UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: August 2018

Module Number: CE7304 **Module Name: Environmental Management**

[Three Hours]

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

Q1. a) The characteristics of a highly variable wastewater out-fall is to be investigated. A sample is proposed to be collected using the 'flow proportionate composite sampling' technique, in which a sample is collected with a fixed volume after a certain quantity of wastewater flow has passed the sampling station. First out of the 7 samples was collected at around 6.00 a.m. Every subsequent sample was collected only after a volume equal to 270 m^3 has passed the sampling location. Given that the hourly average flow rates of the above wastewater out-fall from 6.00 a.m. to 12.00 noon are 100, 55, 60, 65, 45 and 75 *L/s*, respectively and the total volume of the composite sample required is 14 *L*; estimate the time intervals between each subsequent sampling and the volume of each sampling.

[3.0 Marks]

b) Design the size of an equalization tank to balance the flow rates of an industrial wastewater given in Table Q1. Assume a safety factor of 2.0.

Table Q1 Wastewater flow rates.

Time (*h*)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Average flow rate (m^3/s)	0.05	0.04	0.02	0.02	0.02	0.02	0.02	0.04	0.06	0.07	0.07	0.07

[3.0 Marks]

c) (i) Identify five environmental resource factors likely to be affected during the operational phase by a project of your choice from the following list: (1) a sea port construction project; (2) a project for constructing a wastewater disposal system; (3) a project for constructing a cane sugar manufacturing industry.
State an environmental impact, which will be imposed on each identified environmental resource factor.

[2.0 Marks]

(ii) For the selected project, construct an outline of a weighting-scaling checklist that could be used to compare three alternative sites to locate the main component of the project in developing an Environmental Impact

Assessment (EIA) report. The main components of the project 1, 2 and 3 are sea port, wastewater treatment plant and industry, respectively.
One of the alternatives should be an imaginary proposed site. The checklist should include at least 5 decision factors, an imaginary weight for each decision factor and an imaginary scale for each alternative. A composite index for each alternative has to be obtained based on the imaginary weights and scales.

[4.0 Marks]

Q2. a) Calculate the **annual** effluent discharge fee for an industry having the data given by Table Q2 (a).

Table Q2 (a) Effluent discharge data of an industry.

Type	Parameter	Flow rate/ Concentration		Charge (*Rs /kg* or m^3)
		Unit	Value	
	Flow rate	m^3/d	1000	25.00
	Biochemical Oxygen Demand (BOD_5)	*mg/L*	400	50.00
NHP	Total Suspended Solids (TSS)	*mg/L*	500	30.00
	Chemical Oxygen Demand (COD)	*mg/L*	600	
	Total Dissolved Solids (TDS)	*mg/L*	750	
	Total Kdjedahl Nitrogen (TKN)	*mg/L*	30	
	Oil & Grease	*mg/L*	25	
HP	Phenol	*µg/L*	20	100.00
	Chromium (Cr^{3+})	*µg/L*	100	
	Ferrous (Fe^{2+})	*µg/L*	50	
	Led (Pb)	*µg/L*	40	
Management charge (MC)				Rs 25.00 per day

Charge= $A \times Q + B \times BOD_5 + a \times NHP + b \times HP + MC$

a, b, c = coefficients, *Rs/kg* load of the respective pollutant
A = unit charge for wastewater discharge
B = unit charge for BOD_5 load
NHP: Non-hazardous pollutants
HP : Hazardous pollutants

[3.0 Marks]

b) The fee for sewage treatment at a centralized treatment facility can be determined by (1) only the volume of wastewater (Quantity approach); (2) the volume of wastewater and an additional surcharge for every parameter exceeding a pre-determined concentration (quantity-quality approach) or (3) by allowing all users the same amount of treatment per assessment rupee, after which a surcharge is applied (Assessment/surcharge approach). In the 3rd method, every user has to pay a fixed amount of money annually, i.e. 'annual assessment', to the municipality for the sewage treatment.

(i) State the best method in favor of the environment, and explain the reason/s for the answer.

[2.0 Marks]

(ii) A food canning industry produces a wastewater flow of 1000 m^3/d with a BOD_5 value of 1000 mg/L. The industry pays the municipal council to have its wastewater treated and disposed of at a central treatment facility. Calculate the total treatment charge paid by this industry annually using each of above three methods.

Following information is applicable:
In the 2nd method, the predetermined BOD_5 value is 350 mg/L.
The applicable charge rates; Rs 5.00 per m^3 of wastewater discharge, and the surcharge rate of Rs. 50.00 per kg/BOD_5 removed.
A private residence accommodating an average of 4 persons is assessed at Rs 6,000/=. The applicable BOD_5 of wastewater is 200 mg/L and the water consumption is 130 $L/capita.d$. Only 80 % of the water consumption is assumed to contribute to the domestic wastewater.
The average annual assessment of the food canning industry is Rs 2 million.

[3.0 Marks]

c) There are two industries (A and B) willing to create an artificial market on the emission trading. Table Q2 depicts the respective data. The emission standard according to the command and control approach is 100 MT.

Table Q2 Pollutants data of the industries A and B.

Item	Value
Pollutant load to be emitted by A	200 MT
Pollutant load to be emitted by B	200 MT
Cost per reduction of 1 MT pollutants load by A	Rs. 50,000.00
Cost per reduction of 1 MT pollutants load by B	Rs. 100,000.00
Selling cost of 1 MT pollutant by A	Rs. 75,000.00
Saleable emission load	25 MT

(i) State an advantage and a disadvantage associated with each of the artificial market approach and the command and control approach, from the viewpoint of the surrounding environment and the regulator.

[1.0 Mark]

(ii) Explain mathematically how to create an artificial market between the two industries so that both the industries would gain a profit. State the profit earned by each industry.

[3.0 Marks]

Q3. An industrial effluent is equally discharged into two streams (A and B), which connect each other 0.25 km distance downstream the discharge point. Table Q3 (a) (i) shows the details of industrial effluent and stream A and B conditions just upstream the industrial discharge.

Following equations are applicable:

$$D_c = \frac{k}{k_2} L_i e^{-k\theta_H^*} ; \theta_H^* = \frac{1}{(k_2 - k)} \ln \frac{k_2}{k} \left\{ 1 - \frac{D_i(k_2 - k)}{kL_i} \right\}; \quad L = L_i e^{-k\theta_H} ;$$

$$D_{O_2} = \frac{kL_i}{(k_2 - k)} (e^{-k\theta_H} - e^{-k_2\theta_H}) + D_i e^{-k_2\theta_H} ; k_T = k_{20} \times \theta^{(T-20)} ; x = \theta_H u$$

D_i = Initial dissolved oxygen deficit at the point of waste discharge, *mg/L*

D_c = Critical dissolved oxygen deficit, *mg/L*

D_{O_2} = Dissolved oxygen deficit at any point, *mg/L*

θ_H = Hydraulic retention time, *d*

θ_H^* = Critical hydraulic retention time, *d*

k_2 = Re-aeration constant, d^{-1}

k = Carbonaceous organic matter degradation rate constant, d^{-1}

k_T = Reaction rate constant at $T\ ^0C$, d^{-1}

k_{20} = Reaction rate constant at 20^0C, d^{-1}

L_i = Ultimate *BOD* (BOD_u) at the point of waste discharge, *mg/L*

x = Distance from the mixing point, *m*

u = Velocity, md^{-1}

Table Q3 (i) Details of the industrial effluent and the streams *A* and *B*.

Parameter	Industrial Effluent	Stream *A*	Stream *B*
Flow rate, m^3/d	8,000	10,000	30,000
Velocity, *m/d*	-	50	50
Ultimate *BOD*, *mg/L*	30	100	-
Ultimate *BOD* load, *kg/d*	-	-	600
DO (Dissolved Oxygen) load, *kg/d*	24	50	250
Temperature, ^0C	30	25	25
k at 20 ^0C, d^{-1}	0.36	0.36	-
k_2 at 20 ^0C, d^{-1}	-	-	0.60
Temperature coefficient (θ)	1.06		

Table Q3 (ii) Saturated DO concentrations at different temperatures.

Temperature(^0C)	21	22	23	24	25	26	27	28	29	30
Saturated *DO* concentration (*mg/L*)	8.9	8.73	8.56	8.4	8.24	8.09	7.95	7.81	7.67	7.54

a) Find the conditions in terms of BOD_u, *DO* and Temperature just downstream the industrial effluents discharge point in each stream.

[3.0 Marks]

b) Find the conditions in terms of BOD_u, *DO* and Temperature just upstream the connecting point of both the streams.

[5.0 Marks]

c) Find the conditions in terms of BOD_u and DO just downstream the connecting point of both the streams.

[2.0 Marks]

d) Determine the oxygen sag at the critical point of the combined stream.

[2.0 Marks]

Q4. a) Describe briefly 'water resources development project' from the viewpoint of (i) the people in arid zones (ii) the people in wet zones (iii) the engineer and (iv) the environmentalist.

[2.0 Marks]

b) Read the following case and answer the questions below:

Following summary is given for the case study of the imaginary project of diverting the Maha Oya:

There is a proposal to construct a dam and divert water from the Maha Oya to a proposed reservoir through a 20-*km* long canal. The main objectives of the project are preventing downstream flooding, supplying irrigation and safe drinking water to surrounding townships. The average population affected by flooding is 20,000. About 15 % of the affected community is engaged in illegal sand mining in the reaches close to the proposed dam. These reaches are highly polluted due to the illegal disposal of urban waste and possess eroded banks. The majority of the population is engaged in small-scale agriculture like paddy and other crop cultivation and small-scale businesses. People are poor. The percentage of people without access to safe drinking water and sanitation are 35 % and 45 %, respectively. The project area will occupy a few paddy fields.

(i) State **four** operational impacts imposed by the proposed project on each of the (i) dam and reservoir (ii) upstream and (iii) downstream areas, respectively.

[3.0 Marks]

(ii) Construct an interaction matrix suitable for an Environmental Impact Assessment (EIA) report developed for the above project in order to summarize the environmental impacts during the operational phase. Indicate clearly the environmental resource factors.
(Note: Use the impacts identified in the part (b) (i) and consider an imaginary significance level for each impact.)

[4.0 Marks]

(iii) Suggest engineering mitigatory measures for **five** of the identified impacts in the part (b) (i).

[3.0 Marks]

Q5. A wastewater disposal system has been proposed for a coastal urban council area in the semi-arid zone of Sri Lanka. The proposed project includes a collection system, a wastewater treatment plant (WWTP) and an effluent disposal system. The proposed wastewater treatment train consists of a waste stabilization pond (WSP) system. The

sludge accumulated in anaerobic stabilization ponds will be composted and sun dried. The treated effluent will be released into an abandoned irrigation tank (tank 1), which will be rehabilitated before using. The discharge of the treated effluent into the tank 1 may augment the volume of water in another irrigation tank (tank 2), which the overflow water from the former tank drains into. Other than agricultural purposes, the tank 2 is widely used for bathing and washing purposes, particularly by the neighboring residents. The treatment system will treat 12,000 m^3/d of wastewater. The main sewer, WWTP and effluent disposal system will be designed to cater a total design period from the year 2020 to 2050.

a) Name **two** viable alternatives for the proposed (i) WSP system (ii) treated effluent disposal system, and (iii) sludge treatment/disposal system.

[3.0 Marks]

b) Check whether the ambient BOD_5 value in the tank 1 and 2 will comply with the ambient water quality standards after the discharge of treated effluent in the year 2050. Assume that 25 % of the total volume of water from the tank 1 will overflow into the tank 2 after receiving the treated effluent; and there is no other pollutant inflow to both the tanks.

Table Q5 (b) Data on treated effluent disposal.

Item	Unit	Value
Effluent BOD_5 (Biochemical Oxygen Demand)	*mg/L*	10
Present ambient BOD_5 in the tank 1	*mg/L*	7.6
Present ambient BOD_5 in the tank 2	*mg/L*	6.8
Maximum possible capacity of the tank 1	m^3	30,000
Maximum possible capacity of the tank 2	m^3	100,000
Ambient water quality standard for BOD_5 in both the tanks	*mg/L*	4.0

[5.0 Marks]

c) At present, the water quality of the tank 1 deteriorates due to the disposal of untreated wastewater through 4 drainage lines connected to the tank. The implementation of the proposed project is expected to improve its water quality by gradually eliminating the pollution load carried by the above 4 drainage lines as the people will not tend to release untreated wastewater into surface water. It is expected that the total pollution load carried by these lines will entirely disappear at the design year, 2050. Table Q5 (c) depicts the wastewater data of the 4 drainage lines. Estimate the net economic benefit gained through the improvement of the water quality of the tank 1 due to the implementation of the proposed project. The treated effluent characteristics given in Table Q5 (b) are applicable. The shadow price for BOD_5 is Rs. 2.00 per 1 *kg* of the pollutant load.

Table Q5 (c) Wastewater data of the 4 drainage lines.

Drainage No	Cross Sectional Area (m^2)	Velocity (ms^{-1})	BOD_5 (mg/L)
C1	0.24	0.04	138
C2	0.06	0.15	164
C3	0.06	0.14	221
C4	0.78	0.03	94

[4.0 Marks]