

National Exams May 2011

04-Env-B3 – Contaminant Transport

3 hours duration

**NOTES:**

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK EXAM.  
A Casio or Sharp approved calculator is permitted.
3. Four (4) problems constitute a complete exam paper.  
The first four problems as they appear in the answer book will be marked.
4. Each problem is of equal value.
5. Note that the questions (a), (b), (c), (d), (e), (f) or (g) of each problem can be treated independently.
6. Most questions require an answer in essay format. Clarity and organization of the answer are important. Some of the questions require calculations please show all your steps.

**Problem 1 (25 marks)**

(a) Most physical transport in the environment occurs in the fluids that are air and water. There are primarily two kinds of physical processes by which chemicals are transported in fluids and into the environment. These are advection and diffusion.

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(i) Explain in concise manner the meaning of these two types of transport processes and what differentiate them.

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(ii) Provide the mathematical equation(s) that describe each type of transport process.

(b) The average settling velocity of a particle can be approximated by the Stokes equation , which applies to spherical particles as follow:

$$w_f = [(2/9)*g*((\rho_s/\rho_f) - 1)* r^2] / \eta_f$$

$w_f$ : Settling velocity  
 $G$ : Gravitational constant  
 $\rho_s$ : Density of spherical particle  
 $\rho_f$ : Density of the fluid  
 $r$ : Radius of the particle  
 $\eta_f$ : Kinematic viscosity of the fluid

If a stream of 2m depth has an average velocity of 1 m/sec. This stream receives particles that are about 250  $\mu\text{m}$  in diameter from a storm drain. Calculate the distance travel by the particles before settling to the river bottom.

**Assumptions:**

Particle density = 2600 kg / m<sup>3</sup>  
 $\eta_f = 1.3 \cdot 10^{-2}$  cm<sup>2</sup>/Sec at 10 °C

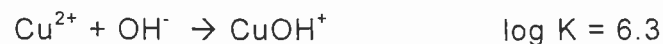
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**Problem 2 (25 marks)**

(a) Explain in a concise manner the difference between primary and secondary air pollutants. Provide an example for each type.

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(b) The reaction between copper and hydroxide ions dissolved in water is represented by the following equation:



Calculate the ratio of  $\text{Cu}^{2+}$  to  $\text{CuOH}^+$  ion in water if the hydroxide ion ( $\text{OH}^-$ ) concentration is  $10^{-4}$  mol/liter.

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- (c) Provide a concise description or definition of an aerosol in air pollution terminology.

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### Problem 3 (25 marks)

- (a) Explain in a concise manner and by using a graphic, what is referred to as "MIXING HEIGHT" in atmospheric science and how it is estimated.

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- (b) A chemical may be removed from the atmosphere either by physical processes or by chemical transformation. Describe in a concise manner, three physical processes by which a contaminant may be removed from the atmosphere.

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- (c) Two water wells (#1 and #2) are located 150 m apart in an unconfined sandy aquifer. Well #2 is directly down gradient of Well #1. The water head in the first well is 21 m and in the second well is 18 m. The hydraulic conductivity is estimated using a pump test as  $10^{-3}$  cm/sec.

- (i) Calculate the specific discharge between the two wells?

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- (ii) Calculate the rate at which non-sorbing chemicals dissolved in the groundwater move between wells if the aquifer porosity is about 0.3.

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**Hint:**

Darcy's Law:  $q = -K * dh/dx$

Seepage velocity:  $v = q/n$

### Problem 4 (25 marks)

- (a) Explain in a concise manner how atmospheric stability is defined?

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- (b) Sources of surface water pollution are generally grouped into two categories based on their origin: point sources and non-point sources. Explain concisely and briefly the meaning of these two terms.

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- (c) Bacteria in a contaminated bottle of wine has started to attack the ethanol ( $C_2H_5OH$  or  $H_3C-CH_2OH$ ) present in the wine and converting it into acetic acid ( $H_3C-COOH$  or  $CH_3COOH$ ) according to the reaction:



When the bottle of wine was opened six months later, one quarter of the ethanol has been converted. If the initial concentration of ethanol in the bottle of wine was about 6% by weight, calculate the pH of the bottle of wine after six months of attack from the bacteria.

**Assumptions:**

1. density of wine = 1 kg/Liter
2. All the pH in this case is determined by the acetic acid concentration
3. Equilibrium constant of acetic acid is:



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**Problem 5 (25 marks)**

- (a) Explain in a concise manner what is called "plume rise" in air pollution

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- (b) What are the factors that have greatest impact on plume rise?

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- (c) If the air quality standard for CO (based on an 8h measurement) is 9.0 ppm. Express this standard as a percentage by volume as well as in  $mg/m^3$  at 1 atm and 25 °C.

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- (d) Organic pollutant chemicals are susceptible to biodegradation in groundwater environment, just as they are in surface waters. Explain in a concise manner what is referred to as biodegradation.

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