


5 Feed Water Quality and Pretreatment

5.1 Maximum Feed Concentration and Goals of Pretreatment

NOTE	
	ATTENTION! Observe the following guidelines!

- In some situations, the feed water may contain or may be expected to contain substances that could potentially damage the membrane or membrane fibers or that may cause fouling or scaling which would be too complex to remove even with chemical CIP (Clean-In-Place) cleanings. In such cases it is essential to carry out effective pretreatment steps to remove these substances from the water prior to ultrafiltration.
- The presence of predominantly large particles in the feed water may result in irreversible fouling of the capillaries or in damage to the membrane or membrane fibers. Large and/or sharp particles must therefore be removed by an upstream pre-filter.

The quality of the water fed into a membrane system has a major impact on the membrane's performance, recovery and availability. Substances in the water that permanently exceed a critical concentration or temporarily rise above a maximum concentration can cause flux rates, achievable permeability and recovery rates to fall below the stated design values. This also applies to the dosing of inorganic iron or aluminum-based coagulants and powdered activated carbon. Concentrations that exceed permitted levels may also significantly increase the frequency of chemically enhanced backwashes (CEB) required to maintain stable operation as well as the frequency of chemical Clean-In-Place (CIP) to remove stubborn fouling/scaling substances. This could lead to higher chemical consumption and negatively affect system availability.

No fixed values can be given for critical and maximum concentrations of feed water contaminants. Membrane compatibility of many contaminants will differ depending on the type and even the sub-type of the source-water used and the exact nature of the encountered contaminants, such as e.g. the type and quality of the added powdered activated carbon.

5.2 Microflocculation

General Overview

Dissolved Organic Carbon (DOC) in the UF feed water can cause build-up of a hydraulically hard to remove fouling layer as well as contaminate the UF filtrate water due to passage through the UF membranes. Microflocculation is used to prevent or reduce the negative effects of dissolved organic matter by precipitation and ultimately rejection of the organic molecules on the UF membranes. In many ultrafiltration installations, microflocculation by means of inline-coagulation is thus effectively used as a pretreatment process. In contrast to sedimentation and depth filtration, which require the formation of larger macroflocs, ultrafiltration only requires coagulation with subsequent formation of so-called "microflocs". This has the advantage of reducing the required quantity of coagulants and minimizing the quantity of sludge produced.

Depending on the concentration and characteristic structure of the dissolved organics in the feed water, specific quantities of inorganic coagulant (usually metal salts such as FeCl_3 , or polyaluminum chloride (PACl)) are added to the water prior to ultrafiltration and moderate amounts of energy, in the form of mixing, are then applied to form microflocs. The principal effects are a reduction of free organic contaminants as a result of the binding of the dissolved organics in the iron or aluminum flocs and the formation of a porous coating layer of microflocs on the membrane surface which helps to promote a stable filtration process and high backwash effectiveness and can therefore be used to increase or stabilize the membrane performance.

In addition, proper application of the microflocculation process can improve the filtrate water quality, particularly in regard to the concentration of DOC (which in some cases can be reduced by up to 60%), the SDI (Silt Density Index = clogging index; a key quality parameter for a reverse osmosis system downstream from the UF system), and the phosphate concentration (especially important in Wastewater applications).

When performing microflocculation, it is important to note that the concentration of the residues of dosed metal salts in the filtrate should not exceed 1% of the added metal concentration and should under no circumstances exceed any relevant limits that may apply (e.g. for drinking water treatment).

5.3 Performing Microflocculation

The goal of microflocculation (by using inline-coagulation) is to remove as much DOC as possible while simultaneously maintaining process conditions to minimize the amount of coagulant that remains in the UF filtrate. Achieving this goal requires precise adjustment of the inline-coagulation process. Based on the type of coagulant and the quality of the source water, an acid or caustic must be used to adjust the pH value in order to ensure an optimum pH for coagulation and microflocculation. The required contact time for the coagulant depends on the type and concentration of the coagulant, the water chemistry and the water temperature.

In order to define the best possible coagulation parameters, DuPont™ recommends conducting jar tests in a preliminary phase. The coagulant dosing system can then be designed based on the results of these tests. It is important that the jar tests focus on analytical parameters such as residual concentrations of Al and Fe and DOC removal rather than optical parameters such as floc formation. Table 5.3-1 gives an overview of various coagulants and their key characteristics.

Table 5.3-1 - Inline-Coagulation and microflocculation parameters

Coagulant		FeCl ₃	PACI
Dosage of Fe/Al ¹	[mg/l]	0.3 - 7.0	0.2 - 5.0
Specific dosing (Me ³⁺ /DOC)	[mg/mg]	0.5 - 2.0	0.25 - 0.5
pH range		5.0 - 10.0	6.5 - 7.5
pH Optimum		6.8 - 7.0	6.8 - 7.0
Contact time ²	[s]	30 - 60	30 - 60
DOC elimination rate ³	[%]	10 - 60	10 - 60
Rest quantity (as percentage of dosage) ⁴		1 %	1 %

- ¹ The dosage can be decreased for swimming pool applications (e.g. 0.03 mg/l AL/Fe).
- ² Contact time may show significant variation depending on water temperature, pH value, water chemistry and treatment goals (t < 30 seconds and t > 60 seconds) → potential for optimization.
- ³ Removal of organics depending on water chemistry and coagulation parameters (pH value, etc.).
- ⁴ Significant residues of Me³⁺ (metal salts) above natural pre-existing concentration indicate a problem with the coagulation parameters (mixing conditions, pH value, alkalinity, contact time, dosage) and should be strictly avoided.

It is important to note here that using the pre-filter to mix the coagulant may lead to fouling or scaling of the pre-filter (e.g. precipitation of Al hydroxides). Chemicals may then be required to remove this fouling if it can no longer be removed by backwashing alone. DuPont™ therefore recommends installing the pre-filter upstream from the coagulant dosing station or downstream from the contact zone. In the event that the existing piping does not guarantee sufficient contact time, a contact tank can be installed to increase the coagulant contact time. The following process diagrams show a range of different configurations for inline-coagulation and microflocculation.

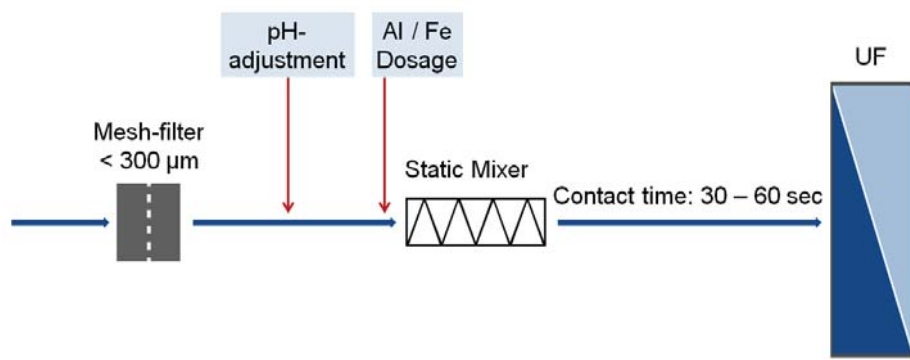


Figure 5.3-1 - Example 1: Pre-filter - Microflocculation - static mixer - UF

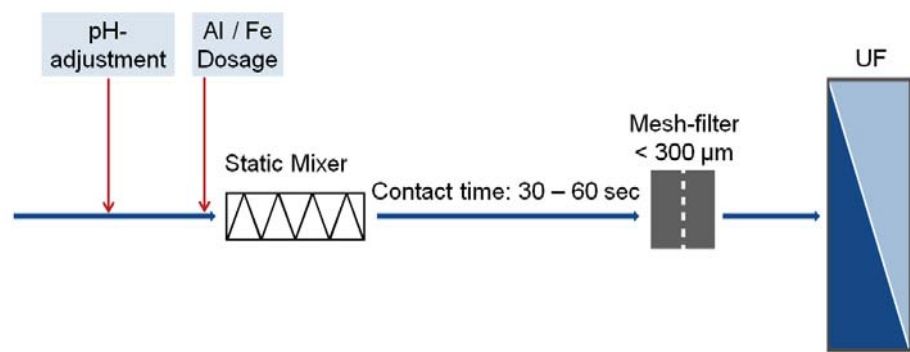


Figure 5.3-2 - Example 2: Microflocculation - static mixer - pre-filter - UF

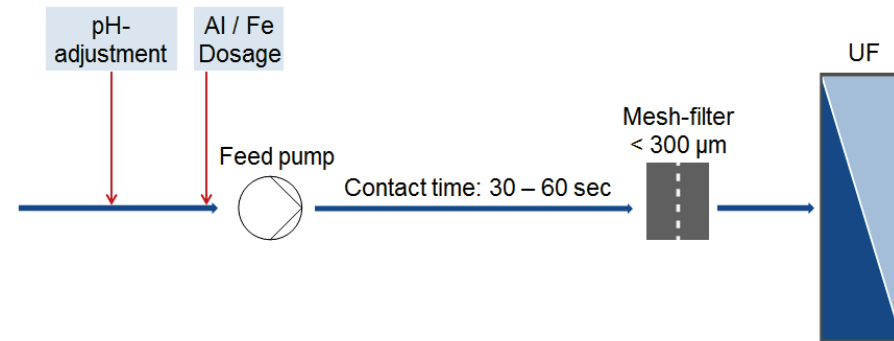


Figure 5.3-3 - Example 3: Microflocculation - feed pump - pre-filter - UF

NOTE



ATTENTION!


Observe the following guidelines!

- It is important to ensure proper mixing and adequate contact time. To achieve the best microflocculation results, the contact time for the chemicals should be adjusted to reflect the source-water quality (e.g. temperature) and the requirements regarding filtrate water quality (e.g. DOC, residual concentration of Al or Fe in the filtrate). Under no circumstances should microflocculation be allowed to take place in the membrane or on the filtrate side of the membrane (this would be the case if coagulants were not able to fully react with the UF feed water due to restrictions in timing and/or mixing and lead to unacceptable precipitation processes in or on the membrane surface).
- All chemicals added to the membranes and modules must at least comply with technical quality grade. Contaminated chemicals can cause irreversible fouling and are not permitted to use.
- When designing the microflocculation, please note that microflocculation processes are significantly slower at low temperatures (< 5 -10 °C). To counter this, DuPont™ recommends using polyaluminum chloride (PACl) which reacts significantly faster than other coagulants at low temperatures.
- When calculating the size and shape of the contact tank, it is important to choose a design that avoids short-circuiting in the tank.
- Special instructions must be followed for CEB and Clean-In-Place (CIP) and regular acid cleanings have to be performed once coagulants are introduced to the UF feed water.
- No organic coagulants or coagulation aids (e.g. polyelectrolytes) may be used either alone or in combination with inorganic coagulants since this may lead to severe, chemically irreversible fouling on the membranes which even CIP cleanings may be unable to remove. In certain special circumstances it may be possible to use substances of this type, but only if this has been tested and approved in writing by DuPont™ in advance.
- To avoid excessive dosing of coagulants, it is important to monitor and document the concentration of coagulants in the source water, feed and filtrate.

5.4 Continuous Chlorination in UF feed water

In some cases, continuous pre-chlorination is used as a form of pretreatment to combat bacterial growth in water treatment facilities. For a number of reasons, it is not recommended to apply pre-chlorination for UF.

Continuous chlorination of the UF feed water is in some cases considered to prevent micro- and macro-biological growth in the UF feed water intake structures, however, it is not recommended to apply such continuous chlorination upstream of the UF system. Instead, DuPont™ advises to implement other intake cleaning strategies such as shock chlorination (see below).

NOTE	
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- Chlorine is a powerful oxidant which can lead to the formation of volatile chlorinated hydrocarbons in water chlorination processes. This by-product occurs as a result of free chlorine reacting with organic material. The best-known by-products are trihalomethanes (THMs), a class of chemicals that includes chloroform, which has been shown to cause cancer in laboratory animals, and chloramines, which are believed to trigger allergies, and which cause the chlorine smell associated with chlorinated swimming pools.
- THMs and other chlorinated hydrocarbons that are formed as by-products in the chlorination process are grouped under the parameter AOX, which stands for absorbable organic halogen compounds. There are threshold values for Wastewater discharge in many countries.
- Experience has shown that the use of continuous chlorination in the feed water to ultrafiltration is highly counterproductive. Chlorination of organic matter creates numerous tiny organic fragments which can cause blockage of the membrane pores.
- In addition, the organic fragments produced by chlorination also tend to be bioavailable, a situation that is compounded by the significant increase in the rate of bacterial growth in the water if the free chlorine is neutralized. Together, these factors lead to an increase in the formation of biofilms (biofouling) on any downstream equipment or processes (e.g. reverse osmosis membranes).
- For this reason, continuous chlorine dosing should not be used as a pretreatment stage.
- A better choice for pretreatment is a process known as shock chlorination, which involves adding a high dose of chlorine to the source-water for a short period of time at less frequent intervals.