THE UNIVERSITY OF NEWCASTLE

EXAMINATION

CALLAGHAN CAMPUS

DEPARTMENT OF CIVIL, SURVEYING AND ENVIRONMENTAL ENGINEERING

NOVEMBER 2001

CIVL1320 ENVIRONMENTAL FLUID MECHANICS

- Environmental Engineering Component

TWO (2) HOURS

* Total number of questions: 8 (Eight)
* Questions are of equal value
* There will be 10 minutes reading time
* Any hand-held calculator may be used
* Text: The following may be used
  Masters: Introduction to Env. Engineering and Science
* One (1) examination answer booklet will be provided

Examiner: Professor Jetse Kalma
1)  
(a) A one-kg sample of soil is analysed for the chemical solvent trichloroethylene (TCE). The analysis indicates that the sample contains 5.1 mg of TCE. What is the TCE concentration in ppm\(_m\) and ppb\(_m\)?

(b) One liter of water is analysed and found to contain 4.8 mg TCE. What is the TCE concentration in mg/L and ppm\(_m\)?

(c) What is the carbon monoxide (CO) concentration expressed in \(\mu g/m^3\) of a 10-L gas mixture that contains \(1.3 \times 10^{-6}\) mole of CO?

(d) A gas mixture contains 0.001 mole of sulphur dioxide (SO\(_2\)) and 0.999 mole of air. What is the SO\(_2\) concentration expressed in units of ppm\(_m\)?

(e) The concentration of SO\(_2\) is measured in air to be 105 ppb. What is this concentration in units of \(\mu g/m^3\)? Assume that the temperature is 28\(^\circ\)C and the pressure is 1 atm.

2)  
The reported chemical analysis of a bottle of mineral water is:

\[
[Na^+] = 0.65 \text{ mg/L}; \quad [K^+] = 0.4 \text{ mg/L}; \quad [Mg^{2+}] = 19 \text{ mg/L}; \quad [Ca^{2+}] = 35 \text{ mg/L}; \quad [Cl^-] = 0.8 \text{ mg/L};
\]
\[
[SO_4^{2-}] = 14.3 \text{ mg/L}; \quad [HCO_3^-] = 189 \text{ mg/L}; \quad [NO_3^-] = 3.8 \text{ mg/L}. \quad \text{The pH of the water is 7.3.}
\]

(a) What is the hardness of this water in mg/L as CaCO\(_3\)?

(b) Is the chemical analysis correct?

3)  
A large coal-fired electric power plant produces 1,000 MW\(_e\) of electricity by burning fuel with an energy content of 2,800 MW. Three hundred and forty MW are lost as heat up the smoke stack, leaving 2,460 MW to power turbines that drive a generator to produce electricity. However, the thermal efficiency of the turbines is only 42%. (a) How much waste heat must be removed by the cooling water? (b) Assume that the cooling water from an adjacent river, which has a total flow rate of 100 m\(^3\)/s, is used to remove this waste heat. By how much is the temperature of the river going to rise as a result of the addition of the waste heat?

4)  
An industrial waste product is treated in a CSTR (Continuously Stirred Tank Reactor) using a reaction that destroys the pollutant according to first order kinetics, with \(k=0.216/\text{day}\). The reactor volume is 500 m\(^3\), the volumetric flow rate at the single inlet and the single exit is 50 m\(^3\)/day, and the inlet concentration is 100 mg/L. What is the outlet concentration?
5) An ice making machine is operating in an indoor ice skating rink. There is only one ventilation air intake point (Point 1) and one ventilation exhaust point (Point 3) for the entire ice rink. Assume that the ice making machine is operating somewhere in the middle (Point 2) emitting carbon monoxide (CO) at the rate of 8 mg/s and that the air is instantaneously mixed. The following conditions apply where Q=flow rate and C=concentration of (non-reactive) carbon monoxide (CO): Point 1: \(Q_1=3 \text{ m}^3/\text{s}, C_1=10 \text{ mg/m}^3\); Point 2: emission rate 8 mg/s of CO; Point 3: \(Q_3\), \(C_3\) unknown. Ice rink volume: \(V=5 \times 10^4 \text{ m}^3\).

(a) Define a control volume as the interior of the ice rink. What is the mass flux of CO into the control volume, in units of mg/s?

(b) Assume that the ice making machine has been operating for a very long time and that the air within the ice rink is well mixed. What is its CO concentration in mg/m\(^3\)?

6) The ice rink described in Question 5 has the following conditions: Point 1: \(Q_1=3 \text{ m}^3/\text{s}, C_1=0 \text{ mg/m}^3\); Point 3: \(Q_3=3 \text{ m}^3/\text{s}, C_3=50 \text{ mg/m}^3\); Ice rink volume \(V=5 \times 10^4 \text{ m}^3\). These conditions apply at the time the ice making machine is turned off.

(a) What is the mass flux of CO out of the control volume at this moment in mg/s?

(b) How long will it take before the CO concentration in the well-mixed air drops below the EPA air quality standard of 40 mg/m\(^3\)?

7) Poorly treated municipal wastewater is discharged to a stream. The river flow rate upstream of the discharge point is \(Q_{uls}=8.7 \text{ m}^3/\text{s}\). The discharge occurs at a flow of \(Q_d=0.9 \text{ m}^3/\text{s}\) and has a BOD concentration of 50 mg/L. Assume that the upstream BOD is negligible.

(a) What is the BOD concentration just downstream of the discharge point?

(b) If the stream has a cross-sectional area of 10 m\(^2\) and if the BOD is removed with a first order decay rate equal to 0.20/day, what would the BOD concentration be 50 km downstream? (Ignore re-aeration in your calculations).
8) On a summer day (stability class C) when the wind speed is 3 m/s, a tank truck loaded with liquid chlorine is involved in an accident which results in a small split in the tank and a leak of 30 kg/min at the top of the tank. The chlorine escaping is all in vapour form. The accident occurs in a city at a location 300 m upwind from a large residential area. The maximum acceptable concentration of chlorine is 3 mg/m³. Assume that gas density differences may be neglected and that the leak is at ground level.

(a) Would you give the order to evacuate the residential area? Why?

(b) How far down-wind would you establish barricades to keep people in the street away from the accident? Why?

Support your answers to (a) and (b) with appropriate calculations.

End of Examination