BIOMETHANATION

Insoluble Organics

↓

Extra Cellular Enzymes Solubilizes organics

↓

volatile Acids by acid producing bacteria (Acetic Acid CO_2, H_2)

↓

Gasification by Methane producing bacteria (CH_4, CO_2)

STOICHIOMETRY

$$CH_3COOH + 0.032\,NH_3$$

$$= 0.032\,C_5H_7NO_2 + 0.92\,CH_4$$

$$+ 0.92\,CO_2 + 0.096\,H_2O$$

$$\mu = \mu_m \left[\frac{1}{1 + \frac{K_s}{HS} + \frac{HS}{K_I}} \right]$$

Graef & Andrews

(1974)

$HS = H^+ + S^-$

$$\mu = \mu_m \left[\frac{1}{1 + \frac{K_s}{HS} + \frac{HS}{K_i}} \right]$$

$K_s = 0.0333 \text{ mmol/L}$

$K_i = 0.667 \text{ mmol/L}$

$HS = S^- + H^+$

$K_a = S^- H^+ / HS$

$pK_a = 4.5 \quad pH - 6.8$

$$(Hs)_{opt} = \sqrt{K_s K_i}$$

$$\sqrt{(0.0333)(0.667)}$$

$$= 0.15 \text{ mmol/L}$$

$$D = \mu = 0.4\left[\frac{1}{1 + \frac{0.0333}{0.15} + \frac{0.15}{0.667}}\right]$$

$$= 0.27/d.$$

$D = \mu = 0.27/d$

$V: \quad F/D = \dfrac{3000\ m^3/d}{0.27/d}$

$= 11111\ m^3$

$HS = \quad S^- H^+ / K_a$

$S^- = \dfrac{0.15\ 10^{-4.5}}{10^{-6.8}} = 29.9\ \dfrac{mmol}{L}$

$= 1795\ \dfrac{mg}{L}$

NPTEL

$S = S^{-} + HS$

$1795 + 9 =$ ~~2004~~ 1804 mg/L

COD LOSS = $F(S_0 - S)$ kg/d

~~600~~ 3000 (~~4~~ 6 − ~~7~~ 1.8) =

12600 ~~12000~~ kg/d

$Y_{CH_4/S} = (0.92)\frac{16}{60} = 0.24$

$Y_{CO_2/S} = (0.92)\,44/60 = 0.67$

Methane Production

$= (12600)\,0.24$

3025

$=$ ~~2880~~ kg/d

CO_2 Production

$(12600)(0.67) =$ ~~8000~~ $\frac{kg}{d}$

8440

NPTEL

Methane Fraction In gas

$$= \frac{2880}{2880+8000} = 0.26.$$

So CH_4 is 26% in biogas

GAS THERMAL VALUE =

$$(0.26)(14000) = 3640 \ \frac{kcal}{kg}$$

$$= 4918 \ kcal/M^3$$

[NOTE 1 kg Gas = 0.74 M^3]

Effluent ~~2000~~ 1804 mg/L

Effluent Treatment

$$D = \frac{1}{B} \frac{\mu_m S}{K_s + S}$$

$$D = \frac{1}{0.3} \frac{0.3 \times 10}{10 + 10} = 0.5/d$$

$$V = F/D = \cancel{\frac{6000}{0.5}} \; \frac{3000}{0.5}$$

$6000 \; M^3$

ETP

COD LOSS (3000) ~~4~~ 1.80 = ~~12000 kg/d~~ 5400 kg/d

Oxygen Supply Needed

@ 1 Kg O_2 / KWH = ~~12000~~ 5400 KWH/d

POWER PRODUCTION = (~~2880~~) 3024 $\frac{14000}{860}$ × 0.3 (OR 0.2) KWH/d

·14770 ~~14 065 KWH/d~~

·9847 ~~9375~~ ~~KWH~~/d

860 Kcal = 1 KWH

FERMENTATION ALCOHOL

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$$

180   88   92

Alcohol : 40 TON/D

$$F(S_0 - S)\,0.4 = 40000/24$$

$$F = \frac{40000}{24(90)(0.4)} = \frac{1111}{24}\,\frac{\dot{M}^3}{D}$$

$$= 46\ M^3/\cancel{D}\ HR$$

$$P = (S_0 - S)\,Y_{P/S} = (100-10)\,0.4$$

$$= 36\ kg/M^3$$

$$\mu = \frac{\mu_m \, S \exp(-kP)}{K_S + S}$$

$$D = \mu = \frac{(0.5)\,10 \exp(-0.017 \times 36)}{(2.2 + 10)}$$

$$= \frac{(0.5)(10)(0.542)}{12.2}$$

$$0.22/HR$$

NPTEL

$F = 46\ M^3/HR$

$D = 0.22/hr$

$V = \frac{46}{0.22} = 206\ M^3$

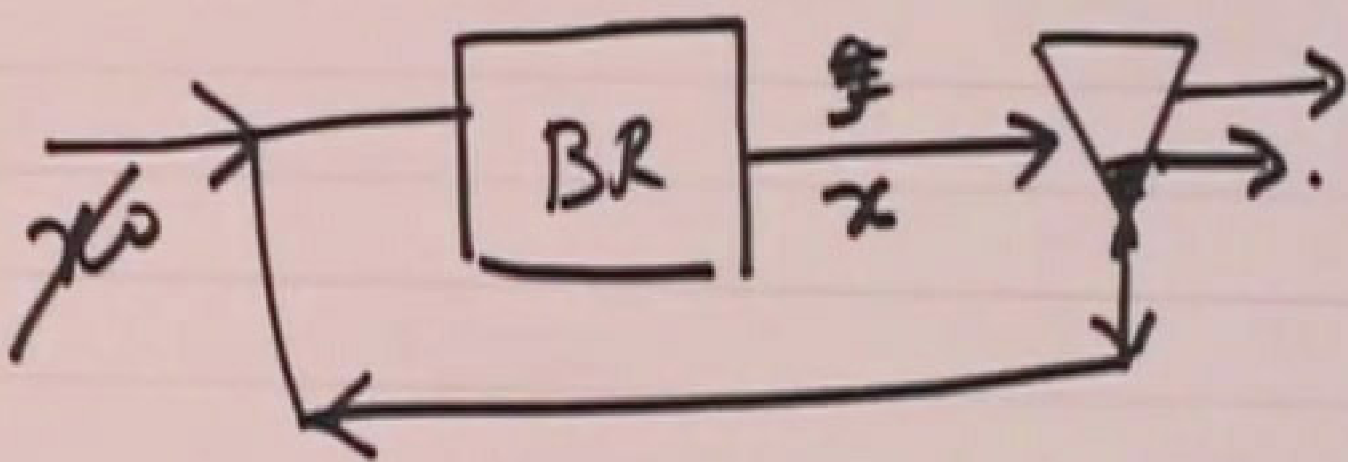
$\text{Productivity} = DP$

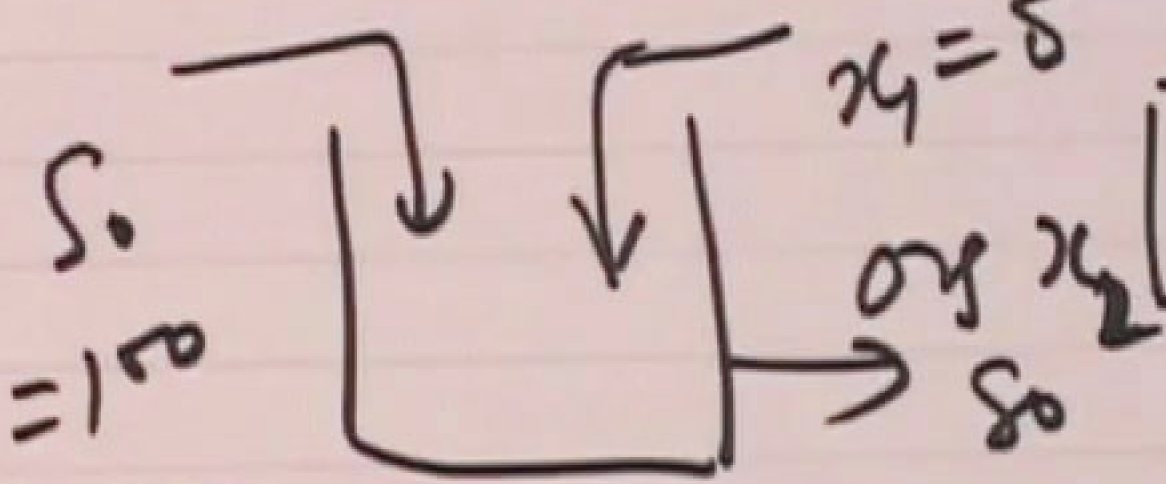
$= (0.22)(36)$

$= 7.9\ kg/M^3 \cdot hr$

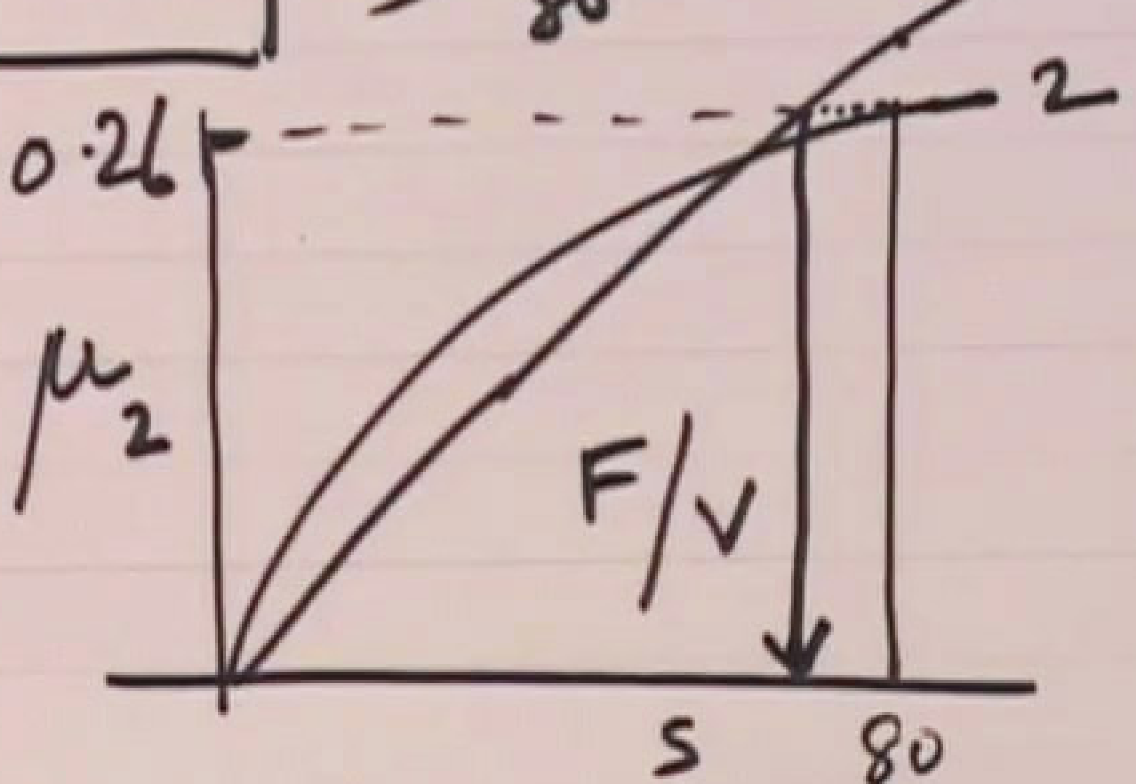
Fermentation Alcohol
Reactor Alternatives

1. Batch
2. Chemostat
3 Immobilized cell Reactor
4. Vacuum Fermentation


BR
x
x_0

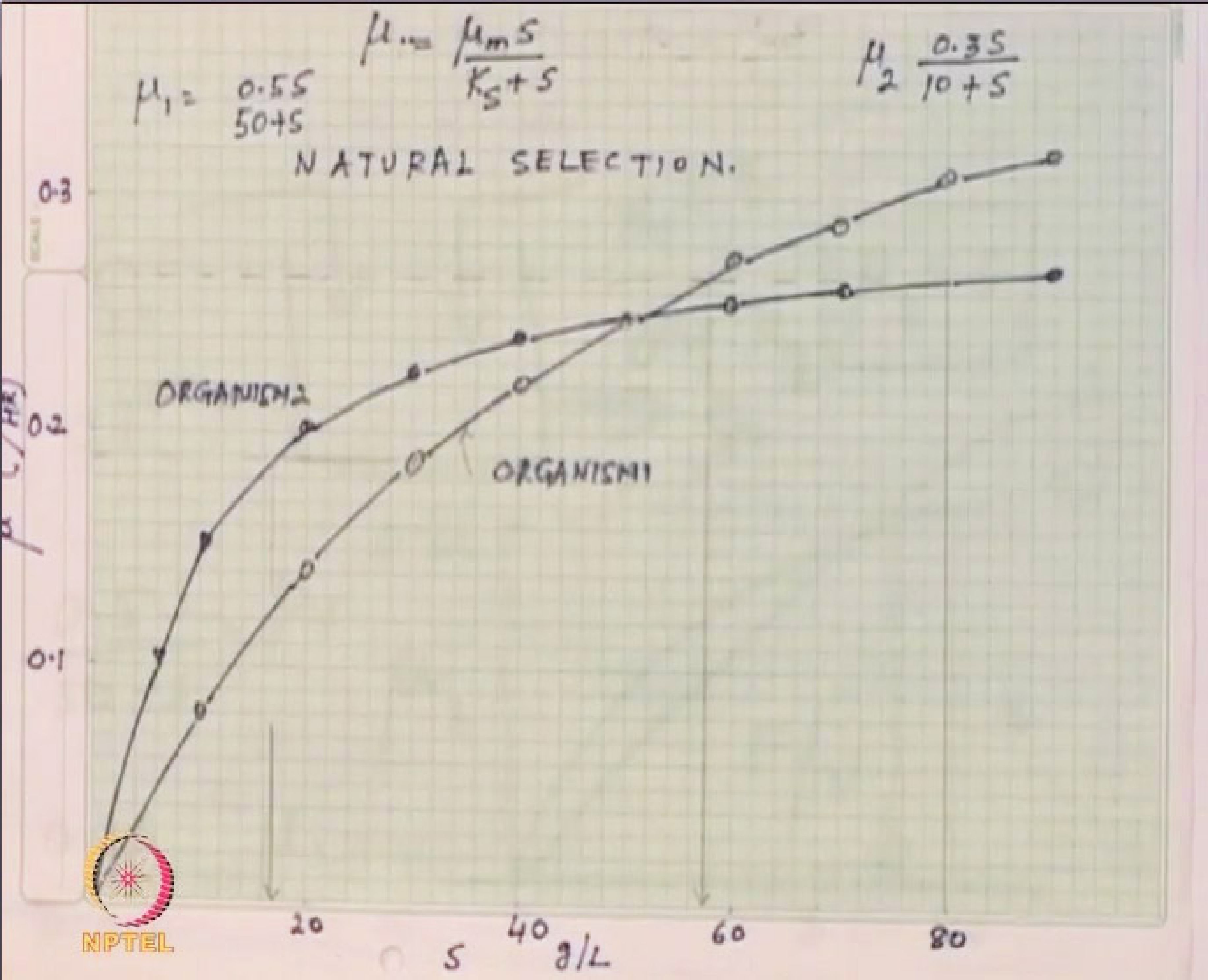


$$\boxed{\mu_2 = D}$$



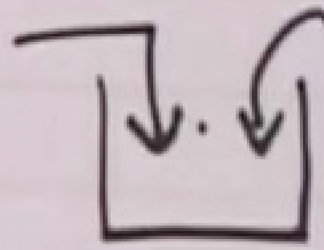
$$\frac{0.5S}{50+S} = \mu_1$$

$$\frac{0.3S}{\frac{30}{10}+S} = \mu_2$$



μ = μm S / (Ks + S)
μ1 = 0.5 S / (50 + S)
μ2 0.3 S / (10 + S)
NATURAL SELECTION.
ORGANISM2
ORGANISM1
0.3
0.2
0.1
μ (1/HR)
20
40
60
80
S g/L

$$F x_{10} - F x_1$$



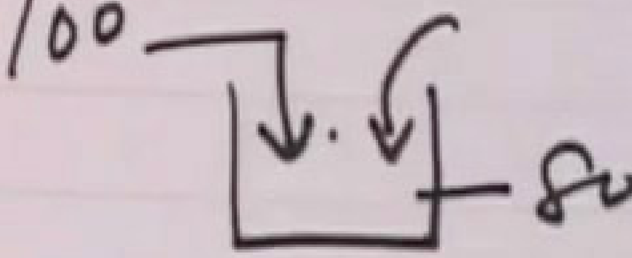
$$\cancel{F x_{20}} - F x_2 + (\mu_2 x_2) V = \frac{d}{dt} V x_2$$

$$F x_{10} - F x_1 + (\mu_1 x_1) V = \frac{d}{dt} V x_1$$

$$F S_0 - F S - \frac{(\mu_1 x_1 + \mu_2 x_2)}{Y} V = \frac{d}{dt} V S.$$

Q2.1

$F x_{10} - F x_1$



$$F \cancel{x_{20}} - F x_2 + (\mu_2 x_2) V = \frac{d}{dt} V x_2$$

$$F \cancel{x_{10}} - F x_1 + (\mu_1 x_1) V = \frac{d}{dt} V x_1$$

$$F S_0 - F s - \frac{(\mu_1 x_1 + \mu_2 x_2)}{Y} V = \frac{d}{dt} V s .$$

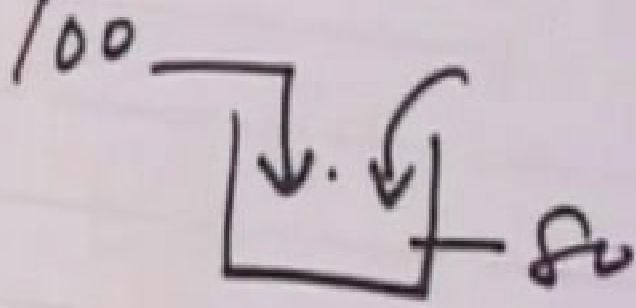
$S_0 = 80;\ x_2 = 10\ g/L \qquad x_1 = \delta\,(0.0019)$

Q 2.2

$$t = 0 \left| \begin{array}{l} S_0 = 1000 \\ S = 30 \\ x_1 = 35\ g/L \\ x_2 = 0.001\ g/L \ (1\ mg/L) \end{array} \right.$$

Q Q2.1

$F x_{10} - F x_1$



$F x_{20} - F x_2 + (\mu_2 x_2) V = \frac{d}{dt} V x_2$

+

$F x_{10} - F x_1 + (\mu_1 x_1) V = \frac{d}{dt} V x_1$

$t = 0^+$

$F S_0 - F S = (\mu_1 x_1 + \mu_2 x_2) V = \frac{d V}{dt}$

$S_0 = 100$

$S_0 = 80, \ x = 10\%$