**Ministry of high Education and Scientific Research**
**Southern Technical University**
**Basrah Engineering Technical College**

# Clarification

**For**

Students of forth class

Water Pollution Control

Environment and Pollution Engineering Department

**By**

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# CLARIFICATION (SEDIMENTATION)

## Third modular unit

## 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 settleable solids and the concentration of the removed solids into a smaller volume of sludge.



## 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

5 – Illustrated Problems

# The Text :-

## Sedimentation :-

### Purpose:

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

Sedimentation is used in waste water treatment to remove:

(i) Inorganic 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.

## 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 are 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 $\longrightarrow$ 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).

## 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**

↙ ↘

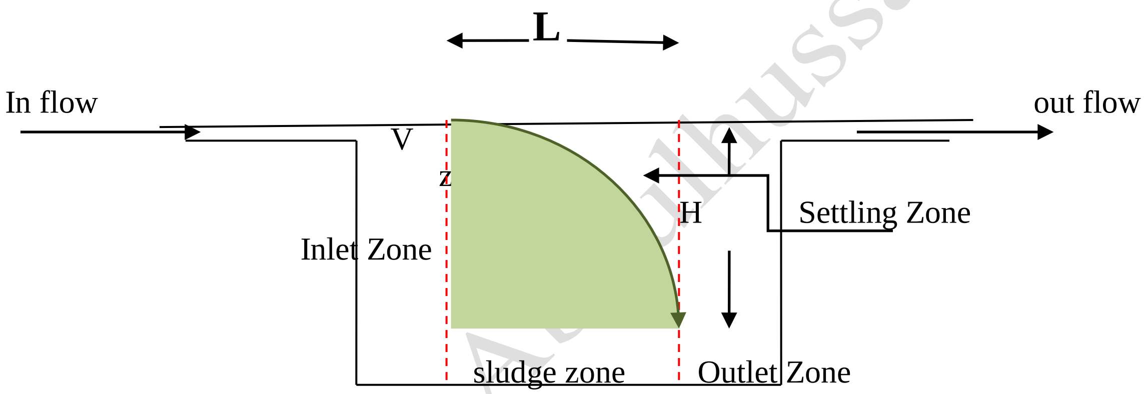
Surface overflow rate (S.O.R) — Detention period (H.R.T)

**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 $m^3/m^2/d$




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.
$V_s$: Settling velocity.
The quantity of water flow through the tank is

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

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

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

For economic condition $\frac{H}{V_s} = \frac{L}{V}$

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

Substituting in equation (1) we get:

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

$\therefore$ $V_s = \frac{Q}{B.L} = \frac{Q}{A} = \frac{Tank\ discharge}{Plan\ Area}$ =S.O.R=Surface Loading

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

## (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.**

## (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 $\frac{Kg}{m^2.d}$

For peak flow $\longrightarrow$ ranges from 170 to 210 $\frac{Kg}{m^2.d}$

## (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 equal to 0.04 for sandy materials and equal to 0.06 for sticky flocculants materials. Displacement velocity of flow is 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. Assume the tank depth is 3.5 m and kinematic viscosity $\gamma$ =5.81*$10^{-7}$ $m^2$/s.

**Solution:**

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

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

$V_{s=}\frac{9.81}{18}$ (2.65-1) $((0.02*10^{-3}\ )^2\ /5.81*10^{-7})$=0.000619 m/s

$V_s \cong 0.62$ mm/s

$\therefore$ Surface loading = $V_s = \frac{0.62*24*60*60}{1000} = 53.5\ \frac{m^3}{m^2.d}$

$\therefore$ The time required for settling

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

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

**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 $\gamma = 1.012*10^{-2}$ $cm^2/s$.

**Solution:**

$V_s = \frac{g}{18}$ (Ss-1).( $d^2/\gamma$)= $\frac{981}{18}$ (2.65-1)$((5*10^{-3})^2/1.012*10^{-2})$= 0.222cm/s

$V_s = \frac{981}{18}$ (0.8-1) $((5*10^{-3})^{-2}/(1.012*10^{-2})$= - 0.0269 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 $lpd/m^2$ and kinematic viscosity $\gamma = 1.011*10^{-2}$ $cm^2/s$.

**Solution:**

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

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

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

For $\eta$=80% and n=0.125

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

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

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

Thus, settling velocity= $V_s$= 0.103 cm/s

0.1=$V_s$=$\frac{g}{18}$ ($S_S$-1).d$^2$/ ɣ =$\frac{981}{18}$ (1.2-1) d$^2$/1.011*10$^{-2}$

∴Diameter of particles=d=0.0099 cm = 0.099 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

*No. of units (tanks)=2

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 $m^3$

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

Provide two tanks of 14.5 m diameter 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 $m^3/m^2$/d (safe)

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

Sludge produced=(4*12000000)/$10^6$=48 $m^3$/day

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

# Test 1:-

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, width 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

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.

# Test 2:-

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.

## Note

- Check your answers in key answer.

# key answer :-

## 1- Test 1:-

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- Test 2:-

**Solution:**

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

2- $\therefore$ 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

W.O.R=$\frac{Q}{\Pi d}$ = ($10x10^3/\Pi x20.6$) = 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

$\frac{1}{Ss}=\frac{0.7}{1}+\frac{0.3}{2.5}$ ∴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=$\frac{Ms}{Pw.Ssl.Ps}$

Here, Pw=1000 kg/$m^3$          Ps= 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=0.024 for concrete

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

10- $0.3=\frac{1}{0.024}x(0.153)^{2/3}.S^{1/2}$

$\therefore S=0.0003737$

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 .

# References:-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