Indian Institute of Technology, Delhi
Centre for Energy Studies
Semester 2, 2016-2017
ESL 330: Energy Ecology and Environment

Major Examinations — Marks: 40
Duration: 120 minutes — 03 May 2017

Answer all questions

[General instruction: Any variable used or assumptions made should be written clearly]

1. Bring out the differences (in one or two sentences) between the following:
   a. Eutrophic and oligotrophic lake
   b. Infiltration and ventilation with respect to air quality
   c. Vadose and Ground water
   d. Biotic and abiotic factors in ecosystems
   e. Radiation and subsidence inversions **[2×5=10]**

2. In terms of environmental air pollution by coal-fired plants the major pollutants exiting from the boiler are flue gases accompanied by particulate matter (PM).
   a. Depending on the sizes of the PM, what are the likely control systems that the plant must install to remove the PM from the exhaust? Explain the operating principle for each control system in brief.
   b. Sulphur is one of the major environmental polluting compounds in the exhaust flue of coal plant. How are they controlled post combustion so that useful products for the construction industry can also be obtained?
   c. How can NO_X emissions in these power plants be reduced using selective catalytic reduction? **[5+3+2=10]**

3. Draw the combined energy and material flow diagram for any community in a general ecosystem. How does the sulphur and phosphorous cycles evolve in nature's biosphere with respect to the flow diagrams just drawn? Explain the cycles using appropriate diagrams. **[2+4=6]**

4. Along a clear deep, slowly moving river, there are two polluting industries A and B, which are dumping their waste. Industry A is 100 km upstream as compared to Industry B. The waste primarily dumped by Industry A has a high percentage of nitrogenous (n) wastes as compared to carbonaceous (c) wastes whereas that dumped by Industry B has a significant fraction of carbonaceous (c) wastes as compared to nitrogenous (n) wastes. The river flow is such that the wastes dumped by Industry A would reach the location of waste dumping by Industry B around five days later. Assume that the water and wastes are uniformly mixed at any given cross-section of river and flow downstream with no dispersion of wastes in the direction of flow. Further assume that the oxygen resources depend only on the removal of oxygen by microorganisms during biodegradation with the replenishment of oxygen through reaeration at the interface between the river and the atmosphere. The ultimate carbonaceous biochemical oxygen demand (CBOD) and the nitrogenous biochemical oxygen demand (NBOD) for the various compositions are represented by the variables:

   L_{0c}^{A}/L_{0n}^{A} → ultimate CBOD/NBOD of mixture of river water and wastewater at the point of industrial A waste discharge respectively,

   L_{rc}^{A}/L_{rn}^{A} → ultimate CBOD/NBOD of river just upstream at the point of industrial A waste discharge respectively,

   L_{wc}/L_{wn} → ultimate CBOD/NBOD of the wastewater,

Also, knowing the following

k_{dc}^A/k_{dn}^A → deoxygenation rate constant for the carbonaceous/nitrogenous waste dumped by Industry A

k_{dc}^B/k_{dn}^B → deoxygenation rate constant for the carbonaceous/nitrogenous waste dumped by Industry B

k_r → rate of reaeration of river

Q_r → volumetric flow rate of river just upstream of the discharge point of Industry A

Q_w^A/Q_w^B → volumetric wastewater flow rate of Industry A/B respectively

Using the above information to answer the following:

a. If the upstream Dissolved Oxygen (DO) are at saturation levels, before dumping of Industry A waste, use qualitative arguments to find out whether anaerobic or even unhealthy conditions set in between the locations of Industry A and B? If yes, under what conditions or assumptions? Explain with appropriate reasoning. Assume unhealthy conditions set in when DO levels are 25% of the saturated level (DO_s).

b. Set up, with proper justification, appropriate differential equation(s) for the DO deficit (D) variation rate just after the dumping point of Industry B.

[2.5+4.5=7]

5. It took about 300 years for the world's population to increase from 0.5 billion to 4.0 billion. If we assume exponential growth at a constant rate over that period of time, what would that growth rate would be? [2]

6. Suppose the following atmospheric altitude versus temperature data have been collected.

Altitude, m	0	100	200	300	400	500	600
Temp. ^{O}C	20	18	16	15	16	17	18

a) What would be the mixing depth?

b) How high would you expect a plume to rise if it is emitted at 21 ^{O}C from a 100-m stack if it rises at the dry adiabatic lapse rate? [1.5+1.5=3]

7. For the temperature profile given in the previous problem, if the maximum daytime surface temperature is 22 ^{O}C, and a weather station anemometer at 10 m height shows winds averaging 4 m/s, what would be the ventilation coefficient? Assume stability class C (exponent is 0.2) and use the wind at the height halfway to the maximum mixing depth. [2]

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