UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
JANUARY 2017 SEMESTER

COURSE : VDB3073 / VCB3073 – WASTEWATER ENGINEERING

DATE : 2 MAY 2017 (TUESDAY)

TIME : 2.30 PM – 5.30 PM (3 HOURS)

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. Do not open this Question Booklet until instructed.

Note :
- i. There are **ELEVEN (11)** pages in this Question Booklet including the cover page and **APPENDICES**.
- ii. **Graph paper** will be provided.

1. a. Propose a treatment process for an industrial wastewater with characteristics given in **TABLE Q1**. Describe the functions of each unit provided in the process.

TABLE Q1

Parameter	Value	Discharge limit
pH	3.4	6.0-9.0
Suspended solids, mg/L	600	50
BOD, mg/L	3500	20
Zn, mg/L	250	0.5

[10 marks]

b. A factory wastewater with no ammoniacal-nitrogen is treated anaerobically. However, during the treatment, an engineer noticed rising ammonia concentration in the reactor effluent.

i. Justify why there is rising ammonia concentration in the effluent.

[2 marks]

ii. If the rising ammonia concentration is not stopped, predict **THREE (3)** impacts on the reactor performance.

[3 marks]

c. An anaerobic reactor operating at 30 °C treats 600 m^3/d of wastewater. If an accidental spill increased the influent sulphate concentration by 1000 mg/L, determine the expected daily decrease in methane production when 1 g sulphate reduction requires 0.67 g COD and 1 g COD is equivalent to 0.4 L methane.

[10 marks]

2. a. Differentiate the fundamental theories between nitrification and denitrification in wastewater treatment.

[4 marks]

b. You are an engineer in a consultancy company, Nice Water Sdn. Bhd. and are tasked to design an activated sludge system with nitrification for a sewage treatment plant company. The characteristics of the raw influent are as follows:

TABLE Q2

Parameters	Value
Q	8000 m^3/day
COD	250 mg/L
TKN	40 mg/L
TP	4 mg/L
Sludge age	35 days
Alkalinity	135 as $CaCO_3$
MLVSS	6000 mg/L
MLVSS:MLSS	0.85
SVI	100
Alkalinity used for nitrification	7.14 g $CaCO_3$/g NH_4-N
Residual alkalinity concentration to maintain pH 7	equivalent to 70 g/m^3 as $CaCO_3$

Use the following kinetic coefficients:

k = 15 g COD/g VSS·day

μ_m = 6 g VSS/g VSS·day

K_s = 20 g COD/m^3

Y = 0.4 g VSS/g COD

k_d = 0.12 g VSS/g VSS·day

f_d = 0.15 g/g

Y_n = 0.12 g VSS/g NH_4-N

k_{dn} = 0.08 g VSS/g VSS·day

i. How much sludge would be produced?

[8 marks]

ii. Calculate the volume, in m^3.

[2 marks]

iii. Calculate the oxygen demand, in kg/h.

[4 marks]

iv. How much alkalinity needs to be added in kg/day $NaHCO_3$.

[5 marks]

v. Calculate nitrogen and phosphorus to be added in mg/L?

[2 marks]

3. a. Sequencing batch reactor (SBR) is one of the aerobic treatment systems. Illustrate and explain the treatment process using SBR.

[5 marks]

b. Why does sloughing occur in a trickling filter?

[2 marks]

c. Suggest **TWO (2)** suitable criteria for packing media used in a trickling filter.

[2 marks]

d. A 28 m diameter trickling filter (recirculation ratio 1:1.5) with a 2 m depth is fed with a 5000 m^3/d wastewater with an average BOD of 130 mg/L. The temperature-activity coefficient of 1.035 is a typical value for trickling filters.

Determine:

i. the hydraulic load, and

[6 marks]

ii. the anticipated effluent BOD at 20 °C and 16 °C, in mg/L.

[10 marks]

4. a. Compare and contrast gravitational settling and dissolved air floatation.

[2 marks]

b. Differentiate discrete particle settling and flocculent settling.

[3 marks]

c. **TABLE Q4** shows the settling data obtained for an activated sludge with initial solids concentration of 2500 mg/L. The height of settling column was 1.5 m. The inflow is 1000 m^3/day and the thickened sludge concentration required is 25,000 mg/L. Determine the area of thickener.

TABLE Q4

Settling time, min	Interface height, m
0	1.5
10	0.8
20	0.36
30	0.2
40	0.14
50	0.12
60	0.1

[20 marks]

-END OF PAPER-

Appendix

Clarifier

$$H_u = \frac{C_o H_o}{C_u}$$

$$A = \frac{Q t_u}{H_o}$$

Activated Sludge System

For completely mixed activated sludge,

ϑ_c = mean cell residence time, time

V = volume of aeration tank, unit volume

Q = influent wastewater flow, unit volume/time

Q_w = rate of excess sludge wasting, unit volume/time

X = concentration of MLVSS in aeration tank, mass/unit volume

X_e = concentration of VSS in effluent, mass/unit volume

Y = growth yield

Y_{obs} = observed growth yield, g of MLVSS/g of soluble BOD

F/M = food/microorganism ratio, g/d of soluble BOD per g of MLVSS

E = soluble effluent BOD removal, %

k_d= microbial decay coefficient, d^{-1}

K_s = saturation constant, mass/unit volume

k = max. rate of substrate utilization per unit mass of biomass, $time^{-1}$

S_o = influent substrate concentration, mass/unit volume

S_e = effluent substrate concentration, mass/unit volume

U = specific substrate utlization rate, $time^{-1}$

= kY

X_{vss} = Volatile biomass concentration in return sludge, mg/L

Mean cell residence time,

$$\vartheta_c = \frac{VX}{Q_w X + (Q - Q_w) X_e}$$

$$\frac{1}{\vartheta_c} = \frac{Y(F/M)E}{100} - k_d$$

$$\frac{1}{\vartheta_c} = \frac{YkS_e}{K_s + S_e} - k_d$$

$$\frac{1}{\vartheta_c} = YU - k_d$$

Food/Microorganism ratio, g/d of soluble BOD applied per g of MLVSS in the aeration tank

$$F/M = \frac{QS_o}{VX} = \frac{S_o}{\theta X}$$

Effluent substrate concentration

$$S_e = \frac{K_s(1 + k_d \vartheta_c)}{\vartheta_c(\mu_m - k_d) - 1}$$

Volume of aeration tank,

$$V = \frac{\vartheta_c YQ(S_o - S_e)}{X(1 + k_d \vartheta_c)}$$

Kinetic model for completely activated sludge:

$$\frac{1}{U} = \left(\frac{K_s}{k}\right)\left(\frac{1}{S_e}\right) + \frac{1}{k}$$

Observed growth yield, g of MLVSS/g of soluble BOD

$$Y_{obs} = \frac{Y}{1 + \vartheta_c k_d}$$

Amount of total waste solids $P_{x,TSS}$

$P_{x,TSS} = X_{TSS}(V)/\theta_c$

Production of excess biomass in waste activated sludge

$$P_{x,vss} = \frac{Q\,Y\,(S_o - S_e)}{1 + k_d\,\vartheta_c} + \frac{(f_d)(k_d)\,Q\,Y\,(S_o - S_e)\,\vartheta_c}{1 + k_d\,\vartheta_c} + \frac{Q\,Y_n\,(NO_x)}{1 + k_{dn}\,\vartheta_c}$$

Oxygen Requirement, R_o, kg/day

$R_o = Q\,(S_o - S) - 1.42\,P_{x,vss} + 4.33\,Q\,(NO_x)$

The nitrogen mass balance, based on the assumption of 0.12 g N/g biomass ($C_5H_7NO_2$ for biomass) is as follows:

$$NO_x = TKN_o - N_e - 0.12P_{x,bio}/Q$$

Where	NO_x	=	nitrogen oxidized, mg/L
	TKN_o	=	influent TKN concentration, mg/L
	N_e	=	effluent NH_4-N concentration, mg/L
	Q	=	flowrate, L/day

Nitrogen required by biomass = $0.12P_{x,bio}/Q$

Phosphorus required by biomass = $0.02P_{x,bio}/Q$