Mixers for Wastewater Clarification

COAGULATION MIXERS

In wastewater treatment plants, the use of coagulants to treat wastewater are well understood, which enables the correct selection of process equipment and chemistry.

Coagulation and flocculation are common, but different, processes used to remove very small particulate matter by forcing them to adhere together so that they can be removed from the wastewater as “sludge”. These processes require very different mixer designs to achieve the desired end result.

Firstly we will look at **coagulation, or flash, mixers**.

Coagulation-Destabilization of Particles

Wastewater typically contains both dissolved and suspended solids that remain after preliminary settling, skimming, and screening, and are typically less than a micron in size. These tiny particles move about in a random motion resulting from their collision with the fast moving molecules of the water which also keeps them in suspension.

The concentration of these tiny particles can be measured as turbidity, the higher the turbidity the more cloudy the water. These tiny particles can be very different in shape, size, make up, and charge. Measuring turbidity is a common test for water quality.

The majority of tiny particles in wastewater have a negative surface charge and repel each other as they come close together rather than sticking or clumping together.

Coagulation is the process of neutralising or reversing the charge on the particles to allow them to clump or stick together, thus facilitating removal from the water stream.

Coagulant Chemicals

The selection of a coagulant chemical depends on various factors. Water conditions such as pH and temperature, nature of the electrical double layer formed, equipment design, before and after unit operations, and of course cost, all have an effect on chemical choice.

Commonly used coagulant chemicals are aluminium and iron salts. When the metal salts are added to water, hydrolysis occurs very rapidly and forms a series of metal hydrolysis species. When added to the wastewater, the charged ions in the colloidal solution neutralize the waste particle surface charge, allowing the particulates to clump together. This is a very simplistic view of the colloidal chemistry involved but explains the mixing requirements for introducing the coagulant solution into the wastewater.

The larger particles formed in the coagulation process are often referred to as micro-flocs, this is not flocculation, which is a separate process. The water surrounding a micro-floc should be clear. If the water is not clear, then all the waste particles may not have been neutralized, and therefore coagulation is not complete. More coagulant may be needed in parts of the volume of wastewater, possibly due to inadequate mixing or insufficient coagulant chemical addition.

The aluminium and iron metal hydrolysis and absorption that takes place is relatively fast which requires rapid mixing with high intensity, this is essential for the coagulation process. Essential since this process is where the waste particles are destabilized and the primary micro-flocs are formed, the characteristics of these greatly influence the subsequent flocculation process.

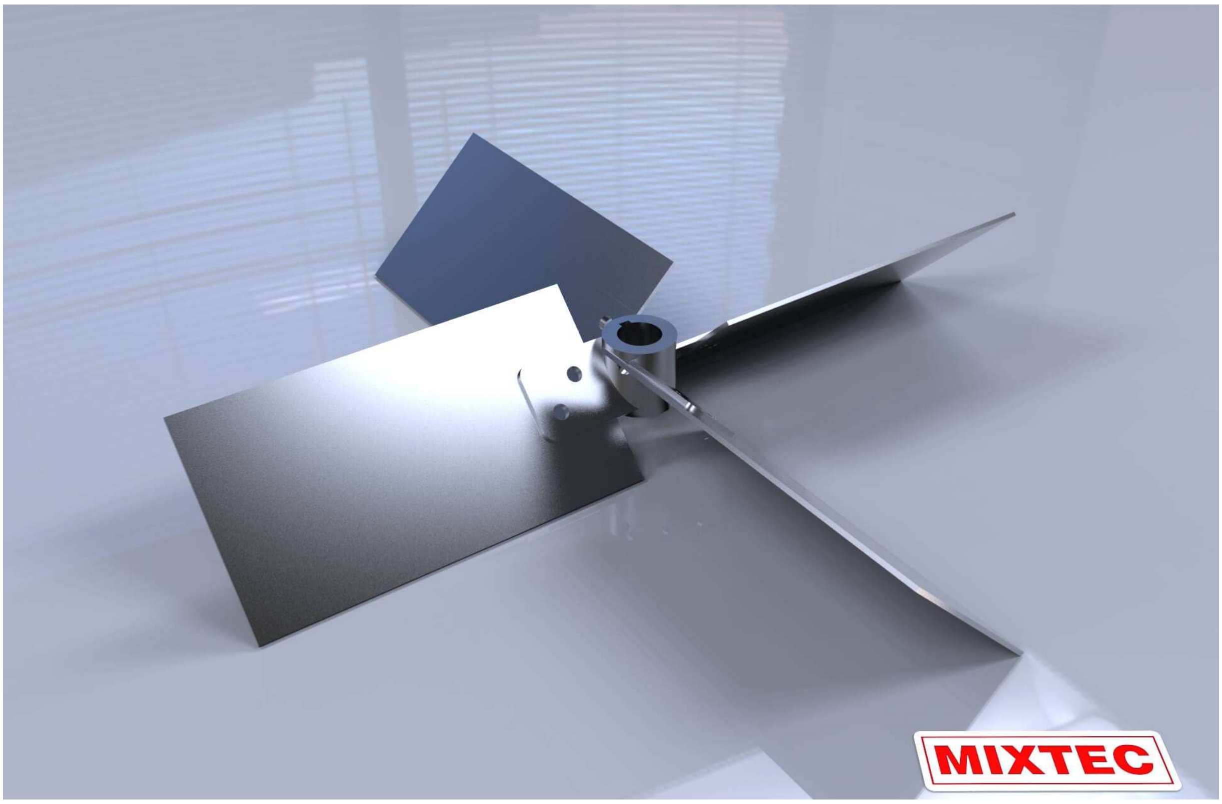
Optimizing a Mixer for Coagulation

Coagulation does not require long retention time but does need fast and thorough mixing to be effective. The velocity gradient, or G-value, is proportional to the mixing intensity, the higher the G-value, the more intense the mixing.

Therefore a coagulation, or flash, mixer design is one which provides aggressive mixing with a high pumping rate, hence a high tank turnover rate. To design a mixer for coagulation the following key factors have to be taken into consideration;

Impeller Selection

For high speed, high shear mixing, pitch-blade impellers are ideal. They have a high pumping rate and create sufficient movement in the tank for solids to contact and adhere to each other.



Mixtec HA745 Pitch Blade Impeller – high shear, high pumping rate

High G-value

The residence time in coagulation tanks is short, usually 30 to 60 seconds, this means the mixer must be engineered with a high G value of between 400 and 1000 sec-1. This has to be calculated by the engineer designing the mixer.

Tank Optimisation

To maximise the efficiency of the coagulation process, consideration also has to be given the tank design in terms of shape, volume, aspect ratio and flow in and out of the tank. Often you will be presented with an existing tank to work with but if you are building a new tank speak to your mixing expert, Mixtec/Western Engineering, before designing the tank.

FLOCCULATION MIXERS

In wastewater treatment, coagulation is normally followed by flocculation.

While coagulation is used to destabilize and agglomerate suspended waste particles, flocculation brings the colloids out of suspension in the form of floc, and allows the particles to be more readily removed from the water stream.

Flocculation

After the coagulation of destabilized tiny particles in wastewater, flocculation is the next process which encourages the newly formed micro-floc to stick together to create fully formed floc. A floc is defined as a type of microbial aggregate that may be contrasted with biofilms and granules, or else considered a specialized type of biofilm. Flocs appear as cloudy suspensions of cells floating in water, rather than attached to and growing on a surface like most biofilms.

When the floc become sufficiently large enough to settle to the bottom of the fluid (sedimentation), or float to the top of the fluid (creaming), they can be more easily removed through filtering.

Flocculant Chemicals

The flocculation process utilizes very different formation mechanisms and chemicals to form flocs. A common chemical used for flocculation is a long chain organic polymer such as polyacrylamide.

In wastewater applications, the organic backbone of polyacrylamide can actually be a copolymer with one or more other chemicals added; giving the polymer localized ionic charge of positive or negative, or in some cases both. Ranging from high to low molecular weight, polymers can be cationic, anionic or both, with a high to low charge density. Because of this, they can be engineered to suit very specific flocculation applications.

A polymer is designed to use two mechanisms to flocculate coagulated waste particles; electrostatic attraction and bridging. These charged forms of polymer enhance the mechanisms that attract and bridge the coagulated particles, increasing and improving the flocculation process.

Orthokinetic Flocculation

Orthokinetic flocculation refers to contacts, or collisions, of colloidal particles resulting from bulk fluid motion, such as mixing or agitation. In mixing systems, the velocity of the fluid varies both from one position to another and from time to time. The spatial changes in velocity are specified by a velocity gradient, or G-value.

This is similar to coagulation in terms of mixing, however, in flocculation, the amount of time the polymer and coagulated waste particles are close or in contact has a significant influence on floc formation.

Mixing Levels

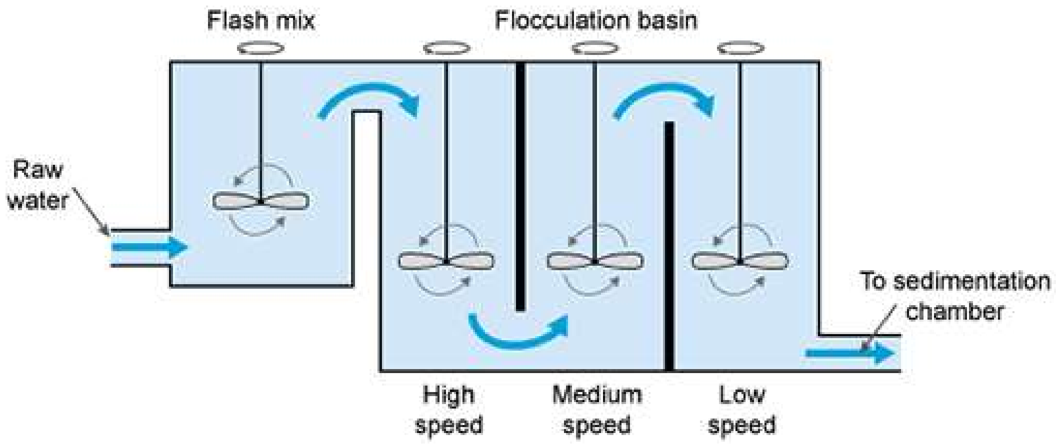
Effective mixing of the entire tank volume is required to maximise the contact of micro-floc, however, this has to be gentle enough to allow the contact to stick. A high G-value will bring many of the reactants together but will not allow time for the floc to form. As the flocs grow, high G-values will cause higher shear rates which may damage the newly formed flocs.

As the flocculation process goes on, larger and larger flocs are formed. The larger flocs have an increased sensitivity to shear, meaning they can easily be broken down and are often difficult to reform.

Mixer Design to Minimize Shear

When designing a flocculation mixer one must consider a long tank retention time in a relatively high volume tank providing low shear effective mixing. The objective being to continuously move a large volume of water gently around the tank without breaking up the newly formed flocs. **A correctly designed flocculation mixer will flocculate the whole tank in the minimum of time, use the minimum amount of chemical additives and will produce excellent water quality.**

In a batch process a VSD (variable speed drive) is essential to reduce the G-value as the floc is formed and increases in size. For continuous processes there are normally multiple tanks which have mixers run at diminishing G-values as the floc is formed. A VSD for each mixer is recommended for multiple tank systems as there are variables such as water quality, chemical performance, temperature, etc. which may require optimising the mixer speed for any given set of conditions.



Typical Coagulation (Flash) and Multiple Flocculation Tank Arrangement

Optimizing a Mixer for Flocculation

The purpose of a flocculation mixer is to keep solids in suspension while encouraging larger floc formation without damaging newly formed floc. The mixer must be engineered with the following criteria in mind:

Impeller Design

A hydrofoil impeller creates the low shear axial flow that is necessary to achieve floc formation whilst avoiding damage to the newly formed floc. The impeller diameter is determined by selecting the optimal ratio between the tank dimensions and impeller diameter. This will create effective mixing with sufficient flow whilst dissipating the input power over a large area. The tip speed of the impeller has to be kept below an empirically established maximum speed to ensure shear rates, and hence, damage to the floc does not occur.

Mixtec HA700 Hydrofoil Impeller – low shear, high pumping rate/unit energy

Low G-value

The absorbed power used by the mixer is calculated based on the G-value, which can be specified by the WWT engineer or calculated based on residence time. Since the residence time for flocculation is relatively long the mixer needs to be designed with a low G-value, normally in the range of 20 to 100sec-1.

Variable Speed Drive

A VSD is recommended for all flocculation mixers. Variable speed drives allow the end user to monitor floc formation and adjust the speed accordingly.

Contact Mixtec/Western Engineering

Contact us for a consultation and proposal on 09 828 3706, sending an email to info@westerneng.co.nz or by completing our on-line enquiry on our website.