UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS TECHNOLOGIAE: *ENGINEERING : CIVIL*
SUBJECT	:	**WASTEWATER TREATMENT TECHNOLOGY IV**
CODE	:	**WWT411**
ASSESSMENT	:	WINTER EXAMINATION (SUPPLEMENTARY PAPER)
DATE		29th JULY 2016
DURATION	:	(SESSION 1) 08:00 - 11:00
WEIGHT	:	40:60
TOTAL MARKS	:	90

ASSESSOR	:	G.K. NKHONJERA
MODERATOR	:	PROF. F.M. ILUNGA
NUMBER OF PAGES	:	PAGES: 15 including the cover page and Annexures.

INSTRUCTIONS :

1. This paper contains 5 questions.
2. 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 During the decomposition of wastes, bacteria may undergo the process of Endogenous Respiration. Briefly, explain what you understand by Endogenous Respiration as experienced in wastewater treatment systems. (2)

1.2 With respect to wastewater treatment, discuss the differences between the following:

a) Aerated grit chambers and Vortex-flow grit chambers. (2)
b) Anaerobes and Denitrifiers. (2)
c) Suspended growth and Attached growth processes. (2)

1.3 Explain clearly, but briefly, the three major steps in Anaerobic Digestion in wastewater treatment systems. (3)

1.4 From your knowledge of wastewater treatment so far, what would you think is the purpose of the following:

a) Microorganisms in biological treatment of wastewater. (2)
b) Recirculation of flow in trickling filters. (2)

QUESTION 2 [15]

2.1 For a horizontal-flow grit chamber, describe fully, THREE main conditions that must be satisfied to ensure the removal of grit particles and the re-scouring of organic matter that settles. (3)

2.2 Wastewater in a grit removal chamber contains both grit particles as well as organic particles. Grit particles have a diameter of 0.22 mm and specific gravity of 2.65 while organic particles are 0.20 mm in diameter but with a specific gravity of 1.10. For both particles, the Reynolds Number is taken as 3 while friction factor, f = 0.02 and sticky dimensionless value, β = 0.060. Assuming that the density of the wastewater is 1000 kg/m^3, determine the following:

a) Settling velocity of the grit particle. (4)
b) Scour velocities of both grit and organic particles. (5)
c) Whether the grit removal chamber is effective, given the horizontal velocity to be 0.05 m/s. State the reasons for your judgement. (3)

QUESTION 3 [20]

A small wastewater treatment plant has a complete-mix activated sludge process as shown below (**Fig. 3.1**) which is built to meet the municipal wastewater effluent standards of 30 mg/L BOD_5 when the wastewater is discharged into the natural streams. Also, allowable suspended solids in the effluent is limited to 35 mg/L, of which 67% of it accounts for BOD. For operational flexibility, the maximum sludge return rate is set to half of that of the design flow rate. Assuming the MLVSS is 2200 mg/L and that it is 75% of MLSS, estimate the following:

a) Volume of the aeration tank. (9)
b) Return activated sludge concentration. (5)
c) Effluent flow rate after secondary clarifier. (4)
d) Food-to-microorganism ratio. (2)

The growth rate constant values are estimated as:
$K_s = 60$ *mg/L BOD;* $k_d = 0.05\ d^{-1}$; $\mu_m = 2.5\ d^{-1}$; $Y = 0.8$ *mg VSS/mg BOD removed.*

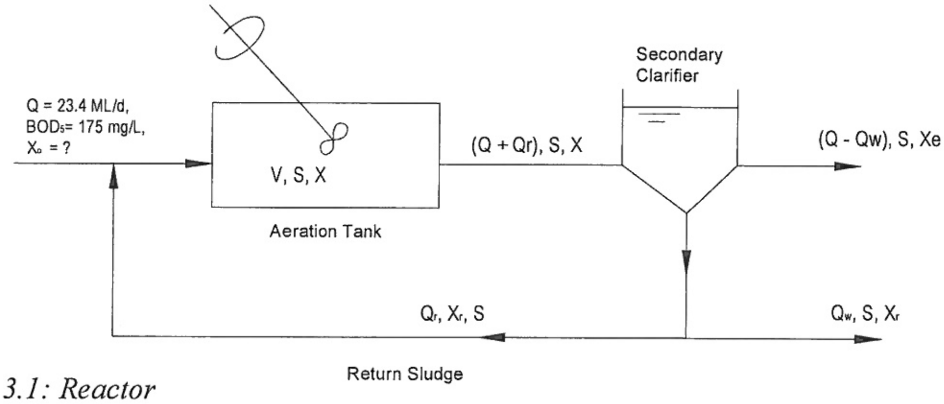

Fig. 3.1: Reactor

QUESTION 4 [20]

You are presented with a wastewater treatment plant that receives an average flow of 43.15 ML/d. However, during low flows, the plant registers the lowest flow rate of 17.7 ML/d. The wastewater contains 250 mg/L BOD5 and 300 mg/L suspended solids at average flow rate. At the lowest flow rate, it contains 150 mg/L BOD5 and 220 mg/L suspended solids. For a primary clarifier with a diameter of 30 m and side water depth of 3.0 m, determine the following:

a) Surface overflow rate and approximate BOD_5 and suspended solids in the effluent at average flow rate. (10)

b) Surface overflow rate and approximate BOD_5 and suspended solids removed from the clarifier when the flow is at its lowest flow rate. (8)

c) Mass of solids (kg/day) that is removed as sludge for average flow condition. (2)

QUESTION 5 [20]

Design a primary treatment clarifier to treat wastewater from a small town in your area, given the following design information:

Total flow to the clarifier, Q = 18450 m^3/d

One (1) Center feed type of tank.
Overflow rate = 30 $m^3/d.m^2$.
Side water depth (SWD) = 4.3 m.
Feedwell detention time = 20 minutes.
Depth of Feedwell = 70% of SWD.
EDI detention time = 10 seconds.
Depth of EDI = 28% of SWD.

Summarise your design output by providing the following information:

Diameter of tank.
Diameter and depth of Feedwell.
Diameter and depth of EDI.
Check flow velocity and provide necessary comments.
Weir loading rates.

GOOD LUCK TO YOU ALL !!!!!

APPENDIX A

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, $$h_L = \frac{1}{C}\left(\frac{V_{thru}^2 - V_{ap}^2}{2g}\right)$$
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_b, $$N = \frac{Width\_of\_channel - bar\_space}{bar\_width + bar\_space}$$
Stoke's Law formula $$V_s = \frac{g(\rho_s - \rho)d^2}{18\mu}$$	Number of spacing, N_{sp}, $$N_{sp} = N_b + 1$$
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 $$QS_o - (\forall)\left(\frac{\mu_m SX}{Y(K_s + S)}\right) = (Q - Q_w)S + Q_w S$$

Mass balance for biomass around the secondary clarifier, $$(Q+Q_r)X=(Q-Q_w)X_e+Q_rX_r+Q_wX_r$$	Quadratic equation, $$ax^2+bx+c=0$$ $$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$
Hydraulic retention time, θ, $$\theta=\frac{\forall}{Q}$$	Mean cell residence time, θ_c, $$\theta_c=\frac{\forall X}{Q_wX_r}$$
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) $$F/M=\frac{QS_o}{\forall X}$$ Also, $$Q_wX'_r=\frac{\forall X'}{\theta_c}$$
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: $$E_1=\frac{1}{1+4.12\left(\frac{QC_{in}}{\forall_1F_1}\right)^{0.5}}$$	Efficiency for the second trickling filter: $$E_2=\frac{1}{1+\frac{4.12}{1-E_1}\left(\frac{QC_e}{\forall_2F_2}\right)^{0.5}}$$

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_b = Number of bars in the bar screen
- N_{sp} = 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.
- $\forall$ = 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
- $\forall$ = 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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APPENDIX B

TYPICAL DESIGN CRITERIA FOR PRIMARY SEDIMENTATION BASINS

Typical design criteria for primary sedimentation basins		
Design Parameter	**Range of values**	**Typical design value/ Comments**
General		
Overflow rate (average flow)	30 to 50 $m^3/d.m^2$	40 $m^3/d.m^2$
Overflow rate (peak flow)	60 to 120 $m^3/d.m^2$	100 $m^3/d.m^2$
Detention time (average flow)	1.5 to 2.5 hours	2.0 hours
Horizontal flow velocity	0.020 to 0.025 m/s	
Weir loading rate	125 to 500 $m^3/d.m$	250 $m^3/d.m$
Sludge hoppers	1.7 vertical : 1 horizontal	Minimum: bottom width < 0.60 m
Geotechnical		Consider potential for floatation when tank is empty.

Design Parameter	Range of values	Typical design value/ Comments
<u>Circular Tanks</u>		
Dimensions		
Diameter	3 to 100 m	12 to 45 m
Side water depth (SWD)	3 to 5 m	4.3 m
Floor slope	1 vertical to 12 horizontal	
Splitter box		
Inlet velocity	< 0.3 m/s	At peak flow

Design Parameter	**Range of values**	**Typical design value/ Comments**
Circular Tanks		
Inlet configuration		
Detention time	20 minutes	Feedwell
Submergence	30 to 75% of depth	Size to prevent scour
EDI detention time	8 to 10 seconds	
Baffles		
Effluent		Below weir
Horizontal		Below feedwell

Typical design criteria for primary sedimentation basins

Design Parameter	**Range of values**	**Typical design value/ Comments**
Rectangular tanks		
Dimensions		
Length	30 to 110 m	30 to 60 m
Width	3 to 24 m	6 m maximum per flight
Depth	2 to 5 m	4.3 m
Floor slope	1%	
Distribution channel		
Velocity	0.3 to 0.75 m/s	
Flow distribution		Prefer orifice or gates

Typical design criteria for primary sedimentation basins		
Design Parameter	Range of values	Typical design value/ Comments
Rectangular tanks		
Inlet configuration		
Ports	3 to 4 per tank at < 3 m	2 m
Energy dissipation		Target or finger baffle
Baffles		
Distance	0.6 to 0.9 m from inlet	
Submergence	0.5 to 0.6 m	
Porosity	Individual openings > 5 cm and < 10 cm	5% open area

APPENDIX C

PHYSICAL PROPERTIES OF WATER

Temperature (°C)	Density, ρ (kg/m^3)	Specific weight, γ (kN/m^3)	Dynamic viscosity, μ (mPa · s)*	Kinematic viscosity, ν ($\mu m^2/s$)*
0	999.842	9.805	1.787	1.787
3.98	1,000.000	9.807	1.567	1.567
5	999.967	9.807	1.519	1.519
10	999.703	9.804	1.307	1.307
12	999.5	9.802	1.235	1.236
15	999.103	9.798	1.139	1.14
17	998.778	9.795	1.081	1.082
18	998.599	9.793	1.053	1.054
19	998.408	9.791	1.027	1.029
20	998.207	9.789	1.002	1.004
21	997.996	9.787	0.998	1
22	997.774	9.785	0.955	0.957
23	997.542	9.783	0.932	0.934
24	997.3	9.781	0.911	0.913
25	997.048	9.778	0.89	0.893
26	996.787	9.775	0.87	0.873
27	996.516	9.773	0.851	0.854
28	996.236	9.77	0.833	0.836
29	995.948	9.767	0.815	0.818
30	995.65	9.764	0.798	0.801
35	994.035	9.749	0.719	0.723
40	992.219	9.731	0.653	0.658
45	990.216	9.711	0.596	0.602
50	988.039	9.69	0.547	0.554
60	983.202	9.642	0.466	0.474
70	977.773	9.589	0.404	0.413
80	971.801	9.53	0.355	0.365
90	965.323	9.467	0.315	0.326
100	958.366	9.399	0.282	0.294

*Pa · s = (mPa · s) × 10^{-3}

*m^2/s = ($\mu m^2/s$) × 10^{-6}