BAB IX

TUGAS KHUSUS

PERHITUNGAN NERACA MASSA DAN NERACA PANAS BIODIGESTER PT. ENERGI AGRO NUSANTARA

XI. 1 Neraca Massa

Basis : 1 jam

Satuan : kg/jam

Volume *spentwash* = 900 m^3/hari

Densitas *spentwash* = 1060 kg/m^3

Massa *spentwash* = Volume × Densitas

= 900 m^3/hari × 1060 kg/m^3

= 954.000 kg/hari

= 39.750 kg/jam

Massa komponen penyusun biogas

Massa COD = Komposisi COD × Volume *spentwash*

= 183.000 mg/L × 900 m^3/hari

= 6862,5 kg/jam

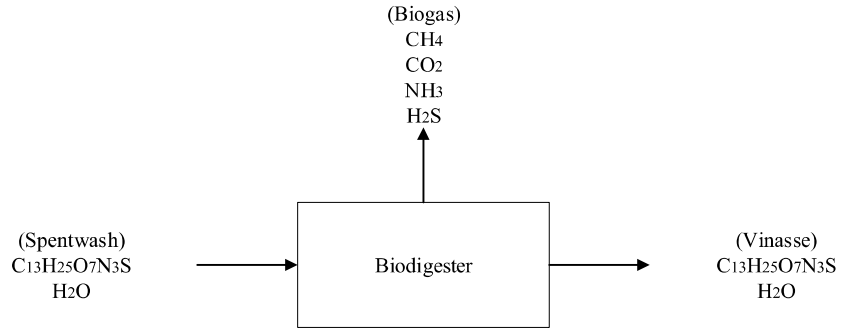
Massa TSS = 2265,375 kg/jam

TSS dianggap sebagai *spentwash*

Massa air = Komposisi air × Massa *spentwash*

= 90% × 39.750 kg/jam

= 35.775 kg/jam



Yield pembentukan metana = 0,395 kg CH_4/kg COD

Persentase COD terdegradasi = 93%

Massa COD terdegradasi = 6862,5 kg/jam × 93%

= 6382,125 kg/jam

CH_4 yang dihasilkan = Massa COD terdegradasi × Yield

= 6382,125 kg/jam × 0,395

= 2520,9393 kg/jam

BM CH_4 = 16,043 kg/kmol

Mol CH_4 terbentuk $= \frac{\text{Massa } CH_4}{\text{BM } CH_4}$

$= \frac{2520{,}9393 \text{ kg/jam}}{16{,}043 \text{ kg/kmol}}$

= 157,1364 kmol/jam

Arus 1

Massa $C_{13}H_{25}O_7H_3S$ awal = 2265,375 kg/jam

BM $C_{13}H_{25}O_7H_3S$ = 367,42 kg/kmol

Mol $C_{13}H_{25}O_7H_3S$ $= \frac{\text{Massa C13H25O7H3S}}{\text{BM C13H25O7H3S}}$

$= \frac{2265{,}375 \text{ kg/jam}}{367{,}42 \text{ kg/kmol}}$

= 6,1656 kmol/jam

Massa H_2O = 35.775 kg/jam

BM H_2O = 18,015 kg/kmol

Mol H_2O $= \frac{\text{Massa H2O}}{\text{BM H2O}}$

$= \frac{35775 \text{ kg/jam}}{18{,}015 \text{ kg/kmol}}$

= 1985,8451 kmol/jam

Reaksi fermentasi (kmol/jam)

	$C_{13}H_{25}O_7H_3S$	+ 6 H_2O	→ 6,5 CH_4	+ 6,5 CO_2	+ 3 NH_3	+ H_2S
M	6,1656	1985,8451				
R	4,3159	25,8956	28,0536	28,0536	12,9478	4,3159
S	1,8497	1959,9495	28,0536	28,0536	12,9478	4,3159

Arus 2

Mol $C_{13}H_{25}O_7H_3S$ = 1,8497 kmol/jam

Massa $C_{13}H_{25}O_7H_3S$ = Mol × BM

= 1,8497 kmol/jam × 367,42 kg/kmol

= 679,6125 kg/jam

Mol H_2O = 1959,9495 kmol/jam

Massa H_2O = Mol × BM

= 1959,9495 kmol/jam × 18, 015 kg/kmol

= 35308,4901 kg/jam

Arus 3

Mol CH_4 = 28,0536 kmol/jam

Massa CH_4 = Mol × BM

= 28,0536 kmol/jam × 16,043 kg/kmol

= 450,0640 kg/jam

Mol CO_2 = 28,0536 kmol/jam

Massa CO_2 = Mol × BM

= 28,0536 kmol/jam × 44,009 kg/kmol

= 1234,6112 kg/jam

Mol NH_3 = 12,9478 kmol/jam

Massa NH_3 = Mol × BM

= 12,9478 kmol/jam × 17,031 kg/kmol

= 220,5143 kg/jam

Mol H_2S = 4,3159 kmol/jam

Massa H_2S = Mol × BM

= 4,3159 kmol/jam × 34,08 kg/kmol

= 147,0872 kg/jam

Tabel XI. 1 Neraca Massa pada Biodigester

Komponen	Arus Masuk	Arus keluar	
	Arus 1	Arus 2	Arus 3
$C_{13}H_{25}O_7H_3S$	2.265,375	679,6125	
H_2O	35.775	35.308,4901	
CH_4			450,0640
CO_2			1.234,6112
NH_3			220,5143
H_2S			147,0872

		35.988,1026	2.052,2767
Total	38.040,38	38.040,38	

XI. 2 Neraca Panas

Basis : 1 jam

Satuan massa : kg dan kmol

Satuan panas : kJ/mol dan kJ

Suhu referensi adalah 25°C atau 298,15 K

Data-data yang digunakan diperoleh dari "*Chemical Properties Handbook*", Yaws, C.L. 1999

1. Kapasitas Panas Cairan

Cp $= A + BT + CT^2 + DT^3$

$$\int Cp\, dT = Cp_A(T - T_{ref}) + \frac{Cp_B}{2}(T^2 - {T_{ref}}^2) + \frac{Cp_C}{3}(T^3 - {T_{ref}}^3) + \frac{Cp_D}{4}(T^4 - {T_{ref}}^4)$$

ΔH = n. $\int Cp\, dT$

Tabel XI. 2 Kapasitas Panas Cairan

Komponen	A	B	C	D
$C_{13}H_{25}O_7N_3S$	86,29	3,5237	-7,3217E-03	6,1001E-06
H_2O	92,053	-3,9953E-02	-2,1103E-04	5,3469E-07
CH_4	-0,018	1,1982	-9,8722E-03	3,1670E-05
CO_2	-3981,02	52,511	-0,2270	3,2866E-04
NH_3	-182,157	3,3618	-1,4398E-02	2,0371E-05
H_2S	80,985	-0,1246	-3,6053E-05	1,6942E-06

2. Kapasitas Panas Gas

Cp $= A + BT + CT^2 + DT^3 + ET^4$

$$\int Cp\ dT = Cp_A(T - T_{ref}) + \frac{Cp_B}{2}(T^2 - {T_{ref}}^2) + \frac{Cp_C}{3}(T^3 - {T_{ref}}^3) + \frac{Cp_D}{4}(T^4 - {T_{ref}}^4) + \frac{Cp_E}{5}(T^5 - {T_{ref}}^5)$$

ΔH = n. ∫Cp dT

Tabel XI. 3 Kapasitas Panas Gas

Komponen	A	B	C	D	E
$C_{13}H_{25}O_7N_3S$	-54,487	1,8046	-1,3388E-03	5,367E-07	-9,2028E-11
H_2O	33,933	-8,4186E-03	2,9906E-05	-1,7825E-08	3,6934E-12
CH_4	34,942	-3,9960E-02	1,9184E-04	-1,530E-07	3,9321E-11
CO_2	27,437	4,2315E-02	-1,9555E-05	3,9968E-09	-2,9872E-11
NH_3	33,573	-1,2581E-02	8,8906E-05	-7,1783E-08	1,8569E-11
H_2S	33,878	-1,1216E-02	5,2578E-05	-3,8397E-08	9,0281E-12

3. Entalpi Pembentukan

Hf = kJ/mol

Tabel XI. 4 Entalpi Pembentukan

Komponen	Hf_{298} (kJ/mol)
$C_{13}H_{25}O_7N_3S$	-1.412,09
H_2O	-241,8
CH_4	-74,85
CO_2	-393,5
NH_3	-45,9
H_2S	-20,6

Panas Masuk :

T masuk = 32°C = 305,15 K

T ref = 25°C = 298,15 K

Tekanan = 1 atm

Tabel XI. 5 Panas Masuk

Komponen	m (kg/jam)	n (kmol/jam)	Cp dT (kJ/kmol)	ΔH (kJ/jam)
C13H25O7N3S	679,6125	6,1656	4552,9442	28071,7598
H2O	35308,4901	1985,8451	528,3337	1049188,9250
Total				1077260,6850

Panas Reaksi Fermentasi :

Reaksi fermentasi (kmol/jam)

$C_{13}H_{25}O_7H_3S + 6\ H_2O \rightarrow 6{,}5\ CH_4 + 6{,}5\ CO_2 + 3\ NH_3 + H_2S$

M	6,1656	1985,8451				
R	4,3159	25,8956	28,0536	28,0536	12,9478	4,3159
S	1,8497	1959,9495	28,0536	28,0536	12,9478	4,3159

Tabel XI. 6 Panas Reaksi pada Biodigester

Komponen	Laju Alir (kmol/jam)	ΔHf 298 (kJ/mol)	ΔH (kJ/jam)
C13H25O7N3S	4,3159	-1.412.090	-6.094.495.043
H2O	25,8956	-241.800	-6.261.565.062
CH4	28,0536	-74.850	-2.099.812.477
CO2	28,0536	-393.500	-11.039.094.318
NH3	12,9478	-45.900	-594.304.872,5
H2S	4,3159	-20.600	-88.908.354,2
Total			-26.178.180.126

$\Delta H°_R$ = $\Delta H°_f$ produk - $\Delta H°_f$ reaktan

= ($\Delta H°_f\ CH_4 + \Delta H°_f\ CO_2 + \Delta H°_f\ NH_3 + \Delta H°_f\ H_2S$) – ($\Delta H°_f\ C_{13}H_{25}O_7N_3S + \Delta H°_f\ H_2O$)

= (-13.822.120.022 – (-12.356.060.105)) kJ/jam

= -1.466.059.917 kJ/jam (Eksotermis)

Panas Keluar :

T keluar = 35°C = 308,15 K

T ref = 25°C = 298,15 K

Tekanan = 1 atm

Tabel XI. 7 Panas Keluar Arus 2

Komponen	m (kg/jam)	n (kmol/jam)	Cp dT (kJ/kmol)	ΔH (kJ/jam)
CH_4	450,0640	28,0536	365,2842	10247,5390
CO_2	1234,6112	28,0536	385,7638	10822,0663
NH_3	220,5143	12,9478	437,1466	5660,0945
H_2S	147,0872	4,3159	343,1650	1481,0794
Total				28210,7792

Neraca Panas Total :

Entalpi Bahan Masuk + Q Supply = Entalpi Bahan Keluar + ΔHRx

Asumsi Q Loss = 5%

Entalpi Bahan Masuk + Q Supply = Entalpi Bahan Keluar + ΔHRx

1.077.260,68 + Q Supply = 28.210,7792 + 5% Q Supply

95% Q Supply = 1.465.010.867,3892

Q Supply = 1.542.116.703 kJ

Q Loss = 77.105.835,13 kJ

Tabel XI. 8 Neraca Panas Total Biodigester

Komponen	Arus Masuk	Arus Keluar	
	Arus 1	Arus 2	Arus 3
$C_{13}H_{25}O_7N_3S$	28.071,75982		
H_2O	1.049.188,925		
CH_4			10.247,5390
CO_2			10.822,0663
NH_3			5.660,0945
H_2S			1.481,0794
Q Reaksi		1.466.059.917	
Q *Supply*	1.542.116.703		
Q *Loss*		77.105.835,13	
TOTAL	1.543.193.963	1.543.165.752	28.210,77919
	1.543.193.963	1.543.193.963	

BAB X
KESIMPULAN DAN SARAN

X. 1 Kesimpulan

1. PT. Energi Agro Nusantara merupakan pabrik yang bergerak dalam pembuatan etanol. Produk utamanya adalah etanol *fuel grade* dengan kemurnian 99,5%, *extra neutral alcohol* dan *technical alcohol*. Sedangkan produk sampingnya berupa CO_2 liquid, alcohol medis 70%, pupuk hayati dan biogas. Dalam produksi etanol, terdapat 2 proses utama yaitu fermentasi dan *refinery*. Pada proses utama tersebut menghasilkan limbah yang akan diolah menjadi biogas dan pupuk hayati.
2. Neraca massa pada biodigester diperoleh sebesar 38.040, 38 kg/jam, sedangkan neraca panasnya sebesar 1.543.193.963 kJ/jam.

X. 2 Saran

1. Spentwash yang sudah digunakan seharusnya di *recycle* kembali karena masih mengandung bakteri metanogen yang dapat memproduksi biogas.
2. Dalam produksi biogas harus dilakukan purifikasi, agar mendapatkan kandungan metana (CH_4) yang lebih tinggi.