Ultrafiltration
Technical Manual

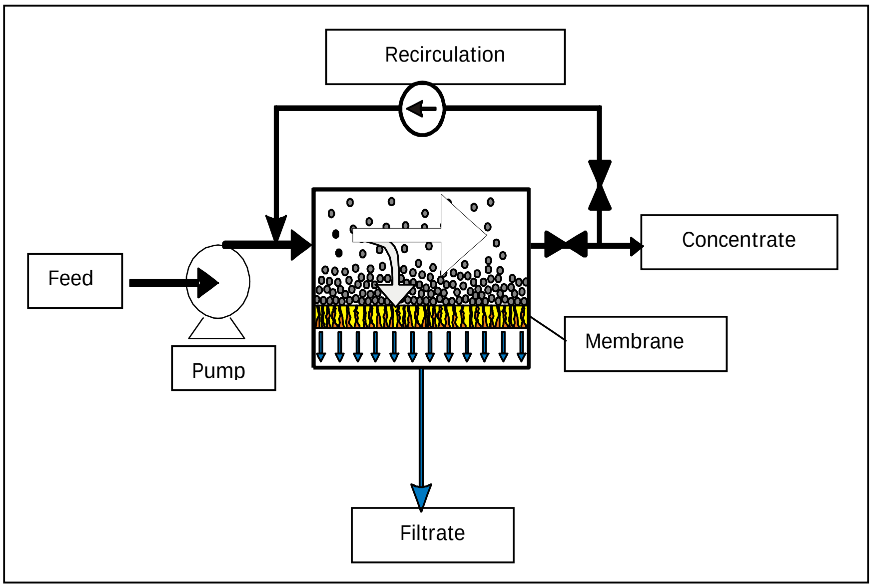
Contents

1. Basics of Ultrafiltration

1.1. Process

Ultrafiltration, being a part of membrane filtration processes, is a pressure driven filtration technology.

A basic process diagram is shown in Graph 1.



Graph 1: Basic membrane process diagram

The feedwater is hereby pressed into the module by a pump, and permeates through the membrane due to the transmembrane pressure (TMP) difference.

Depending on the membrane's pore size, water contaminants are being rejected by the membrane and remain in the feed water.

In order to avoid a too high concentration of rejected contaminants, which can consist of colloids as well as molecules, atoms or ions, a part of the feed is taken out of the system as concentrate.

Too high concentration of contaminants in a membrane system can lead to mineral scaling on the membrane or fouling of colloids, building up a cake layer on the membrane, changing filtration properties and necessary filtration pressures.

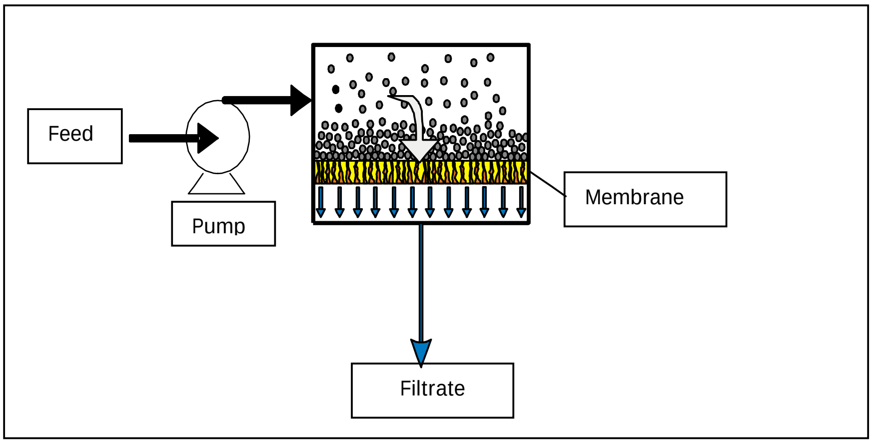
1.1.1. **Dead-End** operation mode

Micro- or ultrafiltration membranes normally can be operated in both ways: Either with a continuous concentrate flow, which is the so called “Crossflow”-mode or in “Dead End” mode, in which all feed water is pressed through the membrane and concentrate is taken out of the system only during backwash sequences.

In both cases, the ratio of feed and filtrate is called “Recovery” and is calculated as:

$$R = \frac{Flow_{Filtrate}}{Flow_{Feed}}$$

Ultrafiltration membranes, applied in regular drinking water treatment processes are usually operated in Dead - End Mode due to increased profitability (cf. shown in Graph 2 below)



Graph 2: Dead-End process schematics

<u>Process Details:</u>

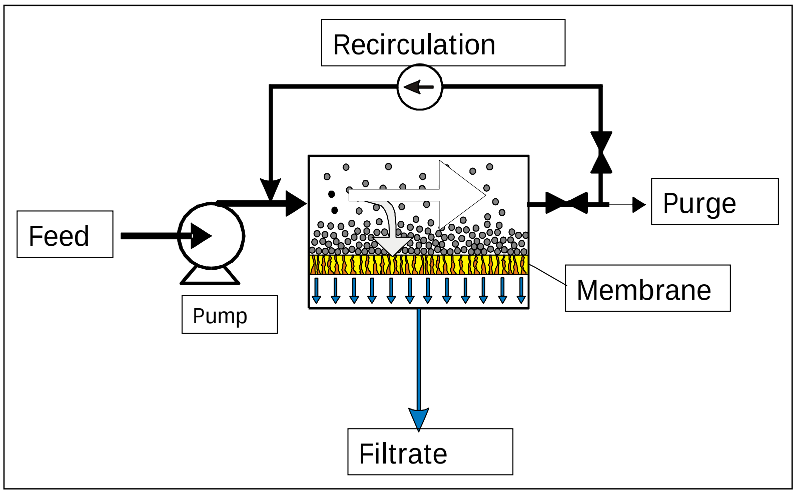
When operating in the Dead-End-mode, no circulation of the water takes place. The total quantity of the feed water is pressed through the membrane.

This mode is mainly used with raw water of high quality and less turbidity (e.g. ultrafiltration for drinking water pre-treatment). In times of higher turbidity, the Dead-End-mode can be switched to Cross-Flow-mode depending of the types of filtration modules used.

Nevertheless, Dead-End-mode is preferred due to improved profitability of the system. It provides lower operation costs (less pump energy required) and higher recovery rates.

1.1.2. **Cross-Flow** operation mode

In the Cross-Flow - mode, concentrate is circulated at a higher flush speed in order to create turbulences over the membrane. Thus, the building of a layer can be avoided. Especially in the ultrafiltration process, also the total concentrate can be re-circulated if the membrane is backwashed regularly. (cf. graph 4). In addition, a certain percentage of concentrate is removed from the system continuously (purge).

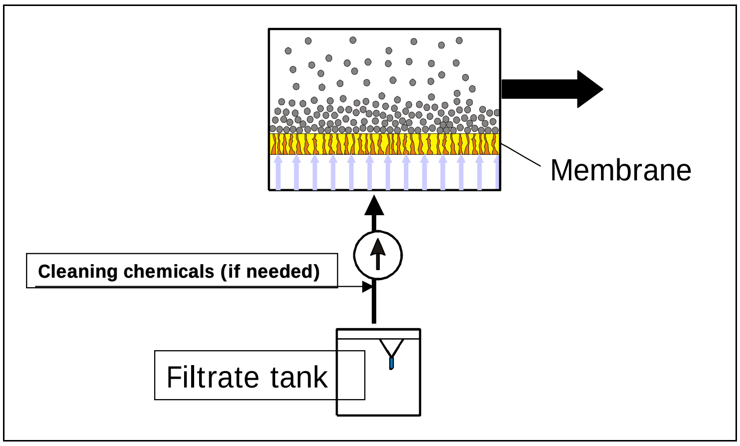


Graph 4: Recirculation with purge - process schematics

1.1.3. Cleaning in **Backwash** - mode

To avoid the formation of a thick fouling layer, the system needs to be backwashed in defined intervals.

In backwash mode, filtrate is pressed from the filtrate to the concentrate side, hereby removing the fouling substances attached to the concentrate side of the membrane. Therefore, filtrate is either stored in tanks, or is supplied by other filtrations units.



Graph 5: Backwash - process diagram

Depending on the type of membrane system, concentrate is taken out of the system continuously or during backwash procedures in defined intervals. Graph 5 shows the basic diagram of a backwash process.

Membranes applied in desalination processes are usually not backwashable due to their construction. In such systems, concentrate is taken out of the system continuously with the aim to avoid a scaling of low soluble salts. Ultrafiltration membranes with capillaries have such a backwash possibility. When backwashing, filtrate is flushed from the permeate´s side to the concentrate´s side, thus removing the layer very effectively.

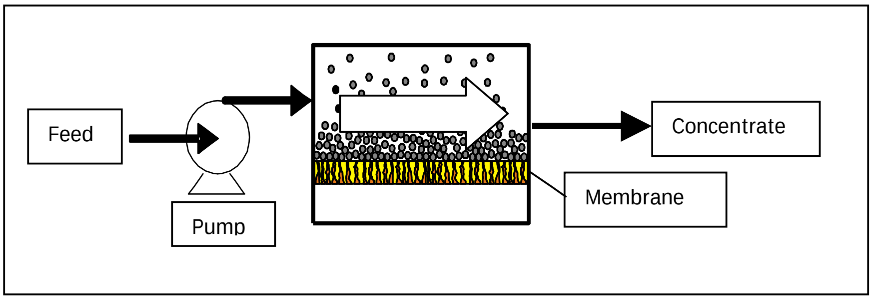
Depending on the membrane system applied, the backwash water may include chemicals like chlorate or hydrogen peroxide.

The frequency of a backwash conforms to the quality of the feed water.

For disinfection purposes, chemicals like Chlorine or Hydrogenperoxide can be added.

1.1.4. Cleaning in **Forward Flush** mode

It is already proved that a short forward flush right before starting the backwash sequence significantly enhances the performance of the backwash. Graph 6 shows the schematics of a forward flush. As this process is not carried out with filtrate but regular feed water, it does hardly influence the overall recovery of the system.



Graph 6: Forward Flush process schematics

1.2. Chemical Cleaning

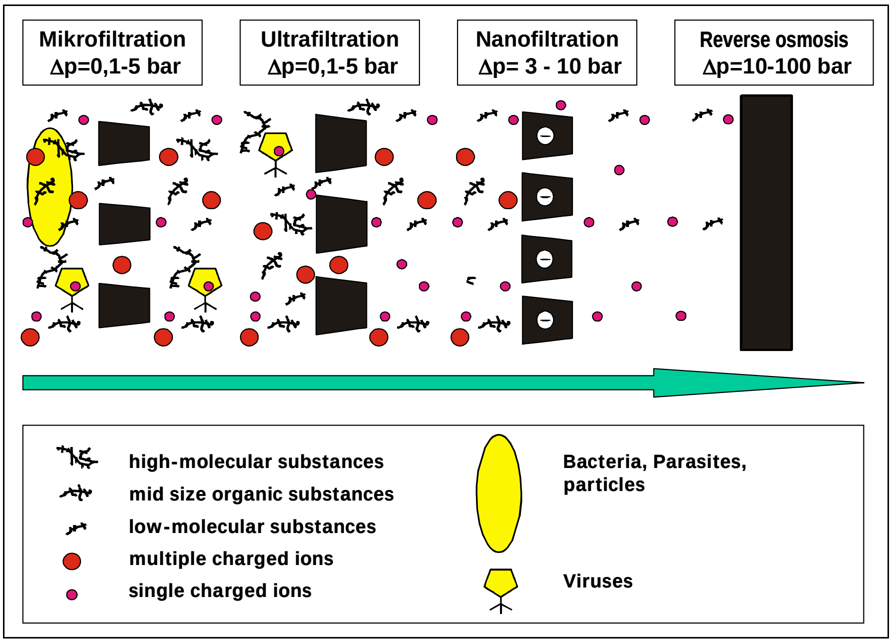
Depending on the type of fouling, a backwash does not remove the fouling layer completely. Therefore, filtration performance decreases over time.

To recover the systems original filtration performance, chemical cleanings are performed in intervals of 3-18 months. Taking into consideration the type of foulant, the appropriate chemical substance is chosen, e.g. Acid, Caustic (Sodiumhydroxide) or varied disinfection and cleaning solutions.

1.3. Rejection capabilities

Mechanisms of rejection vary among the different membrane technologies.

For example Reverse Osmosis membranes that are obtained to be pore-free membranes, are even able to reject single solved ions. Transport through these membranes is described by using Solution / Diffusion – models. Graph 7 shows the Cutoff of different membrane technologies.

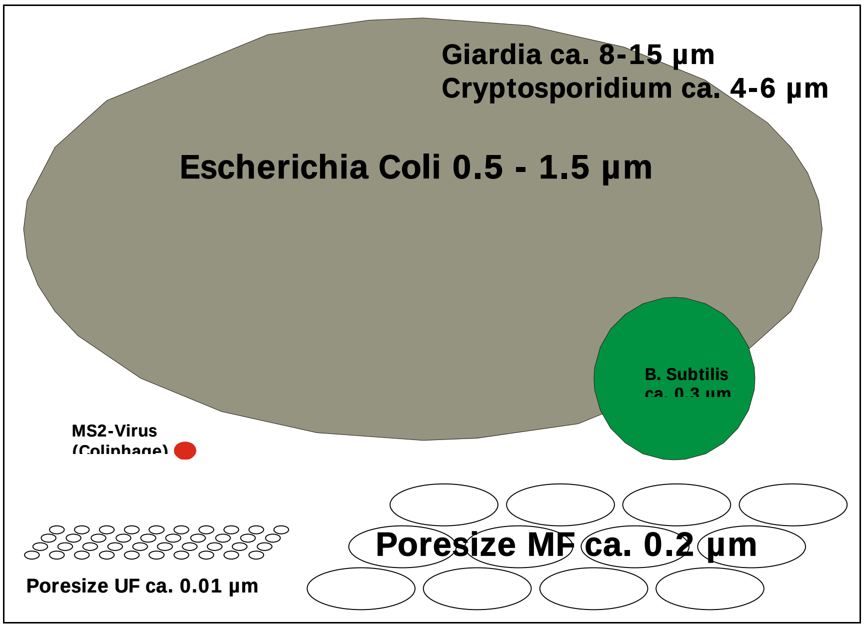


Graph 7: Rejection of different membrane types

Micro- and ultrafiltration membranes are, in opposite to reverse osmosis membranes, porous membranes. Due to this fact, mainly steric effects are responsible for separation in these processes.

Compared with microfiltration, ultrafiltration with its smaller pores is even able to reject not only bacteria and inorganic particles, but also smaller contaminants, such as viruses and macromolecular substances.

Graph 8 is comparing both, pore sizes of ultrafiltration versus microfiltration. In addition, the general size of microorganisms is shown which are relevant in the process of drinking water treatment.



Graph 8: Comparing pore size of UF and MF

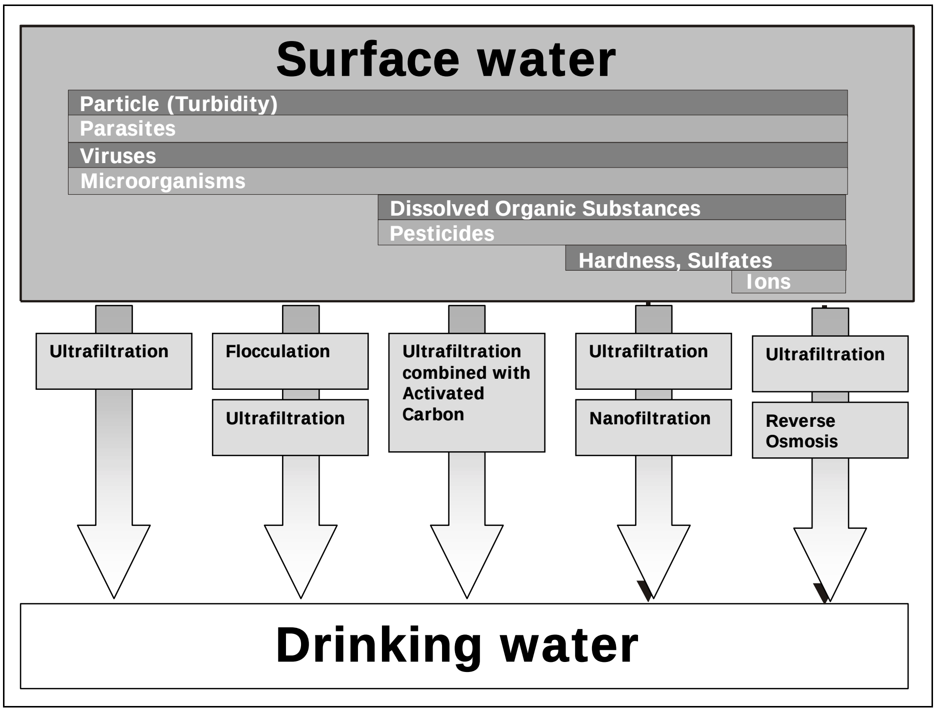
Due to its properties, nanofiltration can be located in between ultrafiltration and reverse osmosis. Average pore sizes of nanofiltration membranes are around 1 nm (nanometer).

Therefore, the rejection of neutral charged contaminants can be considered to be caused by steric effects mainly. It has proven, that bivalent negative charged ions are rejected much better than monovalent ones, due to the negative charge of nanofiltration membranes. For this reason, nanofiltration is often applied to remove hardness and sulfate. Additionally, there are many applications where nanofiltration is applied to reject humic substances and pesticides.

2. Integrating membrane systems

2.1. Combining different membrane technologies

As shown in Graph 9, ultrafiltration as a single treatment step or in combination with other membrane processes, provides a powerful tool to remove all kinds of contaminants from the raw water.



Graph 9: Combining treatment systems

2.1.1. Flocculation and ultrafiltration

The removal efficiency of organic carbons that are very difficult to remove from the raw water in general, can be increased significantly by dosing of flocculant in front of the ultrafiltration system.

Compared to conventional filtration, it is no more necessary to optimize the flocculation with regards to following separation by the filter due to the fact that ultrafiltration is able to reject even very small flocks.

Therefore, flocculation can be optimized towards removal of organic carbons.

2.1.2. Active carbon and ultrafiltration

Adding active carbon in front of the ultrafiltration, substantially improves the removal efficiency of the system for humic substances and pesticides. In case that large quantities of active carbon are required, the application of a nanofiltration instead of an ultrafiltration system should be considered.

2.1.3. Ultrafiltration and nanofiltration

Polar pesticides can be reliably removed by applying a process combination of ultrafiltration and nanofiltration. As a positive side – effect, the water will also be softened and sulfate will be removed.

2.1.4. Ultrafiltration and reverse osmosis

To desalinate water, a reverse osmosis treatment step can be applied after the ultrafiltration process. With ultrafiltration as pretreatment, the reverse osmosis system can be operated more reliably and with higher flux rates.

Ultrafiltration as a pre-treatment for reverse osmosis is a reliable barrier for microorganisms and particles. Furthemore, it almost completely removes fouling causing substances.

2.2. Comparison with conventional treatment

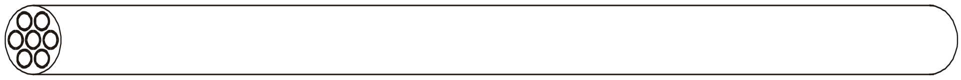
Compared to conventional treatment processes, ultrafiltration offers various advantages:

- Ultrafiltration provides a full barrier against microorganisms and particles
- The quality of the filtrate is not depending on the feed water quality
- Ultrafiltration is able to eliminate chlorine - resistant pathogens.
- Concentrate originated by the ultrafiltration process is only consisting of the water contaminants. The amount of created and to be disposed sludge is significantly lower than with conventional treatments.
- Compact construction of systems provides lower investment for buildings and space than with conventional treatment.
- Ultrafiltration can be automated easily.
- Downstream treatment steps will have higher productivity due to the fact that nearly all foulants will have been already removed by ultrafiltration.
- Investment and operation costs for downstream nanofiltration or reverse osmosis systems are will decrease substantially, since the systems can be operated at higher flux rates and with less cleaning efforts.

3. inge standard: best UF technology

3.1. Membrane concepts

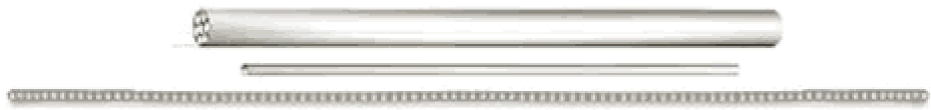
Multibore™ Capillaries provide high safety regarding breakage and therewith avoid any breakage or leckage of the capillaries.



Picture 1: Multibore Capillaries

Different membrane configurations allow outside-in, as well as inside–out operation.

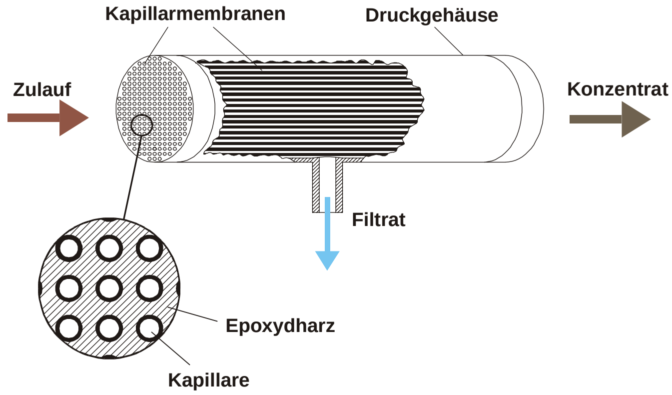
This enables inge AG to operate in a superior way in drinking- water treatment processes with the Multibore membrane. In wastewater, a convincing treatment can be carried out with the Multichannel membrane



Picture 2: Varied Multibore Configurations

3.1.1. Module Schematics

A. dizzer



Picture 3: External dizzer – module, schematic construction

dizzer is a hollow fiber ultrafiltration module with an average molecular weight cut-off of 150,000 Daltons. An 225 mm diameter dizzer module contains ≈ 1.800 Multibore capillaries, each Multibore containing seven 0.8 mm inside diameter fibers. The fibre composition is polyethersulfone with special additives (PESM), a hydrophilic material that resists organic fouling.

The flow pattern is inside-out, i.e. that the feed water flows through the inside of the fibers and filtrate passes radially outward through the membrane “tube” walls.

Ultrafiltration membranes that are used in the dizzer–modules are designed for particulate removal. Water is pressurized through the membrane and particles are left at the membrane surface. Due to the small pore size of the membrane, all suspended solids including microorganisms are removed effectively with this technology. Because these particles build up a fouling layer on the membrane´s surface, the water flow direction is periodically reversed to remove particulate matter (also called backwash).

inge AG is offering various sizes of dizzer modules to match your specific requirements.

To ensure a good flow distribution through the capillaries on the filtrate side, special flow distributing mechanisms have been developed and are integrated in every dizzer module (“grid” construction).

The bacteria/virus rejection capabilities of dizzer-technology makes the module the ideal choice for treating surface and well water for potable purposes. Furthermore, the dizzer system is also most effective at reducing colloidal matter and therefore represents an excellent pre-treatment for reverse osmosis systems.

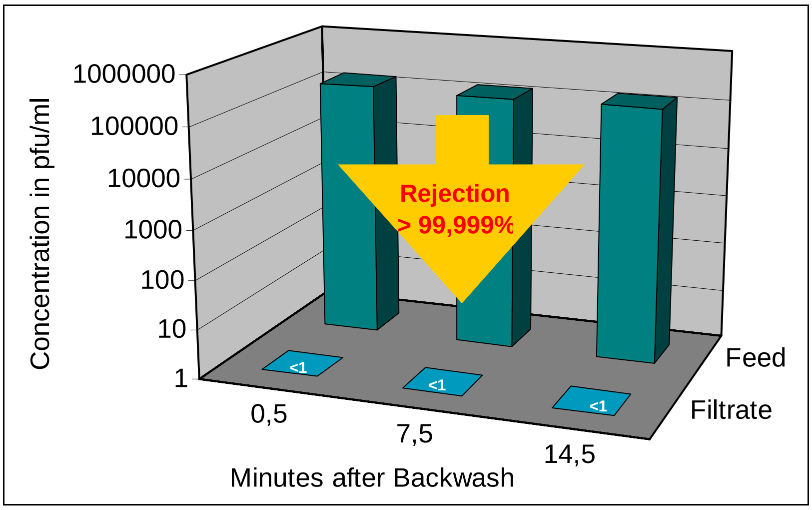
3.2. Rejection Capabilities of dizzer

Reduction of viruses and bacteria usually is given in “log” (e.g. “5 log reduction”). Use following formula to convert log into percent:

$$R = \left(1 - \frac{1}{10^{\log}}\right) \cdot 100 \quad [\%]$$

3.2.1. Reduction of MS2 Phages

The rejection of virus and MS2-phages is difficult to determine. Furthermore, high concentrations of phages have to be dosed over a long enough period of time due to the high rejection performance of the membrane. This process is difficult to realise from the technical point of view: Concentrations of 100,000 phages per liter is the limit that can technically be achieved; but this result is not high enough to overcome the membranes´ rejection. Therefore, the reduction of MS2 Phages is described to be larger than 99,999% (5 log).

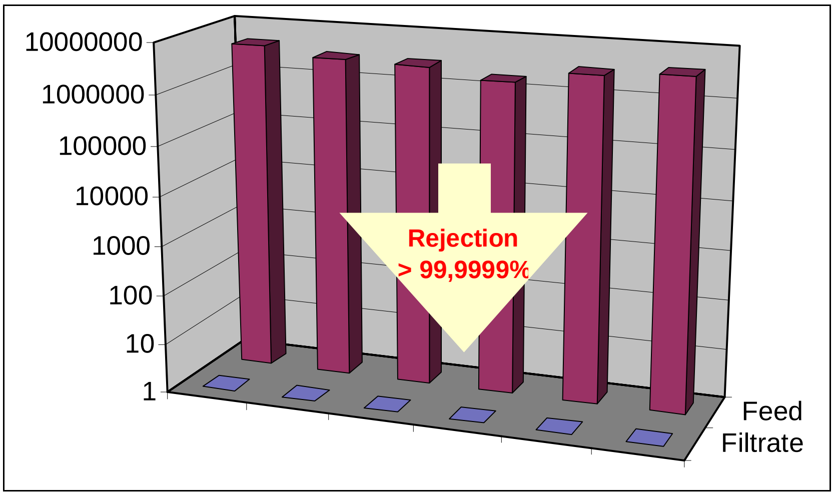


Graph 3: Rejection of MS2 phages by icap

Graph 3 shows the rejection of MS2 phages by the dizzer module, at the time short-time after and just before a backwash process (small cake layer before, no cake layer after backwash). The third measurement has been recorded in the middle of two backwash sequences.

3.2.2. Reduction of Cryptosporidia

In extensive tests, Cryptosporidia (Size 4 – 6 µm) have been reduced by dizzer as shown below.:



Graph 4: Reduction of Cryptosporidia by dizzer

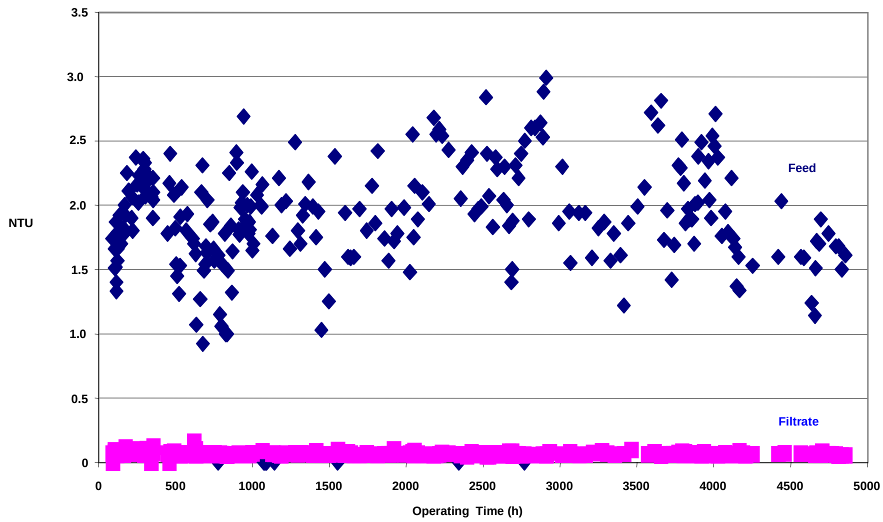
3.2.3. Reduction of Turbidity

The quality of the filtrate is not depending on changes in the quality of the feed.

Especially when peaks in the turbidity of the feed water occur, dizzer guarantees a consistent, superior filtrate – quality.

Therefore, this process can be fully automated easily.

In practical tests at a municipal wastewater site, the dizzer module has proven the following turbidity reduction:



Graph 5: Turbidity reduction of dizzer at a tertiary effluent

3.2.4. Reduction of SDI

The reduction of the fouling index (SDI) as an indicator for the filterability of a water, is primarily depending on the consistency of the feed water to the UF:

Besides particular substances, colloidal contaminants as well as dissolved organics influence the SDI.

Particular and colloidal substances can be removed completely by applying ultrafiltration, while the rejection of dissolved organic matter is depending on the size of such molecules.

By adding flocculants, the removal performance and therewith the SDI can be significantly improved.

Depending on the raw water quality, the filtrate SDI ranges from 1 to 4 even without adding flocculants.

3.2.5. Reduction of TOC

Per definition, the TOC is consisting of particular, colloidal substances and also contains shares of dissolved organic matter.

Since ultrafiltration is rejecting each of these components depending on its molecular weight, the overall rejection performance is a sum of this single figures.

Adding flocculants in front of the ultrafiltration system, helps to increase the removal performance for low - molecular organic matters.

Operation parameters of flocculation can be optimised by focusing on the concentration of the flocculant and pH of the feed water to achieve best possible rejection of the DOC. Compared to conventional treatment, it is not needed to pay attention to sedimentation nor filterability of the flocks, since ultrafiltration performance is not dependent of flock – geometry and – specific weight.

TOC removal of ultrafiltration can reach up to 60%.

Constituent	Removal
TOC Reduction w/o coagulant	0 - 25%
TOC Reduction	25% - 60%

Table 1: TOC Reduction of dizzer[t]

4. Disclaimer

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