Loughborough University

23CGC842

Environmental Protection and Pollution Control

Semester 1 2023/24 | In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **1.5 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Answer **BOTH** questions in this question paper. Each question carries 25 marks.

Candidates should show full working for calculations and derivations.

1. (a) State the Streeter-Phelps equation and explain how the equation can be used in the study of water pollution. State the meaning of each term in the equation in your answer. You do not need to derive the solution of the equation. [3 marks]

   (b) You have been tasked with the design of an effluent treatment plant from the following treatment options: incineration, chemical oxidation, anaerobic digestion and aerobic digestion. With the help of a flow diagram, demonstrate what general criteria you will adopt for selecting the effluent treatment technology taking into account the following three characteristics of the wastewater: chemical oxygen demand (COD), biological oxidation demand (BOD) and biodegradable suspended solids (SS). [4 marks]

   (c) Explain what is meant by disinfection making reference to four key mechanisms that cause disinfection. [5 marks]

   (d) A step aeration activated sludge process consists of three compartments in series as shown in Figure Q1.

      (i) Identify four significant controlling factors for this process which are not already mentioned in this question. [4 marks]

      (ii) Each compartment in the process can be regarded as a complete mix reactor with surface turbine aerators. The feed volume is divided equally between the three compartments. Using the equations and parameters given below, calculate the mixed liquor volatile suspended solids (MLVSS) and mass of oxygen consumed per day in the first reactor. Assume that 1.41 kg of O_2 is required to completely oxidise 1 kg of BOD_L. The feed (Q_o) is cell free and the cell mass concentration (X) in each compartment of the process is equal. [9 marks]

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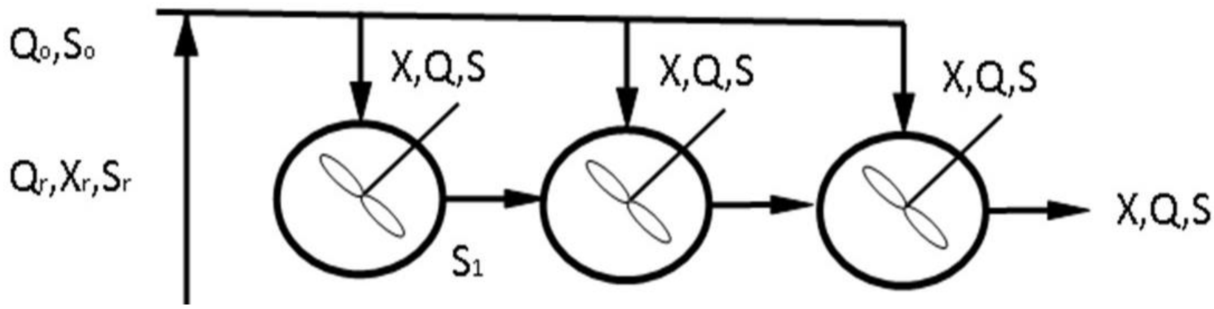
Q1 Continued/…



Recycle from thickener

Figure Q1. Step aeration activated sludge process consisting of three compartments. All symbols in Figure Q1 have their usual meanings.

Table Q1. Relevant data for step aeration activated sludge process in Figure Q1

Q_o	6500 m^3/d
S_o	0.25 kg/m^3
S_1	0.01 kg/m^3
S_r	0.015 kg/m^3
Q_r	400 m^3/d
X_r	10 kg/m^3
V	250 m^3 for each reactor compartment
Y	0.65
K_d	0.05 d^{-1}
BOD_5/BOD_L	0.7

Cell mass concentration (X) in the process (Figure Q1) is given by Equation Q1

$$X = \frac{Y(S_o - S) + X_o}{1 + K_d\theta} \qquad \text{(Equation Q1)}$$

where all symbols have their usual meanings.

2. (a) Figure Q2a shows a schematic diagram of a high efficiency cyclone of diameter 0.5 m with a square inlet that will be used for removing particles from a dusty gas.

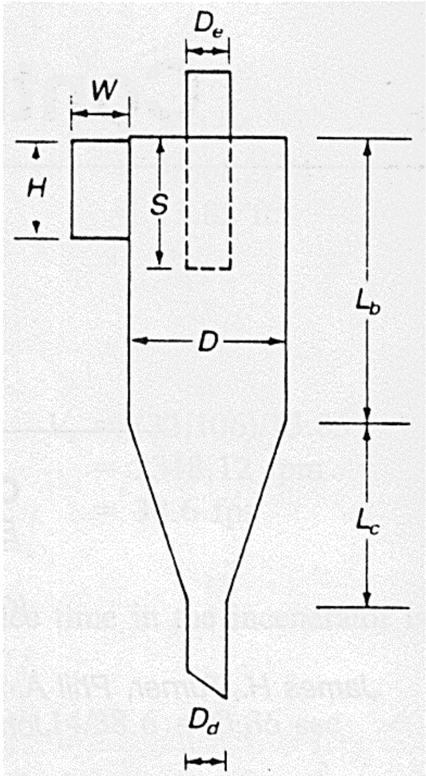


Figure Q2a: Schematic diagram of cyclone where D = 0.5 m

The key ratios of dimensions for the cyclone in Figure Q2a are as follows:

$H/D = 0.5$, $W/D = 0.2$, $D_e/D = 0.5$, $S/D = 0.5$, $L_b/D = 1.5$, $L_c/D = 2.5$, $D_d/D = 0.375$.

(i) If the inlet volumetric flowrate is 50 $m^3\ min^{-1}$, the gas viscosity 2×10^{-5} Pa s and the particle density is 2600 kg m^{-3}, determine the d_{50} value. You should also include the value for the number of turns of the vortex in your answer. [6 marks]

(ii) How will using 5 cyclones of this type in parallel affect the overall pressure drop and separation efficiency if the inlet volumetric flowrate to the combined cyclone system remains the same? [4 marks]

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Q2 Continued/…

(b) A gaseous pollutant is discharged from a chimney of effective height 38 m at a rate of 0.12 kg s^{-1}. The weather conditions are **slightly unstable** with a wind speed of 2 m s^{-1}. Determine the maximum concentration on the ground and the distance that this occurs downwind from the source using the equations provided and Figure Q2b and Figure Q2c.

[7 marks]

(c) A plume rises from a chimney at stable conditions at a velocity of 15 m s^{-1}. The dry adiabatic air temperature gradient, $\frac{dT_{ad}}{dz}$ = -0.0098 K m^{-1} and the atmospheric lapse rate, $\frac{dT_{at}}{dz}$ = -0.004 K m^{-1}. The plume exit temperature is 330°C. The wind has a velocity of 3 m s^{-1} and a temperature of 15°C. The internal diameter of the chimney is 1 m. Calculate the plume height using the equations provided. [8 marks]

Useful equations where all symbols have their usual meanings

$$N_e \cong \frac{1}{H}\left[L_b + \frac{L_c}{2}\right]$$

$$d_{50} = \left[\frac{9\mu W}{2\pi N_e \rho_P v}\right]^{0.5}$$

$$\eta = \frac{\pi N_e \rho_p d^2 v}{9\mu W}$$

$$d_{crit} = \left[\frac{9\mu W}{\pi N_e \rho_P v}\right]^{0.5}$$

$$H_v = K\frac{HW}{D_e^2}$$

$$\Delta P = \frac{1}{2}\rho v^2 H_v$$

$$C(x,y,z) = \frac{Q}{U}\frac{1}{2\pi\sigma_y\sigma_z}e^{\left(\frac{-y^2}{2\sigma_y^2}\right)}\left[e^{\left[\frac{-(z-H)^2}{2\sigma_z^2}\right]} + e^{\left[\frac{-(z+H)^2}{2\sigma_z^2}\right]}\right]$$

$$\Delta h = \frac{V_s d}{u}\left[1.5 + \left(2.68\times10^{-3} P d\,\frac{T_s - T_a}{T_s}\right)\right]$$

$$\delta h = 2.6\left(\frac{F}{U_s S}\right)^{0.33}$$

$$F = \frac{g V_s D_s^2}{4T_a}(T_s - T_a)$$

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Q2 Continued/…

$$S = \frac{g}{T_a}\left(\left(\frac{dT_{at}}{dz}\right) - \left(\frac{dT_{ad}}{dz}\right)\right)$$

$$\delta h = 2.6\left(\frac{F}{U_s S}\right)^{0.33} \quad F = \frac{gV_s D_s^2}{4T_a}(T_s - T_a)$$

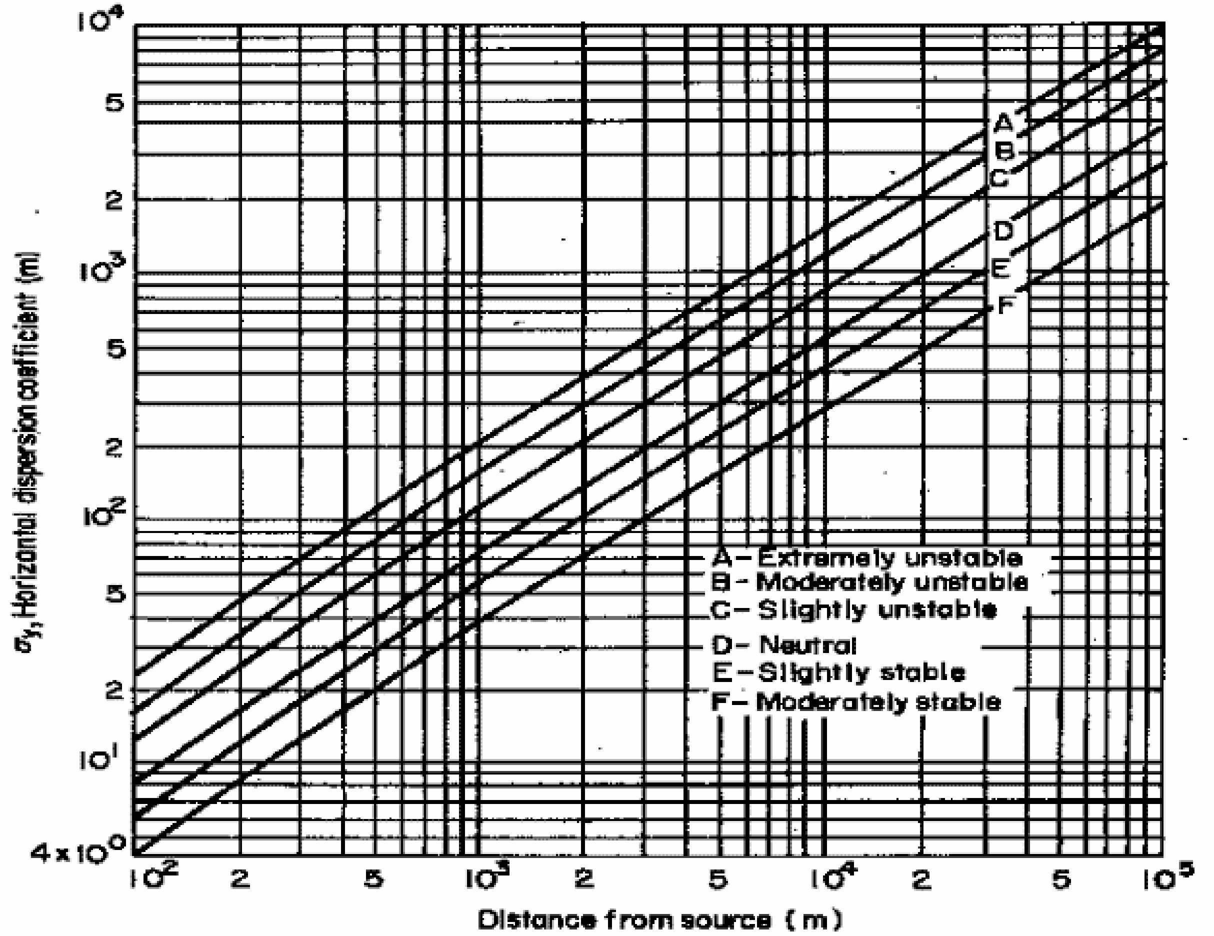

Figure Q2b: Horizontal dispersion coefficient σ_y vs. downward distance x from source

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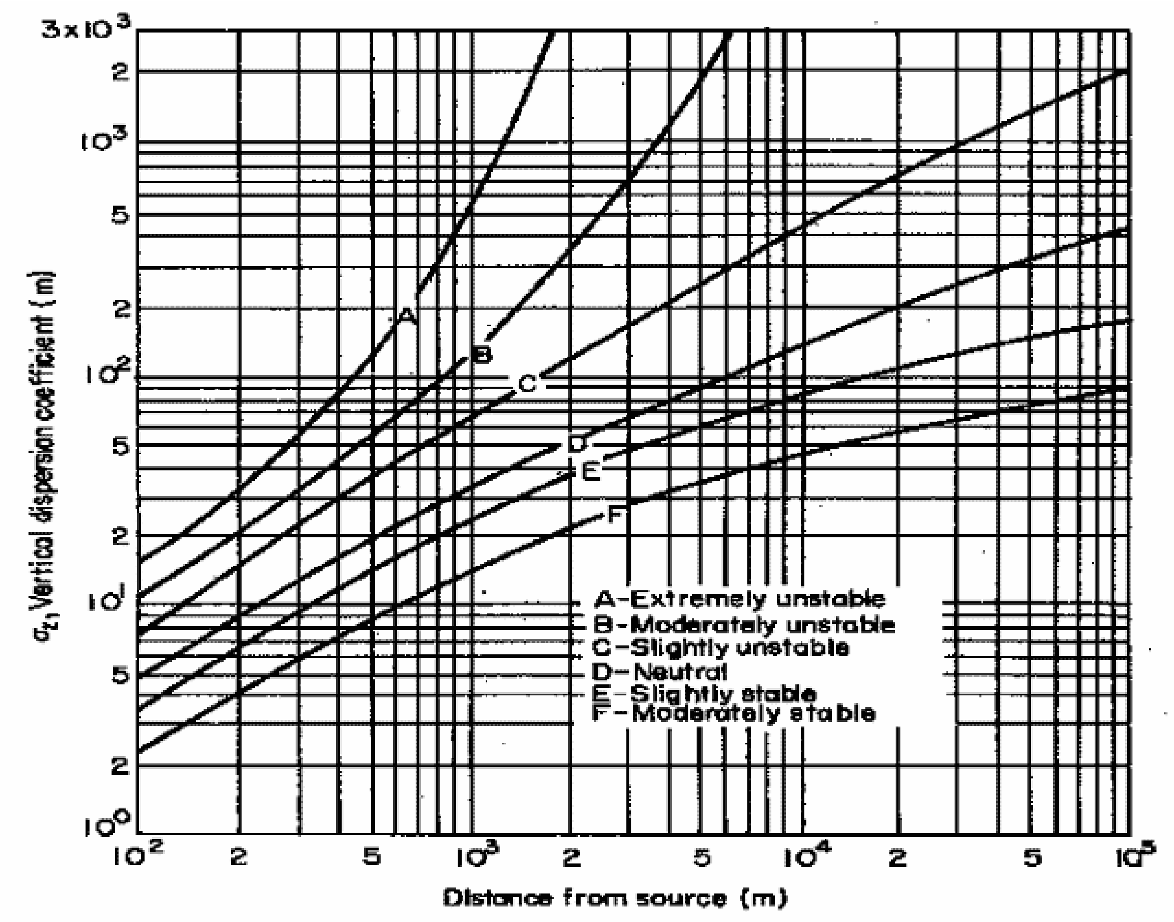

Figure Q2c: Vertical dispersion coefficient σ_z vs downward distance x from source

END OF PAPER

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