UNIVERSITY OF RUHUNA

Faculty of Engineering

Mid-Semester 7 Examination in Engineering: June 2015

Module Number: CE7325 **Module Name: Environmental Engineering Design**

[Two Hours]

[Answer **all questions**, each question carries five marks]

Q1. Design a gravity-flow trunk sanitary sewer for the street given in Table Q1 (a) from the junction *L* to the junction *N* via the junction *M*. Major manholes are located at the junctions *L, M* and *N*. The design should include the design flow rates, pipe diameters, pipe slopes and the pipe invert elevations. Assume that the infiltration rate is negligible. Table Q1 (b) gives the design criteria. For the hydraulic design calculations, use the Manning equation (Figure Q1);$V = (1/n)R^{2/3}S^{1/2}$; where V = velocity(ms^{-1}); n = friction factor (0.013); R = hydraulic radius (m); S= slope of energy grade line (m/m).

Table Q1 (a): Street and sewer network information.

Line	From junction	To junction	Length of sewer (*m*)	Average residential flow (m^3/d)	Average commercial flow (m^3/d)	Average institutional flow (m^3/d)	Ground surface elevation (*m*)	
							At upper manhole	At lower manhole
1	L	M	600	7000	500	1500	23.0	22.0
2	M	N	400	3000	2500	800	20.5	21.0

Table Q1 (b): Design criteria of the gravity-flow trunk sanitary sewer.

Description	Unit	Value
Peaking factors:	-	
Residential areas		2.0
Commercial areas		1.5
Institutions		3.0
The smallest pipe diameter permissible for this situation according to the local building code	*mm*	200
The minimum practical slope of a sewer for construction	*m/m*	0.00085
The allowable minimum velocity	*m/s*	0.75
The minimum depth of the cover over the top of the sewer according to the local building code	*m*	2.0
The pipe wall thickness	*m*	0.05

[5.0 Marks]

Q2. a) Name and explain the task/s of each component of an aerobic suspended growth flow-through aerated lagoon (without solids recycle) system when used for treating a primary treated municipal wastewater.

[1.5 Marks]

b) Table Q2 gives the conditions and requirements for the design of a flow-through aerated lagoon (without recycle). Determine the (i) Surface area *(A)* of the lagoon; (ii) Liquid water temperature in the lagoon (T_w); (iii) Effluent soluble 5-day biochemical oxygen demand ($sBOD_5$) *(S)*; (iv) Effluent *TSS* (Total Suspended Solids) concentration; and (v) Oxygen requirement.

Table Q2: Design criteria of the aerated lagoon.

Description	Unit	Value
Wastewater flow(Q)	m^3/d	20 000
Influent SS (Suspended Solids) concentration; Influent SS are not biologically degradable	g/m^3	300
Influent soluble $BOD_5(S_0)$	g/m^3	250
Influent wastewater temperature (T_i)	^0C	25
Air temperature (T_a)	^0C	20
Kinetic coefficients (for T=15 ^0C-20 ^0C)		
Yield coefficient (Y)	-	0.65
Half velocity constant (K_s)	g/m^3	100
Maximum rate of substrate utilization (k)	d^{-1}	6.0
Endogenous decay coefficient (k_d)	d^{-1}	0.05
Conversion factor (x) for BOD_5 to BOD_L (Ultimate Biochemical Oxygen Demand)	-	0.65
VSS (Volatile Suspended Solids)/TSS ratio	-	0.85
Design solids retention time (SRT)	d	12
Depth of the lagoon	m	2.4
Proportionality factor (f) for temperature correction	-	0.5

Following equations are applicable:

$T_w = \frac{AfT_a+QT_i}{Af+Q}$; $X = \frac{(S_0-S)Y}{(1+k_d.HRT)}$; $S = \frac{K_s(1+k_d.HRT)}{\{HRT.(Yk-k_d)-1\}}$; where HRT= Hydraulic retention time.Oxygen requirement $(kg\ of\ O_2/d) = \{Q(S_0 - S)/x\} - 1.42P_x$;
where P_x = biological solids wasted per day ($kg\ VSS/d$).

[3.5 Marks]

Q3. a) Table Q3 (a) gives the conditions and requirements for the design of an earthen sedimentation basin which follows an aerated lagoon. Determine the total depth of the sedimentation basin excluding the free board. The accumulated sludge will be compacted to an average final value of 10 % of the initial solids volume. Assume that the maximum amount of volatile suspended solids (VSS) accumulated at the end of t^{th} year is given by the following equation:
$(VSS)_t = [0.7+0.4(t-1)]$ X mass of VSS added per year (kg/yr)

Table Q3 (a): Design criteria of the earthen sedimentation basin.

Description	Unit	Value
Wastewater flow	m^3/d	20 000
Hydraulic retention time (HRT)	d	2.5
Liquid level above the sludge layer at its maximum level of accumulation	m	1.25
Total suspended solids (TSS) concentration of the effluent from the aerated lagoon	g/m^3	450
TSS concentration of the effluent from the sedimentation basin	g/m^3	35
Volatile suspended solids (VSS) content of TSS discharged to the sedimentation basin	%	80
Period between two consecutive removals of sludge from the sedimentation basin	years	5
Relative density of the accumulated sludge	-	1.03

[3.0 Marks]

b) An aerobic stabilization pond having the design information as shown by Table Q3 (b), treats an industrial wastewater flow. Figure Q3 shows the value of 'kt' versus percent 5-day Biochemical Oxygen Demand (BOD_5) remaining for various dispersion factors (d). Determine the (i) Hydraulic retention time (t); (ii) Hydraulic surface loading rate; and (iii) Organic surface loading rate in terms of soluble BOD_5.

Table Q3 (b): Design criteria of the aerobic stabilization pond.

Description	Unit	Value
Wastewater flow	m^3/d	5000
Influent SS (Suspended Solids) concentration	g/m^3	negligible
Soluble BOD_5 in the influent	g/m^3	250
BOD_5 removal efficiency	%	90
Water temperature in the pond	^0C	30
Temperature coefficient(θ) at 20 ^0C	-	1.05
First-order soluble BOD_5 removal -rate constant (k) at 20 ^0C	d^{-1}	0.2
Maximum depth of the pond	m	0.8
Dispersion factor of the pond	-	0.0625

Following equation is applicable:

$k_T = k_{20}\theta^{(T-20)}$; where T= Temperature; k_T= 'k' at 'T' temperature

[2.0 Marks]

Q4. a) A series of stabilization ponds system is going to be used to treat the wastewater discharged by a tannery industry. In addition to the stabilization ponds system, the treatment train will consist of preliminary treatments such as coarse and fine screening and post chlorination. Draw the schematic flow diagram of this treatment train. Give a brief explanation on the purpose of each treatment unit process and give reasons for the order of placement of each unit process in the treatment train.

b) [1.5 Marks]

b) A primary treated municipal wastewater is to be treated further using a staged RBC (Rotating Biological Contactors) system with a tapered feed flow for each stage. Table Q4 gives the design information. The soluble 5-day biochemical oxygen demand (sBOD_5) in each stage (S_n) is given by the following equation:

$$S_n = \frac{-1+\sqrt{1+(4)(0.00974)(A_s/Q)S_{(n-1)}}}{(2)(0.00974)(A_s/Q)}$$; where A_s=total disk surface area on stage 'n'; Q=flow rate on stage 'n'; the units for 'S','A_s' and 'Q' are g/m^3, m^2 and m^3/d, respectively.

Table Q4: Design criteria of the staged RBC system.

Description	Unit	Value
Flow rate (Q)	m^3/d	2500
Soluble BOD_5 in the primary effluent	g/m^3	300
No. of stages of the RBC system	-	4
Standard disk density	$m^2/shaft$	9300
Maximum organic loading ($sBOD_5$) on 1st stage for secondary treatment	$g/m^2.d$	18

(i) Determine the number of RBC shafts for the stage 1.

[1.0 Mark]

(ii) If the number of shafts of each subsequent stage decreases by one unit, draw a schematic flow diagram of the RBC system. The flow is perpendicular to the shaft.

[1.0 Mark]

(iii) How much is the soluble BOD_5 in the RBC effluent ?

[1.5 Mark]

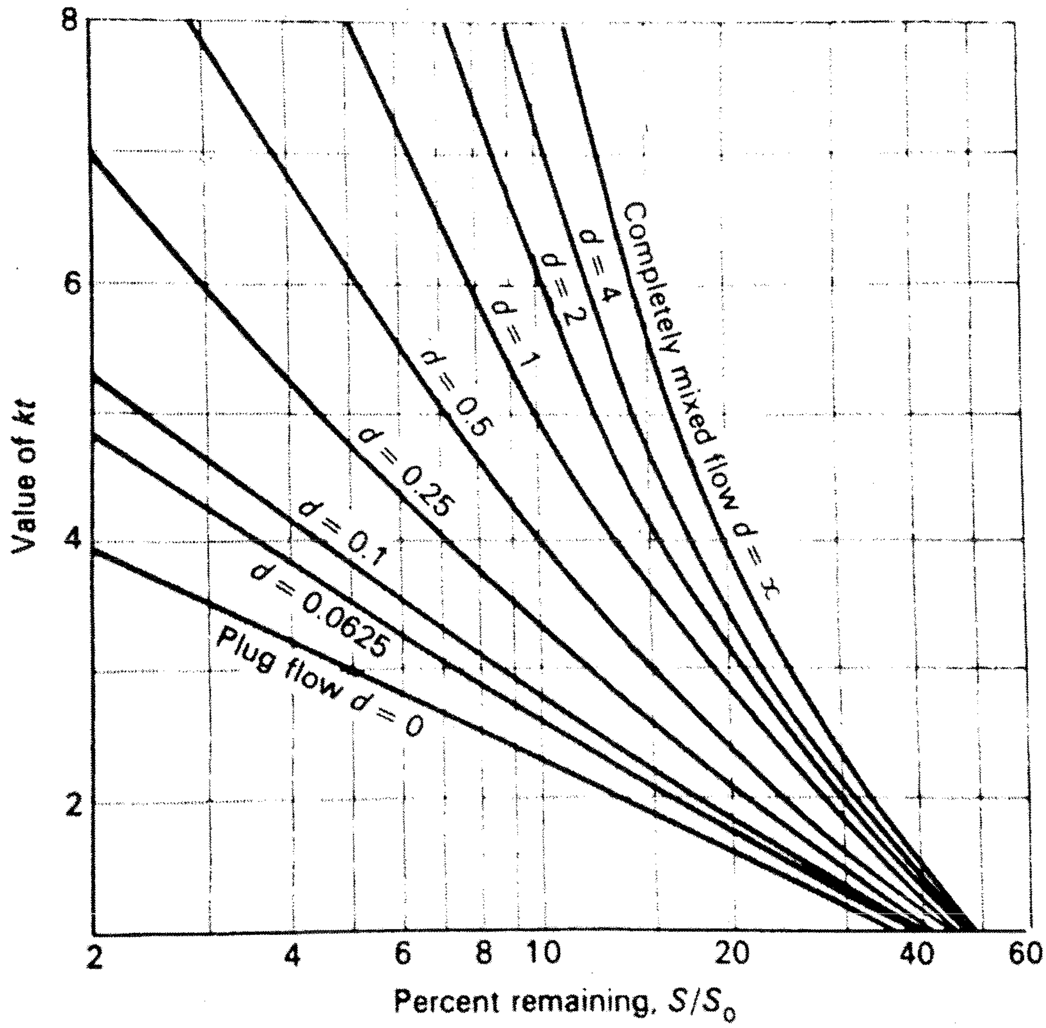

Figure Q3: Value of 'kt' versus percent BOD_5 remaining for various dispersion factors

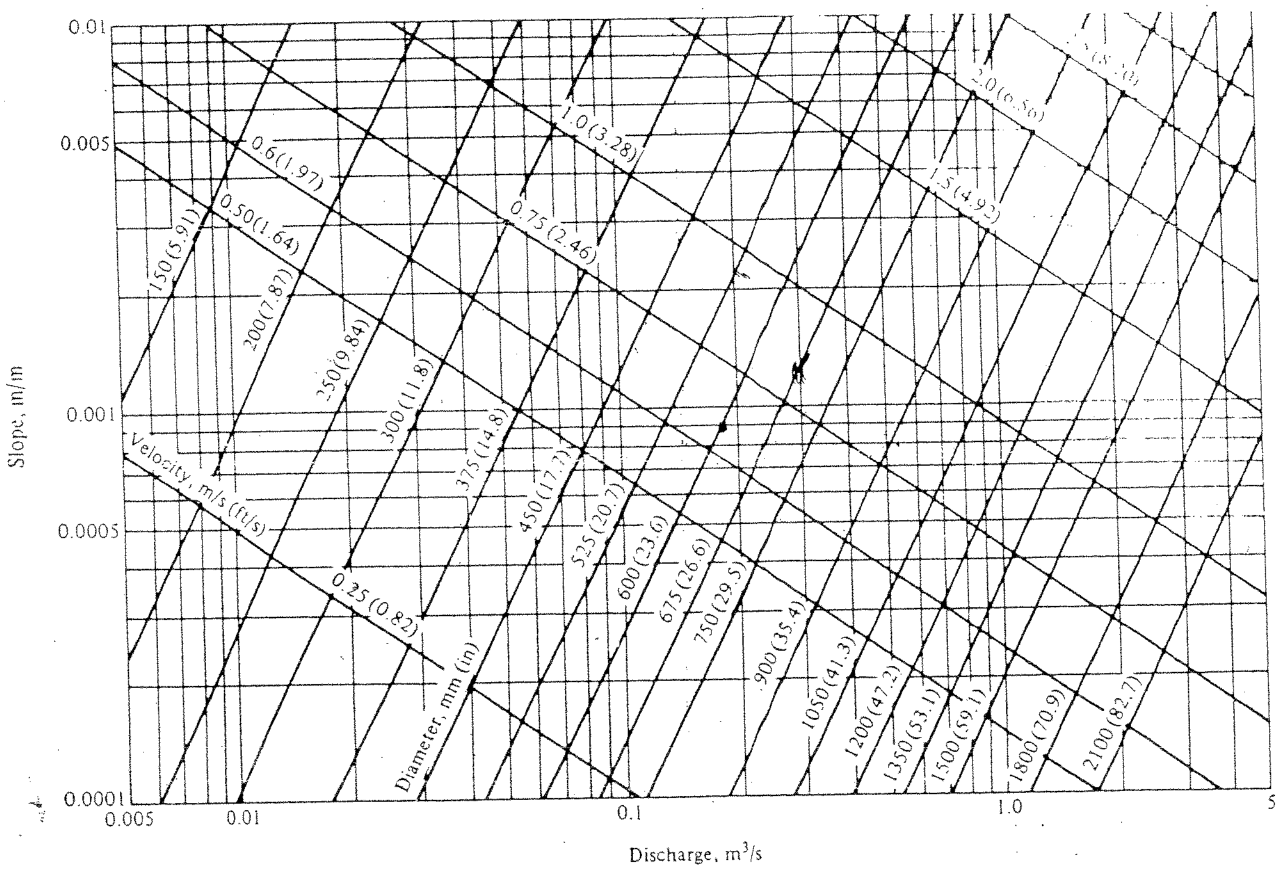

Figure Q1: Nomograph for solution of Manning's equation for n = 0.013