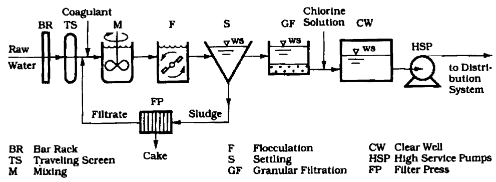
Treatment Processes



Screening → Aeration → Prechlorination → Coagulation → Flocculation → Sedimentation

1

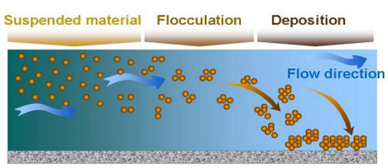
Coagulation and Flocculation

- ***Coagulation and flocculation*** consist of adding a floc-forming chemical reagent to a water to enmesh or combine with nonsettleable colloidal solids and slow-settling suspended solids to produce a rapid-settling floc.
- The floc is subsequently removed in most cases by ***sedimentation***.
- ***Flocculation*** is the slow stirring or gentle agitation to aggregate the destabilized particles and form a rapid-settling floc.

2

Coagulation

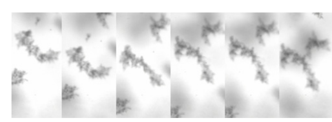
- Large particles can easily be removed by settling. Their mass allows them to settle to the bottom of a tank and then be removed as sludge.
- However, colloidal particles in water have insufficient mass to overcome the fluid forces on their surfaces.



3

Coagulation

- Most naturally occurring particles in water are negatively charged. Since like charges repel, these small particles, or colloids, will remain suspended almost indefinitely.
- Chemicals reduce colloidal surface charge and form precipitates that enhance the clustering process and sedimentation.



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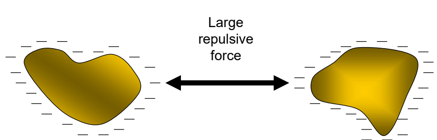
Coagulation

There are two major forces acting on colloids:

1) electrostatic repulsion

(simply, negative colloids repel other negatively charged colloids)



2) intermolecular, or van der Waals, attraction.

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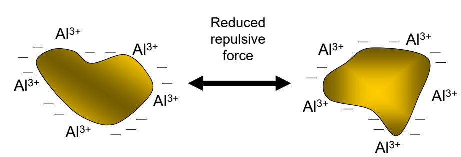
Coagulation

- Coagulants can be used to reduce the electrostatic repulsive forces
- The electrostatic repulsion reduced by the addition of countercharged ions [Al^{3+}]



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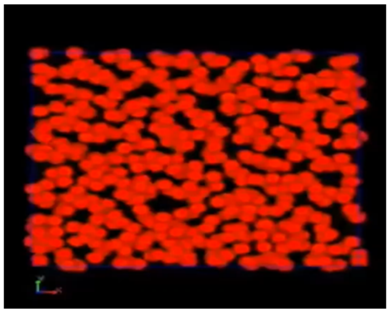
Coagulation



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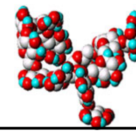
Coagulation

- Gentle mixing or ***flocculation***, then causes the destabilized (reduced charge) colloids to cluster.
- Another method of enhancing agglomeration is to add organic polymers.
- These compounds consist of a long carbon chain with active groups such as amine, nitrogen, or sulfate groups along the chain.



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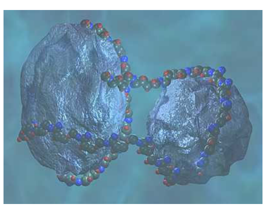
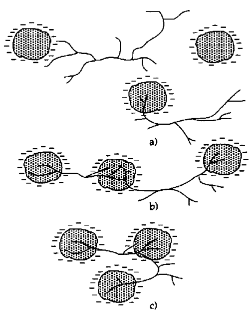
Coagulation

- The chain is long enough to allow active groups to bond to multiple colloids





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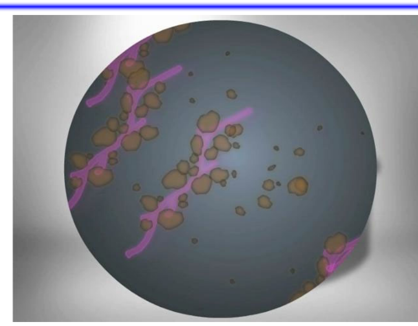
Coagulation



http://www.youtube.com/watch?v=nk0iDt7sdtk

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Coagulation

- Colloids have an extremely large surface area per unit volume of the particles.
- Because of the large surface area, colloids tend to adsorb substances, such as water molecules and ions, from the surrounding water.
- The surface of a colloidal particle tends to acquire an electrostatic charge due to the ionization of surface groups and the adsorption of ions from the surrounding solution.

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Coagulation

- In most colloidal systems, the colloids are maintained in suspension (in other words, stabilized) because of the electrostatic forces of the colloids themselves.
- A colloidal suspension is stable if the particles remain in suspension and do not coagulate.
- The colloidal stability depends on the relative magnitude of the forces of attraction and the forces of repulsion.

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Zeta Potential Model

- The magnitude of these forces is measured by the zeta potential, which is:

$$Z = \frac{4\pi q d}{D}$$

where: ***Z*** is the zeta potential,
q is the charge per unit area,
d is the thickness of the effective charge layer, and
D is the dielectric constant of the liquid.

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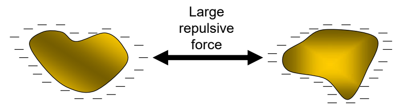
Zeta Potential Model

- The greater the zeta potential, the greater are the repulsion forces between the colloids and, therefore, the more stable is the colloidal suspension.

$$Z = \frac{4\pi q d}{D}$$



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Coagulation

- When a coagulant is added to a water or wastewater, destabilization of the colloids occurs, and a coagulant floc is formed.
- The interactions are:
  - the reduction of the zeta potential to a degree where the attractive van der Waals forces and the agitation provided cause the particles to coalesce;
  - the aggregation of particles by interparticulate bridging between reactive groups on the colloids;
  - the enmeshment of particles in the precipitate floc that is formed.

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Coagulation

- The most widely used coagulants in water treatment are aluminum sulfate and iron salts.
- The principal factors affecting the coagulation and flocculation of water or wastewater are:

  turbidity, suspended solids, temperature, pH, cationic and anionic composition and concentration, duration and degree of agitation during coagulation and flocculation, dosage and nature of the coagulant, and, if required, the coagulant aid.

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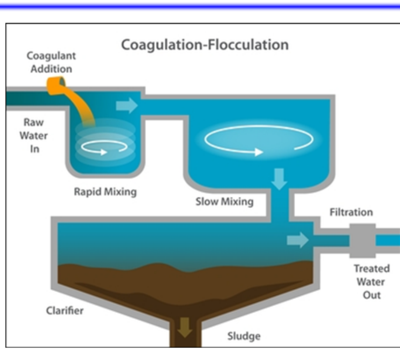
Coagulation



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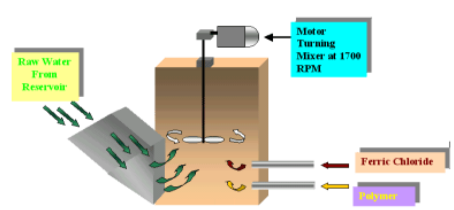
Rapid Mixing

- Prior to entering a flocculation tank, the water flows through a rapid mixing basin. Chemicals are injected just before the first mixing impeller and baffles throughout the basin to minimize short-circuiting.



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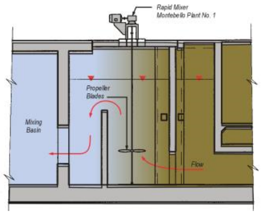

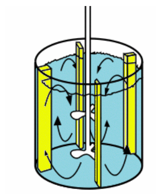

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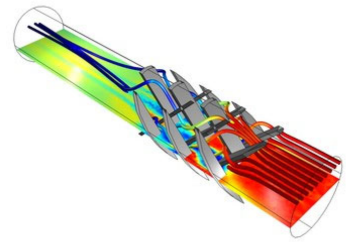
Rapid Mixing

- The rapid-mixing characteristics of a flocculation basin are investigated using high-performance computational models



20

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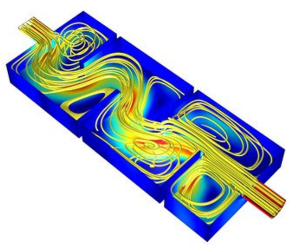

21

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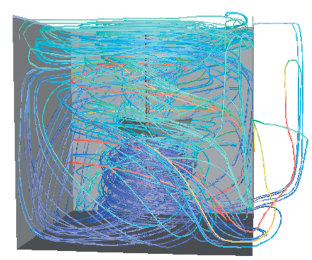

22

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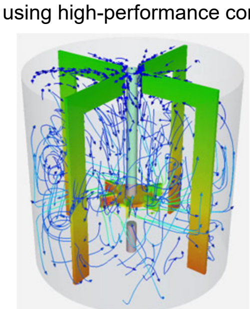

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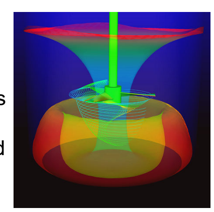
Flocculation

- Flocculation is gentle mixing to speed the agglomeration of colloidal materials.
- The water enters a small tank or section of a tank in which paddles are turning slowly. Their movement causes the small particles to collide and stick together (fast or vigorous mixing would separate combined particles).



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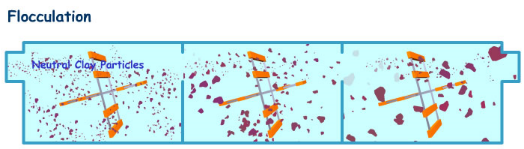
Flocculation

- The gentle mixing combined with the reduction in repulsive surface charges allow the particles to join rapidly.
- The settling velocity of a particle is proportional to the square of the diameter.



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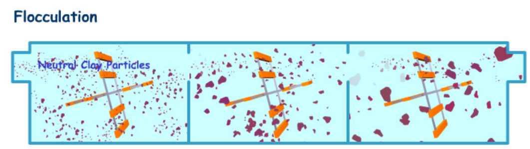
Flocculation

- Doubling the particle diameter increases its settling velocity by a factor of 4.
- The water then flows into the sedimentation basin where the solids settle to the bottom and are removed.



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Flocculation

- In ***rapid-mixing***, intense mixing or agitation is required to disperse the chemicals uniformly.
- In the ***flocculation***, the fine microfloc begins to agglomerate into larger floc particles.
- The types of devices usually used to furnish the agitation required in both rapid mixing and flocculation may be generally classified as: (1) mechanical agitators, such as paddles; (2) pneumatic agitators; and (3) baffle basins.

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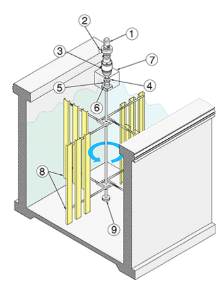
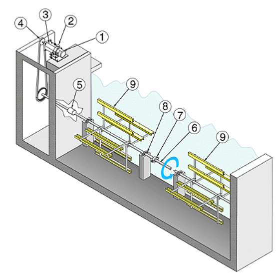
Flocculation

Graphic courtesy of Jim Myers & Sons, Charlotte, NC



Vertical Paddle Wheel



Horizontal Paddle Wheel

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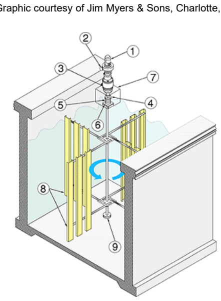
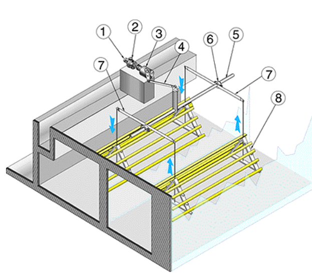
Flocculation

Graphic courtesy of Jim Myers & Sons, Charlotte, NC



Vertical Paddle Wheel



Walking Beam

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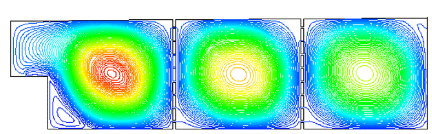
Flocculation

- To improve the efficiency of a flocculator, good mixing is required at the start and must be followed by a long residence time to allow the most settling to occur.



- The mixing characteristics of a flocculation basin are investigated using high-performance computational models

30

Flocculation

- The degree of mixing is based on the power imparted to the water, which is measured by the ***velocity gradient***.

Change in Velocity/Distance

- For example, the velocity gradient of two fluid particles which are 0.05 ft. (0.01524 m) apart and have a velocity relative to each other of 2.0 fps (feet per second) (0.6096 m/s) is:

$$\frac{2\,\text{fps}}{0.05\,\text{ft.}} = 40\,{}^{\text{fps}}\!/\!_{\text{ft}}$$

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Flocculation

- The power requirements, P, to maintain a velocity gradient, G, in a tank is:

$$P = G^2 \mu V$$

where μ is the dynamic viscosity and V is the volume of the tank.

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Flocculation

- Compute the power requirements for a 100-gallon tank mixing water at a velocity gradient of 40 fps/ft:

$$P = \left(40\frac{\text{ft.}}{\text{s ft.}}\right)^2 \left(2\times10^{-5}\frac{\text{lb. s}}{\text{ft.}^2}\right)(100\,gallons)\left(\frac{\text{ft.}^3}{7.48\,gallon}\right)$$

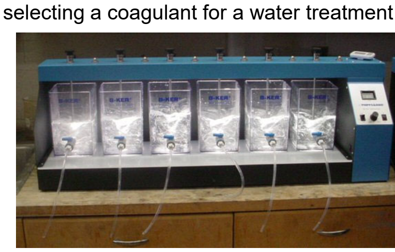
$$P = 0.427\ {}^{lbf}\!/\!_{s}$$

$$P = \left(0.427\ {}^{lbf}\!/\!_{s}\right)\left(\frac{1.355818\,watts}{{}^{lbf}\!/\!_{s}}\right) = 0.58\ \text{watts}$$

33

Jar Test

- The selection of a coagulant requires the use of laboratory or pilot plant coagulation studies
- Usually, laboratory studies using the ***jar test*** are adequate for selecting a coagulant for a water treatment plant



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Jar Test

A ***jar test*** is usually used to determine the proper coagulant and coagulant aid, if needed, and the chemical dosages required for the coagulation of a particular water.

- Samples of the water are poured into a series of containers
- Various dosages of the coagulant and coagulant aid are added
- The contents are rapidly stirred to simulate rapid mixing
- Then the contents are gently stirred to simulate flocculation
- After a given time, the stirring is ceased and the floc formed is allowed to settle.

35

Jar Test

A ***jar test*** is usually used to determine the proper coagulant and coagulant aid, if needed, and the chemical dosages required for the coagulation of a particular water.

- The most important aspects to note are:
  - the time for floc formation,
  - the floc size,
  - its settling characteristics,
  - the percent turbidity and color removed, and
  - the final pH of the coagulated and settled water.
  - The chemical dosage determined from the procedure gives an estimate of the dosage required for the treatment plant.

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Treatment Processes

Any Questions?