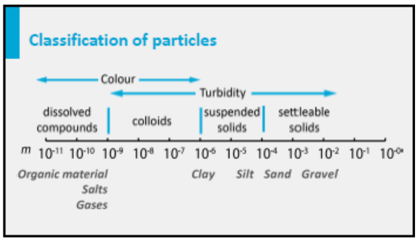
CTB3365x – Introduction to Water Treatment

D5b – Coagulation and flocculation

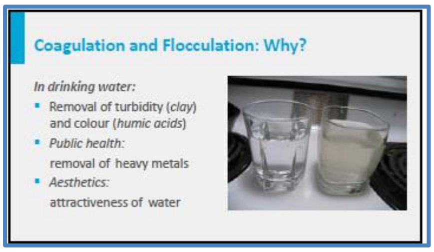
Luuk Rietveld

Surface waters can be very turbid and full of color causing substances.
These must be removed for the production of drinking water.

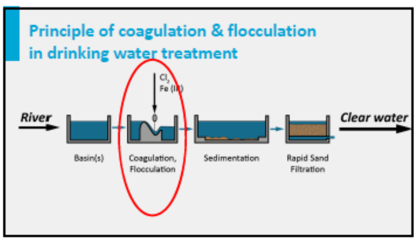
Welcome at the lecture about coagulation and flocculation!



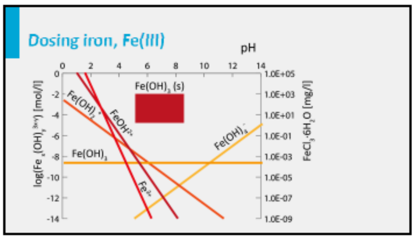
Particles that cause turbidity in surface water are frequently too small to be directly removed by sedimentation.
They are also negatively charged and cannot aggregate spontaneously.



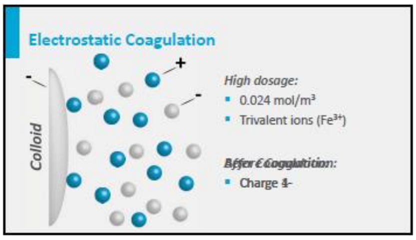
Therefore positively charged coagulants, such as iron chloride and aluminum sulphate, are dosed to destabilize the particles to induce floc formation, flocculation.
In addition, coagulation can, in certain circumstances, remove organic compounds like humic acids, thus improving the color of the water.



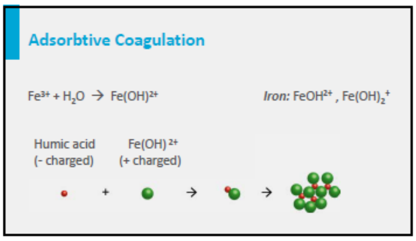
Coagulation and flocculation is normally performed before the sedimentation tank.
It consists of rapid mixing of the coagulant in the water and then gentle stirring in a flocculation tank for optimal floc formation.



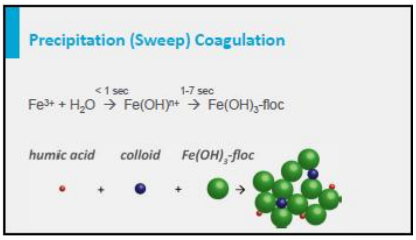
When, for example, iron(III) chloride is dosed, different species of iron ions are formed in the water, depending on the pH. With low pH, mainly positively charged ions are formed and at neutral pH mainly ferric hydroxide is formed.



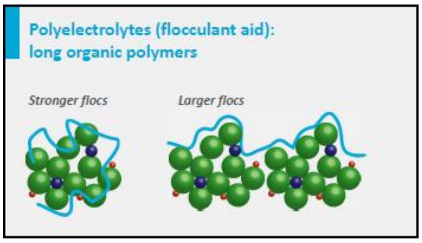
The positive ions can destabilize the particles by so-called electrostatic coagulation, but normally the dosage must be high to have an effect.



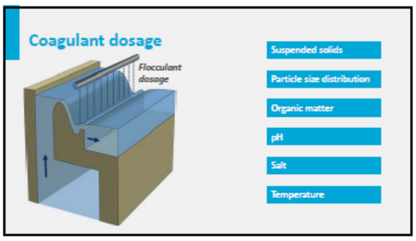
At low pH, the positive ferric hydroxide ions can also be adsorbed onto humic acid molecules, thus forming flocs.



Finally, ferric hydroxide can precipitate, forming large meshes that can capture turbidity causing particles, so-called sweep coagulation.

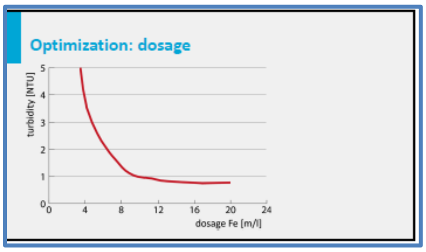


Sometimes, additional polymers, flocculant aids, are dosed to make the flocs larger and stronger.
In the Netherlands they are mainly applied in winter time, when settling is hampered by the high viscosity of the water.

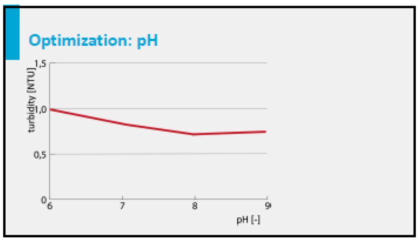


Coagulant dosage is largely dependent on the raw water quality:
concentration of suspended solids, particle size distribution, organic matter content, pH, salt content and temperature.
For a certain surface water, this varies over the year.

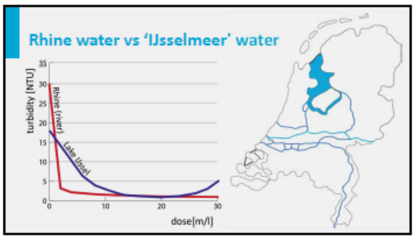
To be able to determine the optimal coagulant dosage so-called jar-tests have to be performed.
These jar-tests simulate the situation at full-scale and the optimal dosage, found in the tests, can afterwards be applied in practice.



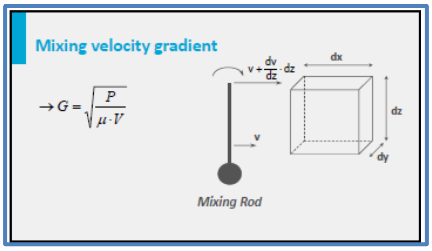
The most important variables to be tested are the coagulant dose and the pH.



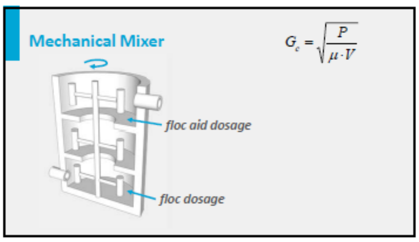
When coagulant is dosed, the pH will drop due to the abstraction of hydroxide ions from the water.
pH can be adjusted by dosing an acid or a base next to the coagulant.
The different combinations of dosage and pH can be tested in parallel and the results are presented in graphs.



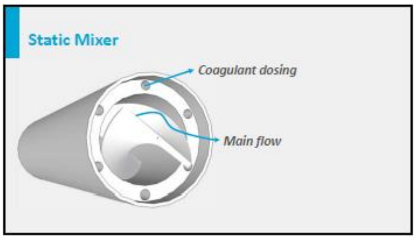
Optimal dosage highly depends on the type of water as can be seen in the example of river and lake water.
Lake water requires much more dosage because of the low concentration of inert material and the relatively high concentration of algae in the water.



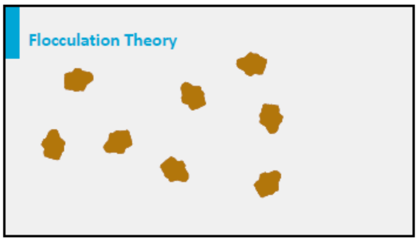
Rapid mixing of the coagulant is of utmost importance, to avoid locally high concentrations of coagulant.
For coagulation, the mixing intensity must thus be high.
A commonly used parameter for determining the mixing intensity is the G-value, defined as the square root of the power input divided by the volume and the viscosity.



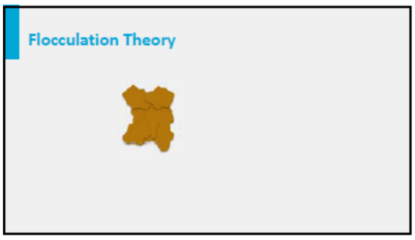
Mixing is done by either mechanical mixers or static mixers.



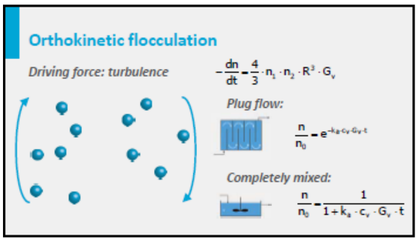
Mostly static mixers are applied in the form of in-line mixing devices or weir mixers.
G-values larger than 2000 per second are common.
The higher the G-value of coagulation is the better the performance of the coagulation – flocculation process.



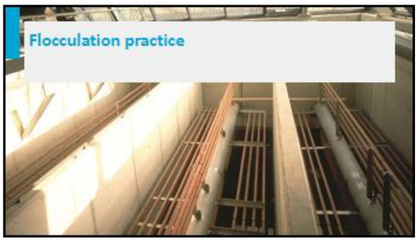
The next step is the flocculation process.
During coagulation destabilized, elementary flocs, so-called pin flocs, are formed,



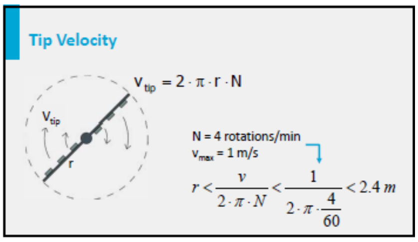
and during flocculation these pin-flocs have to grow until large, settleable aggregates.



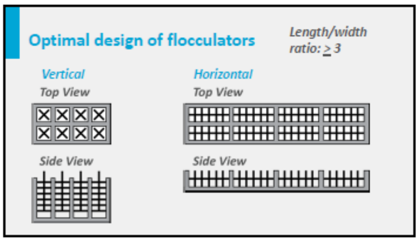
Turbulence, so-called orthokinetic flocculation, is the main driver for the floc formation and mixing intensity and residence time the most important variables.
Obviously the mixing intensity are not so high as during coagulation, with G-values between 5 and 100 per second.



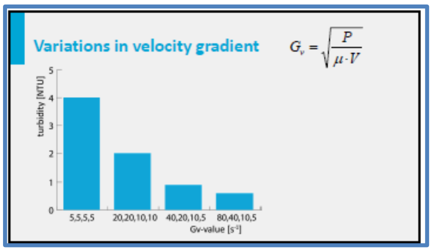
In practice, mostly mechanical mixing is applied, to be able to react on flow variations.
During mixing it is necessary to avoid short circuiting, and large residence time distribution, in the flocculation units.
Therefore, the flow must be parallel and not perpendicular to the stirring axes.



Last important point for the design of a flocculation device is the risk for floc break-up, especially at the tips of the stirring devices where the velocities can locally be high.
To avoid these high tip velocities the radius of the stirring device should be maximized.



In the meantime the flocs will grow with the residence time in the flocculation unit.
Larger flocs are more sensitive for floc break-up and slow mixing is required.
For smaller flocs, however, we need a relatively high mixing intensities to be able to provoke collision of the pin-flocs.
The solution is then to apply tapered flocculation.
In the first compartments higher mixing intensities are applied and gradually the intensities are diminished.

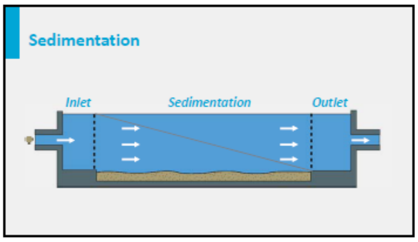


In the graph the effect of tapered flocculation on effluent water turbidity is clearly visible.

Coagulation is thus an integral part of the surface water treatment train.

It is directly linked to the sedimentation and filtration process, making them more efficient.

In the photograph the formed flocs are clearly visible.
However, special attention must be given to the design of coagulation and flocculation.
Especially, the dosage, the mixing intensity and the residence time distribution are important parameters for optimal performance.



Thank you for watching, hope to see you for the next lecture about the subsequent treatment step: sedimentation!