Ministry of Higher Education and Scientific Research
Southern Technical University
Engineering Technical College / Basrah

Water Quality Control

For

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

By

Dr. Ihsan A. Abdulhussein
Assistant Prof.
Department of Environment and Pollution Engineering
Engineering Technical College/Basrah

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SEDIMENTATION AIDED WITH COAGULATION

Forth modular unit

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.

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 Problems

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.

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 to settle down.

b- Properties of common coagulants:

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

(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

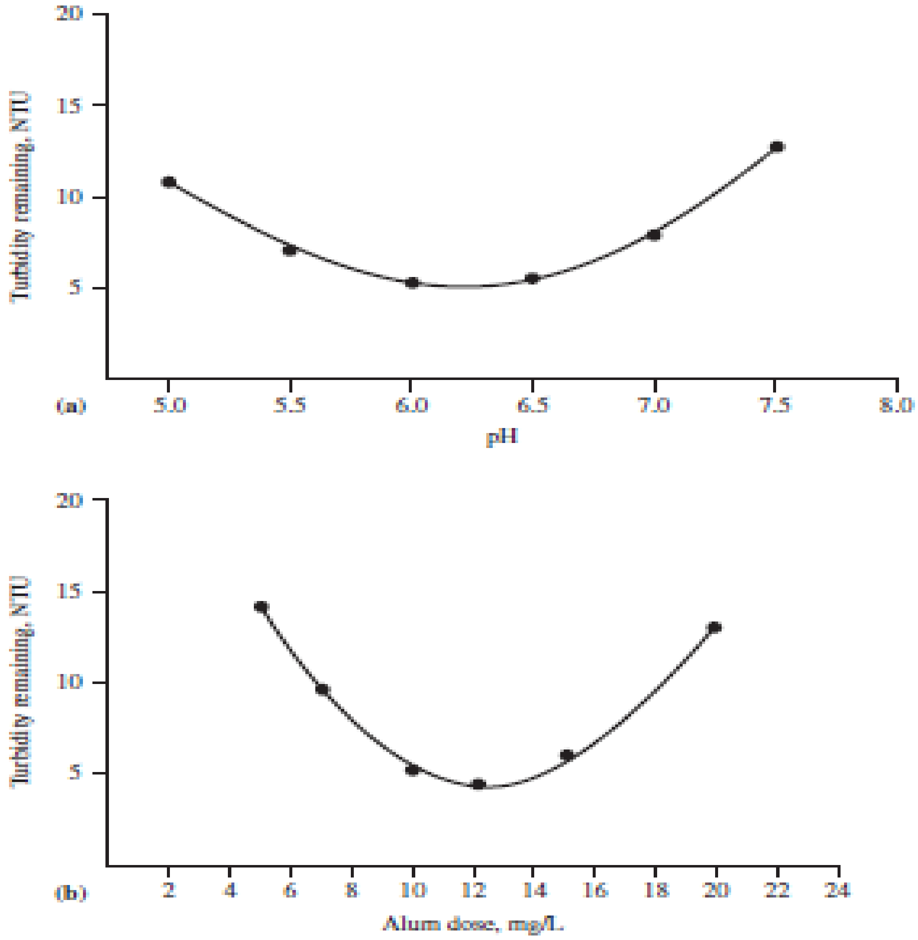
2- Sodium Aluminate ($Na_2Al_2o_4$)

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.

Six beakers are filled with the raw water, and then each is mixed and flocculated uniformly by identical paddle stirrers driven by a single motor (a gang stirrer). A typical test is conducted by first dosing each jar with the same alum dose and varying the pH in each jar. The test is then repeated in a second set of jars by holding the pH constant at the optimum pH and varying the coagulant dose. The amount of coagulants is increased stepwise, and all jars are mixed simultaneously for 10 to 30 minutes. The jar in which flock and gives minimum turbidity is assumed to have received the most economical dose.



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.

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 rpm.

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 settleable 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".

$$G = \{\frac{P}{\mu * V}\}^{1/2}$$

Where, P= Power dissipated in water in kW

V= Volume of tank (m^3)

μ= 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:

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

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)

ρ= density of water

$(V-\gamma)$= relative velocity of impeller and fluid in mps

V_r is taken as 0.5 m/s and γ is 25% of V_r

A= area of impeller blade in m^2 (10 ⟶ 25% tank area)

Design Criteria for Sedimentation-Flocculator

Rotation of turbo flash mixer = 100 rpm

Rotation of puddles in flocculation tank = 1 to 3 rpm

Velocity of water through flocculator Tank = 15 to 20 cm/s

Detention time in flocculator Tank = 30 to 60 min.
Detention time in sedimentation Tank = 1.5 to 3 hrs.
S.O.R sedimentation Tank = 50 -----------70 $m^3/m^2/d$
W.O.R sedimentation Tank ≤ 200 $m^3/m/d$

Illusterated Problem

Problem 1: A water treatment plant treats 250 m^3/hr. of water. Workout the followings with respect to a flocculator.

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

Assume:
1- Absolute viscosity=0.89×10^{-3} N/m. s
2- D.T=30 minutes
3- Velocity of inlet pipe = 1.2 m/s
4- S.W.D= 3m
5- G=40 sec^{-1}
6- Freeboard= 0.3 m

Assume other data suitably. Draw the sketch of the flocculator 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 $=\frac{250}{3600 \times 1.2}=0.058\ m^2$

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

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

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

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

$D = 7.3$ m

Provide tank dia. $= 7.5$m

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

Assuming $G = 40\ sec^{-1}$

$P = (40)^2 x (0.89 x 10^{-3}) x 125 = 178$ W/s

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

Where $C_d = 1.8$

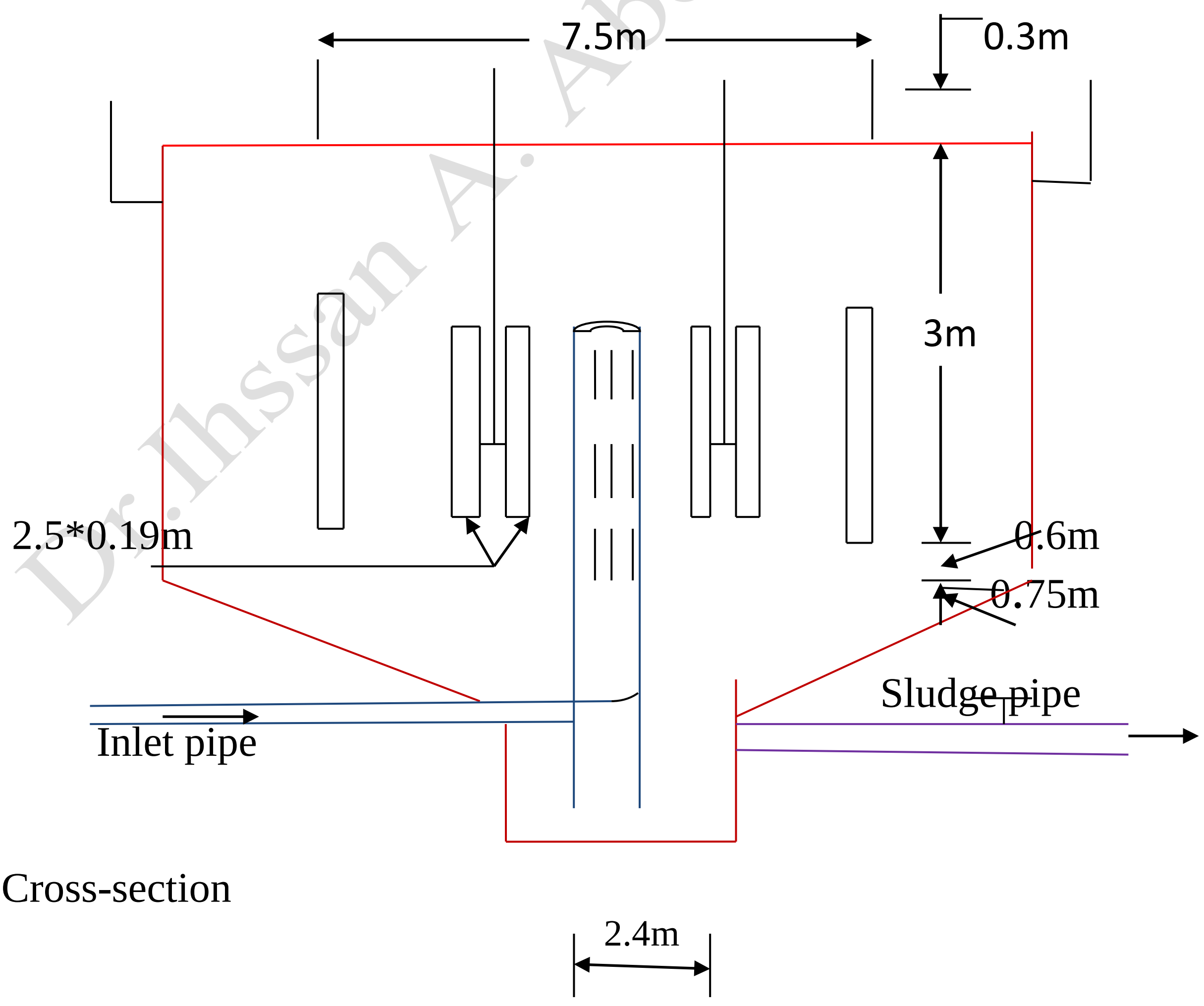
V_r=Velocity of tip of paddle=0.5m/s (assumed)

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

$V_r - \gamma = (0.5 - 0.25 x 0.5) = 0.375$ m/s

$\rho = 1000\ kg/m^3$

$\therefore \quad 178 = \frac{1}{2} x 1.8 x (A) x (1000) x (0.375)^3$



Cross-section

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

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

Thus total Nos. of paddles=8

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

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 =0.3+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.

Problem 2: Design a cylindrical flash mixing basin by determining the basin volume, diameter, dimensions, and required input power using the following parameters:

Flow rate= $11.5*10^3$ m^3/day

Rapid mix time= 5 sec.

Rapid mix G= 600 sec^{-1}

Absolute viscosity= $1.519*10^{-3}$ N/m. s

Height =2 Diameter: Place impeller at one-third the water depth.

Solution:

a. Convert 11.5 X 10^3 m^3/d to m^3/s

$$\frac{11.5*10^3\ m^3/d}{(86400\frac{s}{d})} = 0.133\ m^3/s$$

b. Determine the volume of the rapid mixed basin

V=Q.t=(0.133 m^3/s)(5 s)=0.665 m^3

c. Using the radial impeller guidance from Table 4-1, assume H/T=2.0, that is H=2T. For a round mixing tank

$V = \frac{\pi\ (T)^2}{4}\ (2T)$ and $T = \{\frac{(4)(0.665\ m^3\ )}{2\pi}\}^{(1/3)}$=0.751 or 0.75 m

And H=2(0.75m)=1.5 m

And because impeller is at 1/3 water depth

Position=(0.333)(1.5m)=0.5 m from base

d. The required input water power can be calculated by using the following Equation and assuming that $\mu = 1.519\ X\ 10^{-3}\ \ Pa.s.$

P=(600 s^{-1})^2 (1.519*10^{-3} N/m. s) (0.665 m^3)=363.6 W

Because the efficiency of the transfer of motor power is about 80%, the motor power should be

$$Motor\ Power = \frac{363.6\ W}{0.8} = 450\ W$$

TABLE 4-1

Tank and impeller geometries for mixing

Geometric ratio	Range
D/*T* (radial)	0.14–0.5
D/*T* (axial)	0.17–0.4
H/*D* (either)	2–4
H/*T* (axial)	0.34–1.6
H/*T* (radial)	0.28–2
B/*D* (either)	0.7–1.6

Where,

D = impeller diameter

T= equivalent tank diameter= $\left(\frac{4A}{\pi}\right)^{0.5}$

A= the plan area

H = water depth

B = water depth below the impeller

Test 1:-

Circle the correct answer:-

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

a- Acidity and hardness   b- Alkalinity and hardness

c- Sulphates and Sulphites   d- Carbonates and bicarbonates

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

a- to settle suspended materials   b- to remove the Bacteria's

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

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

Note

- Check your answers in key answer.

- (1) degree for each .

Test 2:-

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 m/s (average 0.3 to 0.4 m/s) .

(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 m/s to 1.5 m/s.

(l) Outlet velocity = 0.3 to 1 m/s.

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

Note

- Check your answers in key answer.

- (1) degree for each .

key answer :-

1- Test 1:-

1. a
2. c
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- Test 2:-

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)

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 m/s

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 .

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