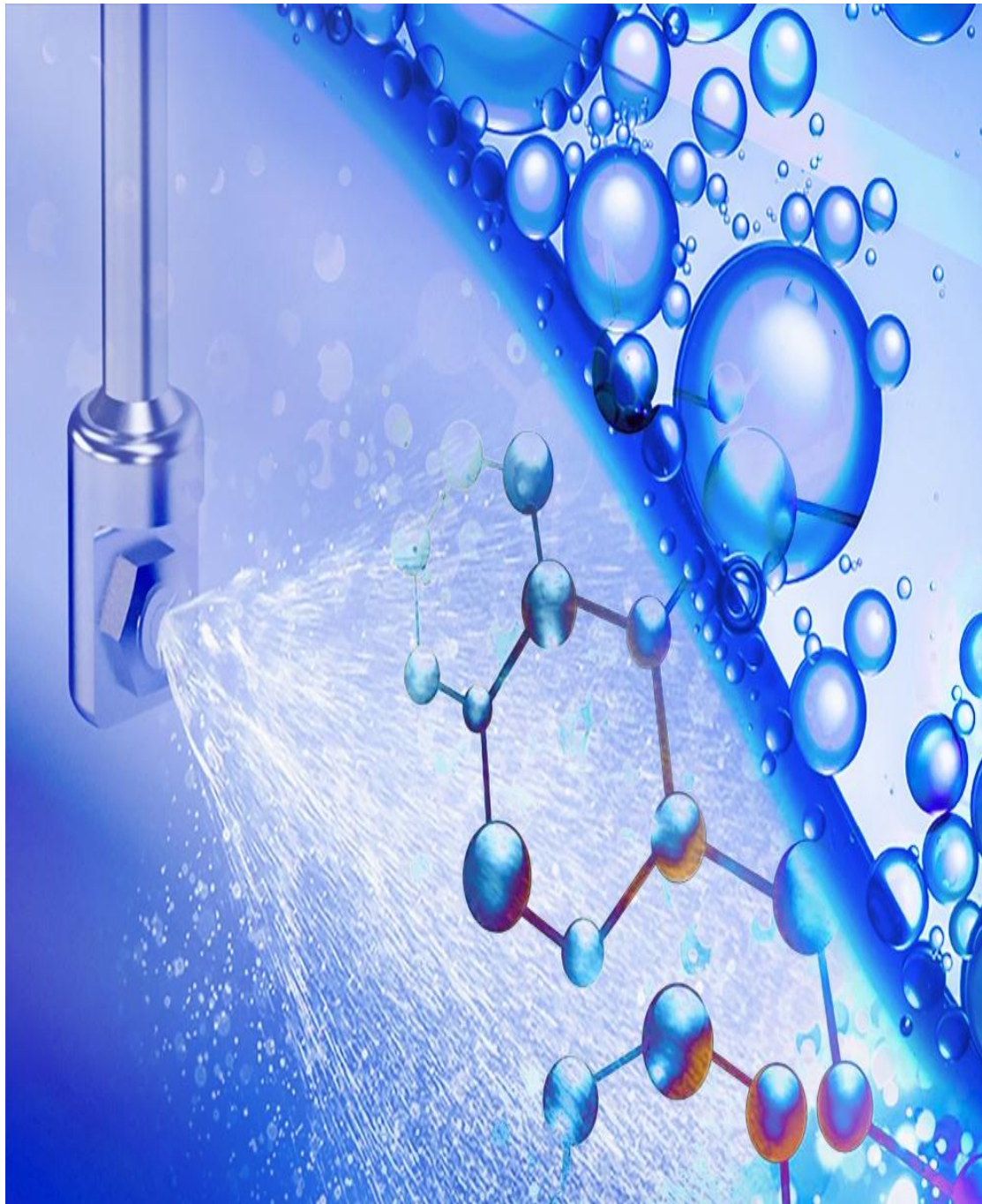




CHEMICALS INJECTION

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ان استأفنت الآخرين قبل ان تطلب منهم شيئا فهذا يدل على ادبك وإذا شكرتهم على ما
قدموه فهذا من اصلك الطيب وإذا دعوت لهم فهذا من كرمك وتذكر ان عنوبة لسانك وحسن
خلقك يجعلهم يحفظونك في قلوبهم

كلمات د/ هاني الناظر

This formation was collected by

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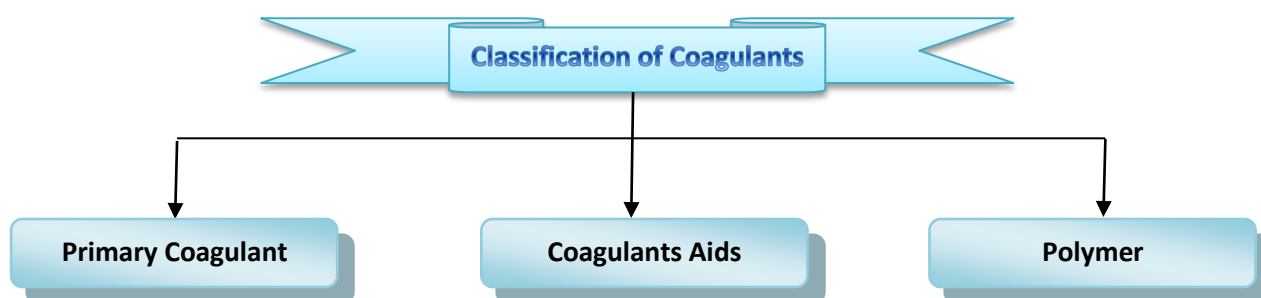
Chemicals Injection

[1] CO-AGULATION: -

The process of removal of suspended solid in water by the use of chemical agents is known as Coagulation.

Particles in water are negative, coagulants usually positively charged.

Classification of Coagulants:-



Primary Coagulants as (Aluminum Sulfate, Ferrous Sulfate, Ferric Sulfate, Ferric Chloride)

Primary Coagulants	pH
Aluminum Sulfate $Al_2(SO_4)_3 \cdot 14H_2O$	5.8 to 8.5
Ferrous Sulfate $FeSO_4 \cdot 7H_2O$	8.5 above
Ferric Sulfate $Fe_2(SO_4)_3 \cdot 9H_2O$	3.5 to 6.5 above 9.0
Ferric Chloride $FeCl_3 \cdot 6H_2O$	4.0 to 8.0

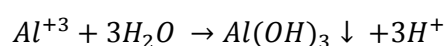
Coagulants Aids as (Bentonite, Calcium Carbonate, Sodium Silicate, Anionic Polymer, Non-ionic polymer).

Polymers are man-made organic compounds made up of a long chain of smaller molecules

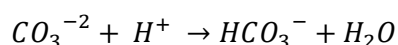
Classified as (Cationic Positively charged, anionic Negatively, Non-anionic Neutrally charged)

* When a solution of **ALUM** is added to the water to be treated the following reactions take place.

Hydrolysis reaction:



If enough alkalinity is present the following reactions can occur:

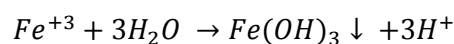


The compounds formed are positively charged and can interact with the impurities like colloids.

The solubility of $Al(OH)_3$, is very low, so precipitation occur in the form of flocs.

The chemical composition of the water is important too because divalent ions like (SO_4^{-2}) and (HPO_4^{-2}) can replace the (OH^{-2}) ions in the complex and hence can influence the properties of the precipitate.

* When a solution of **Iron compound is added** to the water to be treated the following reactions take place.



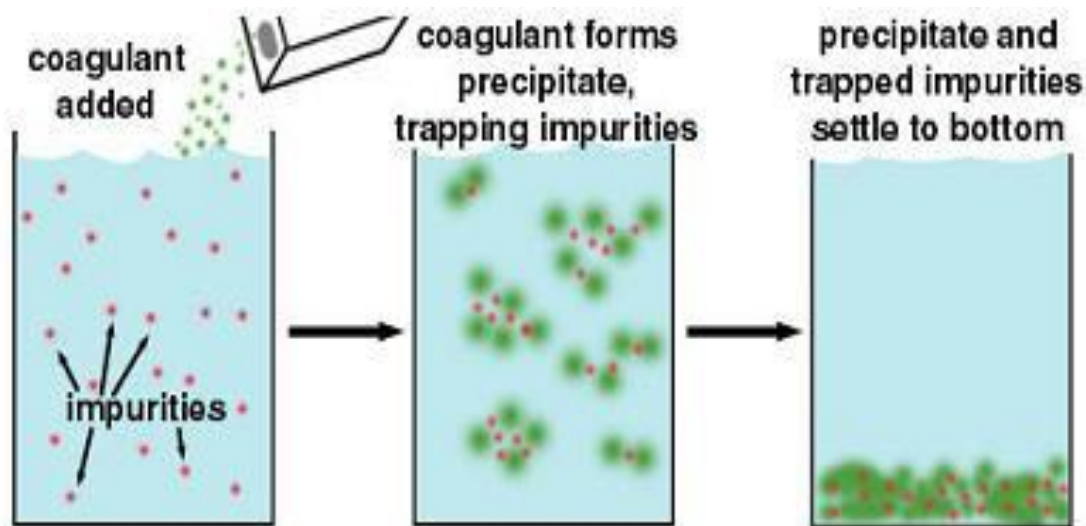
The Formation of Iron compound Occur only at high pH-Values not common in conventional treatment.

FLOCCULATION: -

The agglomeration of destabilized particles into large size particles known as flocs which can be effectively removed by sedimentation or flotation

Factor Impacting Coagulation and Flocculation?

1	Temperature	Cold water negatively impacts
2	Alkalinity	Low Alkalinity negatively impacts
3	Turbidity	Low Turbidity negatively impacts
4	pH	Alum is impacted the most by pH
5	Mixing energy	Too Low= Poor Floc. Formation, Too High= Floc. shear
6	Coagulant dose	Too Low=Insufficient Coagulation, Too High= Colored water
7	Flocculent Aid	Addition of polymer can aid flocculation and setting



Coagulants and flocculants Benefits to you?

- Decreases particulate loading on the RO system
- Extends cartridge filter and membrane element life
- Reduces RO cleaning
- Improves overall operation of filtration system and clarifiers

JAR TEST

JAR TEST to determine the optimum pH and the optimum coagulant dose.

فيديو يوضح شرح تجربه JAR TEST

<https://www.youtube.com/watch?v=72uFoBjSqaI>

Produce: -

- 1- Prepare 1 ppm from Coagulants as example (ALUM)
- 2- Get 6 jar Bottle and take 0.5ml from (1ppm Alum) put it in first jar bottle contain 1L from water sample and repeat it as

Beaker#	1	2	3	4	5	6
Alum (ppm)	0.5	1	1.5	2	2.5	3
Turbidity (NTU)						

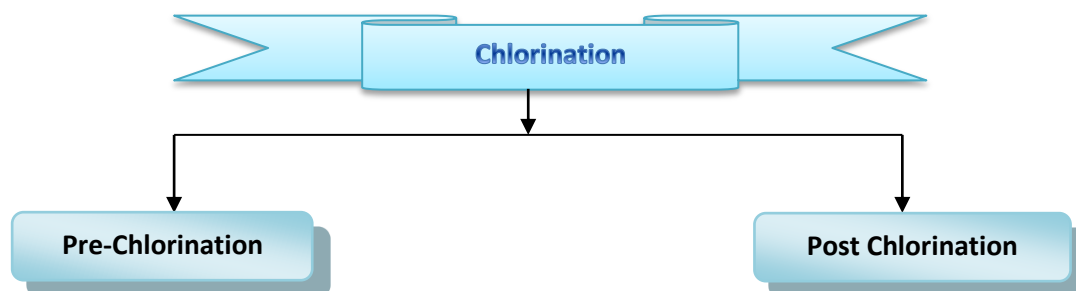
- 3- Rapid Mix each jar at 200 rpm for 2 min.
- 4- Reduce the stirring speed to 20 rpm for 20 min.
- 5- Turn off the mixers and allow flocs to settle for 30 min.
- 6- After 30min. measure the turbidity of sample (by turbidity meter) and recode result

The coagulant dose with the lowest residual turbidity will be the optimum coagulant dose



[2] CHLORINATION: -

Application of chlorine to water, generally for the purpose of disinfection, but also for other purposes such as odor control



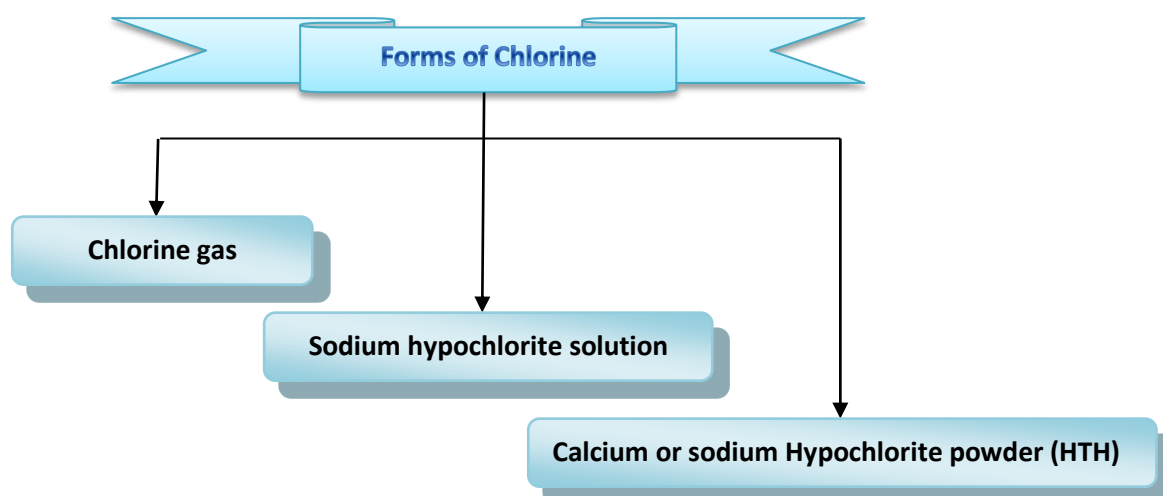
Pre- Chlorination benefits to you?

- ✓ Iron manganese removal.
- ✓ Odor less.
- ✓ Disinfection.
- ✓ Help remove oil.
- ✓ To aid in coagulation and settling when we inject chlorine gas or Ca-hypo Chlorite.

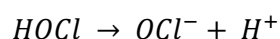
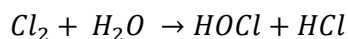
Post Chlorination benefits to you?

- ✓ Avoid bacteria growth in the treated water storage (sterilization)

Chlorine is available in 3 forms:



🌈 The Reaction of Chlorine with water



Hypochlorous acid HOCl is one of two free available chlorine residual forms. Due to the ease with which it penetrates into and kills bacteria, it is the most effective form of free residual for disinfection.

Hypochlorite ion OCl^- is the second type of free available Cl_2 residual and is a relatively poor disinfectant, primarily because of its inability to penetrate into the bacteria.

The effectiveness of Chlorine is based on 5 important factors: -

pH, Temperature, Concentration, Contact Time, Demand

1- pH strongly influences the ratio of $HOCl$ to OCl^-

Low pH values favor the formation of $HOCl$, the more effective free residual.

High pH values favor the formation of OCl^- , the less effective free residual.

Effect of pH on disinfection					
	pH =	6	7	8	9
HOCl	~95%		80 ⇌ 20%		~ 5%
OCl⁻	~ 5%		20 ⇌ 80%		~95%
Disinfection	↑		Maximized		↓
Corrosion	↑		Minimized		↓
Chloramines	Di Tri		Mono/Di		Mono-

2- Temperature

Lower temperatures slightly favor the formation of $HOCl$

Lower temperatures allow Cl_2 residuals to persist somewhat longer.

3- Concentration of Cl_2

As dosage concentration is increased, contact time can be decreased.

4- Contact Time

Contact time must increase under conditions of low water temperature or high pH (alkalinity). Complete mixing of chlorine and water is necessary, and often a holding tank is needed to achieve appropriate contact time

Calculating Contact Time

$$\text{Minutes required} = \frac{k}{\text{Chlorine residual} \left(\frac{mg}{l} \right)}$$

K values to determine chlorine contact time			
Highest	Lowest Water Temperature (degrees F)		
pH	> 50	45	< 40
6.5	4	5	6
7.0	8	10	12
7.5	12	15	18
8.0	16	20	24
8.5	20	25	30
9.0	24	30	36

5- Demand

The inorganic and organic material in raw and finished water takes part in the reactions with Cl_2

Reaction with ammonia (NH_3) is one of the most common.

Uses the chlorine that would otherwise be available for disinfection

Other demand-causing reactions include Fe, Mn, S compounds (stoichiometry), turbidity, TOC/DOC, biofilm.

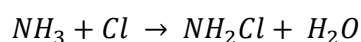
The Reaction of Chlorine with Ammonia

(NH_3) can result from decaying vegetation or from domestic and industrial waste.

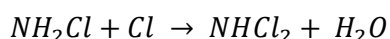
Cl_2 Reacts with (NH_3) to form chloramines, or combined chlorine residual.

The formation of chloramine compounds depends on the pH of the water and the presence of ammonia.

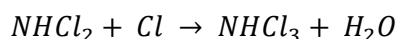
Mono-chloramine ($\text{pH} > 7.5$)



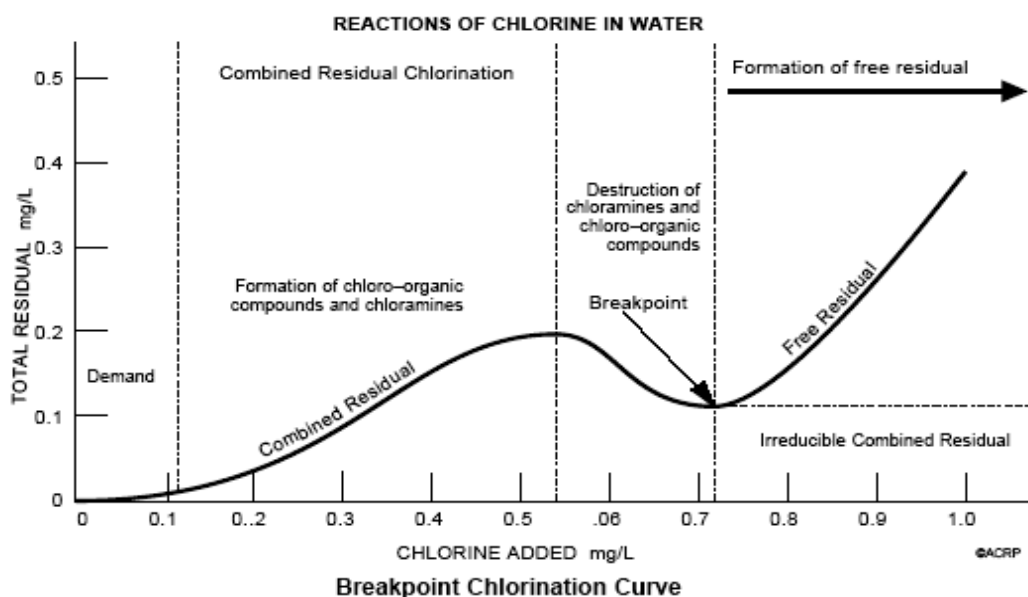
Di-chloramine ($\text{pH} < 7.5$)



Tri-chloramine ($\text{pH} < 7.4$)



In general 8.5: 9.0 mg Cl_2 is required per mg NH_4^+ , in practice more chlorine is required due to presence of organic matter



BREAKPOINT CHLORINATION

The breakpoint is the point at which the chlorine demand has been totally satisfied – the chlorine has reacted with all reducing agents, organics, and ammonia in the water. When more chlorine is added past the breakpoint, the chlorine reacts with water and forms Hypochlorous acid in direct proportion to the amount of chlorine added. This process, known as **breakpoint chlorination**

فیدو یوض فکړه Breakpoint Chlorination

<https://www.youtube.com/watch?v=AH84LOwnhUU>

Produce: -

- 1- Prepare different Conc. Of Chlorine (0.5, 1.0, 1.5, 2.0...)ppm
- 2- Add Conc. of chlorine to different 6 dark bottle and leave them to 20 min. (or according to Contact time planned)
- 3- After 20min., Calculate free residual Chlorine by using some device (as DR-3900...)

Free Chlorine

Apparatus: -

Cuvette, Reagent, device DR-3900

Procedure:-

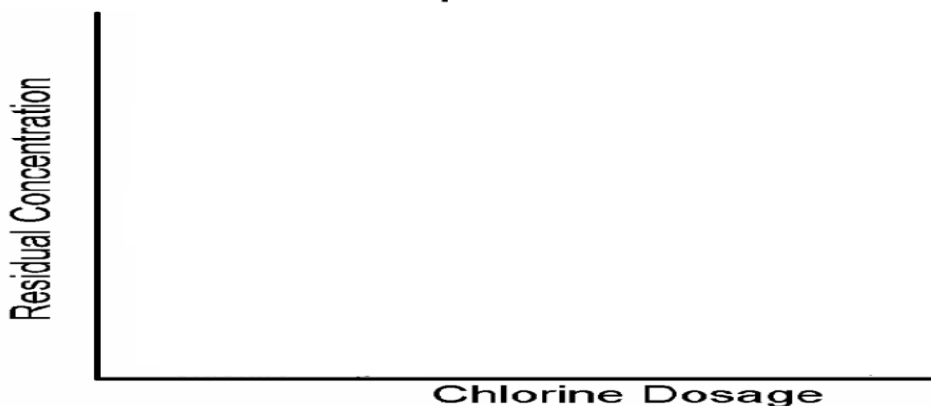
- ❖ Take 10mL of the sample and put it in Cuvette
- ❖ Push Zero the device DR-3900
- ❖ Start a time for 3 minutes
- ❖ Remove Cuvette and Put **DPD reagent** for (Free Chlorine)
- DPD = N,N-Diethyl-P-Phenylenediamine
- ❖ Push read, record the results of (Free Chlorine)

- 4- Record result of Free Chlorine in table

Chlorine Dosage	0.5	1.0	1.5	2.0	2.5
Free Chlorine					

- 5- Draw relation between Free chlorine residual and Chlorine dosage

Breakpoint



- 6- Select the break point and show the dosage of chlorine.

[3] DE-CHLORINATION

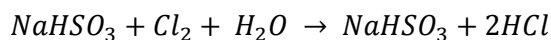
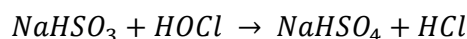
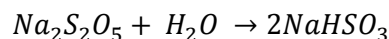
The two most common pretreatment methods for reducing chlorine levels are by absorption onto activated carbon filter media, or by the use of a chemical reducing agent such as sodium bisulfite.

De-chlorination Benefits to you?

- ✓ remove residual chlorine
- ✓ No organic material or carbon fines added to RO feed water
- ✓ Preservative to protect membranes when the system is out of service for a significant period of time.

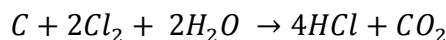
Sodium Meta bisulfite (SMBS) is commonly used for removal of free chlorine, When dissolved in water, sodium bisulfite (SBS) is formed from SMBS

Reaction: -



In theory, 1.34 mg of sodium Meta bisulfite will remove 1.0 mg of free chlorine, in practice however, **3.0 mg of sodium Meta bisulfite is normally used to remove 1.0 mg of chlorine.**

Activated carbon bed is very effective in the de-chlorination of RO feed water according to following reaction:



The advantages of SBS de-chlorination are that it is less capital intensive than carbon filters for large systems, the reaction byproducts are readily removed by the RO, and residual SBS is readily removed by the RO.

Monitoring for de-chlorination can be performed by the use of an Available Free Chlorine monitor, monitoring for a residual bisulfite concentration, or by an ORP monitor

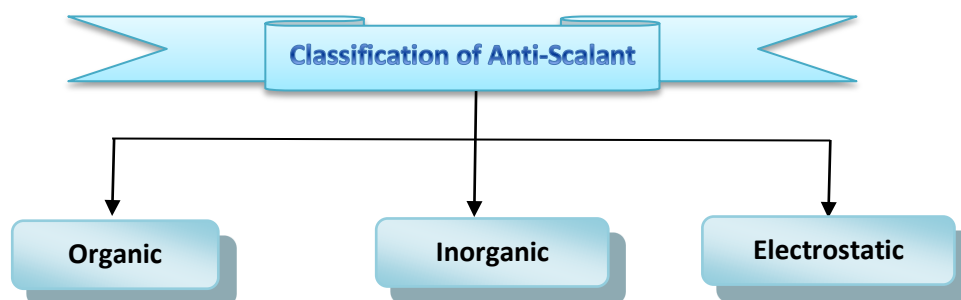
If the ORP value reaches 350 mV, the plant should be shut down until the oxidant concentration can be reduced to a safe value (ORP <300 mV).

[4] ANTI-SCALANT

Anti-Scalant chemicals are used to prevent the scaling of the RO membranes. Scale may consist of mineral fouling such as (calcium sulfate, calcium carbonate ...)

Some Anti-Scaling chemicals using the Threshold mechanism

The choice and dosage level of Anti-scaling will depend on the analysis of the feed water, plant design and operating conditions.



Scale inhibitors or anti-Scalant are generally organic compounds containing sulphonate, phosphonate, or carboxylic acid functional groups and chelating agents such as carbon, alum, and zeolites that sequester and neutralize a particular ion which may be formed.

The majority of scale inhibitors can be classified as threshold inhibitors. In addition, chelating agents such as EDTA (tetra sodium salt of ethylene di amine tetra acetic acid) are used to control hardness (at pH > 6.0) and metallic ion deposits.

Threshold mechanism which Blocking of the growth processes of the growth Crystals means (These materials affect the kinetics of the nucleation and crystal growth of scale forming salts, and permit super saturation without scale formation.

Inorganic and electrostatic work on charge and equivalence which it has no side effect such as (fouling...)

The effectiveness of Scaling formation is based on 4 important factors: -

1	Temperature	High Temperature negatively impacts
2	pH	High pH Favor to Scaling formation (negatively impacts)
3	Flow Rate	High Flow rate Positively impacts
4	Recovery	High Recovery negatively impacts

The Relation between Scaling and Corrosion: -

It is known that high alkaline and pH generally reduce corrosion rates, however, high pH; can increase the scaling potential.

There are two methods to measure Scaling rate:

Langelier Saturation Index (LSI)

We use this method at (TDS<10,000 ppm)

$$LSI = (pH)_{mes.} - (pH)_{sat.}$$

$$(pH)_{sat.} = [9.3 + A + B] - [C + D]$$

Which:-

A = Total dissolved salt (TDS ppm) = (Log [TDS] – 1) / 10

B = Temperature F = [-13.12 * Log (Temp. +273)] + 34.55

C = Calcium Hardness = Log [Ca] – 0.4

D = Max-Alkalinity = Log [alkalinity]

If the LSI is positive, Calcium Carbonate tends to deposit.

If it is negative, Calcium Carbonate tends to dissolved.

If it is zero, the water is at equilibrium.

Stiff & Davis Stability Index (S&DSI)

We use this method at (TDS>10,000 ppm)

$$S\&SDI = 2 (pH)_{sat.} - (pH)_{mes.}$$

If the (S&DSI) is 0.6 or less, scaling increases and the tendency to corrode decrease

(S&DSI) is exceeds 7.0, scaling may not occur at all.

(S&DSI) is rises above 7.5 or 8.0., the probability of corrosion increases

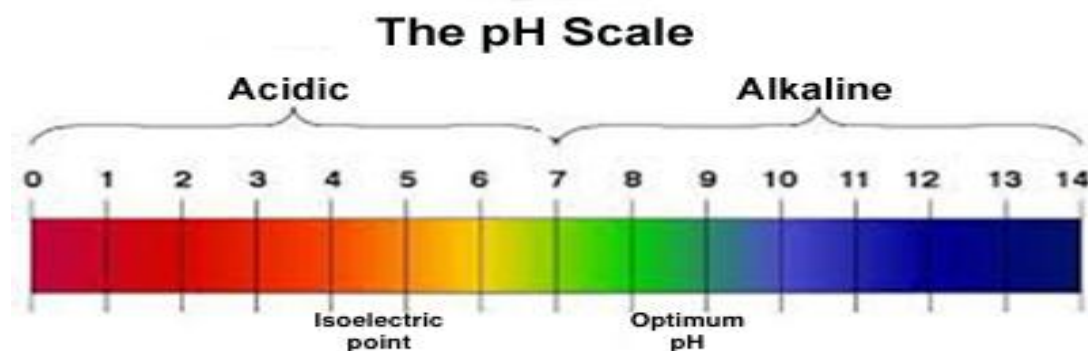
Anti-Scaling benefits to you?

- ✓ Can be used to retard the precipitation and then allow working at a higher recovery.
- ✓ Avoiding membranes changing.

[5] PH ADJUSTMENT

Pure or distilled water has a pH level of 7, which means it is neutral. If you want to increase the pH of water, you must add an alkaline substance, to it. If you want to decrease the pH of water, you add an acidic substance, to it.

$$pH = -\log_{10}[H^+]$$



Adjust pH benefits to you?

- ✓ Many treatment processes are pH dependent such as (Disinfection, Coagulation, Scale inhibitor...)

There are two methods to measure pH: -

- 1- **Approximate:** - color change comparable to color chart
- 2- **Accurate:** - electronically recorded reading (pH meter)

THE DOSING: -

$$PPM \text{ (part per million)} = mg/L = g/M^3$$

- ✚ The dose of Coagulation by using Jar Test.
- ✚ The dose of Chlorination determine by using Break Point Test.
- ✚ The dose of De-Chlorination determine by know the dosage of Chlorination from this relation (**3.0 mg of sodium Meta bi-sulfite is normally used to remove 1.0 mg of chlorine**)
- ✚ The dose of Anti Scaling depends on the analysis of the feed water, the plant design and operating conditions, which this data sent to The Manufacture Company for Anti Scaling and it is select the dosage.
- ✚ The dose of pH adjustment by Jar Test.

Now, we know how you can determine the dosing of Coagulation (PPM), by Jar test

Which: -

We used this law for preparation of Coagulants, Chlorine,

$$Kg = Litre * dil.rate * density * \frac{1}{Conc.}$$

$$\therefore PPM = \frac{(Lit./hr) * dil.rate * density * 1000}{Q_{(M^3/hr)}}$$

حيث ان: -

Lit./Hr. = كثافته المادة , **The density** = عدد اللترات المراد حقنها في الساعه

dilution rate = معدل تدفق مياه التغذية أو المنتجه في الساعه , **$Q_{(M^3/hr)}$** = نسبه تخفيف ماده

For example: -

We need injected ALUM as Coagulant 3 ppm (according to Jar test) which the density of ALUM is 1.21 and concentration 40% and the amount of feed water ($100M^3/hr$).

Answer: - Firstly, we dilute the concentration of ALUM

Suppose dilution rate equal 5%

$$Kg = 200 * 5\% * 1.21 * \frac{1}{40\%}$$

Take 30.25L from material and dissolve it in 200L of water

$$\therefore 3 = \frac{(Lit./hr) * 5\% * 1.21 * 1000}{100}$$

The numbers of liter per hour are adding is equal (4.95L/hr.)

INJECTION PUMPS: -

How you can select the Injection Pump?



Automatic Pump, we need to determine the Flow and Pressure on the Line of injection and put them in software of pump

Manual pump, which we can use this equation to design it to Injection

$$\text{Pump OutPut} = \text{Max Pump OutPut} * \text{Speed \%} * \text{Stroke \%}$$

For example: -

We have injection pump (Max Pressure =150psi, Pump Flow Rate=15 L/hr.) and we need it to inject (4.95L/hr.)

Answer: -

Firstly, we suppose the Stroke =50%

$$4.95 = 15 * \text{Speed \%} * 50\%$$

$$\therefore \text{Speed} = 66\%$$

Now we set the pump on speed= 66% and stroke= 50% and we follow dosing over day.

Reference: -

Coagulation-Flocculation-Jar Test, Assoc. Prof. Kozet YAPSAKLI

Disinfection, Chlorination and Oxidation, Prof. Daniel B. Stephens

Chemical Injection Level 2, Eng. Waleed Besho

PH Adjustment, prof. St. John's

FILMTEC™ Reverse Osmosis Membranes Technical Manual

Eng. /Ahmed Mahmud, Eng. /Mohamed Odam