Loughborough University

22CGC842

Environmental Protection and Pollution Control

Semester 1 2022/23 | 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.

<u>Help during the exam</u>

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. You have been asked to lead the development of a wastewater treatment facility as shown in Figure Q1.

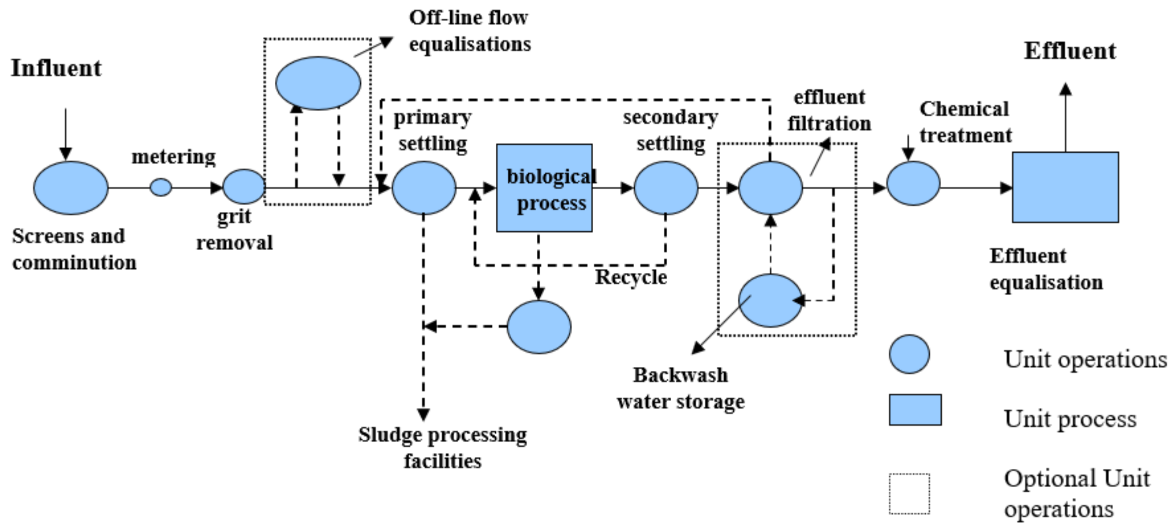


Figure Q1. Proposed wastewater treatment plant

(a) Discuss briefly the key features of the proposed plant and what it tells you about the process requirements. [3 marks]

(b) Discuss briefly what roles toxicity tests can play for the development of the proposed plant. Also, define any two toxicity test criteria that you believe are likely to be relevant in expressing the wastewater toxicity in the plant. [3 + 4 marks]

(c) What chemical treatment method are you likely to adopt in the plant and why? How will you express the treatment kinetics? [2 + 3 marks]

(d) Assuming the following first order reaction kinetics, determine what expressions can be used for the calculation of BOD (biological oxygen demand) in the biological process:

$$\frac{dL_t}{dt} = -kL_t$$

where L_t is the amount of first stage BOD remaining in water at time t and k is the reaction rate constant.

Determine the 3-day BOD and ultimate first-stage BOD for the wastewater flowing through the plant whose 5-day (20°C) BOD is 220 mg l^{-1}. The reaction constant k (base e) has been estimated to be 0.25 d^{-1}. [2 + 2 + 2 marks]

Continued/…

Q1 Continued/…

(e) Draw labelled sag curves showing the dissolved oxygen concentration downstream of the effluent discharge point for cases of mild and heavy pollution of a river. Explain the form the curves take. [2+2 marks]

2. (a) Road transport accounts for around 15% total greenhouse gas (GHG) emission globally.

(i) Define what are primary and secondary air pollutants. Please describe the main pollutants generated from automotive exhaust emissions. [3 marks]

(ii) What are the different ways of controlling automotive exhaust emissions? For catalytic conversion, indicate the reactions associated in a three-way catalytic converter. [5 marks]

(b) A gas cleaning system (Figure Q2A) consists of a standard Lapple cyclone to remove particulates. A gas stream with a flow rate of 8 m^3/s is passed through the cyclone. The diameter of the cyclone D is 2.0 m, and the air temperature is 77°C.

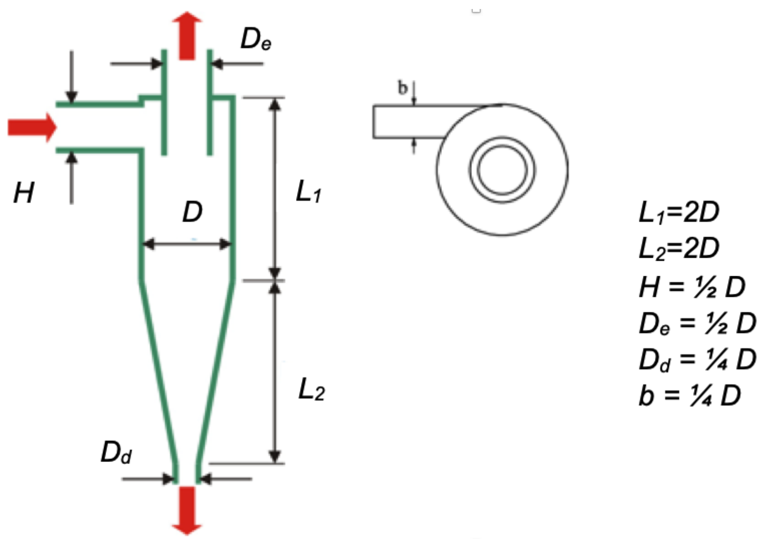


Figure Q2A: Standard-dimension Lapple cyclone collector

Continued/…

Q2 Continued/…

(i) Determine the removal efficiency of the gas cleaning system using Lapple's diagram (Figure Q2B) overleaf for particles with a density of 1.2 g/cm^3 and a diameter of 10 µm. [4 marks]

(ii) Determine the removal efficiency of the system based on b(i) if a bank of 60 cyclones with diameters of 24 cm are used instead of the single large unit. Compare with the results from b(i). [4 marks]

Data

At 77°C, $\mu = 2.1 \times 10^{-5} kg/m \cdot s$

(c) A stack emitting 80 g/s of NO has an effective stack height of 100 m. The wind speed is 4 m/s, and it is a clear summer day with the sun nearly overhead.

(i) Determine atmospheric condition using the Pasquill stability class in Table Q2.

[2 marks]

(ii) Estimate the ground level NO concentration at a point located 2 km downwind and 0.1 km cross wind. Horizontal diffusion coefficient σ_y and Vertical diffusion coefficient σ_z can be determined using Figure Q2C. [5 marks]

(d) Membrane reactors are used in water treatment and purification. Name different types of membrane systems in terms of pollutant size. [2 marks]

List of equations

$$d_{50} = (\frac{9\mu b}{2\pi N_e\, v_i \rho_P})^{\frac{1}{2}}$$

d_{50}= diameter of the particles that is collected with 50% efficiency/m
μ: viscosity of gas, N s/m^{2,}

b: width of cyclone inlet, m

Ne: number of effective turns within the cyclone, estimated as 5.

v_i: inlet gas velocity, m/s

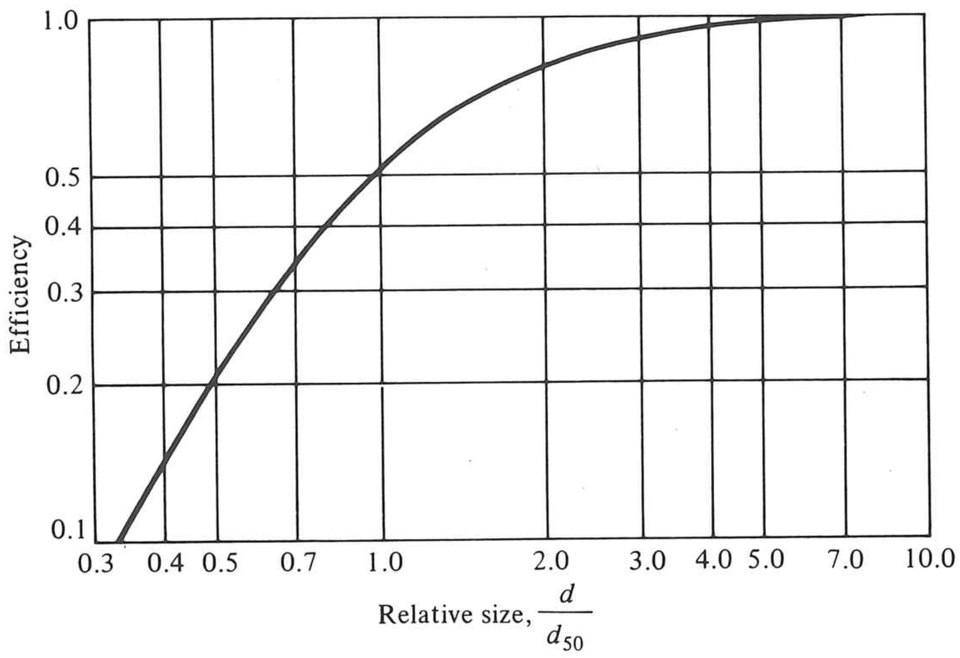


Figure Q2B Lapple's diagram: Empirical efficiency for standard dimension cyclone collector as a function of relative particle size

Gaussian Distribution model

For the concentration of a gas or aerosol at ground level for a distance downwind (x) is given by

$$C_{(x,y,0)} = \frac{Q}{\pi\mu\sigma_z\sigma_y}\exp\,[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2]\exp\,[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2]$$

C: concentration of emission g/m^3

x: distance downwind from the emission source point/m;

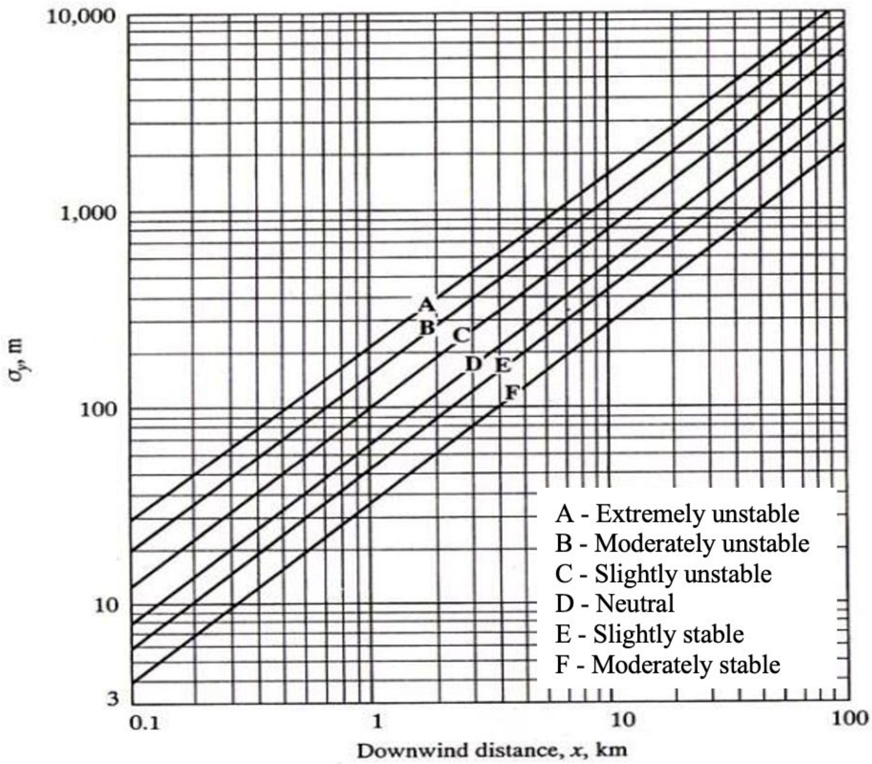
y: distance crosswind from the emission plume centreline/m;

z: height above ground level/m

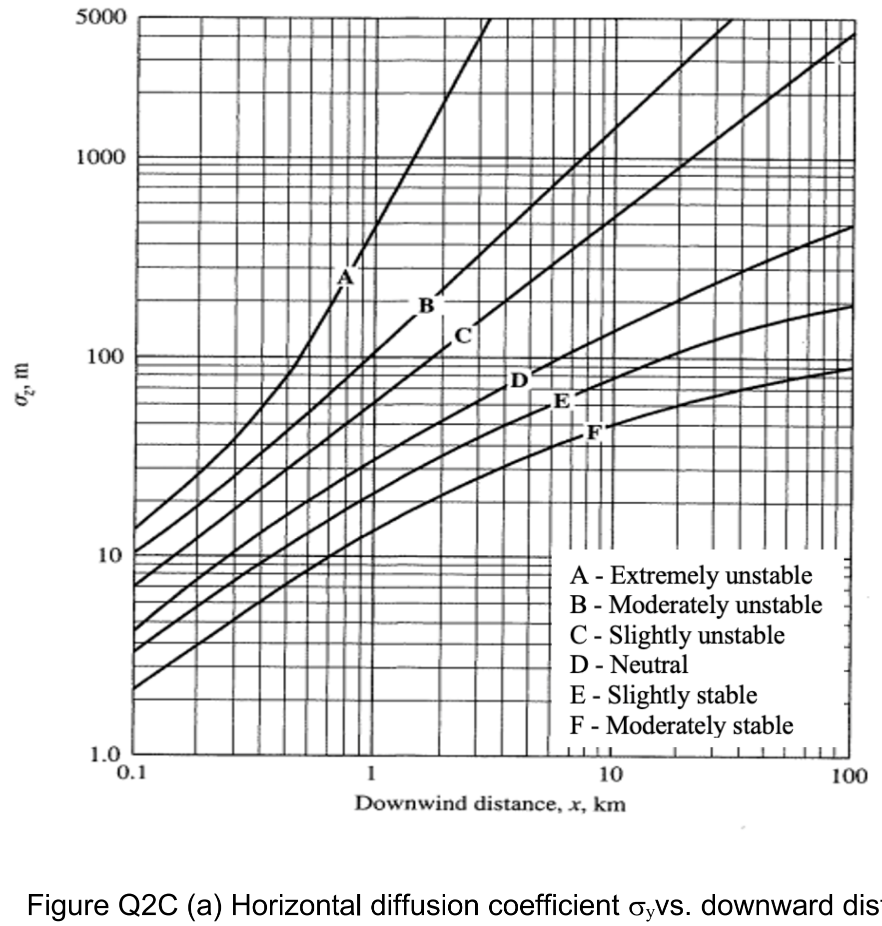
Q: source pollutant emission rate, g/s

μ: horizontal wind velocity along the plume centre line, m/s

H: height of emission plume centreline above ground level, m
σ_z: vertical standard deviation of the emission distribution, m
σ_y: horizontal standard deviation of the emission distribution, m



(a)



(b)

Figure Q2C (a) Horizontal diffusion coefficient σ_y vs. downward distance from source (b) Vertical diffusion coefficient σ_z vs. downward distance from source

Table Q2 Pasquill stability class

Surface wind speed m/s	Day			Night	
	Incoming solar radiation				
	Strong	Moderate	Slight	Mostly overcast	Mostly clear
2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

END OF PAPER

DB Das, E Yu