ENVIRONMENTAL ENGINEERING -1

Lecture 14 – Coagulation & Flocculation

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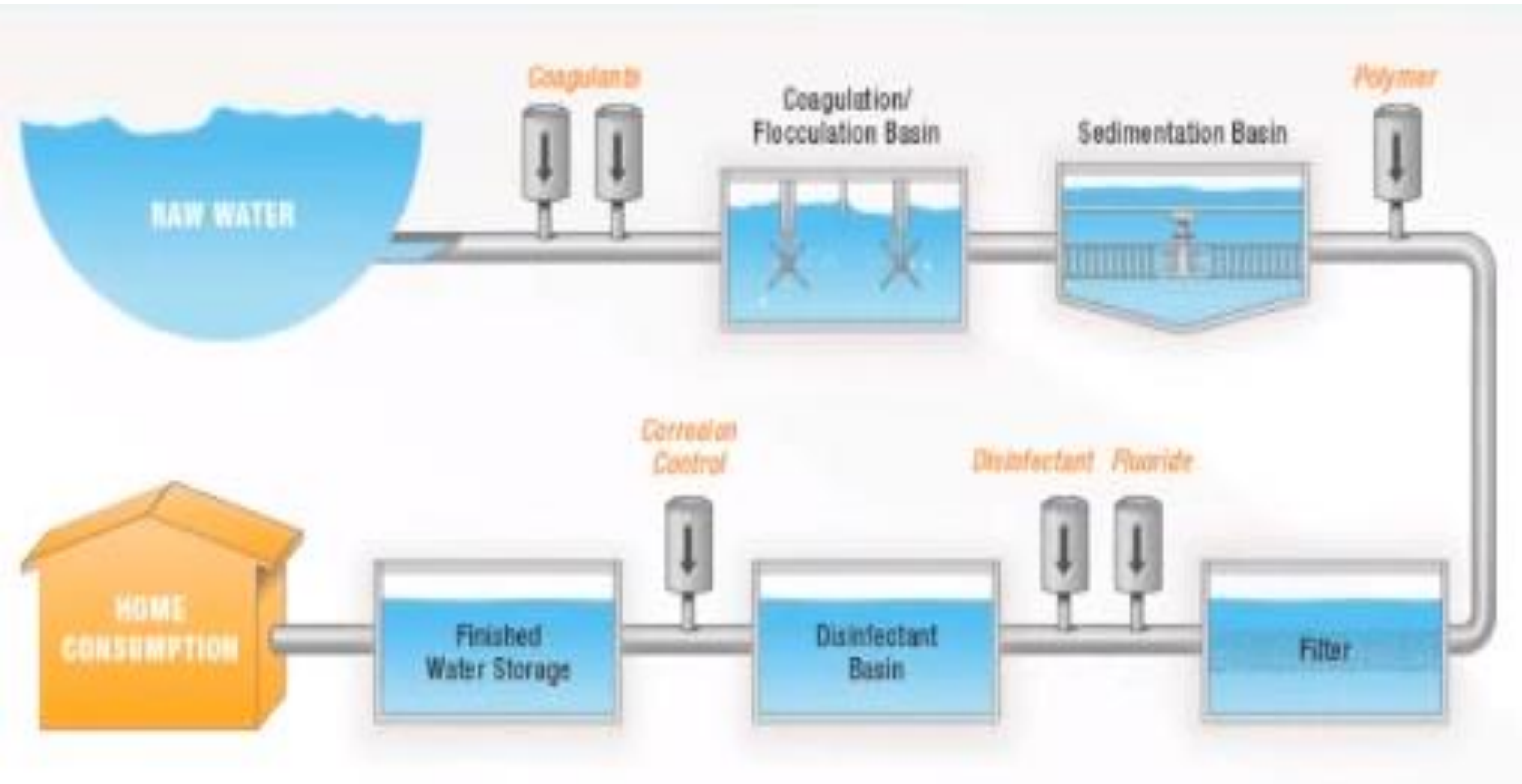
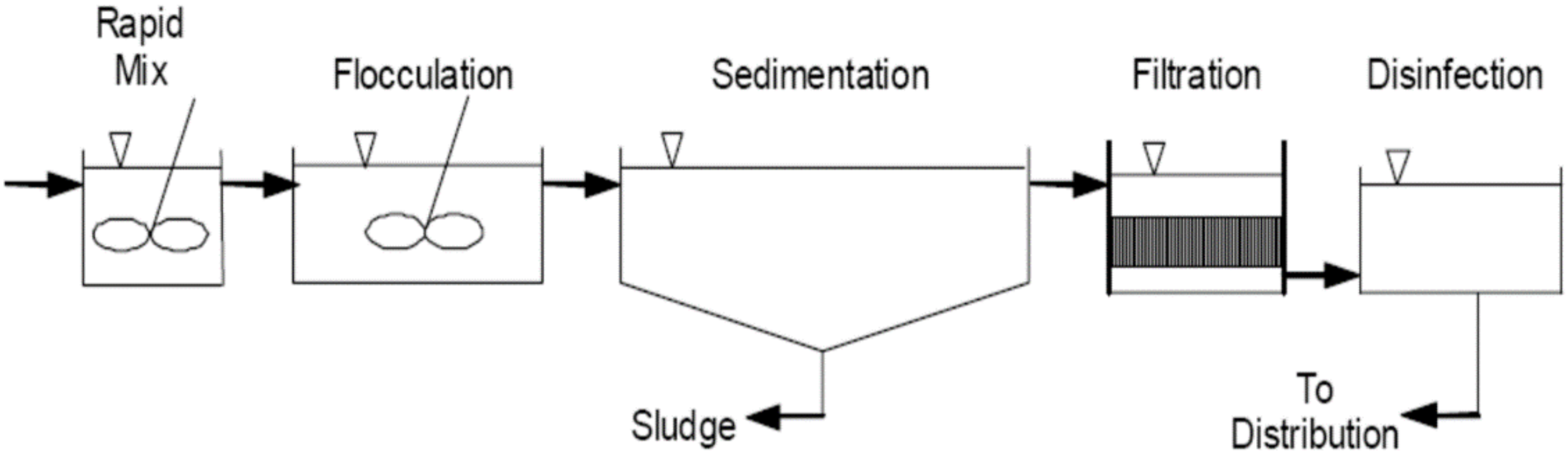

Coagulants
Coagulation/
Flocculation Basin
Sedimentation Basin
Polymer
RAW WATER
Corrosion
Control
Disinfectant
Fluoride
HOME
CONSUMPTION
Finished
Water Storage
Disinfectant
Basin
Filter

Convectional Surface Water Treatment for Drinking Water



Definition

- In Water Treatment coagulation is a chemical technique for the destabilization of colloidal particles. The size of particles remains between 0.1-10µm .
- Mostly colloidal particles in natural water are negatively charge and thus remain in suspension in water due to mutual repulsion

Why Colloidal Particles do not settle?

1. They have a large ratio of surface area to volume. Now as you increase the surface area of an object it tends to float in water
2. Mostly Colloidal particles are negatively charged , this cause particles to remain in suspension

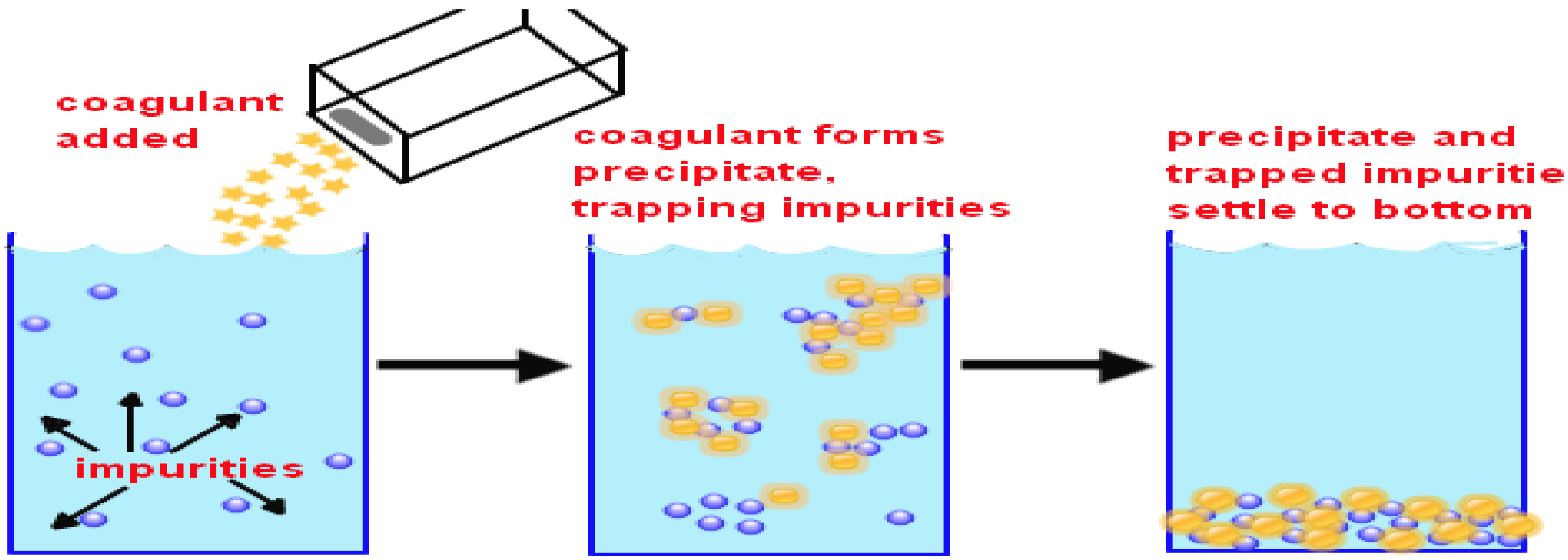
How to remove Colloidal Particles?

1. **Coagulation + Rapid Mixing**

Destabilize the particle by neutralizing the –ve charge

2. **Flocculation(Slow Mixing)**

Use some technique to increase particle size so that settlement under gravity can take place.



How to remove Colloidal Particles?

- **Coagulant :** A chemical which is added to the water during coagulation process in order to destabilized the charge on particle and increase the size of particle to settle under gravity

Coagulant	pH range	Common use
Alum $Al_2(SO_4)_3$	4.0-7.0	Munciplal water supplies
Ferrus sulphate	>8.5	Industrial water
Ferric chloride	3.6-6.5>8.5	Industrial water
Ferric sulphate	3.5-7 >9	Industrial water

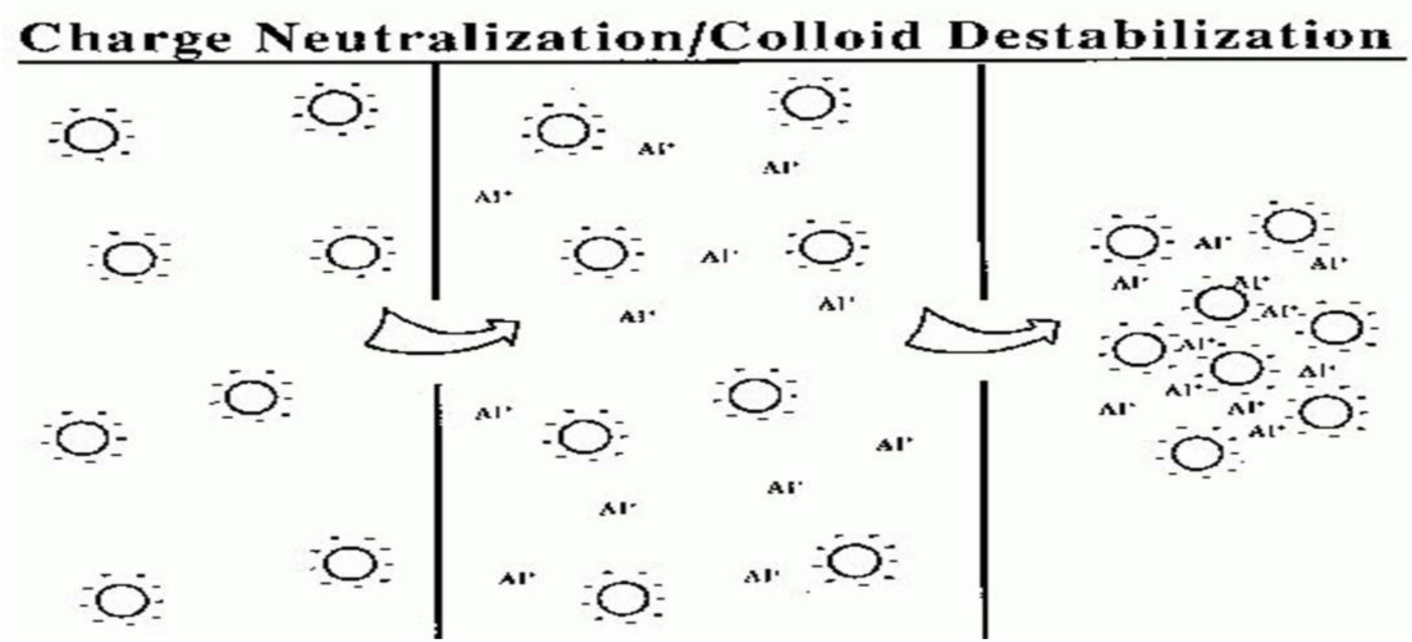
How Coagulants act?

1. Alum $Al_2(SO_4)_3.18H_2O$ dissociate in water to form Al^{+3} ion and SO_4^{-2} ions.

$$Al_2(SO_4)_3 \,.\, 18\, H_2O \rightarrow 2Al^{+3} + 3SO_4^{-2}$$

2. Al^{+3} ions combine with negatively charged collides to reduce their –ve charge.
3. Hydrolysis of Alum result in formation of a $Al(OH)_3$ and Hydrogen ions

$$Al_2(SO_4)_3.18H_2O + 6\, H_2O \rightarrow 2Al(OH)_3 + 3SO_4^{-2} + 18H_2O + 6H^+$$



Use of lime

- Hydrolysis of alum produces **H^+** (pH drop)
- Stops formation of **$Al(OH)_3$**
- Natural alkalinity acts as buffer

$Al_2(SO_4)_3.18H_2O + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 18H_2O + 6CO_2$

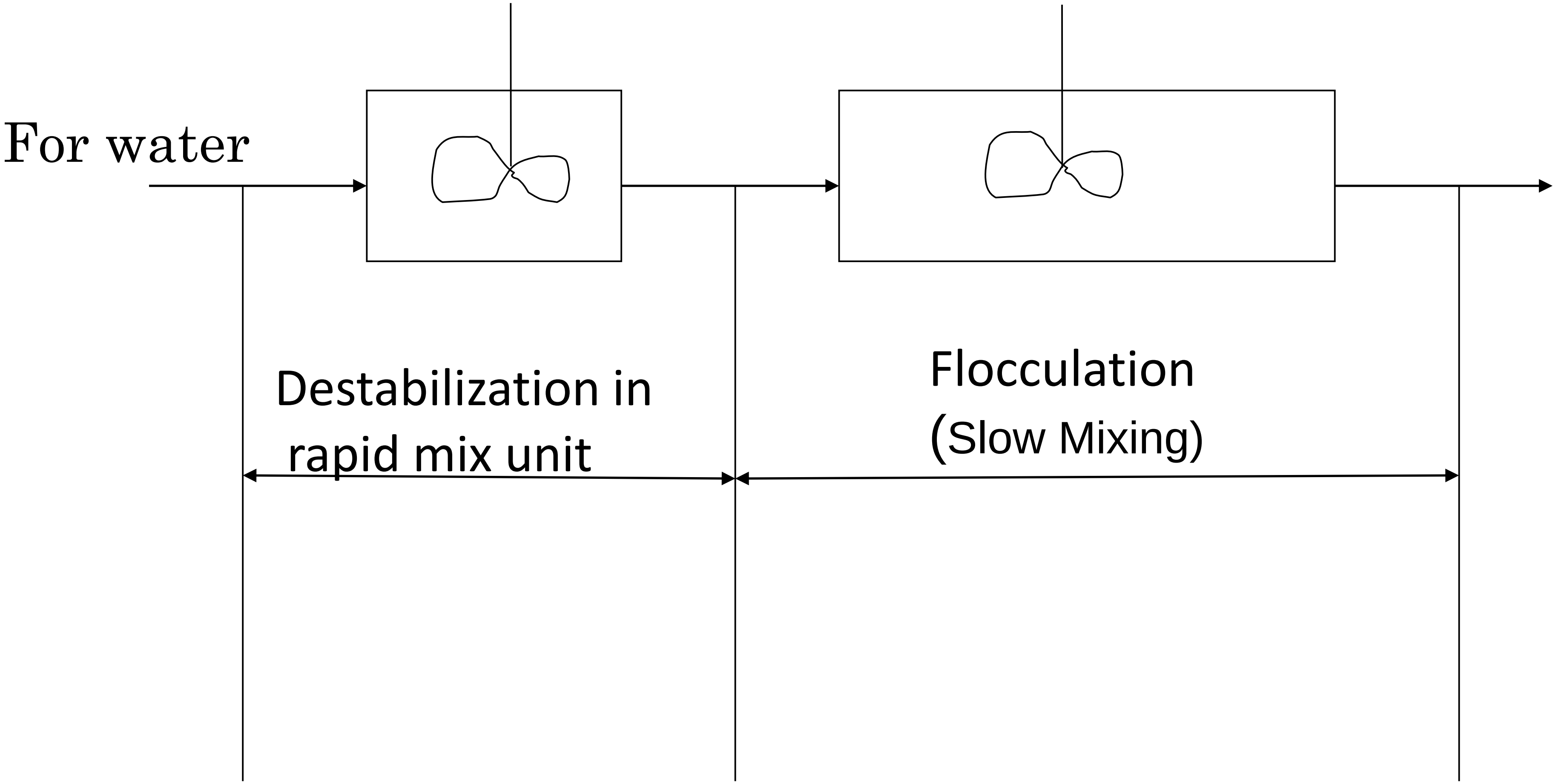
(600) (3x100)

$Al_2(SO_4)_3.18H_2O + 3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 18H_2O$

(600) (3x100) Lime

- For each 1mg/l of alum, 0.5mg/l of alkalinity are required

Coagulation-flocculation unit



VELOCITY GRADIENT "G"

- G is defined as the slope of relative velocity between fluid elements OR rate of change of fluid velocity normal to the direction of velocity
- G is a measure of INTENSITY OF MIXING
- $G = (V_1 - V_2)/O$

- Flocculation results from the velocity differences in the water which causes contact between the moving floc masses. Velocity differences also cause SHEARING STRESSES along planes in the water.

Coagulation in water treatment plant-Flash mixer

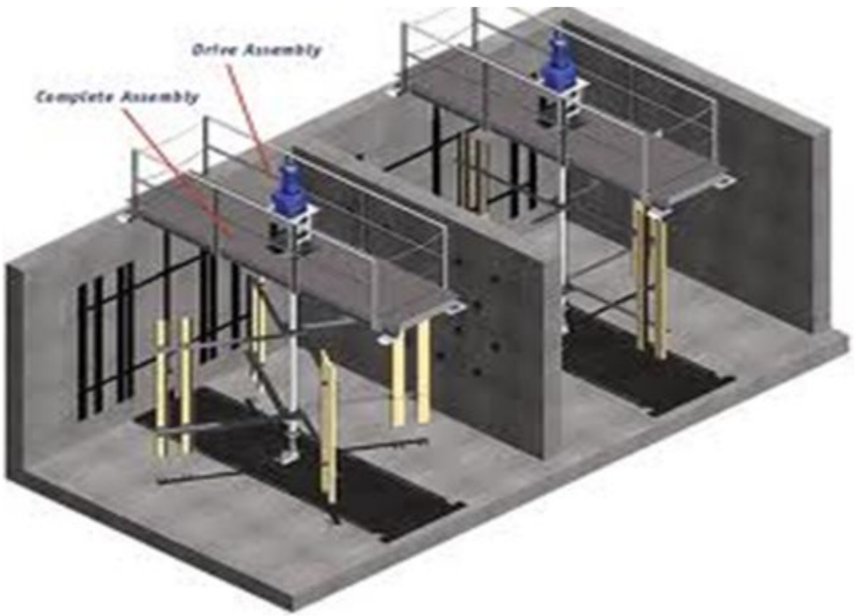
- Coagulation done by **FLASH MIXING**
- **RAPID MIXING** of coagulant to give good distribution of the chemical (require a high degree of turbulence and power dissipation) methods used for flash mixing.

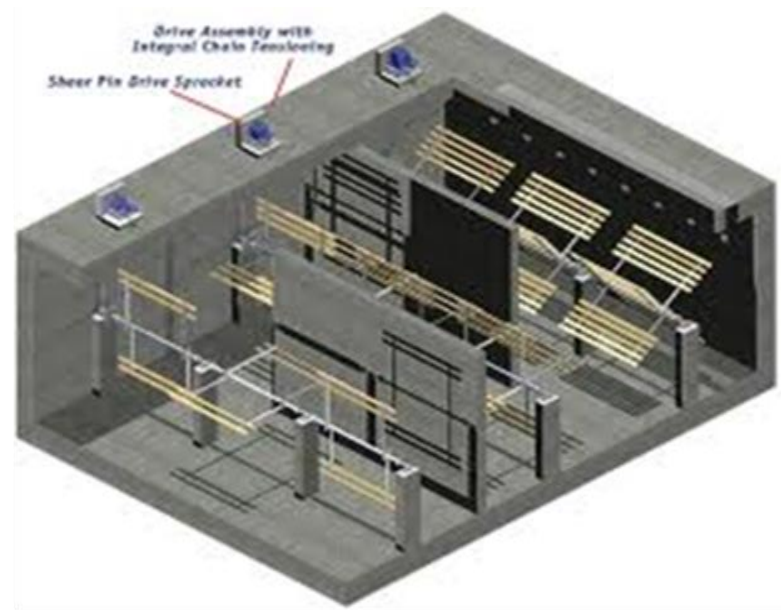
1. Hydraulic jump
2. Paddle mixers

Detention time	10-20 seconds
Speed of Rotation	150 to 1500 rpm
Power Required	2 to 5 kW per m^3/min.
Velocity Gradient:	300 - 500 sec^{-1}

Flocculation

- Slow mixing process
- Bring destabilized particles in contact to form flocs
- Circular tanks with paddles on vertical shaft
- Rectangular tanks with paddles revolving on horizontal shaft
- Area of paddle=10-20% vertical X-sectional area of tank





Type of Flocculators

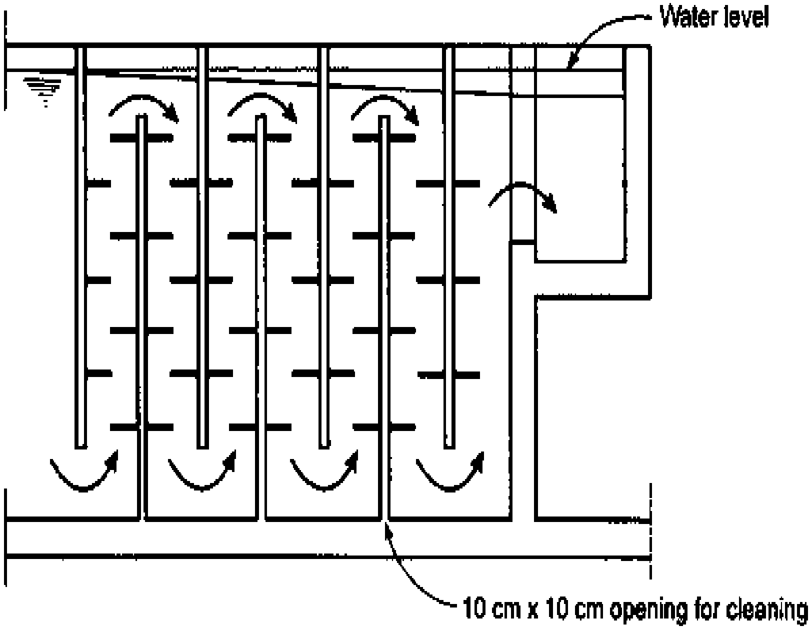
1. Baffled Flocculator
2. Mechanical Flocculator

Baffled Flocculator

- In these basin baffles are placed at 0.75-1m apart. These are seldom employed these days

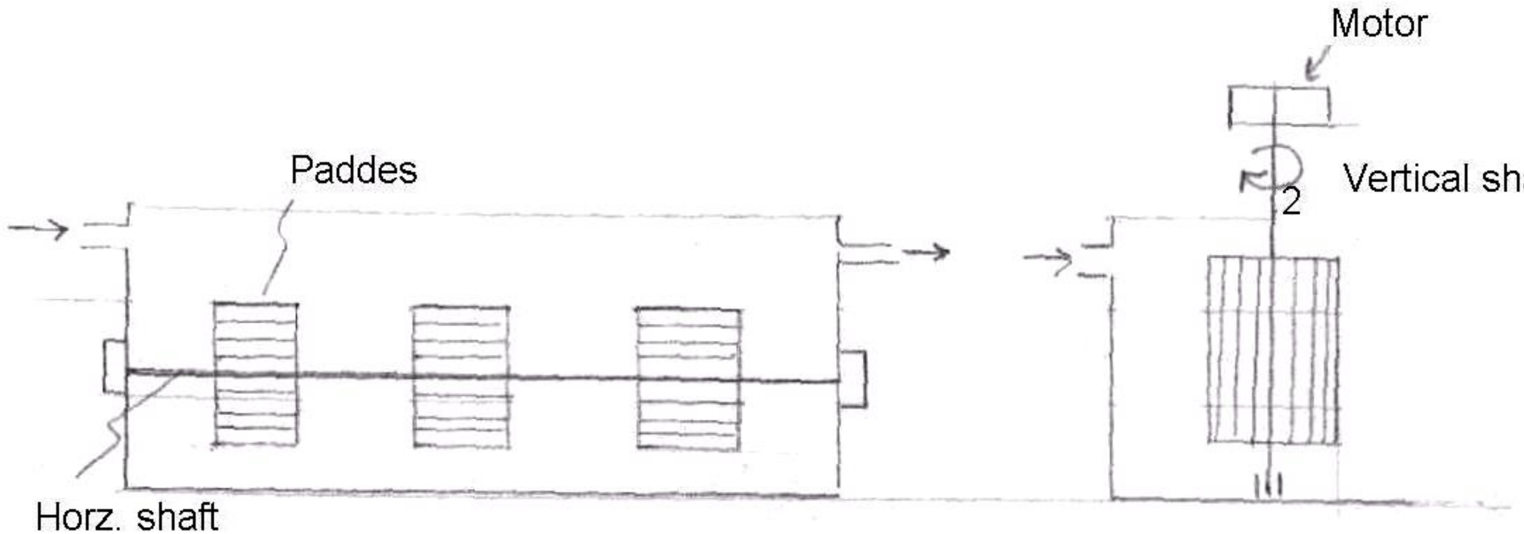
<u>Major disadvantage includes:</u>

- Greater loss of head
- High construction Cost
- No flexibility of operation



Mechanical Flocculator

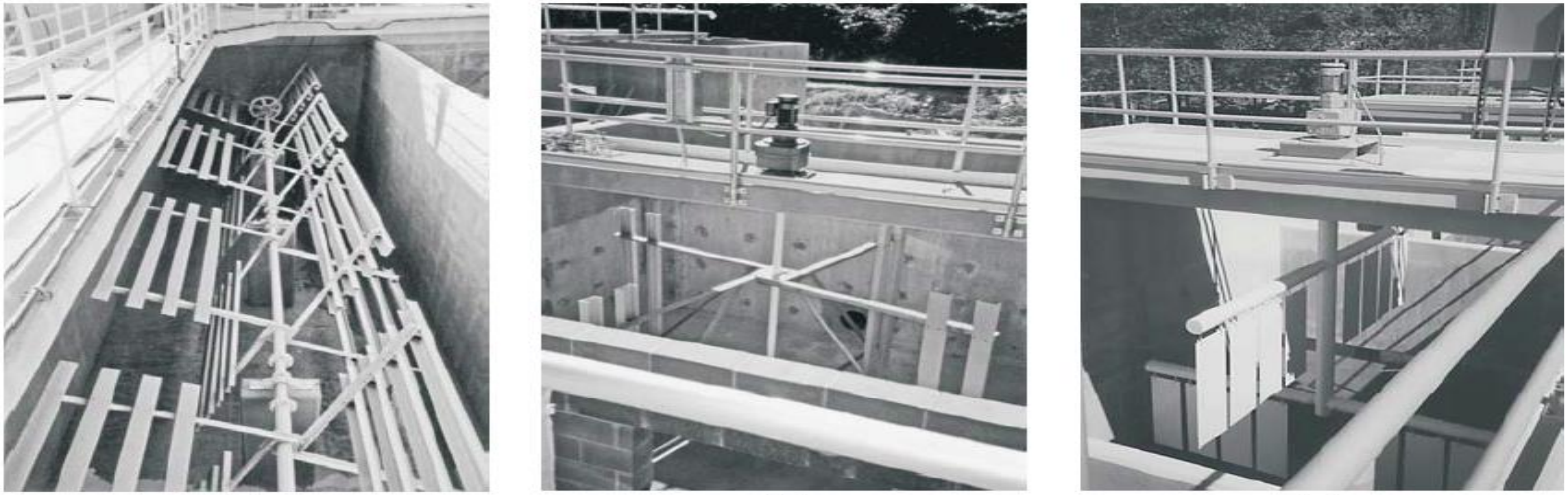
- Their use is very common.
- Mechanical flocculator can have arrangement either in a circular tank with paddles rotating or vertical shaft or rectangular tank with paddle revolving a horizontal shaft.
- Area of each paddle 10 -20 % of vertical X-section area of basin



Mechanical Flocculator

- They have following three advantages

1. More Flexible in operation
2. No loss of head
3. Low cost installation



(a) (b) (c)

Figure 9-39
Views of paddle flocculators: (*a*) horizontal paddle wheel arrangement and (*b*) and (*c*) vertical paddle arrangements. (Courtesy AMWELL A Division of McNish Corp.)

Quantity of Coagulant

- Quantities of chemical coagulants requires very greatly from as low as 1 mg/L to 100 mg/L depending upon the raw water characteristics. This required quantity can however be determined in lab through jar test.

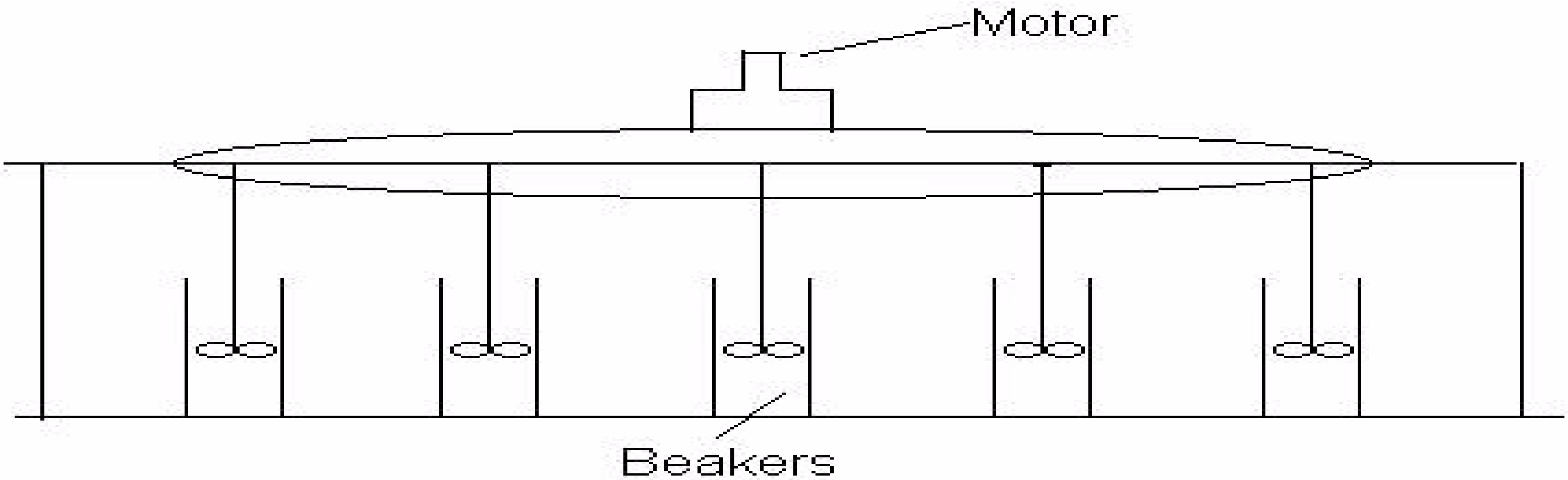
Jar Test

- It is used to determine

1. Optimum coagulant dose

2. Best mixing speed

3. Best mixing timings for a particular water


Motor
Beakers

Jar Test Procedure

1.Measure pH, turbidity and alkalinity of raw water.

2.Take 4 or 5 beakers and add 1 litre of sample water to each.

3.Add varying doses of coagulants(alum0 in different beakers and rapidly mix at 100-300 rpm for desire time (usually up to 30-60 sec).

4.Reduce the speed of machine up to 15-20 rpm and gently mix for 15-30 min.

5.Stop stirring and settle the sample for at least 30 min.

6. Analyze the samples, measure its pH,turbidity and alkalinity. If pH is in desired range the beaker corresponding to lowest turbidity give the optimum dose of coagulant (if pH is not in range 4-7 adjust pH and repeat the test).

Design Criteria

- Rapid → DT=30-60 sec

  G= 100-300 /sec

- Flocculation → DT=20-30 min

  G=10-100 /sec

DESIGN OF FLOCCULATORS

- The design of FLOCCULATORS is generally based upon G

$$G = \sqrt{\frac{P}{\mu V}}$$

- Where

P = Power Input, Kgm^2/sec^3 (Watts)

μ = absolute viscosity, kg/m.sec

V = volume of tank, m^3

DESIGN OF FLOCCULATORS

$$P = \frac{C_d \rho V^3 A}{2}$$

for rotating paddles

Where

C_D = Drag co-efficient 1.8 to 1.5 for paddles.

A = Total area of paddles, m^2

P = Mass density of fluid, Kg/m^3

V_r = Relative velocity or velocity differential of paddles in water, usually about 0.7 – 0.75 – 0.8 of paddle speed, m/sec

Velocity of paddle =2πrn (n=distance of centreline of the paddle from shaft;r=revolution of paddle /second)

DESIGN OF FLOCCULATORS

$$\sqrt{\frac{g\,H}{\nu\,t_d}}$$

Where

ν = kinematic viscosity, m^2/sec

t_d = detention time in the flocculator, sec

H = Head losses in flocculator, m

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

Numericals

1. Determine the theoretical power required to achieve a G value of 50 per sec in an tank with volume of 2800m3.Assume μ as 1.07×10^{-3} N-sec/m^2 at 20°C.
2. A plant treating 30000m^3/d of water uses 13 mg/L of $Al_2(SO_4).18H_2O$.Calculate the daily chemical consumption and the required dosage of $Ca(OH)_2$ (lime) assuming that there is no alkalinity present in water.
3. A 0.6kW mixer unit is used to mix the chemical of a water flow of 70 l/s. The td in tank is 20s. The temperature is 18°C and μ=1.06 $\times10^{-3}$.Calculate the velocity gradient G.

Numericals

4. A flocculator designed to treat 76000m^3/d of water is30m long 12.5 m wide and 5.5 m deep. It is equipped with 12 m long and 0.3 m wide paddles moved by four horizontal shaft which rotate at a speed of 2.5 rpm. Two paddles are mounted on each shaft are opposite to other and centerline of paddles is 2m from the shaft. The drag coefficient is 1.8 and μ= 1.31 *10^{-3} N-sec/m^2 find the power input ,velocity gradient and detention time.
5. A flocculator is 30 m long, 12.5 m wide and 5.5 m deep equipped with 12m long and 300mm wide paddles moved by four horizontal shafts having two paddles moving opposite to other. The centerline of paddle is 2m from shaft.C_D is 1.8 ,G=30 sec-1,and μ= 1.31 *10^{-3} N-sec/m^2 . Find the speed at which horizontal shaft will rotate.