# CE 370

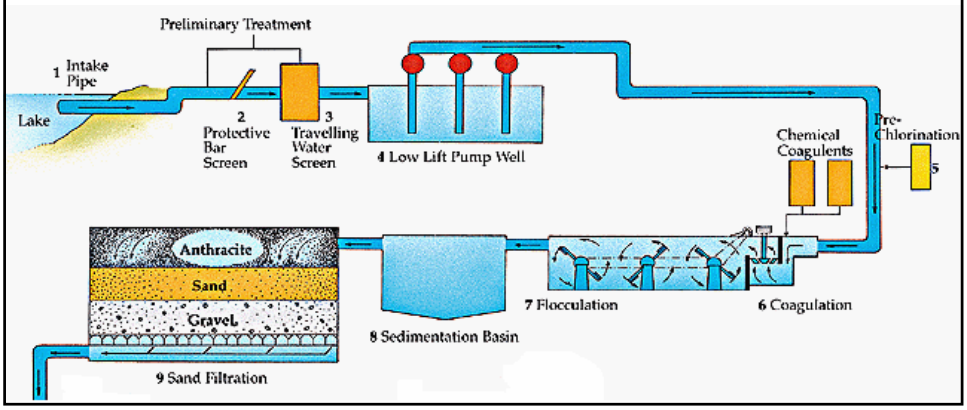
# Coagulation and Flocculation

Part 1

## Overview of the Process

### ➢Location in the Treatment Plant

- After the source water has been screened and has passed through the optional steps of pre-chlorination and aeration, it is ready for coagulation and flocculation.



## Overview of the Process

### ➢ Purpose

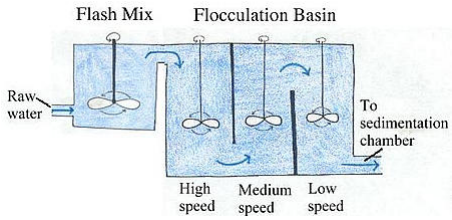
- The primary purpose of the coagulation/flocculation process is the removal of turbidity from the water.
- **Turbidity** is a cloudy appearance of water caused by small particles suspended therein. Water with little or no turbidity will be clear.
- Water with a high turbidity can be very difficult to properly disinfect. As a result, the maximum allowable level of turbidity in water is 0.5 NTU, while the recommended level is about 0.1 NTU.
- In addition to removing turbidity from the water, coagulation and flocculation removes many bacteria which are suspended in the water and can be used to remove color from the water.

No Turbidity 80 NTU

## Overview of the Process

### ➢Process Steps

- In theory and at the chemical level, coagulation and flocculation is a three step process, consisting of flash mixing, coagulation, and flocculation. However, in practice in the treatment plant, there are only two steps in the coagulation/flocculation process - the water first flows into the flash mix chamber, and then enters the flocculation basin.




## Overview of the Process

### ➢Process Steps

- In the **flash mixer**, coagulant chemicals are added to the water and the water is mixed quickly and violently. The purpose of this step is to evenly distribute the chemicals through the water. Flash mixing typically lasts a minute or less.
- After flash mixing, coagulation occurs. During **coagulation**, the coagulant chemicals neutralize the electrical charges of the fine particles in the water, allowing the particles to come closer together and form large clumps.
- The final step is **flocculation**. During flocculation, a process of gentle mixing brings the fine particles formed by coagulation into contact with each other. Flocculation typically lasts for about thirty to forty-five minutes.

## Overview of the Process

- **Floc**
  - The end product of a well-regulated coagulation/flocculation process is water in which the majority of the turbidity has been collected into
  - Consists of clumps of bacteria and particulate impurities that have come together and formed a cluster.
  - The floc will then settle out in the sedimentation basin, with remaining floc being removed in the filter.
  - The best floc size is 0.1 to 3 mm. Larger floc does not settle as well and is more subject to breakup in the flocculation basin. Smaller floc also may not settle.

## Overview of the Process

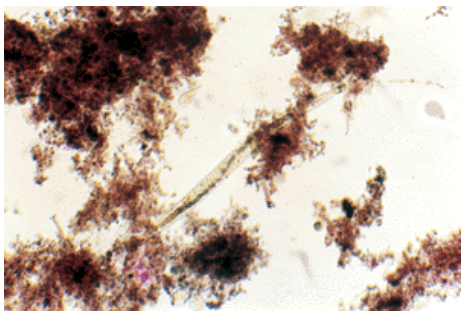


**Image of floc under microscope**

## Theory and Chemistry of the process

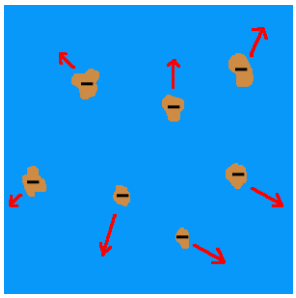
### ➢Particles in Water

- There are three types of substances which can be found in water. These substances are chemicals in solution, colloidal solids, and suspended solids. Coagulation/flocculation will remove colloidal and suspended solids.
- **Chemicals in solution:** are completely dissolved in the water. An example of a chemical in solution is sugar in water.
- **Colloidal solids:**
  - Do not dissolve in water although they are electrically charged.
  - The particles are so small that they will not settle out of the water.
  - Colloidal solids range between 1 millimicron ($10^{-6}$ mm) and 1 micron ($10^{-3}$ mm) in size and can be seen only with a high-powered microscope.
  - Examples include bacteria, fine clays, and silts.
- **Suspended solids:** will settle out of water over time, though this may be so slow that it is impractical to merely allow the particles to settle out in a water treatment plant.

## Theory and Chemistry of the process

### ➢Electrical Charges

- The chemistry of coagulation and flocculation is primarily based on the electrical properties of the particles. Like charges repel each other while opposite charges attract.
- Most particles present in water have a negative charge, so they tend to repel each other. As a result, they stay dispersed in the water.



## Theory and Chemistry of the process

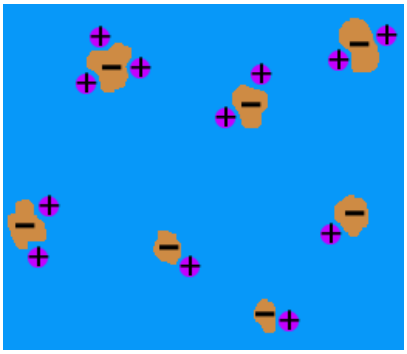
### ➢Electrical Charges

- The purpose of most coagulant chemicals is to neutralize the negative charges on the colloidal particles to prevent those particles from repelling each other.
- The amount of coagulant which should be added to the water will depend on the **zeta potential**, a measurement of the magnitude of electrical charge surrounding the colloidal particles. You can think of the zeta potential as the amount of repulsive force which keeps the particles in the suspension. If the zeta potential is large, then more coagulants will be needed.

## Theory and Chemistry of the process

### ➢Electrical Charges

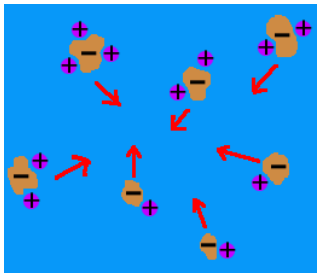
- Coagulants tend to be positively charged. Due to their positive charge, they are attracted to the negative particles in the water, as shown below.



## Theory and Chemistry of the process

### ➢Electrical Charges

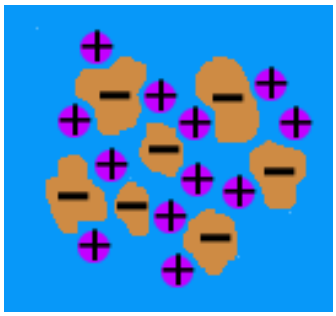
- The combination of positive and negative charge results in a **neutral**, or lack, of charge. As a result, the particles no longer repel each other.
- The next force which will affect the particles is known as van der Waal's forces. **Van der Waal's forces** refer to the tendency of particles in nature to attract each other if they come close enough.



## Theory and Chemistry of the process

### ➢Electrical Charges

- Once the particles in water are not repelling each other and due to their motion in water, they will come close to each other (collide) so that van der Waal's forces of attraction can make the particles stick to each other. When enough particles have joined together, they become floc and will settle out of the water.



## Coagulant Chemicals

### Types of Coagulants

- **Primary coagulants:** neutralize the electrical charges of particles in the water which causes the particles to clump together.
- **Coagulant aids** add density to slow-settling flocs and add toughness to the flocs so that they will not break up during the mixing and settling processes.
- Primary coagulants are always used in the coagulation/flocculation process. Coagulant aids, in contrast, are not always required and are generally used to reduce flocculation time.
- Chemically, coagulant chemicals are either metallic salts (such as alum) or polymers. **Polymers** are man-made organic compounds made up of a long chain of smaller molecules. Polymers can be either **cationic** (positively charged), **anionic** (negatively charged), or **nonionic** (neutrally charged.)

## Coagulant Chemicals

### Common coagulants

- Mainly aluminum and iron salts
  - Aluminum sulfate
  - Ferrous sulfate
  - Ferric sulfate
  - Ferric chloride
  - Lime [Ca(OH)2]
- Aluminum salts are cheaper but iron salts are more effective over wider pH range

## Coagulant Chemicals

### ➢ Coagulant Aids

- In many cases, coagulant aids are not required during the normal operation of the treatment plant, but are used sometimes to aid in producing a dense and rapid settling floc.
- **Lime** is a coagulant aid used to increase the alkalinity in waters where natural alkalinity is insufficient to produce a good floc.
- **Bentonite** is a type of clay used as a weighting agent in water which would not form floc large enough to settle out of the water. The bentonite joins with the small floc, making the floc heavier and thus making it settle more quickly.

## Coagulant Chemicals

### ➢ Jar Test

- Is a laboratory technique used to determine:
  - Proper coagulant
  - Proper coagulant aid
  - Proper coagulant dose

## Theory and Chemistry of the process

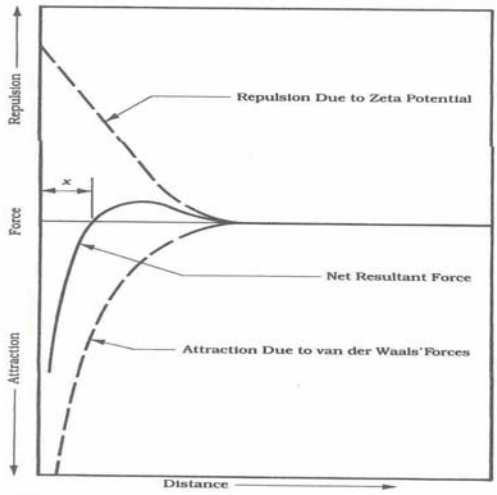



FIGURE 8.4 *Colloidal Interparticulate Forces versus Distance*