Ministry of Higher Education and Scientific Research
Foundation of Technical Education
Technical College / Basrah

Training Package
in

Water Pollution Control

For
Students of forth class
Department of Environment and Pollution Engineering
Technical College/Basrah

By

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September/2011

INTRODUCTION TO TREATMENT PROCESS

first modular unit

1/ Over view

1 / A –Target Population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

Water pollution control is a very important subject to be studied in order to have a full knowledge about the processes and units used to getting rid of or control the harmful contaminants in water and waste water, for this reason I have designed this modular unit for this knowledge to be understood .

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1 / C –Central Idea :-

1 - Introduction to Treatment Process

2 – Method of treatment

a - Physical process

b – Chemical process

c –Biological process

3- Treatment of Water

4 – Sewage Treatment

1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
   - Get 8 or more you do not need to proceed.
   - Get less than 8 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
   - Get 8 or more, so go on studying the next modular unit.
   - Get less than 8, go back and study the current modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the current modular unit, the student will be able to:-

1. Defines water pollution control.
2. Knows the methods of treatment.
3. Decides the processes used to remove different types of impurities in water and waste water treatments.

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3/ Pre Test :-

Circle the correct answer:-

1. **Water may not contains much impurities if its source is :-**

a- Reservoir b- stream flowing in plains

c- Lakes in lower region d- spring along hill slopes

2. **Underground water is obtained from :-**

a- surface runoff b- rivers

c- Lakes d- springs

3. **Well treated water is generally supplied for :**

a- Domestic use b- public use

c- Commercial use d- all of above

4. **Quality of water is said to be good if it is :**

a- Free from suspended matter b- tasteless

c- Free from pathogenic organisms d- colorless

5. **Floating is removed by :**

a- Screening b- Aeration

c- Filtration d- Softening

Note

- Check your answers in key answer page 13, (2) degree for each.

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4/ The Text :-

Introduction to Treatment Process

Contaminate may be present as:

1. Floating or large suspended solid.
2. Small suspended & colloidal solid.
3. Dissolved solid.
4. Dissolved gases.

Methods of Treatment

There are three main classes of treatment process:

a. Physical process: - these methods depend essentially on Physical properties of the impurity.

   e.g :- Particle size , specific gravity , and viscosity .

   Typical example of this type of process is: screening, sedimentation, filtration and gas transfer.

b. Chemical process: - this method depends on chemical properties of the impurity or the chemical properties of added reagent.
   e.g :- coagulation , precipitation , ion exchange.

c. Biological process: - these methods utilize biochemical reaction to remove soluble or colloidal impurities.

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- Aerobic biological processes including biological filtration and activated sludge.
- Anaerobic oxidation processes and used for the stabilization of organic sludge and high strength.

Quiz 1

What is the difference between aerobic and anaerobic oxidation?

Note

- Check your answers in key answer page 13.

Treatment of Water

The various treatment method and nature of impurities removed by employing them are given in the table below:

Water Treatment

N	Process	Impurity removal
1	Aeration	Testes and odor removal, oxygen deficiency
2	Screening	Floating mater
3	Plain sedimentation	Large suspended solids
4	Coagulation	Fine Particle
5	Filtration	Colloidal Particles , Micro Organisms
6	Activated Carbon	Element causing tastes and odors
7	Softening	Hardness
8	Disinfection	Living organisms including Pathogens

Quiz / 2

How could you remove these impurities:- Fine particles, Hardness, Tastes, Living organism, Microorganisms.

Note

- Check your answers in key answer page 13.

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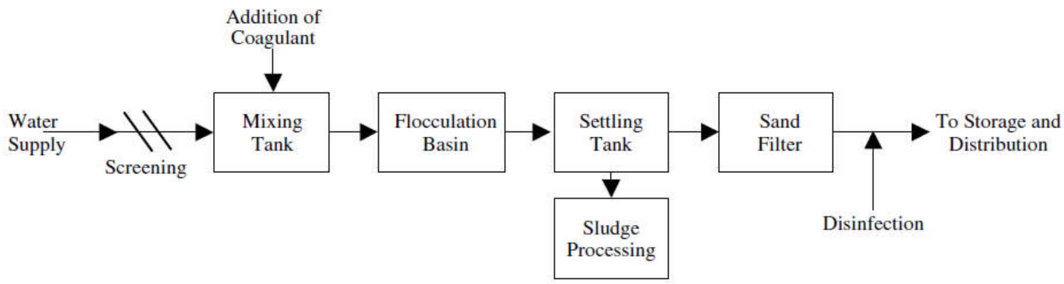

Figure (1) Typical Water Treatment Plant

Sewage Treatment

a. Preliminary treatment :

This will make sewage fit for further treatment. Also, this process removes about 10% of total solids (inorganic).

i. Screen
ii. Shredder or communitors
iii. Grit chamber
iv. Detritus tank

b. Primary treatment :

In this case attempts are made to remove the settable organic matter.

Plain sedimentation tank
- Removes 40% total solids
- Removes 30-40% B.O.D

c. Final or complete treatment : (Biological Treatment)

Non- settle able and dissolved organic matter get removed. This process removes about 90% of total solids and 85% of B.O.D.

I. Activated sludge process.
II. Trickling filter.
III. Intermittent filter.

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i.	Screen	Preliminary
ii.	Shredder	
iii.	Grit chamber (sand trap)	
iv.	Primary sedimentation	Primary treatment
v.	Trickling filter	Final treatment
vi.	Activated sludge	
vii.	Secondary sedimentation	
viii.	Disinfection	
ix.	Thickener	
x.	Digester	
xi.	Drying beds	

* One unite is shown dotted as in general, both are not simultaneously used for a treatment plant.

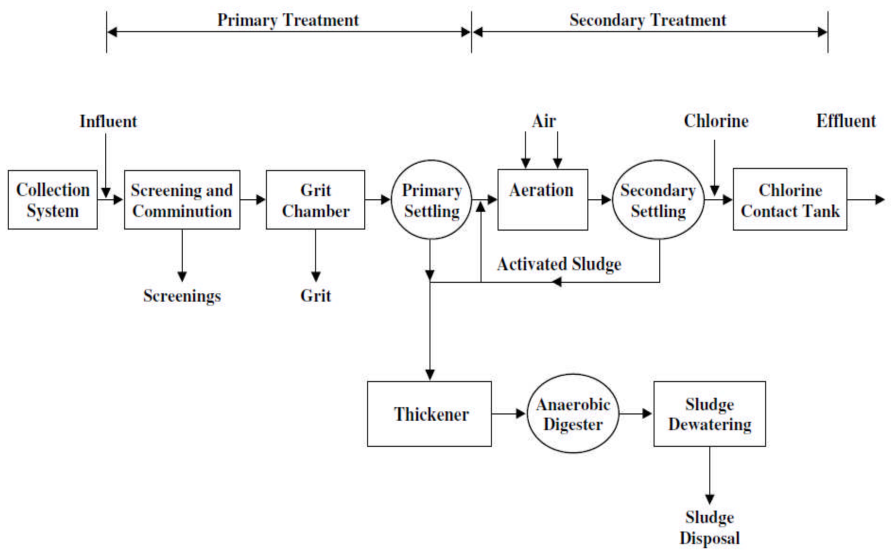

Figure (2) Schematic of Conventional Wastewater Treatment Process

Quiz3

Fill in the blanks with suitable answer:-

1. Biological Treatment removes about________of total suspended solid and __________ of BOD.
2. We use drying beds to _______ the sludge.

Note

- Check your answers in key answer page 13.

5/ Post Test :-

1- Sedimentation is a:

a- Biological process b- chemical process

c- Physical process d- other method

2- Coagulation is used to remove:

a- Large suspended solids b- Fine particles

c- Taste and odour c- Hardness

3- Disinfectant is a chemical substance used for:

a- Living objects b- Nonliving objects

c- Living and nonliving objects d-none

4-Preliminary treatment removes about:

a- 10% of total inorganic solid b- 10% of bacteria
c- 10% of total organic solid d- all of above

5- Contamination:

a- is the opposite of sterility b- means sterility

c- Always air borne d- can not be minimized

Note

- Check your answers in key answer page 13, (2) degree for each.

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<u>6/ key Answer :-</u>

1- Pre Test:-

1. a
2. d
3. d
4. b
5. a

2- Post Test:-

1. c
2. b
3. a
4. a
5. a

If you:-

- Got 8 or more, so congratulation your performance, go on studying modular unit two.
- Got less than 8, go back and study the first unit; or any part of it; again, and then do the post test again.

Quiz No. 1 /

Return to page (9) for the answer.

Quiz No. 2 /

Return to page (9) for the answer.

Quiz No. 3/

1. 90%, 85%.
2. Dewatering.

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7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

3- Principles of water quality control, by T.H.Y. Tebbutt

4- Water Supply, Water Treatment, Dept. of the Army and the air force, Sept. 1985, TM 5-813-3/AFM 88-10, Vol 3l.

5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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PRELIMINARY TO TREATMENT PROCESS

second modular unit

1/ Over View

1 / A –Target Population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

To protect the main units of a treatment plant and to aid in their efficient operation it is necessary to remove the large floating and suspended solids which are often present in the inflow. These materials include leaves, twigs, paper, plastics, rags and other debris which could obstruct flow through a plant or damage equipment in the plant. Therefore, I have designed this modular unit for this knowledge to be understood.

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1 / C –Central Idea :-

1 - Introduction

2 –Screening

a - Purpose

b – Types of Screens

c – Design Consideration

3 – Grit Chamber (Sand Trap)

a - Purpose

b – Types of Grit Chambers

c – Design Consideration

4- Velocity Control Device.

4-1 Proportional Flow Weir

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
   - Get 9 or more you do not need to proceed.
   - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
   - Get 9 or more, so go on studying modular unit three.
   - Get less than 9, go back and study the second modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Design medium and coarse screens.
2. Design conventional and aerated grit chamber.
3. Design velocity control device.

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3/ Pre Test :-

Circle the correct answer:-

1. **Screening of sewage is done essential for removing:-**

a-Floating matter b- Suspended solid

c- Bacteria d- All of above

2. **Screens are classified as per:-**

a-Size of opening b- Shape

c- Method of seating d- Method of cleaning

e- All above

3. **Horizontal velocity through screen chamber ranges from:**

a- 0.3- 0.6 m/s b- 0.15-0.5m/s

c- More than 0.6m/s d- Less than 0.1m/s

4. **The width of screen ranges from :**

a- 0.3-2.5 m b- 0.6-1.5m

b- 0.6-2.0m d- 1.0-2.0 m

5. **Slope of screen channel governed by:**

a- Darcy's equation b-Hazen Willam's eq.

c- Manning formula d- Newton formula

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6. Grit chamber is provided to :

a- Protect mechanical equipment b- Reduce size of digester

c- Reduce formation of heavy deposit d- All of above

7. Settling velocity of laminar flow is computed by :

a- Stock's law b- Newton's law

c- Hazen modified formula d- Transition law

8. The efficiency of ideal grit chamber basin is equal to:

a- S.O.R b- Settling velocity

c- 100% d-All of above

9. Detention period of aerated grit chamber ranges :

a- 45-60 sec b- 3-5 minutes

c- 90-120 sec d- 15-20 minutes

10- The velocity of scouring should be :

a- Greater than horizontal velocity b- Less than horiz. velocity

c-Greater than or equal d- Equal to horiz. velocity

Note

- Check your answers in key answer page 20.

- (1) degree for each .

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4/ The Text :-

Screening:-

a- Purpose:

Screening of sewage is done for removing floating matter like pieces of wood, charcoal, leaves, etc. In a nutshell screen while treating sewage, traps and eliminates the gross floating solids which may otherwise:

i. Clog the pumps
ii. Form ugly sludge banks at the disposal done without treatment.
iii. Clog the trickling filter bed.
iv. Interfere in the activated sludge treatment unite.

Screens mechanically or manually cleaned normally used for this purpose.

Quiz / 1

Numerates the problems appear from outselling screen while treating sewage.

Note

- Check your answers in key answer page 21.

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b- Type of screens:

Screens are classified into different categories as given below:

i. As per size of opening: fine, medium &coarse screens.
ii. As per shape: disc, drum, cage, wing, bar….etc.
iii. As per method of setting: fixed, moving, movable ….etc.
iv. As per method of cleaning: manual cleaning or mechanical cleaning.

The opening in coarse screen is 50 mm or above medium screen is varying from 20-50 mm fine screen is smaller than 20 mm.

For large size sewage treatment plants mechanical screens are found more suitable. Wherever the average quantity of sewage exceeds $400 m^3/hr.$, mechanical screens are recommended. All mechanically cleaned medium screens should be preceded by a coarse screen which is manually cleaned.

c- Design considerations:

i. Horizontal velocity through a screen chamber:

$V_H > 0.6$ m/s (grit bearing sewage)
$V_H > 0.3$ m/s other sewage

ii. Effective area of the screen should be such as to product a velocity through the screen opening not exceeding 1.2 m/s at maximum discharge.

iii. Min. freeboard is 300 mm above the highest flow level.
iv. The screen bars are provided with flats of 10 mm maximum thickness and not less than 50 mm deep.
v. Maximum screen width is 1.5 m and min. width is 0.6 m.

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vi. The angle of inclination of manually cleaned screen are 45^0 to 60^0 with the horizontal and 75^0 to 80^0 for mechanical screens.

vii. Head loss:

$$h_L = 0.0729 (V^2 – v^2)$$

in which ,

h = head loss in (m)
V = velocity through the screen (m/s)
v=approach velocity through the channel (m/s)

Allowable head loss , clogged 150 mm =15cm
Max. head loss , clogged 800 mm = 80cm

viii. Length of screen channel:

$$L= (d_c + 0.3) \text{ co} + () +1.73 (w_c +d)$$

Where:

L = length of screen channel ,(m)
d_c = depth of flow in screen chamber ,(m)
() = angle of the screen with the horizontal plane
w_c = width of screen chamber ,(m)
d = diameter of incoming screen sewer ,(m)

The length of screen channel should be sufficient, so that the screen can be properly hones, working space should be available, flow can be stabilized and eddies are avoided.

Note: after computation of cross - sectional area of screen and fixing the size and spacing of bars ….etc , checking has to be done for determining the velocity of the flow.

ix. Net area of screen (first approximation) is computed with hydraulic loading of 30(Ml/ m^2 / day) for average flow.

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Or: 20 (Ml/ m^2 / day) for computing the gross screen channel area including the area of openings and area of bars.

x. Slope of the channel :
It is computed using Manning's formula.

$$V = (1/n) . (R)^{2/3} . (s)^{1/2}$$

V = velocity through the channel ,(m/s)
n = roughness parameter
R = hydraulic radius = A/P , P: wet parameter (m)
A: wet area (m^2)
S = slop of the channel

xi. Total area or Channel x- sectional Wet Area=

[Net Area] / [Eff. Coeff. for bars]

Eff. Coeff. for bars = Opening size / (Opening size +bar thickness)

Net area of opening = Discharge / Hydraulic loading

Quiz / 2

The following date are given :-
Q= 0.425 m^3/s, Velocity through the screen = 0.82m/s, Cross-sectional area of channel = 0.7m^3 .
Check for quarter plugged flow and find the head loss.

Note

- Check your answers in key answer page 21.

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Grit Chambers (Sand Trap)

Grit chambers are constructed primarily to remove grit, consisting of sand, gravel, cinders and other inorganic heavy materials of course sizes, along with grit some heavier particles of organic maters get settled in the grit chamber.

a- Purpose:

i. Grit chamber is provided to protect mechanical equipment from abrasion and abnormal wear.

ii. To reduce formation of heavy deposits in pipe and conduits.

iii. To reduce the size or frequency of cleaning of digesters.[12]

b- Type of grit chambers:

i. As per method of cleaning: manual or mechanical cleaning

ii. As per flow: horizontal flow spiral movement (Aerated grit chamber)

iii. Detritus tank: grit chamber with rotating arms for collection of grits in square tanks.

c-Design consideration:

i. Settling velocity:

Grit chamber may be designed on a rational basis by considering it as a sedimentation basin. The grit particles are treated as discrete particles settling with their own settling g velocities. The minimum size of the grit to be removed is (0.2) mm.

a) Stok`s law

$$V_S = \frac{g}{18} \cdot \frac{(P_s - P)}{P} \cdot \frac{d^2}{V}$$

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or

$$V_s = \frac{g}{18}(s_s - 1)\frac{d^2}{V}$$

Where:
V_s = settling velocity (m/s)
g = acceleration due to gravity, (= 9.81m/s^2)
P_s = mass density of grit particle, kg/m^3
P = mass density of liquid, kg/m^3
S_s = specific gravity of grit particle, dimensionless (=2.5)
d = size of the particle, m
V = kinematics viscosity of sewage, (= 1.01 * 10^{-6} m^2/s)

This relation corresponds to particles of sizes less than 0.1 mm. the flow conditions are laminar where viscous forces dominate over inertia forces.

b) Transition law :

The design of grit chamber is based on removal of grit particles with minimum size of 0.2 mm or 0.15 mm and therefore, stock's law is not applicable to determine the settling velocity of the grit particles for design purposes.

The settling velocity of a disc rate particle is given by the general equation:

$$V_s = \sqrt{\frac{4}{3}.\frac{g}{c_D}.\frac{(P_S - P)}{P}.d}$$

Where, c_D is the Newton coefficient or drag which is a function of Reynolds number. The transition flow conditions held when Reynolds number is between 1 and 1000. In this range, c_D can be approximated by:

$$C_D = \frac{18.5}{R^{0.6}} .= \frac{18.5}{(\frac{V_S.d}{V})^{0.6}}$$

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Substituting the value of c_D in above equation and simplifying:

$V_S = \left[0.707(S_s - 1).d^{1.6}.V^{-0.6}\right]^{0.714}$ For grit particles in the range of (0.1mm&1mm).

The settling velocity of grit particles in the transient zone is also calculated by the Hazen`s modified formula:

$V_S = 60.6(s_s - 1)\, d\, .\frac{3T + 70}{100}$ To remove particle size of 0.15 mm or 0.2 mm.

When d in above equation is in cm and T is the temperature in degree and V_S in cm/s.

c) Newton`s law:

When the particle size increases beyond 1mm and Reynolds number beyond 1000, the coefficient of drag C_D assumes a constant value of 0.4 and the flowing equation can be used to determine the settling velocity of grit particles.

$$V_S = \left[3.3\, g\, (S_S - 1).d\right]^{0.5}$$

ii. Surface over flow rate:

Efficiency of an ideal settling basin

$$(\eta) = \frac{V_S\,(settling\; velocity)}{surface\; over\;\; flow\; rate(S.O.R)}$$

$$(S.O.R) = \frac{Q(\;flow)}{A(Plan\; area\; of\;\; the\; \tan k)}$$

In an ideal settling basin, all particles having settling velocity $V_S \geq$ S.O.R are completely removed. However, the behavior of a real grit chamber departs significantly from that of the ideal settling basin due to turbulence. The flowing equation

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could be used to determine the SOR for a real basin for a given efficiency of grit removal and basin per formaree

$$\eta = 1 - \left[\frac{1 + n.V_S}{(S.O.R)}\right]^{\frac{1}{4}}$$

Where,

η = desired efficiency of removal grit particle

V_S= settling velocity of the minimum size of grit particle to be removed

(S.O.R) or (Q/A): design surface over flow rate

n: an index which is a measure of the basin performance

n = 0.125 (very good)

= 0.25 (good)

= 0.5 (poor)

= 1.0 (very poor)

iii. Detention period:

A detention period between 45 to 60 sec is usually adopted for horizontal flow grit chamber and between 3 to 5 minutes for aerated grit chamber is adopted.

iv. Bottom scour and flow through grit chamber:

Bottom scour is an important factor effecting grit chamber efficiency. The scouring process itself determines the optimum velocity of flow through the unit. This may be explained by the fact that there is a critical velocity of flow V_c beyond which particles of a certain size and density once settled, may be again placed in motion and reintroduced in the stream of flow. The critical velocity of scour may be calculated from modified schield`s formula:

$$V_S = \sqrt{\frac{8k}{f}(S_S - 1).g.d} \qquad k=0.04$$

f= 0.03

Note: Horizontal velocity V_h should be less than V_c

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Quiz / 3

$$\frac{real\ efficiency}{ideal\ efficiency} = 0.65 = \frac{1-[1+n\frac{Vs}{S.O.R}]^{\frac{-1}{n}}}{\frac{Vs}{S.O.R}}$$

$S_s = 2.065$, $d = 0.15 * 10^{-3}$m
$V = 1.14*10^{-6}m^2/s$
For the above data prove that stock's Law does not apply.

Note

- Check your answers in key answer page 22.

Velocity Control Device

Numerous devices have been designed in an attempt to maintain a constant horizontal velocity of flow through grit chamber in the recommendation range of 15 to 300 m/s is used at peak flows.

A satisfactory method of controlling velocity of flow through grit chamber is by:

i. Using a control section which placed at the end of channel.
ii. Varies the cross-sectional areas of flow in the section in direct proportion to the flow.

Each grit chamber should provide with separate control device:

i. Throat control weir
ii. Proportional flow weir
iii. Par shall flume

Proportional Flow Weir

The proportional flow weir is a combination of a weir and an orifice. It maintains a nearly constant velocity in the grit channel by varying the cross-sectional area of flow through the weir so that the depth is proportional to flow.

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i- The general equation for determining the flow through weir, Q, is:

$$Q = c.b.\sqrt{2ag}.(H - \frac{a}{3})$$

Where,

c: a coefficient which assumed 0.61 for symmetrical shape – edge weirs.

a: dimension of weir usually assumed between 25 mm and 50 mm

b: base width of the weir

H: depth of flow

ii- To determine the shape of curve forming the outer edges of the cut portion, the flowing equation of curve forming the edge of the weir may be used:

$$x = \frac{b}{2}(1 - \frac{2}{\pi}\tan^{-1}\sqrt{\frac{y}{a} - 1})$$

The weir shall be set 100mm to 30mm above the bottom of grit chamber to provide grit storage or for operation of mechanical grit chamber.

iii. Number of units:

In case of manually cleaned grit chambers at least two units should be provided. All mechanically cleaned units should be provided with a manually cleaned unit to act as a bypass. (At least two units provided).

iv. Dimensions of each unit:

i. The width of tank is fixed with reference to the control device adopted.
ii. The length is worked out on the basis of the select over flow rate.

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iii. The depth of the flow is determined by the horizontal velocity and the peak flow.

$$Total\ Depth = Computed\ water\ depth + Free\ board + Depth\ due\ to\ grit\ storage\ space$$
$$(0.15 - 0.3m) \quad (0.25\ of\ water\ computed\ depth)$$

Illustrated Problems

Problem 1:- Design a manually cleaned bar screen with 20mm clear opening for 18MLD average sewage flow.
Assume bars are made out of flats of 10mm*50mm and inclination of the screen is 60° with the horizontal direction .
Assume the hydraulic loading = 30ML/m^2/d.

Solution:-

Net area of opening = $\frac{Q}{Hyd.loading} = \frac{18}{30} = 0.6\ m^2$

Eff. Coef.of bars = $\frac{clear\ spacing\ between\ flats}{clear\ spacing\ between\ flats + thickness\ of\ flats}$

$= \frac{20}{20+10} = \frac{2}{3}$

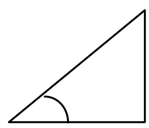
∴ Total or Gross cross – sectional area of channel

$= 0.6 * \frac{3}{2} = 0.9\ m^2$

Total inclined area of screen = $\frac{0.9}{\sin 60°} = 1.04\ m^2$

sin60 = $\frac{0.9}{l}$--- l=$\frac{0.9}{sin60}$ =

0.9



Assuming depth of flow = 1.0 m
Nos. of bars = 30-1=29
Width of the bars = 29 * 10 = 290 mm = 0.29 m
Gross effective width of the screen = 0.6 + 0.29 = 0.89 m

Check for velocities
Discharge, Q= 18MLD = 0.208 m^3/s
Velocity of approach through the channel v= $\frac{0.208}{0.89}$ = 0.24 m/s
Velocity through the screen = $\frac{0.208}{0.6}$ = 0.35 m/s
Both the velocities v and V are much low and should range between 0.6 m/s to 1.2 m/s .

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Hence , considering approach velocity v as 0.6 m/s

Total area of the screen = $\frac{0.208}{0.6}$ = 0.35 m^2

Area of opening through screen = $\frac{0.35*0.6}{0.89}$ = 0.24 m^2

∴ Velocity through the screen = $\frac{0.208}{0.24}$ = 0.87 m/s (O.K)

Head loss = $h_L = 0.0729\ (V^2 - v^2)$

V= 0.87 m/s and v= 0.6m/s

∴ $h_L = 0.0729\ ((0.87)^2 - (0.6)^2) = 0.029m \approx 0.03m = 3cm$

The depth of water = 0.5

∴ width of channel = $\frac{0.24}{0.5}$ = ≈ 0.48 m

No. of opening of screen = $\frac{0.48*1000}{20}$ = 24 Nos

No. of bars = 24-1 = 23

Width of the bars = 23 * 10 = 230 mm = 0.23m

Total width = 0.71 m

Summary:

i) Provide 29 bars of 10 * 50 mm size at an 60° inclination

ii) Provide channel of depth (0.5+0.3)
(depth freeboard) =0.7m and width equal to 0.71m with slope of (0.00237).

*If the screen is half plugged with screening, leaves and other debris and from Q= A.V , the area is directly proportion to the velocity . In other words , if the area is cut in half , the velocity must double . the head loss .

Therefore is :

$H_L = 0.0729\ (\ (1.94)^2 - (0.6)^2\ ) = 0.194m = 19.4cm$

So , the increase in head loss is 6.5 fold (19.4/3) as the screen become half plugged . The need for accurate control of the cleaning cycle and protection against surge loads is thus recommended.

H.W: calculate the length of screen

Assume the diameter of incoming sewer = 0.35m

$L= (d_c + 0.3) \cot \propto + 1.73\ (w_c + d)$

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$L = (0.5 + 0.3)\frac{1}{\tan 60^\circ} + 1.73\,(0.71+0.35)$

L= 2.29m say 2.3 m

Slop of the channel

$V = \frac{1}{n}\,.\,R^{2/3}\,.\,S^{1/2}$

v= 0.6m/s , $R = A/P = \frac{0.5*0.48}{(0.48*2)+(0.5*2)} = 0.162$

$0.6 = \frac{1}{0.024}\,.(0.162)^{2/3}\,.\,\sqrt{5} \longrightarrow S = 0.00237$

Problem 2:- Design a bar screen for 35 MLD sewage flow so that velocity through the screen dose not fall below 0.8 m/s .

Solution :-

Q= 35 MLD = 0.405 m^3/s

Velocity through the screen = 0.8 m^2/s

Area of opening = $\frac{0.405}{0.8}$ = 0.506 m^2

Assume the depth of flow = 0.9 m

Width of clear opening = $\frac{0.506}{0.9}$ = 0.562m

Adopting screen with a bars of flat size 10mm * 50mm and 20mm clear opening

No. of bars = 28-1=27

Gross – width of the screen = 0.562 + $\frac{27*10}{1000}$ = 0.832m

If the angle of inclination of the screen is 60° with the horizontal , the inclined area of the screen .

$= \frac{0.832*0.9}{\sin 60^\circ} = 0.865 m^2$

$V = \frac{0.405}{0.506} = 0.8 m/s$

$v = \frac{0.405}{0.832*0.9} = 0.54 m/s$ (dose this range accepted or not ?)

$h_L = 0.0729\,(\,(0.8)^2 - (0.54)^2\,) = 0.0225m$ discusses for half plugged screen

$h_L = 0.0729\,(1.6^2 - 0.54^2\,) = 0.165m = 16.5$ cm

H.W.:- i) calculate the length of the channel

ii) calculate the slope of the channel

assume the diameter of incoming sewer = 0.5m

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$L = (d_c + 0.3)\cot\alpha + 1.73\,(w_c + d)$

$L = (0.9+0.3)\,\frac{1}{tan60} + 1.73\,(0.832+0.5) = 2.997m \approx 3m$

Problem 3: Design grit chamber to treat peak design flow of 150MLD (3X average waste water flow of 50 MLD) of waste water to remove grit particles upto size 0.15mm and the specific gravity of 2.65. The minimum temperature is 15 degree. The grit chamber is equipped with proportion flow weir as control devise.

Solution:-

i) Computation of settling velocity

Applying stocke`s law

$V_s \, \frac{g}{18}\,(S_S-1)\,\frac{\delta}{v}$

Given $S_S = 2.65$, d= $0.15*10^{-6}$ m^2/s at 15 degree

$V_s = \frac{9.81}{18}(2.65-1)\frac{0.15*10^{-3})^{\;2}}{1.14*10^{\wedge}-6}$ = 0.018 m/s

Check for Reynolds Number, R

$R = \frac{V_S\, d}{v} = \frac{0.018*0.15*10^{-3}}{1.14*10^{-6}} = 2.37 > 0.5$

Hence stocke`s law does not apply

Applying transition law for $0.5<R<10^3$

$V_s = [\,0.707\,(S_s-1)d^{1.6}v^{-0.6}]^{0.714}$

$= [0.707(2.65-1)(0.15*10^{-3})^{1.6}(1.14*10^{-6})^{-0.6}]^{0.714} =$ 0.0168m/s

ii) Computation of surface overflow rate, SOR

The surface overflow rate = settling velocity of the minimum
For 100% removal efficiency size of particle to be removed

In an ideal grit chamber

$\mu = \frac{V_s}{SOR} = 1$

V_S = SOR = 0.0168m/s = 1451.5 m/s

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$$\mu = 1 - \left(1 + n \frac{V_s}{\frac{Q}{A}}\right)^{-1/n}$$

When μ= efficiency of removal of desired particle
n=measure of settling basin performance
=1/8 for very good performance

Assuming μ= 75% , n=1/8

$$\left(\frac{Q}{A}\right) = \frac{V_s\ n}{[1-0.75]^{-n}\ -1} = \text{SOR}$$

$$= \frac{1451.5*\frac{1}{8}}{(1-0.75)^{-0.125}\ -1} = 959 m^3/m^2/d$$

iii) Determination of the dimensions of grit chamber

Plan area of grit chamber = [Q / (Q/A)]

$$959 = \frac{Q}{A} \longrightarrow \quad A = \frac{Q}{959} \longrightarrow$$

$$\frac{150*10^3}{959} = 1564 m^2$$

H.W:- check the dimension with the design criteria

Provide 4channels of 2.5m wide and 16m long

The critical displacement scouring velocity to initiate re-suspension of grit is given by $V_c=[\frac{8k}{f}(S_s-1)gd]^{0.5}$

For k=0.04 , f=0.03 , S_s=2.65 , d=$0.15*10^{-3}$m v_c=0.161m/s

The horizontal velocity of flow V_h should be kept less than critical displacement velocity V_c

Depth= $\frac{1.736}{0.158*2.3*4}$ = 1.1m

$V_h = \frac{1.736}{1.1*4*2.5}$= 0.158m/s <0.161m/s O.K.

$\frac{V_h}{V_s} = \frac{0.158}{0.0168} = 9.4$ closer to 10 hence (O.K.)

The hydraulic residence time at peak flow is

$$\text{HRT} = \frac{volume}{peak\ discharge} = \frac{4*2.5*16*1.1}{1.736} = 101.38\ second$$

Total depth of grit chamber = water depth +free board +grit storage space

=1.1+0.25+0.25=1.6m

Provide 4 channel of grit chamber , each 16m*2.5m*1.6m

iv)Design of proportion flow weir

Peak flow for each weir= (1.736/4) = 0.434m^3/s

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Flow through a proportional flow weir is given by

Q=Cb$\sqrt{2ag}$[h-(a/3)]

For symmetrical sharp – edged weir , c=0.61

Assuming a=35mm(usually between 25-50mm)

h=1.1m at peak flow

0.434=0.61*b(2*0.035*9.81)$^{0.5}$(1.1-0.035/3)

b=0.79 say 0.80m

to determine the coordinates (x,y)of the curve forming the edge of the weir assume suitable four values of y and compute corresponding values of x using equation

x=b/2[1-$\frac{2}{\pi}\tan^{-1}\sqrt{y/a-1}$]

the coordinates for proportional flow weir are listed below

SI.NO.	Y,m	x,m
1	a=0.035	0.400
2	5a=0.175	0.12
3	10a=0.35	0.082
4	20a=0.7	0.057
5	30a=1.05	0.047
6	40a=1.40	0.040

H.W. :- Draw the proportional weir

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5/ Post Test :-

Problem: Design a screen chamber for a peak discharge of 0.5 m^3/s if the following data are given:

i) Diameter of incoming sewer = 0.65m

ii) Inclination of bar screen= 45°

iii) Clear opening of screen =20mm

iv)Bars made of 15mm *50mm of flats.

v) Velocity through the screen =V=0.8m/s

Calculate the length of the screen chamber and the hydraulic loading for peak flow .

Note

- Check your answers in key answer page 20 .

- (1) degree for each step .

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6/ key Answer :-

1- Pre test :-

1. a
2. e
3. a
4. b
5. c
6. d
7. a
8. d
9. b
10. b

If you :-

- got 9 or more you do not need to proceed .
- got less than 9 you have to study this modular unit well .

2- Post test :-

Solution:-

Area of screen opening $w_s = \frac{0.5}{0.8}$ = 0.625 m^2 (1 mark)

Submerged length of screen = $l_s = \frac{Q}{Ws.V} = \frac{0.5}{0.625*0.8}$ = 1.2m (1mark)

Depth of flow = $d_c = l_s .\sin\alpha$ =1.2 *sin45 = 0.85m (1 mark)

Number of screen opening = $\frac{0.625*1000}{20}$ = 31 (1 mark)

Number of bar= 31-1=30 (1 mark)

Width of screen chamber= w_c = 0.625 + $\frac{30*15}{1000}$ = 1.075m (1 mark)

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Approach velocity of chamber

$V = \frac{Q}{Ws*dc} = \frac{0.5}{1.075*0.85} = 0.547$m/s (1 mark)

Length of screen chamber

L= $(d_c+0.3)\cot\propto+1.73\ (w_c+d)$

$=(0.85+0.3)\cot45+1.73\ (1.075+0.65)=4.31$m (1 mark)

Discharge = $0.4m^3/s$=43.2MLD

Hydraulic loading for beak flow

$= \frac{Q}{Wc*dc} = \frac{43.2}{1.075*0.85} = 47\ Ml/m^2/d$ (2 mark)

If you :-

- got 9 or more , so congratulation your performance , go on studying modular unit three .
- got less than 9 , go back and study the second unit ; or any part of it ; again, and then do the post test again .

Quiz No. 1 /

Return to page (9) for the answer.

Quiz No. 2 /

$H_L = 0.0729\ [V^2-v^2]$

V= 0.82 m/s

v=0.425/0.7 = 0.607 m/s

For quarter plugged flow

$V= \frac{Q}{\left(1-\frac{1}{4}\right)A} = \frac{0.425}{(0.75)(\frac{0.425}{0.82})} = 1.0933$m/s

$HL= 0.0729\ [(1.0933)^2 – (0.607)^2]$

$= 0.06028$ m = 6cm

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Quiz No. 3 /

$V_s = \frac{g}{18}(S_s\text{-}1)\,\frac{d}{v}$

$V_s = \frac{9.18}{18}(\,2.65\text{-}1)\,\frac{(0.15*10^{-3})^2}{1.14*10^{-6}} = 0.018\text{m/s}$

$R = \frac{Vs\,.d}{v} = \frac{0.018*0.15*10^{-3}}{1.14*10^{-6}} = 2.37 > 1$

Thus , Stock's Low does not apply.

7/Sources :-

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5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

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Ministry of high Education and Scientific Research
Foundation of Technical Education
Technical College / Basrah

Training package
In
Clarification
For

Students of forth class
Water Pollution Control
Environment and Pollution Engineering Department

By

Dr. Ihssan A. Abdulhussain
Lecturer
Environment and Pollution Engineering Department

September/2011

CLARIFICATION (SEDIMENTATION)

Third modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Environment and Pollution Department

Water Pollution Control

1 / B –Rationale :-

Many of the impurities in water and wastewater occur as suspended matter which remains in suspension in flowing liquids but which will move vertically under the influence of gravity in quiescent or semi-quiescent conditions. Usually the particles are denser than the surrounding liquid so that sedimentation takes place but with very small particles and with low-density particles flotation may offer a more satisfactory clarification process. Sedimentation units have a dual role -the removal of settle able solids and the concentration of the removed solids into a smaller volume of sludge.

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1 / C –Central Idea :-

1 - Definition

2 –Types of Settling

a - Discrete settling

b – Flocculent settling

c – Hindered or zone setting

d- Compression

3 – Types of sedimentation tanks

4 – Design considerations

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
    - Get 9 or more you do not need to proceed.
    - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
    - Get 9 or more, so go on studying modular unit four.
    - Get less than 9, go back and study the third modular unit ; or any part of it ; again and then do the post test again .

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2/ Performance Objectives :-

After studying the third modular unit, the student will be able to:-

1. Define clarification and sedimentation.
2. Know the methods of settling and types of sedimentation tanks.
3. Design the circular sedimentation tanks.

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<u>3/ Pre test :-</u>

Circle the correct answer:-

1. In plain sedimentation tank under normal conditions, impurities are removed up to :-

a- 60%　　b- 70%　　c- 80%　　d- 90%

2. If L,B and D are length, breadth and depth of water in rectangular sedimentation tank of total discharge Q, the settling velocity is :-

a- Q/H　　b- Q/D　　c- Q/(D*B)　　d- Q/(L*B)

3. The ratio of discharge and plain area of a continuous flow type settling tank, is known :

a- surface loading　　b- over flow

c- over flow rate　　d- all the above

4. Normal values of over flow rate for plain sedimentation tank, is :

a- 250 to 500 liters/hr./m^2　　b- 500 to 750 liters/hr./m^2

c- 750 to 1000 liters/hr./m^2　　d- 1000 to 1250 liters/hr./m^2

5. Detention period of settling tank is :

a- average theoretical time required for water to flow through the tank

b- time required for flow of water to fill the tank fully

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c- Average time for which water is retained in tank

d- ratio of volume of basin of sedimentation tank to rate of flow

e- all the above

6. **Detention time for plain sedimentation tank usually ranges from :**

a- 2 to 4 hrs. b- 4 to 8 hrs.

c- 6 to 10 hrs. d- 8 to 12 hrs.

7. **Velocity of flow of water in plain sedimentation tank, is normally kept :**

a- 3 cm/minute b- 10 cm/minute

c- 20 cm/minute d- 30 cm/minute

8. **Design of Secondary Settling Tank depends upon :**

a- S.O.R and detention time b- Solid flux

c- S.O.R and solid flux d- Hydraulic Loading

9. **Design of Primary Settling Tank depends upon :**

a- S.O.R and Hydraulic Loading b- Solid flux

c- S.O.R and detention time d- Detention time

10- Detention time of P.S.T and S.S.T ranges:

a- 1 to 2 hrs. b- 1.5 to 2.5 hrs.

c- 2 to 4 hrs. d- 1.5 to 5 hrs.

Note

- Check your answers in key answer page 20.

- (1) degree for each .

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4/ the text :-

Sedimentation :-

Purpose:

The purpose of sedimentation of raw water or sewage is to separate the settle able solids from liquid.

Sedimentation is used in waste water treatment to remove:

(i) In organic suspended solid (grit chamber).

(ii) Organic and residual inorganic solids. (PST).

(iii) Free oil and grease and other floating materials. (PST).

(iv) Bio-flocculated solids or bio flocks. (SST).

(v) Chemical flocks produced during chemical coagulation and flocculation (SST).

The settable solids to be removed from waste water in primary or secondary settling tanks after grit removal are mainly organic and flocculent in nature, either dispersed or flocculated. The specific gravity of organic suspended solids may vary from 1.01 to 1.2.

Quiz / 1

Numerates the materials removed by sedimentation process.

Note

- Check your answers in key answer page 21.

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Types of Settling

(i) Discrete settling:

Discrete particles do not change their size, shape or mass during settling. Grit in waste water behaves like discrete particles. Stock's law and Transition law applicable.

(ii) Flocculent settling:

Flocculent particles coalesce during settling increasing the mass of particles which settle faster. Removal efficiency are determined using data obtained from settling column studies.

S.S ⟶ P.S.T

Chemical flocks ⟶ S.S.T

Bio flocks ⟶ S.S.T

(iii) Hindered or zone setting:

The particles maintain their relative positions with respect to each other and the whole mass of particles settles as a unit or zone. It is applicable for concentrated suspensions and is found in secondary settling tank following activated sludge unit.

(iv) Compression:

In compression zone, the concentration of particles becomes so high that particles are in physical contact with each other, the lower layers supporting the weight of upper layers. This setting phenomenon occurs at the bottom of deep sludge mass (S.S.T) or (Thickener).

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Types of Sedimentation Tanks

It is classified as: Continuous or Intermittent

Or : Horizontal flow or Vertical flow

Or : Rectangular, Square or Circular.

Design Consideration

P.S.T

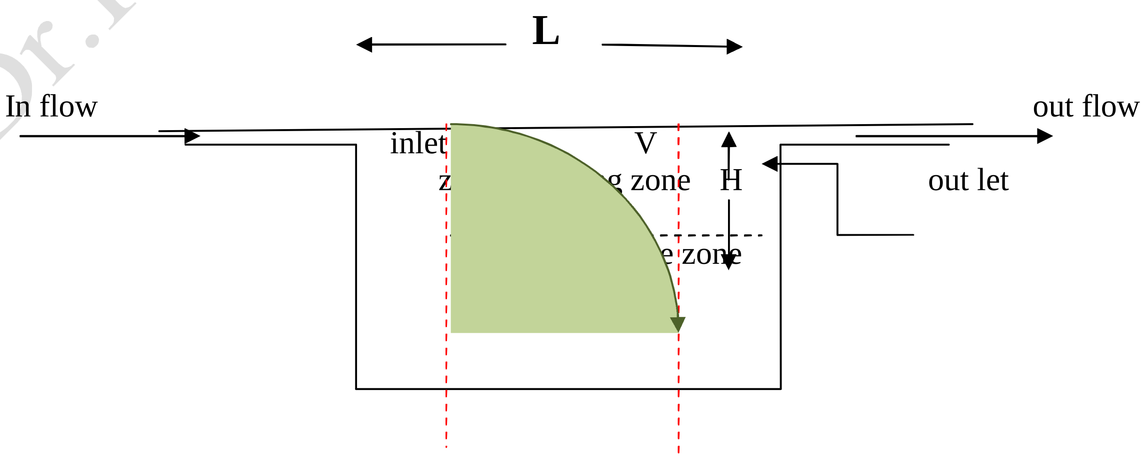
Surface overflow rate (S.O.R) | Detention period (H.T.R)

S.S.T

(S.O.R) | Solid loading rate (Solid flux)

(i) Over flow rate or surface loading rate:

The over flow rate represents the hydraulic loading per unit area of tank in unit time expressed as $m3/d/m^2$



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Horizontal flow settling tank with continuous flow where;
L: Effective length
B: Width of tank
H: Depth of settling zone
V: Horizontal or displacement velocity.
Vs: Settling velocity.
The quantity of water flow through the tank is

$$Q=B.H.T \text{ -------------- } (1)$$

The particles will get removed if it reaches the sludge zone before entering into the outlet zone.

Settling Time: $\frac{H}{Vs} < \frac{L}{V}$ Flow displacement time

For economic condition $\frac{H}{vs} = \frac{L}{v}$

$\therefore$ $V= \frac{L.vs}{H}$

Substituting in equation (1) we get:

$$Q= B.H. \frac{L.vs}{H} \Longrightarrow Q=B.L.Vs$$

$\therefore$ $Vs= \frac{Q}{B.L} = \frac{Q}{A} = \frac{Tank\ discharge}{Plan\ Area}$ =Surface Loading

Usually S.O.R shall be between 10 to 40 $m^3/d/m^2$.

(ii) Detention Period:

Time= $\frac{Capacity\ of\ tank}{rate\ of\ flow} \Longrightarrow$ T=$\frac{C}{Q}$

P.S.T $\Longrightarrow$ T= 2 to 2.5 hrs.
S.S.T $\Longrightarrow$ T=1.5 to 2.0 hrs.

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(iii) Solid loading Rate:

The solid flux represents the solid loading per unit surface

Area of tank per unit time and is expressed as Kgss/m^2.d.

For Average flow $\longrightarrow$ ranges from 70 to 140 $\frac{Kg}{m2.d}$

For peak flow $\longrightarrow$ ranges from 170 to 210 $\frac{Kg}{m2.d}$

(iv) Weir over flow rate:

Performance of existing sedimentation tanks can be improved by merely increasing their weir length. Weir over flow rate (W.O.R) shall be between 100 to 200 m^3/m^2.d.

(v) Depth:

Side water depth (S.W.D) shall be between 3 to 4.5 m

Floor slope could be between 1:12

Sludge storage = 25% of (S.W.D)

(vi) Basin Efficiency:

TSS removal about 45 $\longrightarrow$ 60 %

BOD removal about 30 $\longrightarrow$ 45 %

(vii)Horizontal velocity of flow:

In order that the particles deposited at the sludge zone should not be lifted up and get scoured, the displacement velocity should not exceed that given by formula:

$$V=\sqrt{\left(\frac{8k}{f}\right).g.(Ss-1).d}$$

Where, K=0.04 for sandy materials= 0.06 for sticky flocculants materials.

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Displacement velocity of flow commonly adopted in water works from 0.1 to 0.8 cm/sec or less than (0.3 m/min).

(viii)The settling velocity and basin efficiency:

These parameters are computed by using the same equations described in design of grit chamber.

Illustrated Problems

Problem (1): In a plain sedimentation tank if removal of 0.02mm diameter particles of sp.gr 2.65 is expected. Find out the settling velocity, surface loading and detention time.

$$V=5.81*10^{-7}\ m/s^2$$

Solution:

Since d= 0.02mm less than 0.1mm, so Stock's law applicable.

$$\mathbf{Vs = \frac{g}{18}\ (s_s\text{-}1)\ d^2/V}$$

$$Vs=\frac{9.81}{18}(2.61-1)\ ((0.02*10^{-3})^2\ /5.81*10^{-7})=0.000619\ m/s$$

vs ≅ 0.62 m/s

$\therefore$ Surface loading = Vs= $\frac{0.62*24*60}{1000}$ =53.5 $\frac{m3}{m2.d}$

Supposing the tank depth is 3.5 m

$\therefore$ The time required for settling

$$T=\frac{3.5*1000}{0.62*60}=98\ minutes=1.633\ hrs.$$

Note 1: Actual time is much higher than the theoretical value.

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Note 2: Duck to short circuiting, cross currents, non-quiescent condition of water actual settling velocity will be much lower than the theoretical value as given above.

$Vs= (o.707\ (ss-1).d^{1.6}.V^{-0.6})^{0.714}$

Problem (2): Find the settling velocity of a sphere ($5*10^{-3}$) cm in diameter and sp.gr 2.65. Also, find the rising velocity of the particle of same diameter but sp.gr of (0.8). Assume $V=1.012*10^{-2}$ cm2 /s.

Solution:

$$Vs=\frac{g}{18}(ss-1).(d^2/v)=\frac{981}{18}(2.65-1)((5*10^{-3})^2/1.012*10^{-2})= o.222cm/s$$

$$Vs= \frac{981}{18}(0.8-1)((5*10^{-3})^{-2}/(1.012*10^{-2})= -0.0269\ \frac{cm}{s}$$

* -ve indicates the particle will have rising velocity.

Problem (3): Find the settling velocity and size of particles of sp.gr (1.2) of which 80% are expected to be removed in a very good settling basin at an over flow rate of 50 000 lpd/m^2 $V=1.011*10^{-2}$ cm^2/s.

Solution:

S.O.R= 50000 lpd/m^2 =50 m^3/d/m^2

$$\frac{Q}{A}= 50*\frac{1}{24*60*60}\ m/s= 5.79*10^{-4}\ m/s= 5.79*10^{-2}\ cm/s$$

$$\eta= 1-(1+n.\frac{vs}{s.o.r})^{-1/n}$$

For η=80% and n=0.125

$0.8 = 1-(1+0.125*\frac{VS}{S.O.R})^{-1/0.125}$

$S.O.R = Vs.n/(1-\eta)^{-n} - 1 \Longrightarrow \quad Vs = ((S.O.R).(1-\eta)^{-n} - 1)/n$

$Vs = ((5.79*10^{-2})*(1-0.8)^{-0.125} - 1))/0.125$

$Vs = 0.103$ cm/s

$0.1 = Vs = \frac{G}{18}(S_S - 1).D^2/V = \frac{981}{18}(1.2-1)\ D^2/1.011*10^{-2}$

$\therefore d = 0.0099$ cm = 0.099 mm $\cong 0.1$mm

Problem (4): Design a primary sedimentation tank for a population of 100 000 persons. Assume the following:

*Water consumptions 150 l.p.c.d

*Detention time= 2 hrs

*Depth of tank (S.W.D)= 3 m

*Contribute to sewage flow= 80% of water supply

*Slope of tank= 1 V : 25 H

*Sludge produced= 4 m^3/M.L flow

Find: (i) Volume of tank (ii) Surface area (iii) Diameter

(iv) Total depth at center (vi) W.O.R

(vii)Sludge product

Solution:

Average discharge=Q=0.8*150*100 000=12000000 l/d=12000 m^3/d

$\therefore$ Volume= capacity=C=Q.(D.T)= $\frac{2*12000}{24} = 1000\ m^3$

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Surface Area= $\frac{Volume}{depth}$ = $\frac{1000}{3}$ =333m^2

Provide two tank of 14.5 m dia each.

Total fall slope= $\frac{(\frac{14.5}{2})}{25}$= 0.29 m

Total depth= 3+0.29+(0.25*3) = 3.95 m

S.O.R= $\frac{Q}{A}$= $\frac{12000}{333}$= 36 m^3/m^2-day (safe)

W.O.R= $\frac{12000}{2\Pi D}$ =$\frac{12000}{2\Pi(14.5)}$= 132 m^3/m^2-day (safe)

Sludge produced= $\frac{4*12000000}{106}$=48 m/day

∗ Note: Sludge produced from secondary tanks is 12 to 16 m^3/ML of sewage.

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5/ Post test :-

Design a primary settling tank (PST) if the following data are given:

(i) Surface over flow rate (S.O.R) = 30 m^3/m^2-d

(ii) Weir over flow rate (W.O.R) = 150 m^3/m^2-d

(iii) Discharge (Q) = 10MLD= 0.116 m^3/sec.

(iv) Total suspended solid (T.S.S)= 200 mg/l.

(v) Assume side water depth (S.W.D) = 3.5 m.

(vi) Grit chamber removal 40% of T.S.S.

(vii) P.S.T removed 50% of T.S.S.

(viii) Velocity of flow in channel = 0.3 m/sec.

(ix) Free board = 0.3 m.

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Note

- Check your answers in key answer page 20 .

6/ key answer :-

1- Pre Test:-

1. b
2. d
3. d
4. b
5. e
6. b
7. d
8. c
9. c
10. b

If you:-

- Got 9 or more you do not need to proceed.
- Got less than 9 you have to study this modular unit well.

2- Post Test:-

Solution:

1-S.O.R = $\frac{Q}{A}$ A= $\frac{Q}{S.O.R}$ = (10x 10^3 / 30) = 333.33 cm^2

2- ∴ Volume= 333.33 x3.5= 1166.66 m^3

3-Providing circular PST,

D= $\sqrt{\frac{4A}{\Pi}}$ = $\sqrt{\frac{4*333.33}{\Pi}}$ = 20.6 m say 21m

4- Check for W.O.R

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W.O.R=$\frac{Q}{\Pi d}$ = ($10x10^3$/Πx20.6) = 154.52 m^3/m^2-day > 150 m^3/m^2.day >200 > 154 >100 ∴(O.K)

5- Check for detention time:

T= $\frac{V}{Q}$ = (1166.66/$10x10^3$)= 0.12 day = 2.88 hrs Hence safe

6- Now, slope of 1:20 (V:H)

Depth due to slope at center = (10.5*1/20) = 0.525 m

Hence,

Total depth at the center of clarifier = S.W.D + depth due to slope +depth of sludge storage

Total depth= 3.5+0.525+(0.25*3.5)

= 4.9 m

7- Design of sludge hopper volume:

T.S.S= 200 mg/l

Solid in clarifier =200-(200*0.4)= 120 mg/l

Dry solids=Ms= 120-(0.5*120)= 60 mg/l = 600 kg/day

Assume that the total solids consist of 70% of volatile solids and 30% of fixed solids.

Sp.gr of VSS=1 and sp.gr of F.S=2.5

$\frac{1}{Ssl}=\frac{0.7}{1}+\frac{0.3}{2.5}$ ∴Ss= 1.22

Assume that 3% of solids are dried in clarifier

$\frac{1}{Ssl}=\frac{0.97}{1}+\frac{0.03}{1.22} \Longrightarrow$ Ssl = 1.005

Now, volume of sludge= V=$\frac{Ms}{Pw.Ssl.Ps}$

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Here, P_w=1000 kg/m^3 P_s= 0.003=percentage of solids.

$$V=\frac{600}{1000*1.005*0.03} = 19.9\ m^3/day\ \text{say}\ 20\ m^3/day$$

8- Design of collecting channel:

Area of channel = $(10x10^3)/(2x0.3x86400)=0.193\ m^2$

Assume width of channel=0.6 m

Depth of channel=$\frac{A}{b} = \frac{0.19}{0.6}$ = 0.32 m

Total depth of channel= 0.32+0.3=0.62 m

9- Manning's equation: $V= \frac{1}{n}. R^{2/3}.S^{1/2}$ n=0.014 for concrete

$R=\frac{A}{P} = \frac{0.19}{0.6+(2*0.62)} = 0.153$

10- $0.3=\frac{1}{0.014} x(0.153)^{2/3}.S^{1/2}$

$\therefore S=0.000218$

If you:-

- Got 9 or more, so congratulation your performance, go on studying modular unit four.
- Got less than 9, go back and study the third unit ; or any part of it ; again, and then do the post test again .

Quiz No. 1 /

Return to page (9) for the answer.

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7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

3- Principles of water quality control, by T.H.Y. Tebbutt

4- Water Supply, Water Treatment, Dept. of the Army and the air force, Sept. 1985, TM 5-813-3/AFM 88-10, Vol 3l.

5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

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Ministry of Higher Education and Scientific Research
Foundation of Technical Education
Technical College / Basrah

Training Package
In
Water Quality Control
For

Students of forth class
Department of Environment and Pollution Engineering
Technical College/Basrah

By

Dr. Ihssan A. Abdulhussain
Lecturer
Department of Environment and Pollution Engineering
Technical College/Basrah

September/2011

SEDIMENTATION AIDED WITH COAGULATION

Forth modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

Many impurities in water and wastewater are present as colloidal solids which will not readily settle. Their removal can, however, often be achieved by promoting agglomeration of such particles by flocculation, with or without the use of a coagulant followed by sedimentation or flotation.

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1/ C –Central Idea :-

1- Chemical Aided sedimentation

a- Principles of coagulation

b- Properties of common coagulants

c- Determination of coagulation dose

d- Coagulation plant

2- Flocculation

3- Clariflocculator

4- Design criteria for coagulation-Sedimentation unit

5- Illustrated Problem

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
   - Get 9 or more you do not need to proceed.
   - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
   - Get 9 or more, so go on studying modular unit five.
   - Get less than 9, go back and study the second modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Define Coagulation.
2. Know the principles of coagulation.
3. Know the properties of coagulants.
4. Determine the coagulation dose.
5. Select the necessary coagulant units.
6. Design flocculator.

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3/ Pre test :-

Circle the correct answer:-

1. **Treatment of water with Alum increases:-**

a- Acidity and hardness b- Alkalinity and hardness

c- Salphate and Sulphites d- Carbonates and bicarbonates

2. **Chemical coagulation of drinking water is done:-**

a- to settle suspended materials b- to remove the Bacterias

c- To increase rate of settlement of suspended materials

d- none of these

3. **Mostly used coagulant is:**

a- Chlorine b- Alum

c- Lime d- Bleaching powder

4. **The principle of coagulation is to forming :**

a- Individual particles b- Spongy gelatinous precipitates

c-Light particles d- Unsettlable particles

5. **Coagulation dose is determined by:**

a-Darcy's law b-Hydrometer

c- autoclaving d- Jar test

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6. **Coagulation is a :**

a- Mechanical method
b- Chemical method
c- Physical method
d- Biological method

7. **Detention time in flocculator ranges from:**

a- 15-30 minutes
b- 20-30 minutes
c- 30-60 minutes
d- 1-2 hrs.

8. **Velocity of water through the flocculator tank ranges:**

a- 30-40 cm/s
b- 50-60 cm/s
c- 15-20 cm/s
d- 70-80 cm/s

9. **The properties that a coagulant should posses is:**

a- React in water to give floc
b- Cheap and easy to store
c- React in long range of pH
d-All of above

10- **The essential process in flocculator is :**

a- Flash mixing
b- Gentle mixing
c- Settling process
d- Adding coagulant

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Note

- Check your answers in key answer page 19.

- (1) degree for each .

4/ The Text :-

Coagulation (Chemical Aided Sedimentation)

This is also known as forced sedimentation. While discussing about plain sedimentation it has been observed that the settling velocity of very small particles are very low and the detention period required to get them removed would be very high. Practical difficulties arise in holding water for such a long time.

Avery fine colloidal or dispersed particles contain electric charges and they are continuously in motion known as Brownian motion and they are not settled down by gravity force. For all these reasons coagulation is needed before sedimentation.

Quiz / 1

Define forced sedimentation.

Note

- Check your answers in key answer page 21.

a- Principles of coagulation:

In coagulation, individual particles agglomerate or combine together. When a coagulant is used in water, it forms spongy gelatinous precipitates which absorbs fine size particles in water and bind them together. The whole process results into bigger particle which are heavier and easy settle able.

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b- Properties of common coagulants:

The followings are the desired properties that a coagulant should process:

(i) It should react quickly in water to give spongy gelatinous flocs.

(ii) It should be cheap material.

(iii) It should be easy to handle and store.

(iv) It should not deteriorate inequality with time.

(v) It should be electrolyte in nature to give out positively charged electric ions for attracting the negatively charged colloidal impurity.

(vi) It should produce high valence ions for high efficiency of absorption.

(vii) IT should react in the long range of PH.

Common coagulants used:

1- Alum, $Al_2 (so_4)^3$,18 H^2o

2- Sodium Aluminate ($Na_2Al_2o_4$)

3- Iron salts.

c- Determination of coagulation dose:

The dose of chemical required for coagulation depends on the quality of water. The optimum dosage of coagulant is determined in practice by trail. Commonly the jar tests method is employed for that purpose. The amount of coagulants is increased stepwise, and all jars are mixed simultaneously for 10 to 30 minutes. The jar in which floc first makes it appearance is assumed to have received the most economical dose.

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d- Coagulation plant:

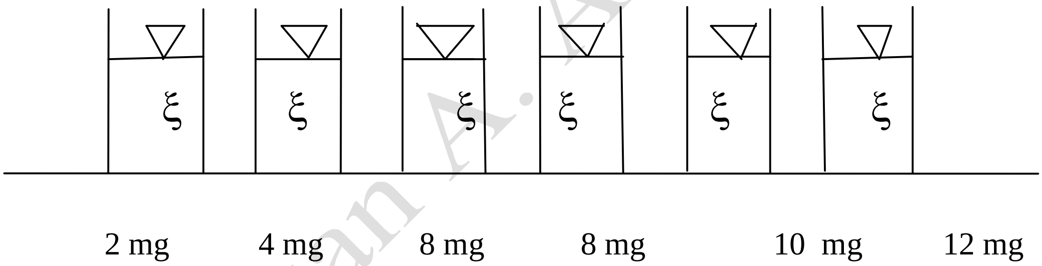
The following process are done in case of coagulation

(i) Feeding of chemical → Dry feeding
→ Solution Feeding

(ii) Mixing of chemical → Flash mix
→ Gentle mix

(iii) Flocculation

(iv) Sedimentation of floc.



JAR TEST

Flocculation

After getting through mixed with coagulant the water is so handled that big size floc may form. This is done in the flocculation channel (basin). Stirring of water should be done in well controlled manner. If stirring is done too fast, flocs formed will shear of. Again too slow stirring will allow forming big size flocs. In fact water when passing through the flocculation channel is subjected to a suitable velocity gradient by slow moving puddles with speed ranging from 1 to 3 r.p.m.

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Paddles may move either in horizontal direction or in vertical direction. This helps in forming stable big size flocs. Water along with flocs enters the sedimentation tank. As already discussed in theory of coagulation flocs agglomerate with suspended colloidal particles and settle down in the sedimentation tank. The process of settling of suspended particles in a sedimentation tank is also known as clarification and the unit is known as clarifier.

Clariflocculator

In this unit attempt has been made to the cost and increased the efficiency of coagulation plant by achieving both the processes of flocculation and clarification in the same unit. It is a usual circular tank but the influent is retained for about 30 minutes in a central circular chamber where it is agitated or flocculated by means of vertical wood paddles, which are moved by the sludge arms and which move between fixed puddles. This move helps in forming big size flocs and increases the efficiency of sedimentation.

The sedimentation tank surrounding the flocculation tank and is sufficient in capacity to hold water for about 2 hrs.

Slow mixing results in the forming of large and readily settle able flocs. These can be removed in settling tanks and filters. Slow mixing is meant to bring the particles to collide and then agglomerate.

"The mixing depends upon the temporal mean velocity gradient 'G'. This is defined as the rate of change of velocity per unit distance normal to a section". The turbulence and resultant intending of mixing is based on the power input into the water and " 'G' can be calculated in terms of power input by the following expression".

$$G=\left[\frac{P}{m*vol}\right]^{1/2}$$

Where, P= Power dissipated in water in kW

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Vol= Volume of tank (m^3)
M= Dynamic viscosity (N.m/s)
G= Temporal mean velocity (sec^{-1})

The desirable value of 'G' vary from 20 to 75 sec^{-1}

Paddles are driven by motors with reduction gears or through drive belts. The power input is given by:

$$P= \frac{1}{2} (d.p.A. (V-\gamma)^3$$

Where; P= power input in watts. (0.5 to 1.5 watts)/m^3/hr. flow
C_d= Coeff. of drag for paddles (1.8 for flat paddles)
P= density of water
($V-\gamma$)= relative velocity of impeller and fluid in mps
V is taken as 0.5 m/s and γ is 25% of V
A= area of impeller blade in m^2 (10 $\longrightarrow$ 25% tank area)

Design Criteria for Sedimentation-Flocculator

Rotation of turbo flash mixer = 100 r.p.m
Rotation of puddles in flocculation tank = 1 to 3 r.p.m
Velocity of water through flocc. Tank = 15 to 20 cm/s
Detention time in flocc. Tank = 30 to 60 min.
Detention time in sedi. Tank = 1.5 to 3 hrs.
S.O.R sedi. Tank = 50 -----------70 m^3 /m^2/d
W.O.R sedi. Tank $\leq$ 200 m^3/m/d

Illusterated Problem

Problem: A water treatment plant treats 250 m^3/hr. of water. Workout the following with respect to a flocculator.

(i) Dimensions of the flocculator unit.
(ii) Power input by paddle to water.
(iii) Size and number of paddles.

Assume:
1- Water temperature 25°c

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2- Absolute viscosity=0.89x10-^{3}N/m.s) .

3- D.T=30 minutes

4-Velocity of inlet pipe = 1.2 m/s
5-S.W.D= 3m
6-G=40 sec^{-1}
7-Freeboard= 0.3 m

Assume other data suitably. Draw the sketch of the flocculation and the paddles.

Solution:

C= (D.T)*Q

$\therefore$ Volume of tank =$1/2$ x250=125 m^3

Q=A.V $\Longrightarrow$ A=$\frac{Q}{v}$

$\therefore$ Tank area required =$\frac{125}{3}$=41.7 m^2

$\therefore$Area of inlet pipe =$\frac{250}{3600x1.2}$=0.058 m^2

$\therefore$Dia. Of inlet pipe = 0.27m= 0.3m (say)

Let the dia. of flocculator tank = D and dia. of inlet pipe= Dp, then,

$$\frac{\Pi}{4}[d^2-(Dp)^2]=41.7$$

Or, $[D^2-(0.3)^2]=41.7$

$D=7.3$ m

Provide tank dia. = 7.5m

Power input by paddles P=$G^2\mu$xvol

Assuming G=40 sec^{-1}

$P=(40)^2x(0.89x10^{-3})x125=178Mm/s$

$P=\frac{1}{2}\,C_d\rho A(V-\gamma)^3$

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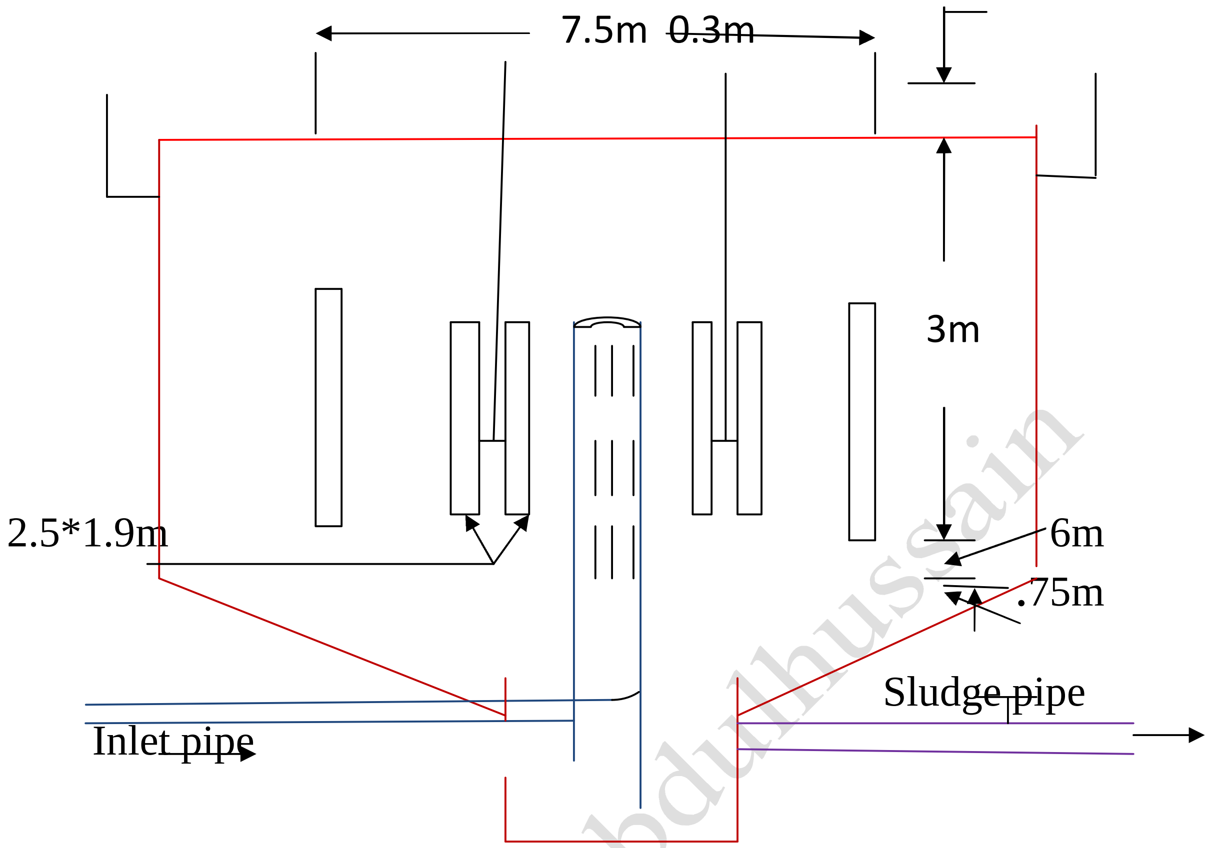
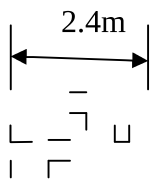
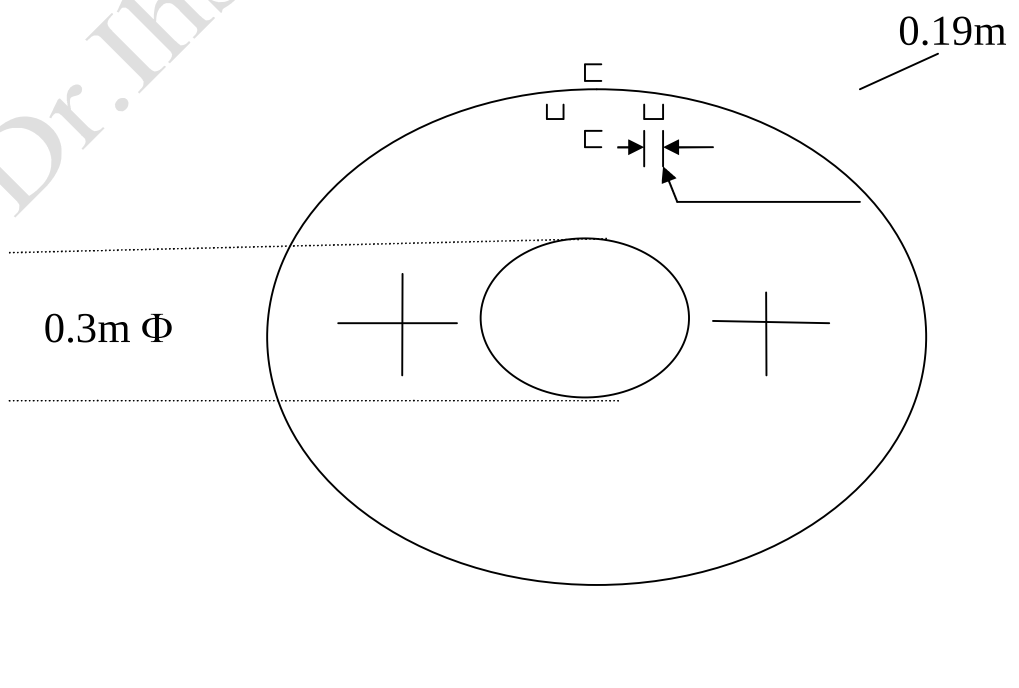


Cross-section





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Where C_d=1.8

V=Velocity of tip of paddle=0.5m/s (assumed)

γ=Velocity of water at paddle tip=25% of V

V-γ=(0.5-0.25x0.5)=0.375 m/s

P=1000 kg/m^3

$\therefore \quad 178=\frac{1}{2}x1.8x(A)x(1000)x(0.375)^3$

$\therefore$Total area of paddle, A=3.75 m^2.

Provide 2shafts for supporting paddles and 4 nos. of paddles supported by each shaft.

Thus total nos. of paddles=8

Area of each paddle $=\frac{3.75}{8}=0.47m^2$.

If 2.5m is the length of each paddles

Width of each paddle = 0.19m

Let velocity of water flow below the partition wall between the flocculator and clarifier be 0.3 m/minute. Area of opening required.

$$=\frac{250}{60x0.3}=13.9\ m^2$$

$\therefore$Depth below partition wall = $\frac{13.9}{\Pi x7.5}$=0.6m

Provide additional depth for sludge storage

=25% OF 3M=0.75M.

Provide free board =0.3m

$\therefore$ Total height of tank =o.3+3.0+0.6+0.75=4.65m

Thus,

(i) Size of tank = 7.5m(dia.)x4.65m (ht.)

(ii) Power input by the paddle to water=178x10^{-3}KW/s

(iii) No. of paddles 8 size of each=2.5m x 0.19m Ans.

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5/ Post test :-

Design a flocculator for 1894 m^3/hour water flow with the following design parameters :

(a) Power input = 0.5 to 1.5 watts per m^3/hour.

(b) Peripheral velocity of paddles = 0.15 to 0.60 mps (average 0.3 to 0.4 mps) .

(c) Energy consumption = 0.25 to 2.00 Kw hr. per mL of water treated.

(d) Detention time / flocculation period = 10 - 40 minutes (average 20 to 30 minutes).

(e) Total paddle area =10 to 25% tank sectional area in the plane of the shaft .

(f) Head loss = 150 mm .

(g) G. Value = 20 to 75 /sec .

T_d = detention time

Limit of $GT_d = 1\times10^4$ to 10×10^4

(h) Depth = 4.5 m.

(i) Side water depth = 1.5 to 1.8 m.

(j) paddle revolution = 1 to 3.5 rpm .

(k) Inlet velocity in the slots = 1 mps to 1.5 mps.

(l) Outlet velocity = 0.3 to 1 mps.

(m) proper dispension chamber with baffles and slots are to be provided to avoid eddy current and short circuit.

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Note

- Check your answers in key answer page 19-20 .

- (1) degree for each .

6/ key answer :-

1- Pre Test:-

1. a
2. b
3. b
4. b
5. d
6. b
7. c
8. c
9. d
10. b

If you :-

- got 9 or more you do not need to proceed .
- got less than 9 you have to study this modular unit well .

2- Post test :-

Provided two 947 m^3/hour units with one stand by capacity of each flocculator.

=947 m^3/hour =0.263 m^3/sec (1 Mark)

Detention time provided = 25 minutes

Capacity of tank =25× 0.263 × 60 = 394.5 m^3 (1 Mark)

Depth of water provided 3.6 m

Floor area to be provided = 109.58 m^2 (1 Mark)

Outside diameter of shaft provided = 1.00 m

Overall diameter of the flocculator = 'D' m

$$\frac{\pi}{4}(D^2 - 1^2) = 109.58$$

D = 11.86 m. (1 Mark)

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Blades. Cross-sectional area of column of water in flocculator = 3.6(11.86 – 1.00) = 39.086 m^2 (1 Mark)
Provided blades having an area equal to 25% of the above area = 9.75 m^2 (1 Mark)
Total number of blades is 16
Area of each blade = 0.61 m^2 (say) (1 Mark)
If the length of the blades is 2.00 m , then the width of each blade will be 0.3 m. (1 Mark)
Design of inlet of Clariflocculators
Design flow = 947 m^3/hour = 0.263 m^3/sec
Assuming inlet velocity through the vertical conduit
i.e. inlet pipe = 0.9 mps
Cross-sectional area = $\frac{0.263}{0.9}$ = 0.292 m^2 (1 Mark)
Diameter of pipe = 0.61 m.
Provide 610 mm dia. pipe . (1 Mark)
Slots. Provided four number of slots of size = 0.75 m × 0.375 m.

If you :-

- got 9 or more , so congratulation your performance , go on studying modular unit three .
- got less than 9 , go back and study the second unit ; or any part of it ; again, and then do the post test again .

Quiz No. 1 /
Return to page (9) for the answer.

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7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

3- Principles of water quality control, by T.H.Y. Tebbutt

4- Water Supply, Water Treatment, Dept. of the Army and the air force, Sept. 1985, TM 5-813-3/AFM 88-10, Vol 3l.

5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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Training Package
in

Water Pollution Control

For
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Department of Environment and Pollution Engineering
Technical College/Basrah

By

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Lecturer
Department of Environment and Pollution Engineering
Technical College/Basrah

September/2011

Dr. Ihssan A. Abdulhussain

FILITRATION

Fifth modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

Filtration of suspensions through porous media, usually sand, is an important stage of the treatment of potable waters to achieve final clarity. Although about 90 per cent of the turbidity and color are removed in coagulation and sedimentation a certain amount of floc is carried over from settling tanks and requires removal. Sand filtration is also employed to provide tertiary treatment of 30:20 standard sewage effluents. Other uses of flow through porous media include ion-exchange beds, adsorption beds and absorption columns where the aim is not to remove suspended matter but to provide contact between two systems.

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1 / C –Central Idea :-

1 – Purpose and definition

2 – Types of filters

3 – Filter operation and control: (Rapid gravity filters)

4 – Design consideration

5 – Flow through sand bed

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
   - Get 9 or more you do not need to proceed.
   - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
   - Get 9 or more, so go on studying modular unit six.
   - Get less than 9, go back and study the five modular unit; or any part of it ; again and then do the post test again .

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Defines filtration.
2. Knows the types of filters.
3. Operates the gravity sand filter.
4. Compares between rapid and slow sand filters.
5. Designs rapid sand filter.

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3/ Pre Test :-

Circle the correct answer:-

1. **Property of earth to allow water to pass through it, is known as**

a- Perviousness b- porosity

c- Permeability c- transmissibility

2. **Capacity of soil to absorb moisture, is generally known as:-**

a- Permeability b- porosity

c- Infiltration capacity d- perviousness

3. **To remove very fine suspended particles from water, the method adopted is:**

a- screening b- sedimentation

c- boiling d- filtration

4. **After cleaning a slow sand filter, filtered water is not used for :**

a- 6 -12 hrs. b- 12-18 hrs.

c- 18-24 hrs. d- 24-36 hrs.

5. **Efficiency of removing bacteria's from raw water by slow sand filter, is :**

a- 80-81% b- 98-99%

c- 90-97% d- 85-86%

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6. **Filtration is a :**

a- mechanical method

b- chemical method

c- physical method

d- other method

7. **In rapid gravity filter:**

a- raw water from the source is supplied
b- Disinfected raw water is supplied
c- Raw water passed through coagulation tank is supplied
c- none of these

8. **Distribution of wash water is provided in:**

a- Sedimentation tank

b- slow sand filter

c- Rapid gravity filter

d- all of these

9. **A high velocity of wash water is required for:**

a- Rapid gravity filter with strainers
b- Rapid gravity filter without strainers
c- Slow sand filter with strainers
d- Slow sand filter without strainers

10- Rapid gravity filters can only remove bacterial impurities up to a maximum of :

a- 50%

b- 60%

c- 75%

d- 90%

Note

- Check your answers in key answer page 20.

- (1) degree for each .

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4/ The Text :-

Filtration

a- Purpose and definition:

Filtration of water is defined as the separation of colloidal and large particles from water by passage through a porous medium, usually sand, granular coal, or granular activated carbon. The suspended particles are removed during filtration range in diameter from 0.001 to 50 microns and larger.

Quiz / 1

Define filtration.

Note

- Check your answers in key answer page 21.

b- Types of filters:

1- Gravity filter → i- Slow sand filters
ii- Rapid gravity filters

2- Diatomite filters (used for swimming pool)

3- Pressure filters → i- Conventional down flow filter
ii- High-rate down flow filters
iii- Up flow filters
iv- Up flow continuous backwash sand filters.

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Methods Filter operation and control: (Rapid gravity filters)

1- Starting the filter:

Fill with water from bed of filter to dismissed air voids without any moving or disturb of the sand media.

2- Repairing period:

Open valve (1) and (3) → water seeps up to bed of filter and drain the product water (10 → 15 minutes)

3- Filtration period:

Open valve (1) and (2) → water seeps up to bed of filter then to the ground tank collection (16 → 36 hrs)

4- Washing process:

Open valve (4) and (5) water rise bed to top of the trough channel to the drainage system (V= 0.5 o.8 m/min) (10-15 minutes)

Design Consideration

1- Comparison of slow sand and rapid gravity filters:

Item	Slow Sand	Rapid Gravity
1- Rate of filtration	2500-6000l/m^2/day	12000-150000 l/m^2/day
2- Size of unit	2000-4000 m^2 in area	4x5 to 8x10 m^2/unit
3-Depth of filter media	Sand → 80-100 cm Gravel → 25-30 cm	Sand → 60-75 cm Gravel → 45-60 cm
4-Size of sand	Effective size → 0.35 mm Uniformity coafficient → 1.	Eff. Size → 0.5-0.7 mm Unif. Coaff. → 1.25-1.35
5-Grain size dist.	Uniform	Stratified with small grain at The top
6-Under drainage syste	Open jointed pipes covered With blocks	(i)Mainfold and laterds (ii)Wheeler bottom (iii)Diffuseer plate
7-Head loss	Initially → 0.1 m Finally → 1 m	Initially → 0.2 m Finally → 3 m
8-Lengh of run	20-40 days	24 to 48 hrs
9-Pentration of S.S	Superficial	Deep

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10-Method of cleaning	Scraping and washing	Back washing
11-Water required for cleaning	0.2 to 0.6 % of water filtered	2% to 6% of water filtered
12-Preparotory treatment	Plain sedimentation	Floccuaation and settling
13-Cost of construction	Higher	Low
14-Cost of operation	Lower	Higher
15-Depreciation of plan	Lower	Higher

Flow through Sand Bed:

The h friction loss through bed of particles of uniform size (d), can be calculated by Carmen-Kozeny equation:

$$h_f=(f.L(1-e)V^2 s)/(e^3 g.d)$$

Where; h_f=Friction loss ,m

L= depth of filter, m

e= Porosity of bed

v_s= filtering velocity ,i.e, the velocity of water just above the bed (total flow Q to the filter divided by the area of filter), m/s

g= acceleration due to gravity ,m/s^2

d= diameter of filter media grains, m

f= coaffi. Of drag around the particles

$f= 150\ \frac{(1-e)}{R}+1.75$ (laminar flow)

Where, $R=\frac{\Phi \rho V s d}{\mu}$

ρ= density(kg/m^3); μ= dynamic viscosity (N.s/m^2)

Φ= shape factor (0.75-0.85)

3-Back wash (filter washing) Hydraulics:

To clean the interior of the bed, it is necessary to expand it so that the granules are no longer in contact with each other, thus exposing all surfaces for cleaning. To hydraulically expand a porous bed, the head loss must be at least equal to the buoyant weight of the particles in the fluid. For a unit area of filter this expressed by:

$$h_{fb} = L(1-e)\ \frac{\rho 1-\rho}{\rho} \text{ ------------------------(1)}$$

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Where; h_{fb}= head loss required to initiate expansion, m

L= bed depth, m

e= porosity of medium

$\rho1$= density of the medium, kg/m^3

ρ= density of water; kg/m^3

The head loss through an expanded bed is essentially unchanged because the total buoyant weight of the bed is constant. Therefore,

Weight of the packed bed = Weight of bed fluidized

$$L(1-e)\frac{\rho1-\rho}{\rho} = L_{fb}(1-e_{fb})\frac{\rho1-\rho}{\rho} \text{---------------(2)}$$

Or $$L_{fb} = L.\frac{(1-e)}{(1-efb)}$$

Where, L_{fb} = Depth of fluidized bed

e_{fb} = Porosity of fluidized bed

The relation between backwash velocity and particle settling velocity is given by

$$\mathbf{e_{fb}=[\frac{VB}{Vt}]^{0.22} \longrightarrow L_{fb}=(L(1-e))/(1-[\frac{VB}{Vt}]^{0.22}}$$

VB: Back wash velocity

Vt: settling velocity

Illustrated Problems

Example: In the rapid sand filter bed, the water is passed through sand bed at a filtering velocity of 0.5 m/hr. The sand grains are 0.25mm in diameter with shape factor of 0.85 and settling velocity equal to five times backwash velocity. The depth of filter bed is 0.9m and porosity is 0.5.

Determine the followings:

a. Head loss through the filter bed.
b. Expanded porosity.
c. Resulting expanded depth.

Assume $\mu=1.002\times10^{-3}$ kg/m.sec.

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Solution:

Velocity through filter=0.5 m/hr = $1.39x10^{-4}$m/s

a- $R=\frac{\emptyset\rho V sd}{\mu}$ =$(0.85x1000x1.39x10^{-4}x0.25x10^{-3})/(1.002x10^{-3})$

R=0.029741 <1 (Laminar flow confirmed)

Friction factor= $150x\frac{(1-0.5)}{0.0297}$ + 1.75=2527

Thus, $h_f=(f.(1-e).V^2{}_s.L)/(e^3.g.d)$

$\therefore h_f=(2527x(1-0.5)x(1.39x10^{-4})^2x0.9)/((0.5)^3x9.81x0.25x10^{-3}$

= 0.0716m= 7.16cm

b- $e_{fb}=(\frac{Vb}{vt})^{0.22}$

$V_t=5\ v_b$

$\therefore\ e_{fb}=(\frac{Vb}{5\ Vb})^{0.22}=(\frac{1}{5})^{0.22}=0.7$

c- $L_{fb}=Lx\frac{1-e}{1-efb}=0.9x\frac{1-0.5}{1-0.7}=1.5$ m

Example: In designing of rapid gravity sand filter for water treatment plant, the following data are given: $15*10^6$ I.P.d, rate of filtration = 150000 I/m^2/day. Find out and check for the following:

- i- Filter area required and number of units if the size of each units is (4.4*5.7 M).
- ii- Total area and number of perforation in one unit if the diameter of perforation is 9 mm.
- iii- Total cross sectional area, number, and diameter of laterals in one unit if the spacing between laterals is 15 cm.
- iv- Area and diameter of central manifold.
- v- Length of lateral.
- vi- Number and spacing of perforations per lateral.
- vii- Quantity of wash water required per filter bed and rate of flow if back wash time is 10 minutes.
- viii- Dimension of wash water troughs if the spacing is 1.5 m and width of trough equal to 0.3 m.

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Solution:

i. Q= $15*10^6$ l/d

Hydraulic loading= 150000 $l/m^2/d$

Filter reg. tree=$(15*10^6)/150000$ = 100 m^2

No. of filters = 100 /(4.4*5.7) = 3.98 ≈ $\boxed{4}$

Provide 2 numbers , so total =$\boxed{6}$

ii . Total area of perforations=

$3*10^{-3}*4.4*5.7$= 0.0753 m^2 = 753 cm^2

Total no. of perf. =$753/(\Pi/4)(0.9)^2$=$\boxed{1183}$

iii . X-sectional tree lateral= 3*753= 2259 cm^2

No. of lateral=$\frac{2*5.7*100}{15}$ =$\boxed{76}$

X- sectional treatment lateral =$\frac{2259}{76}$ =$\boxed{29.7\ cm^2}$

Diameter of lateral = $\sqrt[2]{(29.72*4)\div\Pi}$ = $\boxed{6.15\ cm}$

Provide 7.5 cm

iv. Area of manifold = 2 *2259 = $\boxed{4518\ cm^2}$

Dia. Of center manifold = $\boxed{75.8\ cm}$

v. Length of lateral = $\frac{1}{2}$(4.4 – 0.75)

= $\boxed{1.82cm}$

vi. no. of perf = $\frac{1183}{76}$ = $\boxed{16}$

Spacing = $\frac{1.82*100}{16}$ = $\boxed{11.35\ cm}$

vii. wash water = 0.06 * 15 * 10^6 = $\boxed{900m^3}$

wash water / filter = 900/6 = $\boxed{150m^3}$

rate of flow = $\frac{150}{10*60}$ = $\boxed{0.25\ \frac{m3}{s}}$

viii. no. of troughs = 4.4 / 1.5 = 3

Q = 1.376 $bh^{3/2}$ b=0.4 ∴ h = 0.3

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5/ Post Test :-

A rapid sand filter is required to treat a flow of 0.50 m^3 per second . The filtration rate is 120 m^3 per day per m^2 of filter area and it is provided that the filtration rate with one filter washing is not to exceed 150 m^3 per day per m^2 of filter area . Determine the number of units and the area of each unit to satisfy these conditions .

Each filter is washed for 5 minutes every 24 hours at a wash rate of 10 mm per second per m^2 of filter area . The filter remains out of operation for a total interval of 30 minutes per day . Calculate the percentage of filter output used for washing .

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Note

- Check your answers in key answer page 20 .
- (1) degree for each .

6/ key Answer :-

1- Pre Test:-

1. a
2. c
3. d
4. d
5. b
6. a
7. c
8. c
9. b
10. d

If you:-

- Got 9 or more you do not need to proceed.
- Got less than 9 you have to study this modular unit well.

2- Post Test:-

Maximum flow rate = (0.5 x 60 x 60 x24) m^3 per day

= 43200 m^3 per day

Note : the rate of filtration can also be expressed as m^3 per day per m^2 of filter area because of the relation 1 m^3 = 1000 liters .

Thus 120 m^3 per day per m^2 of filter area is equivalent to ($\frac{120 \times 1000}{24}$) = 5000 liters per hour per m^2 of filter area .

Filter area on the basic Of maximum filtration rate = $\frac{43200}{150}$ = 288 m^2

Filter area on the basis of maximum filtration rate = $\frac{43200}{120}$ = 360 m^2

Area of one filter unit = (360 – 280) 72 m^2

Total numbers of filters = $\frac{\textit{Maximum filter area}}{\textit{Area of one unit}}$

= $\frac{360}{72}$ = 5

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Now , each unit of filter is working at the filtration rate of 120 m^3 per day per m^2 of filter area and the operation of filter is out of order for a period of 30 minutes .

Hence , the total working period per day of each filter is (24 – 0.5) = 23.5 hours .

Output of each unit per day = Area x Filtration Rate x $\frac{Working\ period}{24}$

$= (72 \times 120 \times \frac{23.5}{24})$

$= 8460\ m^3$

Wash rate = 10 mm per second per m^2 of filter area

$= (10 \times 10^{-3} \times 60)$m per minute per m of filter area .

Washing period = 5 minutes

Wash – Water required per day = Area x Wash rate x Washing period

$= 72 \times (10 \times 10^{-3} \times 60) \times 5$

$=216\ m^3$.

Percentage of filter output used for washing = $\frac{Wash-water\ erquired}{output\ of\ each\ unit}$ x 100

$= \frac{216}{8460} \times 100$

= 2.55 %.

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If you:-

- Got 9 or more, so congratulation your performance, go on studying modular unit three.
- Got less than 9, go back and study the second unit; or any part of it; again, and then do the post test again.

Quiz No. 1 /

Return to page (9) for the answer.

7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

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5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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Ministry of Higher Education and Scientific Research
Foundation of Technical Education
Technical College / Basrah

Training Package
in

Water Pollution Control

For
Students of forth class
Department of Environment and Pollution Engineering
Technical College/Basrah

By

Dr. Ihssan A. Abdulhussain
Lecturer
Department of Environment and Pollution Engineering
Technical College/Basrah

September/2011

AEROBIC BIOLOGICAL OXIDATION

Six modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

The amount of organic matter which can be assimilated by a stream is limited by the availability of dissolved oxygen as discussed in Chapter 7. In industrialized areas where large volumes of wastewater are discharged to relatively small rivers, natural self-purification cannot maintain aerobic conditions and waste treatment additional to the removal of suspended matter by physical means is essential. Removal of soluble and colloidal organic matter can be achieved by the same reactions as occur in self-purification, but more efficient removal can be achieved in a treatment plant by providing optimum conditions.

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1 / C –Central Idea :-

1 - Definition

2 –Biological oxidation

a - Principles of biological oxidation

b – Types of aerobic oxidation plant

3 – Activated sludge

a - Activated sludge process variables

b – Classification of Activated sludge process

c- Mixing Regime

d- Definitions

e- Types of process and Modifications

4- Design considerations

5- Illustrated Problems

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
   - Get 9 or more you do not need to proceed.
   - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
   - Get 9 or more, so go on studying modular unit seven.
   - Get less than 9, go back and study the sixth modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the sixth modular unit , the student will be able to:-

1. Defines aerobic oxidation.
2. Knows the types of aerobic oxidation plant.
3. Knows the activated sludge process variables.
4. Classifies the activated sludge process.
5. Selects the mixing regime.
6. Designs activated sludge unit.

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3/ Pre test :-

Circle the correct answer:-

1. **In activated sludge process the F/M ratio should range between:-**

a- 0.2 to 0.4 b- 0.6 to 0.8

c- 0.8 to 1. d- 1.:1.

2. **In activated sludge process the solid ten time should range between:-**

a- 1 to 2 days b- 2 to 5 days

c- 5 to 15 days d- 15 to 50 days

3. **The recommended value of SVI in diffused aeration system should be:**

a- 5 to 10 b- 10 to 25

c- 25 to 55 d- 55 to 155

4. **The recommended value of SVI in mechanical aeration system should be:**

a- 10 to 50 b- 10 to 25

c- 100 to 200 d- 200 to 300

5. **In the treatment by Activated sludge process:**

a- There will be problem from Psychoda fly

b- Initial cost is higher than Trickling filter

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c- Power requirement is higher than Trickling filter

d- The head requirement is higher than Trickling filter

6. Classification of the activated sludge process depends on:

a- Aeration method　　b- Energy method

c- Construction method　　d- other method

7. The ratio of mixed liquor volatile S.S to mixed liquor S.S taken as :

a- 0.7　　b- 0.75　　c- 0.8　　d- 0.85

8. Food to micro-organism ratio of plug flow ranges from:

a- 0.2-0.3　　b- 0.2-0.4　　c-0.2-0.5　　d-0.2-0.6

9. A higher value of (Sludge Volume Index)SVI indicates:

a- stops the growth of bacteria　　b- a light and fluffy sludge

c- kill the bacteria　　d- a heavy and fluffy sludge

10- Attempt to supply air to match oxygen demand along the length of the tank is called:

a- Tapered aeration　　b- conventional system

c- Step aeration　　d- contact stabilization

Note

- Check your answers in key answer page 25.

- (1) degree for each .

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4/ The Text :-

Definition

Aerobic biological oxidation process is used to removal of soluble and colloidal organic matter.

Quiz / 1

Define Aerobic oxidation.

Note

- Check your answers in key answer page 21.

Biological Oxidation

a- Principles of biological oxidation:

It is possible to achieve a rapid rate of removal of organic matter from solution by providing a large population of micro-organisms in the form of a slime or sludge. The large microbial surface permits initial adsorption of colloidal and soluble organics together with synthesis of new cells so that after a relatively short contact time the liquid place contains little residual organic matter. The adsorbed organic matter is then oxidized to the aerobic and products.

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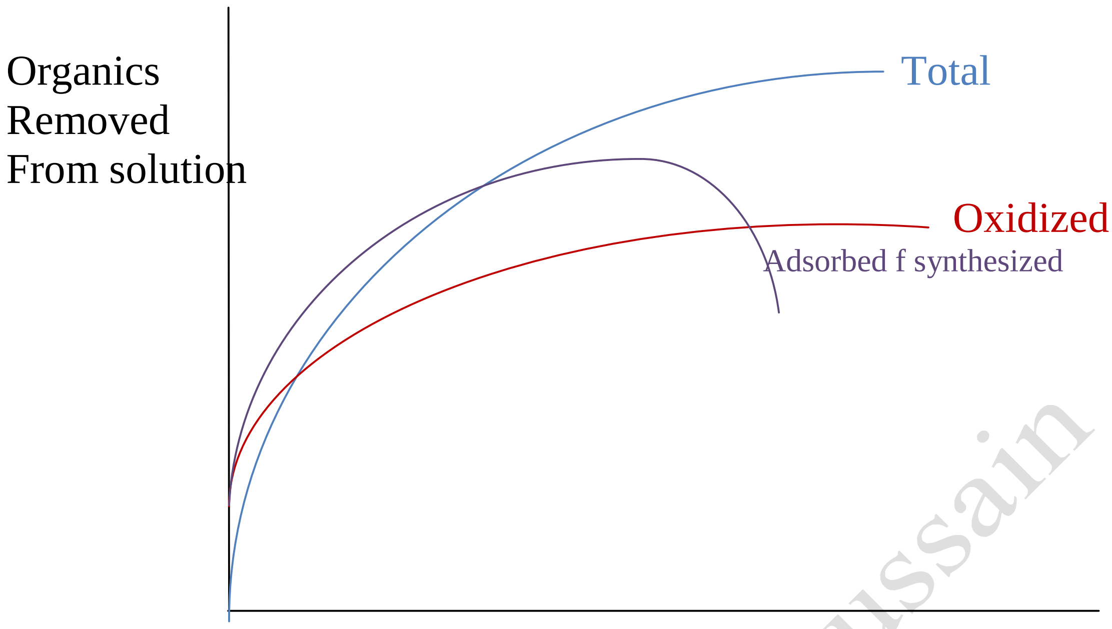
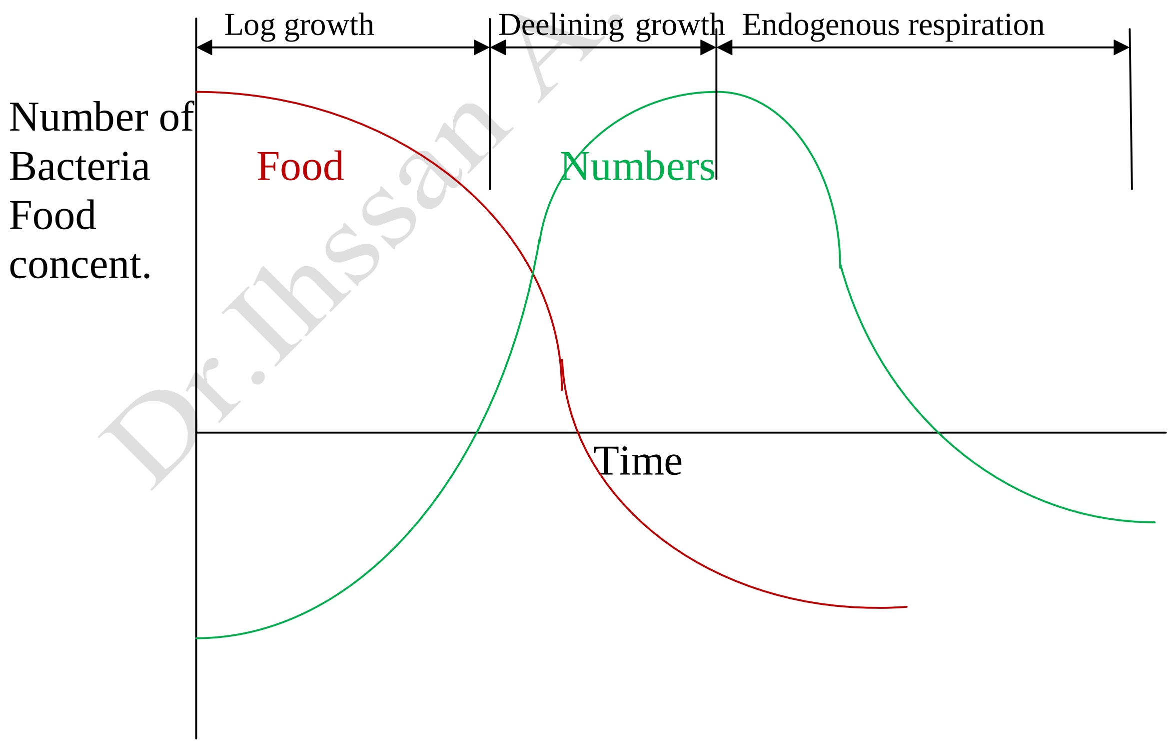


Removal of soluble organics in biological treatment

The rate of removal of organic matter depends on the phase of the biological growth curve.



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To maintain aerobic conditions in the reactor oxygen must be supplied, Since it is utilized for oxidation reactions and for basic cell maintenance.

→ $\frac{1}{3}$ COD of a waste is used for energy.

$\frac{2}{3}$ COD of a waste utilized for synthesis of new cells.

b- Types of aerobic oxidation plant:

Biological treatment reactors provides the high population of microorganisms in the form of either a fixed film on a suitable support surface or as a dispersed growth kept in suspension by an appropriate level of mixing.

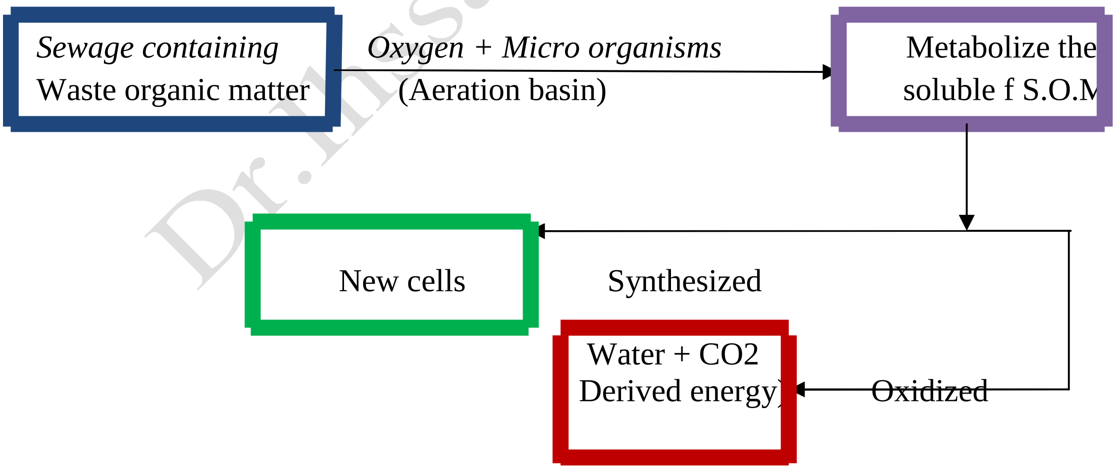
There are four basic types of aerobic reactor:

i. Biological filter, trickling filter or bacteria bed-fixed films systems.

ii. Activated sludge-dispersed growth systems.

iii. Oxidation ponds-dispersed growth systems.

iv. Lend treatment-complex system.



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Activated Sludge

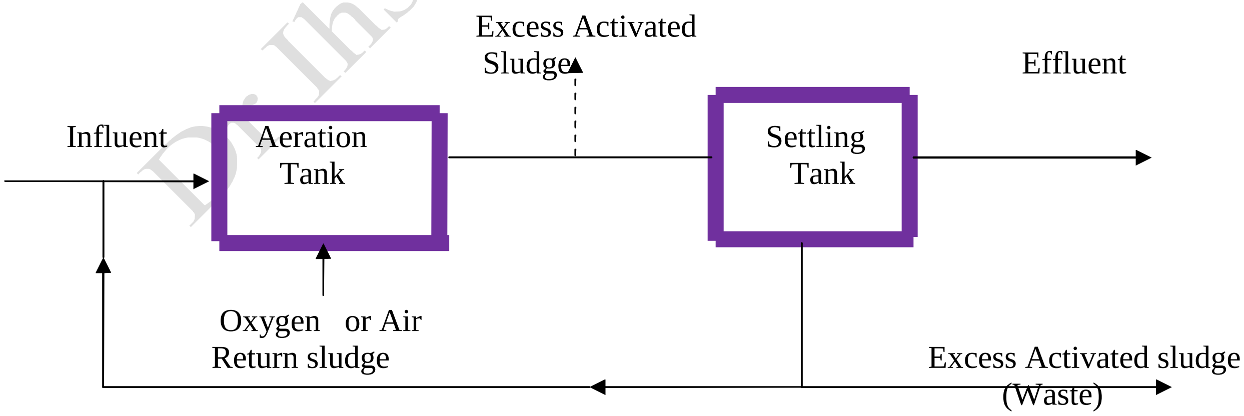
This process depends on the use of a high concentration of microorganisms present as a floc kept suspended by agitation, originally with air of high rates of oxygen.

The effluent from the aeration is again low in dissolved organics but contain high SS which must be removed by sedimentation. The effective use of the process depends on the return of the separated sludge (living microorganisms) to the aeration zone to recommence stabilization.

a- Activated sludge process variables

An activated sludge plant is essentially consists of the following:

i. Aeration tank (containing micro- organisms in suspension).
ii. Activated sludge recirculation system.
iii. Excess sludge wasting and disposal facilities.
iv. Aeration system to transfer oxygen.
v. Secondary sedimentation tank to separate and thick activated sludge.



Conventional Activated sludge
(Typical A.S process)

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b- **Classification of Activated sludge process:**

This process is classified into three main groups depending on the method of aeration:

1- Diffused Aeration tanks (i) Ridge and furrow type
(ii)Spiral flow tanks

2- Mechanical Aeration (i) Simplex type aerator
(ii)Link belt system

3- Combined mechanical and diffused air unit.

c- Mixing Regime:

∗ Plug flow (PF): In this system the sewage moves down progressively along the aeration tank.

∗ Complete mixed flow (CMF): In this system the sewage fed to the aeration tank at multiple points and complex mixed flow involves the rapid dispersal of the incoming sewage throughout the tank.

d- Definitions:

∗ The mixed liquor suspended solids (MLSS)

MLSS content is generally taken as index of the mass of active and dead cells of organisms in the aeration tank.

MLSS $\Longrightarrow$ 1500- 3000 mg/l (PF)

MLSS $\Longrightarrow$ 3000- 6000 mg/l (CMF)

∗ The mixed liquor volatile suspended solids (MLVSS):

MLVSS is a better indicator of activate microbial concentration. (Eliminate the dead cells of O.M). The ratio of MLVSS/MLSS is taken as (0.8).

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∗ F/M Food to Microorganisms Ratio:

It is the organic loading rate is defined as the ratio of kg BODs applied per day (representing microbial feed) to kg MLSS in aeration tank (representing microorganisms).

∗ (PF) $\longrightarrow$ (F/M ratio) and (BODs) very high in inlet and reduce progressively.

(CMF) $\longrightarrow$ Uniform (F/M) and (BOD) $\longrightarrow$ More efficient

More effective

Thus, volume and detention time reduced.

e- Types of process and Modifications:

1- Conventional system: (Fig. 1)

P.F; BOD removal 85-92%

2- Tapered Aeration: (Fig.1)

The application of air to aeration tank shall be at a higher rate near the influent end. The varying oxygen demand supply ratio has led to controlled aeration. (Attempt to supply air to match oxygen demand along the length of the tank).

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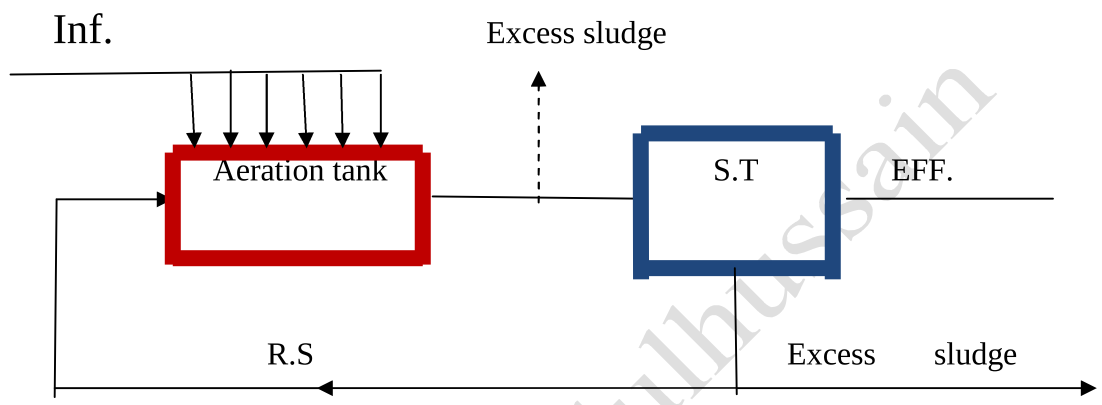
3- Step Aeration:

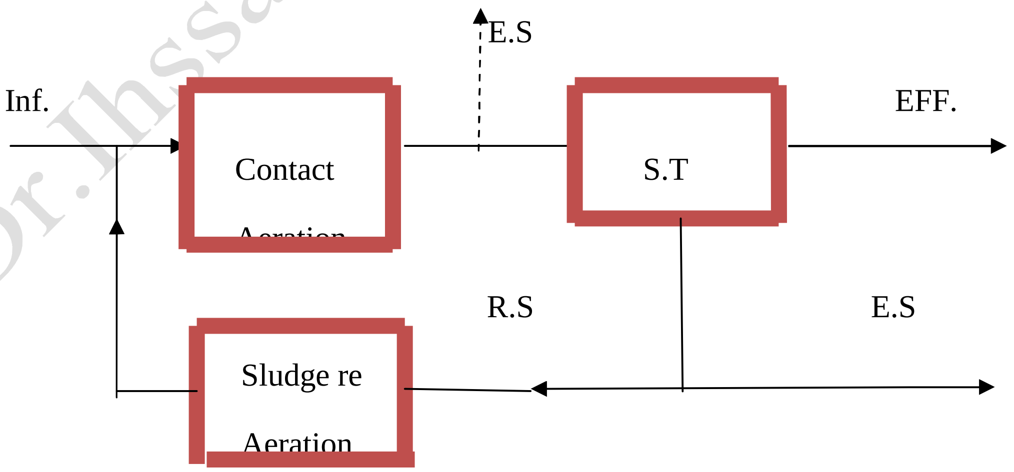
Settled sewage is introduced at several points along the tank length which produced a more uniform oxygen demand throughout.



Step Aeration

4- Contact stabilization:

C-S- Provides for reaction of returns activated sludge from the final clarifier, which allows a smaller aeration or contact tank.



Contact stabilization

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Design Consideration

1-Volume of Aeration tank:

a- Diffused aeration method

$$V = Q \times T$$

Where, V= volume of the tank, m^3

Q= Rate of sewage flow, m^3/hr.

T= Detention period (HRT) in hrs.

Detention period for diffused aeration method is given by formula:

$$B.O.D = 20\,(T+1)$$

Where, B.O.D = BOD in mg/l to be removed

b- Mechanical aeration method.

$$T = (BOD)^{3/4}/10 \Longrightarrow V = Q.T$$

c- Based on organic loading.

$$\frac{F}{M} = \frac{Q*La}{V*MLSS}$$

$\frac{F}{M}$= Food to microorganism's ratio

(P.F)= 0.2 to 0.4

C.M.F) =0.2to0.6

La= Influent B.O.D, mg/l

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d- Rational method:

$$\frac{V*(MLSS)d}{100}=\frac{Total\ B.O.D}{(B.O.D)d}$$

Where, (MLSS)d=Design MLSS to maintain in reactor

Total B.O.D= Influent B.O.D to reactor

(B.O.D) d= B.O.D loading/100 gm. of solids

2- Hydraulic Retention time in reactor

Or

$$T=\frac{V}{Q} \Longrightarrow T=\frac{La*MLSS}{F/M}$$

3-Excess sludge production

M_w= y. F-K_d. M

Where; M_w =Excess solids produced (kg/day) = Q_w. X_s

Y= maximum yield coefficient= 0.5-0.7

F= BOD to be removed (gm/day) =Q*La

K_d= endogenous respiration rate constant

=0.06-0.075d^{-1}

M= Total MLSS in the reactor=V.X

4-Sludge Retention Time (SRT) [sludge Age]

$$SRT=\frac{M}{Mw} \Longrightarrow SRT=\frac{V.X}{Qw.Xs}$$

5-Sludge Recycle:

$$\frac{QR}{Q}=\frac{X}{Xs-X}$$

X=MLSS in reactor (mg/m^3)

Xs= MLSS in returned sludge (gm/m^3) =10000 gm/m^3 (max) Q

Q_R= Return sludge= Sludge recirculation rate (m^3/day)

Q= Flow rate m^3/day

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6-Oxygen Requirements:

O_2 required $\frac{g}{day}=\frac{Q*La}{f}-1.42\ Q_w.\ Xs$ (for carbonacew)

Where, f= ratio of BODs to ultimate BOD

O_{nit}= Oxygen required for nitrification

= 4.6 kg of o_2 for NH_3 to NO_3

OR 1m^3 of air should be supplied for each 15 gm of B.O.D

7-Sludge Volume Index: (SVI)

It is the ratio of the volume of the activated sludge in m^3 for one gram of dry weight of sludge.

$$SVI=\frac{Settled\ volume\ of\ sludge\ in\ 30\ \min\ \%}{MLSS}$$

SVI
- 55 → 150(in diffused aeration)
- 200 → 300 (in Mechanical aeration)

A higher value of SVI indicates a light and fluffy sludge which is not easily settable. Such conditions of sludge bulking shows inefficient operation of the plant. This condition may be overcome by increasing the proportion of return sludge or lowering excess aeration.

7- In activated sludge process, when the soluble BOD in the effluent is restricted to a desired limit and it can be given by the following expression:

$$\frac{1}{SRT}=\frac{QxF/Mx(La-Ls)}{VxMLSS}-k$$

Where L_s= Soluble BOD in the effluent in kg/m^3

K= endogeneous rate constant,d^{-1}

And other terms as already stated earlier in m and kg units. The following example will illustrate the application of the formula.

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Illusterated Problems

Problem 1: A complete mixed activated sludge plant having discharge of 10000 m^3/day and effluent BOD of 150 mg/l should have not more than 5 mg/l effluent should BOD.F/M=0.5; $(MLSS)_{A.T}$=3000 mg/l; $(MLSS)_{w.s}$ =10000 mg/l; K=0.05 d^{-1} SRT=10 days

Determine the following:

(a) Volume of the reactor

(b) The mass and volume of solids that must be wasted/day.

(c) The recirculation ratio.

Solution:

(a) $$\frac{1}{SRT}=\frac{Q*Fm*BOD\ removed}{V*MLSS}$$

$$\frac{1}{10}=\frac{10000*0.5*(0.15-0.005)}{V*3} \Longrightarrow V= 1611m^3$$

(b) At equilibrium conditions:

$$SRT=\frac{Mass\ of\ the\ solids\ in\ reactor}{mass\ of\ the\ solids\ wasted}$$

$$10=\frac{V*(MLSS)A.T}{Qw*(MLSS)w.s}$$

$$10=\frac{1611*3}{Qw*(MLSS)w.s}$$

Or $Qw*(MLSS)_w = \frac{1611*3}{10}$ = 483.3 kg/day

The concentration of solids in the under flow

Q_w*10000 $\frac{mg}{l}$*(10^3/106)= 483.3 kg/day

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$\therefore$ Q_w = 48.33 m^3/day

(c) $$Qr=\frac{Q.(MLSS)A.T-Qw.(MLSS)W.S}{(MLSS)w-(MLSS)A.T}$$

$$Qr=\frac{(10000*3)-(48.33*10)}{10-3}=$$

$$\frac{Qr}{Q}= \qquad =$$

Problem 2: Calculate the sludge volume index for a mixed liquor with 2500 mg/lit of suspended solids having settled volume of 190 ml. with a liter sample. Is this sludge volume index good or poor?

Solution:

2500 mg settles to 190 C.C

$\therefore$ 1 mg settles to $\frac{190\ c.c}{2.5gm}$ = 76 ml/gm

Hence S.V.I =76 c.c/gm

If this from diffused aeration plant, S.I.V value(between 55 to 150) is good.

In case of mechanical aeration this is too low a value.

Problem 3: Design an aeration tank of an activated sludge plant of 10,000 persons and the sewage flow equal to 300 liters per head per day. Given per capita B.O.D per day equal to 0.077 kg and return sludge 30 per cent. Detention period= 6 hours and 35% of B.O.D. being removed in the primary settling tank.

Solution:

Q=10,000x300 liter/day

Return sludge = 30%

Detention period = 6 hr.

$\therefore$ Total volume $=\frac{10,000x300x1.3x6}{24x1000}$= 975 m^3

Provide 50mx5.5mx3.5,deep tank

B.O.D= 10,000x0.65 kg/day. =348 gm/min.

$\therefore$Air supply $=\frac{348}{15}$= 23 cu.m. per min.

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Problem 4: Design a conventional activated sludge plant to treat 5000 m^3/day of domestic sewage having B.O.D of 350 mg/lit. B.O.D of treated waste should be 30 mg/lit. Assume : F/M = 0.6 kg B.O.D./kg. of MLSS.
MLSS concentration in aeration tank= 2500 mg/lit.
Aeration requirement= 0.8 kg O_2 /kg. of B.O.D removed.
Aerator capacity = 1.6 kg O_2/h.p.hr.

Solution: B.O.D $=\frac{350x5000x1000}{1000}$= 1,750,000gm

MLSS= 2500 mg/lit. = 2.5 gm/lit.

Assume tank volume = V liters.

$\therefore$ Solid content in the tank =2.5V

$\frac{2.5V}{100}=\frac{1,750,000}{60}$

$\therefore$ V=1,165,000 lit= 1166m^3

Assume 25% return sludge

$\therefore$ Volume provided = 1165+0.25x1165=1456m^3

Provide 50mx7mx4m deep tank

B.O.D to be removed per liter of sewage=(350-30)=320 mg/lit

Total B.O.D to be removed

= 320x5000 kg/day=67 kg/hr

Air supply required= 0.8x67=54 kg/hr.

Aerator capacity = $\frac{54}{1.6}$ = 33 .7 h.p.hr.

Problem 5: An aeration tank with the diffused air system is to treat 6.8 m.l.d.of settled sewage having a B.O.D. of 200 mg/lit. The final effluent is to have a B.O.D. of 10 mg/lit. Find the (i) Volume of the aeration tank,if the design criteria is 1 cu.
m. for 535 gm. Of B.O.D. in the effluent sewage to the tank. (ii) Volume of the aeration tank, if the suspended solid content of the mixed liquor is 2500 mg/lit and the B.O.D. loading is to be 40 gm of suspended solids; (iii) Period of aeration, if the sludge occupies 25% of the aeration tank.

Solution:

(i) B.O.D.= 200x6.8x10^6/1000 =1,360,000 gm/day

For 535 gm B.O.D. tank volume = 1m^3

$\therefore$1,360,000 B.O.D. tank volume=2542 m^3

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(ii) Suspended solids=2500 mg/lit=2.5 gm/lit

Assume tank capacity = V liters.
$\therefore$ Solid content of the tank=2.5xV gm
From allowable loading conditions

$$\frac{2.5xV}{100}=\frac{1,360,000}{40}$$

$\therefore$ V= $1.36x10^6$ liters=1360 m^3

(iii) Given return sludge 25% $\therefore$ Tank volume

V=1.25x1360 m^3

$\therefore$ Detention period $T=\frac{V}{Q}$= $1.25x1360x24/6.8x10^3$= 6.0 hrs.

Problem 6: A sedimentation tank receives a sewage of 0.3 m^3/s, having suspended solids of 300 mg/l. The suspended solids removal is 60%.Calculate,

(i) SS. In kg/d/m^3 the effluent and

(ii) Kg of sludge per day, if the moisture content is 96%.

Solution:
Sewage flow Q=0.3 m^3/s= 25920 m^3/d
S.S. in the influent = 300 mg/l.
$\therefore$ S.S in the effluent = 0.4x300= 120 mg/d
=$120x1000/10^6$

(i) S.S. =0.12x25920=3110 kg/d.

(ii) Sludge $=\frac{3110x96}{4x1.1}$=67855 kg/d. Ans.

Problem 7: Indicate the approximate sizes of the following units for a complete sewage treatment plant of 4 m.l.d. capacity:

(a)Grit chamber,

(b) Primary settling tank and

(c)Activated sludge unit. Assume B.O.D. of raw sewage is 300 mg/lit.

Solution: Here only the activated sludge unit will be designed as diffused air unit (say).

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Assume the B.O.D. removal in the first two units are 40%
B.O.D. to A.S. Unit= 0.6x300=180 mg/lit.
Expecting 90% efficiency, the B.O.D. removal of A.S. Unit

=0.9x180=162 mg/lit.

$\therefore$ Detention period T is given by

$$162=20(T+1)$$

Or $T=7$ hours

$\therefore$ Tank capacity $C= 7x(4x10^6/10^3x24)=470\ m^3$

Provided a tank = 35mx5mx3m deep.

Rate of aeration will be done 1m^3 for 15 gm of B.O.D.

Total B.O.D. =(180x4x10^6)/(10^{3}x24x60x60)=8.33 gm/sec

Hence free air required = $\frac{8.33}{15}$=0.5 m^3/sec.

Assuming return sludge is 20 per cent.

Actual tank volume provided=470+0.2x470=564 m^3

=40mx5mx3m deep. Ans.

Problem 8: Calculate the sludge volume index for a mixed liquor with 2000 mg/lit suspended solids having settled volume of 200 ml with a liter sample. Is this sludge volume index good or poor?

Solution:

S.V.I. =$\frac{ml.of\ settled\ volume\ of\ sludge}{1\ gm.of\ dry\ wt.of\ solid}$

2000 mg settling gives 200 ml.

Or 1 gm. Settling gives $\frac{200}{2.0}$

Hence S.I.v.= 100

This is a good sludge volume index for diffused aeration.
Ans.

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5/ Post test :-

Design the activated sludge unit for the following:

(i) Population=50,000

(ii) Average sewage flow= 180 l.p.c.d.

(iii) B.O.D. of raw sewage 200=mg/lit.

(iv) Raw sewage suspended solids= 300 mg/lit.

(v) B.O.D. removal in primary treatment = 35%

(vi) Overall B.O.D. reduction desired=80%

(vii) Assume return sludge=20%

Note

- Check your answers in key answer page 25-26 .

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6/ key answer :-

1- Pre Test:-

1. a
2. c
3. d
4. d
5. c
6. a
7. c
8. b
9. b
10. a

If you:-

a. Got 9 or more you do not need to proceed.
b. Got less than 9 you have to study this modular unit well.

2- Post Test:-

Solution:

Flow = 180x50,000 lpd 375 m^3/hr

Overall B.O.D. to be removed

= 0.8x200 = 160 mg/lit (1 Mark)

B.O.D. removed by primary treatment

= 0.35x200=70 mg/lit (1 Mark)

$\therefore$ B.O.D to be removed by A.S.P

= 160-70 =90 mg/lit (1 Mark)

Detention period T is given by B.O.D.

=20(T+1)

Or 90=20(T+1)

Or T= 3.5; keep T=4 hours. (1 Mark)

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Capacity of the tank

$C=QxT=375x4=1500\ m^3$ (1 Mark)

Capacity to be provided=$1500+0.2x1500=1800m^3$ (1 Mark)
Provided two number of tanks each of 50mx6mx3m deep.
B.O.D. applied to A.S.P.=200-70=130 mg/lit. (1 Mark)
Total B.O.D. $=\frac{130x180x50,000}{1,000x24x60x60}=135$ gm/s. (1 Mark)
Assuming 15 gm of B.O.D. needs 1 cu. M free air. (1 Mark)
$\therefore$135 gm needs $135/15=0.9\ m^3$ free air.
Air to be supplied = $0.9\ m^3/s$ (1 Mark)

If you:-

- Got 9 or more, so congratulation your performance, go on studying modular unit seven.
- Got less than 9, go back and study the second unit; or any part of it; again, and then do the post test again.

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7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

3- Principles of water quality control, by T.H.Y. Tebbutt

4- Water Supply, Water Treatment, Dept. of the Army and the air force, Sept. 1985, TM 5-813-3/AFM 88-10, Vol 3l.

5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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Ministry of high Education and Scientific Research
Foundation of Technical Education
Technical College / Basrah

Training Package
in
Water Quality Control

For

Students of forth class
Department of Environment and Pollution Engineering
Technical College/Basrah

By

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September/2011

ANEAROBIC BIOLOGICAL OXIDATION

Seventh modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

With very strong organic wastes containing high suspended solids and with the sludge's from primary sedimentation and biological treatment it becomes difficult to maintain aerobic conditions. The physical limitations of oxygen transfer equipment may prevent satisfaction of the oxygen demand with consequent onset of anaerobic conditions. In such circumstances it may be more appropriate to achieve partial stabilization by anaerobic oxidation or digestion.

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1 / C –Central Idea :-

1 – Anaerobic Oxidation

*Principles of Anaerobic oxidation

2– Applications of anaerobic Treatment (Sludge digestion)

(i)Microbiology of the process

(ii)How to increase the efficiency of digestion

(iii)Type of sludge anaerobic digester

(1) Low rate digester
(2)High Rate Digester

*Storage for digester sludge

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
    - Get 9 or more you do not need to proceed.
    - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
    - Get 9 or more, so go on studying modular unit eight.
    - Get less than 9, go back and study the second modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Know the principle and the application of anaerobic biological oxidation.
2. Know the types and microbiology of the digestion process.
3. Control the efficiency of digestion.
4. Select the type of digester.
5. Determine the volume of digester.

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3/ Pre Test :-

1. **Enumerates the various methods of sludge disposal.**
2. **Enumerates the factors affecting sludge digestion.**
3. **Explain the factors control the capacity of digesters.**

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Note

- Check your answers in key answer page 17.

4/ The Text :-

Anaerobic Biological oxidation

Strong organic wastes
High suspended solids + limitation of Oxygen transfer equipment
P.S.T and A.S

Lead to → Using of Anaerobic oxidation or digestion

*Principles of Anaerobic oxidation

At standard Temperature and pressure (STP),

producer

1kg ultimate BOD (65%) + 1kg COD $\xrightarrow{\text{Oxidized}}$ $\overbrace{0.35\ m^3 \text{ methane gas}}^{\text{Net Energy}}$ CO_2 + H_2O (vapor) + N_2 + Hydrogen sulphide (H_2S)

[Organic matter] Anaerobically

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Quiz / 1

Explain briefly the principle of anaerobic oxidation.

Note

- Check your answers in key answer page 17-18.

Application of Anserobic Treatment

(Sludge Digestion)

The effect of anaerobic stabilization is to reduce the volatile content to less than 50% and the total solids to about two-thirds of the original value.
The volume of sludge increases mainly due to its water content. A small change in moisture content will appreciably reduce the sludge volume.

$$V = \frac{V_f\,(100-P_f)}{(100-P)}$$

Where P and P_f are the percentage of moisture and V and V_f are the corresponding sludge volumes before and after the change of moisture contents .

(i) Microbiology of the process
There are three degradation stages:
1-Hydrolysis 2-Acid formation 3-Methane formation

First stage:
Complex organic matter converted by Simple soluble
(Protein, cellulose, lipids) $\longrightarrow \longrightarrow \longrightarrow$ [Cellular Enzymes] O.M

Second stage:
Simple soluble converted by Acetic Acid + H_2 + CO_2 +
O.M $\longrightarrow \longrightarrow \longrightarrow$ [Acetogenic Bacteria] low molecular weight
organic Acid

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Third stage:

Acetic Acid $\longrightarrow \quad \longrightarrow \quad \longrightarrow$ Methane + Bicarbonate

Methanogenic Bacteria

H_2 + CO_2 $\longrightarrow \quad \longrightarrow \quad \longrightarrow$ Methane

*For satisfactory performance of anaerobic digestion, the second and third stages of digestion should be in equilibrium.
i.e / the volatile organic acid should be converted into methane at the same rate as they are produced.

(ii) How to increase the efficiency of digestion:

(1)Optimum temperature ranges from 37-50 ℃

(2)Mixing of fresh sludge with old one.

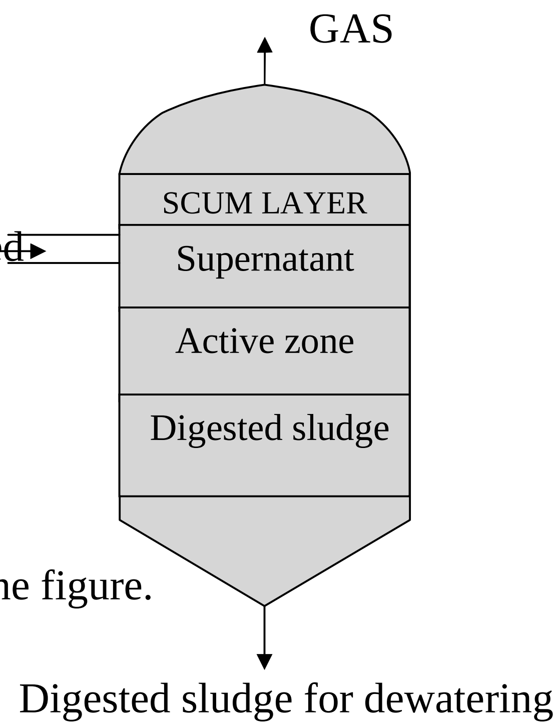
(3)PH slightly in the alkaline range (6.5-7.5).

(iii) Type of sludge anaerobic digester

(i) Conventional digester (Low rate digestion).

(ii) High rate digester.

<u>**1-Low rate digester :**</u>



→ It is the simplest and Oldest process.

→ Raw sludge is fed into the digester intermittently

→ Bubbles of sewage gas provides some mixing.

→ The digester contents forming four layers(stratified) as shown in the figure.

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2-High Rate Digester :

The essential elements of this type are:

→Complete mixing of sludge
 (Homogeneous)

→More or less uniform feeding of raw sludge

→Pre-thickening of raw sludge

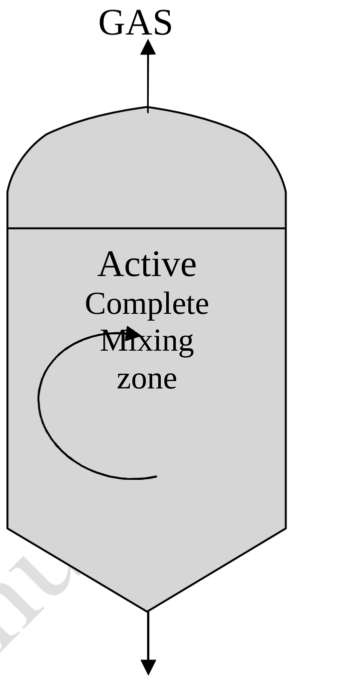
i. Large reduction in digester volume

ii. Better quality of supernatant

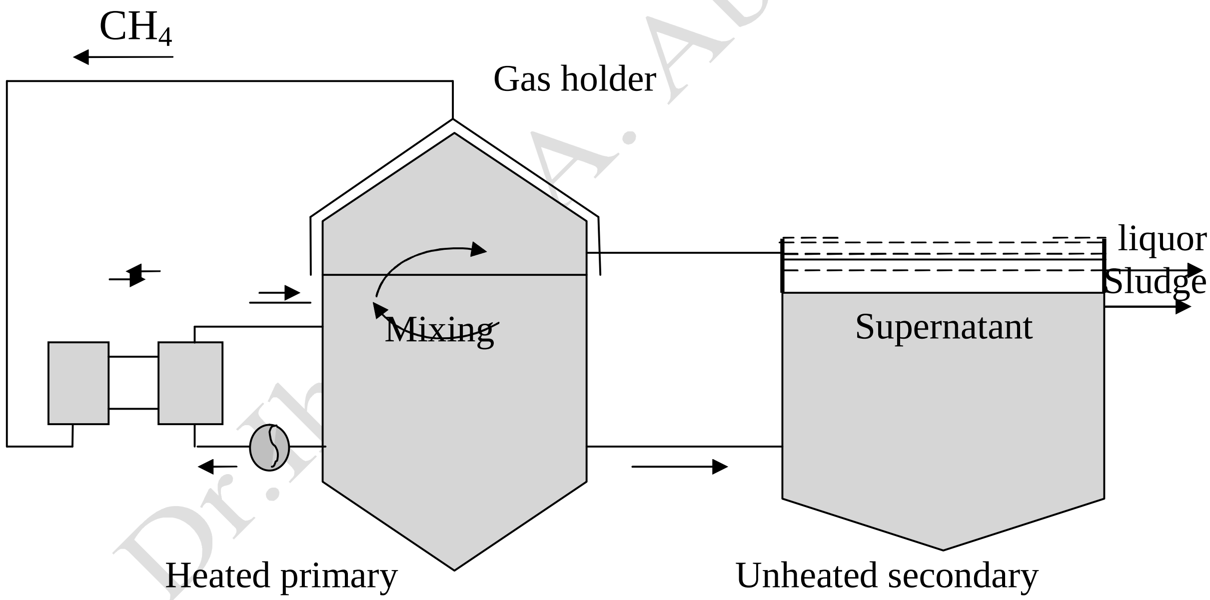
iii. Less heating energy requirement

iv. Less mixing energy

→Heating of the digester contents increases
 the rate of digestion.



Digested sludge for dewatering



Conventional sludge – digestion plant

Storage for digester sludge:

The digester volume will depend upon the quantity of raw sludge, the rate of digestion and the period of digestion.

1. Low Rate Digester Tank:

Since the supernatant is removed during digestion, resulting in decrease in digesting sludge volume, the capacity of digester is given by the expression:

$$V = [\, V_f - \frac{2}{3}(V_f - V_d)\,] \,.\, T_1$$

Where,

V = Volume of digester, m^3

$\mathbf{V_f}$ = Volume of fresh sludge m^3 added per day

$\mathbf{V_d}$ = Volume of digested sludge , m^3 withdrawn per day

$\mathbf{T_1}$ = HRT, days (Digestion time in days)

Additional capacity to store sludge during the monsoon period , when the sludge drying bed option is used for sludge de-watering , is given by the expression :-

Additional monsoon storage volume = $\mathbf{V_d \,.\, T_2}$

Where $\mathbf{T_2}$ = Storage in days, during monsoon.

2. Sizing of high rate digesters

Because of good mixing there is no stratification and hence no less of capacity due to scum or supernatant layers .capacity for high rate digestion may be determined by:

$$V^{I} = V_f \, T_h$$

$$V^{II} = [\, V_f - \frac{2}{3}(V_f - V_d)\,] \,.\, T + V_d \, T_2$$

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Where,

$\mathbf{V^{I}}$ = Volume of first stage digester , m^3

$\mathbf{V^{II}}$ = Volume of second stage digester , m^3

$\mathbf{V_f}$ = Volume of fresh sludge m^3 added / day

$\mathbf{V_d}$ = Volume of digested sludge , m^3 withdrawn / day

T = Digestion time in the second stage digester, which is of the order of (10) days.

T_2 = Storage in days, during monsoon.

*Additional storage capacity needed for the monsoon period can also be provided in the second stage digester.

*When the digested sludge is to be dewatered on sludge drying bed, a second stage digester is normally provided, where separation of supernatant and reduction in volume of sludge due to gravity thickening take place and digester is completed.

Illusterated Pboblems

Problem 1: Sludge of $120m^3$ has moisture content of 95%. Find the volume if moisture content changes to 90%.

Solution:

$$V = \frac{V_f\ (100-P_f)}{(100-P)}$$

$$120 = \frac{V_f\ (100-90)}{(100-95)}$$

$$V_f = \frac{120*5}{10} = 60\ m^3$$

$$\therefore\ V_f = \frac{1}{2} V$$

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Thus, it has reduced to half of its volume by lowering moisture content of 5% only.

Problem 2: Design the sludge digester volume required by the primary sludge produced by 1000 persons. Given the S.S per Capita 91.6 gm. The sedimentation tank removes 55% of S.S. The primary sludge is 91%. The solids reduce by weight is 40% .The detention time is 27 days.

Solution:

The volume of fresh sludge produced daily

$V_f = 91.6 * 0.55 * 1000 * \frac{100}{5} * \frac{1}{1000} = 1007.9$ litters

Volume digested of sludge

$V_d = 91.6 * 0.55 * (1 - 0.4) * 1000 * \frac{100}{9} * \frac{1}{1000} = 335.9$ litters

Average volume of sludge

$= 1007.6 - \frac{2}{3}(1007.6 - 335.9) = 560.6$ litters

Capacity of the tank

$560.6 * 27 = 15100$ litters $= 15.1\ m^3$

Some authors suggested finding the volume against

Average volume above by $(V_f + V_d)/2$

Then the capacity$=27 * \frac{1007.6+335.9}{2} * \frac{1}{1000} = 18.15 cm^3$

Special case should be taken in computation of sludge volume. In case of activated sludge this volume is very high.

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5/ Post Test :-

Design a circular sludge digestion tank with the following data:

Average sewage flow = 20×10^6 l/day
Total suspended solids in raw sewage = 300 mg/l
Solids removed in primary settling tank = 65%
Moisture content of digested sludge = 85%
Moisture content of fresh sludge = 95%
Specific gravity of wet sludge = 1.00
Digestion period = 30 days
Depth of cylindrical digestion tank = 6 m.

Note

- Check your answers in key answer page 17-18.

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6/ key answer :-

1- Pre Test :-

a- The following are the various methods which are used to disposal of sludge:

- Disposal on land.
- Distribution by pipe line.
- Drying on drying beds.
- Dumping in to the sea.
- Heat –drying.
- Incineration.
- Ponding (Lagoon).
- Press and vacuum filters.
- Digestion following by drying.

b- The factors affecting the sludge digestion are:

- Temperature.
- Sludge seeding.
- Mixing.
- pH value.
- Miscellaneous conditions.

c- The capacity of sludge digestion tank depends upon:

- Fresh sludge.
- Dry sludge.
- Detention time.
- Sludge withdrawal and its interval.
- Collection of gas.
- Freeboard.
- Storage for monsoon.
- Type of pre-treatment.

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If you:-

- Got 9 or more you do not need to proceed.
- Got less than 9 you have to study this modular unit well.

2- Post Test:-

Average sewage flow = 20×10^6 l/day

Total suspended solids = 300 mg/l

Weight suspended solids = $\left[\frac{300 \times 20 \times 10^6}{10^6}\right]$

= 6000 kg.

Weight of solids removed in

the primary settling tank = (0.65×6000)

=3900 kg/day.

Now, the moisture content of fresh sludge is 95% which means that 5kg of dry will make 100kg of wet sludge .

. Wet sludge produced per day = $\left[\frac{100}{5} \times 3900\right]$.

= 78000 kg.

As the specific gravity of sludge is unity,

Volume of raw sludge

Produced per day = V_1 = 78 m^3 . . . . (1)

The volume of digested sludge is worked out by the following expression as obtained in problem 30-3 :

$$V_2 = \frac{(100-P_1)}{(100-P_2)} \times v_1$$

$$= \frac{(100-95)}{(100-85)} \times v_1$$

$$= \frac{5}{15} \times 78 = 26 \text{ m}^3\text{/day.}$$

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Capacity of tank for the

Digestion period of 30 days= $\left[V_1 - \frac{2}{3}(V_1 - V_2)\right] \times 30$

$= \left[78 - \frac{2}{3}(78 - 26)\right] \times 30$

$= 1300\ m^3$.

The depth of cylindrical digestion tank is 6 m.

. Cross sectional area of tank = $\left(\frac{1300}{6}\right) = 216.67\ m^2$

. Diameter of tank = $\sqrt{\frac{216.67}{\frac{\pi}{4}}}$

If you:-

- Got 9 or more, so congratulation your performance, go on studying modular unit eight.
- Got less than 9, go back and study the seventh unit; or any part of it; again, and then do the post test again.

Quiz No. 1 /

Return to page (9) for the answer.

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7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

3- Principles of water quality control, by T.H.Y. Tebbutt

4- Water Supply, Water Treatment, Dept. of the Army and the air force, Sept. 1985, TM 5-813-3/AFM 88-10, Vol 3l.

5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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Ministry of high Education and Scientific Research
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Training Package
in

Water Quality Control

For
Students of forth class
Department of Environment and Pollution Engineering
Technical College/Basrah

By

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Lecturer
Department of Environment and Pollution Engineering
Technical College/Basrah

September/2011

Dr. Ihssan A. Abdulhussain

DISINFECTING

Eighth modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

The small size of microorganisms means that complete removal of them from water by processes such as coagulation and filtration cannot be guaranteed. it is thus essential to ensure the elimination of potentially harmful microorganisms from potable waters by the use of a suitable disinfection process.

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1 / C –Central Idea :-

1 - Definition

2 – Disinfection chlorine

a - Theory of disinfection chlorine

b – Action of chlorine for disinfection

c – Chlorine dose

3 – Type of chlorination

4 – Chlorine Dioxide

5– Illustrated Problems

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
    - Get 9 or more you do not need to proceed.
    - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
    - Get 9 or more, so go on studying modular unit ninth.
    - Get less than 9, go back and study the eighth modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Defines disinfecting.
2. Knows the methods of disinfection chlorine.
3. Determines the chlorine dose.
4. Selects the convenient type of chlorination.
5. Knows the different types of disinfectant.

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3/ Pre Test :-

Circle the correct answer:-

1. **Aeration of water is done for removal of:-**

a- Hardness. b- Turbidity

c- Color d- Odour

2. **As minimum of chlorine as possible is used for disinfection:-**

a- To reduce the cost of disinfection

b- T protect consumers from potential health risk

c- To avoid unpleasant odour

d- To achieve all the above

3. **Disinfection of drinking water is done to remove :**

a- Turbidity b- odour

c- Bacterias d- color

4. **The permissible pH value for public water supplies may ranges between:**

a- 4.5 to 5.5 b- 5.5 to 6.5

c- 6.5 to 8.5 d- 8.5 to 10.5

5. **Disinfectant is a chemical substance used for :**

a- living objects b- non living objects

c- living and non living objects d-none

Note

- Check your answers in key answer page .
- (2) degree for each .

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4/ The Text :-

Disinfection :-

Treatment of water is not complete unless the microorganism present in water is removed. As chlorine possesses the necessary qualities, it is universally accepted as water disinfectant.

Quiz / 1

What is the different between disinfection and sterilization?

Note

- Check your answers in key answer page 16.

Disinfection Chlorine

a- Theory of disinfection chlorine

During disinfection the main aim is restricted to kill the unicellular organism, mainly bacteria Chlorination is:

(i) The nature of organisms destroyed: spore forming organism is not easily destroyed by chlorination.
(ii) The temperature of water: The higher the temperature more rapid and efficient is the disinfecting action.
(iii) The contact time: longer the time, higher the percentage destruction (30 minutes at least before use).
(iv) PH value of water: At PH of 5, the chlorination is most efficient.

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(v) The followings substances and compound reduce the efficiency of chlorination: Nitrogenous compound like Ammonia, Iron, manganese and turbidity.
(vi) Chlorine dose.

Quiz / 2

Numerates the factors affecting disinfection chlorine.

Note

- Check your answers in key answer page 16.

b- Action of chlorine for disinfection

The bacteria are burning by chlorine or converted to soluble material.

$$* \; CL_2 + H_2O \longrightarrow HOCL + HCL$$

$$HOCL \rightleftharpoons H^+ + OCL^-$$

$$** \; CL_2 + H_2O \rightleftharpoons HOCL + HCL$$

$$HOCL \longrightarrow HCL + O$$

Negligible effect (HCL) — destroy the bacteria (O)

Quiz 3

Explain the chlorine reaction in chemical equations.

Note

- Check your answers in key answer page 16.

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c- **Chlorine dose:**

(½ to 1) mg/L → Usual

(2) mg/L → Emergency

Chlorine dosage:-

1-Chlorine demand test

2- Chlorine residual — Orthotolidin test / Iodometric method

↓

0.2 - 0.3 mg/L (Usual)

0.6 mg/L (Emergency)

Free residual chlorine | Combined residual chlorine

Quiz4

Fill in the blanks with suitable answer:-

The Chlorine residual comprises of ___________ and_______________.

Note

- Check your answers in key answer page16.

Type of chlorination:-

The classification is depending on the point of application and the extent of chlorination carried out.

1-Plain chlorination – only adding chlorine (no other treatment unit)

2- Pre-chlorination – before coagulation.

3- Post chlorination –chlorine is applied after filtration.

4- Break point chlorination.

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5- Super chlorination –very high dose of chlorine 2 → 3 p.p.m.

6- De-chlorination –to remove taste and odors due to chlorine.

(i)Adding reducing chemical

$$SO_2 + CL_2 + 2H_2O = H_2SO_4 + 2HCL$$

(ii)By passing water through bed of granular activated carbon

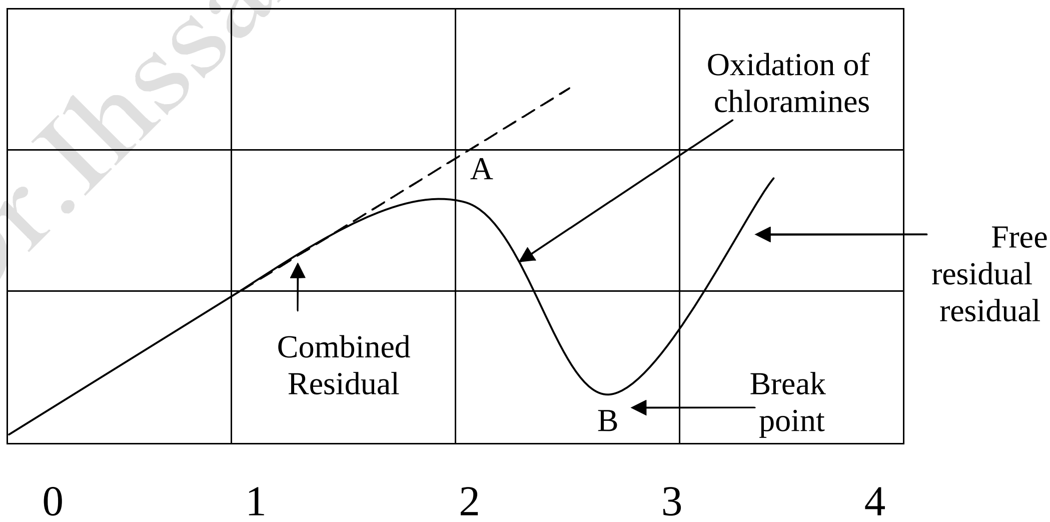
$$C + 2CL_2 + H_2O \neq CO_2 + 4HCL$$

(iii) Aeration.

* O.M in water as Ammonia

*Residual chlorine
- Free
- **Combined with Ammonia** → **chloramines**

0 A → ⇒ Combined Residual chlorine — Same time



Applied point, mg/L

Break point chlorination

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*After point A and if the chlorine dose increased the oxidation of chloramines compound starts and continue till point B which represents the end of oxidation of all chloramines compound .

1-Bleaching powder:
Ca (OCL) Method of adding chlorine:
It is a poor disinfectant giving low available chlorine and increase the PH value of water. The powder contains 30 to 33 % available chlorine which again decreases with time.

2-Calsium hypo chlorite (60-70%) effective

3-Sodium Sodium hypochlorite (15%) effective

It is a strong oxidizing agent. It is formed by the action of chlorine on sodium chlorite. It is suitable for treating waters containing large amount of organic material and phenolic compounds.

Other Disinfectant:
(a) Ozone
(b) Ultra violet Rays
(c) Heating
(d) Addition of time
(e) Addition of Bromine and Iodine
(f) Ultra Sonic Wave.

Quiz5

Explain the purpose and types of De-chlorination.

Note

- Check your answers in key answer page 16.

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Illustrated Problem

A water to be disinfected by using bleaching powder having chlorine demand of (2.3 mg/L). If the daily need of water is ($5*10^6$ L/day) and the available chlorine of bleaching powder is (25%). Find the amount of bleaching powder required per day.

Solution:

Total CL_2 demand = 2.3 + (0.2 as residual CL_2)

∵ Per liter of water required 2.5 mg CL_2

$5*10^6$ l of water required $5*10^6*$ 2.5 mg = 5*2.5 kg of CL_2

Available CL_2 is 25%

OR

1kg of CL_2 is available from 4 kg of powder.

∵ 5*2.5 kg of CL_2 is available from 4*5*2.5 =50 kg of powder

∵ Bleaching powder required = 50 kg / day.

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5/ Post Test :-

The results obtained from chlorine demand test on samples of raw water are as follows:

Sample no.	Chlorine dosage In mg/l	Residual chlorine after 10 minutes in mg/l
1	0.20	0.19
2	0.40	0.36
3	0.60	0.50
4	0.80	0.48
5	1.00	0.20
6	1.20	0.40
7	1.40	0.60
8	1.60	0.80

Draw the chlorine demand curve and find out the break point dosage. Also calculate the chlorine demand at a dosage of 1.20 mg/l.

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Note

- Check your answers in key answer page .

6/ key answer :-

1- Pre Test:-

1. d
2. d
3. c
4. c
5. b

If you:-

- Got 8 or more you do not need to proceed.
- Got less than 9 you have to study this modular unit well.

2- Post Test:-

The chlorine demand curve or in the strict sense, the chlorine residual curve is drawn as shown in fig. 9-2. The break point is represented by point C and hence, the break point dosage is 1.00 mg/l.

Then, Chlorine demand at break point = Applied chlorine – Residual chlorine

= (1.00-0.20) = 0.80 mg/l.

The chlorine demand after the break point becomes constant and all added chlorine subsequently appears as free chlorine .

.. Chlorine demand at a dosage of 1.20 mg/l = 0.80 mg/l.

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Note : The result is in line with given data of chlorine residual of 0.40mg/l with a dosage of 1.20 mg/l giving the chlorine demand of

(1.20-0.40)= 0.80 mg/l.

If you:-

- Got 9 or more, so congratulation your performance, go on studying modular unit ninth.
- Got less than 9, go back and study the eighth unit ; or any part of it ; again, and then do the post test again .

Quiz No. 1 /

Return to page (8) for the answer.

Quiz No. 2 /

Return to page (8-9) for the answer .

Quiz No. 3/

Return to page (9) for the answer .

Quiz No. 4/

Combined and free

Quiz No. 5/

Return to page (12) for the answer .

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7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

3- Principles of water quality control, by T.H.Y. Tebbutt

4- Water Supply, Water Treatment, Dept. of the Army and the air force, Sept. 1985, TM 5-813-3/AFM 88-10, Vol 3l.

5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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Ministry of high Education and Scientific Research
Foundation of Technical Education
Technical College / Basrah

Training Package
in

Water Quality Control

For

Students of forth class
Department of Environment and Pollution Engineering
Technical College/Basrah

By

Dr. Ihssan A. Abdulhussain
Lecturer
Department of Environment and Pollution Engineering
Technical College/Basrah

September/2011

CHEMICAL TREATMENT

Ninth modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

A number of constituents of waters and wastewaters do not respond to the conventional treatment processes already discussed, and alternative forms of treatment must be used for their removal. Soluble inorganic matter can often be removed by precipitation or ion-exchange techniques. Soluble no biodegradable organic substances may frequently be removable by adsorption.

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1 / C –Central Idea :-

1 - Introduction

2 –Softening of water

3- Municipal Water Softening Process

a- The Lim-Soda Process

*Advantage and disadvantage.

b- Ion Exchange Process

*Advantage and disadvantage.

4- Illustrated Problem

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
    - Get 9 or more you do not need to proceed.
    - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
    - Get 9 or more, so go on studying modular unit ten.
    - Get less than 9, go back and study the ninth modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Define softening.
2. Know the methods of softening with the ability to draw a diagram or write chemical equations.
3. Know the advantages and disadvantages of different types of softening.
4. Determine the cost of softening process.

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3/ Pre Test :-

Circle the correct answer:-

1. Zeolite is :-

a- A naturally occurring salt. b- Hydrated Silica

c- Hydrated aluminum silicate d- Silicon carbide

2. Hard water contains :-

a- Calcium b- magnesium bicarbonates

c- Magnesium sulphates d- all the above

3. The main disadvantages of hard water is :

a- Greater soap consumption b- scaling of boilers

c- Corrosion of pipes d- all of above

Hard water for public use is discarded because :

a- It consumes more soap b- it contains a lot of turbidity

c- It contains bacteria d- none of these

4. The temporary hardness of water can be removed by :

a- Boiling b- adding lime

c- Adding alum d- Filtration

5. The permanent hardness is due to the presence of :

a-Sulphates of Calcium and Magnesium b- Chlorides of Calcium and Magnesium

c- Nitrates of Calcium and Magnesium d- All Above

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Note

- Check your answers in key answer page .
- (2) degree for each .

4/ The Text :-

Introduction

Softening of Water

Water sometimes contain very high amount of bicarbonates, salphate and chlorides of Calcium and Magnesium. These dissolved salts make the water hard and cause the following troubles:

(i) This will much increase the washing charges.

(ii) Spoils the fabric of clothes.

(iii) Clogging troubles of pipe lines.

(iv) Formation of scales in boiler causes wastage of fuel and the danger of overheating the boiler.

For all these reasons the removal of hardness or softening of water is required.

The water containing 35 to 45 mg/l carbonate hardness and 100 mg/l total hardness may be termed as soft water. Water containing above 400 mg/l of total hardness is known as hard water.

Quiz / 1

Numerates the troubles caused by dissolved salts.

Note

- Check your answers in key answer page16 .

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Municipal Water Softening Process

There are two methods generally used for softening of water:

1- The Lime-Soda Process.

In this process the hardness is removed by using Lime and Soda ash.
The following chemical reactions take place:

(i) $Ca\ (HCO_3)_2 + Ca\ (OH)_2 \longrightarrow 2CaCo_3 + 2H_2O$

(ii) $Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO^3 + 2H_2O$

(iii) $MgSO_4 + Ca(OH)_2 + Na_2CO_3 \longrightarrow Mg(OH)_2 + CaCO_3 + Na_2SO_4$

(iv) $MgCl_2 + Ca(OH)_2 + Na_2CO_3 \longrightarrow Mg(OH)_2 + CaCO_3 + 2Nacl$

Note that $CaCO_3$ is unsoluble.

(ii) $CaSO_4 + Na_2Co_3 \longrightarrow CaCO_3 + Na_2SO_4$

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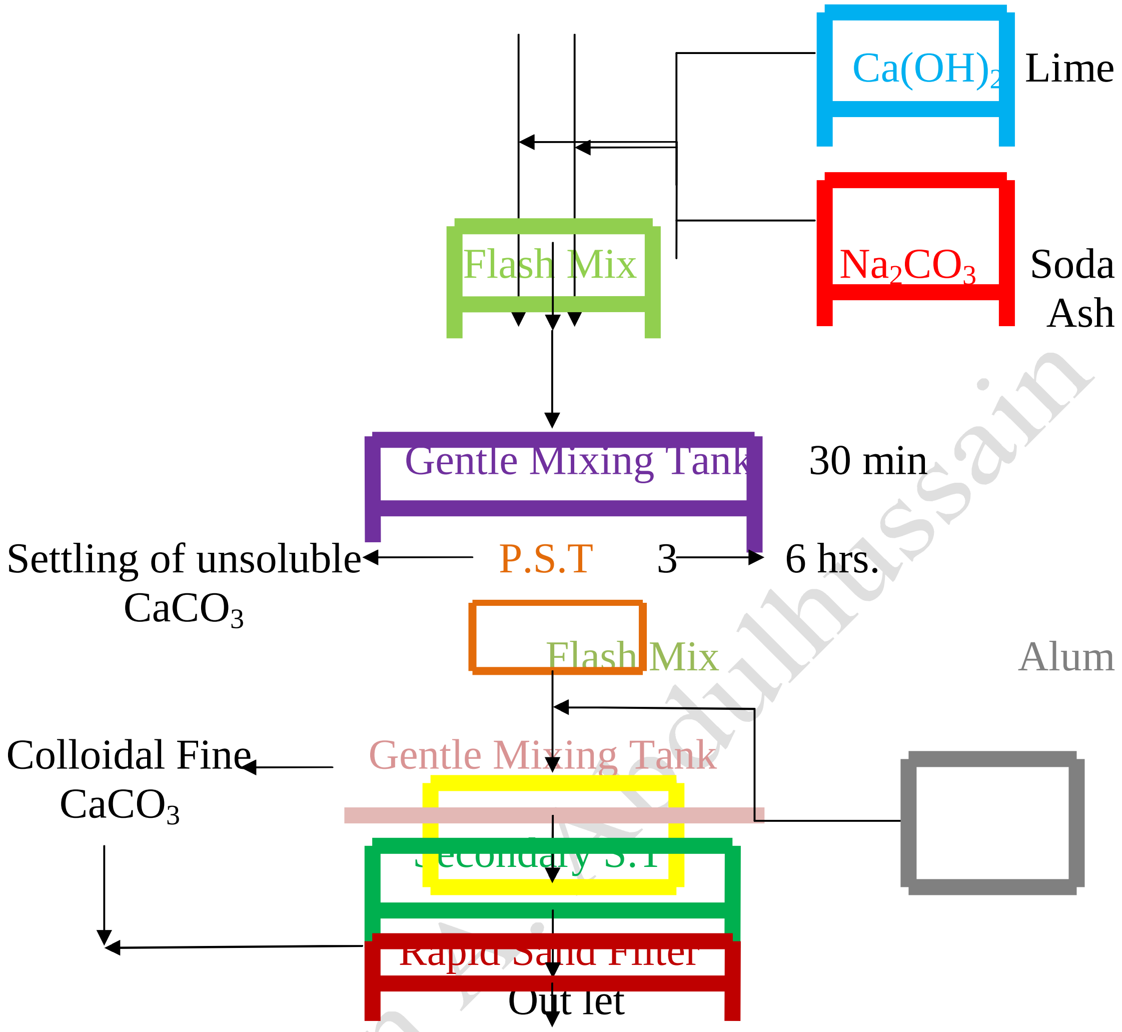
Lime Soda softening plants will include the following units



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By studying the equations, it is observed that the hardness results from bicarbonate calcium and Magnesium and this removed by using lime, Whereas the hardness results from calcium salphate is removed by sodium carbonate.

Finally, the hardness results from magnesium salphate are removed by both sodium carbonate and a lime.

*Advantage and Disadvantage of Lim-Soda Process:

The following are the advantages of lime- Soda process:

(i) Low cost.

(ii) Total mineral content of water gets reduced.

(iii) Reduced the tendency of corrosion of distribution system.

(iv) The amount of coagulation is reduced.

(v) Pathogenic bacteria may be destroyed.

(vi) The process does not require the raw water free of turbidity.

Disadvantages:

(i) Large amount of sludge is formed.

(ii) This process requires close supervision.

(iii) The carrying capacity of distribution pipes is reduced due to deposition of $CaCO_3$.

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2- Ion Exchange Process

In the cation exchange method; Zeolites used in water softening are complex compounds. The type of reactions take place is given below:

Hard water	Exchange bed	Soft water	Zeolites

$$\begin{matrix}Ca\\Mg\end{matrix}\left\{\begin{matrix}(HCO_3)_2\\SO_4\\Cl_2\end{matrix}\right. + Na_2X = Na_2\left\{\begin{matrix}(HCO_3)_2\\SO_4\\Cl\end{matrix}\right. + \begin{matrix}Ca\\Mg\end{matrix}\, X$$

The Sodium of the Zeolite is regenerated by applying the solution of Sodium Chloride.

Regeneration

Exhausted Exchange bed	Salt solution	Fresh bed	Waste water

$$\left.\begin{matrix}Ca\\Mg\end{matrix}\right\}X + Nacl = NaX + \left.\begin{matrix}Ca\\Mg\end{matrix}\right\}Cl_2$$

As the bed may be clogged, the Zeolite process is not suitable for treating turbid water.

(X) $\Rightarrow$ Zeolites $\longrightarrow$ Na Al Slo_4

Zeolite Filter similar to Filter of water

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*Advantage and Disadvantage of Ion Exchange Process:

Advantages of Zeolites process:

(i) Water of zero hardness may be obtained (industries requirement).
(ii) Compact plant and operation is simple.
(iii) The whole process can be made automatic.
(iv) Cheaper process to remove non- carbonate hardness.

Dis advantages:

(i) There is slight increase in the dissolved mineral matter content.
(ii) Water must be free from turbidity, oil……etc.
(iii) High cost.
(iv) Zero hardness obtained by this process is not required many times and such water is corrosive to the distribution system.
(v) In large plant the disposal of spent up brine water is a problem.

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Illustrated Problem

A water containing 600 mg/l of total hardness as $CaCO_3$ is to be softened by a certain exchange resin having a capacity of 65 kg/m^3 and costing 7500 ID/M^3. What is the cost of the resin required for treating $9*10^6$ l/d of water with regeneration after every 24 hours? Using 20% extra bed as stand bye.

Solution:

In one liter hardness is 600 mg

$\therefore$ In $9x10^6$ liter hardness= $600x10^6x10^{-3}$=5400 kg

65 kg of hardness is removed by 1 m^3 resin

$\therefore$ 5400 kg of hardness is removed by

$$\frac{5400}{65} = 83 \text{ m}^3 \text{ of resin}$$

Providing 20% extra bed=1.2x83

=100 m^3

Cost of resin = 7500 ID/M^3

$\therefore$Total cost = 7500x100= 750 000 ID

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5/ Post Test :-

Compare between Lime –Soda and Zeolite processes of softening water supplies with respect to the followings:

- Economy
- Effect on bacteria.
- Hardness of treated water
- Hardness which can be treated
- pH of treated water
- Post treatment
- Removal of color due to iron and manganese
- Size of plant
- Sludge formation
- Turbidity

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Note

- Check your answers in key answer page .

- (1) degree for each .

<u>6/ key answer :-</u>

1- Pre Test:-

1. c
2. d
3. d
4. a
5. d

If you:-

- Got 8 or more you do not need to proceed.
- Got less than 8 you have to study this modular unit well.

2- Post Test:-

No.	Item	Lime – process	Zeolite process
1	Economy	Economical	Costly
2	Effect on bacteria	Can remove pathogenic bacteria	No effect on bacteria
3	Hardness of treated water	Can produce water up to hardness not less than 50 mg/l.	Water of zero hardness can be obtained
4	PH of treated water	It increases the pH value of treated water	It does not affect the pH value of treated

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			water
5	Post treatment	Re-carbonation is necessary after sedimentation & filtration	No such treatment is necessary
6	Removal of color due to iron and manganese	Can remove such color to a very small extent	Can remove such color but proves very costly
7	Size of plant	Bulky and large	Compact and small
8	Skilled supervision	Necessary	Not necessary
9	Sludge formation	Large quantity of sludge is formed	No sludge is formed
10	Turbidity	Highly turbid and acidic waters can be treated	Difficult to treat highly turbid water

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If you:-

- Got 9 or more, so congratulation your performance, go on studying modular unit ten.
- Got less than 9, go back and study the tenth unit; or any part of it; again, and then do the post test again.

Quiz No. 1 /

Return to page (9) for the answer.

7/Sources :-

1-Water supply and sewage, E.W. Steel, McGraw-Hill Book Company, Inc., New York , 1960.

2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

3- Principles of water quality control, by T.H.Y. Tebbutt

4- Water Supply, Water Treatment, Dept. of the Army and the air force, Sept. 1985, TM 5-813-3/AFM 88-10, Vol 3l.

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6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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Training Package
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By

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Lecturer
Department of Environment and Pollution Engineering
Technical College/Basrah

September/2011

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SLUDGE DEWATERING

Tenth modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

For many sludge-disposal methods preliminary dewatering is essential if the costs of disposal are to be kept under control and a variety of dewatering methods are employed depending upon land availability and the costs related to the particular situation.

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1 / C –Central Idea :-

1 – Sludge Thickening (Conditioning)

- Gravity thickener
- Air Floatation
- Centrifugation

2 –Sludge drying bed (De-watering)

- Design consideration
- Illustrated problem

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit .
3. Do the pre test and if you :-
    - get 9 or more you do not need to proceed .
    - get less than 9 you have to study this modular unit well .
4. After studying the text of this modular unit ,do the post test , and if you :-
    - get 9 or more , so go on studying modular unit three .
    - get less than 9 , go back and study the second modular unit ; or any part of it ; again and then do the post test again .

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Define sludge conditioning and de-watering.
2. Know the methods of conditioning.
3. Determine the mechanism of thickening.
4. Design the drying bed for sludge de-watering.

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3/ Pre test :-

1. **Enumerates the methods of sludge thickening (conditioning)**
2. **Under flow solid concentration is governed by :-**

a- Sludge blanket b- Detention time

c- Sludge blanket and detention time d- dry heat

3. **The thickeners over flow may have about a B.O.D of 1000 mg/l and 100 mg/l of S.S.:**

a- High BOD b- Low BOD

c- Very high BOD d- Very low BOD

4. **Enumerates the important factors for design of drying beds.**
5. Drying bed can be used where:

a- adequate land is available b- Low population

b- BOD is very high d- SS is very high

Note

- Check your answers in key answer page 13.

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4/ The Text :-

Sludge Thickening (Conditioning):-

This process is adopted for reducing the volume sludge (60% reduction).

This will permit:

1- Increase of loading to the digesters.
2- Increase feed solids concentration to vacuum filters.
3- Minimize the land requirement as well as handling costs when digested sludge has to be disposed of.
4- Sans fuel costs when incineration of sludge is practiced.

1- Gravity Thickener :

Hydraulic Loading ⟶ 20000 to 25000 lpd /m^2 .

Solid Loading ⟶ 40 to 100 Kg/day/m^2

Solid concentration ⟶
- With primary (8-10%)
- With primary+ trickling filter(6- 8%)
- With primary+ activated sludge (2-6%)

Under flow (75% organic) <40% of sludge weight

Under flow solid concentration is governed by:

1- The depth of sludge blanket up to 1m.

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2- Increased with detention time (24 hours required).

Thickeners over flow may have about a B.O.D of 1000 mg/l and 100 mg/l of S.S.

It is necessary to ensure provision for ,

1- Regulated the quantity of dilution water needed
2- Adequate sludge pumping capacity to maintain any desired solids concentration , continuous feed and under flow pumping
3- Production against to rque over load
4- Sludge leaked detention.

2-Air floatation:

This unit employs floatation of sludge by air under pressure or vacuum and are normally used for thickening of waste A.S.

The efficiency of air floatation units is increased by addition of chemicals like alum.

3-Centrifugation :

This method involves high maintenance and power costs. Therefore , it is used only when the space limitation or sludge characteristics will not permit the adoption of the other two methods.

Sludge Drying Bed (Dewatering)

The digested sludge is applied on a well-drained bed and the dried sludge is used as a manure or soil conditioner.

This method can use where adequate land is available.

The dissolved gases in the digested sludge buy up and float the solids leaving a clear liquid at the bottom which drain through the sand rapidly.

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Volume of the sludge, climate, temperature and location are the important factors for design criteria.

Area required
or drying beds range from 0.1 to 0.125 m^2/capita
primary

Dry solid loading $\longrightarrow$ 80-100 Kg/m^2 of bed/year
sludge

Area required $\longrightarrow$ 0.125-0.25 m^2/capita
mixed

Dry solid loading $\longrightarrow$ 60-120 Kg/m^2 of bed /year
sludge
Slope of the bottom $\longrightarrow$ 0.5%
Width $\longrightarrow$ 6-8 m
Length $\longrightarrow$ 30 to 40 m

*Drainage from beds shall be returned to primary settling tank
Duration $\longrightarrow$ 2 weeks
Volume reduction $\longrightarrow$ 20% $\longrightarrow$ 40%
Moisture content $\longrightarrow$ less than 70%
*When moisture content reduced to 40% the cake become higher and suitable for grinding .

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Illusterated Problem:

Design a sludge drying beds for digested sludge from sewage treatment plant with trickling filter serving 200000 populations. The solids in digested sludge from mix primary and trickling filter is (40 gm/c/d).

Assume:-

1) Dry solid loading = 100 kg/m^2/yr
2) Width * length = 8m* 40m
3) Two mouths for rainy season/ year and two weaks for drying one weak for preparation and repair of beds .
4) M.C. of digested sludge = 92%
5) Sp.gr. of digested sludge =1.1

Solution:-

Daily solids = 200000*40gm=8*10^6gm= 8000kg /d

Area of beds = $\frac{8000*365}{100}$ = 29200m^2

Check for per capita area = $\frac{29200}{200000} = 0.146$

(within the range 0.125-0.25)

∴ No. of beds= $\frac{29200}{8*40}$ = 91.25 = 92beds

No. of cycle per year = $\frac{12mouths - 2mouths}{\frac{3}{4}mouths}$ = 13 cycle

Volume of digested sludge = 8000 * $\frac{100}{8}$ * $\frac{1}{1.1}$ * $\frac{1}{1000}$ = 90m^3/d

Depth of application = $\frac{90*365}{92*8*40*13}$ = 0.087m = 8.7 cm

This can be safely increased to $\frac{90*365}{(0.125*200000)*13}$ = 0.1m=10cm

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5/ Post test :-

Design a sludge drying beds for digested sludge from sewage treatment plant with activated sludge serving (150000) population. The solids in digested sludge from mix primary and activated sludge is (30 gm/c/d)

Assume:

i. Dry solid loading= 90 kg/m2/yr.

ii. Width x length=8m x 30m.

iii. Two months for rainy season/year and one week for drying and one week for preparation and maintenance.

iv. Moisture content of digested sludge =93%.

v. Sp. gr. Of digested sludge= 1.09

Find: Area of beds, Number of beds, Number of cycle/year, Volume of digested sludge, Depth of application. Then check the results for drying beds ranges and dry solid loading.

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Note

- Check your answers in key answer page 13.

<u>6/ key answer :-</u>

1- Pre test:-

1. **Gravity thickener, air floatation and centrifugation.**
2. **c**
3. **c**
4. **Volume of the sludge, climate, temperature and location.**
5. **a**

If you :-

- got 9 or more you do not need to proceed .
- got less than 9 you have to study this modular unit well .

2- Post test:-

Daily solids = 150000 x 30 gm = 4.5 x 10^6 gm

= 4500 kg/d

Area of beds = $\frac{4500 \times 365}{90}$ **= 18250 m^2**

Check for per capita area = $\frac{18250}{150000}$ **=0.1216**

Out of the range 0.125 – 0.25

So , Area of beds should be 0.125 x 150000 = 18750 m^2

No. of beds = $\frac{18750}{8 x 30}$ **= 78.125**

= 79 beds

No . of cycle / year = $\frac{12-2}{\frac{1}{2} month}$

= 20 cycle

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Volume of digested sludge = 4500 x $\frac{100}{7}$ x $\frac{1}{1.09}$ x $\frac{1}{1000}$

= 60 m^3 /day

Depth of application

$$= \frac{60 \times 365}{79 \times 8 \times 40 \times 20}$$

= 0.0433 m = 4.33 c m

If you:-

- got 9 or more , so congratulation your performance , go on studying modular unit three .
- got less than 9 , go back and study the second unit ; or any part of it ; again, and then do the post test again .

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Technical College/Basrah

By

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TERTIARY TREATMENT

Eleventh modular unit

1/ Over view

1 / A –Target population :-

For students of forth class

Technical College/Basrah

Department of Environment & Pollution Engineering

Water Pollution Control

1 / B –Rationale :-

Although conventional sewage treatment processes can achieve a considerable degree of purification, this may be insufficient in situations with little dilution or where potable water abstractions or water-based recreational activities occur downstream. In such cases an additional stage of treatment to remove most of the remaining SS and the associated BOD is often stipulated by the regulatory authorities. This type of additional removal is usually termed tertiary treatment. The increasing concern at the accelerated eutrophication of some surface waters has resulted in the development of nutrient removal techniques and the EC urban wastewater treatment directive requires nutrient removal for discharges in sensitive areas.

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1 / C –Central Idea :-

1 - Introduction

2 –Types of tertiary treatment

a - Filtration:

- Rapid filtration
- Slow filtration

b – Micro-straining:

c – Upward – flow clarifier

3 – De-nitrification

4 – Phosphorus removal process

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1 / D –Instructions:-

1. Study over view thoroughly.
2. Identify the goal of this modular unit.
3. Do the pre test and if you :-
    - Get 9 or more you do not need to proceed.
    - Get less than 9 you have to study this modular unit well.
4. After studying the text of this modular unit ,do the post test , and if you :-
    - Get 9 or more, so go on studying modular unit twelve.
    - Get less than 9, go back and study the second modular unit; or any part of it; again and then do the post test again.

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2/ Performance Objectives :-

After studying the second modular unit, the student will be able to:-

1. Defines tertiary treatment.
2. Know the methods of tertiary treatment with the ability to draw a diagram.
3. Determine the mechanism of de-nitrification.
4. Determine the processes necessary of phosphorus removal.

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3/ Pre Test :-

1. **Enumerates four methods used for tertiary treatment.**

2. **The standard product of an effluent is of:**

a- 75% SS b- 30% SS

c- 40% SS d- 90% SS

3. **The main purpose of tertiary treatment is to produce effluent of BOD less than:**

a- 10%% b- 1%

c- 5% d- 20%

4. **Explain the advantages of de-nitrification.**

Note

- Check your answers in key answer page 15.

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4/ The Text :-

Tertiary Treatment (Water reclamation and Re-use)

Although conventional sewage treatment processes can achieve a considerable degree of purification, this may be insufficient in situation with little dilution or where potable water abstractions or water-based recreational activates occur downstream .In such cases an additional stage of treatment to remove most of the remaining SS and the associated BOD is often stipulated by the regulatory authorities .This type of additional removal is usually termed tertiary treatment.

In areas where water resources are limited, Toilet flushing do not need potable water and recycled effluent may be appropriate for a dual supply .Some industrial uses of water can be satisfied quite easily by conventionally or tertiary treated sewage effluent and such source can be perfectly acceptable for irrigation use under carefully controlled conditions.

The removal of dissolved inorganic constituents that are unaffected by conventional water treatment processes.

Quiz / 1

Define tertiary treatment.

Note

- Check your answers in key answer page 15.

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Types of Tertiary Treatment

To produce an effluent of better than 30 mg/L SS and 20 mg/L BOD at time The need for tertiary treatment in a particular situation should therefore be assessed in the light of the circumstances relevant to that situation, i.e. dilution , re-aeration characteristics, downstream water use and water quality objectives for the receiving water .

The BOD determination is by its very nature a somewhat unreliable parameter and BOD standards should be 20,15,10 and exceptionally 5mg/L Most forms of tertiary treatment have been aimed at removal of some of the excess SS in the effluent from a well operated conventional works . Tertiary treatment should be considered as technique for improving the quality of good effluent and not as a method of trying to convert a poor effluent in to a very good –quality discharge.

There are four methods of tertiary (advance) treatment:-

1- Rapid filtration :

This process is frequently employed in large plants .Because of the wide variation in filtration characteristics of suspended matter it is always advisable to carry out experimental work on a particular effluent before proceeding with design work .

It is generally assumed that rapid gravity filters operated at a hydraulic loading of about $200m^3/m^2$ day should remove 65-80 percent SS and 20-35 percent .

BOD from a 30:20 standard effluent . The SS removal is not significantly affected by the hydraulic loading 1.0-2.0 mm grading

2- **Slow filtration**

On small works slow sand filters are some times employed for tertiary treatment at loadings of 2-5 m^3/m^2 day .Remove 60-80 percent SS and 30-50 percent BOD . Slow filters provide a significant amount of biological activity , thus encouraging BOD removal and providing a degree of nitrification .

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In addition they can provide significant removals of bacteria and other microorganisms .

3- Micro straining :

Removals of SS and BOD depend upon the mesh size of the fabric used and the filterability characteristics of the suspended matter . Reported removals range from 35 to 75 percent SS and 12 to 50 percent BOD . Micro straining should reliably give an effluent of 15 mg/L SS , and 10 mg/L SS should be possible with a good final tank effluent . Typical filtration rates are 400-600 m^3/m^2 day

4- **Upward – flow clarifier**

Surface overflow rates of 15-25 m^3/m^2 day. Removals of 30-50 percent SS can be achieved, dependent upon the size of gravel and the type of solids.

It will be clear from forgoing comments that to obtain a wholesome potable supply of water from heavily polluted sources such as sewage effluent, conventional water treatment alone is not sufficient. To achieve the desired end quality a number of alterative courses of action could be adopted, as listed below:-

1-Provide additional treatment stages at wastewater and/or water treatment plants to deal with contaminants not affected by normal treatment.

2-Provide a completely new form of wastewater and/or water treatment

3-Use conventional treatment processes and blend the finished water with another water of higher quality so that the mixture is of acceptable quality.

4-Dispense with separate wastewater and water treatment facilities (and the intervening receiving water) and introduce an integrated water reclamation facilities.

Completely closed –cycles system for water and wastewater are of considerable interest in space – vehicle development ,but in this application costs are of secondary importance .

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It would thus seem likely that for large – scale use of wastewater as a raw water source the first and third courses of action are most likely to have the greatest application .

Dissolved organics

More substantial removal of soluble organics can be achieved by adsorption on activated carbon .Both powdered and granular forms of activated carbon can be employed to give relatively high removal of COD and TOC . Powdered carbon may be satisfactory with the addition being made to the coagulation sedimentation stage or to the filters . Where continuous use of activated carbon is necessary the granular form is more appropriate and provision must be made for regeneration either on-site or in a central facility . As well as reducing COD and TOC levels. Activated carbon treatment is usually also able to give significant reductions in the color and in the taste and odour of waters. Ozone can break down complex organics such as pesticides either into inorganic end products or into simpler organic compounds which are more readily removed by biological oxidation or by activated carbon treatment.

Dissolved solids

Ground waters are found with TDS levels in excess of those acceptable in potable supplies and in arid areas these ground waters or seawater may be the only available source of water . Sea water has a TDS level of around 35000mg/L whereas the TDS levels of most effluents are around 1000mg/L. The distillation of seawater in evaporation has long been an accepted procedure for obtaining high-purity water although the finished product is not acceptable for drinking water until it has been aerated and chemically treated .Depends upon the phenomenon of osmosis in which certain types of membrane will permit the passage of freshwater whilst preventing or restricting the movement of soluble material.

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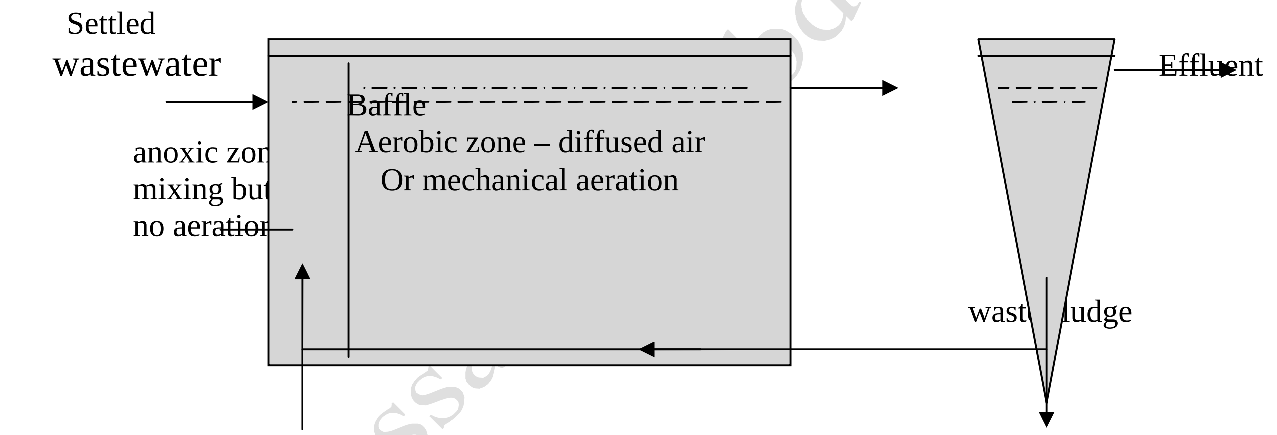
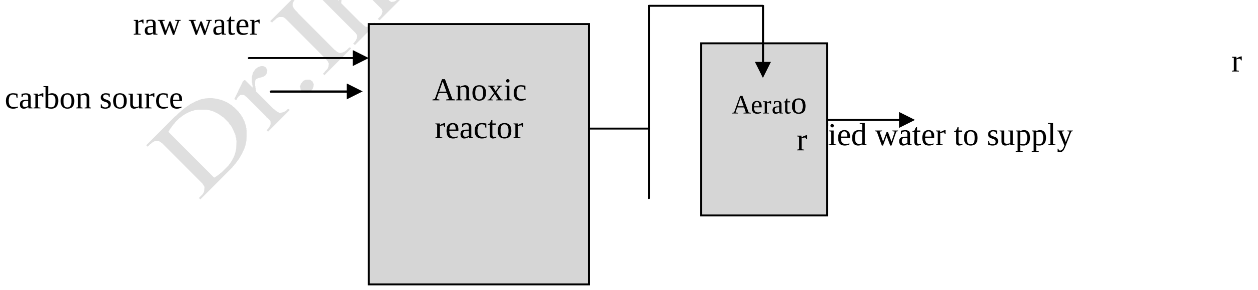
Nitrogen Compounds

The amount of ammonia present in sewage effluent can be reduced to low levels by biological nitrification either at the sewage works before discharge to the receiving water , which will prevent fish toxicity problems, or by pretreatment at the water works . The ammonia is of course oxidation to nitrate which is undesirable in other than small amount in raw water supplies Air stripping of ammonia can give good removals but tends to be very costly because of the large air flows required and the chemicals necessary to produce the high PH . Ion exchange using clinoptilolite to remove ammonia is possible although the exchange capacity of the material is relatively low . High removals of nitrate produced by biological nitrification .



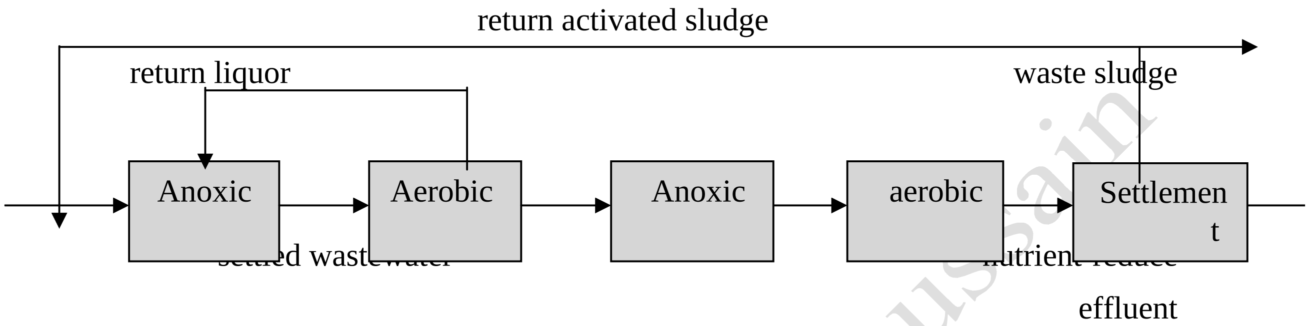
De-nitrification of wastewater



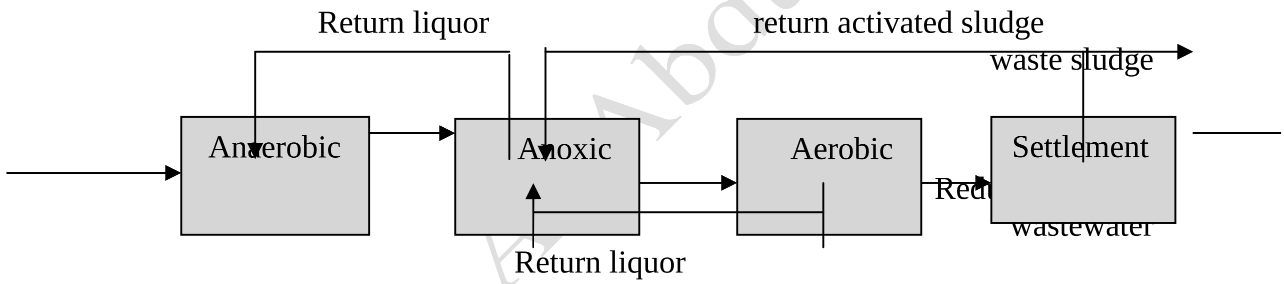
denitrification of drinking water

Phosphates

phosphate in wastewater effluents are normally present as orthophosphate and can be fairly easily removed by chemical precipitation with aluminum or iron salts .



Bardenpho nitrogen and phosphorus removal process



UCT nitrogen and phosphorus removal process

Microorganisms

Membrane treatment can provide a very high degree of removal of microorganisms from reclaimed waters .

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5/ Post Test :-

1- Explain and draw nitrogen and phosphorus removal process.
2- Explain and draw the de-nitrification of drinking water.

Note

- Check your answers in key answer page 15.

6/ key answer :-

1- Pre test :-

1. Rapid filtration, slow filtration, micro straining and upward flow clarifier.
2. b
3. d
4. The effluent is aerated to provide dissolved oxygen and to drive off entrained nitrogen, and the sludge recycled to the contact tank.

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If you :-

- got 9 or more you do not need to proceed .
- got less than 9 you have to study this modular unit well .

2- Post test :-

1- Return to page (12) for the answer.
2- Return to page (13) for the answer.

If you :-

- got 9 or more , so congratulation your performance , go on studying modular unit three .
- got less than 9 , go back and study the second unit ; or any part of it ; again, and then do the post test again .

Quiz No. 1 /
Return to page (9) for the answer.

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7/Sources :-

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2- Water supply, Waste Disposal and Environmental Engineering, by A.K.Chatterjee

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5- Handbook of Water and Wastewater Treatment Plant Operations, Frank R. Spellman, Lewis Publishers, 2003.

6- Manual on Sewerage and Sewage Treatment, Ministry of Urban Development, New Delhi, Dec., 1993.

7- Water and Sanitary Engineering, Rangwalla, Charotar Pub. House, India, 2006.

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