

## SURFACE WATER TREATMENT

The type of treatment needed for surface water supplies depends on the contaminants present. These contaminants are grouped into five general categories: minerals, turbidity, bacteria, tastes and odors, and color. Before treatment processes can be discussed, the contaminants associated with each of these groups must be identified.

### MINERALS

The mineral problems in water are caused by inorganic contaminants. These are usually dissolved metals and dissolved gases. Some of the more common mineral problems include iron and manganese, famous for causing "red water" problems, and hardness. Carbon dioxide gas can cause corrosion problems and hydrogen sulfide gas is noted for the "rotten egg" odor that is sometimes found in water. All of the inorganic chemicals are listed under the SDWA Primary and Secondary standards are also included in this category.

### TURBIDITY

Silt and clay are primarily responsible for the turbidity in water. However, any suspended material that will not readily settle is considered to be turbidity. Some clay particles are so small that they will not settle at all. These particles in suspension are known as "colloids." Most turbidity particles carry a slight negative electrical charge that causes them to repel each other. Zeta Potential is the term used to identify this electro-chemical repulsion. The treatment to remove these particles must neutralize these charges and bring them together until a particle is formed that is large enough to settle.

### PATHOGENS

Microbiological contamination has been covered in a previous chapter. It should be noted at this time that the presence of turbidity in the water could affect the disinfection process. A clump of turbidity can "hide" bacteria. This greatly reduces the effectiveness of the disinfectant and is the main reason turbidity is a primary contaminant in the SDWA. The possible presence of protozoa like *Giardia* or *Cryptosporidium* can affect treatment strategies due to the need for higher free residuals and extended contact times.

### TASTES AND ODORS

The main source of taste and odor problems in surface supplies is algae (small floating water plants). These are organic compounds that impart a mossy or fishy odor. The most common source of taste and odors in ground water supplies are inorganic chemicals. Hydrogen sulfide gas (H<sub>2</sub>S) causes a "rotten egg" odor. Iron and manganese can also impart a rusty taste to the water when present. Tastes and odors are less noticeable when the water temperature is colder.

## COLOR

Organic compounds released into the water by decaying vegetation cause true color. These organic "dyes" are dissolved in the water and cannot be removed by filtration like turbidity. As leaves fall into the water, tannic acid is leached out giving the water a brownish color. Decaying aquatic plants or humus can create a green color in the water. Apparent color is caused by small particles of oxidized iron or manganese that create red or black water problems respectively. This type of "color" is actually small red flakes of rust that can be removed by filtration.

## SOLUBILITY OF SALTS

Most methods of chemical treatment rely on the solubility of different salts to remove undesirable minerals from the water. A salt is formed when a metal combines with a non-metal. For instance, when a metal like sodium combines with a non-metal like chlorine, sodium chloride, NaCl, or table salt is formed. The most common metals and non-metals that combine to form soluble salts in drinking water supplies include:

<b>CHEMICAL NAMES AND SYMBOLS</b>	
<b>METALS</b>	<b>NON-METALS</b>
Calcium – Ca	Carbonate – CO <sub>3</sub>
Magnesium - Mg	Bicarbonate - HCO <sub>3</sub>
Manganese – Mn	Hydroxide – OH
Iron – Fe	Sulphate - SO <sub>4</sub>
Aluminum – Al	Chloride – Cl
Sodium – Na	
Copper - Cu	
<b>CHEMICAL COMPOUNDS</b>	
Calcium carbonate -	CaCO <sub>3</sub>
Magnesium hydroxide -	Mg(OH) <sub>2</sub>
Aluminum sulphate -	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>
Ferric (iron) chloride -	FeCl <sub>3</sub>
Copper Sulphate -	Cu SO <sub>4</sub>

Some salts dissolve very readily in water while others may not dissolve at all. Those that do not dissolve in water are known as insoluble salts. For instance, alum (aluminum sulphate) will dissolve in water but aluminum hydroxide,  $\text{Al}(\text{OH})_3$ , is insoluble in water. Calcium bicarbonate,  $\text{Ca}(\text{HCO}_3)_2$ , is very soluble but calcium carbonate,  $\text{CaCO}_3$  will not dissolve once the pH reaches 9.0-9.5.

Many of the undesirable minerals in water are present in the form of soluble salts. By adding certain other chemicals and adjusting the pH of the water, chemical reactions will take place that will change those soluble salts into insoluble salts. These insoluble salts can then be removed by either sedimentation or filtration.

### COMMON NAMES FOR WATER TREATMENT CHEMICALS

There are a number of water treatment chemicals that are better known by their common names than their chemical names.

Chemical Name	Chemical Symbol	Common Name
Aluminum Sulphate	$\text{Al}_2(\text{SO}_4)_3$	Alum
Calcium Hydroxide	$\text{Ca}(\text{OH})_2$	Lime
Sodium Hydroxide	$\text{NaOH}$	Caustic Soda
Sodium Carbonate	$\text{Na}_2\text{CO}_3$	Soda Ash
Ferrous Sulphate	$\text{FeSO}_4$	Copperas

### pH

The pH of the water is the measurement of the acidity or alkalinity of the water. Water is considered to be acid when it has more hydrogen ions ( $\text{H}^+$ ) in it than hydroxide ions ( $\text{OH}^-$ ). Some of the chemicals that add hydrogen ions ( $\text{H}^+$ ) to the water are hydrochloric acid,  $\text{HCl}$ , sulfuric acid,  $\text{H}_2\text{SO}_4$ , nitric acid,  $\text{HNO}_3$ , and carbonic acid,  $\text{H}_2\text{CO}_3$ ,

Water is considered to be alkaline when there are more hydroxide ions ( $\text{OH}^-$ ) present than hydrogen ( $\text{H}^+$ ) Sodium hydroxide,  $\text{NaOH}$ , calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , and magnesium hydroxide,  $\text{Mg}(\text{OH})_2$ , all add hydroxide ions ( $\text{OH}^-$ ) to the water. When the number of hydrogen ions and hydroxide ions are the same the water has a neutral pH. Pure water,  $\text{H}_2\text{O}$  or  $\text{H-OH}$ , has a neutral pH because the number of hydrogen ions ( $\text{H}^+$ ) and hydroxide ions ( $\text{OH}^-$ ) are equal.

<b>pH SCALE</b>														
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
						^								
More Acidic						Neutral		More Basic						

The pH of water is measured on a scale that reads from 0 to 14. The midpoint of the scale is 7. Water with a pH of 7 is neutral. If the water has a pH less than 7, the water is acidic and if the pH is greater than 7 it is basic or alkaline. For every whole number that the pH changes the strength of the acidic or alkaline properties of the water will change by a factor of ten times. Water that goes from a pH of 9 to a pH of 10 becomes 10 times more alkaline and water at pH of 5 is 10 times more acid than water at a pH of 6.

### **pH AND WATER CHEMISTRY**

Adjustments to the pH of the raw water may be necessary to achieve the formation of insoluble compounds. Acids and bases are used for pH adjustment. Acids add hydrogen ions ( $H^+$ ) to lower the pH and bases, or alkalis, add hydroxide ions ( $OH^-$ ) to raise the pH.

<b>Acids</b>	<b>Bases</b>
HCl - Hydrochloric Acid	Ca(OH) <sub>2</sub> - Calcium Hydroxide
H <sub>2</sub> SO <sub>4</sub> - Sulfuric Acid	NaOH - Sodium Hydroxide
H <sub>2</sub> CO <sub>3</sub> - Carbonic Acid	Mg(OH) <sub>2</sub> - Magnesium Hydroxide
HNO <sub>3</sub> - Nitric Acid	

### **CHEMICAL DISSOCIATION AND IONS**

When acids or bases are added to water some of the molecules split into their ionic components. This is known as dissociation. Hydrochloric acid molecules will split into hydrogen ions and chloride ions in water. Sodium hydroxide will split into sodium ions and hydroxide ions. These ions will have either positive or negative charges associated with them. Not all of the molecules of an acid or base will dissociate though. The strength of an acid or base is determined by how many molecules split this way.



Stronger acids and bases will dissociate more completely than weaker acids and bases. Weak acids such as carbonic acid ( $\text{H}_2\text{CO}_3$ ) or weak bases like magnesium hydroxide ( $\text{Mg}(\text{OH})_2$ ) do not dissociate as completely and, as a result, do not change the pH as much as the same amount of sulfuric acid ( $\text{H}_2\text{SO}_4$ ) or sodium hydroxide ( $\text{NaOH}$ ) would.

## PHYSICAL/CHEMICAL TREATMENT

The purpose of chemical treatment is to remove any undesirable contaminants and produce water that is safe and acceptable to consumers. Undesirable impurities can be removed, using conventional treatment, including Pretreatment, Coagulation, Flocculation, Sedimentation, and Filtration.

**Pretreatment** refers to treatment of the raw water before it enters the treatment plant. It usually occurs at the raw water intake and involves some type of chemical addition with no physical treatment other than mixing. Chemicals used in pre-treatment include oxidizing agents for color or tastes and odors, activated carbon for tastes and odors, and aeration for iron or hydrogen sulphide gas.

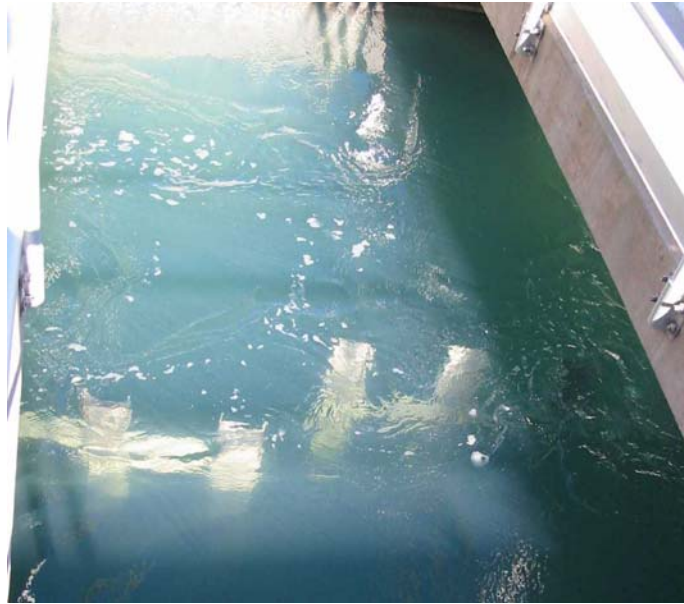
**Coagulation** is the chemical reaction that changes soluble salts into insoluble salts. This is accomplished by adding certain chemicals, known as coagulants, to the raw water. Coagulant aids are used to adjust pH and help in the formation of insoluble salts. These salts are referred to as floc. The formation of floc is accomplished by the even and thorough dispersal of the coagulant in the raw water by "rapid" or "flash" mixing. Changes in water quality or water temperature can have an adverse affect on the coagulation process.



**Coagulation Basin**

**Flocculation** is the process that follows the rapid mix. The velocity of the water is reduced and a gentle mixing action is created to allow the formation of insoluble salts, clay, and other suspended matter into floc particles. The negatively charged colloids are attracted to a positively charged coagulant and begin colliding to form a large neutral floc particle that will settle out during the sedimentation process. This process of bringing positive and negative charged particles together to form a floc that has a neutral charge, and is large enough to settle is called agglomeration.

A flocculation tank will use baffles or mechanically driven paddles for mixing. It is important to keep the velocity of the water slow enough to prevent "hydraulic shear" This will prevent the floc particles from breaking up before they reach the sedimentation tank. One of the more common problems occurring in flocculation basins is formation of pin floc. Underfeeding or overfeeding the coagulant chemicals usually causes pin floc. Pin floc can also be a problem when the raw water is cold or has a low turbidity. The addition of coagulant aids such as bentonite clay, activated silica, and polymers can improve the flocculation process.



**Flocculation Basin**

**Sedimentation** is the process of slowing the water velocity to allow the floc to settle out. Clear water is then drawn off the top of the basin for filtration. Sedimentation basins are usually the largest tanks in the treatment process. These basins should have baffles placed in them to prevent "short-circuiting." Baffles are usually made out of wood or metal and used as an obstruction to the normal flow of water. Short-circuiting is a condition caused by allowing the influent to flow straight across the basin to the effluent weir in less time than it would take if the flow were distributed evenly across the tank.

In circular basins the flow is directed down and in rectangular basins it is spread evenly across the influent end of the tank. As the water flows through the basin, the floc settles to the bottom forming a sludge blanket. Sludge is removed by means of a raking device that pushes the sludge to the center of circular basins or the end of rectangular basins where it is pumped out of the tank. Bulking occurs when sludge is not removed from the process often enough. This is a result of decomposition of organics in the sludge that causes gases to form and sludge to float to the surface. This decomposition can also create taste and odor problems.

**Filtration** is the final step in the removal of chemical impurities in water. Any organic or inorganic particles that have not been removed during the sedimentation process must be filtered out in order to meet the SDWA standards of 0.3 NTU's in the finished water. The turbidity of the water in the filter influent should not exceed .15 NTU's, and should actually be less than 5 NTU's, or filter runs will be reduced dramatically. When the filter becomes dirty it must be backwashed. Since the backwash water is treated potable water, the length of the filter run directly impacts the cost of the filter operation. The backwash water must either be returned to the head of the plant or mixed with the raw water flow or impounded so that sludge can be separated.

Some impurities are removed using other treatment processes like chemical adsorption with activated carbon, gas stripping with aeration, softening and demineralization. Chemical adsorption with activated carbon removes tastes and odors and organic precursors (TOC) that may create THM problems.

## **COLOR REMOVAL**

The dissolved organic compounds that cause true color in water can be removed if the pH of the water is lowered to between 3.5 and 5.5. Under these acidic conditions, the color compounds become gelatin-like solids that will settle out in the sedimentation tanks. This pH adjustment can be accomplished by adding alum or acids. Most of the other treatment processes will require a pH of 6.5 to as high as 11.5. If color is to be removed, the pH must be lowered first. If the pH is raised, the color may become set (much the same way that hot water will set laundry stains) and will be nearly impossible to remove. Older treatment plants are usually not equipped to handle this type of treatment, however, some up-flow units can be adapted to remove color because alum can be added to lower the pH prior to raising the pH for other types of treatment.

Color can also be removed by oxidation. Chlorine is sometimes used to oxidize color compounds and remove them. However, this can result in the formation of Trihalomethanes or THM's and is not usually recommended. Other oxidizing agents such as ozone or potassium permanganate do a better job and do not create the THM byproducts associated with the use of chlorine.

## **PATHOGEN REDUCTION**

Most pathogenic organisms tend to die out in surface water supplies. Sedimentation and filtration can also remove about 90% of the pathogens that do survive. However, those that are not removed during the treatment must still be destroyed with disinfecting agents. The possible presence of *Giardia* in surface waters is the main reason that filtration is now mandatory for all surface supplies. Higher chlorine residuals may also be necessary to meet the new  $C \times T$  standards for *Giardia*. Using ozone as a disinfectant can reduce the difficulties created by the increased contact time needed to kill *Giardia*. Chlorination may still be required to meet secondary contamination considerations.

## **TASTE AND ODOR REMOVAL**

Taste and odors in water can come from several sources. Both organic and inorganic compounds can cause tastes and odors. The most common source of organic taste and odors is algae. These algae can be divided into two main groups that are responsible for most of these problems. They are classified, according to their color, into green algae and blue-green algae. Green algae are usually responsible for grassy or musty odor in water while the blue-green algae cause rotten fish types of odors.

Algae problems develop during hot, dry weather in the early summer. Algae blooms will begin in shallow coves as the water temperature rises. These blooms spread so rapidly that, in a week or two, enough algae is present to cause serious taste and odor problems. Some blue-green algae release poisonous by-products that can result in fish kills in severe cases. Algae blooms can also result in pH fluctuations in the impoundment as the CO<sub>2</sub> uptake increases during the daylight hours driving the pH higher. Diatoms are another group of algae that may be present in surface waters. They do not cause the offensive odors that the blue-green algae do, but their shells tend to plug filters. Tastes and odors can also be caused by inorganic compounds and dissolved gases. Iron and manganese can cause rusty tastes. Hydrogen sulphide gas can cause a rotten egg odor.

### **COPPER SULFATE TREATMENT**

Algae in lakes and reservoirs can be killed with copper sulfate, CuSO<sub>4</sub>. It usually requires dosages of about 0.5 to 1.0 mg/l to kill most algae blooms. However, if the action is taken early in the spring before these algal blooms occur, dosages as low as 0.1 mg/l may be sufficient. Copper sulphate is most effective when it is applied to soft waters that have a low hardness and a high pH. Never add copper sulfate in dosages higher than 1.0 mg/l. Copper sulfate will kill many game fish at very low concentrations. Brown trout will not survive concentrations greater than 0.14 mg/l. Always contact state health officials before attempting this type of treatment.

### **IN-PLANT TREATMENT**

There are three methods of removing taste and odors at the treatment plant. Activated carbon can be used to adsorb the organic compounds that cause the problem. Powdered activated carbon (PAC) is added to the water flow to adsorb the organic compounds. A dosage of 15 to 25 mg/l is usually required to accomplish this. In severe cases, dosages may need to be as high as 100 mg/l. Activated carbon should be added as far upstream as possible from the point where coagulant chemicals are added. If it is added at the same time as coagulant chemicals, it may become tied up in the floc particle before it has time to adsorb the organic taste and odor compounds. Activated carbon is very expensive and difficult to feed. It is also dangerous to handle because it can create an explosion if dispersed in the air and ignited. Granulated activated carbon (GAC) is also used to adsorb organics from filtered water.

The other method of taste and odor removal is by the addition of an oxidizing agent such as chlorine. The problem again is the creation of THM's as a byproduct of the chlorination process. The use of other oxidizing agents like chlorine dioxide, ozone, or potassium permanganate should be considered for this type of treatment.

Tastes and odors caused by inorganic compounds like iron or hydrogen sulphide may be removed by aeration. Diffused air bubblers or stripping towers are the most common means of aeration. The dissolved oxygen will oxidize the iron and manganese and cause hydrogen sulfide to be forced out of the water. Removal of iron still requires some type of filtration to remove the oxidized rust particles that are formed. Use of aeration for treatment also has a drawback. In low pH waters dissolved oxygen can create serious corrosion problems in the system. Oxidizing agents can also be used to remove inorganic tastes and odors.

## TURBIDITY REMOVAL

Turbidity is removed during the treatment process by addition of coagulants and coagulant aids. Aluminum sulphate,  $\text{Al}_2(\text{SO}_4)_3$ , or alum, is the most widely used coagulant in the treatment of water. Its pH range is 5.0 to 7.0 and is most effective at 6.5. When the alum dissolves in water it reacts with the alkalinity present to form aluminum hydroxide, which is an insoluble salt. As the particles of aluminum hydroxide clump together the turbidity particles are attracted to and entrapped in the floc. This causes the pH to drop because the alkalinity is being removed from the water. Lime,  $\text{Ca}(\text{OH})_2$ , is added to compensate for the drop in alkalinity and maintain the pH at 6.5. For every 2 mg/1 of alum added, about 1 mg/1 of lime must be added to replace the alkalinity removed by the reaction. Alum can also be used for TOC removal at a pH of 5.5-6.0.

### COMMON COAGULANT CHEMICALS

Aluminum Sulphate	$\text{Al}_2(\text{SO}_4)_3$
Ferric Sulfate	$\text{Fe}_2(\text{SO}_4)_3$
Ferrous Sulfate	$\text{FeSO}_4$
Ferric Chloride	$\text{FeCl}_3$
Sodium Aluminate	$\text{NaAlO}_3$

These chemicals work as coagulants because the iron and aluminum ions are large and have a high positive charge needed to attract the negatively charged turbidity particles. Alum is used most often because it is the least expensive coagulant. The other coagulants are used because they will form floc over a wider pH range. Sodium aluminate will work at any pH. However, adjusting the pH with lime and using alum is usually the most economical choice. It should be noted that all of the coagulant chemicals will precipitate as ferric hydroxide or aluminum hydroxide and will remove alkalinity from the water. Ferric chloride is becoming more widely used in areas where arsenic is a problem. Treating water with low turbidity may present problems in forming a floc particle that is heavy enough to settle out. In some cases a weighting agent must be added such as activated silica or bentonite clay.

The use of polymers as coagulant aids has become more common in surface supplies that have relatively low turbidities. They are organic compounds that can be positively charged, negatively charged, or carry a neutral charge. When mixed with water, polymers form long jelly-like chains that entrap floc particles allowing more rapid settling. Polymers are usually added before the coagulant in the coagulation process.

Polymers that are positively charged are called cationic polymers and those that are negatively charged are called anionic polymers. Cationic polymers are most commonly used in surface water treatment to attract negatively charged turbidity particles. Polymers in their concentrated form are coiled like a spring. They must be diluted in water and allowed to “unwind” before they will work effectively in the flocculation process. This usually takes 40-60 minutes after mixing.

## MINERAL REMOVAL

Mineral problems can be grouped into two major categories. These are problems related to hardness and problems related to other metals and gasses not associated with hardness such as iron, manganese, hydrogen sulfide, ammonia, and carbon dioxide.

## HARDNESS

Metals that are dissolved in water cause hardness. Calcium (Ca) and Magnesium (Mg) are the two metals that dissolve the most easily in water. They are considered to be the main cause of hardness. Other metals also cause hardness in water but very few are soluble enough to contribute to hardness problems. The two metals that do not cause hardness in water are (Na) sodium and (K) potassium. Water with hardness of 0-60 mg/l is considered to be soft water. Moderately hard water is considered to be between 60-120 mg/l, while very hard water has hardness of 150 mg/l and up.

Hardness causing compounds are broken into two groups; carbonate hardness and non-carbonate hardness. Carbonate hardness is hardness that can be removed by boiling water. Non-carbonate hardness cannot be removed by boiling water. Carbonate and non-carbonate hardness are both a result of dissolved calcium and magnesium in water. It is the non-metals that combine with the calcium and magnesium that will determine whether it is carbonate or non-carbonate hardness.

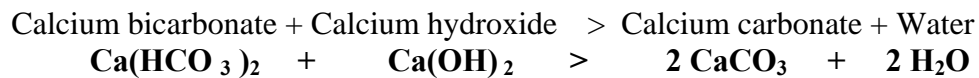
<b>HARDNESS COMPOUNDS</b>			
<b>Carbonate</b>		<b>Non-Carbonate</b>	
Calcium carbonate	CaCO <sub>3</sub>	Calcium sulfate	CaSO <sub>4</sub>
Magnesium carbonate	MgCO <sub>3</sub>	Magnesium sulfate	MgSO <sub>4</sub>
Calcium bicarbonate	Ca(HCO <sub>3</sub> ) <sub>2</sub>	Calcium chloride	CaCl <sub>2</sub>
Magnesium bicarbonate	Mg(HCO <sub>3</sub> ) <sub>2</sub>	Magnesium chloride	MgCl <sub>2</sub>
Calcium hydroxide	Ca(OH) <sub>2</sub>		
Magnesium hydroxide	Mg(OH) <sub>2</sub>		

Carbonate hardness is formed when calcium or magnesium combines with a form of alkalinity (carbonate, bicarbonates, or hydroxides.) Non-carbonate hardness is formed when calcium and magnesium combine with anything other than alkalinity. Chlorides and sulfates are the two most common forms of non-carbonate hardness.

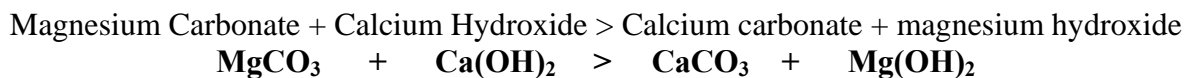
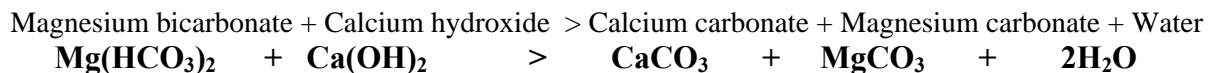
### SOFTENING CHEMICAL REACTIONS

Carbonate hardness is removed by adding lime,  $\text{Ca(OH)}_2$ , to the water. The lime softening process requires the addition of enough lime to raise the pH to a point where the reaction can take place. The pH must be between 9.0-10.5 to remove carbonate hardness. Calcium compounds are removed at a pH of 9.0-9.5. Magnesium compounds require a pH of 10.0-10.5.

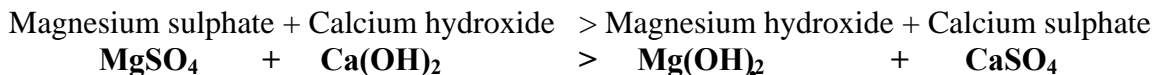
The reaction between lime and calcium bicarbonate results in the formation of calcium carbonate and water. At the proper pH calcium carbonate has a solubility of about 40 mg/l. The rest of the calcium will settle out as a floc.



Magnesium hydroxide is the least soluble of the magnesium compounds. First magnesium bicarbonate reacts with lime to create magnesium carbonate and calcium carbonate. The calcium carbonate precipitates out and then the magnesium carbonate reacts with lime to create calcium carbonate and magnesium hydroxide that will both precipitate out.



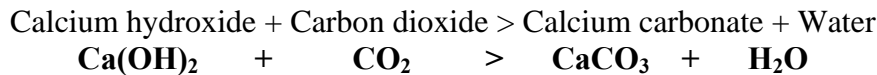
Non-carbonate or permanent hardness can be removed by the addition of sodium carbonate or soda ash,  $\text{Na}_2\text{CO}_3$ . Lime is usually added to adjust the pH of the raw water. This lime-soda ash process requires a pH of 10.0-10.5 to remove calcium compounds and a pH of 11.0 - 11.5 to remove magnesium compounds. When the proper pH conditions are met, the reaction between the sodium carbonate and the calcium sulphate results in the formation of sodium sulfate and calcium carbonate.



The reaction is basically same for calcium chloride, except sodium chloride is created instead of sodium sulphate. The sodium does not cause hardness and the calcium carbonate that is insoluble will settle out. Magnesium compounds react directly with lime to precipitate as magnesium hydroxide. This results in the formation of calcium chloride or sulphate with must then react with soda ash to form calcium carbonate.

## RECARBONATION

After non-carbonate softening has taken place, the finished water will likely have pH of 10-11. This is a result of the lime addition that was needed to drive the softening reaction. If this water is pumped to distribution at this pH, the excess lime will cause calcium deposits in pipes and fixtures. Recarbonation is the process of stabilizing the water by lowering the pH and precipitating the excess lime as calcium carbonate. In large systems the amount of lime needed may make reclamation of the lime from the calcium carbonate sludge feasible. The sludge is heated in a furnace. The heat causes calcium carbonate to breakdown and calcium oxide, CaO, and carbon dioxide gas, CO<sub>2</sub>, are the result. The calcium oxide is “slaked” with water to form calcium hydroxide that is then reused in the softening process. The carbon dioxide gas is then used to react with the excess lime to lower the pH and precipitate more calcium carbonate. Recarbonation also requires additional coagulation, flocculation and sedimentation since it occurs after the initial softening process.



## IRON AND MANGANESE

Iron and manganese (Fe & Mn) can be found in reservoirs and lakes that are used for furnishing water to municipal systems. These minerals are also found in undesirable concentrations in waters from shallow wells or from wells drilled into shale or sandstone formations. The presence of large amounts of Fe and Mn can cause stains on plumbing fixtures, a rusty appearance and taste in the water (red water). Iron in excess of 0.3 mg/l will cause red water problems and manganese in excess of 0.05 mg/l will cause black water problems.

The least expensive means of controlling Fe and Mn in surface water supplies is to raise the raw water intake so that the water is taken from a point nearer the surface of the supply. This may reduce concentrations of Fe and Mn in the raw water because the concentrations of these minerals are normally higher at greater depths in the reservoir. The second alternative is to artificially supply dissolved oxygen by means of aeration. This can be accomplished by installing a small aeration tower prior to the coagulation process. Aeration may also be achieved by forcing air into the water with blowers. Either method can provide the dissolved oxygen necessary to oxidize the Fe and Mn so it will settle out in the sedimentation tanks. Aeration requires longer contact time than other forms of oxidation. If it is used in a direct filtration process, a holding tank may have to be added after aeration to allow time for the reactions to take place. The remaining three alternatives require the addition of chemicals.

Pre-chlorination, or the addition of chlorine to the water before it reaches the sedimentation tanks, is an effective means of removal. In this case the chlorine acts as the oxidizing agent to precipitate the Fe and Mn. To achieve satisfactory percentages of removal enough chlorine must be added to provide a one part per million residual at the point of filtration.

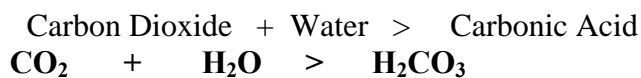
Another oxidizing agent that can be added to remove Fe and Mn is potassium permanganate,  $\text{KMnO}_4$ , it too should be added prior to coagulation. Enough potassium permanganate should be added to give the water a slight pink color as it goes to the filters. This method may also be used along with pre-chlorination. Never add  $\text{KMnO}_4$  to water when the pH is less than 7.2 or manganese may actually be added to the water.

The final method of control is the addition of a sequestering agent. Polyphosphates, including sodium hexametaphosphate, also known as Calgon, are the most common sequestering agent used. This should be done as far in advance of the sedimentation process as possible if this is used by itself. If it is used in a conventional treatment plant, it should be added after sedimentation and before filtration. Polyphosphates should be used in small dosages, usually less than 5 mg/l. If excessive amounts are added it will begin to soften rust deposits in the distribution system and cause them to break loose. When this happens, serious plugging of hydrants or services can occur.

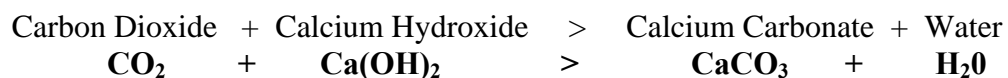
It should be noted that polyphosphates do not remove Fe and Mn, but they do surround or sequester these ions and keep them in solution rather than allowing them to be oxidized and precipitate in the distribution system. Over time the polyphosphates will break down and release the Fe and Mn. They will then oxidize and create the red or black water. The proper dosage is just enough to keep the iron or manganese tied up for 4 days.

## DISSOLVED GASES

Carbon dioxide and hydrogen sulfide are the main causes of problems related to dissolved gases. Carbon dioxide will react with water to form carbonic acid and can create corrosive conditions in the water.



Carbon dioxide can be removed by aeration down to concentrations of 5 mg/l. Hydrogen sulphide can be completely removed by aeration. Lime may be added to further reduce the  $\text{CO}_2$  concentration. The lime will react with the  $\text{CO}_2$  and precipitate out as calcium carbonate.



## **ARSENIC REMOVAL**

The lowering of the MCL for Arsenic to 0.01 mg/L (10.0 ppb) has created a need for arsenic removal treatment in many water systems in the Southwest. A great deal of research has been ongoing for the last several years in an attempt to determine the most cost effective means of reducing arsenic levels in drinking water. Demineralization processes like reverse osmosis and electro-dialysis have been proven to be effective, but the treatment costs are high. They are generally used in point of use (POU) treatment applications or very small water systems.

Ion exchange and chemical precipitation processes are also being used to remove arsenic. An activated alumina ion exchange process has been used for arsenic removal for over 20 years. It is similar to an ion exchange process for water softening. Chemical precipitation processes, using iron salts as a coagulant, are being considered for larger systems. Ferric chloride is as the coagulant in most cases. Systems that have a high level iron in the raw water have been found that iron removal by oxidation also results in dramatic reductions in arsenic levels. Arsenic is chemically attracted to ferric iron when it precipitates. This reaction is most effective at a pH of 7.3.

The ferric chloride or iron oxidation precipitation processes are usually accomplished by direct filtration. The pH adjustment and ferric chloride are added to a flash mix or coagulation chamber followed by filtration. The solids that are backwashed from the filter are thickened and de-watered for disposal. Backwash water may be sent to a wastewater treatment plant for processing rather than de-watering at the water treatment facility.

## **CHEMICAL STABILITY**

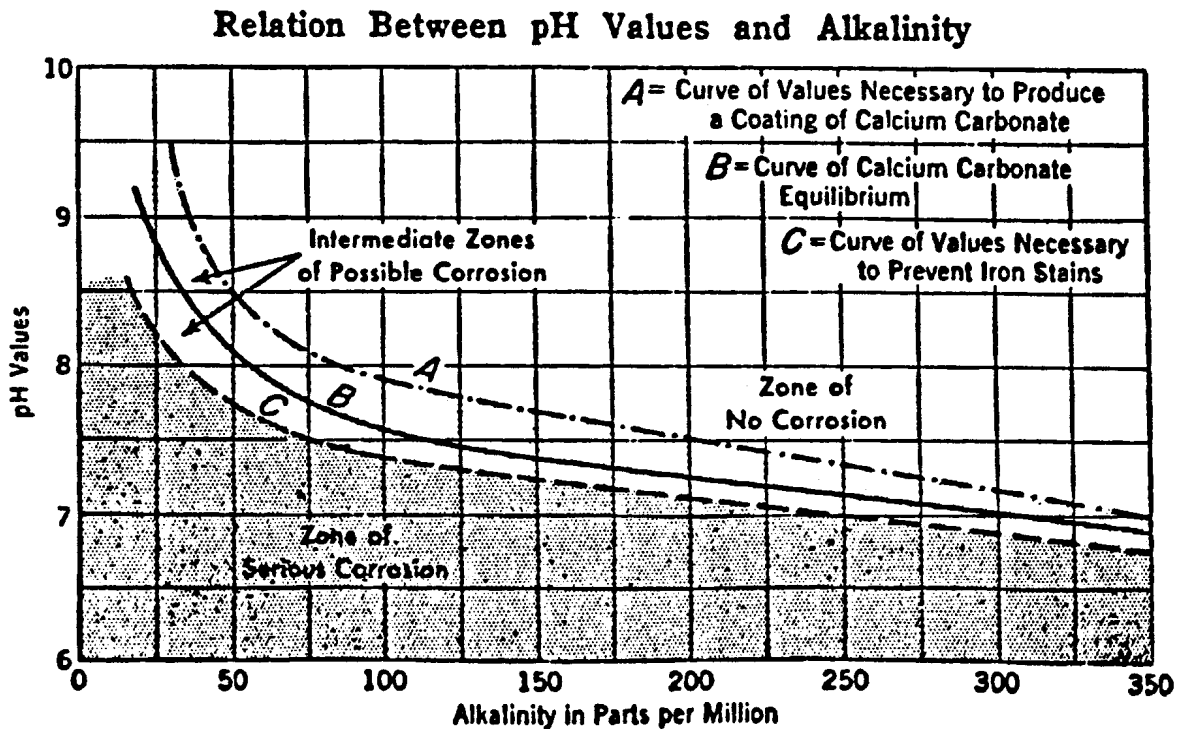
Chemical stability of the finished water is very important. Water that is chemically unstable will either cause corrosion or calcium carbonate scaling in the distribution system. Water that is corrosive will attack all of the metal components of the distribution system including storage tanks, pipe, valves and meters. It will cause rust and tuberculation in iron pipe and steel storage tanks. Tuberculation can dramatically increase the friction loss and reduce the carrying capacity of a distribution line. Corrosive water can also result in problems from lead and copper that can leach out of the customers plumbing fixtures.

Water will be corrosive or scaling if the proper relationship between the pH and the alkalinity of the water does not exist. Alkalinity, in the form of hydroxides, carbonates and bicarbonates, must be present in water to act as and absorb acids to prevent corrosive conditions. Too much alkalinity will create scaling conditions and result in calcium carbonate scale in piping. This buildup of scale in the piping will greatly reduce the carrying capacity of the pipe. Scaling conditions can be created during softening processes. The high pH needed to precipitate calcium carbonate is usually achieved by the addition of lime. This can create scaling conditions in the finished water..

The Baylis Curve and the Calcium Carbonate Stability Test (Marble Test) are two of the methods used to determine the chemical stability of water. Chemical stability of corrosive water can be achieved by pH adjustment with lime or the addition of carbonate alkalinity like sodium carbonate or calcium carbonate. The recarbonation process is used to lower the pH in order to precipitate out the excess alkalinity before it can cause scaling.

## BAYLIS CURVE

One method of determining whether the pH and alkalinity are properly adjusted to produce stable, non-corrosive water is with the Baylis Curve. Plotting the pH and alkalinity of the water on this chart will indicate whether the water is corrosive or not. If the point where the pH and alkalinity cross is below the curve (dark gray area) the water is corrosive and will attack metal tanks and pipes in the system. If the point is above the curve the water is not corrosive but does have excessive amounts of alkalinity present, which will cause the formation of lime scale in the lines. This scale formation can restrict the flow of water in the line if allowed to build up over a long period of time and can be as bad for the system as corrosive water. When the point falls within the dotted lines or on the curve itself, the water is stable and will not cause corrosion problems.



## Baylis Curve

## **CALCIUM CARBONATE STABILITY TEST**

The first step in the calcium carbonate stability test or marble test is to record the alkalinity of a sample. Calcium carbonate is then added to the sample and allowed to set for 24 hours. A second alkalinity is run on the sample. If the alkalinity has increased, the water is corrosive. If the alkalinity decreased, the water is scaling.

## **LANGLIER INDEX**

The Langlier Index also factors water temperature into the equation. It is more commonly used for industrial water treatment. An index number is calculated based on pH, alkalinity and temperature. If the index number is a positive number, the water is scaling. If the index number is a negative number, the water is corrosive.

## **CHEMICAL FEEDERS**

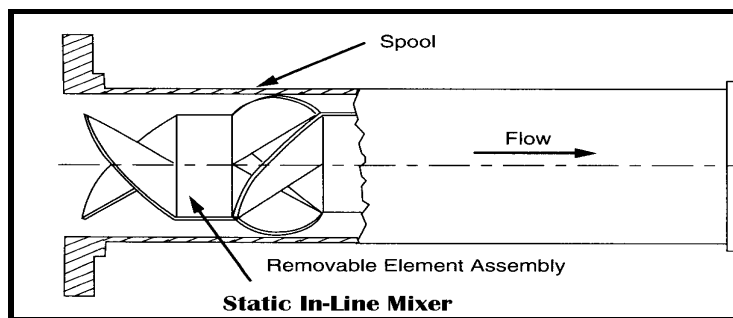
Chemical feeders are necessary to assure that the proper amount of each chemical is added to the water on a continuous basis. Each feeder must have a storage bin, a device that feeds the chemical into a solution tank where it is dissolved, and a delivery system to add the chemical at the proper point in the treatment process. Chemical feeders are either volumetric or gravimetric. Volumetric feeders are the most common. They include auger feeders and positive displacement metering pumps.

The actual proportional feeding device may be a screw auger, a rotating disc, an oscillating shelf, or a variable speed conveyor belt. The feeder control may be calibrated in pounds per day but usually the scale simply reads from 1 to 10 or 1 to 100. The manufacturer may provide a chart that can be used to determine what the feed rate is a given setting. If not, the operator can calibrate the machine manually. This should be done periodically to determine if the machine is in need of cleaning or maintenance due to clogging or belt slippage. The first step is collecting and weighing the amount of chemical fed in one minute at several different settings. These figures multiplied by 1,440 minutes per day will give pounds per day feed rate. These points can be plotted to create a straight-line graph that can be used to accurately set the feed rate.

Each chemical used in water treatment has specific safety considerations regarding its handling and storage. Operators should be aware of the potential hazards always use appropriate personal safety equipment when handling these chemicals or working around feed equipment. Respiratory protection is always appropriate when handling any dry chemicals. Activated carbon dust can be explosive and wet activated carbon can deplete the atmosphere of oxygen. Alum and polymers become very slippery when wet. The ferric and ferrous salts are very corrosive. Oxidizing agents are also very corrosive. Chlorine gas is also toxic and any chlorine product, including HTH and bleach, will react violently with organic compounds and react with acids to release chlorine gas. Always check the Material Safety Data Sheet (MSDS) if there are any questions regarding handling or use of any chemicals. These may be obtained directly from the chemical supplier or manufacturer.

## PRETREATMENT EQUIPMENT

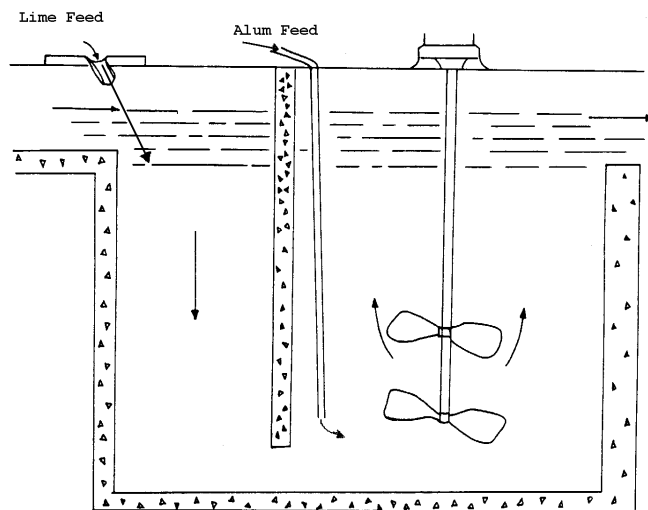
Pretreatment equipment usually refers to chemical feeders and in-line mixers that are used prior to coagulation when oxidizing agents or activated carbon are being used for taste and odor removal. Air stripping towers or other aeration equipment would also be included in this category. Other reasons for pre-treatment might include disinfection as pretreatment to maximize contact time for *Giardia* removal or pH adjustment for color removal. Mixing can be accomplished using mechanical mixers, static in-line mixers, or simply injection at the suction side of the raw water pump, using the pump as a mixer. Pretreatment should occur as far upstream from the treatment as possible in order to maximize the contact time prior to coagulation.



## COAGULATION EQUIPMENT

The coagulation process, or rapid/flash mix, is most often accomplished using mechanical mixers in a tank that has a detention time of 1-3 minutes. Mixing velocities should be between 5-7 ft/sec. The tank may be dual-chambered. This design allows the coagulant aids to be added first. The raw water should have the proper pH and alkalinity, and have other aids like polymers or bentonite clay present before the flow enters the mixer chamber. In-line mixers may also be used for coagulation and flash mixing.

In either case, it is important to add the coagulant aid far enough upstream that the pH adjustment occurs before the coagulant is added. The raw water should be tested for pH, alkalinity, turbidity, temperature, tastes and odors, and color. If softening is an issue, hardness tests should also be run. pH should also be checked after coagulation.

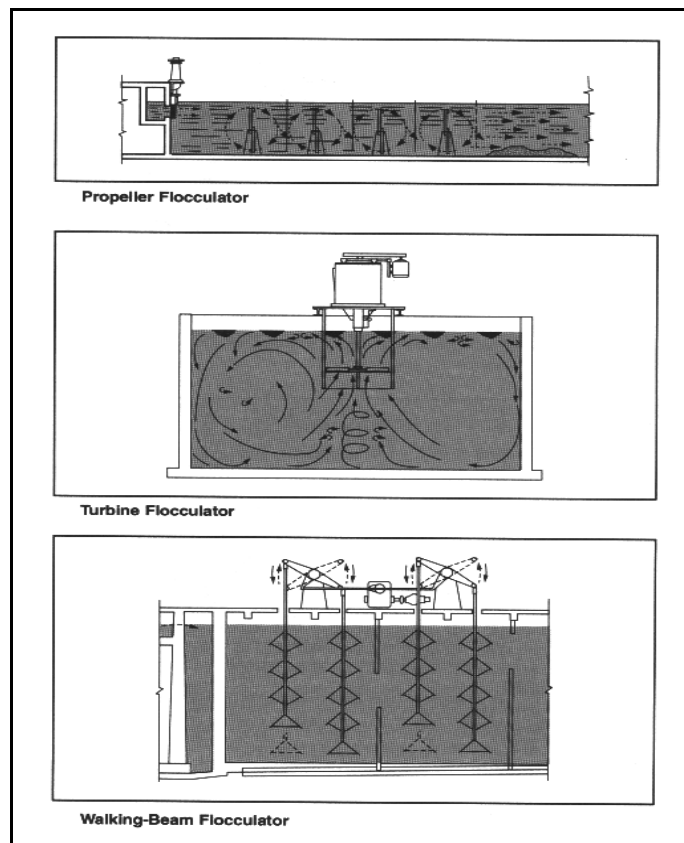


Dual Compartment Rapid Mix

Jar tests should run on the raw water to determine the optimum coagulant dosage. The amount of coagulant needed for good floc formation can be affected by changes in the raw water quality. Raw water should be checked for turbidity, pH, alkalinity, temperature, color, and tastes and odors. Floc does not form as well or as fast in colder temperatures requiring higher coagulant doses. Changes in pH will change the amount of coagulant aid needed. Changes in turbidity will have an effect on the amount of coagulant required. Higher turbidities do not necessarily mean more coagulant will be used. Because there are more particles available in highly turbid water, it may actually require less coagulant to form a good floc particle. In fact, waters with very low turbidities may require the addition of a coagulant aid, like bentonite clay or activated silica that increases the turbidity in order to produce a better floc particle.

## FLOCCULATION EQUIPMENT

The flocculation process takes place in a much larger basin. The average detention time is 30-60 minutes. Changes in temperature can necessitate longer detention times because floc formation takes longer in colder water. The velocities in the flocculation basin should be about 1 ft/sec. This velocity will provide the maximum particle collision rate without causing hydraulic shear. If the velocity drops below 1 ft/sec, settling may occur in the corners of the basin. The proper velocity is maintained by means of mechanical mixers. It is important to have the ability to adjust the mixer speed to compensate for changes in flow and temperature that can impact floc formation. The flocculation effluent should be checked visually prior to sedimentation.



## SEDIMENTATION EQUIPMENT

Conventional treatment plants will use either rectangular or circular sedimentation basins. Every sedimentation basin can be divided into four zones:

The **Influent Zone** is inlet to the sedimentation basin. Water enters the end of a rectangular tank and the center of a circular or square tank. The influent zone will be equipped with a baffle. Circular tanks will have a collar-type circular baffle that directs the water down as it enters the center of the tank. Rectangular tanks will have a perforated wall that spreads the water laterally across the inlet end of the tank. The purpose of the baffle is to prevent short-circuiting. Short-circuiting reduces the detention time in the tank causing floc to carry over onto the filters and causes uneven distribution sludge

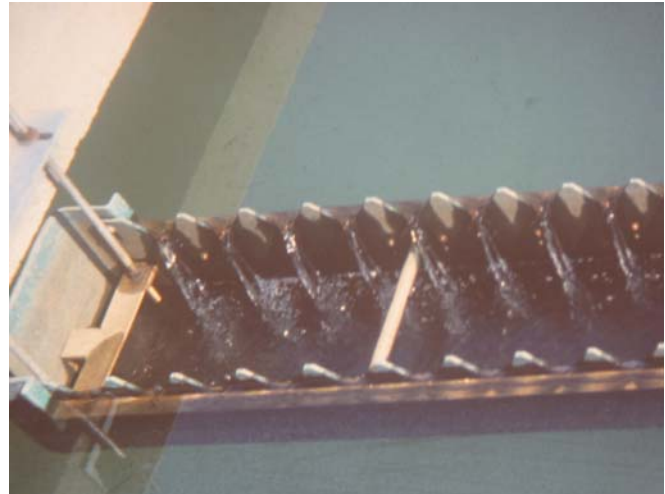


### Influent Structure and Baffle Ring

The **Settling Zone** represents the largest portion of the tank. The water velocity is reduced to 0.01-0.03 ft/sec and the detention time is 4-6 hours. Slowing the water down for this long allows the sludge to settle to the bottom while the water is removed from the top of the tank. Sedimentation tanks are usually only about 8-12 feet deep and have a surface loading rate of about 800 gpd/sq.ft. This keeps the upward velocity of the water low enough to minimize floc carryover. A tank that is 20' x 50' (1000 sq.ft.) and designed with a surface loading rate of 800 gpd/sq.ft. would have a maximum design flow of 800,000 gallons/day. Tube settlers are sometimes used in sedimentation basins to improve settling rates.

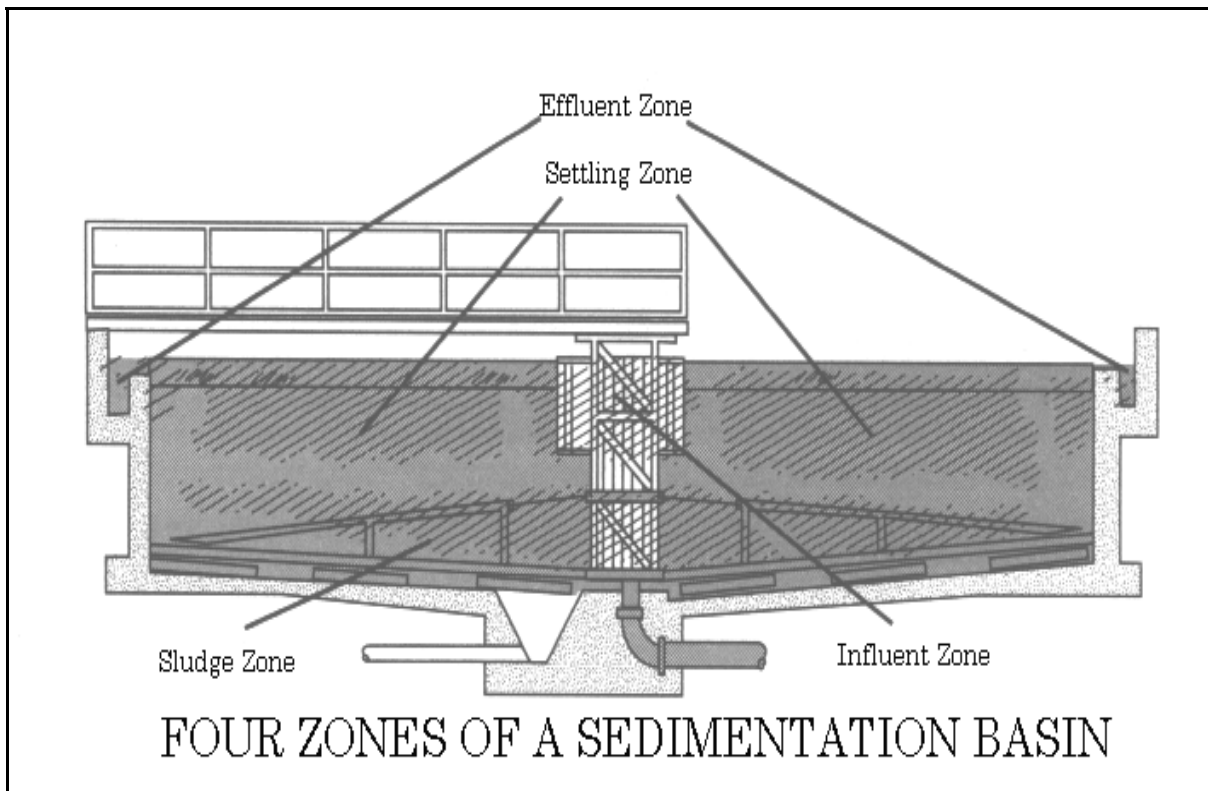
The **Effluent Zone** is the part of the tank where the settled water leaves to go to the filters. In rectangular tanks the water leaves at the end opposite the influent. In circular or square tanks the water leaves at the edge of the tank. A channel called the effluent launder collects the effluent flow and directs it to the effluent piping. Weirs are installed along the edge of the effluent launder channel to skim the water evenly off the surface of the tank. The most common type of weir is a V-notch weir. A V-notch weir is a plate that has notches that are about 2-3 inches deep, cut in it every 8-12 inches. If the weir is clean and level, it will remove water evenly all the way around the edge of the tank. This minimizes the upward velocities near the effluent launder to reduce floc carryover.

If the weir plate is not level or part of the weir becomes clogged with algae or chemical scale, short-circuiting will result because more water will pass over the low, clean side of the weir. The result will be poor settling and uneven sludge blanket buildup. A baffle plate, in the form of a ring 6-8 inches inside the weir, may also be installed to prevent floating solids from going over the weir. The design criterion for weirs is the weir overflow rate.

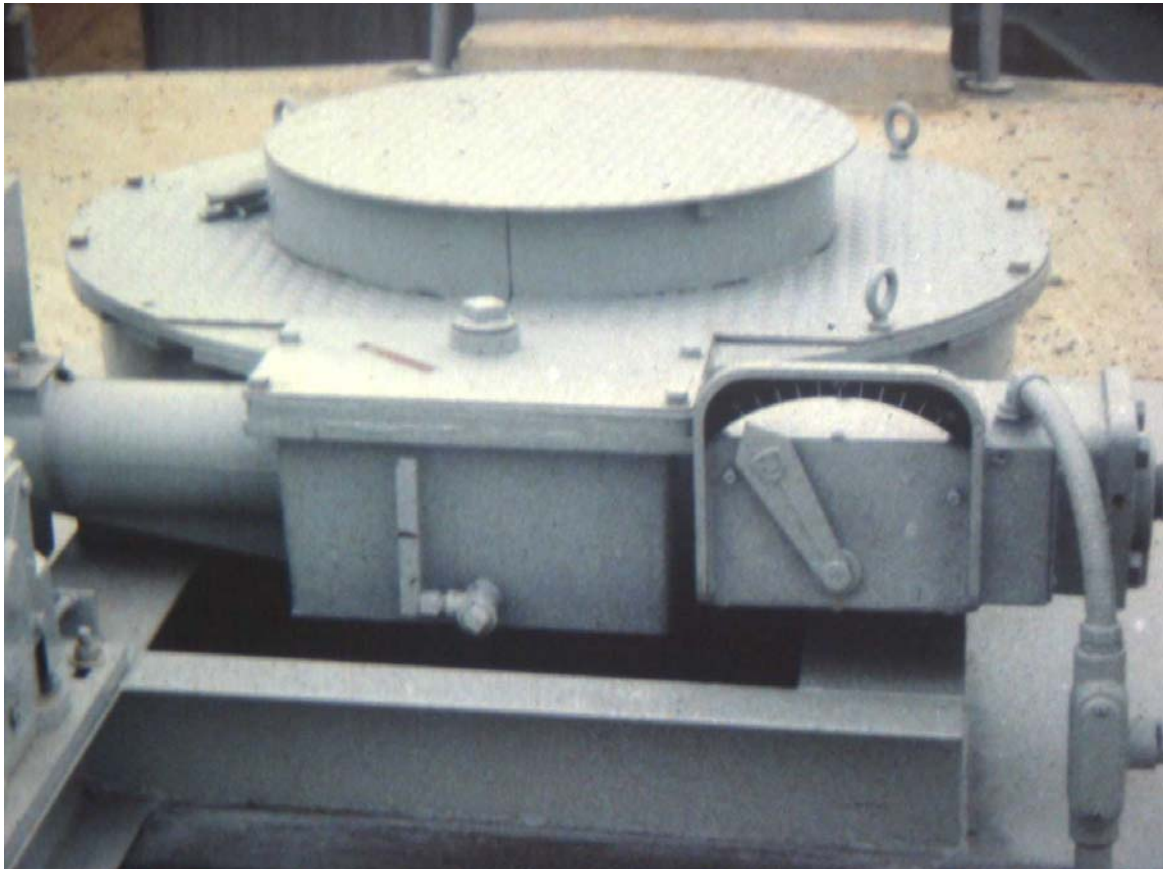


### V-Notch Effluent Weir Channel

The weir overflow rate determines how many gallons can pass over each foot of weir each day. The standard weir overflow rate is between 10,000-14,000 gpd/ft. Our basin with a design flow of 800,000 gpd would require about 57 feet of weir to maintain a 14,000 gpd/ft weir overflow rate ( $800,000\text{gpd}/14,000\text{gpd/ft} = 57.15\text{ft}$ ).



The **Sludge Zone** is the bottom of the tank where the settled sludge collects. Sludge blanket depth should be measured periodically and sludge should be removed every shift or at least once a day. Sludge rakes push the sludge to one end or the center of the tank so that it can be pumped out. The rake drive is usually equipped with a torque indicator. The torque indicator resembles the indicator on a torque wrench. A needle moves across a graduated scale that indicates how much force is needed to move the rake through the sludge. If too much torque is applied, a shear pin in the drive shaft will break to prevent damage to the gearbox or drive shaft. A fluctuating torque reading indicates uneven sludge buildup in the sludge zone. Short-circuiting in the tank usually causes this. Failure to remove sludge often enough will result in bulking. The sludge can become septic and float to the top where it can be difficult to remove. It can also result in taste and odor problems.

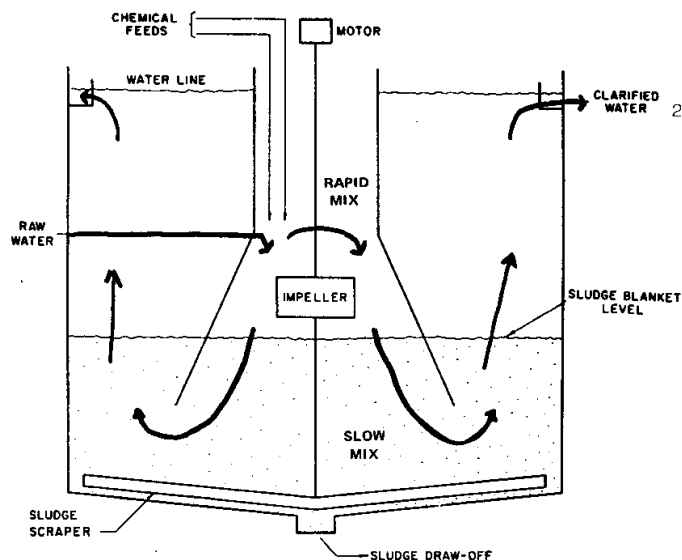


**Sludge Rake Gear Box and Torque Indicator**

## UP-FLOW CLARIFIERS

Many new plants use up-flow or solids-contact type clarification equipment instead of conventional equipment. Up-flow clarifiers combine coagulation, flocculation, and sedimentation all in one unit. This can save money because less space is needed and the cost of the construction is less. One type of up-flow unit utilizes a sludge blanket that the water must pass through as it leaves the tank. The influent enters the center of the tank where chemicals are added and mixed by an impeller. The water flows downward and out under the hood that is in the center of the tank as the hood widens at the bottom, the velocities are reduced and flocculation begins. The floc is just starting to form as water passes up through the sludge blanket. The sludge blanket filters out the floc particles as the clarified water leaves the unit. Since the floc does not have to get big enough to settle, and the sludge blanket filters it, true settling is not required. The detention times in these units can be as little as 2 hours. This means that a much smaller tank can be used and because there is no need for separate coagulation and flocculation basins installation costs for these types of processes is much lower than conventional treatment.

Process control is accomplished by adjusting the turbine or mixer speed and regulating the sludge blanket density. The mixer supplies the energy for mixing, flocculation and sludge blanket suspension. Adjustments that are made to compensate for flow or temperature changes must be very gradual. The adjustment should not exceed 2-3% at a time. The sludge blanket is monitored by drawing sludge samples and spinning them in a centrifuge. Chemical sludges should be maintained between 12-18% by volume in the centrifuged sample. Once an optimum range has been determined, sludge removal should occur as often as needed to maintain that particular density.



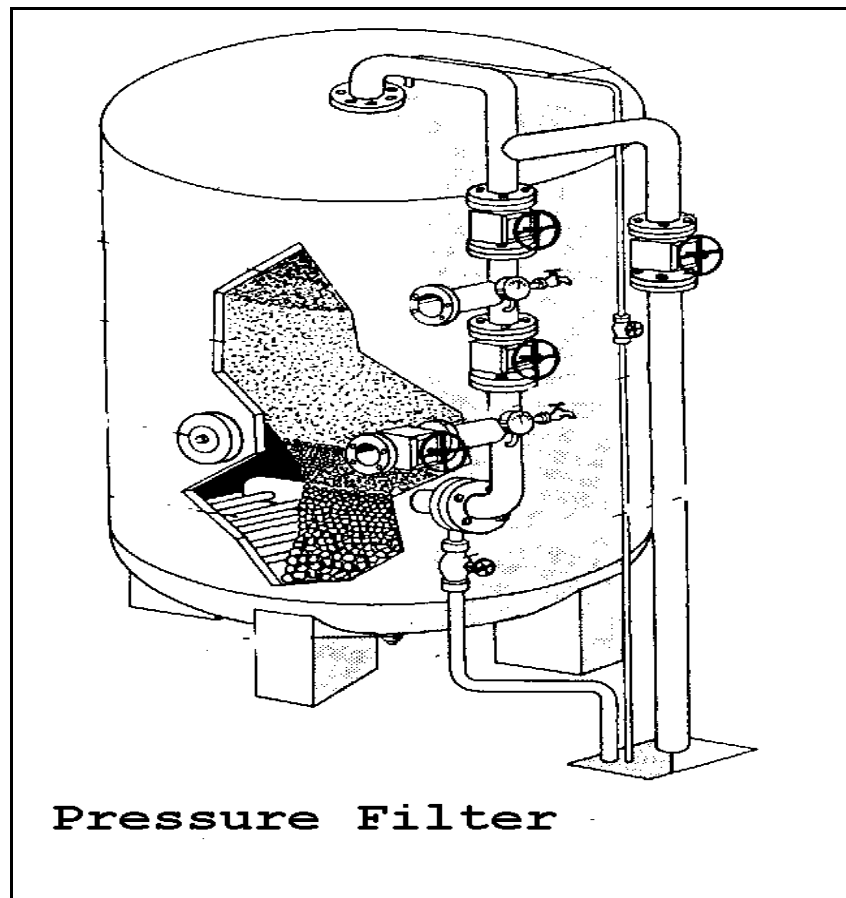
**Up-Flow Clarifier**

## FILTRATION EQUIPMENT

Filtration is can be accomplished using either pressure or gravity filters. Pressure filters are more common in swimming pools and small systems while large systems will probably have one of the three types of gravity filtration. Gravity filters can be slow sand filters, rapid sand filters, or high rate filters. Filtration normally follows sedimentation in surface water treatment. Direct filtration refers to filtration without sedimentation, and is only effective when raw waters have very low turbidity.

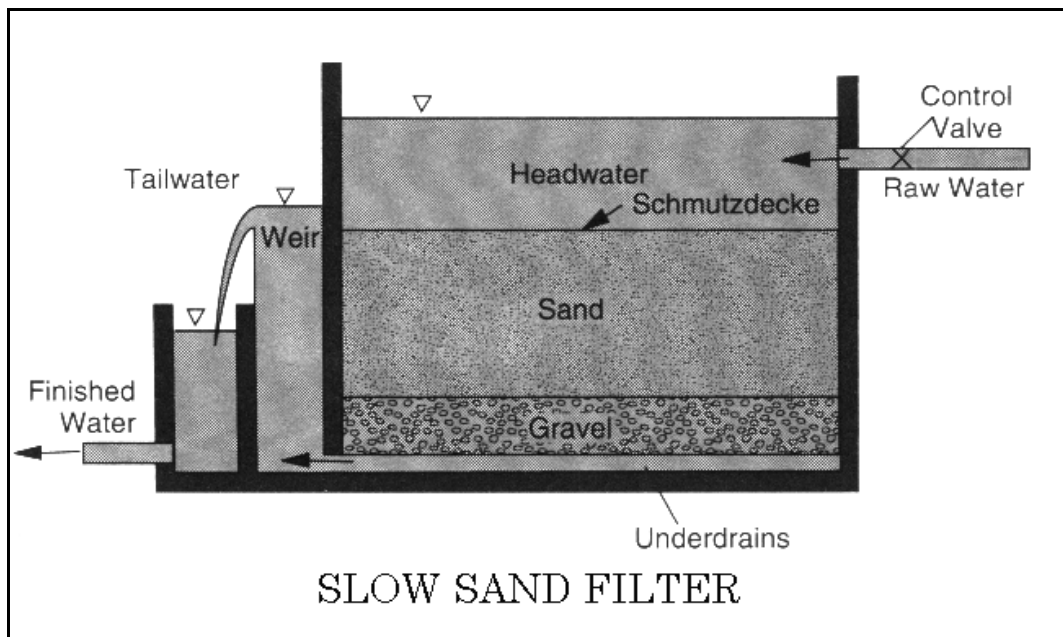
### PRESSURE FILTERS

Pressure filters operate under the same principles as gravity filters except the influent is forced through the filter under pressure. Pressure filters are steel cylinders that use sand or other media to remove particulates. They must be backwashed when the media gets clogged with solids. This is usually accomplished by manually operating the filter valves to reverse the flow through the filter bed. Pressure filters have about the same filter rate as gravity filters with the same type of media. Diatomaceous earth is another type of media that may be used instead of sand in some pressure filters.



## SLOW SAND FILTERS

Slow sand filters were the first type of gravity filter used for water treatment. They consist of a box and underdrain that is filled with about 3.5 ft. of filter sand. Suspended material collects on the surface of the filter bed and forms a layer known as a smutzdecke. When the filter gets clogged it is taken out of service and cleaned by scraping the top inch of sand off of the filter bed. This material must be replaced after several cleanings to restore the original media depth. After a filter is cleaned, it must be filtered to waste for several days before it can be put back in service. Because of this, a system must have two filters to provide continuous service. The filtration rate of a typical slow sand filter is about 0.05-0.15 gpm/sq.ft.

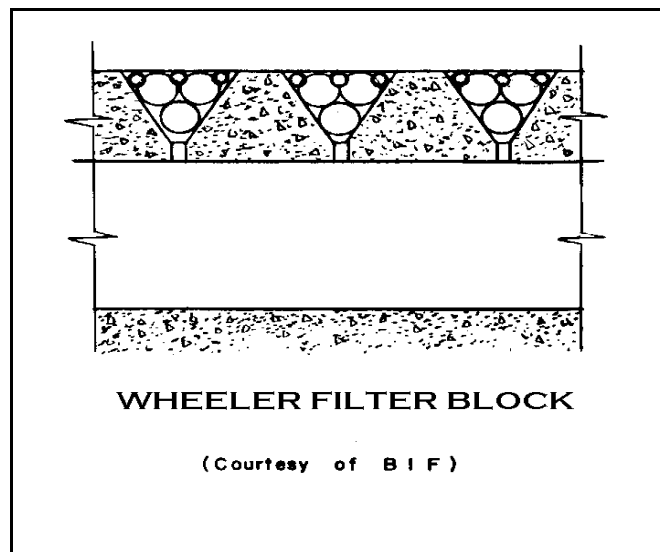
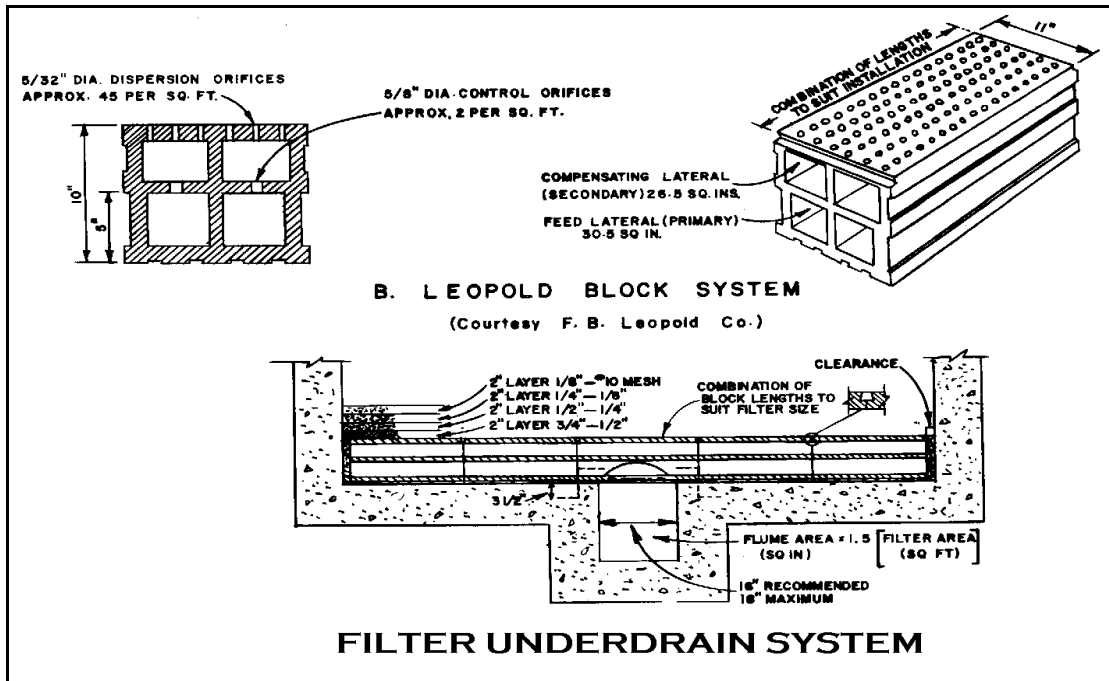


## RAPID SAND FILTERS

Conventional rapid sand and mixed media filters have many design similarities. The basic components of the filters include all of the components described below. The main differences will be in the type of media that is used and the valving configurations.

**Filter boxes** may be constructed as rectangles, squares, round, or as the outer segment of a ring. A filter box is approximately ten feet deep, though its surface dimensions may vary depending on the volume of water to be filtered.

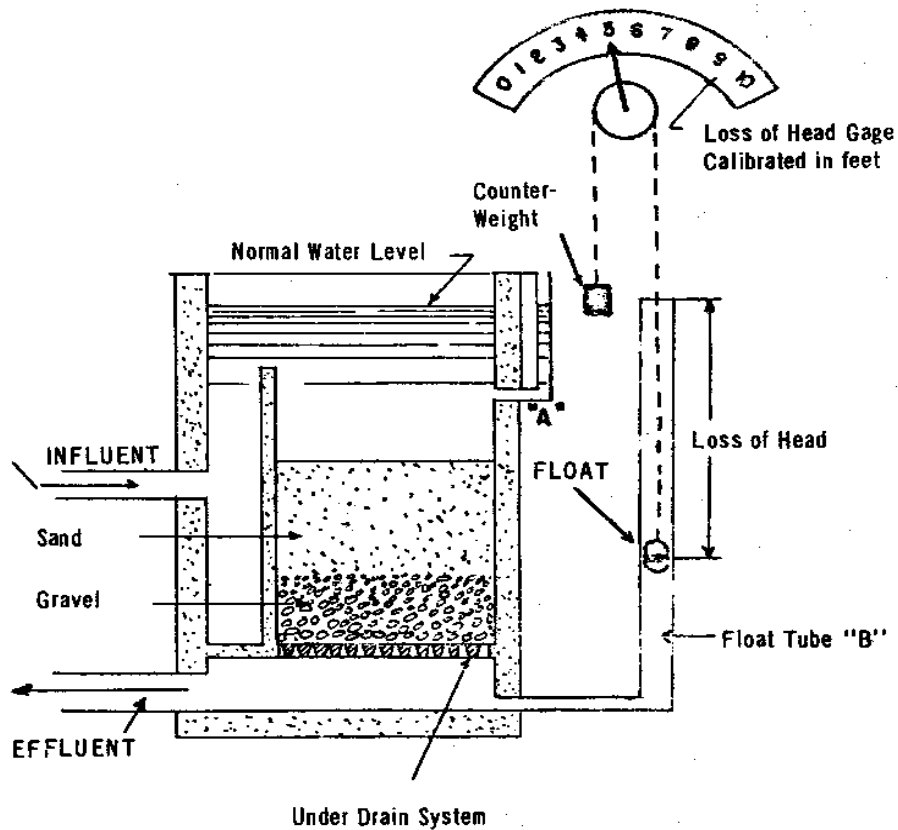
The **underdrain** serves three basic functions. Although it supports the filter media and collects the filtered water, its most important function is to evenly distribute the backwash water throughout the filter. Leopold tile and Wheeler blocks are two popular types of underdrain systems



**Filter media** consists of sand, gravel, and small rocks of varying sizes. Six to eight inches of small rock is placed on top of the filter underdrain. A layer of pea gravel is placed on top of the rocks, usually three to six inches in depth, followed by layer of gravel of increasingly smaller size. This material will support the sand and keep it away from the underdrain. The actual filter media is a layer of medium size sand about 24 inches in depth. This sand should be sized so that the grains are between 0.3 to 0.6 millimeters in diameter. The uniformity coefficient for the sand media should be at least 0.9. This means that 90% of the grains will fall within the 0.3-0.6 mm range.

The **rate of flow controller** maintains a constant flow of water throughout the filter run. As the filter media becomes clogged the rate of flow controller opens a valve on the effluent line that compensates for the head loss through the filter. When the head loss reaches 8 feet, the rate of flow controller is fully open.

**Loss of head gauge** indicates when the filter is in need of backwashing. The loss of head is determined by the difference between the level of water in the filter and the level of a column of water that represents the pressure in the effluent line. This is referred to as the feet of head loss through the sand bed. When the head loss reaches 8 feet the filter should be backwashed.



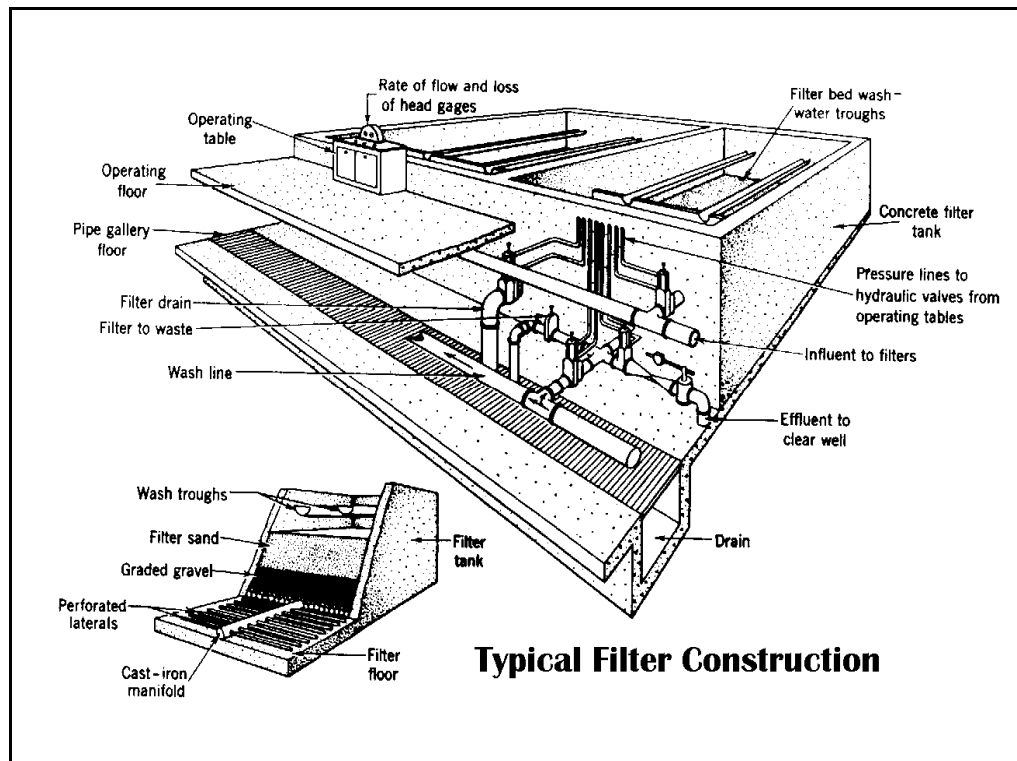
**Loss of Head Gauge**

Five valves are needed to properly operate a filter. The "influent" and "effluent" valves are open during normal operation and closed during backwash. The "backwash valve" provides a means for cleaning the filter and the "waste valve" allows the backwash water to leave the filter. A "filter-to-waste valve" is used to waste the first few minutes of the filter run allow the filter media time to compact. This is important to prevent turbidity or *Giardia* from passing through the filter before the media is compacted. A sixth, the "surface wash valve", is also used when surface washers are installed. Surface washers of some type will usually be found on all new filter installations.

**Backwash troughs** collect the backwash water and transport it out of the filter. These troughs should be no farther than six feet apart and the rim of the trough should be 24-28 inches above the filter media. This is known as the freeboard of the filter. In filters that use anthracite coal in the media, the freeboard should be 32-36 inches to prevent loss of media during backwash.

**Surface washers** are used during the backwash cycle to agitate and break up the top layer of the sand where most of the dirt is trapped. This step helps reduce the amount of backwash water needed for a filter by reducing the time it takes to properly clean the filter.

A **backwash pump** or tower is used to supply the backwash water to the filter. It must be capable of supplying at least 15 gpm/sq. ft. of filter area. Enough backwash water must be available to run the backwash for 7-15 minutes on average.

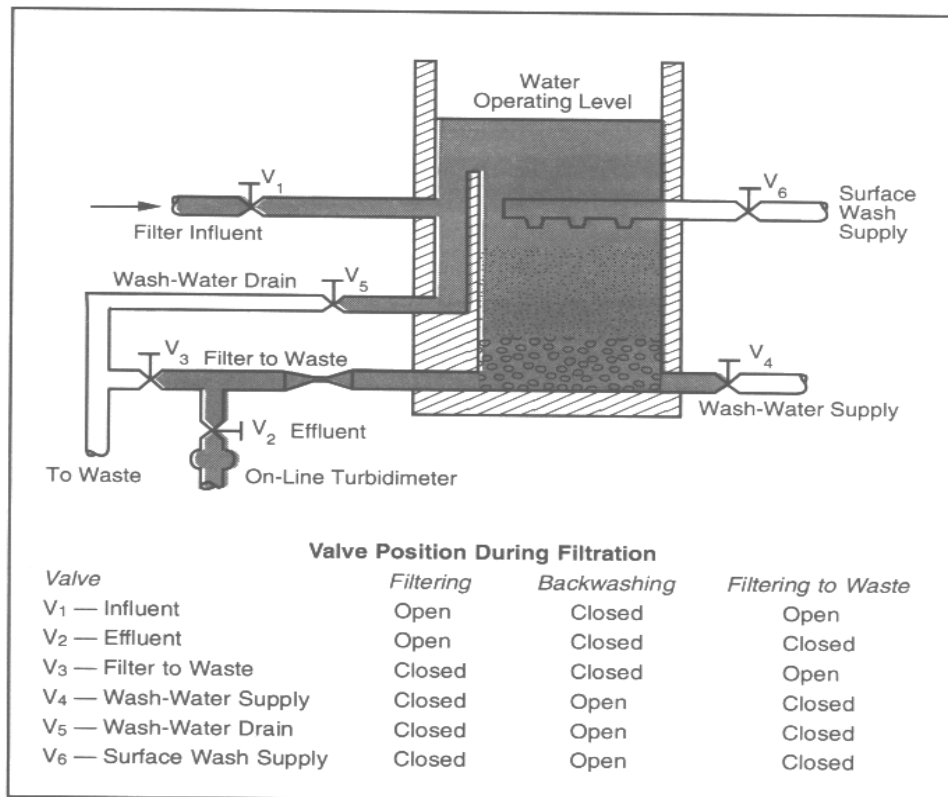


## FILTER OPERATION

Rapid sand filters are designed to filter water at a rate of 2 gpm/sq.ft. of filter area. A clean filter will have a small amount of head loss (2-6"), but as the filter run continues the head loss will steadily build up. When head loss reaches 8 feet the filter should be backwashed. Running a filter at an excessively high head loss may cause the filter to become air bound. Air bound filters will have a high head loss immediately after backwash. This happens because the part of filter that is air bound is not filtering water and the clean part of the bed is filtering at a rate higher than 2 gpm/sq.ft. as a result. Filter runs should not exceed 100 hours without backwashing even if the head loss is less than 8 feet. After 100 hours the media may begin to pull away from the side of the filter and allow water to pass through without being filtered. This results in filter breakthrough and will result in high effluent turbidity. This is the primary cause of sudden increases in effluent turbidity readings. Short filter runs can result from poor chemical treatment and sedimentation. Jar tests should be run to improve the upstream processes to correct this problem.

## BACKWASHING FILTERS

When a filter has been in operation for its optimum number of hours or its head loss reaches 8 feet the filter is taken out of service and backwashed. The proper procedure for backwashing filters is very important. This is a typical procedure for backwashing a sand filter. However, the operator should always follow manufacturer's instructions too avoid possible damage to the underdrain or media bed.



## **FILTER BACKWASHING PROCEDURES**

- 1 - The filter is taken out of service by closing the influent valve and letting the water filter down to about 6 inches from the top of the sand.
- 2 - Open the drain or waste valve.
- 3 - Slowly open the surface wash valve until it is operating at full efficiency.
- 4 - Once the surface wash valve is fully open, begin opening the backwash water valve very slowly until the optimum wash rate has been reached. If the filter is air bound the filter wash water valve should only be opened enough to bleed the air off. The filter should not be backwashed at the normal flow until all the air has been purged. Opening the backwash water valve too fast will "surge" the filters resulting in damage to the underdrain and media. If the backwash water is not evenly distributed, gravel support media may be displaced in the areas of higher flow.
- 5 - After a few minutes close the surface wash valve.
- 6 - When the wash water begins to clear, the backwash water valve should be closed slowly.
- 7 - Close the drain valve
- 8 - Open the influent valve about 10% to 25% so the filter fills slowly.
- 9 - When the water reaches the top of the back wash trough, open the filter to waste valve and allow the filter to run for about 30 minutes to waste.
- 10 - Close the filter to waste valve and open the effluent valve to put the filter back in service.

The backwash rate for sand filter should be 15 gpm/sq.ft. of filter area. This flow rate is needed to expand the sand bed 30-50% in order to separate the sand grains so that they can be thoroughly cleaned. Always continue to backwash until the wash water is clean. Failure to do so can result in the formation of mudballs. Once mudballs form, the only way they can be removed is by removing and replacing the filter media. If a backwash flow meter is not provided, a simple hook gauge can be used to determine the backwash rate.

A hook gauge is made using a length of board with nails or hooks driving into it that are 6 inches apart. The gauge is then placed on the side of the filter with the bottom hook just above the top of the backwash trough. While backwashing the filter, the waste valve is closed. The amount of time it takes for the surface of the water to rise from the point of one hook to the point of the other hook is measured.

The waste valve must be opened immediately after the test to prevent the filter from overflowing. A backwash water rate of 15 gpm/ft<sup>2</sup> will result in the water level over the sand rising 6 inches in 15 second or 24 inches in one minute, since 2 cubic feet of water is about 15 gallons.

## **TROUBLESHOOTING FILTER PROBLEMS**

There are three basic operational problems associated with filter operations. Although they have been mentioned before, here is a list of the problems and causes:

**Filter breakthrough** - Identified by a sudden increase in effluent turbidity. Running the filter at too high a filtration rate or too long a run time causes it. This causes cracking and media separation from the filter wall.

**Air binding** - Identified by abnormally high headloss on recently backwashed filters. Caused by running a filter at too high a head loss. This creates low pressures in the filter that may result in the release of dissolved gases that become trapped in the filter bed or underdrain.

**Mudballs** - Identified by shortened filter runs and loss of filter capacity. They are created when the filter is not properly backwashed. The flow rate may have been too low or it was not backwashed long enough.

## **CLEANING FILTER BEDS**

Sometimes filter media becomes coated with scale from the chemical treatment processes. Algae can also buildup in outdoor filters that are exposed to sunlight. If this becomes severe the filter may have to be taken out of service so that the media can be chemically cleaned. Sodium hydroxide is used to dissolve alum deposits. Hydrochloric acid is used to dissolve lime deposits. Chlorine or oxidizing agents are used to kill algae growth.

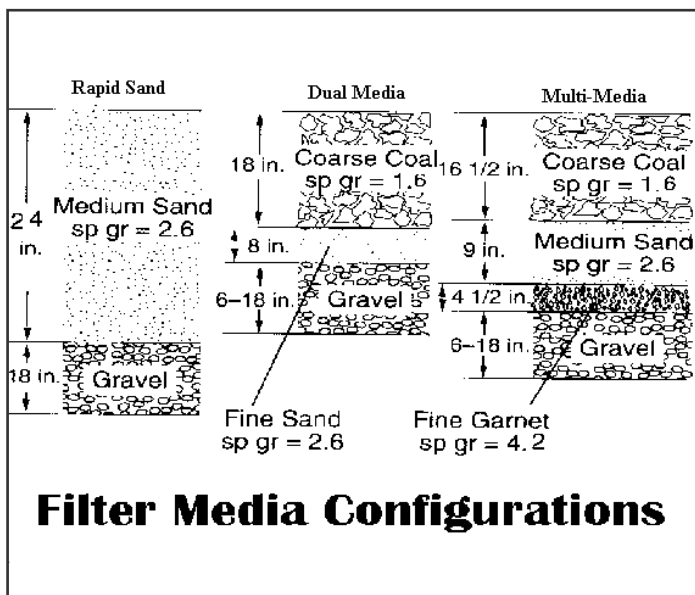
## **HIGH RATE FILTERS**

Recent designs have included the use of different types of filter media other than sand in an effort to increase filtration rates and lengthen filter runs. Using two or more types of media with different particle sizes allows filterable solids to penetrate deeper into the filter bed. This allows the filter to be operated at higher flows. These filters are referred to as high rate filters

The most common type of media used in high rate filters, other than silica sand, is anthrafilt. Anthrafilt is anthracite coal screenings that are larger than filter sand. Particle size will be about 0.60 to 0.70 mm as compared to silica sand media of 0.40 to 0.60 mm. Some

advantages of using anthracite media are higher filtration rates, longer filter runs, and less coating of the grains with lime and other materials. It is important that the backwash velocity be carefully controlled to prevent the anthracite from being carried over into the wash troughs and out of the filter box. Anthracite filters require at least 32 inches of free board on the backwash troughs because of its lighter weight.

Dual-media filters use a filter bed of both anthracite coal and silica sand. There is usually 12-18 inches of coal on top of 8-12 inches of sand. The upper layer of the lighter and coarser anthracite has voids about 20% larger than the sand, resulting in a larger to smaller grading of the media in the direction of flow. Dual media filters have a filter rate of 3-5 gpm/sq.ft. After backwashing, the filter media separates with the heavier sand falling to the bottom and the lighter coal on top. The larger floc particles are trapped in the surface of the coal layer while the finer particles are held in the sand. This creates deeper particle penetration into the filter bed and allows higher filtration rates.



Multi-media filter beds using coal, silica sand, and garnet sand provide the highest filtration rate of any gravity filter. Filter rates for multi-media filters are from 5-8 gpm/sq.ft. Garnet sand, has a specific gravity of about 4.2, which is greater than coal (1.6 S.G.) or silica sand (2.6 S.G.). A multi-media filter bed will consist of 4-6 inches of garnet sand on the bottom, 8-10 inches of silica sand in the middle, and 12-18 inches anthracite coal on top.

Because of the difference in specific gravities, separation of the different media occurs after backwashing with little intermixing. A typical mixed media filter has particle sizing gradually decreasing from about 0.7 mm at the top to 0.2 mm at the bottom. In addition to gravity filters, mixed media filters are also being used in pressure filters.

## ACTIVATED CARBON MEDIA

Some filter systems are now using granulated activated carbon instead of anthracite coal in multi-media filters. The GAC is used to adsorb TOC compounds prior to disinfection. This measure will reduce the formation of THM's. The activated carbon, over time, will become saturated and will no longer remove organic compounds. The spent media must be regenerated or, more commonly, replaced. Spent activated carbon can be regenerated in a furnace. One of the important control parameters is empty bed contact time (EBCT). It is the amount of time the water is in contact with the media. The minimum EBCT is 5 minutes.

## **TASTES AND ODORS**

### **BASIC STUDY QUESTIONS**

1. Which organisms are responsible for organic tastes and odors?
2. Which chemicals create inorganic tastes and odors?
3. Which chemical is responsible for rotten egg odors?
4. What causes color in surface water supplies?
5. What is GAC?

### **ADVANCED STUDY QUESTIONS**

1. What is the best way to remove organic tastes and odors?
2. What types of tastes and odors can be removed by aeration?
3. Which kinds of algae cause most of the organic tastes and odors?
4. Which chemical can be used to kill algae in a lake?
5. Where should activated carbon be added in a surface water treatment plant?

## **COAGULATION AND FLOCCULATION**

### **BASIC STUDY QUESTIONS**

1. What is a coagulant chemical used for?
2. What is hydraulic shear in a flocculator?
3. How do colder temperatures affect coagulation and flocculation?
4. Where does rapid mixing occur in a surface water treatment plant?

### **ADVANCED STUDY QUESTIONS**

1. Which two chemicals are commonly used to remove turbidity?
2. List three substances that would be considered to be coagulant aids.
3. Which insoluble form of aluminum precipitates as a floc particle?
4. What is the detention time for a rapid mixer?
5. What type of polymer will attract negatively charged turbidity particles?
6. What is the pH range for alum precipitation?
7. What happens to the pH when iron and aluminum salts are added to the water?
8. What is the pH range for precipitation of color?

## **IRON AND MANGANESE**

### **BASIC STUDY QUESTIONS**

1. What color is associated with manganese problems?
2. Red Water problems occur when iron concentrations exceed \_\_\_mg/l.
3. What other treatment process is required if iron is removed by aeration?

### **ADVANCED STUDY QUESTIONS**

1. What is a sequestering agent?
2. What is the common name of the chemical used to sequester iron?

## **SEDIMENTATION**

### **BASIC STUDY QUESTIONS**

1. Why are baffles important in a sedimentation basin?
2. What is the notched plate used to remove water from the basin called?
3. What is the detention time for a sedimentation basin?
4. What can happen when sludge is not removed often enough?

### **ADVANCED STUDY QUESTIONS**

1. Why is the weir overflow rate important?
2. What type of device protects the sludge removal equipment in a sedimentation basin?

3. An upflow clarifier will contain which of the conventional treatment processes?
4. Pin floc leaving a sedimentation basin may indicate a problem with which part of the process?

## **FILTRATION**

### **BASIC STUDY QUESTIONS**

1. What are the three kinds of gravity filters?
2. What is the primary function of the filter underdrain?
3. What does loss of head mean in a filter?
4. What is freeboard in a filter?

### **ADVANCED STUDY QUESTIONS**

1. What does the uniformity coefficient mean regarding filter media sand?
2. What is the backwash rate for a rapid sand filter?
3. What is the maximum run time for a gravity filter?
4. During backwash, how much should the filter bed expand?
5. If the backwash time is too short, what problems may result?
6. If the filtration rate is too high, what kind of problems may result?

### BASIC SAMPLE TEST QUESTIONS

1. Which two chemicals are used for turbidity removal?
  - A. Alum and Lime
  - B. Iron and Manganese
  - C. Soda Ash and Caustic soda
  - D. Chlorine and ozone
2. Hardness compounds become insoluble at a high pH.
  - A. True
  - B. False
3. Which of the following is considered to be a coagulant aid for turbidity removal?
  - A. Lime
  - B. Polymer
  - C. Bentonite clay
  - D. All of the above
4. Alum works best when the pH is.
  - A. 3.5-5.5
  - B. 6.5-7.0
  - C. 8.0-8.3
  - D. 9.0-10.5
5. Powdered activated carbon is not:
  - A. Expensive
  - B. Difficult to handle
  - C. Used for turbidity removal
  - D. Potentially explosive
6. All kinds of tastes and odors can be removed using:
  - A. Activated Carbon
  - B. Oxidizing Chemicals
  - C. Aeration
  - D. Polyphosphates

### ADVANCED SAMPLE TEST QUESTIONS

1. Which two chemicals are used for non-carbonate softening?
  - A. Alum and Lime
  - B. Iron and Manganese
  - C. Soda Ash and Caustic soda
  - D. Chlorine and Ozone
2. Carbonate hardness compounds become insoluble at what pH.
  - A. 3.5-5.5
  - B. 6.5-8.5
  - C. 9.0-10.5
  - D. 10.0-11.5
3. Which of the following is a coagulant aid for turbidity removal?
  - A. Lime
  - B. Polymer
  - C. Bentonite clay
  - D. All of the above
4. Color can be removed by lowering the pH to:
  - A. 3.5-5.5
  - B. 6.5-7.0
  - C. 8.0-8.3
  - D. 9.0-10.5
5. Chemical precipitation of arsenic is accomplished using:
  - A. Lime
  - B. Ferric chloride
  - C. Sulfuric acid
  - D. All of the above

6. Alum can be used to precipitate organic compounds at a pH of:
  - A. 3.0
  - B. 4.5
  - C. 6.0
  - D. 9.
  
7. Daily fluctuations in the pH in a reservoir could mean:
  - A. Taste and odor problems coming
  - B. The pH meter is broken
  - C. The hardness is also changing
  - D. The lake may turnover
  
8. Recarbonation is used to prevent:
  - A. Tastes and odors
  - B. Corrosion
  - C. Scaling in the distribution system
  - D. Turnover in the lake
  
9. The detention time in a coagulation basin should be:
  - A. 1-3 minutes
  - B. 20-30 minutes
  - C. 60-90 minutes
  
10. Sludge that rises to the surface of a sedimentation basin is caused by:
  - A. Not removing sludge often enough
  - B. Removing sludge too often
  - C. pH is too low
  - D. Surface loading rate is too low
  
11. What should the detention be in a sedimentation basin?
  - A. 1-3 minutes
  - B. 2-3 hours
  - C. 4-6 hours
  - D. 8-10 hours
  
12. Always add the coagulant aids first in a coagulation basin.
  - A. True
  - B. False
  
13. The filter backwash rate should be:
  - A. 2 gpm/ft<sup>2</sup>
  - B. 3-5 gpm/ft<sup>2</sup>
  - C. 5-8 gpm/ft<sup>2</sup>
  - D. 15 gpm/ft<sup>2</sup>
  
14. The Langlier Index is used for:
  - A. Turbidity
  - B. Corrosion control
  - C. TOC removal
  - D. Determining zeta potential
  
15. Air binding in a filter is caused by:
  - A. Filtering too long
  - B. Filtering too slow
  - C. Filtering with too much head loss
  - D. Changes in specific gravity

