

WATER AND WASTEWATER TREATMENT

C9 1B

TITLE: DRINKING WATER TREATMENT

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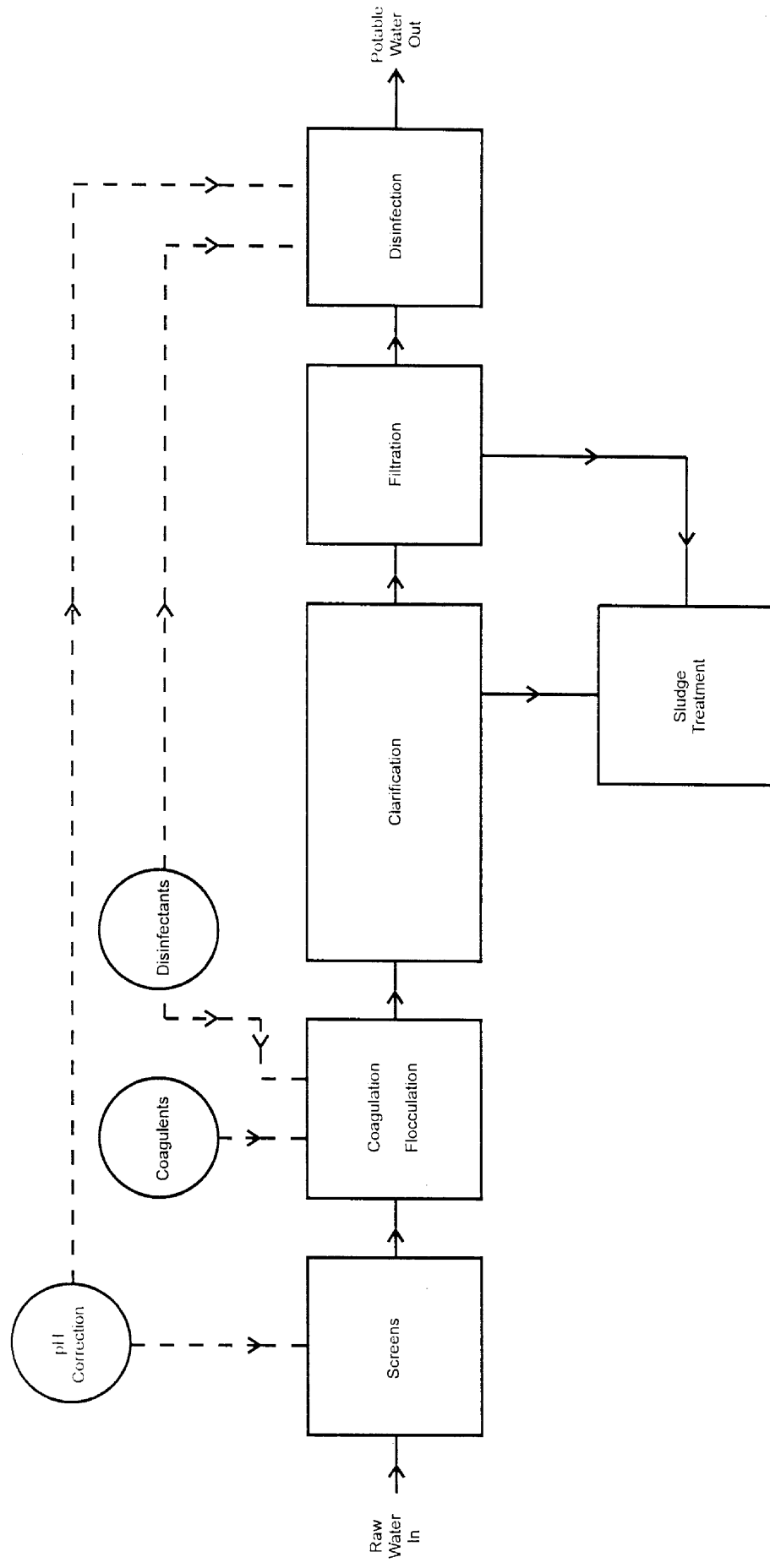
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Basic Water Treatment Diagram

Overview of treatment processes for drinking water

Surface water treatment

Primary objectives are to

- Remove suspended material (turbidity) and color;
- Eliminate pathogenic organisms
- Remove hardness and other minerals

Treatment technologies largely based on coagulation, flocculation, precipitation and disinfection

Key treatment units:

Screening

Chemical Mixing (coagulation), and flocculation

Flotation/Sedimentation

Filtration

Softening

Disinfection

Distribution, Pumped to community

Screening

Carried out at the inlet to prevent large debris entering the process plant

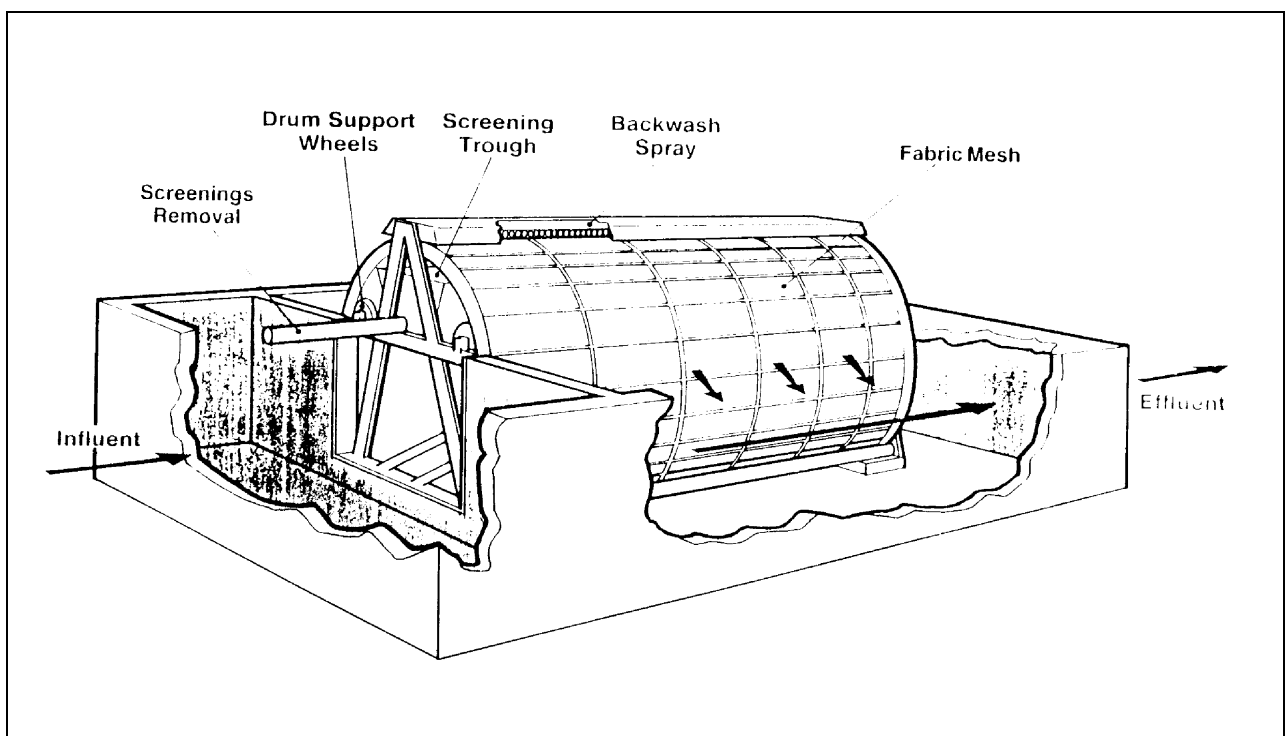
Coarse bar screens 50-100mm spacing, positioned at 60° to 80° to the horizontal for hand raking small works only

Fine bar screens 5-20mm spacing, usually mechanically raked, approach flow rate not greater than 1.4 m/s to avoid drawing in fish

Band screens rotating band of screen panels, river intakes with a high flood level

Rotary screens (cup or drum)

Microstrainers rotary drum screens with very fine mesh. Remove fine solids



Coagulation & Flocculation

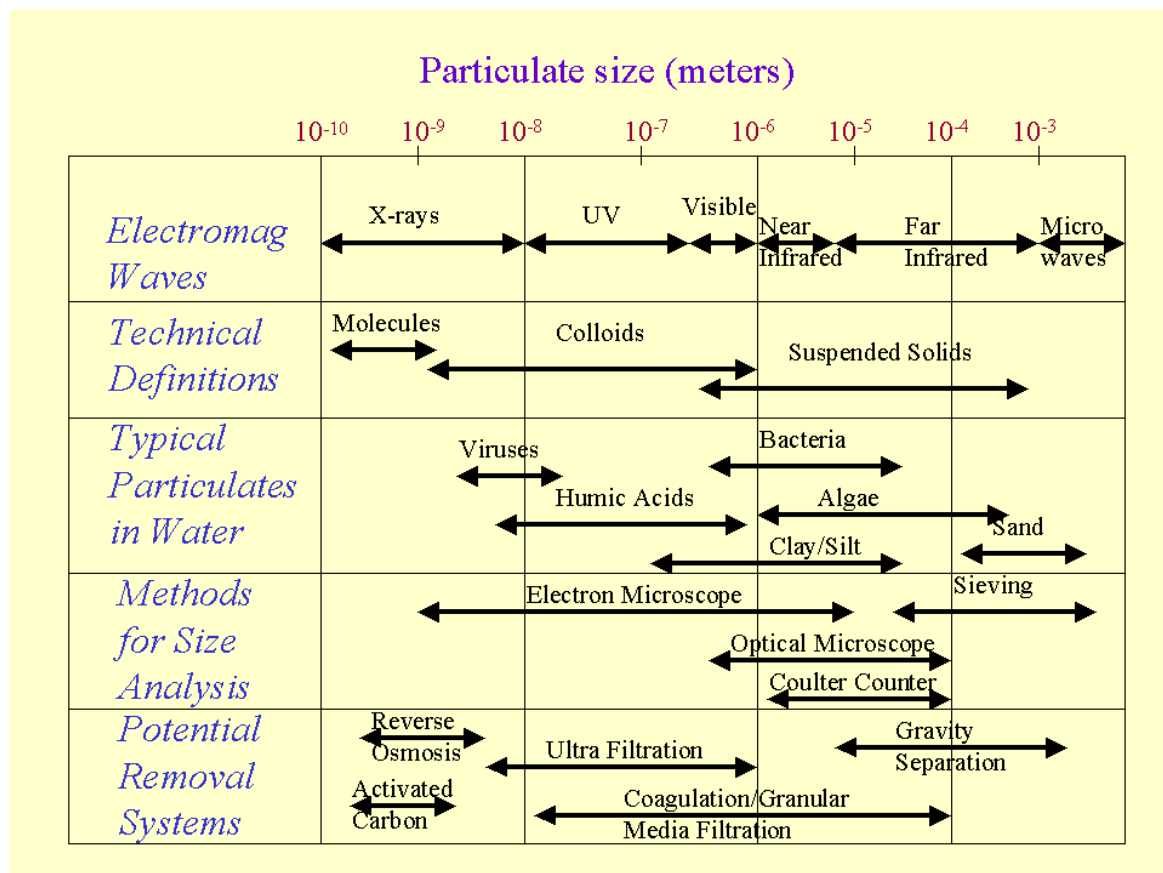
Coagulation

Many of the contaminants in water and wastewater contain matter in the colloidal form. These colloids result in a stable “suspension”. In general the suspension is stable enough so that gravity forces will not cause precipitation of these colloidal particles. So they need special treatment to remove them from the aqueous phase. This destabilization of colloids is called “coagulation”.

River and reservoir water usually contains dissolved (true) colour and finely divided material, often colloidal, which will not readily settle out and cannot be easily filtered out. Coagulants, usually salts of iron or aluminium, can be added to form precipitates termed floc, containing these impurities. The floc can then be separated out using a conventional separation process. The process of flocculation, in which floc growth is encouraged by gentle mixing, is sometimes carried out depending on the requirements of the solid-liquid separation process.

Typical colloidal in water and wastewater

- Size range: 10^{-3} – $1 \mu\text{m}$. (some where in the range between a molecule and bacteria in size).
- 50 – 70 % of the organic matter in domestic wastewater is composed of colloidal matter.
- In water treatment colour, turbidity, viruses, bacteria, algae and organic matter are primarily either in the colloidal form or behave as colloids.
- Usually negatively charged



Causes for colloidal stability

Most colloids and non-settleable particles in water and wastewater have a net negative surface charge that cause the particles repel each other.

Removal of Colloids from water

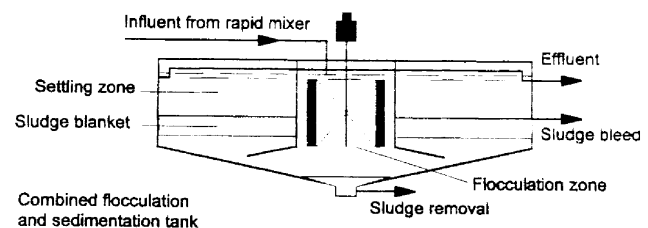
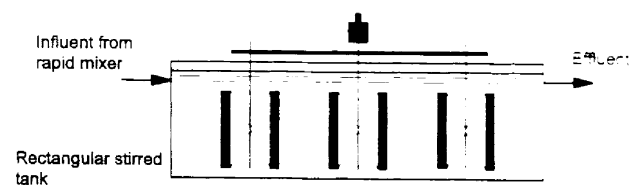
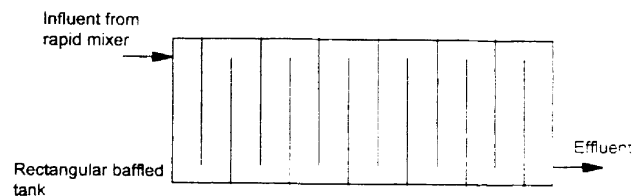
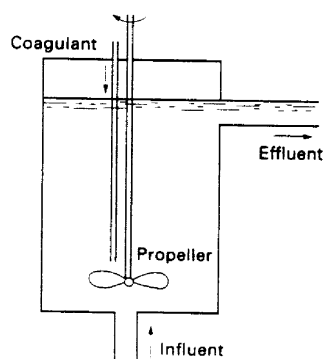
Removal of hydrophobic colloids in water and wastewater treatment processes involves two steps: coagulation and flocculation.

Destabilization (or Coagulation) - reduce the forces acting to keep the particles apart after they contact each other (i.e., lower repulsion forces).

Flocculation – process of bringing destabilized colloidal particles together to allow them to aggregate to a size where they will settle by gravity.

Coagulation and Flocculation Chemicals

Aluminium Sulphate (Alum)	Widely used particularly for upland surface waters
Ferric Sulphate	Commonly used for lowland surface waters
Ferrous Sulphate	Used in chlorinated form must be stored with added acid to maintain stability
Ferric chloride	Very corrosive, requires careful handling
Cationic polyelectrolyte	Expensive requires make -up system to ensure good dissolution
Anionic polyelectrolyte	Expensive requires make -up system to ensure good dissolution
Nonionic polyelectrolyte	Expensive requires make -up system to ensure good dissolution



Sedimentation and Flotation

Effect of the Particle Concentration

- Dilute suspensions (Type I settling)
 - Particles act independently
 - Discrete particle settling
- Concentrated suspensions (Type II and III settling)
 - Particle-particle interactions are significant
 - Particles may collide and stick together (form flocs)
 - Particle flocs may settle more quickly
 - Particle-particle forces may prevent further consolidation

Type I settling (free settling).

Type II settling (settling of flocculated particles).

Type III settling (zone or hindered settling, high concentrations of particles, wastewater treatment)

Particles that will settle within a reasonable period of time can be removed in sedimentation basin (also called clarifier). Sedimentation or Clarification is the removal of particulate matter, chemical floc and precipitates from suspension through gravity settling.

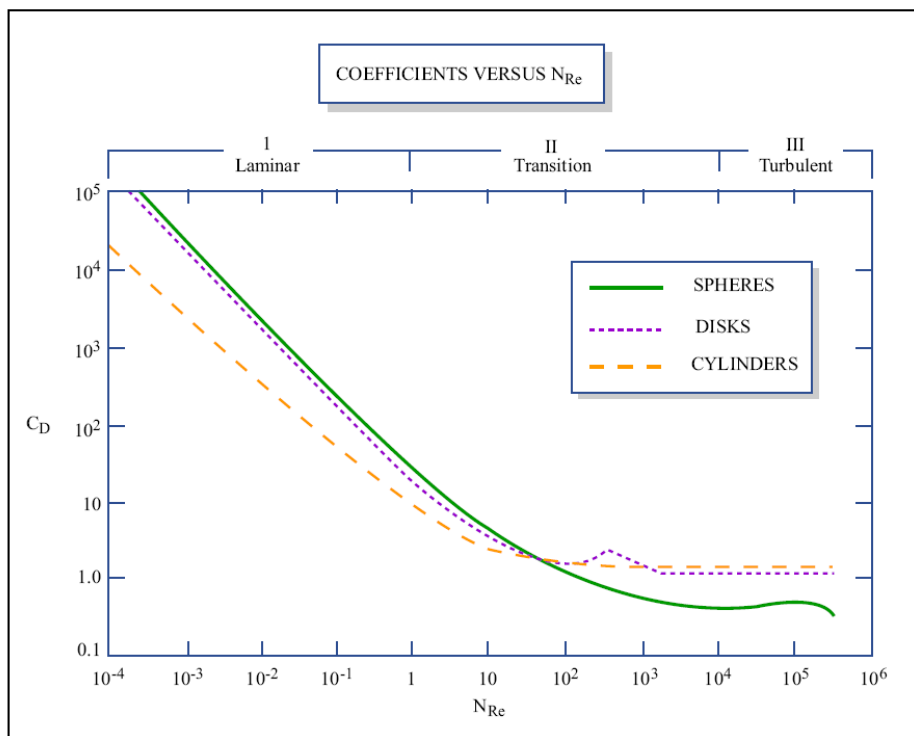


Figure by MIT OCW.

Adapted from: Reynolds, T. D., and P. A. Richards. *Unit Operations and Processes in Environmental Engineering*. 2nd ed. Boston, MA: PWS Publishing Company, 1996.

Key parameter is settling velocity – determines how fast particles will settle and thus how much volume (or residence time) treatment systems require.

$$u_t = \sqrt{\frac{4}{3} \frac{gd (\rho_p - \rho_w)}{C_D \rho_w}}$$

u_t = particle settling velocity;

ρ_p = density of particle;

ρ_w = density of fluid

d = diameter of particle;

μ = coefficient of dynamic viscosity;

g = acceleration due to gravity.

Three regions in graph:

I: Laminar flow, $Re < 1$, $C_D = \frac{24}{Re}$

$$Re = \frac{u_t d \rho_w}{\mu}$$

$$u_t = \frac{d^2 g (\rho_p - \rho_w)}{18 \mu}$$

Note: if assume laminar flow, need to check assumption $Re < 1$ after calculating u_t .

II. Transition flow, $1 < Re < 10^4$,

$$C_D = \frac{24}{Re} + \frac{3}{Re^{1/2}} + 0.34$$

$$u_t = \sqrt{\frac{4}{3} \frac{gd (\rho_p - \rho_w)}{C_D \rho_w}}$$

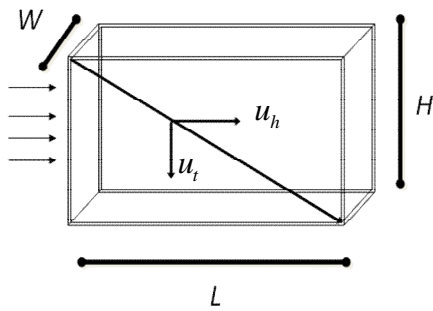
Can only solve for u_t by iteration: guess Re , compute C_D , computer u_t , keep iterating until u_t converges.

III. Turbulent flow, $Re > 10^4$

$C_D = 0.4$,

$$u_t = \sqrt{\frac{4}{3} \frac{gd (\rho_p - \rho_w)}{C_D \rho_w}}$$

How does it work in a reactor?



$$\text{Settling time} = t_s = \frac{H}{u_t}$$

$$\text{Detention time} = t_R = \frac{L}{u_h}$$

$$u_h = \frac{Q}{HW}$$

u_t : settling velocity

u_h : horizontal velocity

To get desired settling with most efficient tank size want, $t_s = t_R$ occurs when $u_c = u_t$
 u_c is known as overflow rate,

$$\frac{u_c}{u_h} = \frac{H}{L}$$

$$u_c = \frac{Hu_h}{L} = \frac{H(\frac{Q}{HW})}{L} = \frac{Q}{LW}$$

$$u_c = \frac{Q}{LW} = \frac{Q}{A_s}$$

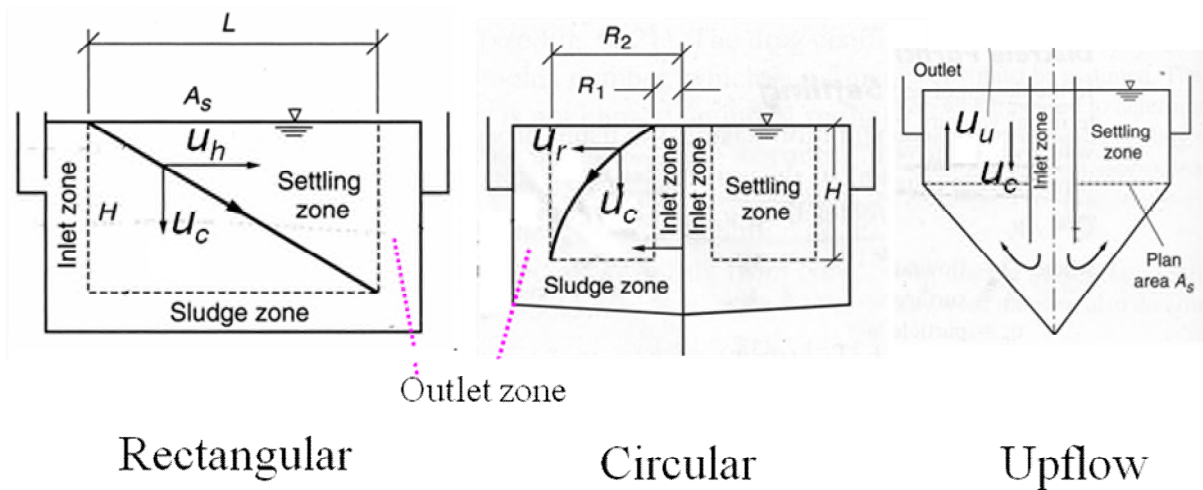
A_s = surface area of tank

It implies that the removal of a horizontal clarifier is independent of the depth and the detention time. It depends only on the surface overflow or loading rate (Q/A_s) for particles with a specified settling velocity u_c .

Particle settling $u > u_c$ can all be removed.

Particle settling $u < u_c$ can be partially removed.

Most settling basins in water treatment are up-flow clarifiers where the water rises vertically for discharge through effluent channels.



A sedimentation or clarification basin is to be designed so that it will remove 100% of all particles, which have a settling velocity of 0.3 mm/s.

- For a flow of $10 \text{ m}^3/\text{min}$, determine appropriate dimensions for a rectangular basin in which the length is 4 times the width assuming the detention time is 2 hours.
- Determine the total weir length required if the overflow rate is $250 \text{ m}^3/\text{day}$. Show how you would locate this weir on a sketch of the basin.

Typical sedimentation time of particles

Nature of solids	Settling velocity (mm s^{-1})	Retention time for settling to occur in 3 m deep tank (hours)
Clay, silt	0.07	11.9
Primary organic waste	0.42	1.98
Aluminium and iron flocs	0.83	1.00
Activated sludge	2.00	0.42
Grit	20.00	0.042

Typical sedimentation tank overflow rate

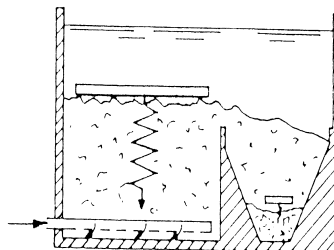
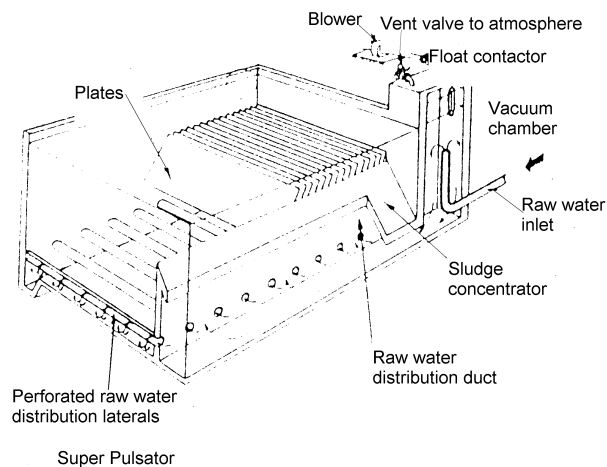
Application	Rectangular or circular ($\text{m}^3/\text{d.m}^2$)	Upflow solid contact ($\text{m}^3/\text{d.m}^2$)
Al³⁺ or Fe³⁺ coagulation		
Turbidity removal	40	50
Color removal	30	35
Lime softening		
Low Mg	70	130
High Mg	57	105

SUPERPULSATORS

Polyelectrolyte is added at the inlet to aid coagulation and the formation of a sludge blanket. The water enters the superpulsator through low level inlet channels and is evenly distributed over the floor of each tank through a row of lateral pipes fixed across the tank. The water then flows upwards between inclined glass reinforced plastic baffle plates where the flocculated matter forms a sludge blanket. The sludge blanket is formed by the upward velocity of the water counteracting the settling velocity of solids and hence concentrating the solids in the centre of the tank depth. A properly formed blanket helps to filter the flocculated matter from the water leaving clarified water to be collected by further lateral pipes fixed across the top of the tank.

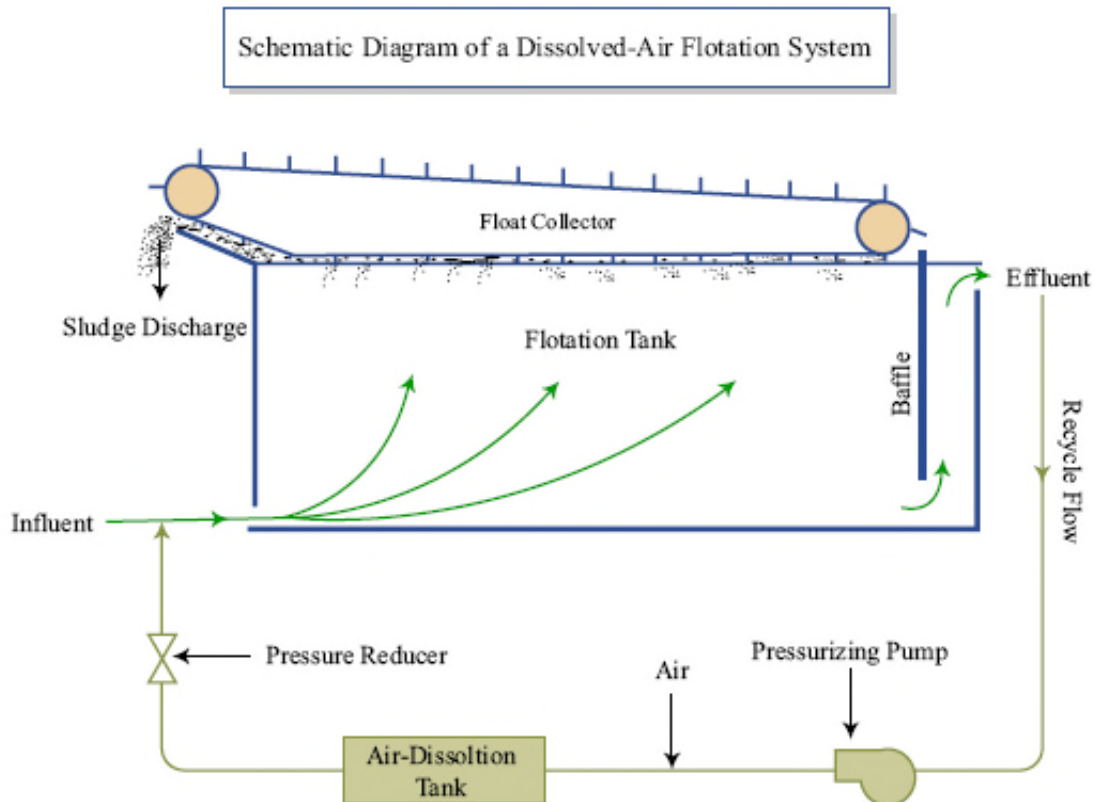
At the inlet to each superpulsator a vacuum fan, running constantly, induces a vacuum in a sealed chamber above the water. The water level in the inlet chamber therefore rises and when a predetermined level (approx. 0.9m above TWL) is reached the vacuum is released and the water discharges instantaneously increasing the velocity of the water entering the superpulsator inlet channel. This periodic release of water, or pulsing is the origin of the name ' Superpulsator.' The pulsing action helps to form a homogenous sludge blanket by giving the blanket a gentle shake.

Sludge from the blanket decants into hoppers along the dividing walls between the units. Sludge is intermittently bled from the hoppers to maintain the sludge blanket conditions. Clarified water from the upper lateral pipes is collected in the outlet channels and passes to the Contact tank.



DISSOLVED AIR FLOTATION

Dissolved air flotation is achieved by releasing fine air bubbles that attach to fine floc particles and cause them to float. Water enters the bottom of the flotation tank where it is merged with recirculated flow that contains compressed air. On pressure release air dissolved in the recirculated flow forms fine bubbles that agglomerate with the suspended solids. The clear water continues to the filters. The overflow, discharged by a mechanical skimming device, which contains the floc particles is taken away to the sludge treatment plant. Polyelectrolytes or other flocculents are usually added to increase the size of the solids to make them easier to collect.



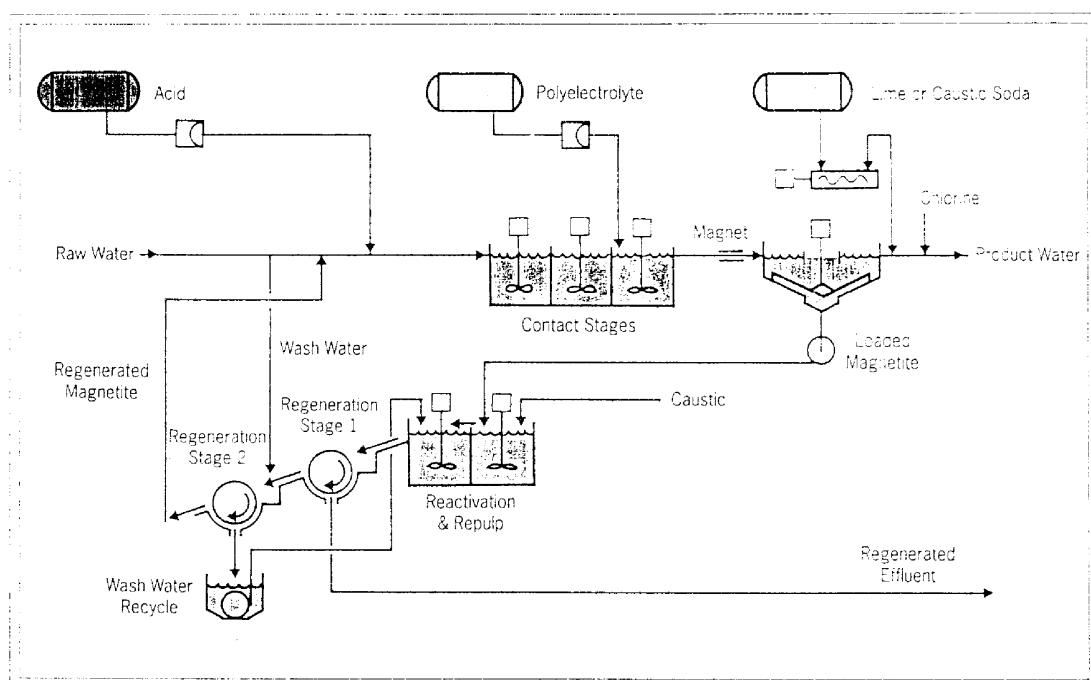
THE SIROFLOC PROCESS

The process avoids the addition of potentially harmful coagulant chemicals by using finely divided magnetite, a naturally occurring iron oxide. Magnetite has a high density, magnetic properties and a controllable surface charge. Under acidic conditions the particles carry a positive charge thus attracting negatively charged materials. When the pH level is raised the particles become negatively charged and the attached materials are repelled. The reversible surface charge is used to remove colour, iron compounds, aluminium compounds and turbidity from raw water and then to shed these contaminants as a concentrated effluent allowing the magnetite to be continually reused.

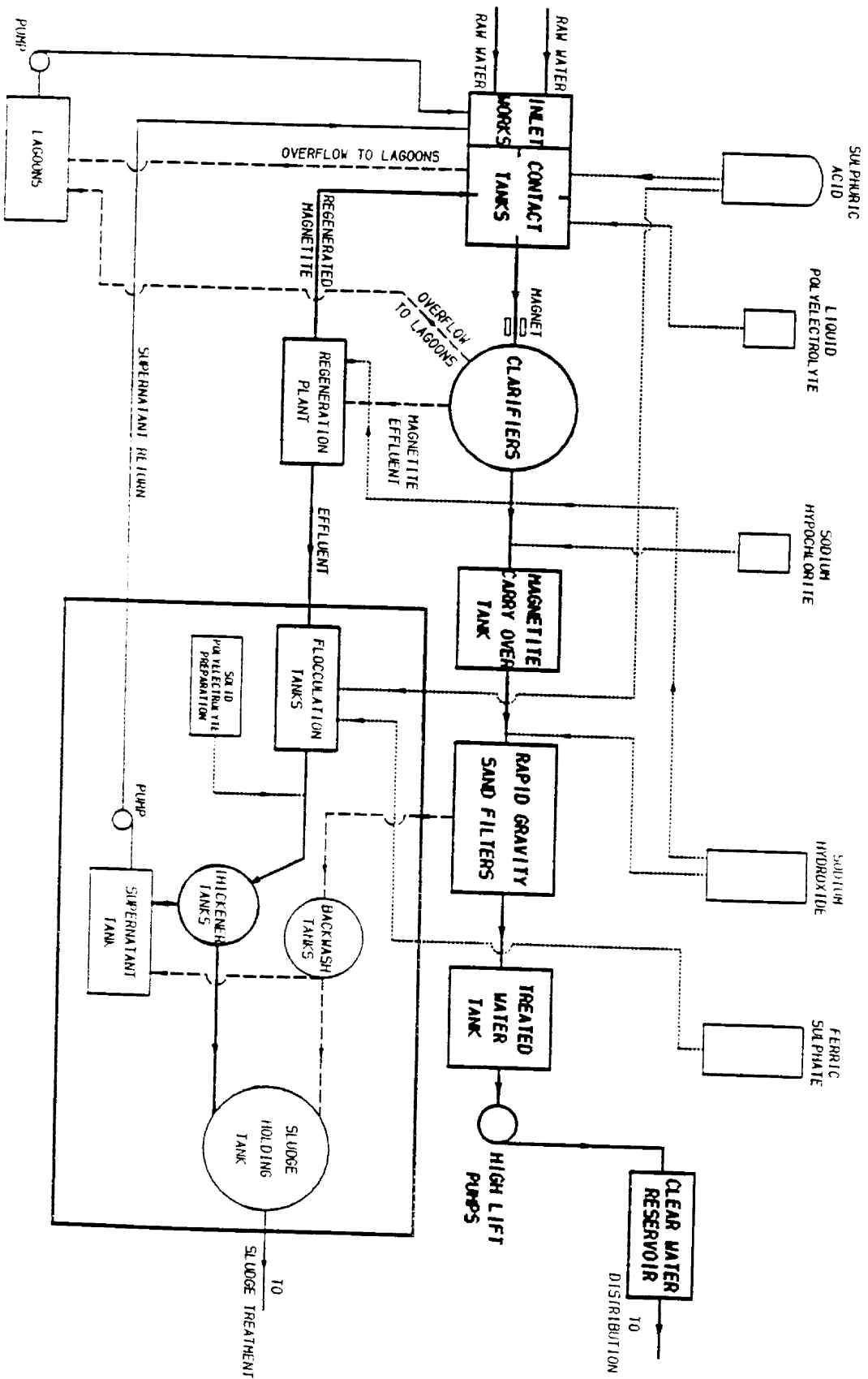
Raw water first passes through a series of contact tanks where it is mixed with magnetite. Acid is added and the impurities are adsorbed onto the magnetite, assisted if necessary by the addition of a polyelectrolyte. The loaded magnetite then passes through the poles of a permanent magnet before entering a clarifier. The magnetic field causes the magnetite particles to flocculate and this, together with their high-density results in rapid separation of the loaded magnetite in the clarifier.

The supernatant from the clarifier, now free from colour, iron, aluminium and suspended matter, flows to a filtration stage where, by increasing the pH and the addition of chlorine, any manganese present in the water is removed. The supernatant is returned to the head of the works.

The loaded magnetite slurry from the clarifier is pumped to a regeneration section. Here caustic soda is added to reverse the surface charge on the magnetite and the contaminants disengage with the help of high shear stirrers in the reactivation and repulp tanks. Downstream of these the clean magnetite is recovered from the liquid effluent using proprietary magnetic drum separators and is recycled. The liquid effluent can then be discharged directly from the plant or treated on site.



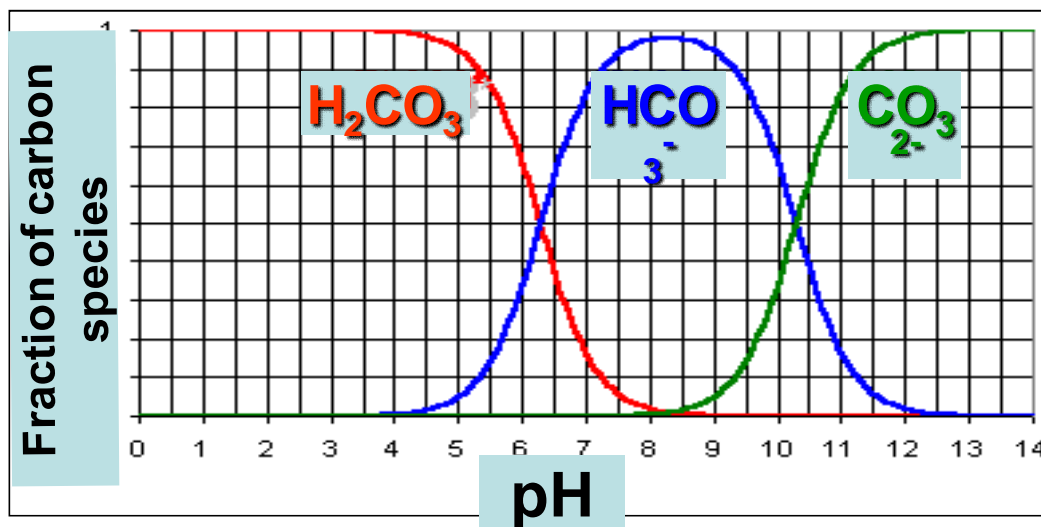
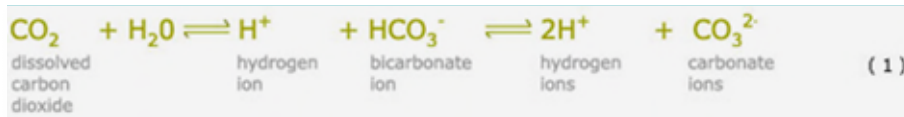
RIVELIN WATER TREATMENT WORKS SCHEMATIC PROCESS FLOW DIAGRAM



Softening

Background - Carbonate in natural water

- CO₂ is soluble in water, 1 m³ of water at 20°C will hold 878 g CO₂
- Low pH, more CO₂ stays in water, high pH, more carbonate and bicarbonate



Note – 100% CO₂ for pH < ~ 4.5; 100% bicarbonate for pH ~ 8 and 100% carbonate for pH > ~ 12) <http://waterontheweb.org/curricula/ws/>

A water is 'hard' if

- Soap does not easily form a foam or lather
- Water leaves scale in hot-water pipes, boilers ect.

Total Hardness

Technically - the sum of all polyvalent cations (Ca²⁺, Mg²⁺, Mn²⁺ and Fe²⁺...)

Practically - the amount of Ca²⁺, Mg²⁺ ions (predominant, >70% of the total cations in natural waters)

It is divided into carbonate and noncarbonate hardness.

'hard' waters – mainly from groundwater sources are generally undesirable

Advantages of softening:

- 1) more pleasant to use, many people object to water containing hardness >150 mg/L
- 2) saving of soap/detergents
- 3) laundering with soft water gives fabrics longer life
- 4) reduction of deposits in boilers/pipes/hot water tanks

Objectives of softening treatment

- Remove *iron*, which leaves rust-colored stains on clothing, sinks, tubs, etc.

- Reduce *hardness*, or dissolved minerals, which decrease the effectiveness of soap and cause "scale" in water heaters, boilers, etc.
 - Remove *dissolved gases*, such as hydrogen sulfide, which can contribute to taste and odor problems.
- a) general desirable
 - b) important to provide a constant hardness
 - c) reduce to 80 – 100 mg/1 CaCO_3 usually by treating a proportion to approximately 20 mg/1 CaCO_3 and mixing with higher concentrations.
 - d) treatment is expensive – only used if absolutely necessary
 - e) Types of softening
 - 1) Precipitation softening
Add lime – calcium and hydroxyl ions react with carbonates, product is precipitated out
 - 2) Precipitation is best achieved in same tanks as used for settling after coagulation
 - 3) A small excess of time is desirable
 - 4) However “after precipitation” may occur in the mains if adequate settling time is not allowed.

Softening Treatment Methods

Lime-soda ash softening

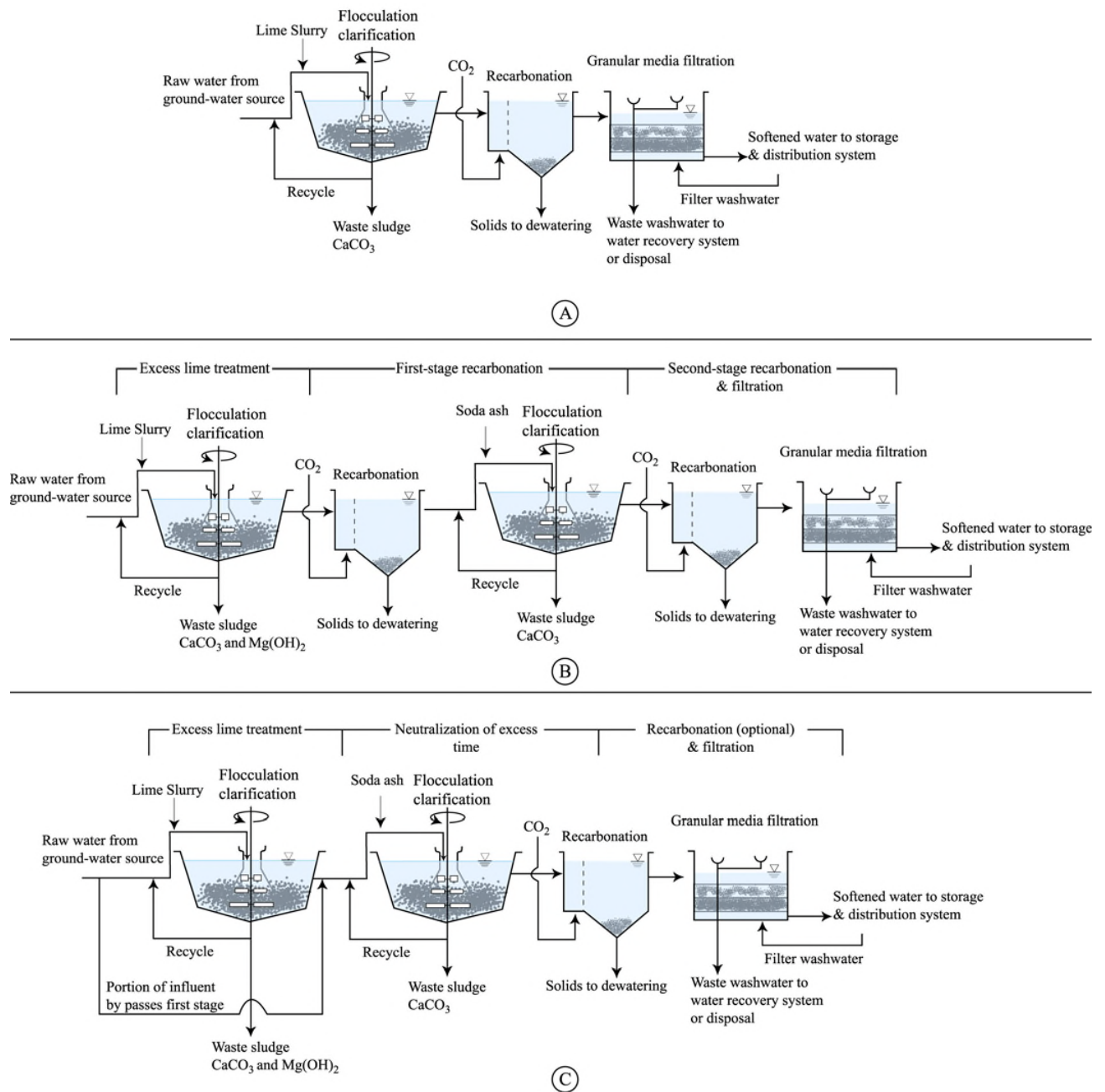
For waters low Mg and high Ca,

- Carbonate hardness is removed by adding lime $\text{Ca}(\text{OH})_2$
- Recarbonation is needed because addition $\text{Ca}(\text{OH})_2$ raises pH of water to 10.2-10.5
- Recarbonation consists of bubbling CO_2 through treated water, lowering pH to 8.7 to 9.0
- Recarbonation is also done to ‘stabilize’ the water
 - if water is supersaturated with CaCO_3 , it will precipitate as ‘scale’
 - if water is undersaturated, water can be aggressive and cause pipe corrosion
 - ideal is to keep water slightly oversaturated to maintain thin protective coat of CaCO_3 on inside of pipe

For waters with non-carbonate hardness, single-stage softening is insufficient. Leftover hardness is removed by addition of soda ash (Na_2CO_3)

Lime-soda ash treatment is usually treated by two-stage softening. Recarbonation is needed to neutralize high pH

Typical softening treatment



Process flow diagram of common softening treatment techniques: (a) Single-stage lime treatment; (b) two-stage excess lime-soda treatment; (c) split-flow lime treatment

Summary of chemical dosage calculations required for lime & lime-soda ash softening*

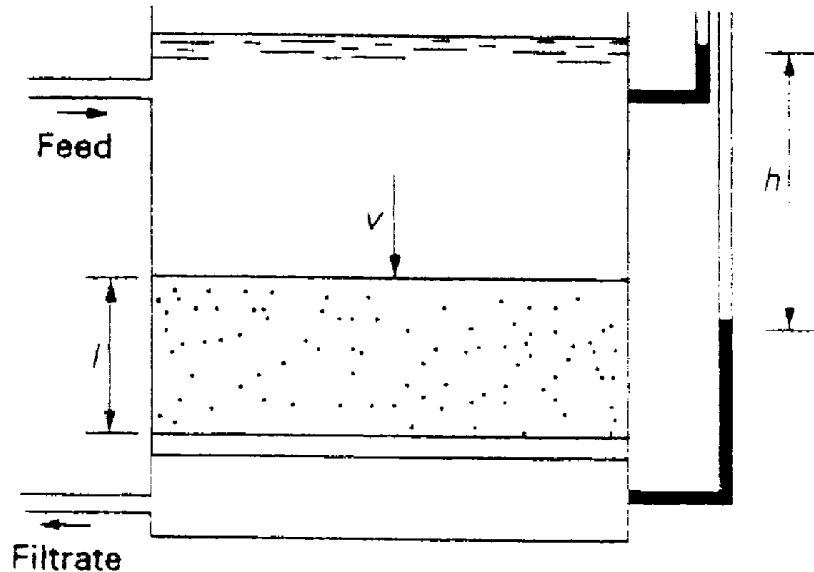
PROCESS	REQUIRED CHEMICAL DOSAGE CALCULATIONS
Single-Stage Lime: For waters with high calcium, low magnesium, & carbonate hardness	Lime addition for softening: $\text{CaO} = \{\text{carbonic acid concentration}\} + \{\text{calcium carbonate hardness}\}$ Soda ash addition for softening: $\text{Na}_2\text{CO}_3 = \text{none}$ Carbon dioxide for pH adjustment after softening: $\text{CO}_2 = \left\{ \begin{array}{l} \text{estimated carbonate} \\ \text{alkalinity of softened} \\ \text{water} \end{array} \right\} = \left\{ \begin{array}{l} \text{source water} \\ \text{alkalinity} \end{array} \right\} - \left\{ \begin{array}{l} \text{source water} \\ \text{calcium} \\ \text{hardness} \end{array} \right\} + \left\{ \begin{array}{l} \text{estimated residual} \\ \text{calcium hardness} \\ \text{of softened water} \end{array} \right\}$
Excess Lime: For waters with high calcium, high magnesium, and carbonate hardness; process may be one or two stages	Lime addition for softening: $\text{CaO} = \left\{ \begin{array}{l} \text{carbonic acid} \\ \text{concentration} \end{array} \right\} + \left\{ \begin{array}{l} \text{total alkalinity} \end{array} \right\} + \left\{ \begin{array}{l} \text{magnesium} \\ \text{hardness} \end{array} \right\} + \left\{ \begin{array}{l} \text{excess lime} \\ \text{dose} \end{array} \right\}$ Soda ash addition for softening: $\text{Na}_2\text{CO}_3 = \text{none}$ Carbon dioxide for pH adjustment after softening: $\text{CO}_2 = \left\{ \begin{array}{l} \text{source water} \\ \text{alkalinity} \end{array} \right\} - \left\{ \begin{array}{l} \text{source water} \\ \text{total hardness} \end{array} \right\} - \left\{ \begin{array}{l} \text{excess lime} \\ \text{dose} \end{array} \right\} + \left\{ \begin{array}{l} \text{estimated residual} \\ \text{calcium hardness} \\ \text{of softened water} \end{array} \right\} + 2 \left\{ \begin{array}{l} \text{excess lime} \\ \text{dose} \end{array} \right\} + \left\{ \begin{array}{l} \text{estimated residual} \\ \text{magnesium hardness} \\ \text{of softened water} \end{array} \right\}$
Single-Stage Lime Soda Ash: For water with high calcium, low magnesium, & carbonate and noncarbonate hardness	Lime addition for softening: $\text{CaO} = \{\text{carbonic acid concentration}\} + \{\text{calcium carbonate hardness}\}$ Soda ash addition for softening: $\text{Na}_2\text{CO}_3 = \{\text{calcium noncarbonate hardness}\} \text{ and/or } \{\text{magnesium noncarbonate hardness}\}$ Carbon dioxide for pH adjustment after softening: $\text{CO}_2 = \left\{ \begin{array}{l} \text{source water} \\ \text{alkalinity} \end{array} \right\} + \left\{ \begin{array}{l} \text{soda ash} \\ \text{dose} \end{array} \right\} - \left\{ \begin{array}{l} \text{source water} \\ \text{calcium} \\ \text{hardness} \end{array} \right\} + \left\{ \begin{array}{l} \text{estimated residual} \\ \text{calcium hardness} \\ \text{of softened water} \end{array} \right\}$
Excess Lime - Soda Ash: For waters with high calcium, high magnesium, and carbonate and noncarbonate hardness; process may be one or two stages	Lime addition for softening: $\text{CaO} = \left\{ \begin{array}{l} \text{carbonic acid} \\ \text{concentration} \end{array} \right\} + \left\{ \begin{array}{l} \text{calcium carbonate} \\ \text{concentration} \end{array} \right\} + 2 \left\{ \begin{array}{l} \text{magnesium} \\ \text{carbonate} \\ \text{hardness} \end{array} \right\} + \left\{ \begin{array}{l} \text{magnesium} \\ \text{noncarbonate} \\ \text{hardness} \end{array} \right\} + \left\{ \begin{array}{l} \text{excess lime} \\ \text{requirement} \end{array} \right\}$ Soda ash addition for softening: $\text{Na}_2\text{CO}_3 = \left\{ \begin{array}{l} \text{calcium} \\ \text{noncarbonate} \\ \text{hardness} \end{array} \right\} + \left\{ \begin{array}{l} \text{magnesium} \\ \text{noncarbonate} \\ \text{hardness} \end{array} \right\}$ Carbon dioxide for pH adjustment after softening: $\text{CO}_2, \text{ first stage} = \left\{ \begin{array}{l} \text{estimated hydroxide} \\ \text{alkalinity of softened} \\ \text{water} \end{array} \right\} = \left\{ \begin{array}{l} \text{excess lime} \\ \text{dose} \end{array} \right\} + \left\{ \begin{array}{l} \text{estimated residual} \\ \text{magnesium hardness} \\ \text{of softened water} \end{array} \right\}$ $\text{CO}_2, \text{ second stage} = \left\{ \begin{array}{l} \text{estimated hydroxide} \\ \text{alkalinity of softened} \\ \text{water} \end{array} \right\} = \left\{ \begin{array}{l} \text{source water} \\ \text{alkalinity} \end{array} \right\} + \left\{ \begin{array}{l} \text{soda ash} \\ \text{dose} \end{array} \right\} - \left\{ \begin{array}{l} \text{source} \\ \text{water total} \\ \text{hardness} \end{array} \right\} + \left\{ \begin{array}{l} \text{estimated residual} \\ \text{hardness of softened} \\ \text{water} \end{array} \right\}$

* All quantities are expressed as mg/L as CaCO₃

Filtration

Filtration of suspension through porous media, usually sand, is an important stage of the treatment process to achieve final clarity. Although about 90% of the turbidity and colour are removed in coagulation and clarification a certain amount of floc is carried over from the clarification tanks and requires removal.

Hydraulics of filtration



Mechanisms:

- Straining
- Diffusion
- Sedimentation
- Interception
- Flocculation
- Biofilm growth

Slow sand filters

- Oldest form of filters
- Fine sand loaded at low rates: 0.05-0.2 m/h
- The schmutzdecke is the top layer of the sand filter with a few millimetres thick of algae, plankton and other microscopic plant life forms on the top (Schmutzdecke is German for film or deck of dirt).
- Treatment by physical straining and biological degradation
- Clean by scraping top layer every few weeks or months
- Simple operation, no chemicals
- Usually used for small systems where simple operation is advantageous, raw water turbidity must be < 50 NTU

Note: NTU= nephelometric turbidity unit

Lake: 1-20 NTU

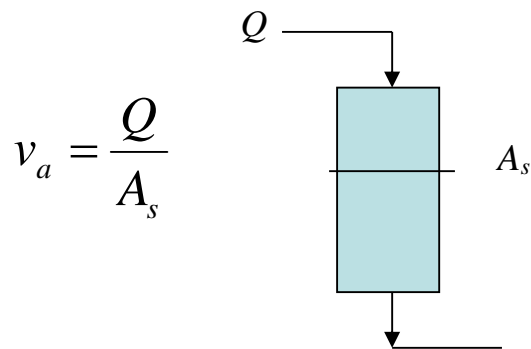
River: 10->4000 NTU

Required for finished water = 0.3 NTU

Most system < 0.1 NTU (non-detectable)

Rapid sand filters

- Much more common. Replaced slow sand filters in 20th Century
- Much higher loading rates than slow sand filters, >100 times, typically 5-15 m/h
- Media are coarser, more uniform
- Removal is not by physical straining on surface. Conceptually rapid filtration is like sedimentation
 - particles need pre-treatment with coagulant to destabilize electrical charge
 - destabilized particles adhere to grains in filter medium and are removed
 - depth filtration – removal through entire depth of bed occurs
- Headloss in filter increases with time as filter clogs and gets lower hydraulic conductivity
- At end of filter run, filter is 'backwashed'.



where

v_a = face velocity (m/day) or loading rate ($\text{m}^3/\text{day} \cdot \text{m}^2$)

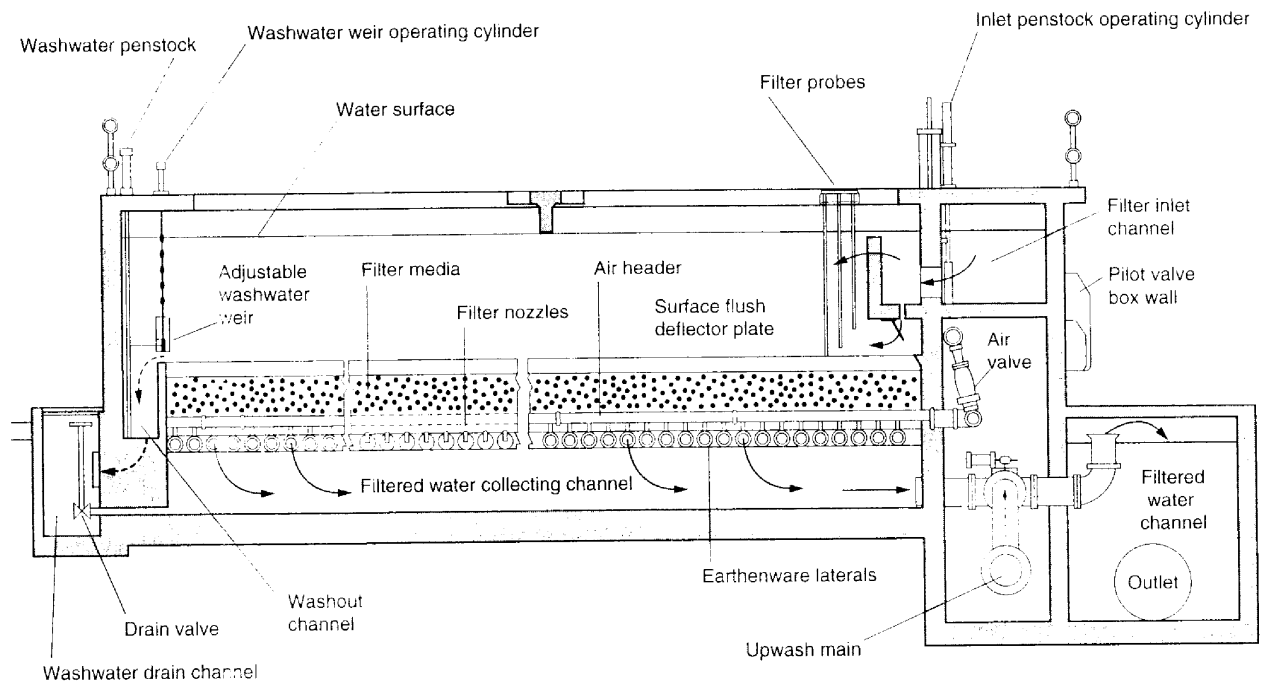
Q = flow rate (m^3/day)

A_s = filter surface area (m^2)

- Slow sand filters:
 $v_a = 2.9 - 7.6 \text{ m}^3/\text{d} \cdot \text{m}^2$
- Rapid sand filters:
 $v_a = \geq 120 \text{ m}^3/\text{d} \cdot \text{m}^2$

Conclusion

- Rapid filtration requires pre-treatment (coagulation) to create favourable chemistry for particle capture;
- Particles larger than $1 \mu\text{m}$ are captured by sedimentation and interception
- Particles smaller than $1 \mu\text{m}$ are captured by diffusion
- Most difficult particles to capture are about $1 \mu\text{m}$ size
- Dual media provide better capture than single media
- Design requires consideration of mixing, coagulation, flocculation and filtration.



Schematic layout of a rapid gravity filter

Example

A rapid gravity filtration plant is required for a population of 15000. The nominal filtration rate is 100 m/day and is not to exceed 150 m/day with one filter being backwashed. Calculate the number of units required and the individual filter area. What percentage of the treated water is required for backwashing the filters if the backwash rate is 1 m/min, the duration is 10 mins and the filters are backwashed once a day?

Disinfection

CHLORINATION

Used because

readily available as gas, liquid or powder

cheap

easy to apply – high solubility (7000 mg/l)

leaves a residual in solution which is not harmful and helps protect distribution system

very toxic to most micro-organisms

There are four ways of chlorine dosing:

Simple/marginal process

- i) suitable for low organic matter water
- ii) chlorine available as liquefied gas
- iii) dosing is in small quantities 0.5 kg/hr – 10 kg/hr
- iv) contact tank to allow 30 mins contact time
- v) leave “residual” chlorine approximately 0.2 ppm

Ammonia – Chlorine Process (Chloramine)

- i) residual chlorine may produce tastes and odours – chlorine reacting with organic matter.
- ii) if ammonia present chlorine combines with this instead of organic matter – forms chloramines
- iii) still same safety but contact time in tank at least 2 hours
- iv) ammonia best added first
chlorine: ammonia ratio 2:1 to 5:1

SUPERCHLORINATION/DECHLORINATION

- i) used where pollution high – lowland river waters
- ii) heavy initial dose of chlorine added – kills everything
- iii) any objectionable excess removed by dechlorination using sulphur dioxide
- iv) contact time 20 – 30 mins
- v) leave a small amount of residual chlorine

BREAKPOINT CHLORINATION

- i) chlorine added to water containing organic matter and ammonia passes through three stages

First Stage

- 1) Residual available chlorine increases,
Organic matter is oxidised or combines with the chlorine

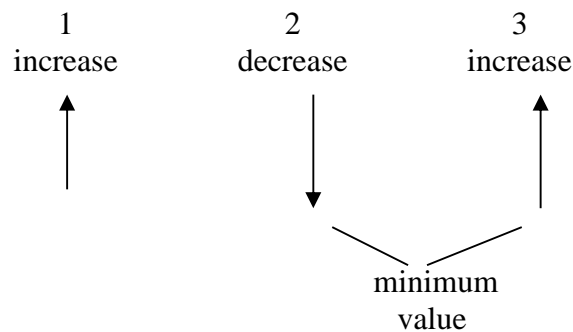
- 2) Ammonia is converted to chloramines
- 3) Chlorine is available as:
“combined available chlorine”

Second Stage

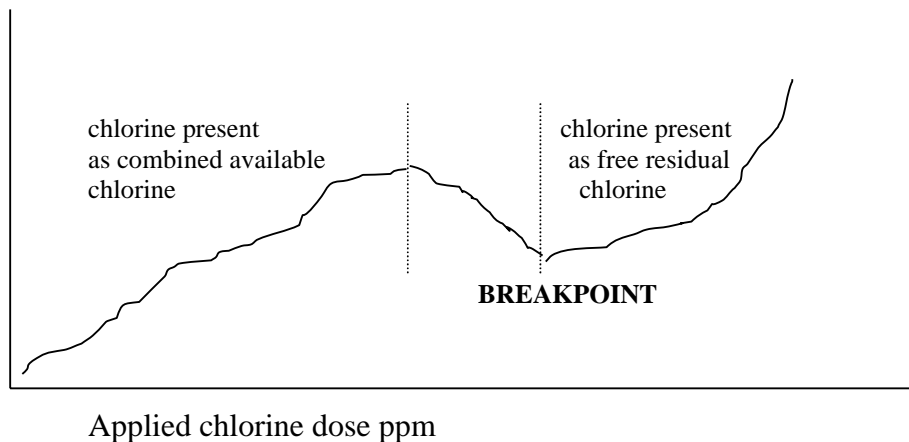
Total residual chlorine decreases,
Chloramines are oxidised into mainly hydrochloric acid

Third Stage

Total residual chlorine increases in proportion to the applied dose



The point of minimum value is known as the “breakpoint”



ADVANTAGE

“Combined residual available chlorine” does not affect taste.
Free residual chlorine acts more vigorously on bacteria

DISADVANTAGE

difficult to control in variable quality water

OZONIZATION

- a) Removes taste and odour as well as dissolved/colloidal organic matter
- b) Highly unstable toxic blue gas produced on site as close to the point of use as possible
- c) Contact time 5 mins

- d) Very effective but expensive
- e) Good colour removal

Advanced treatment

- Air stripping
- Membrane treatment
- Adsorption
- Ion Exchange

References

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