Rapid Mix Tank

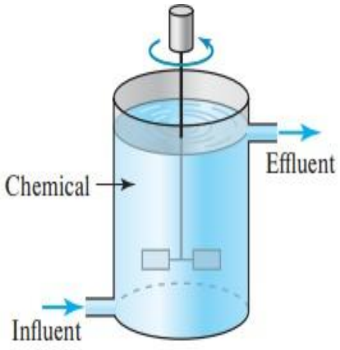
Power requirements: Power required for turbulent mixing is traditionally based on the velocity gradient or G values proposed by Camp and Stein (1943). The mean velocity gradient G for mechanical mixing is:

$$G = \left(\frac{P}{\mu V}\right)^{1/2}$$

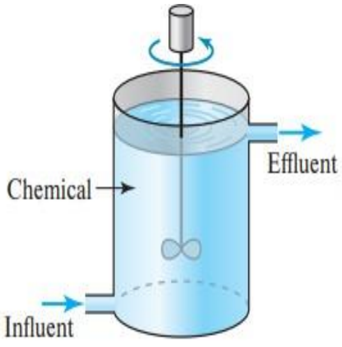
G= velocity gradient, s^{-1}:
P = Power input, W
V = Tank volume, m^3;
μ = Dynamic viscosity, (Pa.s)

- In practice, G values of 3000 to 5000/s are preferable for rapid mixing (ASCE and AWWA, 1990).

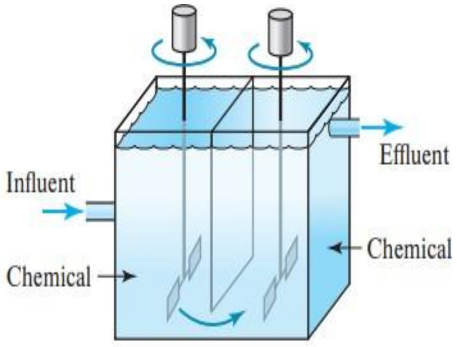
- t (time) generally 60 to 120 s.



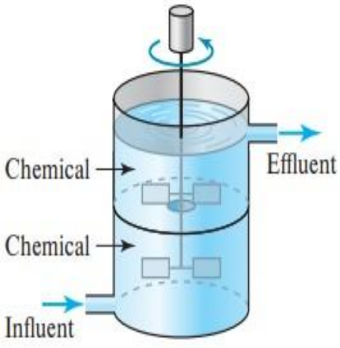
(a) Turbine chamber



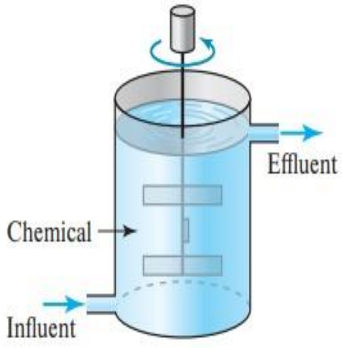
(b) Propeller chamber



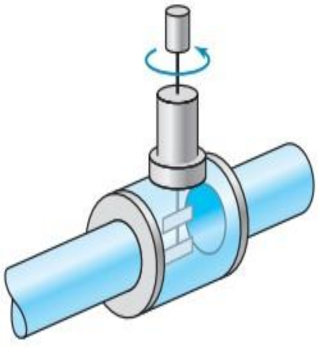
(c) Double-compartment turbine chamber



(d) Double-compartment turbine chamber



(e) Paddle chamber



(f) In-line blender

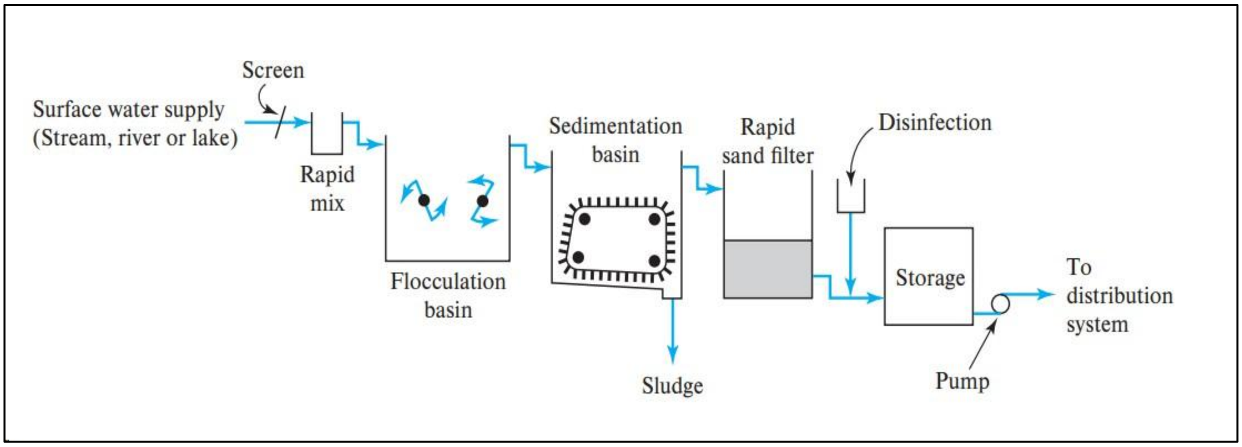
Example: A rapid mixing tank is 1mx1mx1.2m. The power input is 746 W (1 hp

Find the G value at a temperature of 20 °C.

Example: A square rapid mixing basin with a depth equal to 1.5 times the width is to be designed for a flow of 10000 m^3/d. The velocity gradient is to be 3000 s^{-1}, the mixing time is 60 s. Determine the basin dimensions and the power required?

Water Treatment Coagulation

Water Treatment Plant (WTP): ***conventional surface water treatment plant***



3.1. Coagulation Tank (Rapid mix)

Coagulation is the destabilization of colloids by addition of chemicals that neutralize the negative charges.

Colloids: clay, algae, microorganisms, organic and inorganic materials …etc. All these matters can be measured by Turbidity test.

Turbidity (NTU): Insoluble particles of soils, microorganism, and other materials impede the passage of light through water by scattering and absorbing the rays. Units of turbidity are Nephelometric turbidity unit (NTU)

Turbidity > 5 NTU can be noticed by visual observation.

Treated drinking water is commonly less than 1 NTU.

Water Treatment Coagulation

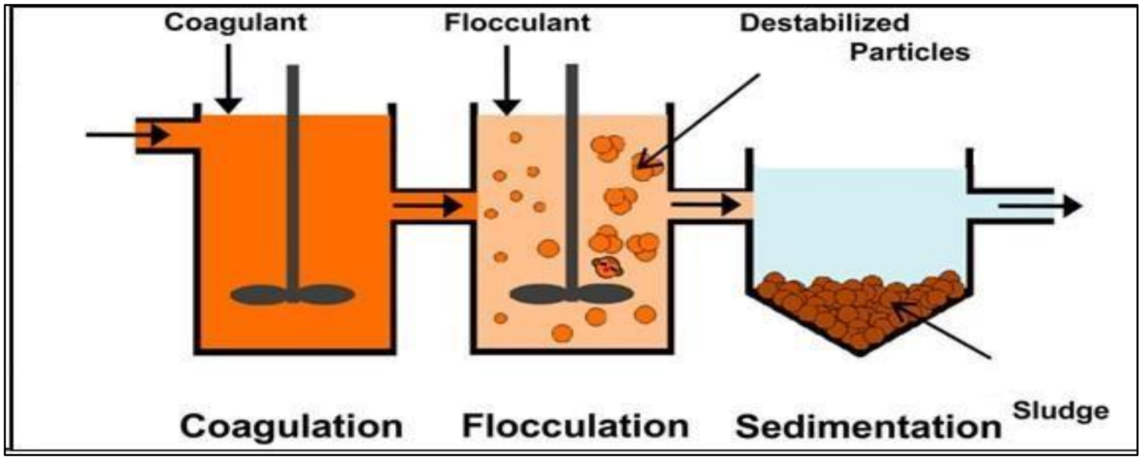
A coagulant has three key properties:

1. Trivalent cation. As discussed previously, naturally occurring colloids are most commonly negatively charged; hence cations are required to achieve charge neutralization.

2. Nontoxic. Obviously, for the production of potable water, the coagulant must be nontoxic.

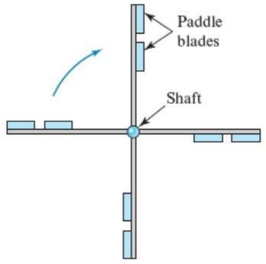
3. Insoluble in the neutral pH range. High concentrations of the coagulant in treated water are undesirable. Therefore, a coagulant is usually relatively insoluble at the pH values desired.

The two most commonly used metallic coagulants are aluminum (Al^{3+}) and ferric iron (Fe^{3+}). Both meet the preceding three requirements, and their reactions are outlined here.

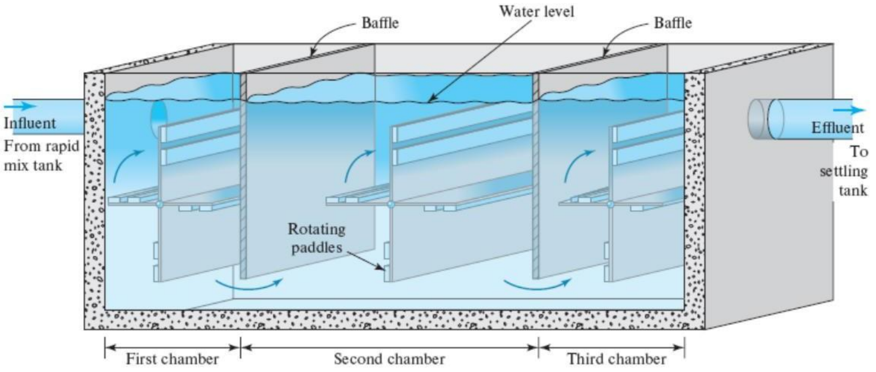


4. Flocculation Tank

The objective of flocculation is to allow the particles to adhere to one another, and grow to a size that will settle readily



Cross section of paddle wheel



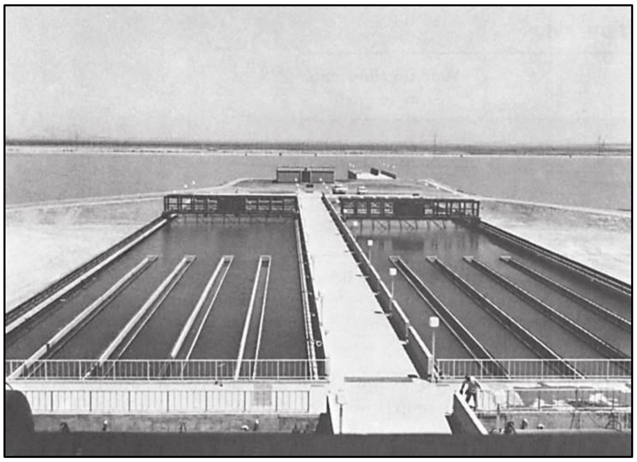
- Detention time of 20 to 50 minutes, typical 30 minutes. G range (20 -80) s^{-1}. محددات مثالية لهذا الحوض
- Water depths in the basin range from 3 to 5 m. صافي ارتفاع المياه في الحوض من 3 الى 5 متر
- The flocculation basin should be divided into at least three compartments. عادة هذا الحوض يتم تقسيمه الى 3 اقسام

Q: Flocculation tank is to be designed for a total flow rate of 40,000 m^3/d. The following conditions apply to the design: total detention time of 45 min, tank depth of 3.5 m and length/width=3, **3 flocculation stages** of same dimensions, the first stage G is 50 s^{-1}, the second stage G is 35 s^{-1}, and the third stage G is 20 $s^{-1.}$

Determine the dimension of the tank and power of each motor.

Solution:

Settling tank



The settling tank is designed so as to remove the settled water from the tank without carrying away any of the floc particles. In ideal sedimentation process, the average velocity of the water is equal to its flow rate divided by the area through which it flows:

$$\boxed{v = \frac{Q}{A_c}}$$

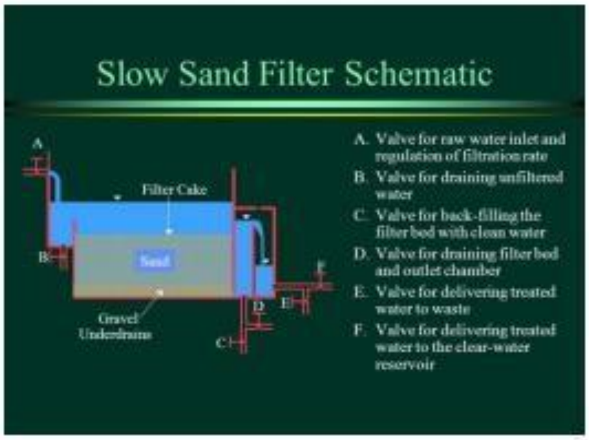
where v = water velocity (in $m \cdot s^{-1}$) ≡ overflow rate
Q = water flow (in $m^3 \cdot s^{-1}$)
A_c = cross-sectional surface area (in m^2)

Q: The design flow rate is 3800 m^3/day and overflow rate is 20 m/day. Determine the surface area of this tank. Determine the length of the tank, using length=3xwidth. Determine the tank depth, assuming a detention time of 2 hours.

Filters can be classified as following

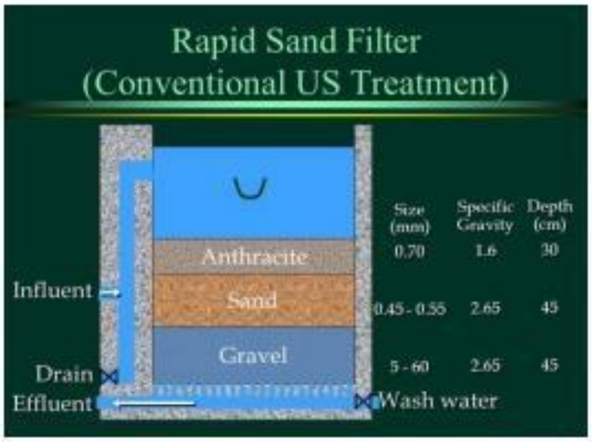
1) According to the filtration rate:

a) Slow sand filtration (SSF)
b) Rapid sand filtration (RSF)



Slow Sand Filter Schematic

A. Valve for raw water inlet and regulation of filtration rate
B. Valve for draining unfiltered water
C. Valve for back-filling the filter bed with clean water
D. Valve for draining filter bed and outlet chamber
E. Valve for delivering treated water to waste
F. Valve for delivering treated water to the clear-water reservoir



Rapid Sand Filter (Conventional US Treatment)

Size (mm)	Specific Gravity	Depth (cm)
0.70	1.6	30
0.45 - 0.55	2.65	45
5 - 60	2.65	45

Slow Sand Filter المرشح الرملي البطيء

هو ابسط مرشح يستخدم لتنقية المياه حيث يتم امرار المياه على طبقة من الرمل الناعم ثم على طبقة من الحصو الى نظام لسحب المياه. هذا النوع من المرشحات لا يحتاج الى معالجة كيميائية قبلها وفى بعض الاحيان لا يحتاج الى عملية ترسيب قبله اذا كانت نسبة المواد الصلبة الذائبة في الماء صغيرة.

-تتم تنقية المياه في هذا المرشح في الطبقة التي تتكون على سطح الرمل و تتغلغل في جزء من بداية طبقة الرمل وهى عبارة عن طبقة مكونة من البكتريا والطحالب تتكون عند بداية تشغيل المرشح وتتغذى على الكائنات الدقيقة والاملاح الذائبة في الماء وتسمى schmutzdecke.

Rapid Sand Filter المرشح الرملي السريع

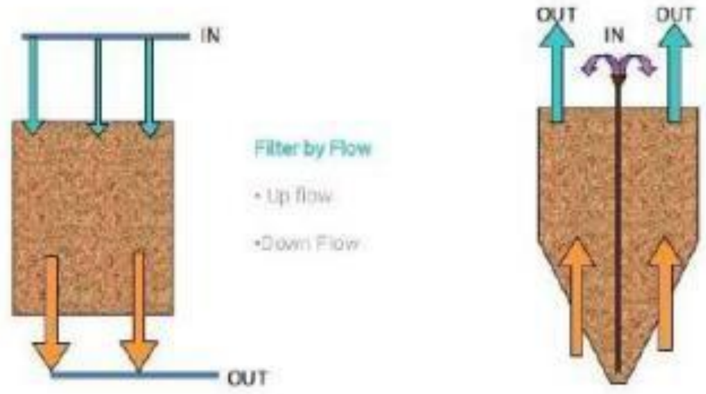
وهو المرشح الاكثر استخداما في الوقت الحاضر وذلك لان معدل الترشيح فيه اعلى بكثير من حيث يصل ال 120:240 م^3 /م^2 باليوم وبالتالي فانه يوفر المساحة المطلوبة والوقت اللازم للترشيح ايضا.
يتواجد هذا المرشح في المحطات الحديثة اي انه لابد ان يسبق بعمليات التخثير والتلبيد والترسيب .يحدث الترسيب في هذا المرشح في كامل طبقة الرمل وليس في السطحية فقط .في هذا المرشح يقل عمق الرمل ويزداد عمق الماء ويستخدم رمل بحبيبات اكبر من المستخدم في المرشح البطئ.

Slow sand filter	Rapid sand filter
• تحتاج مساحات واسعة	• تحتاج مساحات اقل
• معدل الترشيح واطئ	• معدل الترشيح عالي
• كفاءة الترشيح عالية	• كفاءة الترشيح اقل
• تغسل وتنظف بالقشط	• تغسل بالتدفق الراجع
• غير اقتصادية مقارنة بالمرشحات السريعة	• اقتصادية

2) According to the direction of flow:

a) Down flow filter
b) Up flow filter

يحتاج المرشح من نوع الجريان من الأسفل الى الأعلى الى ضغوط عاليه لرفع الماء من الأسفل الى الأعلى لذلك يكون المرشح الذي يمرر الماء من الأعلى الى الأسفل الأكثر شيوعا وعادة مايستخدم الفحم الحجري على شكل حبيبات بدلا من الرمل.



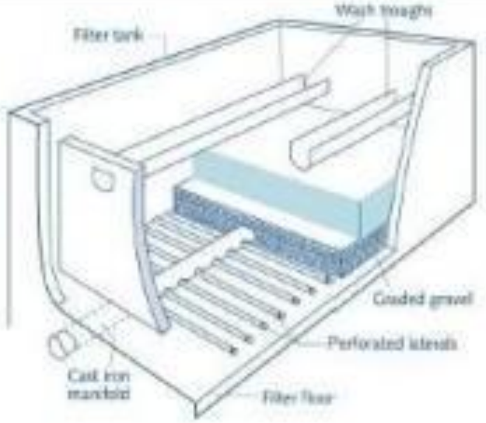
3) According to the used media:

a) Fine to coarse media
b) Coarse to fine media

ويعتبر المرشح الناعم الى الخشن هو النوع الشائع الاستخدام والمرشح المكون من مادة واحدة يسمى مرشح الوسط الأحادي ,ويعتبر مرشح الرمل والحصى من هذا النوع من المرشحات لان الحصى يستخدم كمواد ساندة للرمل.

اما المرشحات التي تحتوي على مادة إضافية مع الرمل مثل الفحم الحجري فتسمى مرشحات ثنائية الوسط والمرشحات التي تحتوي على اكثر من مادتين تسمى مرشحات الأوساط المتعددة. ويعتبر مرشح الرمل والحصى هو المرشح الأكثر استخداما وذلك لرخص المواد المستخدمة.

4) According to the pressure:
a) Gravity filter
b) Pressure filter

Gravity filter	Pressure filter
	

Gravity filter	Ptessure filter
• تحتاج الى احواض مفتوحة بمساحات واسعة • معدل الترشيح واطئ • كفاءة الترشيح عالية • تغسل بالتدفق الراجع لإزالة الكدرة والاطيان المترسبة • تستخدم في المدن الكبيرة • تحتاج الى ضغط قبل ضخها الى المدينة	• لاتحتاج الى مساحات واسعة وتستخدم خزانات فولاذية تتحمل الضغط المطلوب • معدل الترشيح عالي • كفاءة الترشيح واطئة • تغسل بالتدفق الراجع • تستخدم في التجمعات السكانية الصغيرة • تضخ المياه الى المدينة بضغط المرشح

Design

$$\mathbf{OFR = Q/A}$$

OFR= over flow loading rate. $m^3/m^2.d$, the typical OFR for rapid sand filter is 120 $m^3/m^2.d$.

Q= flow rate, m^3/d
A= surface area of filter. m^2

Example (finding the number and surface area): A city is to install rapid sand filters downstream of clarifiers. The design loading rate is selected to be 160 $m^3/m^2.d$. The design capacity of the waterworks is 0.35 m^3/s. The maximum surface per filter is limited to 50 m^2. Design the number and size of filters and calculate the normal filtration rate.

Solution:

Step 1: Determine the total surface area required:

$$A = \frac{Q}{OFR} = \frac{0.35\ m^3/s}{160\frac{m^3}{m^2.d}} = 189\ m^2$$

Step 2: determine the number (n) of filters

$$n = \frac{189\ m^2}{50\ m} = 3.78$$ Select four filters

The surface area (a) for each filter is

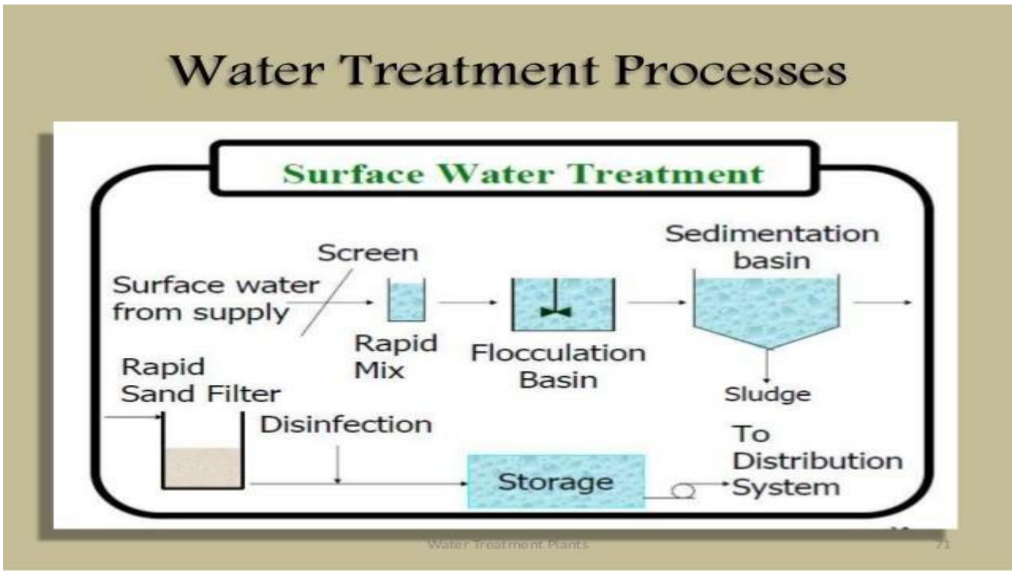
$$a = \frac{189}{4} = 47.25\ m^2$$

We can use 7 m x 7 m or 6 m x 8 m, or 5.9 m x 8 m (exact) المساحة الحقيقية Step 3:

if 7 m x 7 m filter is installed, the normal filtration rate is

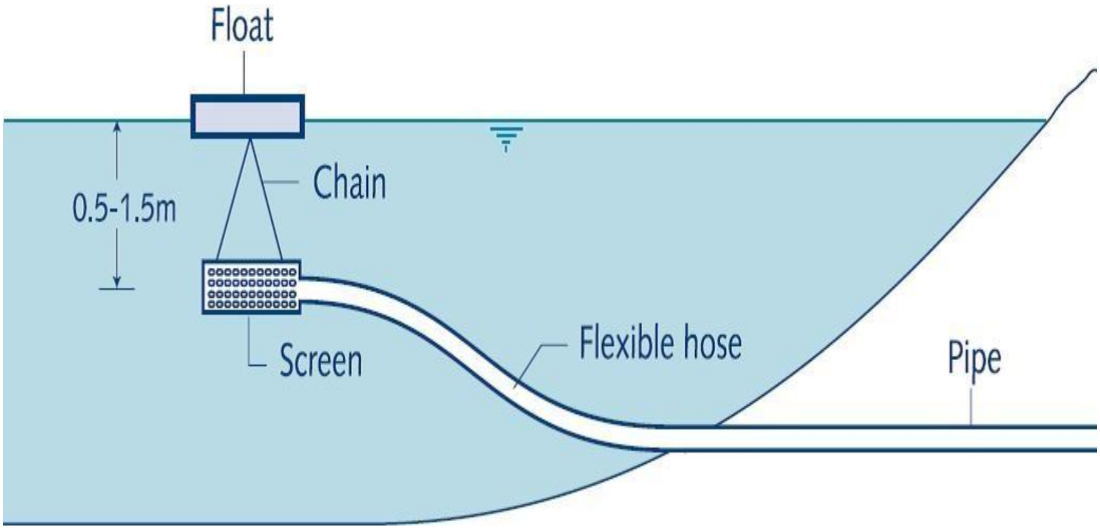
$$OFR = \frac{Q}{A} = \frac{0.35\frac{m^3}{s} x\ 86400\frac{s}{d}}{4\ x\ 7\ x\ 7} = 154.3\ \frac{m^3}{m^2.d}$$ هذا الحقيقي وليس160

Distribution works.



1. Intakes

Intakes consist of the opening, strainer, or grating through which the water enters, and the conduit conveying the water, usually by gravity, to a well or sump. From the well the water is pumped to the mains or treatment plant. Intakes should be so located and designed that possibility of interference with the supply is minimized and where uncertainty of continuous serviceability exists, intakes should be duplicated.



The following must be considered in designing and locating intakes:

1- The source of supply, whether impounding reservoir, lake, or river (including the possibility of wide fluctuation in water level).
2- The character of the intake surroundings, depth of water, character of bottom, navigation requirements, the effects of currents, floods, and storms upon the structure and in scouring the bottom.
3- The location with respect to sources of pollution.
4- The prevalence of floating material such as ice, logs, and vegetation.

2. Type of Intakes

1. Intakes from Impounding Reservoirs

The water of impounding reservoirs is likely to vary in quality at different levels, making it usually desirable to take water from about a meter below the surface. This, with the fluctuations of water level which may be expected in reservoirs, makes it advisable to have ports at various heights. Where the dam is of earth, the intake is usually a concrete tower located in deep water near the upstream toe of the dam. Access to the tower so that the gates of the various openings may be manipulated is obtained by means of a footbridge. The ports may be closed by sluice gates or by gate valves on short lengths of pipe. Where the dam is of masonry, the intake may be a well in the dam structure itself, also with openings at various heights.

2. Lake Intakes

If the lake shore is inhabited, the intake should be so located that danger of pollution will be minimized. This may require study of currents and effects of winds with particular attention to movement of sewage or industrial wastes, if these are discharged into the lake. It is also advisable to have the intake opening 2.5 m or more above the bottom so that large amounts of silt will not be carried in with the water. *Entering velocities must be low,* or excessive amounts of floating matter, sediment, fish, and frazil ice may be carried in. Entering velocities less than 0.15 m/s have been used successfully. Offshore winds tend to stir up sediment which will be carried out for long distances. Water depth (6-9 m).

3. River Intakes

Small cities may use pipe intakes similar to those described under lake intakes. The bottom *must be sufficiently stabl*e, and the *water deep enough to allow asubmergence* of at least 1 m at all times with a clear opening beneath the pipe so that any tendency to form a bar is overcome. Intakes of this type should have provision for reversing flow to clear the strainer openings or screens. On *rock bottoms* where it is inadvisable, on account of navigation requirements, to have the intake project above the river bottom, an intake box of steel plates has been placed in a trench.

On *soft bottoms* intake boxes have been supported on piles. Where the river bottom changes considerably, a shore intake is used. It is located on the low-water bank and may consist of a trench or tunnel paralleling the stream with one or more ports leading the river water in. The ports may be protected by bar gratings. It may be advisable to provide facilities for quick removal of silt from the vicinity of the ports. To prevent such silting, low diversion dams have been built to deflect the main current past the intake during low-river stages. River intakes are especially likely to need screens to exclude large floating matter which might injure pumps. Submerged crib intakes may use wood bars for this purpose; other intakes employ vertical gratings of steel bars. Automatically cleaned bar screens can be obtained from various manufacturers and are sometimes used. It may not be necessary to operate the automatic cleaning feature at all times. Movable fine screens, if installed, are usually placed in the more accessible pump well at the entrance to the suction pipes.

4. The Intakes Conduit

A shore intake may also be the supply well for the suction pipe leading to the pumps. Intakes located long distances from the pumps usually deliver their water to the pump well at the shore end by gravity. This necessitates a large pipe or conduit so that velocities will be low but not low enough to allow sedimentation. The conduit may be a submerged pipe or a tunnel. Tunnels are expensive but less likely to be damaged than are pipes. A submerged pipe should be protected by burying it in a trench or by surrounding it with rock or holding it in place with piling.

3- Intake Structure parts

1. Intake structure.

2. Intake conduits.

3. Raw water lift pump station.

4. Transmission lines.

4- Purpose of intake structure

1. Collect the water from the source.

2. Protect the embankment sides slopes from failure.

3. Prevent clogging of intake conduits (because the intake structure consists of screen prevent the entrance of the undesired matters).

5- Factors affecting the location of intake

1. Located on straight part of the water source (hydraulic and structural stability) to prevent settling and scoring.
2. The site should be near the treatment plant so that the cost of convying water to the city is less.
3. The intake must be located in the purer zone of the source to draw best quality water from the source, thereby reducing load on the treatment plant.
4. The intake must be upstream the served city to prevent the direct pollution and never be located at the downstream or in the vicinity of the point of wastewater disposal.

5. The site should permit greater withdrawal of water, if more quantity is need in a future.

6. The intake must be located at a place from where it can draw water even during the driest period of the year, and it should remain easily accessible during floods and should not get flooded.

6- Factors affecting the choice of intake structure type

1. Water source dimensions (width – depth) (Narrow or wide) (Shallow or deep).

2. Character of bottom.

3. Effect of currents, floods and storms upon the structure.

4. Water source pollution (on shore – on surface).

5. Navigation requirements.

6. Fluctuation in water level.

The distance between the centerline (Φ) of the pump and the low water level elevation (L.W.L) not exceed 5 m .

7- Design of Intake

i. Intake conduit

Purpose: To transmit raw water from source to low left pump (L.L.P).

Design criteria:

1. Units should be in duplication.

2. Detention time (15–30) min.

3. The effective depth effect by L.W.L.

4. Bottom of the well is 1 m below the river bed.

5. Provide enough space inside well for repair and maintenance.

6. Clearness between check valve and the well bottom = 0.6 m to prevent the settling inside basin which may effect on the pump performance.

7. Flow velocity through the gravity pipe is 0.6–1.5 m/sec, maximum ≤ 2 m/s.

8. Flow velocity through wash pipe is 3 m/sec.

9. Discharge for the wash pipe= 1/3 discharge for gravity pipe.

10. Number of pipes $n \geq 2$

10. Friction losses $hf = \frac{4flv^2}{2gd}$

f = Mody chart
l = 30 – 50 m (for shore intake).
l = 50 – 100m (for pipe intake).

ii. Suction well (sump – wet well)

Purpose: Distribute the raw water uniformly on the total number of pumps.

Design criteria:

1. Well (Sump) should be water tight.

2. Length ≥ 5 times the diameter of the intake conduit.

3. Length = number of pumps x (1.5 – 2.5).

4. Width= 1 – 3 m.

5. Depth (m) ≥ (H.W.L – bed level) – hf + 0.5

6. t (min.) = 5

$V\ (m^3) = Q\ \text{design} \times t$

$A\ (m^2) = V/d,\ A = B \times L$

iii. Low lift pump

Purpose: It is used to raise the raw water from the source level to water level in the first tank in water treatment plant.

Design criteria:

Qdesign = Qmax= f*Qavg.

$H_{total} = H_s + hf + h_s$

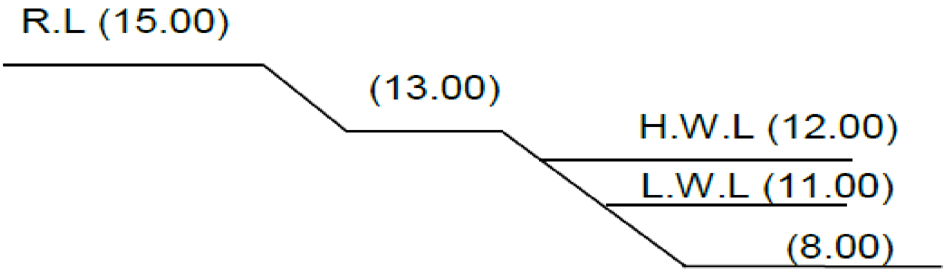
Hs = static head it is the difference between L.W.L. and the water level (W.L) in the first tank in the water treatment plant (W.T.P) ~ 5m above land level.

= (G.L – L.W.L) + 5

hf = friction losses = $hf = \frac{4\,f\,l\,v^2}{2gd}$

Hs = secondary losses = 10 % hf

Example: It is required to design the collection works for a city of population 24,000 capita and average water consumption 180 l/c/d if pumps work 20 hr/d. The source of water is narrow and navigable canal, its dimensions as shown in figure. Calculate the intake conduit.



Solution:

Qave. = pop x consumption rate

$$= \frac{24000 \times 180}{1000 \times 20 \times 60 \times 60} = 0.6\ m^3/s$$

Qdesign = Q max. monthly x 1.1

= 1.5 x Qave x 1.1 = 1.5 x 0.06 x 1.1 = 0.099 m^3/s

Qmin = 0.7 x Qave x 1.1 = 0.7 x 0.06 x 1.1 = 0.046 m^3/s

<u>**Intake conduit**</u>

Q design = A x v (v= 0.6 – 1.5 m/s)

Take v = 1 m/s

A= n ($\pi D^2/4$, n: pipes number

Take n = 3 ∴ D = 0.205 m

$A = Q_{design}/v = 0.099 / 1 = 0.099\ m^2$

$V_{act} = Q_{design} / A_{act}$

$= 0.99 / 3\pi (0.6)^2 /4 = 1.167$ m/s >1.5 and > 0.6 ∴SAFE

When one pipe is broken

$V_{max} \leq 2.5$ m/s , n=2 ,

$V_{max} = Q_d / (n-1)\ \pi\ \varphi^2\ /4$

$= 0.99/2\pi\ (0.6)^2\ /4 = 1.75$ m/s >2.5 safe

At Q_{min}

$V_{min} = Q_{min}/n\ \pi\ \varphi^2\ /4$

$= 0.64/\ 3\ \pi\ (0.6)2\ /4 = 0.54$ m/s >0.6 unsafe

Close one pipe at the month of Q_{min}

$V_{min} = Q_{min}/(n-1)\ \pi\ \varphi^2\ /4$

$= 0.46/2\ \pi\ (0.6)^2\ /4 = 0.81$m/s <0.6 Safe

Sump

$V = Q_d \times T$

$= 0.99 \times 5 \times 60 = 297 m^3$

$V = B \times L \times d$

d = H.W.L – bed level –hf +0.5

= 12- 8 - 0.18 + 0.5 =4.32m

B= 1-3 m take B=2m

$L = 297/2 \times 4.32 = 34.375$m

Check

Length ≥ 5 times the diameter of the intake conduit

$L = 5 \times 3 \times 0.6 = 9$m Safe

L.L.P

$H_{total} = Hs + hf + hs$

Hs = (G.L – L.W.L) + 5 =7m

$$hf = \frac{4\ f\ l\ v^2}{2gd} = \frac{4\ 0.008 \times 50 \times (1.167)^2}{2 \times 9.81 \times 0.6} = 0.18m$$

hs =10% hf = $0.1 \times 0.18 = 0.018$m

HT = 7+0.18+0.018 = 7.198m

Disinfection

It is the process of killing the microorganism causes disease (pathologic) that it may contain.

Method of disinfection:

1. Physical disinfection:

a) Boiling water for 15 – 20 min b) Exposed water to sun ray.

2. Chemical method: using chemical matter such as:

a) Halogen (Br, Fl and Cl) b) Potassium permanganate ($KMnO_4$)

c) Ozone (O_3)

CHLORINATION

Chlorination is the addition of chlorine to kill the bacteria Chlorination is very widely adopted in all developing countries for treatment of water for public supply.

Advantages

- ❖ Cheap
- ❖ Residual for network
- ❖ Available
- ❖ Easy to store, and stored for a long time.
- ❖ Simple equipment required.
- ❖ Easy to use.

Disadvantages

- ❖ High chlorine dose may cause change in the water colure and taste.
- ❖ Chlorine reacts with organic compound that appears in water and the results are cancer compounds.

Factors affecting efficiency of chlorination:

- Temperature directly proportional
- Ph value inversely proportional: more efficient at pH less than 7.
- Chlorine dose

Chlorine dose 0.5 – 1 mg/l is required to give the residual from 0.1 – 0.3 mg/l.

- Adequate mixing
- Retention period (½ hr)

Optimal dose of chlorine

Optimum dose depends up on:

a) Water quality (bacteria, suspended particles, elements content such (fe), and organic matter)
b) Boundary condition (temperature and pH)
c) Contact time

Point of chlorination

a) Prechlorination: Chlorine applied prior to the sedimentation and filtration process. It is practiced when the water is heavily polluted and to remove taste, odour, colour and growth of algae on treatment units. Pre-chlorination improves coagulation and post chlorination dosage may be reduced.

b) Post Chlorination

When the chlorine is added in the water after all the treatment is known as Post chlorination.

c) Re-Chlorination

In long distribution systems, chlorine residual may fall tendering the water unsafe.

Behavior of Chlorine in water

When chlorine is dissolved in water forms hypo chlorous acid and hydrochloric acid.

$Cl_2 + H_2O \rightarrow HOCl + HCl$ ---------- (1)

After some time hydo chlorous acid further ionizes as follows

$HOCl \longleftrightarrow H^+ + OCl^-$ -------------- (2)

The two prevailing species (HOCl) and (OCl -) are called free available chlorine are responsible for the disinfection of water.

Chlorine reacts with ammonia in water to form Monchloramine, (NH_2Cl), dichloramine ($NHCl_2$) and trichloramine, (NCl_3) released and their distribution depends on the PH value of water.

Dosage of Chlorine

(A) Plain Chlorination

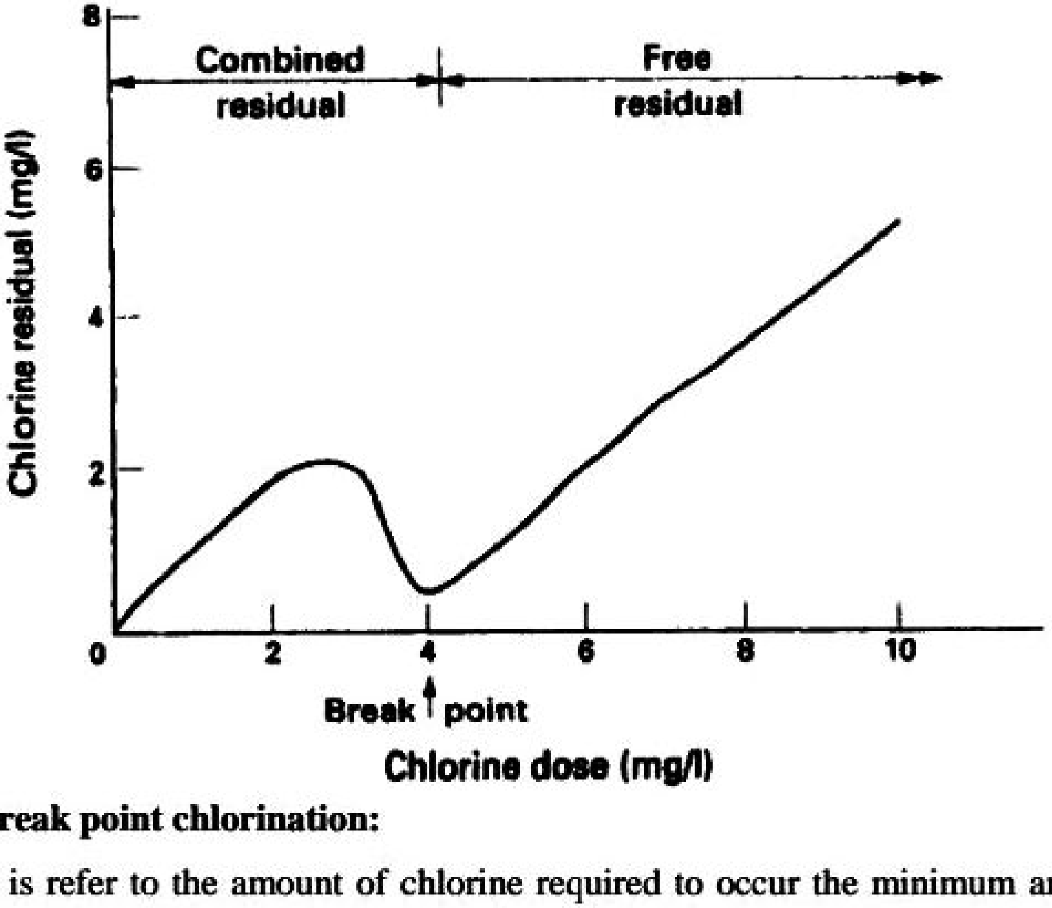
It is the process of addition of chlorine only when the surface water with no other treatment is required. The amount of chlorine should be maintained in resided chlorine of 0.2 mg/L.

(B) Super Chlorination

It is defined as administration of a dose considerably in excess of that necessary for the adequate bacterial purification of water. About 10 to 15 mg/L is applied with a contact time of 10 to 30 minutes.

(C) Break point Chlorination

When chlorine is applied to water containing organics, microorganisms and ammonia the residual chlorine levels fluctuate with increase in dosage as shown.



Break point chlorination:

It is refer to the amount of chlorine required to occur the minimum amount of residual chlorine.

Contact time:

It is refer to the time required for chlorine to killing pathological microorganisms such as bacteria.

Contact time can be obtained from Chick's low: $t = -\left(\frac{1}{k}\right) * \log\frac{N}{N_o}$

Where:

t: time; k: constant $\left(\frac{1}{time}\right)$

N: Number or percent of microorganisms in time t.

N_o: Number or percent of microorganisms in initial time (t=0).

Example: Find the contact time required for chlorine to kill 99.9% from microorganisms if $k=0.06\ sec^{-1}$.

Solution:

$$t = -\left(\frac{1}{k}\right) * \log\frac{N}{N_o} \quad t = -\left(\frac{1}{0.06}\right) * \log\frac{100-99.9}{100} = 67\ sec$$

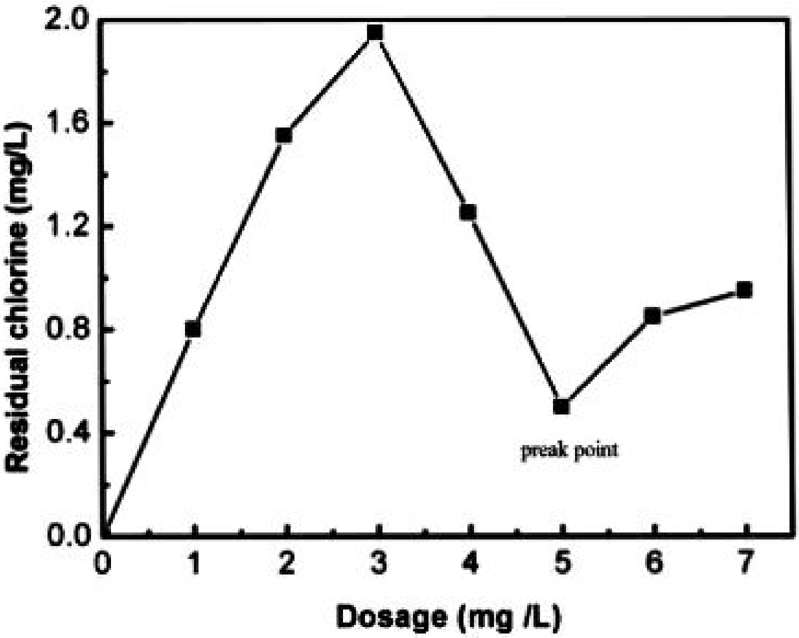
Example: determine thr preak point dosage of chlorine given the data below which was obtained from chlorination experiment.

Dosage (mg/L)	1	2	3	4	5	6	7
Required Cl_2 (mg/L)	0.2	0.45	1.05	2.75	4.5	5.15	6.03

Solution:

Residual chlorine (mg/L) = dosage – required

Dosage (mg/L)	Required (mg/L)	Residual (mg/L)
1	0.2	0.8
2	0.45	1.55
3	1.05	1.95
4	2.75	1.25
5	4.5	0.5
6	5.15	0.85
7	6.03	0.95



So break point chlorination obtained at dosage of 5 mg/L

5. Volume of water tank will need to hold

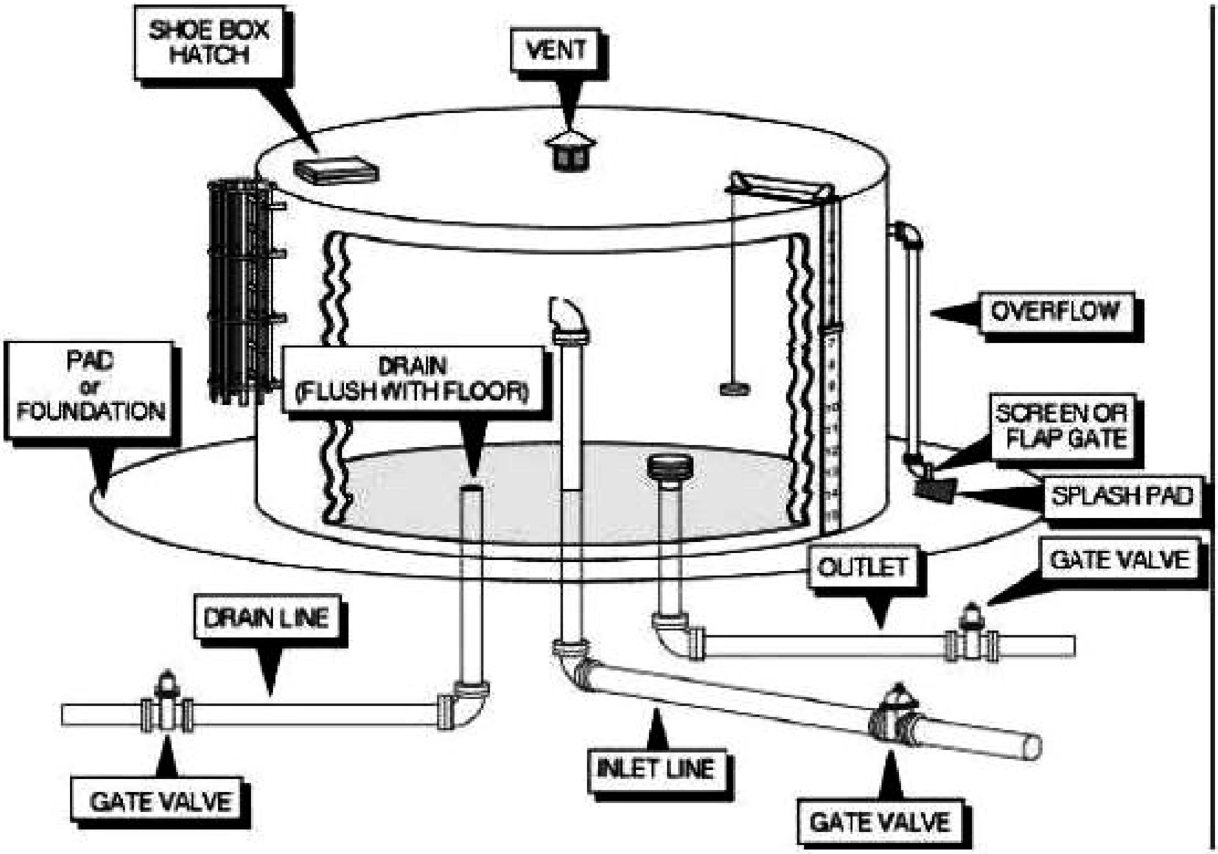
Large volume → ground

Small volume → elevated

Capacity= 15-20% of average daily consumption. For moderate size systems take 30 – 40%.

Note: Several smaller storage units are better than one central site;

Smaller distribution pipes &uniform water pressure.

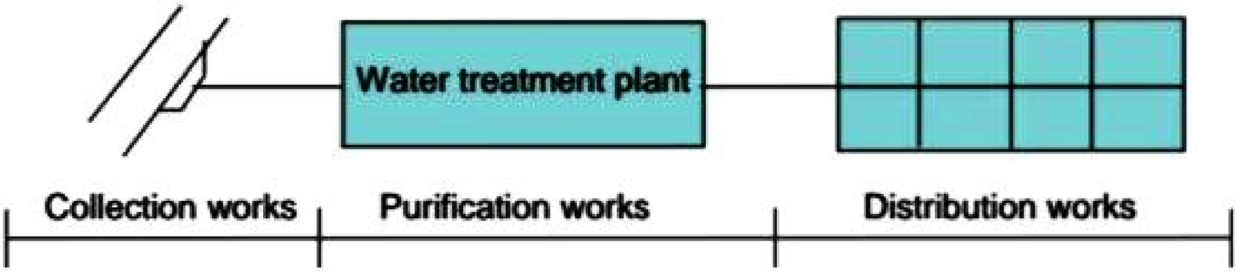


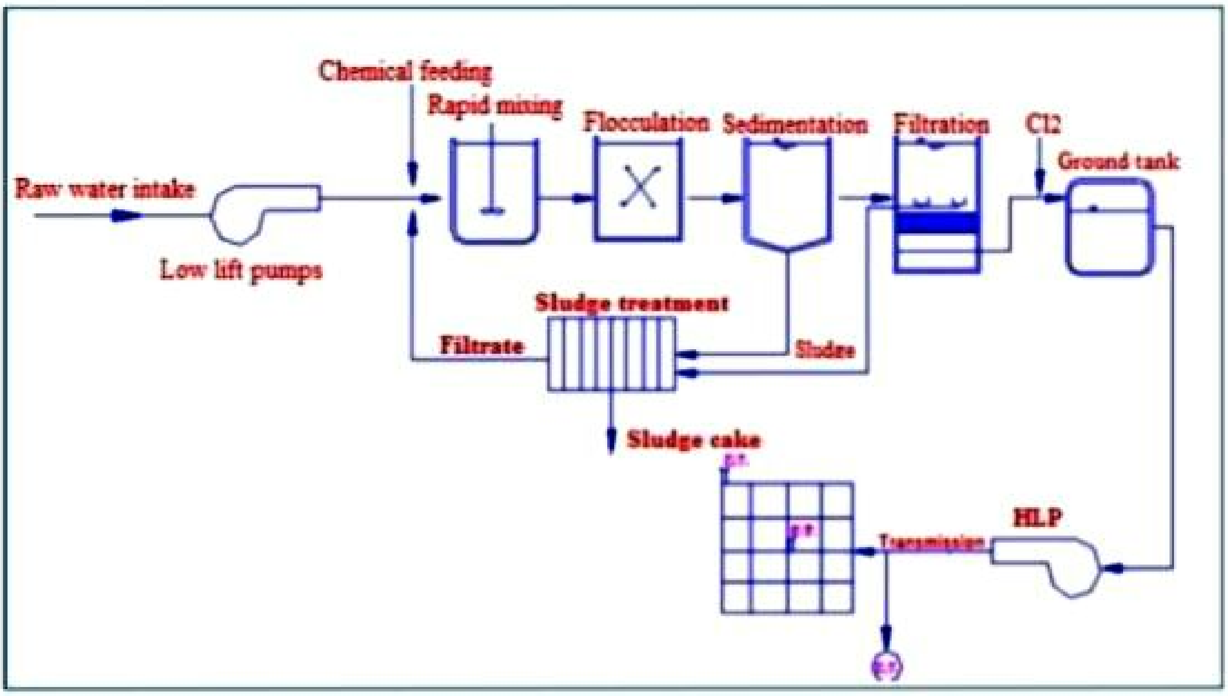
Components of a Storage Tank

Water supply works

Water supply works consists of three main stages:

1- Collection works.
2- Purification works.
3- Distribution works.





Collection works for surface water

Collection works consist of:

1- Intake and intake conduit.

2- Sump.

3- Low lift pumps.

It is the destabilization of colloids by addition of chemicals that neutralize the negative charges

Kind of coagulants

1- Hydrous aluminum sulfate (Alum) $Al_2(SO_4)_3.18H_2O$

- easy to use
- cheap
- available

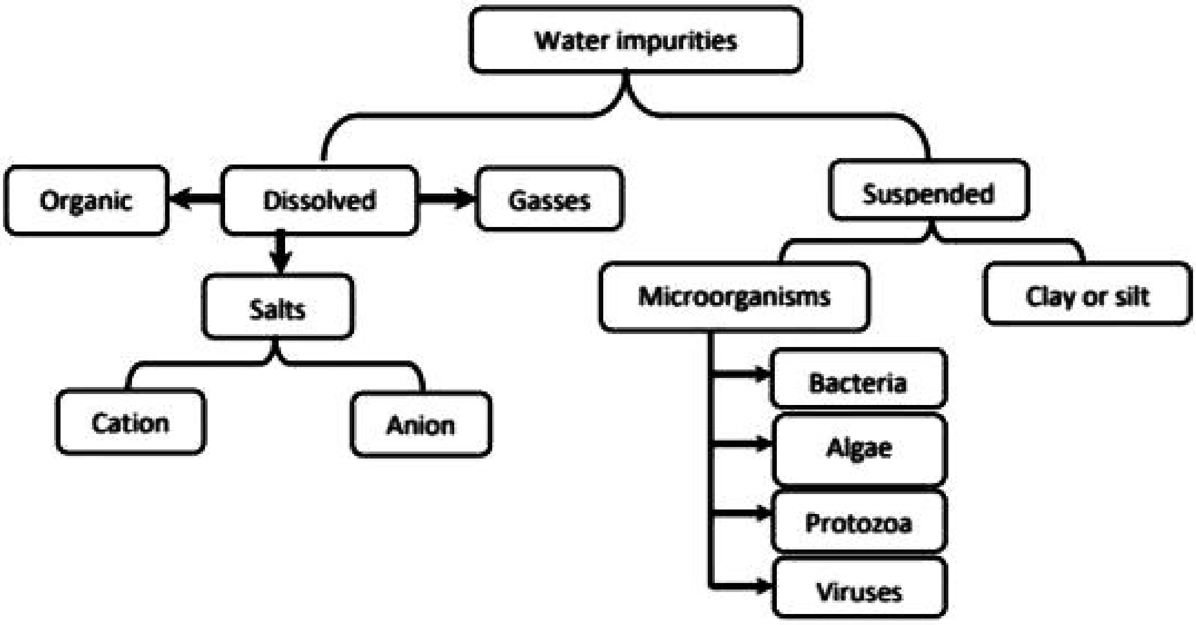
2- Ferrous sulfate $Fe_2 (SO_4)_3$

3- Ferric sulfate $Fe (SO_4).7H_2O$

4- Ferric chloride $Fe Cl_3$

Polymers: it is molecule consist of a series of chemical unit held together by covalent bond.

Water impurities:



Colloidal particles: it is small particles floated or suspended in water have small size ($10\ \mu, 1\mu, 0.1\ \mu$)

Note: ($\mu = 1 * 10^{-3}\ mm$)

Methods of feeding coagulant:

1- Dry feeding: (powder or granular)

Advantages:

1- Control the added dose.

Disadvantages:

1- Needs of a good aerated place to store.

2- Arch action.

3- Non homogeneous solution.

2- Wet feeding:

Advantages:

1- Homogeneous solution.

Disadvantage:

1- It needs mechanical maintenance.

2- Construction of alum solution preparation tanks.

Factors affect the coagulation efficiency

1. pH of raw water and temperature.
2. Mixing.
3. Coagulant type.
4. Feeding method (dry – wet).

Mixing coagulant

Purpose:

Distribute the coagulant uniformly in raw water.

1- Injection the solution of the coagulant in the delivery pipe of the low lift pump.

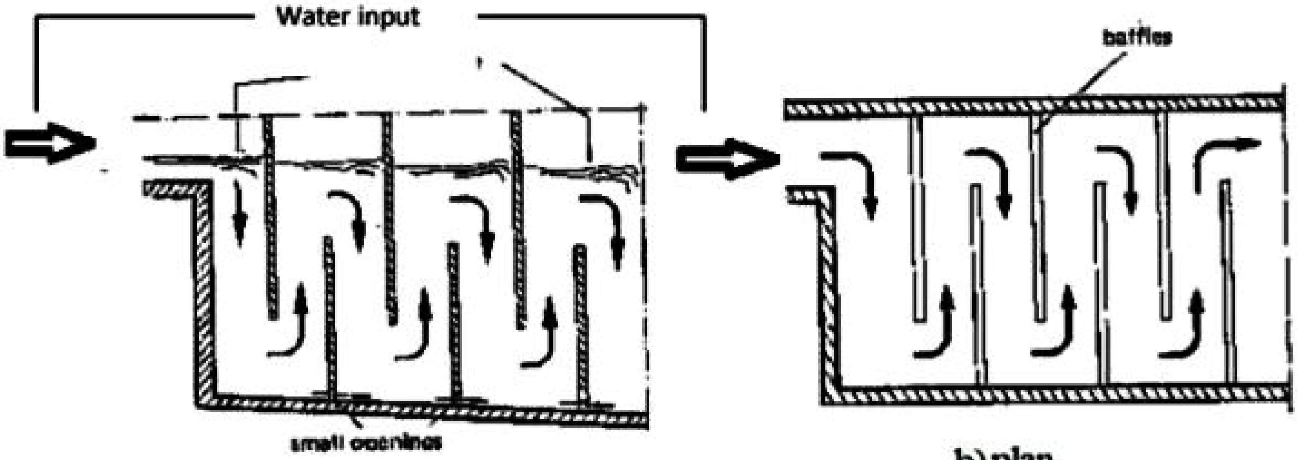
2- Adding the coagulant solution in a venture so that the turbulence which occurs mixes the coagulant with water.

3- Using flash mixing tank.

Mixing method

1) static (hydraulic) mixing

- economic (not need to mechanical or electrical power)
- The concentration level of coagulant is decrease when the water nearest to out flow because of head losses (0.5–1 m).
-



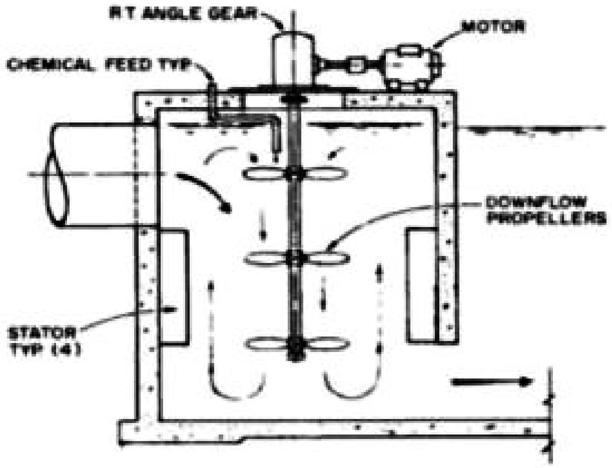
a) section

b) plan

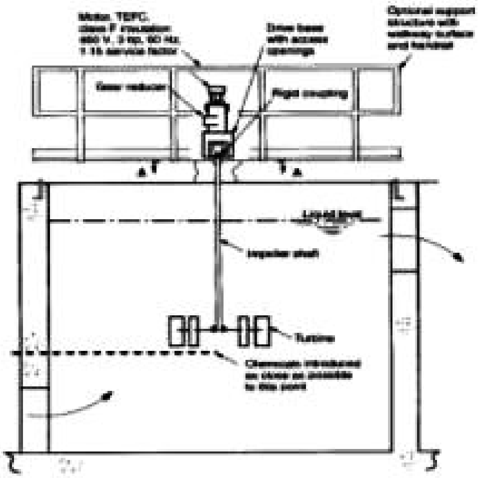
Hydraulic mixing in coagulation tank.

3. Mechanical mixing

Using impeller or turbine for mixing coagulant material

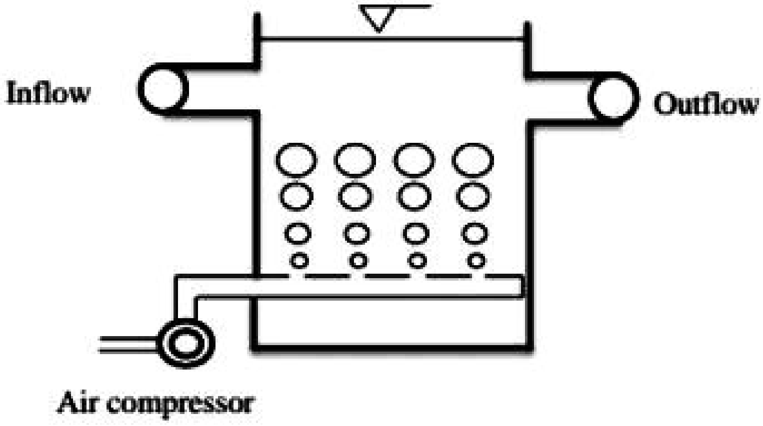


Propeller-type mechanical flash



Turbine- type mechanical flash

3- Air mixing



Design criteria:

- retention time = T = (60 - 120) sec
- depth = (1- 3) m
- Diameter ≤ 35 m
- No. of tanks ≥ 1
- Speed of impeller = (100 - 300) R.P.M
- Volume = Qd x T
- Power required = 2–5 kw for each 1 m^3/min

Power input in mixing and flocculation is frequency expressed in terms of the mean velocity G (1/T) (sec^{-1})

$$G = \sqrt{\frac{P}{\mu\, v}}$$

Where:

G: gradient velocity

P: the power dissipated (watt, watt = $\frac{N.M}{sec}$)

μ: the absolute viscosity ($\frac{N.sec}{m^2}$)

v: volume to which power is applied (m^3).

GT= 30000–60000

Example Design a rapid mixing unit (mechanical) for a discharge of 5 mgd. What is the total amount of Alum if the dose is 50 mg/L? G= 300 sec $^{-1}$, T= 60 sec and μ= 1.027 *10$^{-3}\frac{N.sec}{m^2}$

Solution

Vol. = Q* D.T., assume D.T. = 1 min

$$Q = 5 * \ 10^6 \ \frac{gal.}{day} * 3.78 \ \frac{L}{gal.} * \frac{m^3}{1000\ L} = 18900\ m^3/day$$

$$Q_d = 18900 * 1.1 = \ 20790\ m^3/day$$

$$vol. = 20790\ \frac{m^3}{day} * \ \frac{day}{1440\ min} * 1\ min \ = 14.44\ m^3$$

Use two units (basin)-cubic shape

Volume of one tank = 14.44/2= 7.22 m^3

D=$\sqrt[3]{7.22}$ = 1.933 m

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

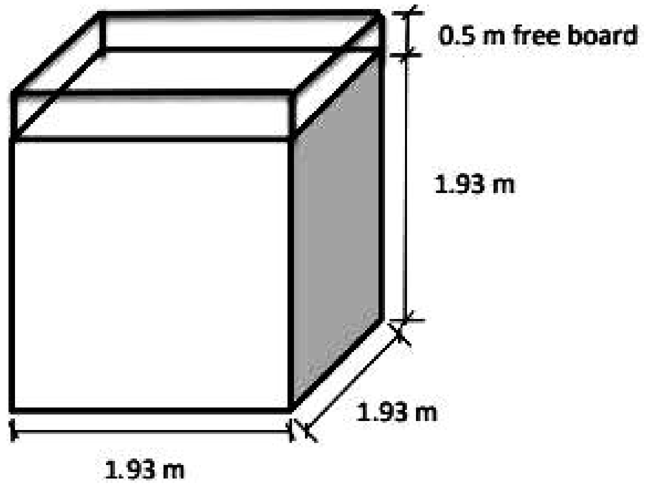
P= 90000 * 7.22 *1.027 * 10^{-3}= 667.35 watt = $\frac{667.35}{745.7} = 0.89\ hp$

Alum dose = 50 $\frac{mg}{L} * \frac{1000\ L}{m^3} * \frac{gm}{1000\ mg} = 50\frac{gm}{m^3}$

Total alum quantity = Q * dose

Total quantity = 20790$\frac{m^3}{day} * 50\ \frac{gm^3}{m^3} = 1039500\ \frac{gm}{day}$ = 1039.5 kg/day

Use 2 cubic tank as coagulation tank as shown in figure



Ex:- Design a rapid mixing unit (mechanical) for a discharge of 5 mgd. What is the total amount of alum if the dose is 50 $\frac{mg}{L}$? $G = 300\ Sec^{-1}$, $T = 60\ sec$ and $\mu = 1.027 \times 10^{-3}\ \frac{N\ Sec}{m^2}$ and assume $L = 1.5\ W$?

Solution

$Q = 5\ mgd$

$$= 5\,000\,000\ \frac{gal}{\cancel{d}} * 3.78\ \frac{L}{gal} \cdot \frac{m^3}{1000\ L} * \frac{\cancel{d}}{24\ \cancel{hr}} \cdot \frac{\cancel{hr}}{60 * 60\ sec}$$

$$\therefore Q = 0.218\ \frac{m^3}{sec}$$

$$Q = \frac{V}{t} \Rightarrow V = Q * t$$

$$V = 0.218 * 60\ sec \Rightarrow 13.125\ m^3$$

assume $n = 2$

$$\therefore V = \frac{13.125}{2} \Rightarrow V = 6.56\ m^3$$

If cubic tank:

$$V = d^3$$

$$6.56 = d^3$$

$$\therefore d = 1.87\ m$$

If circular tank :

$A = 3.28\ m^2$

$A = \frac{\pi}{4} d^2$

$3.28 = \frac{\pi}{4} d^2 \Rightarrow d = 2.04\ m$

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

$$300 = \sqrt{\frac{P}{1.027 \times 10^{-3} \times 6.56}} \Rightarrow P = 606 \text{ watt}$$

- مطلوب السؤال الثاني هو: حساب كمية الشب الكلية اذا كل لتر من الماء الخام نضيف له 50 mg/L من الشب.

amount of alum = $Q \times dose$

$$= 18900 \frac{\cancel{m^3}}{d} \times 50 \frac{\cancel{mg}}{\cancel{L}} \times \frac{1000 \cancel{L}}{\cancel{m^3}} \times \frac{\cancel{gm}}{1000 \cancel{mg}} \times \frac{Kg}{1000 \cancel{gm}}$$

$= 945\ Kg/d$

If rectangular tank :

from design criteria depth = (1 – 3) m

$\therefore$ assum depth = 2m

$V = A * \text{depth}$

$6.56 = A * 2 \Rightarrow A = 3.28\ m^2$

$L = 1.5\,W$ -- ①

$A = L * W$

$A = 1.5\,W * W$

$A = 1.5\,W^2$

$3.28 = 1.5\,W^2$

$\therefore W \simeq 1.5\ m$

نعوض بالمعادلة ① لايجاد قيمة L

$L = 1.5 * 1.5$

$= 2.25\ m$

$\therefore$ d = 2m

W = 1.5 m

L = 2.25 m

المحاضرة الاولى

ENVIRONMENT

Water Resources

Five type of water resources are commonly known and they are:

1. Participates
2. surfaces waters
3. Ground waters
4. desalinization waters
5. treating for disposal liquid

Drinking Water:

It is the water that flow in a water supply distribution net for domestic uses net which include (houses, small local industries, commercial uses)

- Housing consumption 45%
- Local industries consumptions: 18%
- Commercial consumptions: 15%
- General consumptions: 12%
  Include (fire, garden irrigation and street washing)
- Losses: 10% --→ leeks from net pipes

Factors Affecting Water Consumptions

1- Cities size and level of living.
2- Climate status (warm, hot, cold, humid …. etc)
3- Water quality and degree of treatment.
4- Water pressure through the net.
5- Availability of sewerage net.
6- Present of counters and pricing politic for water.
7- Civilization and building status
8- Uses of water for cooling. (air-cooler)

Quality Criteria for Drinking Water

- Must be transparent (without any color)
- Has a good taste
- Save (absence of any micro-organisms such bacteria or viruses

For biological specification, the following conditions must be available:

1- 95% of samples (100 ml size) should be free of coliform bacteria – through one year.
2- Absence of Diseases bacteria.
3- Coli-from bacteria must be not more than 10 cells (in 100 ml sample)
4- Coliform bacteria must be not founded in two alternative samples.

In additional to WHO specifications there are some other specifications such as:

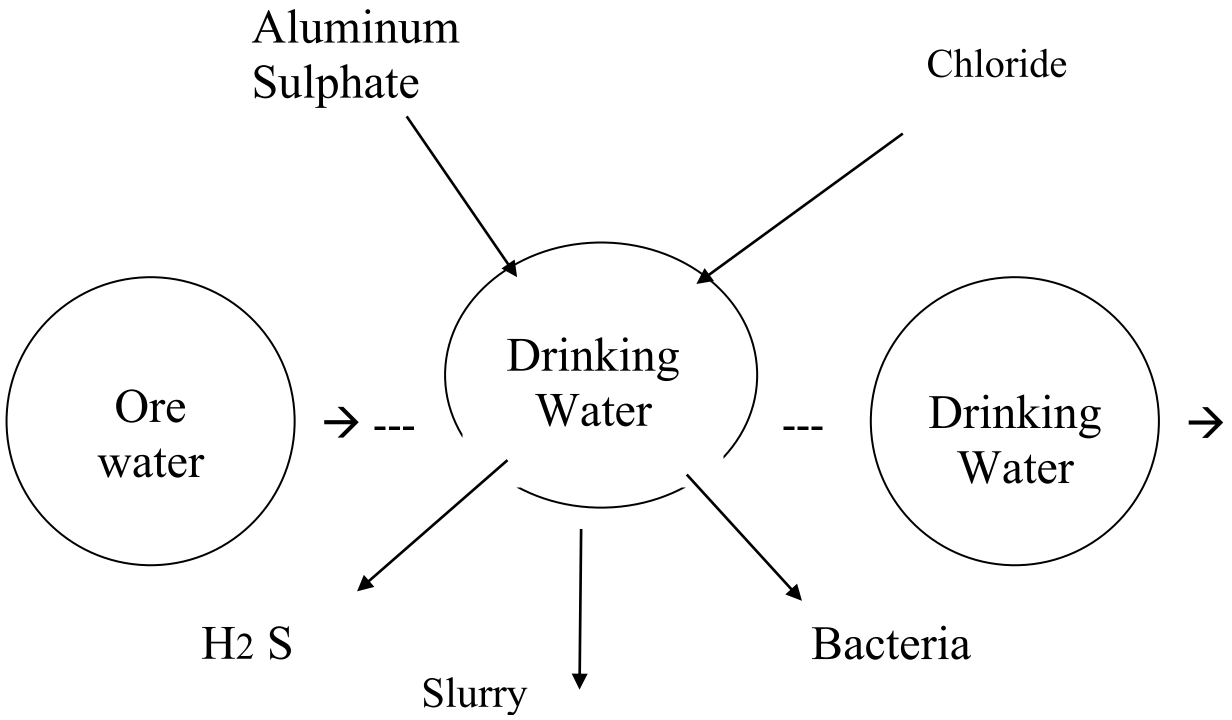
- USPHS specification (United States Public Health Section)
- Egyptian Specification
- Iraqi Specification

There are two ways to put specifications for any pollutants:

1- By monitoring the people habitations and pollutants in attach.
2- By laboratory investigations

Water Treatment for Drinking Water

Treatment means: modification of ore water quality by reducing (or sometimes adding) some tarnish concentration to obtain pure drinking water.



Treatment of Surface Water resource degree depends on:

1- Quality of Water resources
2- Degree of specification
3- Economical Cost
    - Cost of construction
    - Annual Cost of operating
    - Cost of Chemicals
    - Cost of skilled labors

Treatment of Ground Water degree depends on:

1- Layer that contains the water
2- Age of ground water
3- Nature of earth layers those the water pass throws them.

Conventional Units for Drinking Water Treatment

Treatment Plant should be:

1- Acceptable cost
2- Could be with available workers and skilled
3- Ability to face quality changes in water resources (for different seasons.
4- Enough Capacity to produce the needs of the cities with good qualities.

Some Types of resources and Required treatments

1- Ground Waters (most times) doesn't need any treatment. Governments add chloride to prevent polluting water through flow in pipes
2- Water resources at its fountainheads has very little bacteria
3- Rivers with limited degree of pollutions but has high number of suspended Solids (S.S), need sedimentations, filtration and disinfecting.
4- Some ground resources and rivers at its outfalls need softening plant to remove chemicals and hardness.

There are hundreds of pollutants which need different procedures (like: aeration to remove H_2S, Fe, and Mn) to remove it

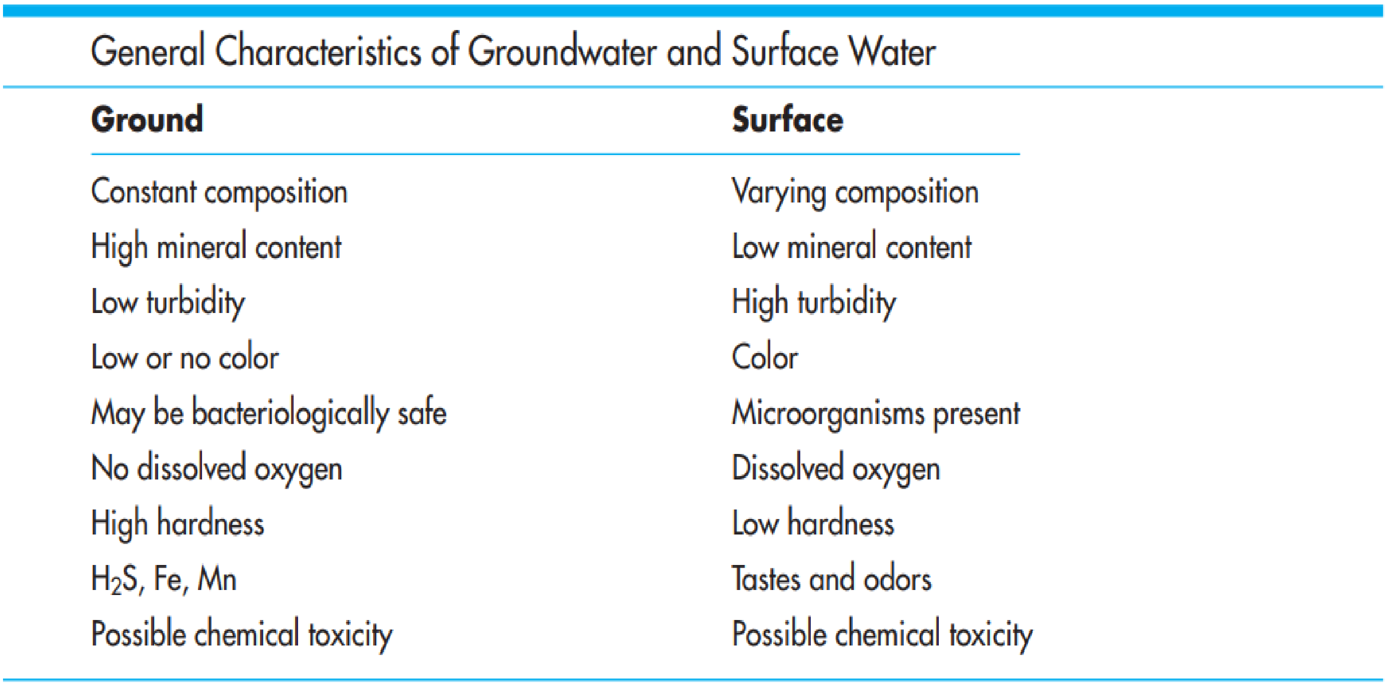
Treatment Systems:

Water treatment facilities in developed countries are coagulation plants.

(Figure1) are typically used to treat surface water and remove color, turbidity, taste and odors, and bacteria. Most plants use coagulation, flocculation, followed by sedimentation and then filtration and disinfection.

However, higher quality (low turbidity and color) surface waters can be treated using direct filtration, in which case, sedimentation is omitted, as shown in (Figure 2).

Softening plants (Figure 3) are typically used to treat groundwater that has a high hardness (predominantly calcium and magnesium ions).



General Characteristics of Groundwater and Surface Water

Ground	**Surface**
Constant composition	Varying composition
High mineral content	Low mineral content
Low turbidity	High turbidity
Low or no color	Color
May be bacteriologically safe	Microorganisms present
No dissolved oxygen	Dissolved oxygen
High hardness	Low hardness
H_2S, Fe, Mn	Tastes and odors
Possible chemical toxicity	Possible chemical toxicity

As shown in Figure 1, the raw surface water is pumped from a stream, river, lake, or reservoir using low-lift pumps into the coagulation plant.

The water is first screened to remove large material including twigs, plant material, and fish.

During rapid mixing, chemicals called coagulants are added and rapidly dispersed through the water.

In the flocculation basin, the chemical reacts with the colloidal particles in the water to form larger particles. Once the particles are a sufficient size to precipitate, they are usually removed by gravity in sedimentation basins. Following sedimentation, the clarified water is distributed to rapid sand filters to remove residua turbidity. Disinfection is then used to reduce the number of pathogenic organisms to levels that will not cause disease.

It is usually achieved by the addition of chemicals (chlorine, ozone) or the application of UV radiation. Fluoridation, the addition of fluoride to strengthen teeth and reduce the number of cavities, especially in children, can also be a part of the treatment process, as can corrosion control, which prevents corrosion of the pipes in the distribution system.

The precipitated chemicals, along with particles, that are removed from the sedimentation basins are present in the sludge that accumulates at the bottom of the tank. This sludge, which contains approximately 94–98% water must be treated further and then disposed of properly. The backwash water from the filters also contains particulate matter and bacteria, along with precipitated chemicals. It, too, must be treated and disposed of.

Coagulants

is a chemical that is added to the water to cause the particles to coagulate. A coagulant has three key properties:

1. Trivalent cation. naturally occurring colloids are most commonly negatively charged; hence cations are required to achieve charge neutralization. are much more effective than monovalent or divalent simple cations, such as sodium and calcium.

2. Nontoxic. Obviously, for the production of potable water the coagulant must be nontoxic.

3. Insoluble in the neutral pH range. High concentrations of the coagulant in treated water are undesirable. Therefore, a coagulant is usually relatively insoluble at the pH values desired. The two most commonly used metallic coagulants are aluminum (Al3+) and ferric iron (Fe3+). Both meet the preceding three requirements.

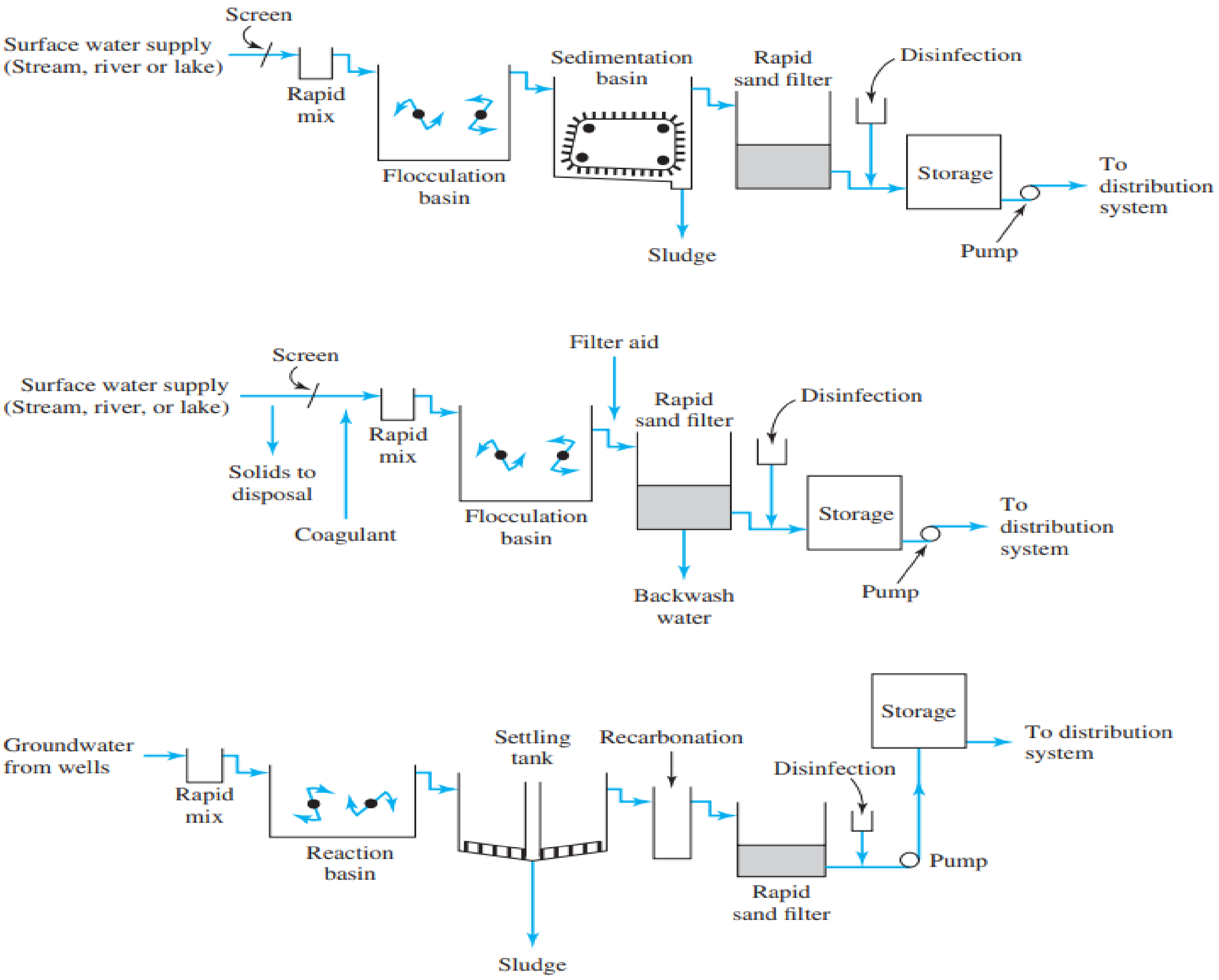


FIG (1)

Aluminum Sulfate.

Aluminum sulfate can be dry or liquid alum (Al2(SO4)3 · 14H2O). Commercial alum has an average molecular weight of 594, with approximately 14 waters of hydration. Alum reacts with alkalinity according to the following reaction:

$$\mathrm{Al_2(SO_4)_3 \cdot 14H_2O + 6HCO_3^- \rightleftharpoons 2Al(OH)_3(\mathit{s}) + 6CO_2 + 14H_2O + 3SO_4^{2-}} \qquad (10\text{–}1)$$

such that each mole of alum added uses six moles of alkalinity and produces six moles of carbon dioxide. The preceding reaction shifts the carbonate equilibrium and decreases the pH. However, as long as sufficient alkalinity is present and CO2(g) is allowed to evolve, the present to neutralize the sulfuric acid production

$$\mathrm{Al_2(SO_4)_3 \cdot 14H_2O \rightleftharpoons 2Al(OH)_3(\mathit{s}) + 3H_2SO_4 + 8H_2O} \qquad (10\text{–}2)$$

If pH control is a problem, lime or sodium carbonate may be added to neutralize the acid, thereby stabilizing the pH

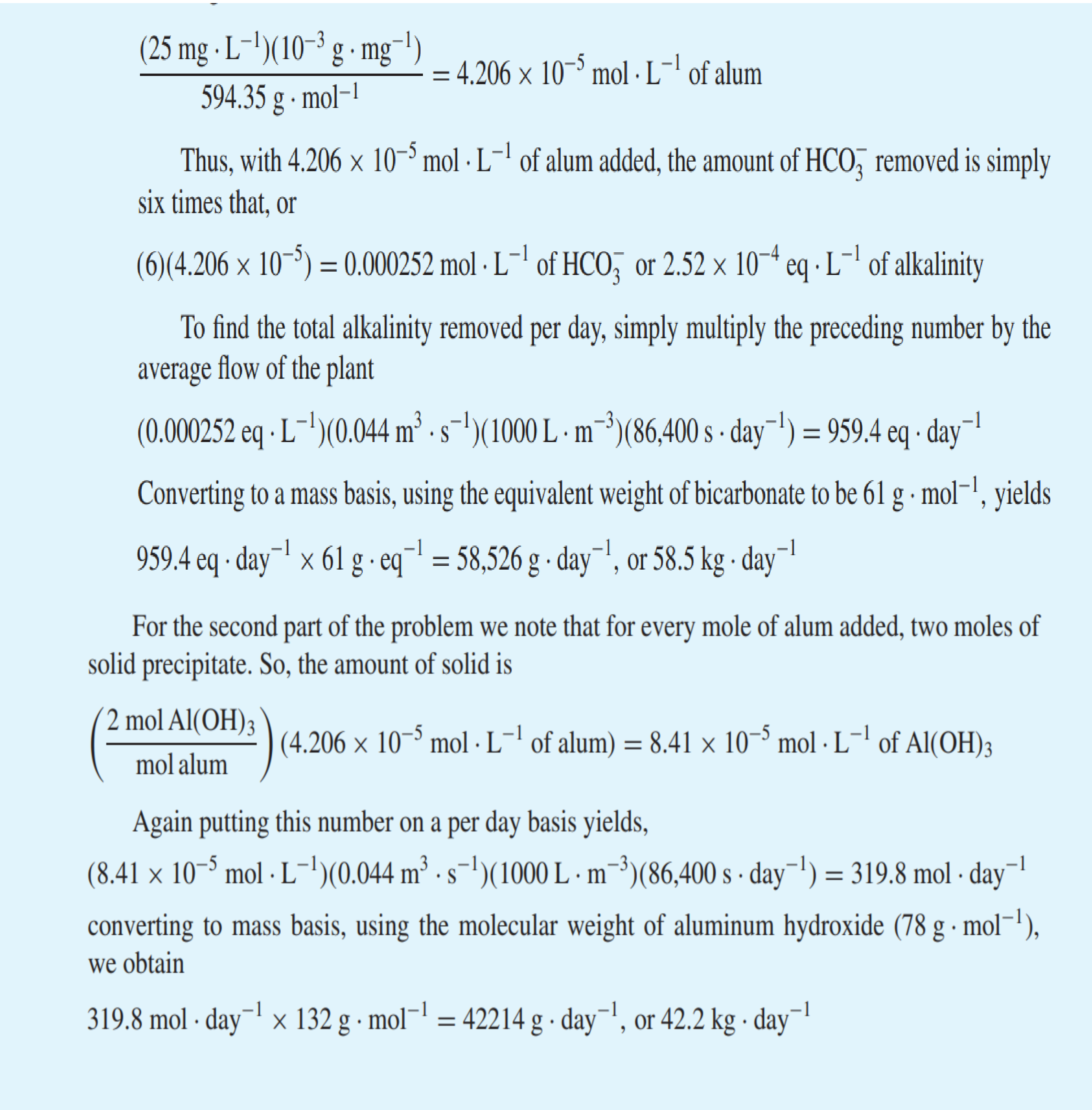
Two important factors in coagulant addition are pH and dose. The optimum dose and pH must be determined from laboratory jar tests. The optimal pH range for alum is approximately 5.5–6.5, with adequate coagulation possible at pH between 5 and 8 under some conditions.

EX: -

A water treatment plant with an average flow of Q = 0.044 m3 · s−1 treats its water with alum (Al2(SO4)3 · 14H2O) at a dose of 25 mg · L−1. Alum coagulation is used to remove particulate matter, reduce the concentration of organic matter, and reduce the alkalinity of the water according to Equation 10–1. If the organic matter concentration is reduced from 8 mg · L−1 to 3 mg · L−1, determine the total mass of alkalinity consumed and the total mass of dry solids removed per day.

Solution

First determine the total amount of alkalinity consumed. We do this by noting that, according to Equation 10–1, for each mole of alum added, six moles of alkalinity (bicarbonate form) are removed. Now convert the alum dose into molar units using its molecular weight of 594.35 g ·



$$\frac{(25\ \text{mg}\cdot\text{L}^{-1})(10^{-3}\ \text{g}\cdot\text{mg}^{-1})}{594.35\ \text{g}\cdot\text{mol}^{-1}} = 4.206\times10^{-5}\ \text{mol}\cdot\text{L}^{-1}\ \text{of alum}$$

Thus, with $4.206\times10^{-5}\ \text{mol}\cdot\text{L}^{-1}$ of alum added, the amount of HCO_3^- removed is simply six times that, or

$$(6)(4.206\times10^{-5}) = 0.000252\ \text{mol}\cdot\text{L}^{-1}\ \text{of}\ HCO_3^-\ \text{or}\ 2.52\times10^{-4}\ \text{eq}\cdot\text{L}^{-1}\ \text{of alkalinity}$$

To find the total alkalinity removed per day, simply multiply the preceding number by the average flow of the plant

$$(0.000252\ \text{eq}\cdot\text{L}^{-1})(0.044\ \text{m}^3\cdot\text{s}^{-1})(1000\ \text{L}\cdot\text{m}^{-3})(86{,}400\ \text{s}\cdot\text{day}^{-1}) = 959.4\ \text{eq}\cdot\text{day}^{-1}$$

Converting to a mass basis, using the equivalent weight of bicarbonate to be $61\ \text{g}\cdot\text{mol}^{-1}$, yields

$$959.4\ \text{eq}\cdot\text{day}^{-1}\times 61\ \text{g}\cdot\text{eq}^{-1} = 58{,}526\ \text{g}\cdot\text{day}^{-1},\ \text{or}\ 58.5\ \text{kg}\cdot\text{day}^{-1}$$

For the second part of the problem we note that for every mole of alum added, two moles of solid precipitate. So, the amount of solid is

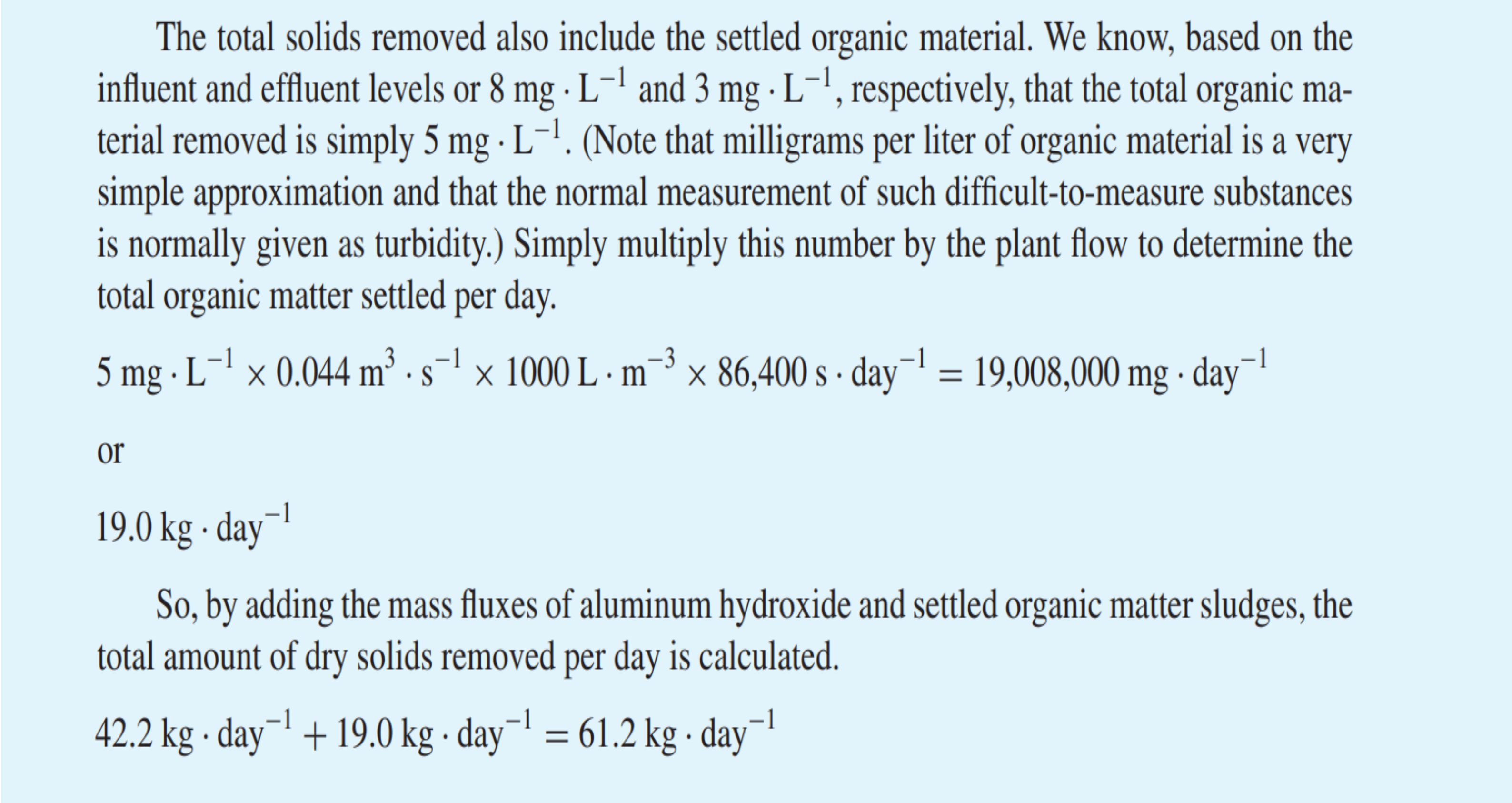
$$\left(\frac{2\ \text{mol Al(OH)}_3}{\text{mol alum}}\right)(4.206\times10^{-5}\ \text{mol}\cdot\text{L}^{-1}\ \text{of alum}) = 8.41\times10^{-5}\ \text{mol}\cdot\text{L}^{-1}\ \text{of Al(OH)}_3$$

Again putting this number on a per day basis yields,

$$(8.41\times10^{-5}\ \text{mol}\cdot\text{L}^{-1})(0.044\ \text{m}^3\cdot\text{s}^{-1})(1000\ \text{L}\cdot\text{m}^{-3})(86{,}400\ \text{s}\cdot\text{day}^{-1}) = 319.8\ \text{mol}\cdot\text{day}^{-1}$$

converting to mass basis, using the molecular weight of aluminum hydroxide ($78\ \text{g}\cdot\text{mol}^{-1}$), we obtain

$$319.8\ \text{mol}\cdot\text{day}^{-1}\times 132\ \text{g}\cdot\text{mol}^{-1} = 42214\ \text{g}\cdot\text{day}^{-1},\ \text{or}\ 42.2\ \text{kg}\cdot\text{day}^{-1}$$



The total solids removed also include the settled organic material. We know, based on the influent and effluent levels or 8 $mg \cdot L^{-1}$ and 3 $mg \cdot L^{-1}$, respectively, that the total organic material removed is simply 5 $mg \cdot L^{-1}$. (Note that milligrams per liter of organic material is a very simple approximation and that the normal measurement of such difficult-to-measure substances is normally given as turbidity.) Simply multiply this number by the plant flow to determine the total organic matter settled per day.

$$5\ mg \cdot L^{-1} \times 0.044\ m^3 \cdot s^{-1} \times 1000\ L \cdot m^{-3} \times 86{,}400\ s \cdot day^{-1} = 19{,}008{,}000\ mg \cdot day^{-1}$$

or

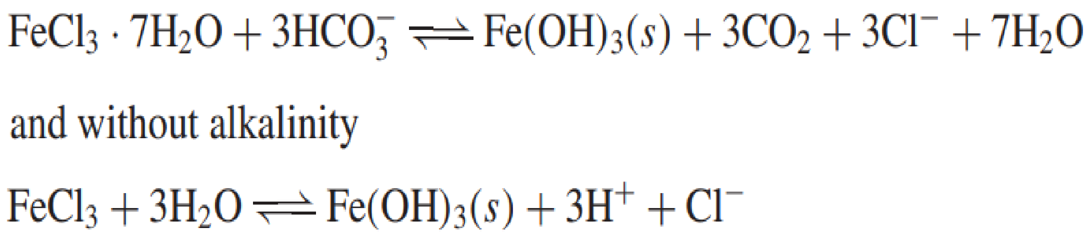
$$19.0\ kg \cdot day^{-1}$$

So, by adding the mass fluxes of aluminum hydroxide and settled organic matter sludges, the total amount of dry solids removed per day is calculated.

$$42.2\ kg \cdot day^{-1} + 19.0\ kg \cdot day^{-1} = 61.2\ kg \cdot day^{-1}$$

Iron

Ferric cations can be supplied by adding either ferric sulfate (Fe2(SO4)3 · 7H2O) or ferric chloride (FeCl3 · 7H2O). The properties of iron with respect to coagulation efficiency, dose, and pH curves are similar to those of alum. An example of the reaction of
FeCl3 in the presence of alkalinity is FeCl3 ·



$$FeCl_3 \cdot 7H_2O + 3HCO_3^- \rightleftharpoons Fe(OH)_3(s) + 3CO_2 + 3Cl^- + 7H_2O$$

and without alkalinity

$$FeCl_3 + 3H_2O \rightleftharpoons Fe(OH)_3(s) + 3H^+ + Cl^-$$

(10–4) If the alkalinity is insufficient, the addition of ferric chloride results in the release of three moles of protons (H+) for every mole of ferric chloride added. The release of protons lowers the pH. Ferric salts generally have a wider pH range for effective coagulation than aluminum, that is, pH ranges from 4 to 9.

Coagulant Aids.

The three basic types of coagulant aids are activated silica, clay, and polymers. Activated silica is sodium silicate that has been activated with sulfuric acid When activated silica is added to water; it produces a stable sol (i.e., solid colloidal particles dispersed in a liquid) that has a negative surface charge. The activated silica can react with the positively charged metal hydroxide floc, resulting in a larger, denser floc that settles faster and enhances enmeshment. The addition of activated silica is especially useful for treating highly colored, low-turbidity waters because it increases the density of the floc. However, because activation of silica requires proper equipment and close operational control, many plants are hesitant to use it. Clays can act much like activated silica in that they have a slight negative charge and can increase the density of the flocs, thus increasing the settling of the floc. Clays are also most useful for treating colored, low-turbidity waters.

The most effective polymers used in water treatment as coagulant aids are the anionic and nonionic polymers. Polymers are long-chain carbon compounds of high molecular weight that have many active sites. The type of polymer, dose, and point of addition must be determined for each water and requirements may change within a plant on a seasonal, or even daily, basis.

WATER SOURCES

Water is the most abundant compound in nature. It covers 75% of the earth surface. About 97.3% of water is contained in the great oceans that are saline and 2.14% is held in icecaps glaciers in the poles, which are also not useful. Barely the remaining 0.56% found on earth is in useful form for general livelihood. **The main sources of water are:**

1. Rain water

2. Surface water (fresh – salt) (Rivers – Lakes – Seas – Oceans)

All the sources of water can be broadly divided into

1. Surfaces sources and
2. Sub surface sources

The surface sources further divided into :(i. Streams; ii. Rivers; iii. Ponds;
iv. Lakes; v. Impounding reservoirs, ….. etc).

STREAMS AND RIVERS

Rivers and streams are the main source of surface source of water. But some rivers dry up wholly or partially in summer. So they require special arrangements to meet the water demand during hot weather. Mostly all the cities are situated near the rivers discharge their used water of sewage in the rivers; therefore much care should be taken while drawing water from the river.

IMPOUNDING RESERVOIRS

In some rivers the flow becomes very small and cannot meet the requirements of hot weather. In such cases, the water can be stored by constructing a bund, a weir or a dam across the river at such places where minimum area of land is submerged in the water and max. quantity of water to be stored. In lakes and reservoirs, suspended impurities settle down in the bottom, but in their beds algae, weeds, vegetable and organic growth takes place which produce bad smell, taste and colour in water. Therefore this water should be used after purification. When water is stored for long time in reservoirs it should be aerated and chlorinated to kill the microscopic organisms which are born in water.

3. SUBSURFACE SOURCES "Ground water" (fresh – salt) (Wells)

These are further divided into

(i) Infiltration galleries

(ii) Infiltration wells

(iii) Springs

WELLS:

A well is defined as an artificial hole or pit made in the ground for the purpose of tapping water.

The three factors which form the basis of theory of wells are

1. Geological conditions of the earth's surface
2. Porosity of various layers
3. Quantity of water, which is absorbed and stored in different layers.

The following are different types of wells

1. Shallow wells
2. Deep wells
3. Tube wells
4. Artesian wells

WATER QUALITY

Absolutely pure water is never found in nature and contains number of impurities in varying amounts. The rainwater which is originally pure also absorbs various gases, dust and other impurities while falling. This water when moves on the ground further carries salt, organic and inorganic impurities. So this water before supplying to the public should be treated and purified for the safety of public health, economy and protection of various industrial process, it is most essential for the water work engineer to thoroughly check analyse and do the treatment of the raw water obtained the sources, before its distribution. The water supplied to the public should be strictly according to the standards laid down from time to time.

Proposes of studying water quality:

1. Determine the degree of pollution.
2. Determine of design steps for water treatment process, (drinking water – industrial water – swimming ponds).
3. Assessment of treatment units.
4. Check the effluent of WTP with environmental.

<u>Quality of raw water depends on:</u>

1- Suspended solids.
2- Organic matter.
3- Dissolved solids.
4- Microorganisms.
5- Bacteria (pathogenic).
6- Algae.

<u>Physical characteristics of water:</u>

1- Temperature.
2- Odor, taste, color.
3- Turbidity < 5 NTU (nephelometric instrument).
4- Total dissolved solids 500 – 1000 mg/l.
5- Clarity. (Potable, palatable).

Chemical characteristics of water:

1- pH 6.5 – 8.5.

2- Iron ≤ 0.3 mg/l.

3- Manganese ≤ 0.1 mg/l.

4- Hardness. ($CaCO_3$ > 150 mg/l)

5- Fluoride 0.5 – 1.5 mg/l.

6- Nitrate ≤ 45 mg/l.

Biological characteristics of water:

Fecal coli forms, total coli forms, E.coli.

The existence of any E. coli bacteria indicates a recent contamination of water.

Properties of an ideal indicator:

1. Applicable for all types of water.
2. Always present when pathogens are present.
3. Non-pathogen for the lab. Personal.
4. Have a longer survival time outside the human body (24 hrs)

Water Pollution

Pollution Source

1. Wastewater discharge
2. Solid waste and its leakage
3. Acid rain
4. particle Settlement in air
5. Polluted Runoff with fertilizer and ;
6. others

Classification of Water Pollutants

A) Classified according to the nature of its origin:

- Point source: effluents from a pipe, channel, or any other confined and localized source
- Dispersed (nonpoint) source : broad, unconfined area from which pollutants enter a body of water/not at only one particular point
- Surface runoff from agricultural areas
- Acidic runoff from mining areas is a dispersed pollutant
- Storm water drainage systems in towns and cities

B) Classified on their environmental or health effects

- Domestic sewage: *pathogenic organism, oxygen-demanding substances, plant nutrients*---conventional sewage treatment processes+advanced sewage treatment
- Agriculture pesticide, industrial activity: *Toxic organic and inorganic chemicals*--- proper management of toxic and other hazardous wastes
- *Sediment:* smothers benthic and disrupts the reproductive cycles of fish and other life forms---sedimentation
- Oil
- Heat (thermal pollution*)*
- Radioactive substances

Thermal Pollution

Thermal pollution: Thermal enrichment cause: mainly from cooling water in power plants---increase by up to 15℃

Control: cooling pond or cooling tower

Heat: dissipated into the air

Water: discharged to the water or reuse as cooling water

Chapter Two
Air Pollution

Introduction:

- Air pollutants are most dangerous than other types of pollutions because:
  1. Air resources are very limited
  2. people consume air 8-10 times of water and about 25 times of food.
  3. people may be patient for food for weeks and for water for days, but cannot patient for polluted air more than few minutes.

Types of Pollutants:

- There are two major types of air pollutants:

  1. Gases pollutants: which also could be classified as

    A. inorganic gases: like (SO_2, NO_x, H_2S)

    B. organic gases like (CO, Hydrocarbon, Alcohols and Ozone O_3)

  2. Particles pollutants: Solid particles – which stay in air either few seconds to many months according to its weights, and could be classified as

    1- Total suspended particles – which could be collected by (large volume sampler)

    2- Dust full: Could be collected by (dust fall sampler)

- **Air pollution sources could be classified as**:

1. Point sources.
2. Non-Point sources.
3. Linear sources.
4. Area Sources.
5. Mobile Sources.

1-**Point sources Definition**: Pollution sources that emit pollutants from a specific and identifiable location, Examples

1 Factory chimneys .

2- Power plants .

- Characteristics

1-Their geographical location can be precisely identified .

2-They are usually stationary sources .

3-Emissions can be measured directly.

2- **Non-Point Sources Definition**: Pollution sources that emit pollutants from widespread and non-specific areas, Examples: -

1- Vehicle emissions on highway

2- Agricultural emissions (e.g., from fertilizers and pesticides)

Characteristics :-

1-Their geographical location is difficult to pinpoint.

2-They are usually mobile or diffuse sources.

3- Emissions are difficult to measure directly.

3- **Liner Sources Definition**: Pollution sources that emit pollutants along a specific line Examples: -

1- Highways with heavy traffic.

2- Railway lines .

Characteristics -

1- Emissions follow a linear path

2- They are usually associated with vehicle or transport movement

4- **Area Sources Definition**: Pollution sources that emit pollutants . from a large geographical area, Examples: -

1-Large industrial zones .

2-Major cities .

3-Large farms.

Characteristics

1-Emissions are spread over a large area .

2- It is difficult to identify a specific emission point .

5-**Mobile Sources Definition**: Pollution sources that move and emit pollutants while in motion

:Examples -

1- Cars and trucks 2- Aircraft 3- Trains

Characteristics

1- Emissions are linked to the movement of the source .

2- They are usually non-stationary sources .

These classifications help in understanding the nature of air pollution sources and facilitate their monitoring and control.

- But the classification which may be most important to us is:
  1. Natural sources.
  2. Human activity sources.

Natural sources of air pollution include

Natural sources of air pollution occur without human intervention and include:

1. **Volcanoes:** They release gases such as sulfur dioxide (SO_2), carbon dioxide (CO_2), and fine particles that pollute the air.
2. **Wildfires**: They produce large amounts of smoke, carbon monoxide (CO), and suspended particles.
3. **Dust and Sandstorms**: They transport dust and fine particles through the air, leading to pollution.
4. **Biological Processes**: Such as the decomposition of organic matter, which releases gases like methane (CH_4) and nitrogen oxides (NOx).
5. **Seas and Oceans**: They release water vapor, salt, and gases like hydrogen sulfide (H_2S) into the air.

Human Activities Sources:

- Human activities sources would be arranged according to its important as:

1. Transportations:

The main pollutants are (CO) which could be reach (10-15) ppm

2. **Industries**:

It is responsible for about 20% of total pollutions in US. The main pollutants are the (SO_x), particles, NO_x and CO.

3.Electricity generating stations:

It consumes much amount of fuel. Thus, it dispatches much quantities of (SO_x) which is responsible of (acid rains)

4. **Warming:**
   could be found at any place.
5. **Solid waste burning**:
   When burning solid waste, the pollution will transfer to air due to much quantities of gases will produce.

Nature of Air Pollutants:

Primary Air pollutants:

the dangerous of air pollutants depends on:

A - the pollutants concentration.

B - time of exposing to the pollutants

- if these two conditions be equal in effect, then we can arrange its dangerous.
- CO was taken as a main criterion for measuring the danger of other pollutants.
- Table 2-1 show the comparison between several pollutants

جدول (1-2) يبين معامل تأثير الملوثات الرئيسية المختلفة		
الملوث	مستوى الاحتمال $\mu g/m^3$	معامل التأثير
CO	5600	1
SO_X	365	15.3
Particles	260	21.5
NO_X	250	22.4
HC	45	125

- **Bearing level** term means: the maximum concentration of pollutant element could be bearing by human.
- Mono carbon oxide (CO) is less toxic for human than other pollutants, thus it can be taken as indication for other pollutant to find the bearing level of other pollutants.
- Bearing level for (SO_x) = 5600/365 = 15.3
  This mean: if (SO_x) is found in concentration of 5600 $\mu g/m^3$, then it is effect will be (15.3) times more than the effect of (CO).
- **Dangerous level** of any pollutant could be found by dividing its concentration in pollutant air on its bearing level.

As example: the dangerous level of 100 $\mu g/m^3$ of (NOx) will be:
Dangerous level = 100 / 250 = 0.4 see

While for hydrocarbons (HC) will be: 100/45 = 2.22

- There is no danger from any pollutant if its Dangerous level is less than (1.0).
- It is possible to evaluate the dangerous of pollutants those emission from any country and then arrange them in a serious according to their toxicity by take in consideration the coefficient of **bearing effect** and annual **discharge.**
- As example: for US you can see table (2-2) which shows the arrangement of pollutants according to their toxicity.
- This arrangement could be same for many countries.

جدول (2-2) يبين مقارنة الخطورة الاجمالية لمختلف الملوثات الرئيسية			
الملوث	معامل التأثير	وزن المطروح السنوي (مليون طن)	الوزن المؤثر = الوزن × معامل التأثير
CO	1	147.2	147.2
NO_X	22.4	22.7	508.5
SO_X	15.3	33.9	518.7
HC	125	34.7	4337.5
Particles	21.5	25.4	546.1

1.Hydrocarbons

- It contains (C, H & O) and could be found in thousands of types depending on the number of carbon cells.
  - a- one carbon cell --------→ gas phase
  - b- (2-5) carbon cells ----→ liquid phase
  - c- more than 5 cells -------→ solid phase.
- Most hydrocarbons sources are natural. Like: the biological decomposition emission 310 million ton/ year.
- Trees emission about 170 million ton/ year. And thus, it is also natural source of hydrocarbons
- Using and refining of petrol is another source for hydrocarbons. Its emission about 88 million ton/ year, but it is most important than other natural sources because it is emission in small areas and it has site effect.
- Hydrocarbons concentration varies through the day due to using of cars and transportation medias.

2.Sulphate oxide (SOx)

- **SO_2 has the following features**:
  - a- Transparence.
  - b- Could not be burned.
  - c- Run riot odor, effect on nose, eyes and mouth.
  - d- Exposing to it for long time cause to big damages in lungs.
  - e- Secondary pollutants from hydrocarbons is more dangerous than (SO2).

- **SO_3 has the following features**:
  - a- Less emission to air than SO_2
  - b- Rapid dissolving with air humidity and thus convert to (H_2SO_4) which is responsible on acid rains.
- Industrial emission of SO_2 is about 146 million ton/ year
- Sulphate is founded in all types of petrol.
- Secondary pollutants from SO_2 is more danger than itself. Like (H_2SO_4) has more effects on water resources and plants than SO_3.
- SO_3 with industry smokes at unsuitable climate produce (Sulphric smog)(الضباب – الدخان الكبريتي

3.Nitrogen oxide (NOx)

Three main types of nitrogen oxide are available:

A- (N_2O): has the following features:

1- Non – toxic
2- transparence
3- sweet taste
4- can’t be burned

B- (NO): has the following features:

1-Non – toxic
2- can’t be burned
3-Transparence
4-Has no odor

C- (NO_2): has the following features:

1-Can not be burned
2-Brown color
3-Choke odor

- In additional to these famous gases there are several other types like (NO_3, N_2O_5, N_2O_4, N_2O_3) but in less concentration.

- **Sources of (NO_x)**
  - **a- Natural sources:**
    - **1-** Decomposition of nitrogen components in soils.
    - **2-** thunder storm: add a little quantity of (NO).
  - **b- Non - Natural sources:**

    This source is due to fuel burning. In this operation the nitrogen will unit with oxygen due to the high temperature**.** (that means from fuel directly not like (SO)

    Human activities applied about 106 million ton/year

4.Carbon mono oxide (CO)

- Most common pollutant
- It is found at the lower layers of atmosphere
- Has the following properties:
  1- It is transparence
  2- No odor, No taste, No color
  3- Less dissolving in water
  4- Burning with blue color flame
  5- Its specific density = 0.965
  6- Exposing to this gas for long time cause death. (due to the unity of this gas with blood hemoglobin) which effect on oxygen transferring.

Human activities applied about 250 million ton/ year due to:

A- Un complete burning of fuel and oils.
B- Reduction of CO_2 to CO, due to high temperature.
C- Dissociate of some burning product due to the high temperature.

4.Particulate

- Particulate is solid or liquid materials depressed in air with volume (0.0002-50micron) which could be settled in seconds or remain months in air. Depending on its weight.

- Pollutions by particulate could be seen in two cases:
  - a- When the particulate has diameter of 100 micron, thus could be seen by absolute eyes.

b- When the very finite particulate has the feature of hiding or obstruct the light rays, or absorb or reflect it.

- Particulate could be transfer to air by one or more of the following ways:
  1- Solid material grinding or crushing.
  2- Transfer of spraying.
  3- Liquid spraying
  4- Moving and transferring of powder due to mechanical vibration.
  5- Chemical reaction between gases.

- Particulate could be named in different methods like:
  1- Dust:
  Which represent a solid material with big variance in diameter.
  2- Smoke:
  Represent solid particulate (often carbon), or condensed drops which has diameter range between (1-10) micron.
  3- Fog:
  Represent condensed water particulate. Which present in air in high amount.
  4- Fumes:
  Represent metal and organic particulate with diameter range between (0.01-1.0) micron.
  5- Spray

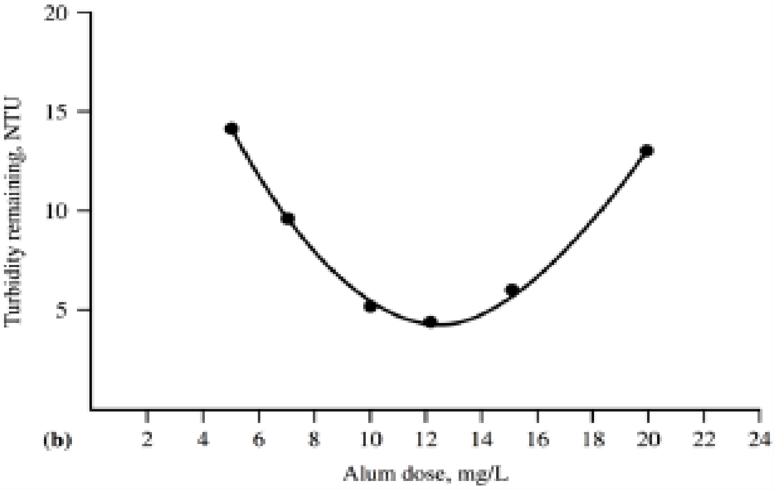
2.2 Jar Test فحص الجرة (إيجاد افضل تركيز مضاف للشب او أى مخثر نحتاجه لتنقية المياه)

Jar test helps to determine the right amount of treatment chemicals: the lowest dose of chemicals that provides satisfactory settling is the dose used to treat the water (see figure below)

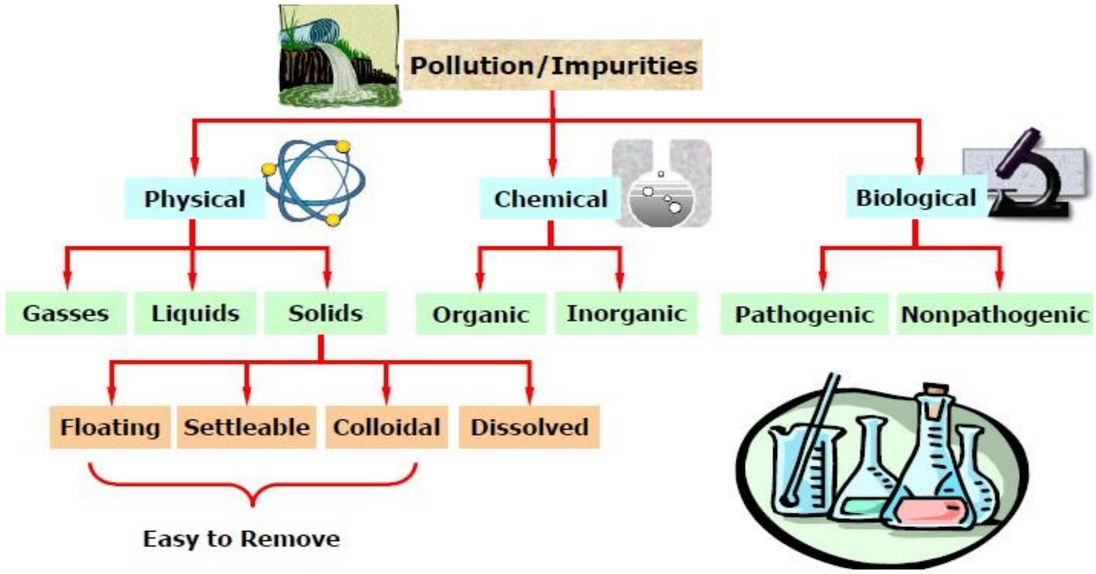
Example 1: set of data below of jars tests were conducted on a raw water containing turbidity of **15 NTU**. The objective is to find the optimal coagulant dose.إيجاد القيمة المثلى للمادة المخثرة

Jar number	a	b	c	d	e	f
Alum dose (mg/L) **التركيز المضاف**	5	7	10	**12**	15	20
Turbidity (NTU) **المتبقي**	14	9.5	5	**4.5**	6	13

Solution: The results of the jar tests are plotted in Figure and the optimal alum dose was estimated to be about **12 mg/L**.



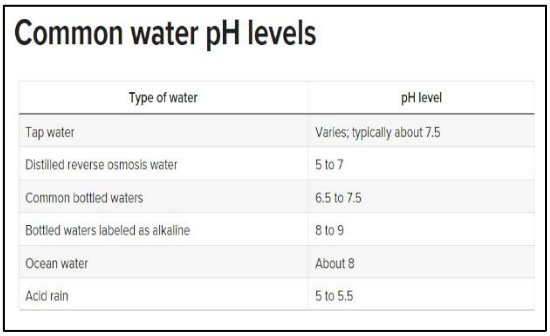
1. Introduction



pH, Temperature, TSS, TDS, Turbidity, Alkalinity, Hardness, Chloride, BOD, COD, Microbiology

اهم الملوثات التي تتعلق بمحطات معالجة مياه الشرب هي:

A) pH and Temperature



Common water pH levels

Type of water	pH level
Tap water	Varies; typically about 7.5
Distilled reverse osmosis water	5 to 7
Common bottled waters	6.5 to 7.5
Bottled waters labeled as alkaline	8 to 9
Ocean water	About 8
Acid rain	5 to 5.5

B) Total suspended Solid (mg/L)

Total suspended solids (TSS) include all particles suspended in water which will not pass through a filter.

C) Total Dissolved Solids (mg/L)

The material remaining in the water after removal suspended-solids by filtration is called total dissolved solids. This material is left as a solid residue upon evaporation of the water. Dissolved material results from the solvent action of water on solids, liquids, and gases.

D) Turbidity (NTU)

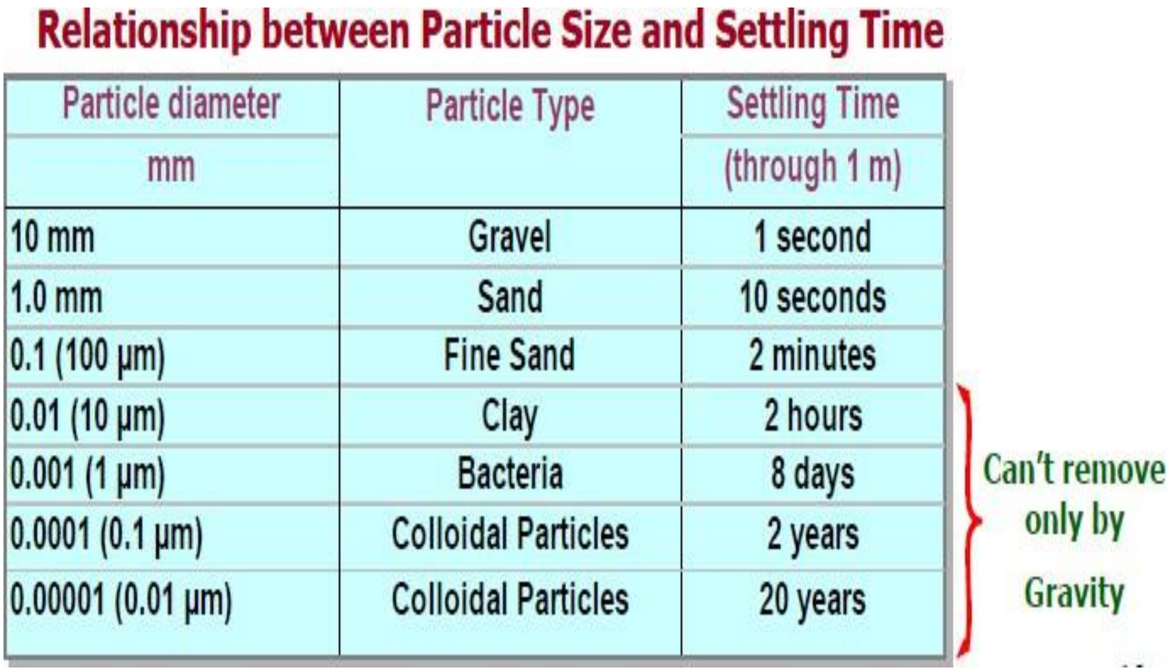
Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. Suspended matter in water scatters or absorbs light and does not allow free passage, the visual depth of such water samples are restricted.

Turbidity meters

E) Biological Water Quality Parameters (number/ml)

The Biological water quality parameters include the pathogens like bacteria, virus, protozoa and helminths.

امثلة: عن الفايروسات والبكتريا المرضية في المياه: الجدول ادناه مهم
في عمليات المعالجة:



Relationship between Particle Size and Settling Time

Particle diameter mm	Particle Type	Settling Time (through 1 m)
10 mm	Gravel	1 second
1.0 mm	Sand	10 seconds
0.1 (100 µm)	Fine Sand	2 minutes
0.01 (10 µm)	Clay	2 hours
0.001 (1 µm)	Bacteria	8 days
0.0001 (0.1 µm)	Colloidal Particles	2 years
0.00001 (0.01 µm)	Colloidal Particles	20 years

Can't remove only by Gravity

2. Estimation of water consumption

The demand of water can be divided into the following:

a) Domestic water demand: drinking, cooking, washing, bathing, sanitary purposes…etc.

حسب عدد السكان والمحددات الدولية للاستهلاك الفردي (المناخ والعادات تؤثر بصورة كبيرة على قيمة الاستهلاك) مثلا العراق 200-250 L/c.d . يصل من 50 الى 60 % من الاستهلاك الكلي.

b) Industrial water demand: factories, offices, hotels, hospitals…etc.

حسب نوع المصنع والطاقة الانتاجية ويشكل تقريباً من 20 الى 25 %.

c) Public use: parks, gardens, roads, losses…..etc.

ملاحظة: قبل البدء بعملية التصميم لمحطة مياه الشرب، يجب في البداية تحديد كمية الاستهلاك الحالية وكذلك عمر مشروع محطة مياه الشرب لذا يجب في البداية تحديد النمو السكاني للمدينة المخدومة بمحطة مياه الشرب.

3. Population Estimation

Arithmetic method

This method of forecasting is based upon the hypothesis that the rate of increase is constant. If may be expressed as follows:

$$\frac{dp}{dt} = k_a$$

$$\boldsymbol{p_1 = p_0 + k_a t}$$

Where p_1 = population at future time

p_0 =Present population, usually use p_0 value of latest census.

2.2 Geometric growth rate method

The hypothesis of growth rate method is assumed that the rate increase is proportional. It can be written as

$$\frac{dp}{dt} = k_p . P$$

$$\boldsymbol{\ln p1 = \ln p0 + k_p(t1 - t0)}$$

Example 1: A city recorded population of 113000 and 129000 in the 1980 and 1990 census, respectively. Estimate the population in 1999 by using Arithmetic method?

Solution: At first we should find k_a value from previous population data

$$k_a = \frac{129000-113000}{10} = 1600 \text{ capita/year}$$

p_t for 1999 is:

p_{1999}=p_o+k_a t= 129000 capita+1600 capita/year *9 year

Example 2: Solve Example 1 using geometric rate method?

Solution: At first we should find k_a value from previous population data

$$k_p = \frac{ln\ 129000 - ln\ 113000}{10} = 0.01324$$

p_t for 1999 is:

ln p_t=ln p_o+k_p (t-t_o)= ln(129000) +0.01324 *(1999-1990)

p_{1999} =145 325 capita