

KATHMANDU UNIVERSITY  
End Semester Examination  
February/March, 2018

Marks Scored:

Level : B. Tech.  
Year : IV

Course : ENVE 432  
Semester: I

Exam Roll No. :

Time: 30 mins.

F. M. : 20

Registration No.:

Date **MAR 07 2018**

SECTION "A"  
[10Q × 1 = 10 marks]

Make reasonable assumptions for any missing data or information. Circle the best answer (s).  
Note that there could be more than one correct answers.

1. Release of methane from the sludge in an anaerobic digester refers to:  
(a) solid – gas mass transfer (b) liquid-gas mass transfer  
(c) liquid – liquid mass transfer (d) gas-gas mass transfer
2. Which of the following is (are) not essential to include in a mass balance diagram?  
(a) inputs (b) outputs  
(c) system boundary (d) physical boundary
3. In environmental systems, the term 'substrate' refers to:  
(a) carbon sources (b) energy sources (c) biomass (d) nutrients
4. Following the Monod Equation, when there is an excess of limiting food, the growth rate constant  $\mu$  is approximately equal to:  
(a)  $\mu_m$  (b) half of  $\mu_m$  (c)  $(\mu_m / K_s) S$  (d)  $2 \mu_m$
5. Biofilm kinetics is described by the following equation:

$$\epsilon = \frac{\tanh\alpha}{\alpha}$$

The variable  $\epsilon$  in the equation is called:

- (a) Half velocity constant (b) Efficiency factor  
(c) Diffusion co-efficient (d) Reaction rate constant
6. Type I (Discrete settling or free settling) settling phenomena refers to:  
(a) process where particles flocculate or coalesce  
(b) process where particles settle as individual entities  
(c) process where the mass of particles settle as a unit  
(d) process where the particles form a structure and settling is done with compression
7. The ratio of  $V_p/A_p$  for a spherical particle is given by  
(a)  $\frac{1}{2} d_p$  (b)  $\frac{1}{3} d_p$  (c)  $\frac{2}{3} d_p$  (d)  $\frac{1}{4} d_p$
8. If Q is the discharge of the water received by a sedimentation tank of surface areas A, the overflow rate or surface loading rate is expressed as:  
(a) Q A (b) A / Q (c) Q / A (d) Q / 2A

9. The Wastewater Treatment Plant at Guheshowri has the following units:  
 (A) Oxidation ditch (B) Secondary Clarifier (C) Sludge drying bed (D) Grit removal system. Which of the following order best represents the process flow diagram?  
 (a) A, B, C, D (b) C, A, B, D (c) C, B, A, D (d) D, A, B, C
10. A constructed wetland designed to receive an Organic Loading Rate (OLR) of 100 kg/(ha.day), if the organic load to the system is 50 kg/day, what bed area is essential?  
 (a) 2 ha (b) 0.5 ha (c) 1 ha (d) 5000 ha

SECTION "B"  
 [10 Q × 0.5 = 5 marks]

Fill in the blanks:

11. Two key issues associated with flocculation/sedimentation/sand filtration processes in drinking water treatment are:  
 (i).....
12. and (ii) .....
13. For the particles less than 50 μm size, the surface phenomena predominates over mass phenomena and, therefore, principle of agglomeration of particles to increase their effective size and ..... is employed.
14. Rate of bacterial growth rate is given as :  
 $r_g = \frac{dX}{dt} = \mu X$ , where,  
 X is .....and its unit is .....
15. In a continuous culture without recycle, the micro-organism balance in a reactor yields the following equation.  
 $\frac{1}{T} = \mu - k_d$  where, T is hydraulic retention time, μ is growth rate constant and  $k_d$  is endogenous decay co-efficient. The significance of the above equation is .....
16. Referring to Fig. 1, when  $x = 0$ ,  $S_{vf} = \dots\dots\dots$   
 when  $x = L$ ,  $S_{vf} = \dots\dots\dots$

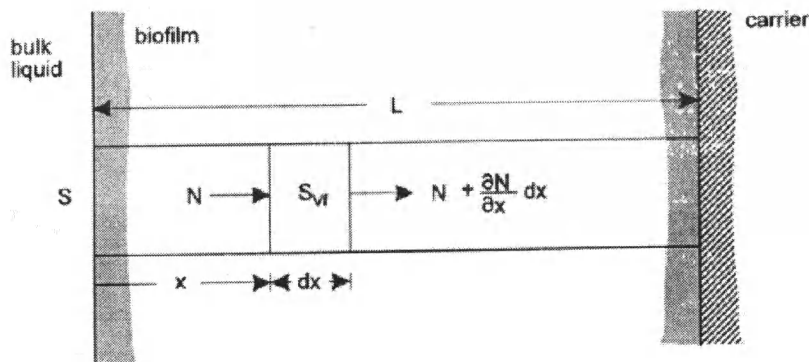


Fig. 1: Schematic diagram of the biofilm attached to a carrier

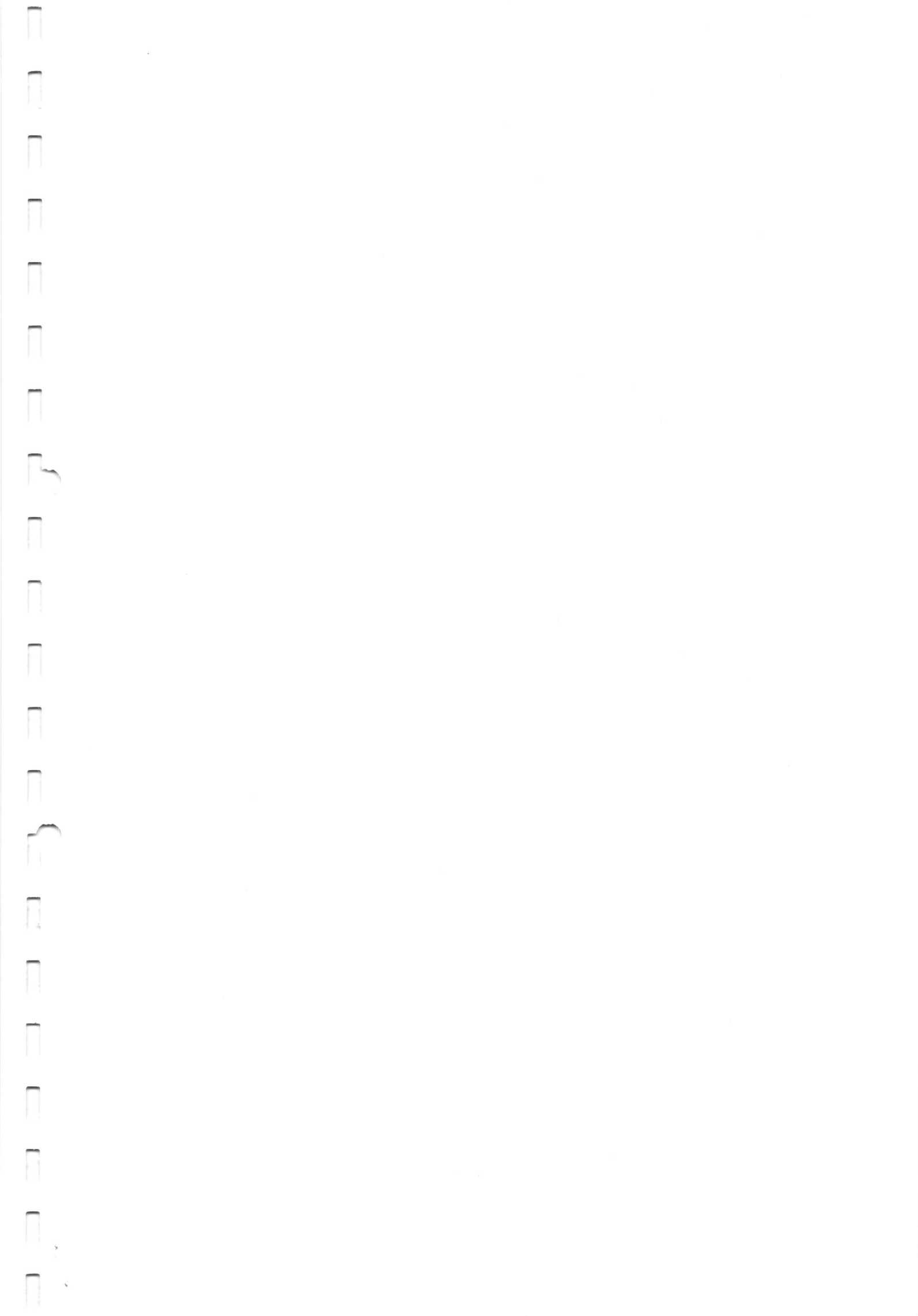
17. Bonnybrook WWTP currently treats a flow of 420,000 m<sup>3</sup>/day generated from a catchment area population of 800,000. The per capita wastewater generation based on these figures and in Liter per day is .....
- The ratio of mass of substrate (BOD) entering the aeration tank per unit time and mass of microorganisms in the aeration tank is called .....
18. Two design parameters of an activated sludge treatment unit are:  
(i) .....  
(ii) .....
19. Two operational parameters of sedimentation tank are:  
(i) .....  
(ii) .....
20. The constructed wetland treating wastewater in KU can be considered as a ..... scale treatment unit.

SECTION "C"

[10 × 0.5 = 5 marks]

Define in a single sentence.

21. ppm:
22. Mass-balance diagram:
23. Saturation constant or half velocity constant:
24. biofilm filter (used for wastewater treatment):
25. Sand Stratification:
26. Retrofitting of BNR Reactors:
27. Jar Test:
28. NOM:
29. Enhanced Phosphorous uptake:
30. THM Formation Potential:



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SECTION "D"  
(Long answer questions)  
[5Q × 4 = 20 marks]

Make logical assumption for any missing data or information.

1. Calculate the output conditions and F/M ratio of the activated sludge system shown in Fig. 1 [4]

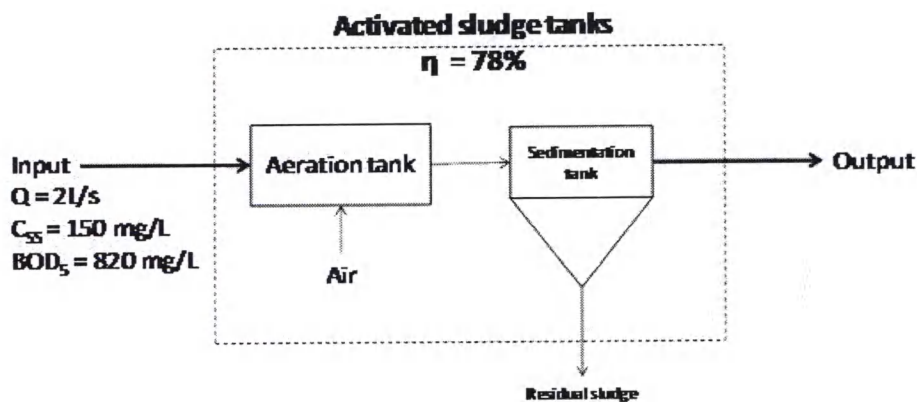


Fig. 1: An example of Activated Sludge System

2. The relationship between growth rate constant and substrate concentration in mixed culture is given by Monod Equation as given below.

$$\mu = \mu_m \frac{S}{K_s + S}$$

- (a) What will be the relationship between  $\mu$  and  $\mu_m$  when  $S = 1000 K_s$ ,  $K_s = 1000 S$  and  $S = K_s$
- (b) If  $K_s = 60 \text{ mg/L}$  and  $\mu_m = 5 \text{ day}^{-1}$ , determine the values of  $\mu$  when  $S$  is  $5 \text{ mg/L}$ ,  $60 \text{ mg/L}$  and  $5000 \text{ mg/L}$ . [4]
3. A settling tank is 20 m long, 10 m deep and 10 m wide. The flow rate to the tank is 10 m<sup>3</sup>/minute. The particles to be removed all have a settling velocity of 0.1 m/minute or more.
- (a) What is the hydraulic retention time?
- (b) Find the overflow rate and horizontal velocity of the particles.
- (d) Will all the particles be removed? Give reasons. [4]
4. A schematic diagram of an activated sludge process with an arrangement of wasting sludge from the aeration tank is shown in the Figure below. Considering a system boundary including the aeration tank and the secondary clarifier, answer the followings. [4]
- (a) Write word and equation statements for microorganisms mass balance in the system.
- (b) Considering the reasonable assumptions, derive an expression for the sludge retention time ( $\theta_c$ ).

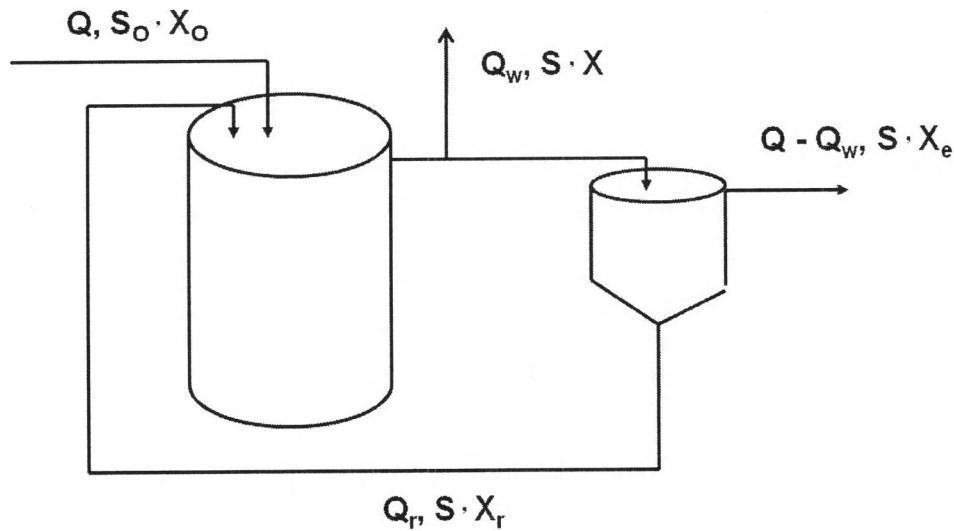


Fig. 2 : Activated sludge system with wasting from aeration tank

5. A list of unit operations contained in the Bonnybrook Wastewater Treatment Plant is given below. Draw a process flow diagram indicating the influent line, effluent line, recycle line and sludge flow.

UV Light disinfection, gravity thickener, anaerobic digester, sludge drying lagoon, dissolved air flotation, grit chambers, secondary clarifier, primary clarifier, bar screen, BPNR Reactor (anoxic), BPNR Reactor (aerobic), BPNR Reactor (anaerobic). [4]

SECTION "E"

[ 5Q × 7 = 35 marks]

Attempt ALL questions.

1. a. A schematic diagram of a typical biofilm is shown in the Fig. 3. Write down the mass balance equation for substrate and derive a differential equation using the Ficks Law. Assume that first order reaction prevails.

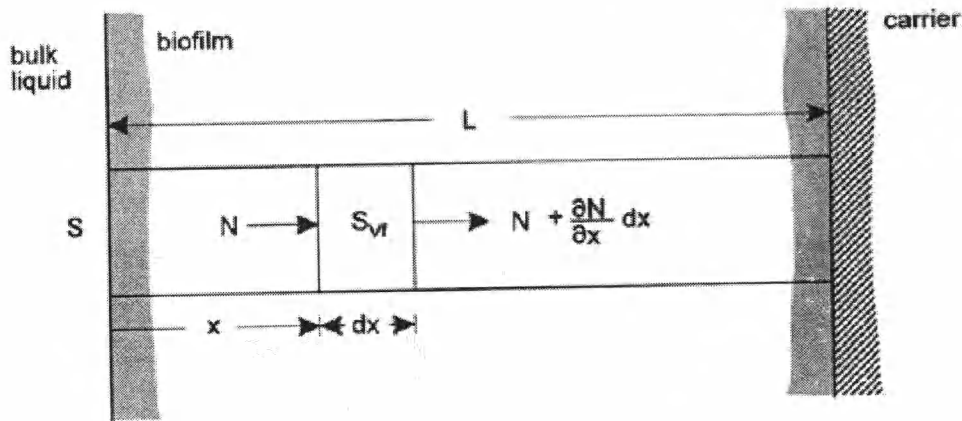


Fig. 3 : Schematic diagram of an attached biofilm

- b. A biofilm has a thickness of 200  $\mu\text{m}$  and the first order reaction rate in the biofilm is 30,000  $\text{day}^{-1}$ . Find the value of the factor  $\alpha$  using the following formula. Take the diffusion coefficient as  $0.4 \times 10^{-4} \text{ m}^2/\text{day}$ . What is the unit of  $\alpha$  ?

$$\alpha = \sqrt{\frac{k_{1vf} L^2}{D}}$$

[5 + 2]

2. a. "One of the principle of water and or wastewater treatment is to remove the larger particles first." Give examples illustrating the above statement
- b. Determine the settling velocity of a spherical particle with a diameter of 0.1 mm and a density of  $2650 \text{ kg/m}^3$  using Stoke's equation as shown below. Density of water is  $1000 \text{ kg/m}^3$  and dynamic viscosity is  $9.2 \times 10^{-4} \text{ N-s/m}^2$ .

$$v = \frac{1}{18} \frac{(\rho_s - \rho_l) g d_p^2}{\mu}$$

where

$v$  = terminal velocity

$\rho_s$  = particle density

$\rho_l$  = fluid density

$d_p$  = diameter of the particle

$g$  = acceleration due to gravity

- c. Determine how long it will take for the particle in 2 (b) above to settle down a distance of 1 m [2 + 3 + 2]
3. a. The activated sludge unit designed for removing carbonaceous BOD needs to be modified to accommodate additional aeration basin and a clarifier in order to remove nitrogen from the wastewater stream. Draw the modified flow diagram and indicate the mechanism of removal of nitrogen.
- b. An activated sludge system is to be used for secondary treatment of  $10,000 \text{ m}^3/\text{day}$  of municipal wastewater. After primary clarification, the BOD is  $150 \text{ mg/L}$  and it is desired to have not more than  $5 \text{ mg/L}$  of soluble BOD in the effluent. A completely mixed reactor is to be used and pilot-plant analysis has established the following kinetic values.  $Y = 0.5 \text{ kg/kg}$ ,  $k_d = 0.05 \text{ day}^{-1}$ . Assuming an MLSS concentration of  $3000 \text{ mg/L}$ , an underflow concentration of  $10,000 \text{ mg/L}$  from the secondary clarifier, and a mean cell residence time of 10 days, determine:
- (i) the volume of the reactor
- (ii) the mass and volume of the solids that must be wasted each day

The following expressions are given.

$$X = \frac{\theta_c Y(S_0 - S)}{T(1 + k_d \theta_c)}$$

$$\theta_c = \frac{V X}{Q_w X_r}$$

[3+2+2]

4. a. A schematic diagram of a Rapid Sand Filter (RSF) is given in Fig. 4.

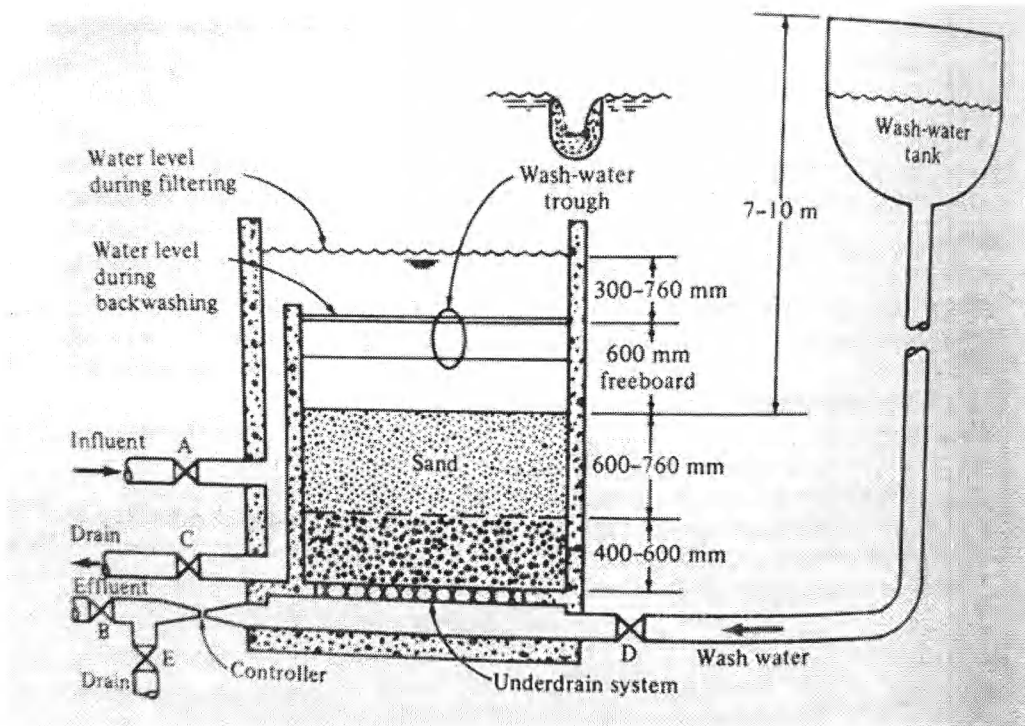


Fig. 4 : Schematic diagram showing the operation of a typical RSF

The operation schedule of the RSF is demonstrated below.

Activity I

- (i) Open Valve A (Allows influent water to flow into the filter)
- (ii) Open Valve B (..... ?.....)
- (iii) Close Valve C (..... ?.....)
- (iv) Close Valve D (..... ?.....)
- (v) Close Valve E (..... ?.....)

Activity II

- (i) Open Valve C (..... ?.....)
- (ii) Open Valve D (..... ?.....)
- (iii) Close Valve A (..... ?.....)
- (iv) Close Valve B (..... ?.....)
- (v) Close Valve E (..... ?.....)

Activity III

- (i) Open Valve A (..... ?.....)
- (ii) Open Valve E (..... ?.....)
- (iii) Close Valve B (..... ?.....)
- (iv) Close Valve C (..... ?.....)
- (v) Close Valve D (..... ?.....)

You need to name the Activities I, II and III and fill the blanks indicated by Question Marks.

- b. Determine the head loss across a bed of uniform-size particles when clean water is passed through a bed at a filtering velocity of 5.0 m/h . The sand grains are 0.4 mm in diameter with a shape factor of 0.85 and a specific gravity of 2.65. The depth of the bed is 0.67m and the porosity is 0.4.

Head loss is given by Carmen- Kozeny equation.

$$h_f = \frac{f' L (1 - e) v_s^2}{e^3 g d_p}$$

where,

$h_f$  = friction loss through bed of particles of uniform size  $d_p$ , m;  $L$  = depth of the filter, m;  $e$  = porosity of the bed;  $v_s$  = filtering velocity, m/s;  $g$  = acceleration due to gravity,  $m/s^2$ ;  $d_p$  = diameter of filter media grain, m ;  $f'$  = friction factor

The friction factor  $f'$  can be calculated using the following formula

$$f' = 150 \frac{(1 - e)}{R_e} + 1.75$$

Reynold's Number is given by

$$R_e = \frac{\phi \rho_w v_s d_p}{\mu}$$

where,  $\rho_w$  = density of water ( $998.2 \text{ kg/m}^3$ );  $\mu$  = dynamic viscosity of water ( $1.002 \times 10^{-3} \text{ Ns/m}^2$ );  $\phi$  = shape factor [3 + 4]

5. Table 1 describes the results of groundwater sampling and analysis in Kathmandu Valley.

Table 1 : Comparison with WHO guideline values

Parameters	WHO guideline value (WHO, 1996)	No. of samples exceeding the guideline*	Highest concentration observed
NH <sub>3</sub> , mgN/L	1.3	19	62.0
NO <sub>3</sub> <sup>-</sup> , mgN/L	12	5	25.0
Fe, mg/L	0.3	12	12.1
Mn, mg/L	0.1	17	1.17
As, µg/L	10	4	73.8
Hg, µg/L	1	23	303.0
DOC, mg/L	0.2 - 15**	5	63.6

\* Total number of samples = 31, \*\* Typical range in groundwater (Thurman, 1985)

- (a) Construct two water samples with water quality parameter values of all the parameters shown in Table 1 as follows. (i) Sample 1 - Ammonia, Nitrate, and Iron exceeding the WHO guideline Value but within the highest concentration observed. Other parameters are within the WHO guideline value. (ii) Sample 2 - Highest concentration values of Mercury, Manganese and Nitrate but other parameters are in between the WHO guideline and Highest concentration values.
- (b) A deep well in Kopundole is found to have Ammonia as 60 mg/L, Iron as 10 mg/L and DOC as 58 mg/L, Write possible reasons for this.
- (c) Suggest treatment options for the ground water described in 5 (b). [4+2+1]

