Pressure and Submerged Membranes in Multi Barrier Systems for the Treatment of Surface Water

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Abstract
Modern multi barrier systems (MBS) for the treatment of surface water will, in an increased number of applications, include a membrane filtration stage for efficient particle removal and disinfection purposes. Depending on the raw water quality, ultra filtration membranes might be placed in front or at the end of the treatment chain. Therefore both, pressure and submerged type membranes are being used with high filtration performance and excellent operation reliability.
Membranes can reduce the number of treatment stages required in a multi barrier system; at the same time the drinking water quality is greatly improved.

Keywords
pressure and submerged membranes; multi barrier system; water reuse

INTRODUCTION

Some 17% of the drinking water in Switzerland is produced from lake water; in water supply organisations, which cover more than 50'000 inhabitants, the share is over 50%. Due to this fact, the treatment of lake water is of great importance. The treatment technology has been developing from simple filtering systems to complex multi barrier systems. As a result of very effective water pollution control and the progress made in membrane technology, the number of treatment stages necessary can be reduced again without having a negative effect on drinking water quality, on the contrary, the standard of the drinking water is improved.

Classical multi barrier systems have been built for lake water treatment in Switzerland for almost 50 years. Due to the number of stages, a very reliable production of drinking water is guaranteed, even if one of the stages has operational difficulties. Modern systems using membranes must maintain this high level of supply security.

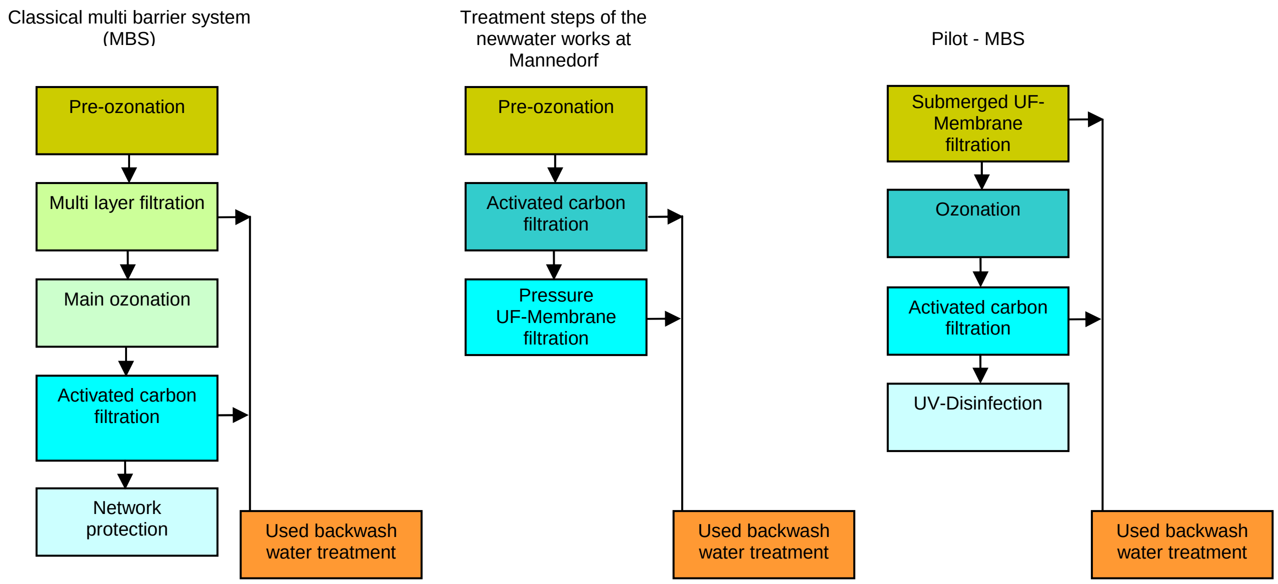


Figure 1: Process development for the treatment of surface water

Full scale multi barrier system

The new 3-stage multi barrier system in Mannedorf at Lake Zurich has been in operation since December 2005. The raw water is captured about 600 m from the edge of the lake in a depth of 43 m.

Ozonation

Each line has its own ozone generator, 200 g/h O_3 each, using treated air for the ozone production. Booster pumps generate a sub pressure in the injectors by which the ozone gas is mixed into the side stream. This highly ozonated water is led into the raw water pipeline where a fast mixing is secured by static mixing elements.
The water from 2 lines enters into a contact chamber, designed as a plug flow reactor. The ozonated lake water flows into the 4 activated carbon filters after a minimum contact time of 10 Minutes.

Activated carbon filters

The average filtration velocity in the down flow activated carbon filters (ACFs) is 7.4 m/h. The coal based granular type activated carbon (GAC) is an 8/16 grading with a high adsorption capacity. The activated carbon adsorbs mainly organic matter, traces of pharmaceuticals and hormonal substances. The carbon is an excellent carrier for the micro organism which permanently reduce the assimilated organic carbon to low levels; < 30 µg/l.
The ACFs outlet, the so called biological stable filtrate, is stored in an intermediate storage tank.
The backwashing of the ACFs is programmed with several options so that the intensity of the air and water backwash cycles can automatically adapt the changing lake water qualities. It is foreseen to change the carbon after 3 – 4 years of operation. Each filter cell has therefore a fixed installation for the removal and filling of GAC.

Membrane filtration

The filtrate of the ACFs is further transported by frequency controlled centrifugal pumps to the 4 membrane lines. Each line consists of 41 vertically arranged ultra filtration membrane modules (Picture 1). The modules are fed in a top/bottom mode, the modules are dead-end operated.

Picture 1: Membrane line with 41 pressure membrane modules

Backwash water treatment
The used backwash water from the activated carbon filters and the membranes is collected in a used backwash water holding tank. This water is treated by 2 lines of submerged membranes (Picture 2). The excellent permeate quality allows a direct discharge back to the lake or even a recycling to the beginning of the treatment process.

Picture 2: Filtration tank with submerged membranes

Experimental data as well as practical operational data prove that membranes are an asset in most multi barrier systems.

RESULTS

The lake water treatment plant at Lake Zurich has been operated for almost 4 years. The same process technology is tested on a technical scale at the Water Supply Company Zürich as from the beginning of 2006.

Pressure membranes at the lake water works in Mannedorf
Since the membrane stage comes at the end of the treatment chain, the pre-ozonation and activated carbon filtration is reducing particle content and organic substances, hence reducing the load onto the membranes significantly.
The plant is operated almost continuously whereby the flux rate varies between 55 – 80 l/m^2*h. The membranes are always operated in a dead-end mode, filtration cycle times can be held between 45 – 120 minutes, feed cycles are alternated top/bottom. After a filtration cycle, the membranes are backwashed with permeate for 30 s with a surface velocity of 250 l/m^2*h.

Figure 2 shows that frequent chemical enhanced backwashing (CEB) is necessary to maintain stable operating conditions.

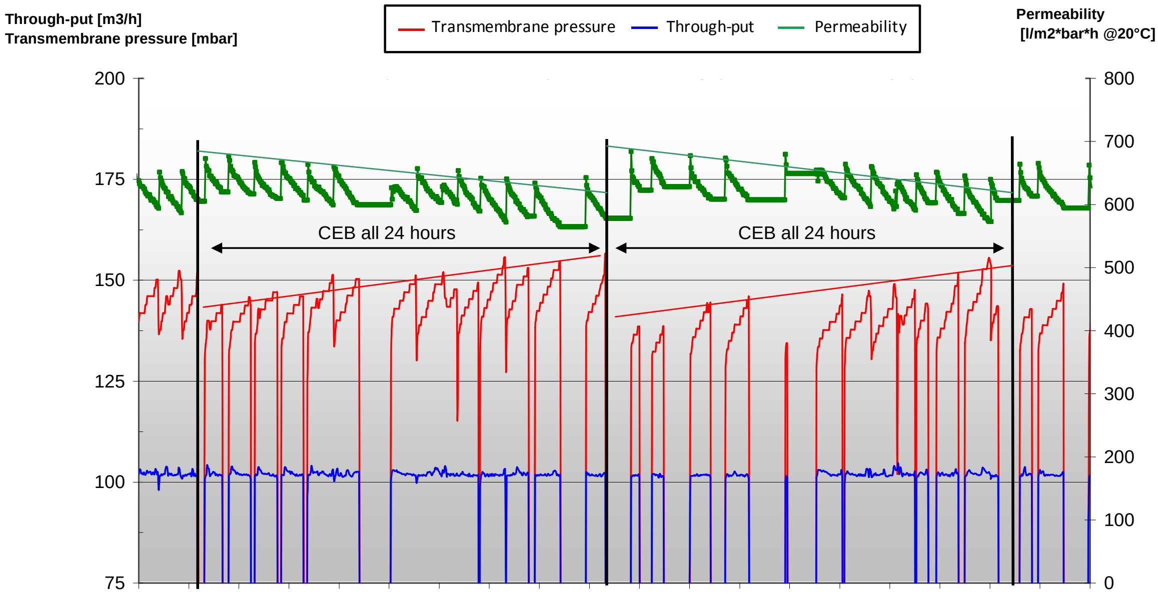


Figure 2: Influence of Chemical Enhanced Backwash (CEB)

In order to recuperate the loss of permeability, every 24 h a CEB with 50 – 70 mg/l of active chlorine (as NaOCl) was performed initially. The NaOCl concentration used has some influence to the cleaning efficiency, higher impact though could be observed by changing the contact time. Both parameters can easily be adjusted on the PLC, the CEB contact time frame is between 20 – 45 minutes. A higher contact time becomes also necessary when CEB frequency is prolonged in order to prevent any fouling. When CEBs with NaOCl are performed, plenty of permeate is needed to flush out the residual chlorine from the membranes in order to avoid any AOX formed getting into the drinking water. Alternative washes replacing chlorine by H_2O_2 or NaOH were not as effective. Higher flush water consumption had to be accepted, increasing overall wash water demand to almost 15%.

In order to reduce the potential of AOX formation; decreasing the flush water consumption; maintaining a permeability level of 500 - 650 l/m^2*h* bar and reducing the total backwash water demand to some 10% of the raw water quantity, the following measures were taken.

- reduction of chlorine concentration to 30 – 50 mg/l
- increasing the filtration cycle time by 50% in average
- half the number of CEBs

Above described operational changes were possible by introducing a new backwash mode, named "boosted CEB". The boosted CEB is performed every 14 days and consists of a pre-flush against atmospheric conditions. Prior to the flush, the air release valve in the feed water manifold is opened until overpressure is completely reduced. Through this process, also the water in the modules is partly discharged.

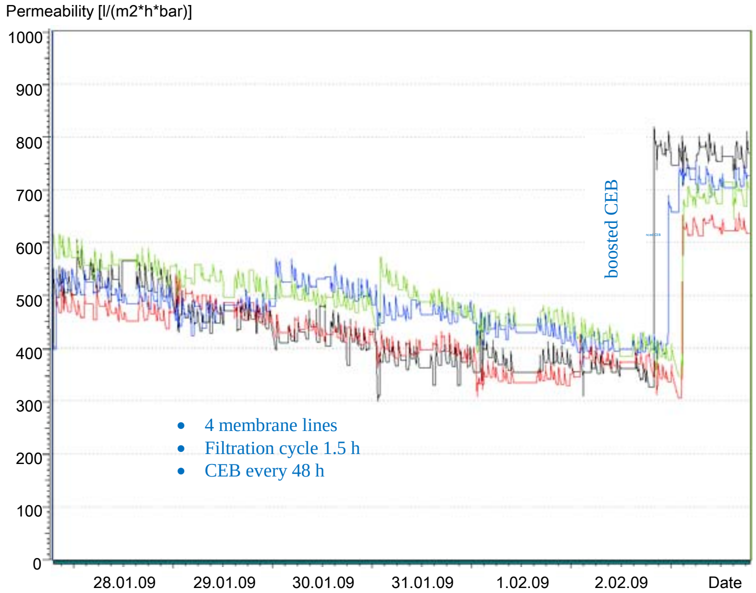


Figure 3: Performance of membranes after a "boosted CEB"

This makes the first water flush more efficient by creating a kind of turbulent condition removing accumulated particles from the membranes' surface. This leads to a permeability recovery of up to 400 lmh (Figure 3). This special back washing procedure is only used during the algae bloom season.

The filtration performance is permanently checked by measuring particles in the permeate in a size ranging 0.2 – 20 µm.

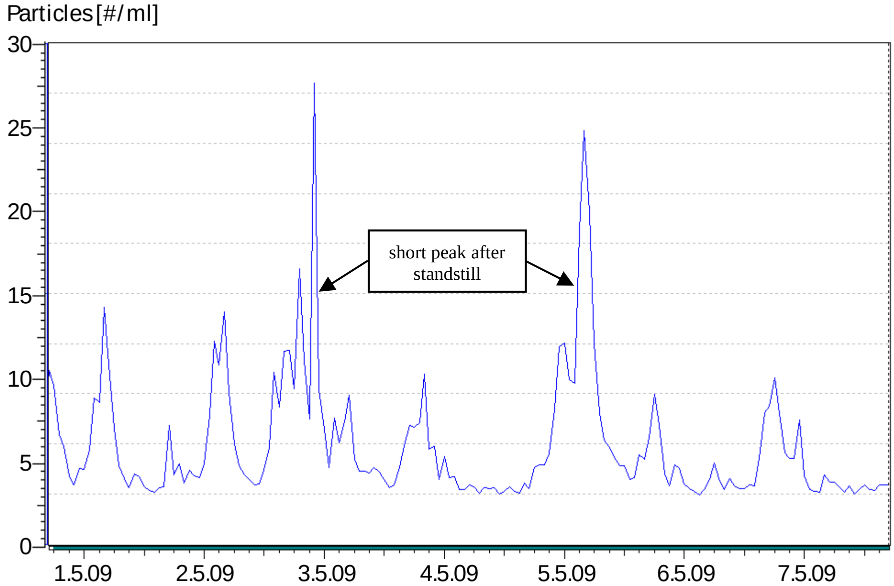


Figure 4: Typical total particle count in permeate

Turbidity is also continuously recorded; the values are clearly below 0.02 NTU. This measurement is not sensitive enough for membrane fibre supervision. The turbidity in the drinking water must be monitored though as a quality parameter; the required Swiss standard is < 0.2 NTU, therefore permeate is more than 10 times better than required.

When NaOCl was used for net work protection, the dosing rate was between 0.02 – 0.08 mg/l Cl_2, some taste problems occurred in the drinking water. Mostly at remote points of the net and during summer time when the water heats up, an increased number of consumers complaints were recorded. Since the chlorination was stopped, the sensory analysis, regularly performed by test persons, became all negative. In any case, membranes reduce substantially the number of particles; particles which might have masked taste and odour causing substances before, when the drinking water at the plant was produced with a MBS without a membrane stage.

Particle count of below 50 numbers per ml ensures that no significant numbers of fibres are broken, particle count measurement can be used as a tool for continuous fibre quality checking.
Nevertheless an automated integrity test is performed 4 times per year. Figure 5 shows the latest test performed in May 2009.

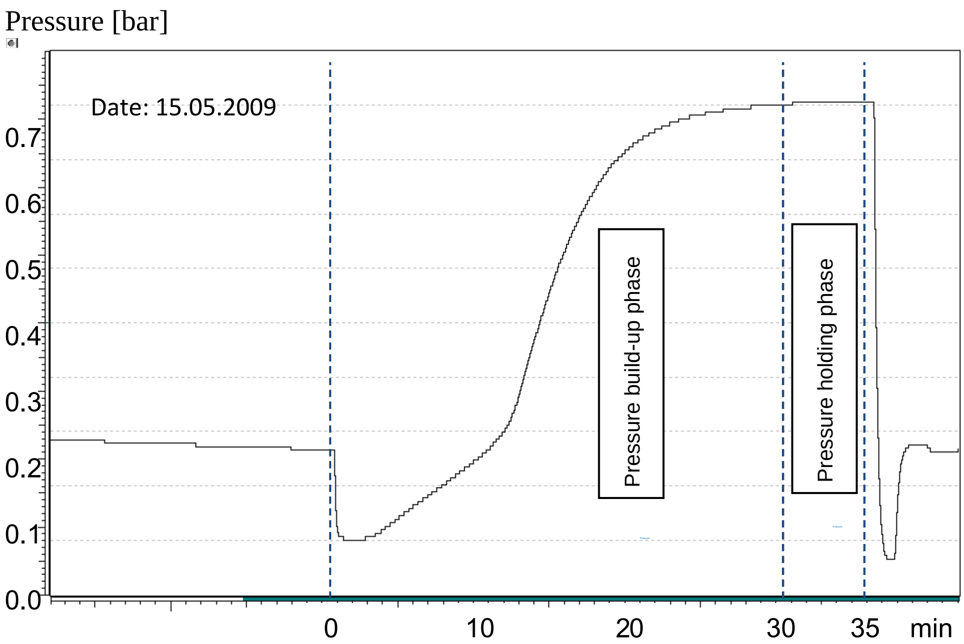


Figure 5: Integrity test on rack with 41 modules – 2000 m^2 filtration surface

Not any pressure drop (0 mbar) was recorded during the pressure holding phase. The membranes, Inge dizzer 5000 type, multibore technology, prove their excellent mechanical stability after more than 3.5 years of daily operation.

Submerged membranes at the lake water works in Mannedorf
Submerged membranes, Zenon 500 D-type, are being operated since January 2006 for the treatment of the used back wash water resulting from AC-filter and pressure membrane back washing. The membranes flux is depending on the quality of the used back wash water as well as on the quantity stored in the holding tank. The load management programmed in the PLC comprises of 5 stages resulting in a flux range of 8 – 35 l/m^2*h. These changing conditions favour the performance of the membranes, due to the varying mechanical stress on the fibres. Therefore only a small continuous decrease of the permeability is observed.

Depending on the solid load in the used backwash water, filtration cycles vary between 8 – 20 minutes. Normal permeate backwash is done for 40 s, every 5^{th} backwash, some 30 mg/l of chlorine (as NaOCl) is added for maintenance.

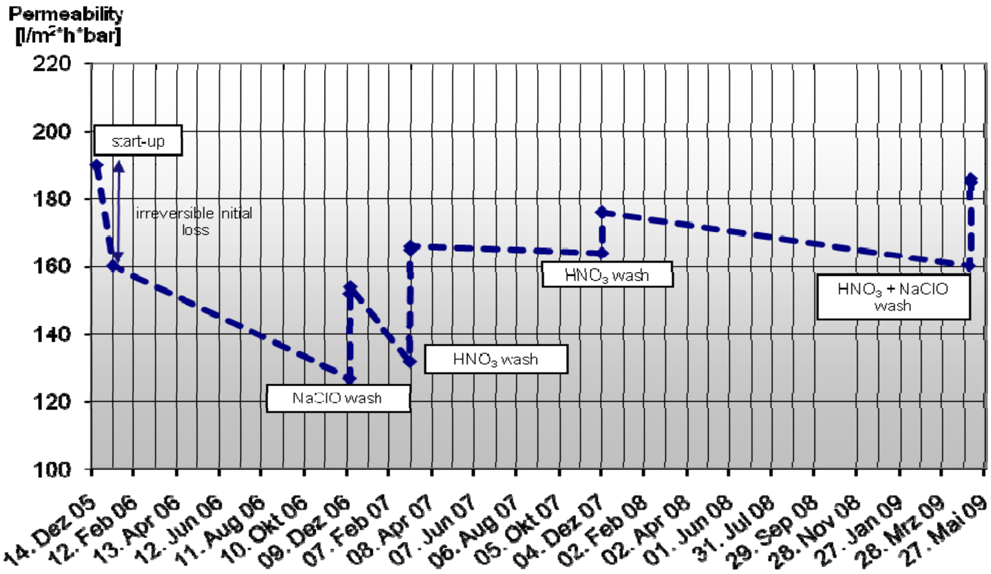


Figure 6: Stable conditions using acid recovery wash

After a total of 18 to 32 operation hours, a complete tank drain followed by a maintenance wash is carried out. This cleaning process is by far the most effective; its frequency depends on the solid content in the used backwash waters.

During the first 15 months of operation, no acid wash was performed and higher permeability decrease was recorded, most probably due to the presence of fine calcium carbonate particles formed under alkaline conditions during the NaClO wash alone. Since a recovery acid wash with HNO_3 at pH 2 is performed, the level of permeability remains stable (Figure 6). If both, an oxidative and acid wash process is made; the acid wash shall be the latter.

The permeate quality achieved allows a full reuse of this water by returning it into the treatment process, only the water volume of the tank drains is lost. The total water quantity discharged to the WWTP is smaller 2% of the produced quantity.

The following table shows the water balance sheet of May 2009, giving details of the water usage in the lake water treatment plant of Mannedorf.

Monthly production in m^3	Backwash water consumption in m^3	Recycle quantity in m^3		Sludge water to WWTP in m^3	
147'232	20'598	17'747		2'851	
Monthly production in %	Backwash water consumption in % to monthly production	Recycle quantity in % to monthly production	Recycle quantity in % to backwash water	Sludge water in % to monthly production	Sludge water in % to backwash water
100	14.0	12.1	86.2	1.9	13.8

Table 1: Water balance sheet May 2009

At present we are comparing the performence of pressure and submerged membranes as a first stage in a multi barrier system on a technical scale (Figure 7). The raw water is surface water from Lake Zurich.

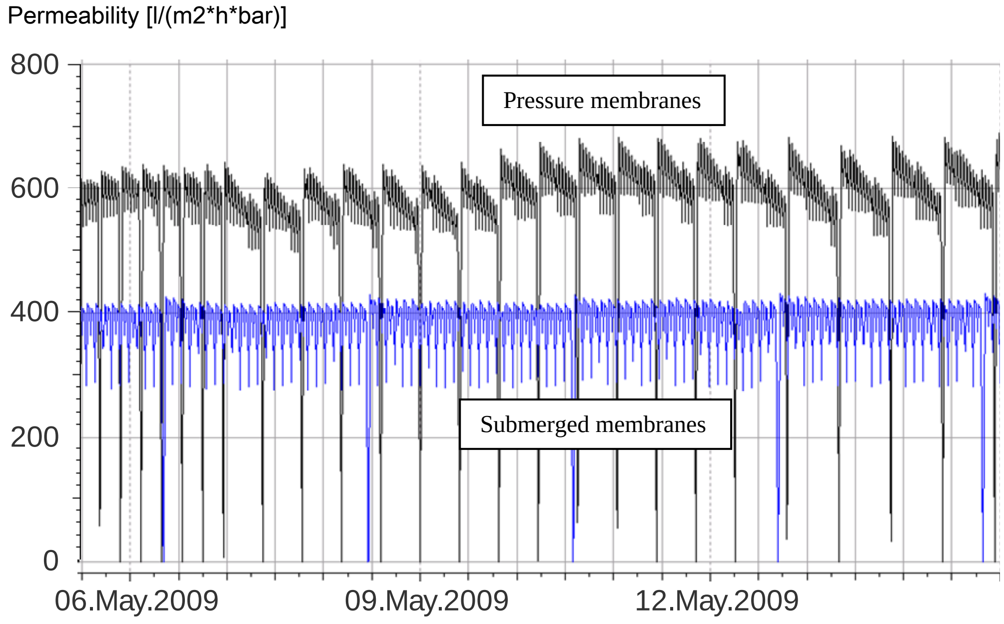
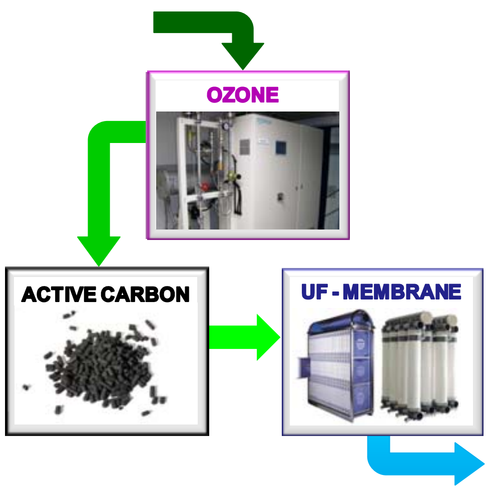
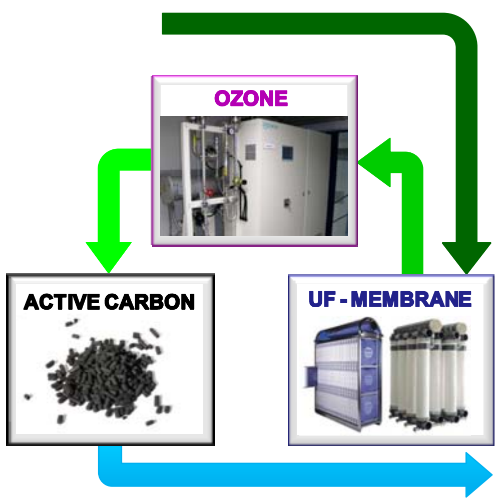


Figure 7: UF as first treatment stage

The submerged system is working stable at a permeability level of 400 lmh, it showed no reaction to changing water characteristics and a CEB with NaOCl was only performed once every 36 h. The pressure membranes can be driven at a 50% higher flux rate but need CEB every 6 – 12 h. An increased organic load of the feed water calls rather for submerged membrane systems; pressure membranes though have their main advantage in the higher flux rates applicable. Both membrane systems should be evaluated for surface water treatment; the final choice is also depending on the place of the membrane stage in the multi barrier system (Picture 3a + 3b).



Picture 3a: 3-stage MBS for lower loaded surface water



Picture 3b: 3-stage MBS for higher loaded surface water

Both process configurations have their advantages:

for membranes being the final stage of a MBS

- organic load is kept away leading to higher permeability, stable operating conditions, less chemical consumption, higher life expectancy

for membranes being the first stage of a MBS

- particular organic and inorganic matter is removed, making the ozonation and AC-stage more economical, due to lesser ozone consumption and higher life expectancy of the activated carbon

CONCLUSION

Membranes have become an asset to multi barrier systems for the treatment of surface water. Membranes allow a reduction or a scale down of treatment stages and improve the water quality; in particular by reducing bacteria and virus to levels $< 1*10^{-6}$, so the drinking water becomes extremely safe in this respect. When membrane technology is applied for the treatment of used back wash water, the recycling of such water is no longer to be regarded critical.

By implementing optimised operational data into the daily operation, membranes can be run more economically due to their prolonged life time.

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