Two Stage Ultrafiltration for Drinking Water Treatment– Summary
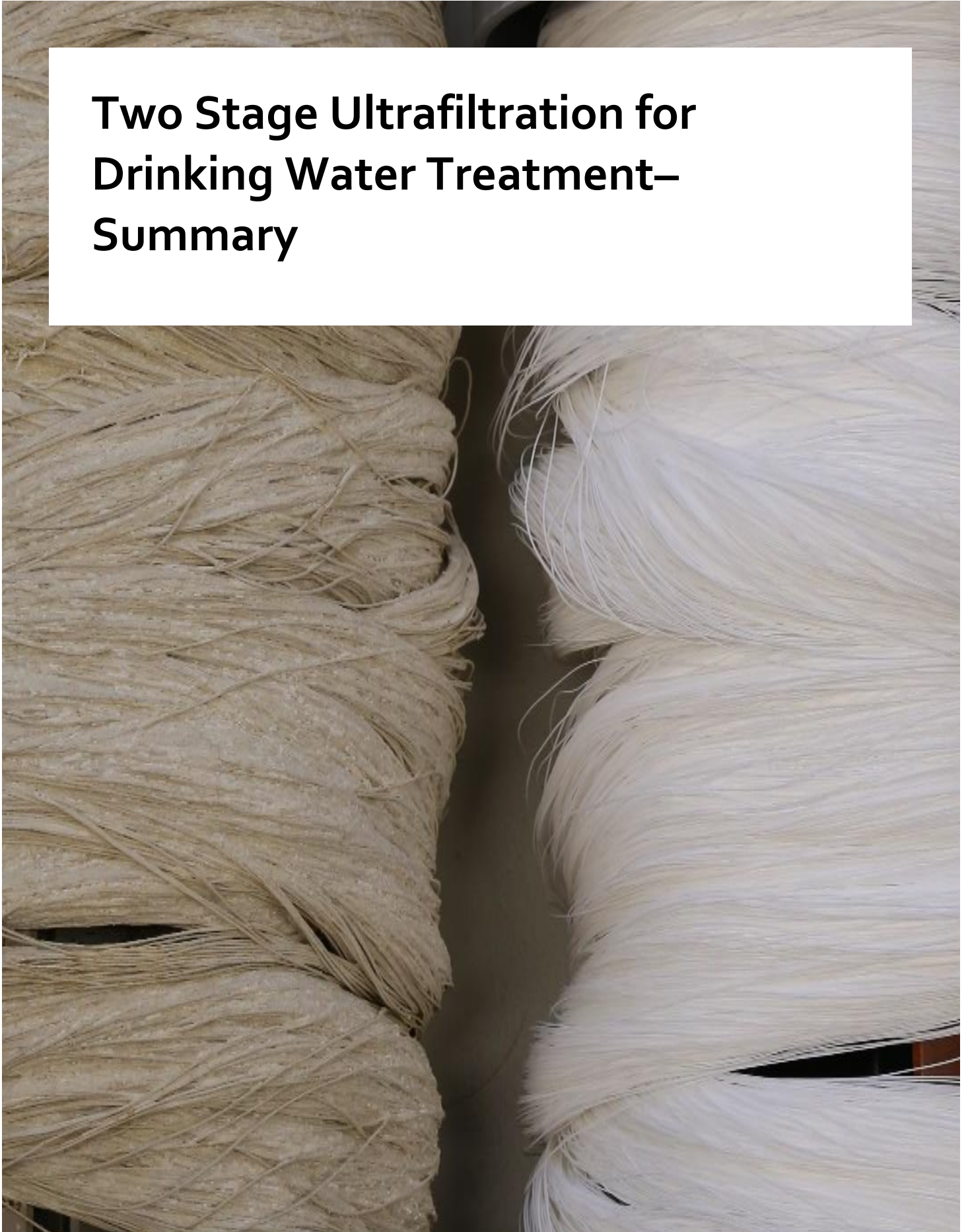
Two Stage Ultrafiltration for Drinking Water Treatment– Summary

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Content

1 Challenges and objectives

In Austria, water supply services rely almost only on ground water or spring water resources. In many cases, these water resources can be used as drinking water without any further treatment. Quite often, even without disinfection. However, occasionally occurring turbidity (spring water) or pollution by humic substances (groundwater) can be present in many of these resources. These substances can cause potential problems within the distribution network or in relation to conventional disinfection methods (chlorine, ozone or UV).

Generally, membrane filtration has been proven to retain microbiological contaminants. Since membrane filtration processes do not change the water chemistry, there is no decomposition of humic substances, and no additional substrates for enhanced microbiological aftergrowth are created. Furthermore turbidity does not affect the performance of membrane filtration.

Nevertheless, so far no membrane filtration plants are built without downstream disinfection measures. This is since the risk of an undetected integrity failure of single membrane modules or fibres.

The objective of the research project is to provide evidence for the applicability of a two-stage membrane concept (two-stage ultrafiltration - UF2) as an alternative treatment method. The concept shows high reliability against undetected integrity failures and thus, can be used without any downstream disinfection measures.

2 Solution–The UF2 concept

The idea is based on two principles: (i) the concept of the two-stage ultrafiltration (UF2) to achieve a high level of reliability against undetected integrity failures and (ii) the possibility of improving the treatment performance with regard to relevant substances in drinking water resources by using a modified ultrafiltration membrane as a second stage.

Firstly, by the two-stage concept the second, downstream ultrafiltration membrane is protected against damage from water born particles by the first stage membrane. Secondly, this setup helps to meet the requirement for highest safety level against an undetected integrity failure of the whole filter system by the use of automated integrity tests. The applied integrity test (DAF = Diffusive Air Flow) is a direct and discontinuous test which is simple for automatization, cost-effective and highly sensitive.

Thus, the advantages of the purely physical type of treatment can be used. Disinfection by-products are no issue because no reactive substances are added during the process. An unsafe disinfection result due to turbidity-included bacteria is impossible, since the UF membrane largely retains particles.

By modification of the ultrafiltration fibres (as the second stage of the plant), a smaller nominal pore size is created. The modification is done either by a permanent coating of the membrane surface or by altering the production process of the hollow fibre membranes (stretch factor). There are advantages and disadvantages with each of the methods. In the present research project, the modification was realized via the change of the stretch factor.

The simplified flow scheme of the pilot plant is shown in Figure 1. The raw water is pumped by the feed pump through the two serial ultrafiltration membranes. Treated water for backwashing is buffered in a subsequent storage tank. The treated water constantly flows through the tank to prevent stagnation.

Backwashing takes place according to scheduled intervals or is based on condition-oriented parameters (trans membrane pressure - TMP). Coming from the permeate side, treated water from the storage tank flows backwards through the membrane and removes particles from the membranes feed side surface. The backwash flow is induced by compressed air only which is further used for the DAF integrity test. There is no need for an additional backwash pump. Right after backwashing, the DAF integrity test starts.

Figure 1: Simplified scheme of the pilot plant

UF2 Pilot plant scheme
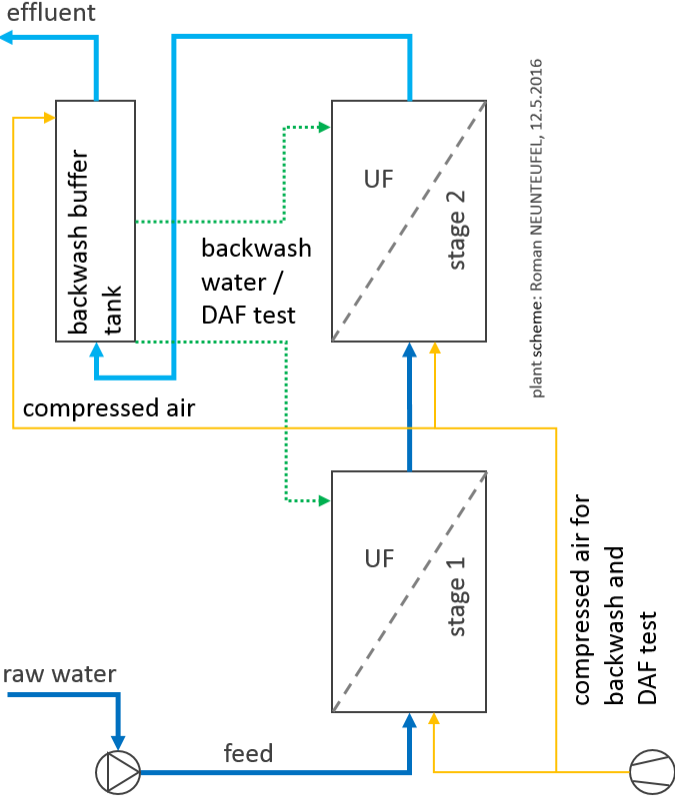
3 Experimental setup–Overview

The experiments were divided into three phases:

1) Pilot operation in order to determine operational parameters including energy consumption (operating costs) and DAF thresholds of the integrity tests.
2) Challenge tests in order to analyse the bacterial and viral retention (MS2 phages were used as a surrogate for viruses), the retention of micro pollutants and the long-term durability against biofilm penetration (pseudomonas aeruginosa) through the membranes.
3) Field test in order to assess the retention of humic substances. As the laboratory can't produce humic acids identical to the once in native waters nor in sufficient volume for a continuous operation, the pilot plant was moved to a water supply utility suffering from a well that carries humic substances.

4 Summary of the Results

4.1 Operational parameters

As for the degree of fouling of the membranes, different total pressure losses occur across the entire system. In the course of the pilot plant operation, total pressure losses between 1.3 bar and 3.3 bar were found. At higher pressure losses, the system would automatically go for a backwash cycle or shut down completely. With an electricity price of € 0.18 per kWh, maximum costs of about 14 cents per m³ apply. The average electricity consumption and cost range per m³ permeate production is 0.4 kWh and 7 cents, respectively. By optimizing the feed pump the energy costs could be cut to 3.5 cents per m³. Other power consumption of the system than the feed pump is negligible.

In total the running costs (energy consumption of a well-optimized pump) and the investment and reinvestment costs (membrane replacement), amount to about € 0.35 per m³. This is under the assumption of a useful life of the whole plant of 10 years and annual membrane replacement. With an extended service life of 20 years and biannual membrane replacement only, costs of less than 20 cents per m³ are easily possible.

The lowest possible DAF limits that were met by every automated integrity test were determined to be at 20 mln / min (mililiter of air at normalized pressure per minute). According to the membrane manufacturer, compliance with a DAF value of 60 mln / min is sufficient to prove the integrity of the membrane.

4.2 Challenge-Tests–microbiological and micropolutants retention

The UF Membranes showed a very good performance with regard to the retention of E.Coli, Coliform bacteria, Enterococci and Pseudomonas aeruginosa. The required log4 reduction were met by the membranes. The two-stage concept offers high safety against short-term bacterial contamination. The average retention of MS2 phages was about 80% with a bandwidth of 55% to 88%.

With regard to the long-term durability against biofilm penetration (pseudomonas aeruginosa) through the membranes, no clear result were obtained for the "worst case scenario" (high water temperature 25 °C and more and continuous recontamination of the raw water). Under "normal conditions" and under "normal conditions with increased nutrient

availability" (water temperature 18 - 20 ° C, continuous recontamination of the raw water and glucose dosage, respectively) no contamination of permeate with Pseudomonas aeruginosa were detected, even in large sample volumes of up to 5 liters and after a period up to 2 months.

For the micro pollutants carbamazepine, diclofenac, simazine, atrazine and diuron no significant removals by the ultrafiltration membranes were found. However, there is a tendency for an improved removal by means of the two-stage ultrafiltration when flocculants are added to the raw water. However, these findings need to be interpreted carefully and with regard to the high analytical uncertainties within the range of micro pollutant concentrations.

4.3 Field test–retention of humic substances

The humic acid retention potential was analysed by means of the parameters DOC, SAC, UV-VIS spectra and the molar masses (determination by means of HPLC).

The predominant humic substances present in the native water resource were found to be fulvic acids (low-molecular humic substances). As for their small size these substances could not be removed with the sole ultrafiltration. However, adding a little flocculant to the raw water increased the reduction rate of the two stage ultrafiltration substantially. Up to 75% to 80% of the humic substances were removed.

This leads to the conclusion that the two-stage membrane filtration supported by flocculant is particularly suitable for the treatment of waters that carry humic substances which potentially cause problems with oxidative or UV treatment processes.