Program: B. Sc. in Civil Engineering | **Date: 20 February 2023**
Semester: 8th Semester | **Time: 10:00 am – 11:30 am**

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Mid-Semester Examination | **Summer Semester: 2022 - 2023**
Course Number: CEE 4835 | **Full Marks: 75**
Course Title: Environmental Modeling | **Time: 90 Minutes**

There are **4 (four)** questions. Answer **any 3 (three)** questions. Marks of each question and corresponding CO and PO are written in brackets. The figures in the right margin indicate marks. The symbols have their usual meanings.

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1. A lake with a single inflow stream has the following characteristics:
Mean depth = 5 m
Surface area = 11×10^6 m^2
Residence time = 4.6 year
An industrial plant presently discharges pesticide (carbophos) ($W = 20 \times 1000 \times 10^6$ g yr^{-1}) to the lake. In addition, the inflowing stream also contains carbophos (c_{in} = 15 mg L^{-1}). Note that, the volumetric rate of inflow and outflow are equal. Assume that a first-order decay reaction can be used to characterize carbophos decay (k = 0.1 yr^{-1}).

1a) For this system write a mass-balance equation for carbophos. **(3) (CO1) (PO1)**

1b) If the lake is at steady-state, compute the in-lake carbophos concentration. If the lake is at steady-state, what industrial plant loading rate must be maintained to lower the lake's concentration to 30 ppm? Express your result as a percent reduction. **(8) (CO2) (PO2)**

1c) Evaluate each of the following engineering options to determine which is the most effective for lowering the steady-state concentration: **(14) (CO2) (PO2)**
i. Reduce the present loading rate of the industrial plant by building a waste treatment facility that will remove 50% of the carbophos from the plant's effluent.
ii. Double the lake's depth by dredging.
iii. Double the lake's outflow rate Q by diverting carbophos-free water from a nearby unpolluted stream into the lake.

2. A well-mixed lake has a steady-state concentration of 5 μg L^{-1} of total phosphorus. At the beginning of 2010, it received an additional loading of 500 kg yr^{-1} from a fertilizer processing plant. The lake has the following characteristics:
Inflow = outflow = 5×10^5 m^3 yr^{-1}
Volume = 4×10^7 m^3
Surface area = 5×10^6 m^2
Phosphorus settling rate = 8 m yr^{-1}

2a) Write down the expression for computing the concentration in the lake for the year of 2021, due to the contribution of fertilizer processing plant. **(3) (CO1) (PO1)**

2b) Suppose that, rather than a fertilizer plant, a small subdivision will be located on the lake in 2015. The population of this subdivision can be described by an exponential model: $p = (200)\, e^{Gpt}$ where Gp = first-order population growth rate = 0.2 yr^{-1}. If each person generates 0.5 kg yr^{-1} of total phosphorus, calculate the concentration in the lake in 2021. **(8) (CO2) (PO2)**

2c) Suppose that, in addition to the abovementioned waste sources, phosphorus loadings are also introduced from the lakeside agricultural lands. This phosphorus loading can be characterized by the following equation: **(14) (CO2) (PO2)**

$$W(t) = 10^9\,(t - 2012), \quad 2012 \le t \le 2021$$

where W(t) has units of μg yr^{-1}. Calculate the in-lake concentration due to the three types of phosphorus loadings for the year 2021.

Also determine the concentration in the lake for the year 2021, if the fertilizer plant, the subdivision, and the lakeside phosphorus loadings are allowed to discharge total phosphorus.

Note that, particular solution for -

Impulse loading $C = \frac{m}{V}\, e^{-\lambda t}$

Step loading $C = \frac{W}{\lambda V}(1 - e^{-\lambda t})$

Linear loading $C = \pm \frac{\beta 1}{\lambda^2 V}(\lambda t - 1 + e^{-\lambda t})$, where $W(t) = \pm \beta_1 t$

Exponential loading $C = \pm \frac{We}{V(\lambda+\beta)}(e^{\beta t} + e^{-\lambda})$, where $W(t) = We\ e^{\pm \beta t}$

3. In 2015 total phosphorus loadings to the water bodies around Dhaka were:

Parameters	Units	Turag	Shitalakhya	Buriganga
Loading	Tonnes yr^{-1}	4,000	6,950	4,575
Mean Depth	m	146	85	59
Surface Area	$10^6\ m^2$	82,100	57,750	59,750
Volume	$10^9\ m^3$	12,000	4,900	3,500
Outflow	$10^9\ m^3\ yr^{-1}$	20	20	20

Total phosphorus settled at a rate of approximately 16 m yr^{-1}.

3a) Calculate the steady-state concentration for each lake. **(8) (CO2) (PO2)**

3b) Determine how much of each lake's concentration is due to upstream water bodies. Determine the contribution in percentages. **(14) (CO2) (PO2)**

3c) What is transfer function? How does it give an idea regarding the purging mechanism of a water body? **(3) (CO1) (PO1)**

4. A pond with a single inflow stream has the following characteristics:
Mean depth = 3 m
Surface area = $2 \times 10^5\ m^2$
Water residence time = 2 weeks
Inflow BOD concentration = 4 mg L^{-1}
BOD decays at a rate of 0.1 d^{-1} and settles at a rate of 0.1 m d^{-1}.
A subdivision housing of 1000 people will discharge raw sewage into this system.
Each individual contributes about 150 gal $capita^{-1}d^{-1}$ of wastewater and 0.25 lb per capita per day of biochemical oxygen demand (BOD).

4a) Write down the expression for determining the BOD concentration of the wastewater. **(3) (CO1) (PO1)**

4b) Calculate the assimilation factor for the pond prior to building the subdivision. **(8) (CO2) (PO2)**
Which of the purging mechanisms are most effective? List them in decreasing order of effectiveness.

4c) Determine the steady-state concentration for the lake with and without the installation of subdivision. **(14) (CO2) (PO2)**