-1}
Product COD	=	19,900	mg L^{-1}
%COD removal	=	(37,700-19,900)/37,700	
	=	48.579%	

E 6. Raw Data of Hydrogen Content in Produced Gas for Judging the Steady State of the Experiments

***Set A** COD Loading Rate = 10 kg m^{-3} d^{-1}, pH = Not Controlled,*

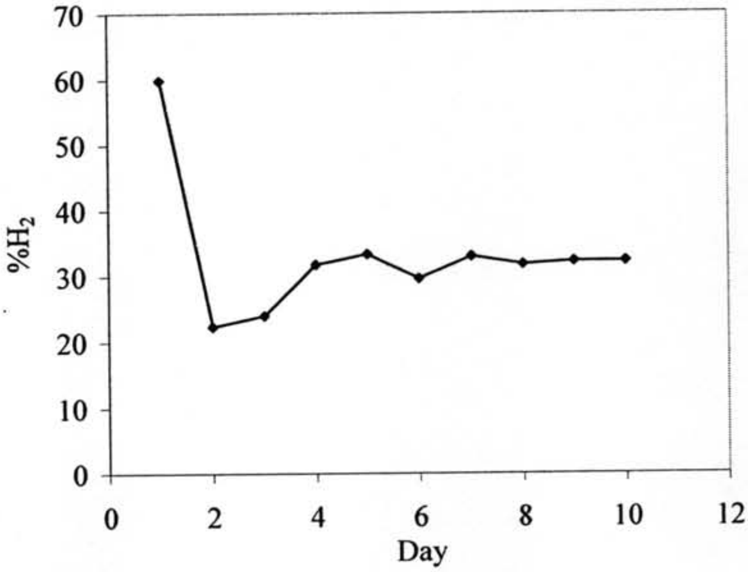
Temperature = 37°C

Day	%H_2	Amount of each component (mL)			Peak area		
		H_2	CO_2	CH_4	H_2	CO_2	CH_4
1	40.05	0.0556	0.083224	0	10916	4161185	0
2	32.478	0.0419	0.087109	0	8046	4355450	0
3	32.065	0.0478	0.101273	0	9274	5063641	0
4	27.693	0.0469	0.122457	0	9078	6122838	0
5	21.096	0.0236	0.088271	0	4388	4413545	0
6	17.048	0.0265	0.128939	0	4964	6446952	0
7	19.682	0.0291	0.104294	0	4459	4876582	0
8	19.925	0.0227	0.091225	0	4213	4561327	0
9	21.252	0.0257	0.095231	0	4812	4761526	0
10	20.02	0.0271	0.108265	0	5078	5413251	0



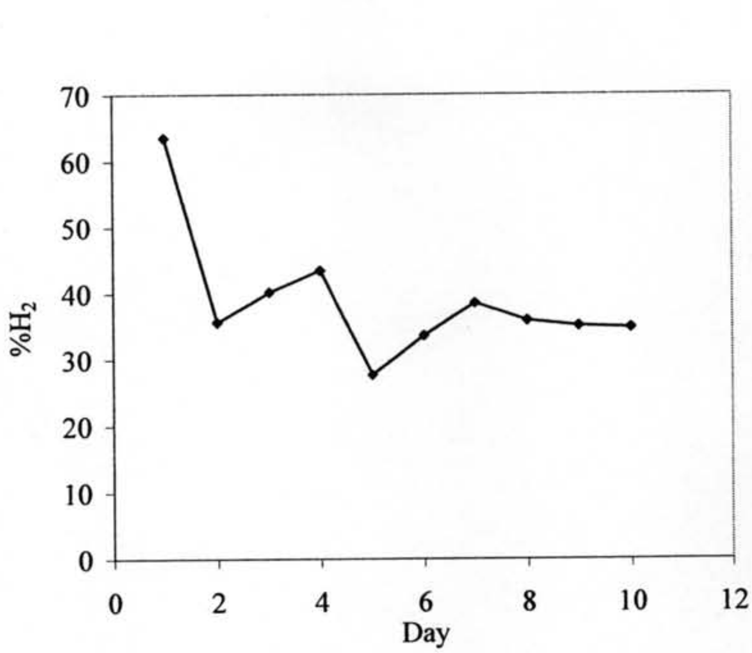
Set B *COD Loading Rate = 20 kg m^{-3} d^{-1}, pH = Not Controlled, Temperature = 37°C*

Day	%H_2	Amount of each component (mL)			Peak area		
		H_2	CO_2	CH_4	H_2	CO_2	CH_4
1	59.83607016	0.1368	0.09182464	0	30451	4591232	0
2	22.34316661	0.03	0.10426924	0	5641	5213462	0
3	24.00103851	0.0345	0.10924378	0	6549	5462189	0
4	31.76089383	0.06	0.12891156	0	11986	6445578	0
5	33.34352769	0.0459	0.0917579	0	8871	4587895	0
6	29.63013688	0.054	0.12824688	0	10571	6412344	0
7	32.99037716	0.0612	0.12430864	0	12123	6215432	0
8	31.79134367	0.0571	0.12250864	0	11231	6125432	0
9	32.20801257	0.0458	0.09640064	0	8846	4820032	0
10	32.265437	0.0528	0.1108426	0	10324	5542130	0



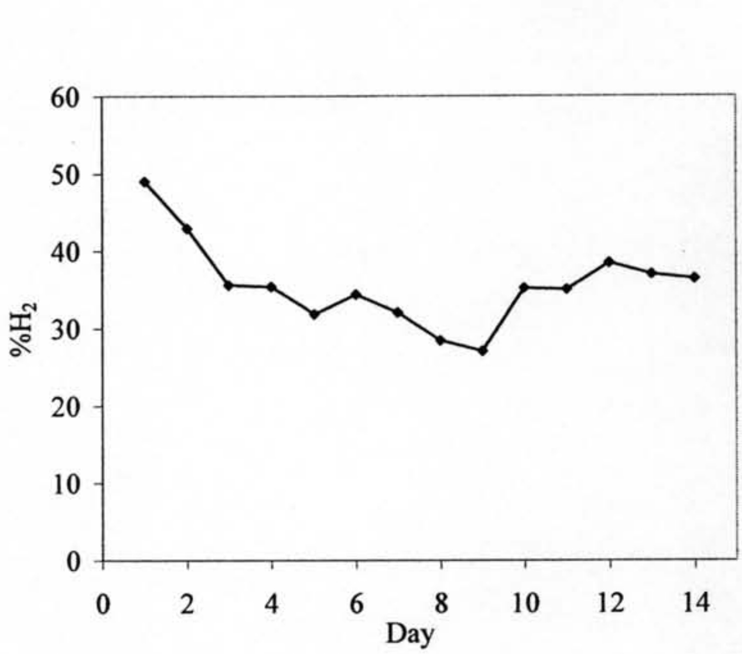
Set C *COD Loading Rate = 30 kg m^{-3} d^{-1}, pH = Not Controlled, Temperature = 37°C*

Day	$\%H_2$	Amount of each component (mL)			Peak area		
		H_2	CO_2	CH_4	H_2	CO_2	CH_4
1	63.56143781	0.1539	0.08822794	0	35083	4411397	0
2	35.64508548	0.0614	0.11085376	0	12167	5542688	0
3	40.18381412	0.0614	0.09139784	0	12182	4569892	0
4	43.44774287	0.0811	0.10556102	0	16585	5278051	0
5	27.65161111	0.0465	0.1216638	0	8993	6083190	0
6	33.62977813	0.033	0.06512732	0	6235	3256366	0
7	38.49664857	0.0571	0.0912246	0	11235	4561230	0
8	35.88434503	0.0524	0.09362468	0	10234	4681234	0
9	35.0437791	0.0506	0.09379082	0	9845	4689541	0
10	34.74316877	0.0443	0.08320708	0	8542	4160354	0



Set D *COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = Not Controlled, Temperature = 37°C*

Day	$\%H_2$	Amount of each component (mL)			Peak area		
		H_2	CO_2	CH_4	H_2	CO_2	CH_4
1	49.012	0.1562	0.16249464	0	35726	8124732	0
2	42.956	0.1232	0.163604	0	26878	8180201	0
3	35.639	0.0626	0.11304914	0	12434	5652457	0
4	35.446	0.0678	0.123475	0	13582	6173726	0
5	31.835	0.0588	0.1259045	0	11599	6295225	0
6	34.402	0.06474	0.123447	0	12892	6172358	0
7	27.072	0.0492	0.13253918	0	9563	6626959	0
8	35.056	0.0661	0.1224527	0	13207	6122635	0
9	38.497	0.0763	0.121897	0	15482	6094842	0
10	31.380	0.0614	0.1342557	0	12162	6712785	0
11	36.457	0.0702	0.122352	0	14124	6117590	0
12	38.304	0.0702	0.11306884	0	15631	5653442	0
13	38.213	0.0731	0.118197	0	14765	5909842	0

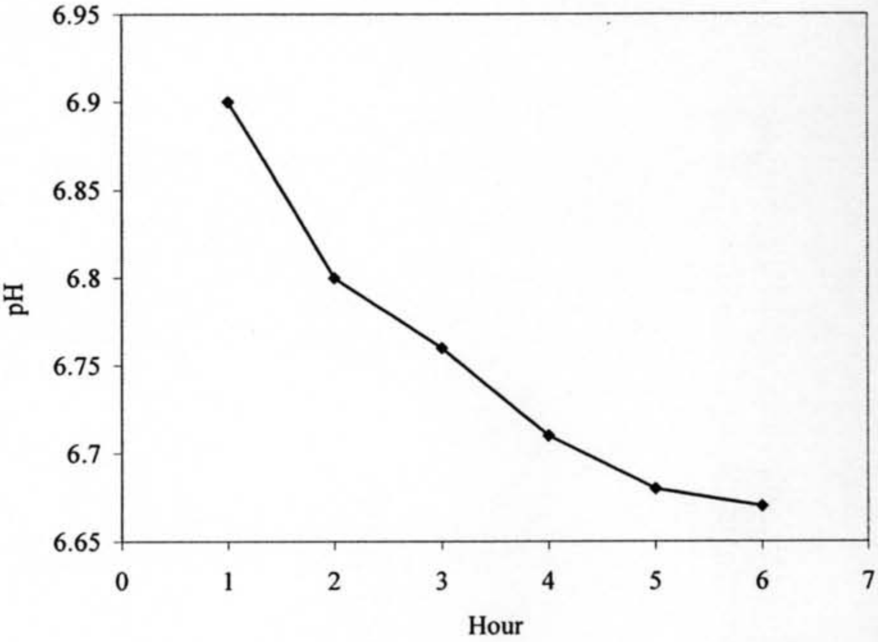


E 7. Raw Data of pH of the System

Set A *COD Loading Rate = 10 kg* m^{-3} d^{-1}*, pH = Not Controlled,*

Temperature = 37°C

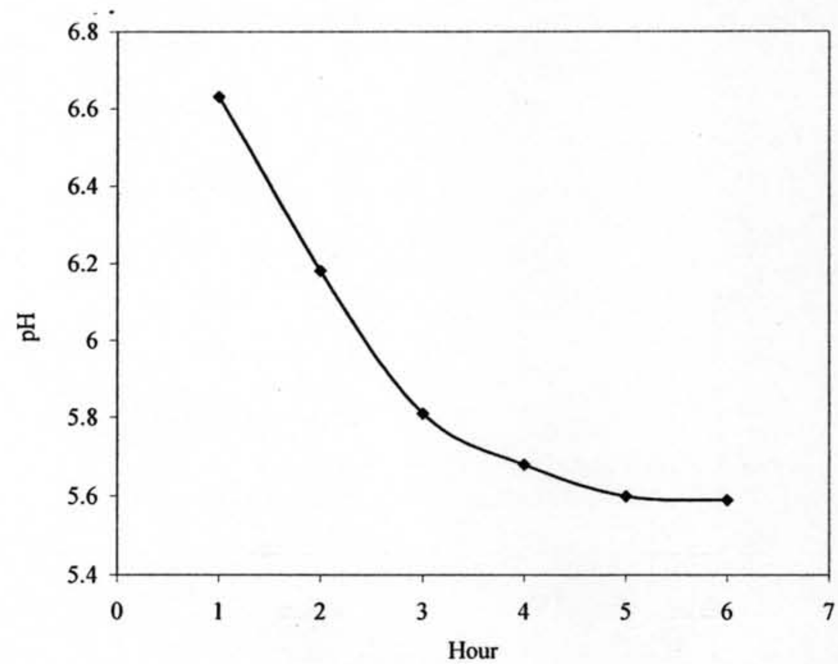
Hour	1	2	3	4	5	6
pH	6.9	6.8	6.76	6.71	6.67	6.67



Set B *COD Loading Rate = 20 kg m^{-3} d^{-1}, pH = Not Controlled,*

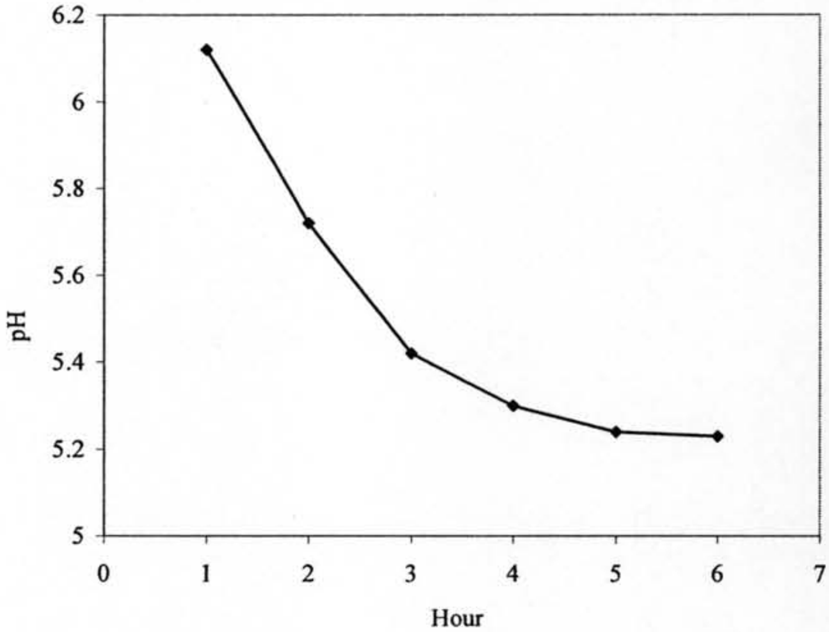
Temperature = 37°C

Hour	1	2	3	4	5	6
pH	6.63	6.18	5.81	5.63	5.60	5.59



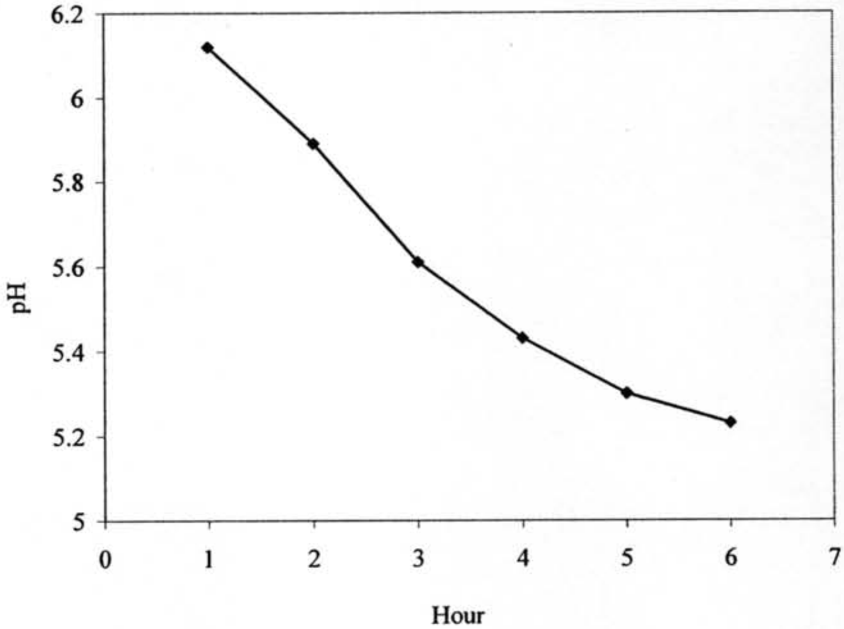
Set C *COD Loading Rate = 30 kg* m^{-3} d^{-1}*, pH = Not Controlled, Temperature = 37°C*

Hour	1	2	3	4	5	6
pH	6.12	5.72	5.42	5.30	5.24	5.23



Set D *COD Loading Rate = 40 kg* m^{-3} d^{-1}*, pH = Not Controlled, Temperature = 37°C*

Hour	1	2	3	4	5	6
pH	6.12	5.86	5.67	5.47	5.36	5.23



Appendix F Experimental Data of The Effect of COD Loading at Optimum pH (pH = 5.5)

F 1. Volatile Suspended Solids (VSS) Determination

***Set A** COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = 5.5, Temperature = 37°C*

Volume of solution			=	50	mL
Weight of filter paper			=	0.1231	g
Weight of residue + filter paper (100°C)			=	0.1676	g
Weight of residue + filter paper (500°C)			=	0.1246	g
(VSS)					
VSS	=	(0.1676-0.1246)/50	=	8.60×10^{-4}	g mL^{-1}
			=	860	mg L^{-1}

***Set B** COD Loading Rate = 50 kg m^{-3} d^{-1}, pH = 5.5, Temperature = 37°C*

Volume of solution	=	50	mL
Weight of filter paper	=	0.1231	g
Weight of residue + filter paper (100°C)	=	0.1639	g
Weight of residue + filter paper (500°C)	=	0.1230	g

(VSS)

VSS	=	(0.1639-0.1230)/50	=	8.18×10^{-4}	$g\ mL^{-1}$
			=	818	$mg\ L^{-1}$

F 2. Valatile Fatty Acids as Acetic Acid Determination by Distillation

Formula

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{\text{mL NaOH x N x 60,000}}{\text{mL sample x f}}$$

where

N = Normality of NaOH solution

f = recovery factor

Set A *COD Loading Rate = 40 kg* $m^{-3}\ d^{-1}$, *pH = 5.5, Temperature = 37°C*

Distillate	=	10	mL
NaOH 1 M	=	2	mL

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{2 \times 1 \times 60{,}000}{10 \times 0.6935}$$

$$= 17{,}303.53 \quad \frac{\text{mg VFA as acetic acid}}{L}$$

Set B *COD Loading Rate = 50 kg* $m^{-3}\ d^{-1}$, *pH =5.5, Temperature = 37°C*

Distillate	=	15	mL
NaOH 1 M	=	1	mL

$$\frac{\text{mg valitile acids as acetic acid}}{\text{L}} = \frac{1 \times 1 \times 60{,}000}{15 \times 0.6935}$$

$$= 5{,}767.844 \quad \frac{\text{mg VFA as acetic acid}}{L}$$

F 3. Glucose Determination in Effluent using UV Spectrophotometer

Formula

$$\frac{\text{mg glucose}}{\text{mL}} = \frac{(\Delta A) \times (TV) \times (F) \times (0.029)}{SV}$$

***Set A** COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = 5.5, Temperature = 37°C*

A(sample blank) = 0.348

A(reagent blank) = 0.026

A(total blank) = 0.374

A(test) = 0.4888

ΔA = A(test)-A(total blank) = 0.4888-0.374 = 0.1148

mg glucose/mL = (0.1148x2x10x0.029)/2

= 0.0333 g/L

%glucose removal = (9.375-0.0333)x100/9.375

= 99.645%

***Set B** COD Loading Rate = 50 kg m^{-3} d^{-1}, pH = 5.5, Temperature = 37°C*

(Note: Dilute sample 100 times)

A(sample blank) = 0.815

A(reagent blank) = 0.027

A(total blank) = 0.842

A(test) = 1.638

ΔA = A(test)-A(total blank) = 1.638-0.842 = 0.799

mg glucose/mL = (0.799x2x150x0.029)/2

= 3.476 g/L

%glucose removal = (18.75-3.476)x100/18.75

= 81.462%

F 4. <u>Hydrogen Productivity (Yield of Hydrogen) Determination</u>

***Set A** COD Loading Rate = 40 kg m^{-3} d^{-1}, pH = 5.5, Temperature = 37°C*

Amount of used glucose = 37.5-0.0333

= 37.4667 g L^{-1}

(1 day) Amount of used glucose = 37.467x4

= 149.868 g

Mole of used glucose = 149.868/180

= 0.8326 mole

Volume of H_2 in 1 day = 0.43x2.876x24

$= \quad 29.68\ L$

Mole of H_2 produce in 1 day

$$n = \frac{PV}{RT} \qquad ; R = 0.082\ \frac{L \cdot atm}{mol \cdot K}$$

$$n = \frac{1x29.68}{0.082x(273+25)}$$

$= \quad 1.215$ mole of H_2

Yield of hydrogen production $= \dfrac{1.215}{0.8326}\ \dfrac{\text{mole of } H_2}{\text{mole of glucose}}$

$= \quad 1.46\ \dfrac{\text{mole of } H_2}{\text{mole of glucose}}$

Set B *COD Loading Rate = 50 kg* $m^{-3}\ d^{-1}$*, pH = 5.5, Temperature = 37°C*

Amount of used glucose $=$ 46.875-3.476

$=$ 43.399 g L^{-1}

(1 day) Amount of used glucose $=$ 43.399x4

$=$ 173.596 g

Mole of used glucose $=$ 173.596/180

$=$ 0.964 mole

Volume of H_2 in 1 day $=$ 0.3x1.328x24

$=$ 9.562 L

Mole of H_2 produce in 1 day

$$n = \frac{PV}{RT} \qquad ; R = 0.082\ \frac{L \cdot atm}{mol \cdot K}$$

$$n = \frac{1x9.562}{0.082x(273+25)}$$

$= \quad 0.391$ mole of H_2

Yield of hydrogen production $= \dfrac{0.391}{0.964}\ \dfrac{\text{mole of } H_2}{\text{mole of glucose}}$

$= \quad 0.406\ \dfrac{\text{mole of } H_2}{\text{mole of glucose}}$

F 5. COD Removal Determination

***Set A** COD Loading Rate = 40 kg m^{-3} d^{1}, pH = 5.5, Temperature = 37°C*

Feed COD	=	41,500	mg L^{-1}
Product COD	=	8,200	mg L^{-1}
%COD removal	=	(41,500-8,200)/41,500	
	=	80.241%	

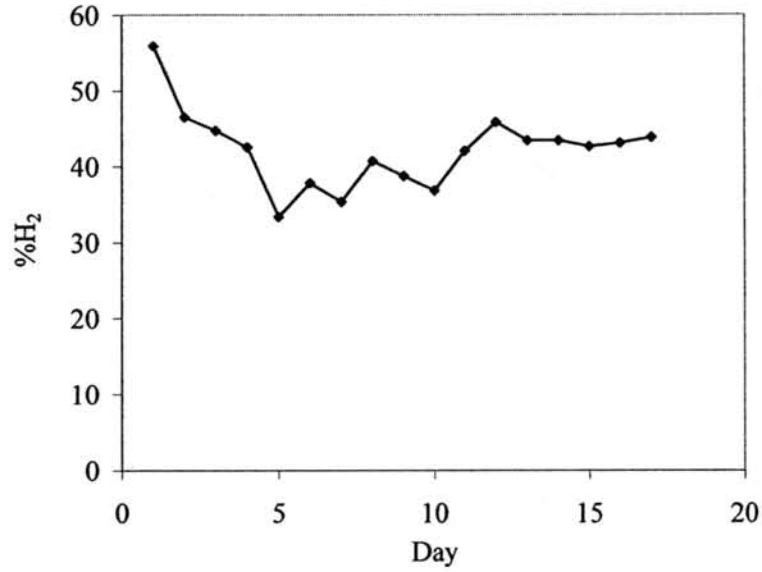
***Set B** COD Loading Rate = 50 kg m^{-3} d^{1}, pH = 5.5, Temperature = 37°C*

Feed COD	=	53,500	mg L^{-1}
Product COD	=	31,000	mg L^{-1}
%COD removal	=	(53,500-31,000)/53,500	
	=	42.056%	

F 6. Raw Data of Hydrogen Content in Produced Gas for Judging the Steady State

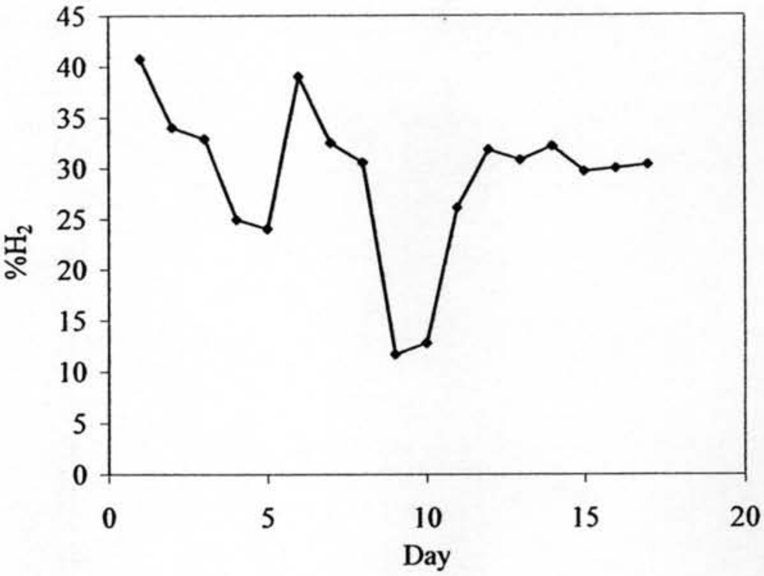
***Set A** COD Loading Rate = 40 kg m^{-3} d^{1}, pH = 5.5, Temperature = 37°C*

Day	%H_2	Amount of each component (mL)			Peak area		
		H_2	CO_2	CH_4	H_2	CO_2	CH_4
1	55.92518325	0.0622	0.04902002	0	12354	2451001	0
2	46.45882489	0.0679	0.07825092	0	13604	3912546	0
3	44.73693549	0.0711	0.08782908	0	14324	4391454	0
4	42.5235306	0.0623	0.08420712	0	12372	4210356	0
5	33.36837998	0.0452	0.09025758	0	8717	4512879	0
6	37.80323442	0.0443	0.07288574	0	8542	3644287	0
7	35.35384982	0.0469	0.08575882	0	9071	4287941	0
8	40.70471146	0.0703	0.10240728	0	14127	5120364	0
9	38.73670561	0.0694	0.10975824	0	13933	5487912	0
10	36.80960134	0.0463	0.0794824	0	8945	3974120	0
11	42.03269394	0.0707	0.0975024	0	14232	4875120	0
12	45.82339602	0.06	0.07093748	0	11874	3546874	0
13	43.43384211	0.0464	0.06042914	0	8974	3021457	0
14	43.43095241	0.0524	0.06825128	0	10325	3412564	0
15	42.64228554	0.0493	0.06631294	0	9754	3315647	0
16	43.08033642	0.0569	0.07517882	0	11203	3758941	0
17	43.83650902	0.0507	0.06495702	0	9875	3247851	0



***Set B** COD Loading Rate = 50 kg m^-3^ d^-1^, pH = 5.5, Temperature = 37°C*

Day	$\%H_2$	Amount of each component (mL)			Peak area		
		H_2	CO_2	CH_4	H_2	CO_2	CH_4
1	40.75108578	0.0631	0.0917425	0	12543	4587125	0
2	34.01897701	0.0573	0.1111354	0	11294	5556770	0
3	32.93008613	0.054	0.10998378	0	10586	5499189	0
4	24.97538411	0.0462	0.13878214	0	8941	6939107	0
5	24.05166934	0.0469	0.14809686	0	9087	7404843	0
6	39.04549075	0.0809	0.12629422	0	16545	6314711	0
7	32.52147805	0.0633	0.1313406	0	12595	6567030	0
8	30.58035015	0.0556	0.1262161	0	10906	6310805	0
9	11.71190281	0.0126	0.09498286	0	2315	4749143	0
10	12.78057133	0.0186	0.1269334	0	3429	6346670	0
11	26.112346	0.0425	0.12025826	0	8167	6012913	0
12	31.81851624	0.0506	0.1084269	0	9845	5421345	0
13	30.83937031	0.0622	0.13949024	0	12354	6974512	0
14	32.17366315	0.0676	0.14250974	0	13542	7125487	0
15	29.69693313	0.0507	0.1200247	0	9874	6001235	0
16	29.9983578	0.0525	0.12250958	0	10254	6125479	0
17	30.35112937	0.0512	0.11749224	0	9987	5874612	0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CURRICULUM VITAE

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