UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS TECHNOLOGIAE: *ENGINEERING : CIVIL*
SUBJECT	:	**WASTEWATER TREATMENT TECHNOLOGY IV**
CODE	:	**WWT 411**
ASSESSMENT	:	WINTER EXAMINATION (MAIN PAPER)
DATE		7th JUNE 2014
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40:60
TOTAL MARKS	:	110

ASSESSOR	:	G.K. NKHONJERA
MODERATOR	:	PROF. F.M. ILUNGA
NUMBER OF PAGES	:	PAGES: 9 including the cover page and Annexures.

INSTRUCTIONS :

1. This is a closed-book type of Exam.
2. This paper contains 6 questions: ANSWER **ALL** QUESTIONS
3. Make sure that you understand what the question requires before attempting it.
4. Any additional material is to be placed in the answer book and must indicate clearly the question number, your name, and Student number.
5. Where necessary, answers without calculations will not be considered.

ANSWER **ALL** QUESTIONS

QUESTION 1 [15]

1.1 With respect to the preliminary treatment processes in wastewater treatment, briefly describe the purpose of the following:

a) Flow Measurements. (2)
b) Screens. (2)
c) Flow Equalization. (2)

1.2 Discuss the major differences between the following terms:

a) Hydraulic loading and Organic loading. (2)
b) Nitrification and Denitrification. (2)
c) Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). (2)

1.3 With respect to the decomposition of wastes in wastewater treatment, describe clearly the Anoxic Decomposition. (3)

QUESTION 2 [15]

2.1 Explain, clearly, the principles of operations of the following oxidation ponds:

a) Facultative ponds. (2)
b) Maturation ponds. (2)

2.2 With a well labelled sketch of a flow diagram, discuss how biological oxidation is achieved in a conventional ACTIVATED SLUDGE PROCESS. (7)

2.3 A clarifier linear flow-through velocity is limited to 72 m/hr in order to prevent scouring. The sticky material coefficient, $\beta = 0.040$; Darcy-Weisbach friction factor, $f = 0.025$; wastewater density, $\rho = 1\ g/cm^3$. If the diameter of the particle, $d = 200\ \mu m$, estimate the specific gravity of the particle. (4)

QUESTION 3 [20]

3.1 With examples where necessary in wastewater treatment, discuss the philosophy of the use of coarse solids reduction versus the use of screens. (4)

3.2 A bar rack screen is installed in a rectangular channel carrying wastewater flow of 120000 m^3/d. The dimensions of the channel are 1.75 m wide and 1.6 m deep (effective water depth). Estimate the headlosses incurred in the bar screen when the screen is:

a) Completely clean. (8)
b) 36% unclogged. (4)
c) 55% clogged. (4)

You may be free to use the following assumptions:

- *Bar width = 15 mm.*
- *Bar spacing (Clear Distance) = 25 mm.*
- *Discharge coefficient, C = 0.6*
- *Bar rack is mechanically cleaned.*

QUESTION 4 [20]

A secondary treatment process unit is to be built that can meet a stringent effluent standard of 10 mg/L BOD. The municipality prefers a completely mixed activated sludge system (CMAS) as shown in **Fig 4.1** below. The wastewater flow rate to the CMAS reactor is 34500 m^3/d. The influent BOD to the reactor is 250 mg/L. The growth rate constant values are estimated as: K_s = 100 mg/L BOD; k_d = 0.03 d^{-1}; μ_m = 3 d^{-1}; Y = 0.6 mg VSS/mg BOD removed. If the MLVSS is 3000 mg/L and underflow concentration rate from the secondary clarifier is 12000 mg/L, determine the following:

a) Required volume of the reactor tank. (8)
b) Volume of solids wasted each day. (4)
c) Sludge recirculation ratio. (4)
d) Food to Microorganism (F/M) ratio. (2)
e) Specific utilization rate. (2)

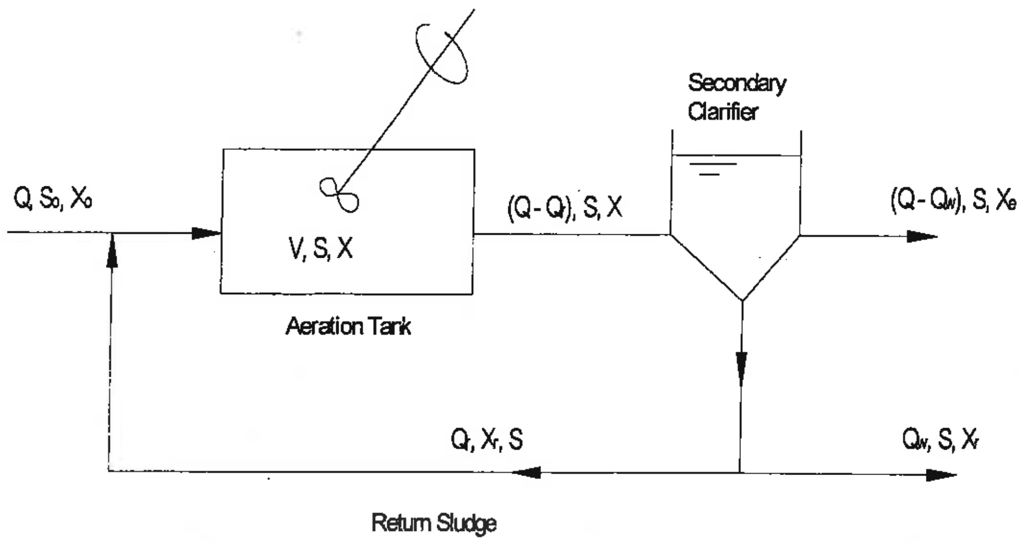

Fig. 4.1: Completely Mixed Activated Sludge System (CMAS)

QUESTION 5 [20]

Design a centre-feed clarifier that can treat wastewater flow rate of 10.2 ML/d. In order to make sure that the flow is distributed uniformly and that the energy from the inlet pipes is well dissipated, the tank will have energy dissipating inlets (EDI) devices installed. The following design information is available for you:

Overflow rate = 35 $m^3/d.m^2$.
Side water depth (SWD) = 4.0 m.
Feedwell detention time = 20 minutes.
EDI assembly detention time = 10 seconds.
Depth of Feedwell = 55% of SWD.
Depth of EDI assembly = 30% of SWD.

To complete the design, provide the following:

- *Diameter of tank.*
- *Diameter of Feedwell.*
- *Diameter of EDI. Also check whether the diameter is between 10 and 13% of the tank diameter and then comment on your answer.*
- *Check the velocity across the sludge zone.*
- *Weir loading.*

QUESTION 6 [20]

Below (**Fig. 6.2**) is a schematic flow diagram of a proposed two-stage rock media trickling filter of a wastewater treatment plant. The municipal wastewater standards, with respect to BOD, is 30 mg/L when the wastewater temperature is 20°C. You are required to determine the size of the two filters (Diameters) given the following design information:

- Wastewater flow, Q = 10 ML/day.
- Influent BOD = 370 mg/L.
- Depth of first filter, d_1 = 2.5 m.
- Depth of the second filter, d_2 = 2.2 m.
- Recirculation flow rate on the first filter, Q_{r1} = 0.097 m^3/s.
- Recirculation flow rate on the second filter, Q_{r2} = 0.011 m^3/s.
- Removal efficiency of the first and second filters is to be maintained at 73% and 70% respectively.
- Check whether the filters will remove the BOD to the required municipal standards.
- Assume the NRC Equation apply.

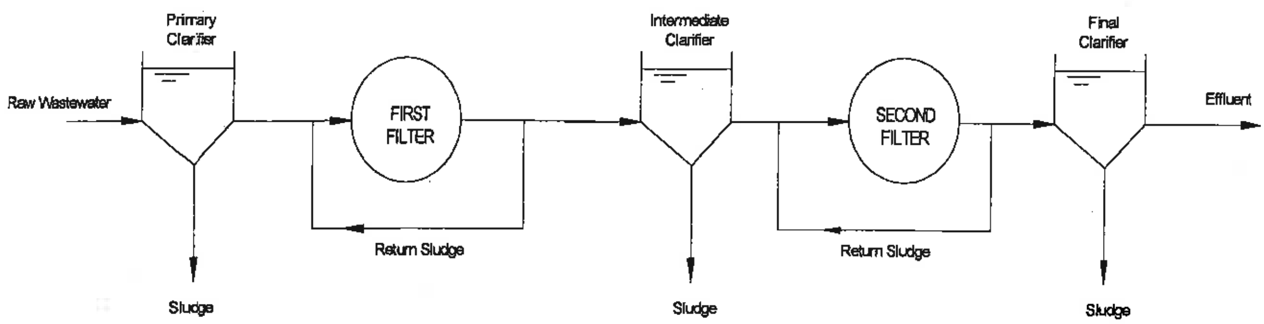

Fig. 6.2: *Two-Stage rock media trickling filter*

GOOD LUCK TO YOU ALL !!!!!

APPENDIX

FORMULAS

Newton's Law formula $$V_s = \sqrt{\frac{4g(\rho_s - \rho)d}{3C_D\rho}}$$ Where: $$C_D = \frac{24}{N_R} + \frac{3}{\sqrt{N_R}} + 0.34$$	Headlosses in the screen, h_L, $$h_L = \frac{1}{C}\left(\frac{V_{thru}^2 - V_h^2}{2g}\right)$$
Scour Velocity, V_{sc}, $$V_{sc} = \sqrt{\frac{8\beta(\rho_s - \rho)gd}{1000f}}$$	Weir loading, WL $$WL = \frac{Q}{Length}$$
Detention time, t_d, $$t_d = \frac{\forall}{Q}$$	Number of bars, N, $$N = \frac{Width\_of\_channel - bar\_space}{bar\_width + bar\_space}$$
Stoke's Law formula $$V_s = \frac{g(\rho_s - \rho)d^2}{18\mu}$$	Number of spacing, S, $$S = N + 1$$
Mass Balance Equation for Biomass $$QX_o + (\forall)\left(\frac{\mu_m SX}{K_s + S} - k_d X\right) = (Q - Q_w)X_e + Q_w X_r$$	Mass Balance Equation for Substrate $$QS_o - (\forall)\left(\frac{\mu_m SX}{Y(K_s + S)}\right) = (Q - Q_w)S + Q_w S$$

Hydraulic retention time, θ, $$\theta = \frac{\forall}{Q}$$	Mean cell residence time, θ_c, $$\theta_c = \frac{\forall X}{Q_w X_r}$$
Concentration of rbsCOD in the effluent, S, $$S = \frac{K_s(1+k_d\theta_c)}{\theta_c(\mu_m - k_d)-1}$$	Concentration of biomass in the reactor, X, $$X = \frac{\theta_c(Y)(S_o - S)}{\theta(1+k_d\theta_c)}$$
Specific substrate utilization rate, U, $$U = \frac{S_o - S}{\theta X}$$ Also, $$\frac{1}{\theta_c} = YU - k_d$$	Food to Microorganism (F/M) $$F/M = \frac{QS_o}{\forall X}$$
Recirculation ratio, R, for trickling filters $$R = \frac{Q_r}{Q}$$	Recirculation factor, F_1, for 1st trickling filter, $$F_1 = \frac{1+R_1}{(1+0.1R_1)^2}$$
Efficiency for the first trickling filter: $$E_1 = \frac{1}{1+4.12\left(\frac{QC_{in}}{\forall_1 F_1}\right)^{0.5}}$$	Efficiency for the second trickling filter: $$E_2 = \frac{1}{1+\frac{4.12}{1-E_1}\left(\frac{QC_e}{\forall_2 F_2}\right)^{0.5}}$$

Percentage removal, R, of BOD and TSS,

$$R_{BOD/TSS} = \frac{t}{a+bt}$$

Where:

R = Expected removal efficiency, (%).
t = Nominal detention time, (hours).
a,b = Empirical constants as shown below.

Typical values of the empirical constants at 20°C

Items	a	b
BOD	0.018	0.020
TSS	0.0075	0.014

Where:

- N_R = Reynolds number, dimensionless
- C_D, = Drag coefficient, dimensionless
- V_h = Average horizontal fluid velocity in tank, m/s
- β = Sticky material coefficient, dimensionless
- f = Darcy-Weisbach, friction factor
- ν = Kinematic viscosity, m^2/s ; $\nu = \mu/\rho$
- μ = Dynamic viscosity, Pa · s
- ρ = Density of fluid, kg/m^3
- ρ_s = Density of the particle, kg/m^3
- d = Size of the particle (m)
- V_s = Settling velocity (m/s)
- V_o = Overflow rate (m/s or $m^3/s.m^2$)
- V_{thru} = Velocity through the bar screen (m/s)
- h_L = headloss (m)
- C = Empirical discharge coefficient
- $\forall$ = Volume of the tank (m^3)
- WL = Weir loading ($m^3/d.m$)
- N = Number of bars in the bar screen
- S = Number of spacing in the screen

For Suspended growth (Completely mixed reactor) ,

- Q = wastewater flow rate into the aeration tank, m^3/d
- X_o = microorganism concentration (volatile suspended solids or VSS) entering aeration tank, mg/L.
- = volume of aeration tank, m^3
- μ_m = maximum growth rate constant, d^{-1}
- S = readily biodegradable soluble COD (rbsCOD) in aeration tank and effluent, mg/L.
- X = microorganism concentration (mixed-liquor volatile suspended solids or MLVSS) in the aeration tank, mg/L.
- K_s = half velocity constant.
- Also, K_s = soluble BOD_5 concentration at one-half the maximum growth rate, mg/L.
- k_d = decay rate of microorganisms, d^{-1}
- Q_w = flow rate of liquid containing microorganisms to be wasted, m^3/d.
- X_e = microorganism concentration (VSS) in effluent from secondary settling tank, mg/L.
- X_r = microorganism concentration (VSS) in sludge being wasted, mg/L.
- Y = yield coefficient.
- U = specific substrate utilization rate.
- S_o = influent readily biodegradable soluble COD (rbsCOD), mg/L.

For Attach growth (trickling filter),

- E_1 = fraction of BOD_5 removal for first stage at 20°C, including recirculation and sedimentation
- Q = wastewater flow rate, m^3/s
- C_{in} = influent BOD_5, mg/L
- = volume of filter media, m^3
- F = recirculation factor
- R = recirculation ratio = Q_r/Q
- Q_r = recirculation flow rate, m^3/s
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