A primer on coagulation and flocculation

From drinking water to wastewater, these processes help reduce turbidity.

By Mario C. Uy

All natural water contains suspended particles that can be detrimental to the water's intended use and application. Problems can range from poor product quality, to high maintenance and operating costs, to premature equipment failure.

As the water is further processed, such as in heating, cooling, cleaning, it picks up more particles along the way, which eventually become pollutants in wastewater discharge.

To minimize these problems, the suspended particles are typically removed or reduced to an acceptable level prior to use and discharge.

Large particles can be easily removed mechanically by filtration or settling. Finer particles, also known as colloidal particles, are harder to filter or settle out.

Colloidal particles and turbidity

Colloidal particles are very fine in size, ranging from 0.1 to 1 micron. This is larger than a molecule but smaller than a grain of sand; small enough to be invisible to the naked eye.

Colloidal particles impart turbidity. The higher the particle count, the more turbid the water gets.

Slight turbidity may not be noticed until a beam of light is passed through the colloids. The particles will cause the light to scatter so that the path of the light beam can be clearly seen.

Colloidal particles are electrically charged. All of the particles of a given colloid take on the same charge (positive or negative) and, thus, are repelled by one another.

Generally, above 4.0 pH, colloidal particles are negatively charged and below 4.0 they are positively charged. This "like" charge forms an energy barrier, causing the particles to repel each other so they remain dispersed indefinitely.

Furthermore, the repulsion causes the particles to stay in constant motion as they are perpetually repelling each other.

The colloidal particles in some wastewater are even more complex if the wastewater contains particles that were chemically dispersed, such as in the production of slurries. Suffice to say that the colloidal particles are too fine and have such a long dispersion life that they cannot be removed from the water efficiently.

To overcome this, coagulation and flocculation techniques are applied to help the particles agglomerate. The particles

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For more information:

For more information on this topic, go to **www.watertechonline.com** and enter keywords: **Flocculation** or **Coagulation.**

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Application considerations

Coagulation and flocculation can be used in applications ranging from drinking water to wastewater where water clarification is required.

The obvious choice of these materials will depend on the applications. Polymers are classified in terms of:

- Type (anionic, cationic, or non-ionic);
- Molecular weight;
- Charge density; and
- Potability.

The best way to determine which coagulant, flocculant, dosage, and pH to use is to do jar testing to determine the combinations, variables, and/or sequence of additions that will engender the optimum results.

Once the particles are agglomerated sufficiently, they can be easily removed mechanically, via clarification, filtration or dissolved air flotation.

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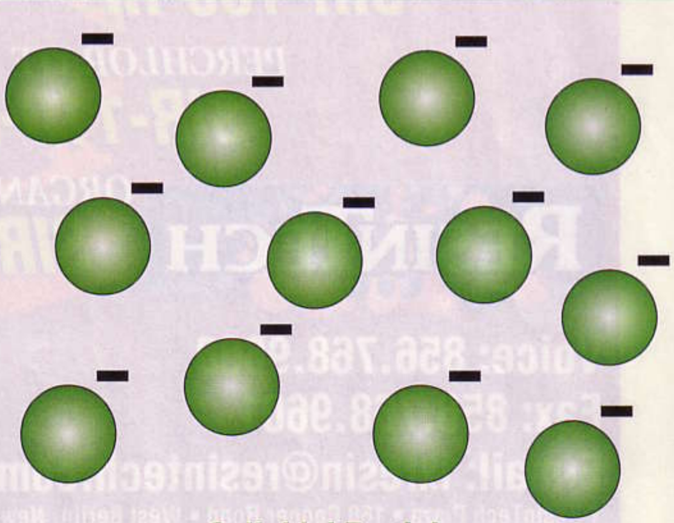

Colloidal Particles

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can then be removed efficiently via filtration or settling.

Interchangeable terms?

The terms coagulation and flocculation are often used interchangeably. Although both will agglomerate the colloidal particles, they accomplish this in different ways:

- ***Coagulation*** neutralizes the charges on the particles to remove the repulsion forces between particles, allowing them to come closer, and to agglomerate.
- ***Flocculation*** bridges the particles to make them even bigger so they can be removed effectively and efficiently.

In the coagulation stage, coagulants are added to neutralize the charges on the colloidal particles. If the particles are negatively charged, then a positively charged coagulant is used and vice versa.

Overdosing of coagulants will result in a charge reversal, redispersing them under the same "like" charge dispersion principle.

Van de Waals principle

High-speed mixing is applied to help bring the colloidal particles together via collision and allowing them to agglomerate naturally via the Van de Waals principle. Simply stated, the Van de Waals principle says that there exists a gravitational force between particles.

When particles are brought close enough to each other — such as via collision caused by agitation — this gravitational force pulls the particles together.

In essence, coagulation is the process of breaking or destabilizing the energy barrier. Once the barrier is destabilized, the particles will begin to bridge together, forming "pin" flocs, which are generally above 50 microns in sizes and are visible to the naked eye.

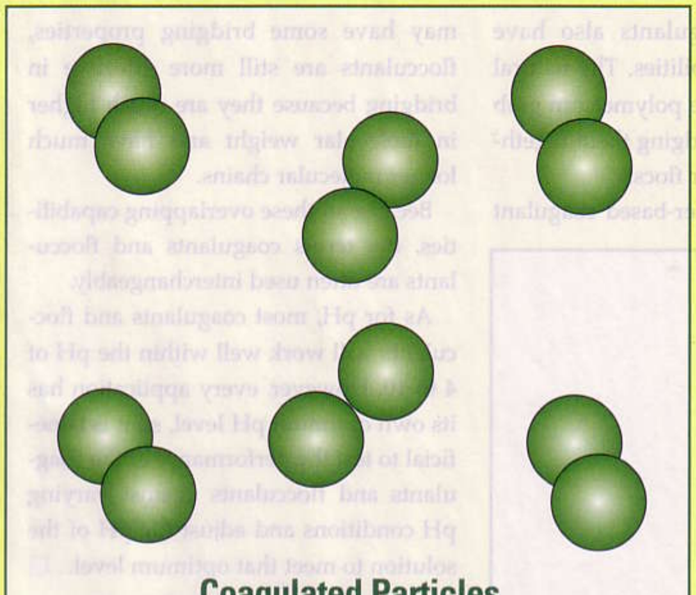
Aside from charge neutralization, certain coagulants, such as aluminum and ion salts, are added in excess to co-precipitate with the natural alkalinity in the water to form hydrous metal oxides.

If the alkalinity does not naturally exist or is insufficient, it can be increased by the addition of caustic or other similar chemicals. In this process, the colloidal particles are literally being entrapped in the hydrous metal oxide precipitation.

This has been referred to as the sweep floc technique, much like using an oil absorbant to soak up spilled oil. The downside of this technique is the large production of sludge volume.

Most popular coagulants are aluminum and ferric salts. Newer coagulants are polymer-based polyelectrolytes, such as Dadmacs and Epi-Amines.

Polymers are more expensive but their operating costs could be lower due



Coagulated Particles

to reduced sludge volume and the reduced need for pH adjustments.

Adding flocculants

After coagulation, the pin flocs are usually still too small to settle or filter efficiently. A flocculant is added to help bridge the pin flocs to form larger flocs, improving their filterability or settling rate.

Flocculants are high in molecular weight and have long molecular chains. One might think of the flocculant as the octopus tentacles with several suction cups to grab onto the agglomerated pin flocs.

Flocculants can be anionic, cationic or non-ionic and come in powder or emulsion form. In either form, the flocculant must be diluted down to about 0.5 percent before using.

This dilution opens up the polymer chain for optimum bridging. Otherwise, the polymer chain would remain coiled up and would be less effective.

The dilution also facilitates a faster dispersion and distribution of the flocculant to the particles.

The diluted polymer does not have a very long shelf life. After a few days, it begins to lose its effectiveness. It is best to prepare the flocculant only for the day's use.

Flocculants can be diluted in a batch tank or via some continuous polymer blending system. It is best to age the diluted flocculant for a few minutes to allow the chain to fully uncoil.

Mixing is also employed to the water while adding the flocculant to ensure adequate distribution of the flocculant. The mixing rate is done at a much slower speed to prevent shearing the already formed flocs.

Overlapping characteristics

Coagulants and flocculants have some overlapping capabilities. Aside from bridging, charged flocculants (anionic or

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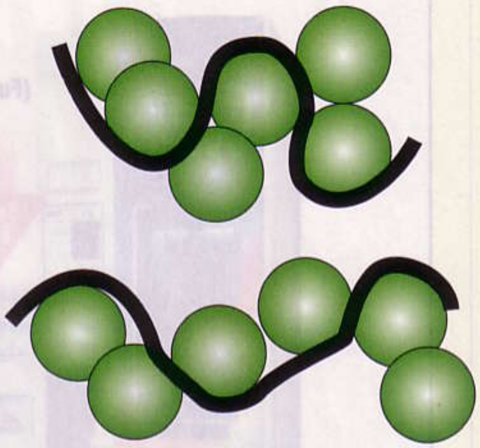
cationic) can also neutralize charges on the colloidal particles. However, coagulants are still more effective because they have higher charge density.

Aside from charge neutralization, polymer-based coagulants also have some bridging capabilities. The natural chain structure of the polymer can grab onto the colloids, bridging them together and forming larger flocs.

Although a polymer-based coagulant may have some bridging properties, flocculants are still more effective in bridging because they are much higher in molecular weight and have much longer molecular chains.



Flocculated Particles

Because of these overlapping capabilities, the terms coagulants and flocculants are often used interchangeably.

As for pH, most coagulants and flocculants will work well within the pH of 4 to 10. However, every application has its own optimum pH level, so it is beneficial to test the performance of the coagulants and flocculants against varying pH conditions and adjust the pH of the solution to meet that optimum level. □

Mario C. Uy is with WET International Inc., which specializes in private label water treatment products for water treatment dealers. Uy can be reached by e-mail at info@wet-international.com or by phone at (877) 938-4621.

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