Flocculation

Flocculation is the next step in most treatment plants (in-line filtration plants being the exception). Flocculation is the “snowballing” of small particles into larger particles (called “floc”). It is a time-dependent process that directly affects clarification efficiency by providing multiple opportunities for particles suspended in water to collide through gentle and prolonged agitation. The process generally takes place in a basin equipped with a mixer that provides agitation. This agitation should be thorough enough to encourage inter-particle contact, but gentle enough to prevent disintegration of existing flocculated particles. Particles grow by colliding with other particles, and sticking together. Detention time is necessary for the formation of floc. The longer the detention time, the larger the floc. Temperature and pH also affect the flocculation process. Several issues regarding flocculation should be evaluated by utilities to ensure optimal operation of flocculation basins.

Effect on Turbidity

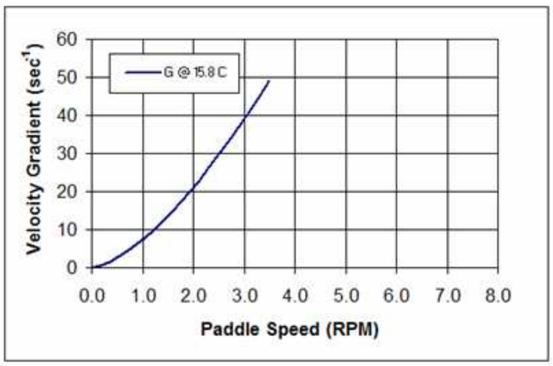
As with coagulation, the purpose of flocculation is not to directly reduce turbidity or suspended solids, but to prepare the solids for subsequent removal. Flocculation reduces the number of suspended solids particles as smaller particles combine to form larger ones. This process may, or may not, result in reduced turbidity in the flocculation chamber.

Slow Mixing

Slow mixing is a key aspect of the flocculation process. In slow mixing, the water is stirred to encourage floc particles to clump together. Stirring too fast can break large particles apart, while stirring too slowly can prevent particles from clumping enough. A wide variety of flocculation-mixing mechanisms have been used in water treatment. They include vertical shaft mechanical mixers, horizontal shaft mechanical mixers, and hydraulic mixing systems.

Often, optimum performance is achieved by reducing the intensity of mixing as the water proceeds through flocculation (known as tapered or staged flocculation). Engineers have developed methods of determining appropriate stir rates, called “mixing intensity values” or “velocity gradient” abbreviated as the letter “G.” Generally, slow mixing should start out relatively fast (G values of 60 to 70 sec^{-1}) to promote clumping, and end up slower to prevent the larger clumps from breaking apart (G values of 10 to 30 sec^{-1}) (Kawamura, 2000). Many plants have found that changing mixers or mixing speed can improve floc characteristics, leading to lower clarified or settled turbidity before filtration. The figures below show an example of a typical horizontal paddle-type flocculator and a velocity gradient curve.

Typical horizontal paddle-type flocculator



To evaluate mixing, the system should consider:

1. How many stages are present in the flocculation system? Three or four are ideal to create plug flow conditions and allow desired floc formation.
2. Is the mixing adequate to form desired floc particles? The system should consider decreasing the mixing rate for each subsequent stage. "G" values should be variable through the various stages from 70 sec^{-1} to 10 sec^{-1}.
3. Are mechanical mixers functioning properly? Are flocculator paddles rotating at the correct speed or rates?
4. If flow is split between two flocculators, are they mixing at the same speed and "G" value?

Detention Time

The amount of time the water spends in the flocculation process is a key performance parameter. Adequate time should be provided to allow the generation of particles that are large enough to be removed efficiently in subsequent treatment processes. There is a wide range of optimum particle sizes, depending on what treatment processes are used downstream. For example, when sedimentation is used (conventional treatment), large floc particles are typically desirable because they readily settle out of suspension. If filtration directly follows the flocculation process (direct filtration), smaller floc particles may be the most desirable since they tend to be stronger and less susceptible to breaking up from the shear forces within the filters. Overall detention time in the flocculation process typically ranges from 10 to 30 minutes and is generally provided in several different basins or basin segments so the mixing intensity can be varied through the process.

Flocculator Inlets and Outlets

Short-circuiting occurs when water bypasses the normal flow path through the basin and reaches the outlet in less than the normal detention time. Inlet and outlet turbulence is sometimes the source of floc-destructive energy and short-circuiting in flocculation basins. The system should evaluate the following:

1. Do basin outlet conditions prevent the break-up of formed floc particles? Basin outlets should avoid floc breakup. Port velocities should be less than 0.5 feet per second (fps).
2. Do inlet conditions prevent the breakup of formed floc particles? Inlet diffusers may improve the uniformity of the distribution of incoming water. Secondary entry baffles across inlets to basins may impart headloss for uniform water entry.
3. What size are the conduits between the rapid mix basin and the flocculation basin? Larger connecting conduits help reduce turbulence which may otherwise upset floc.

Flocculator Basin Circulation

Baffles are used in flocculation basins to direct the movement of water through the basin. Baffling near the basin inlet and outlet improves basin hydraulics and achieves more uniform flow patterns. Systems should consider the following items when evaluating flocculation:

1. Is current baffling adequate? Can baffling be added to improve performance, or does existing baffling require repair? Serpentine baffling is more effective than over/under because it provides for slower flow conditions and more time for floc formation. Baffling should prevent short-circuiting and promote plug flow conditions.
2. If the system uses solids contact units (SCUs), it may want to evaluate the recirculation rate of water through primary and secondary reaction zones, sludge blanket depth and percent solids, and raw water flow rate. Sudden changes in raw water flow rate may upset the sludge blanket and cause sludge carry-over to the effluent collectors. There are several types of SCUs, and each has unique flow patterns and sludge blanket requirements. Therefore, the system should consult the SCU operations manual for proper operation and troubleshooting of performance problems.