# NATIONAL EXAMS MAY 2019

## 16-Chem-B2, Environmental Engineering

## 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 with a candidate prepared $8\frac{1}{2}''$ x $11''$ double sided Aid-Sheet allowed.

3. Candidates may use one of two calculators, the Casio or Sharp approved models. Write the name and model designation of the calculator on the first inside left hand sheet of the exam work book.

4. Any five (5) questions constitute a complete paper. Only the first five (5) answers as they appear in your work book(s), will be marked.

5. Each question is worth a total of 20 marks with the section marks indicated in brackets ( ) at the left margin of the question. The complete Marking Scheme is also provided on the final page. A completed exam consists of five (5) answered questions with a possible maximum score of 100 marks.

## Problem 1

Provide answers to the following questions related to *engineering aspects of air and water pollution abatement and effluent treatment.*

(6) (i) Calculate the concentration in $\mu g/m^3$ for sulfur dioxide ($SO_2$) in the air at 0.60 ppm at STP and state any assumptions in your calculation. Briefly explain how $SO_2$ air monitoring or sampling would be done to ensure the pollution source(s) are adequately abated to meet established air quality standards.

(7) (ii) Give an example of a regulatory water pollution abatement method and explain two (2) advantages and two (2) limitations when compared to a technology based pollution abatement method.

(7) (iii) Eutrophication in rivers and lakes has been indirectly attributed to high total suspended solids (TSS) loadigs in effluents from sewage treatment plants. Briefly explain an effective treatment method that would reduce the TSS loading to the receiver. In your explanation of the treatment processes, briefly explain two (2) important design or operating parameters to ensure good performance.

## Problem 2

Provide answers to the following questions related to *control methods for particulates, gases and vapours.*
For the three (3) technology types (below) describe how each may be used to control the contaminant types identified. In your explanation, briefly describe the main technology principle, provide two (2) advantages, two (2) limitations and one (1) specific application where each technology may be used. A table or matrix is recommended to organize your answer.

(7) (i) Electrostatic precipitator (ESP) for particulates (e.g. $PM_{20}$)

(6) (ii) Air scrubbers for gases (e.g., $SO_2$)

(7) (iii) Adsorption technology for odorous vapours (e.g., VOCs)

## Problem 3

Provide answers to the following questions related to *characterization of water contaminants and their measurement*, *biochemical oxygen demand* and *sedimentation*.

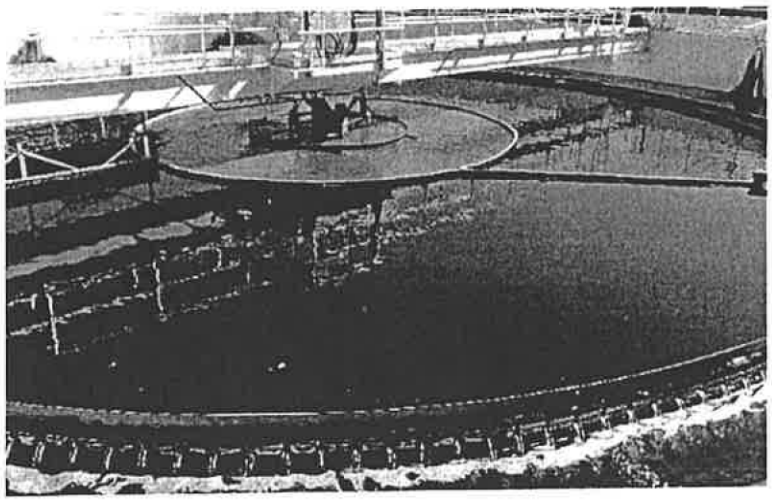
(8) (i) A drinking water treatment plant uses surface water from a river where the water intake is downstream of a heavily farmed community. Give one (1) inorganic and one (1) microbiological contaminant that typically need to be treated for surface water supplies. Provide two (2) treated water measurement methods (one for each contaminant type) that may be used to ensure the water is free from the inorganic and microbiological contaminants identified. Briefly discuss how you would ensure that the measurement methods used will provide a guarantee that contaminants are sufficiently reduced.

(ii) A BOD test is conducted at standard temperature conditions using 300 $mL$ of tertiary effluent mixed with 150 $mL$ of water. The initial DO in the mix is 8 $mg/L$. After 5 days, the DO is 2 mg/L and after 20 days the DO has stabilized at 0.2 mg/L. Assume that nitrification has been inhibited so that only $CBOD_5$ (5-day carbonaceous biochemical oxygen demand) is being measured.

(3) (a) Calculate the 5-day CBOD of the final effluent in $mg/L$; and

(3) (b) Estimate the ultimate CBOD in $mg/L$.

(6) (iii) Give three (3) important design parameters for a secondary sedimentation system (i.e., a secondary clarifier), briefly explain how the three (3) parameters influence the performance of the system and give typical design values (with units for each parameter) used in any wastewater treatment application. A typical secondary clarifier unit is shown below.



## Problem 4

Provide answers to the following questions related to *pH control*, *ion exchange*, *reverse osmosis* and the *activated sludge process*.

(i) Explain one (1) key operating approach and one (1) monitoring method to ensure the effective performance of the application of each technology applied to water or wastewater treatment:

(3) (a) pH control (e.g., Cr and Cu in wastewater)

(4) (b) ion exchange (e.g., surface water softening for Ca or Mg)

(3) (c) reverse osmosis (e.g., remove total dissolved solids from groundwater)

(ii) An activated sludge plant is to treat 100,000 $m^3/d$ of municipal wastewater. You have been asked to assist the senior process design engineer by calculating the following:

(3) (a) The required aeration tank volume $V$ in $m^3$ and the aeration tank hydraulic retention time ($\phi$) in hours;

(4) (b) the quantity of sludge to be wasted daily ($Q_w$) in $kg/d$; and

(3) (c) the return sludge recycle ratio ($Q_r/Q_o$).

**Use the following process information:**

- Influent $BOD_5$ and $TSS = 200\ mg/L$;
- effluent $BOD_5$ and $TSS = 15\ mg/L$;
- yield coefficient, $Y = 0.6$;
- decay rate, $k_d = 0.04\ d^{-1}$ ;
- average MLSS in the aeration tank, $X = 4{,}000\ mg/L$;
- waste MLSS from the clarifier, $X_w = 10{,}000\ mg/L$; and
- mean cell residence time, $\phi_c = 10\ days$;

## Problem 5

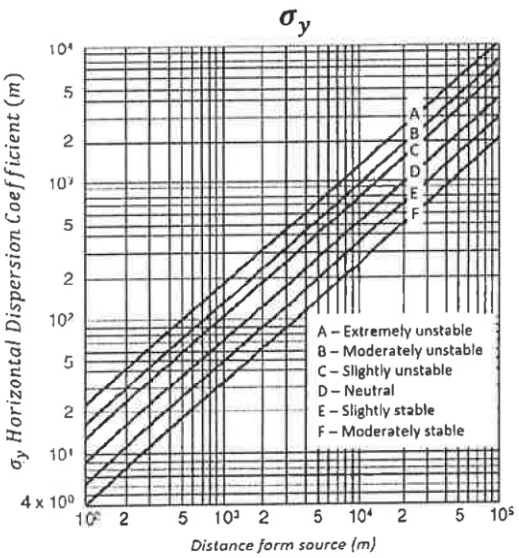
Provide answers to the following questions related to *sources and dispersion of atmospheric pollutants*.

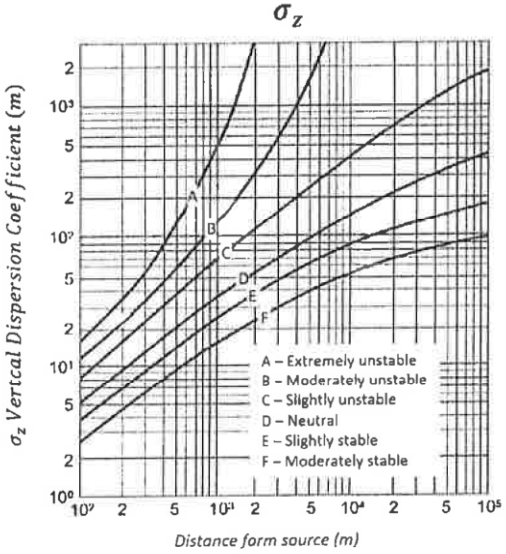
An industrial boiler is burning at the rate of 12 tons of 2.5% sulfur coal/hr with an $SO_2$ emission rate of 200 g/s. The following exist: the stack height, H = 100 m, the wind speed, u = 7 m/s, y = 0 m, z = 0 m. It is one hour after sunrise, and the sky is clear.

(10) (i) Find the downwind centerline ground level $SO_2$ concentration at a distance x = 3000 m from the stack. State clearly any assumptions made.

(10) (ii) Provide three (3) possible engineering measures that may be used to reduce the ground level $SO_2$ concentration and compare each method in terms of the overall carbon footprint.

Assume an estimate of the dispersion parameters is provided by the following figures and stability classes in the following table:




| | Day | | | Night | |
|---|---|---|---|---|---|
| | Incoming Solar Radiation | | | Thinly Overcast | |
| Wind Speed, 10 m (m/sec) | Strong | Moderate | Slight | >4/8 Cloud | <3/8 Cloud |
| <2 | A | A–B | B | E | F |
| 2–3 | A–B | B | C | D | E |
| 3–5 | B | B–C | C | D | D |
| >6 | C | D | D | D | D |

## Problem 6

Provide answers to the following questions related to engineering aspects of *photochemical reactions, noxious pollutants and odour control.*

Car and truck exhausts, together with power plants, are the most significant sources of outdoor $NO_2$, which is a precursor of photochemical smog found in outdoor air in urban and industrial regions and in conjunction with sunlight and hydrocarbons, results in the photochemical reactions that produce ozone and smog.

(6) (i) Briefly explain how smog is produced by considering the physical atmospheric conditions and the associated chemical reactions.

(7) (ii) Air pollution is defined as the presence of noxious pollutants in the air at levels that impose a health hazard. Briefly identify three (3) traffic-related (i.e., from cars or trucks) noxious pollutants and explain an engineering solution to reduce these pollutants.

(7) (iii) Identify an effective biochemical based engineered odour control technology for VOC emissions, at a power plant, and briefly explain its design and operational principles to ensure effective and efficient performance.

## Problem 7

Provide answers to the following questions related to *contaminant soil remediation* and *measurement techniques* as applied to environmental engineering.

(6) (i) Provide an example and explain one (1) appropriate technology that may be used in soil remediation of a site that has soil contamination from heavy metals (e.g., Cd, Cu, Zn) and these metals are leaching into a nearby lake used as a drinking water source.

(6) (ii) Describe three (3) typical steps in the overall contaminated site management process leading to final site remediation and closure.

(8) (iii) Discuss three (3) important elements of good measurement techniques. Consider the assessment of the air or drinking water quality in a residential community and the measurements taken will form part of a monitoring program for regulatory compliance intended to protect human health.

# Marking Scheme

1. (i) 6, (ii) 7 (iii) 7 marks, 20 marks total

2. (i) 7 (ii) 6 (iii) 7 marks, 20 marks total

3. (i) 8 (ii) (a) 3, (b) 3 (iii) 6 marks, 20 marks total

4. (i) (a) 3, (b) 4, (c) 3 (ii) (a) 3, (b) 4, (c) 3 marks, 20 marks total

5. (i) 10 (ii) 10 marks, 20 marks total

6. (i) 6 (ii) 7 (iii) 7 marks, 20 marks total

7. (i) 6 (ii) 6 (iii) 8 marks, 20 marks total