ULTRAFILTRATION Pre-Test (UFPT)
First experiences with a small size Ultrafiltration test system as a quick performance test

Martin König[a], Norbert Selzer[a], Adam Tymoszewski[b], Jan Pagel[c]

[a] Membrana GmbH, D-42289 Wuppertal, Öhder Str.28, Germany, Tel.+49(0)202 6099-0

[b] Student during his Master Thesis at Membrana GmbH

[c] Student during his Bachelor Thesis at Membrana GmbH

Email: martin.koenig@membrana.de; norbert.selzer@membrana.de; tymoszewski@gmail.com; J.Pagel@uni-wuppertal.de

Keywords: Ultrafiltration, Membrane, In-Out, PES, Pre-Test, Performance Test

1. Background

Performing a pilot test for an Ultrafiltration system to generate information about the behaviour of the membrane with specific water quality is often difficult. There are various reasons for this difficulty, including lack of time, limited resources, or concerns about high installation costs of a pilot system with a large test module at an early stage of a planning. However, because water quality varies greatly between raw water sources it is very important to obtain initial data on whether a reasonable operation is possible.

2. Test System Design

Given these challenges the idea was to develop a small scale test set-up for gaining Ultrafiltration membrane performance data using a small amount of original water, for example a canister with 20 or 30 liter.

The test module should contain original Ultrafiltration membrane of similar length to a standard UF module, but be reduced in size by using fewer fibers. Therefore it was decided to use a module with 10 fibers of UltraPES™ 0.8 hollow fiber membrane representing a filtration area of approx. 0.02m². The length was fixed to 1.0m, which is slightly shorter than the standard Liqui-Flux® W10 module with 1.25m length. This length allows for easy transportation to a customer's site. The 10 fibers are potted into a PVC housing made from standard tubing with 10mm outer diameter.

The easiest way to feed raw water to the module is to use hydrostatic pressure by installing a simple small tank hanging 3 m above the module. This ensures a pulsation free and stable feed pressure.

The permeate quantity is determined by gravimetric measurement with a scale. Backwashing the module can be performed in a defined mode using the collected filtrate.

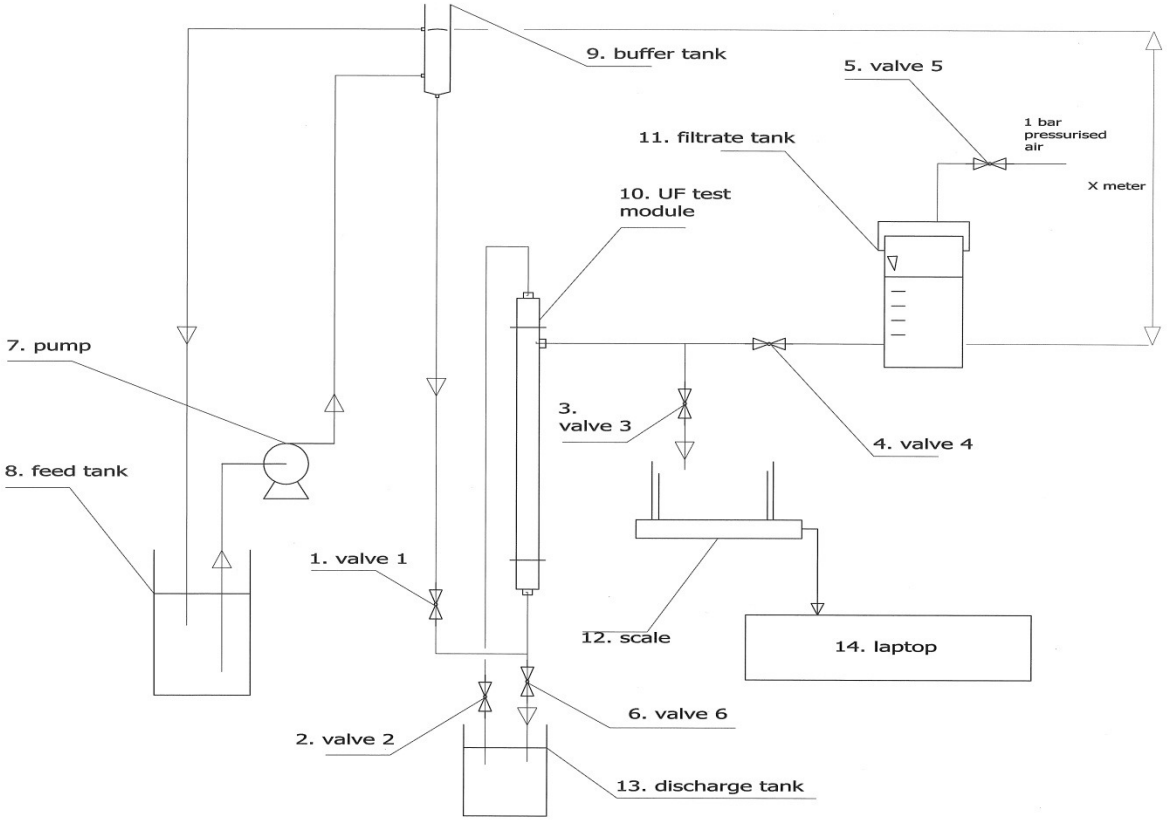

Figure 1: PID of the UF Pre-Test

All the needed equipment can easily be found in any basic laboratory.

3. First results

Different water qualities were tested with a stable feed pressure of 0.3 bar. Each water source was tested using a new module with 0.02 m². The filtration interval was set to 60 minutes, followed by a backwash with filtrate at 1.0 bar for 45 seconds.

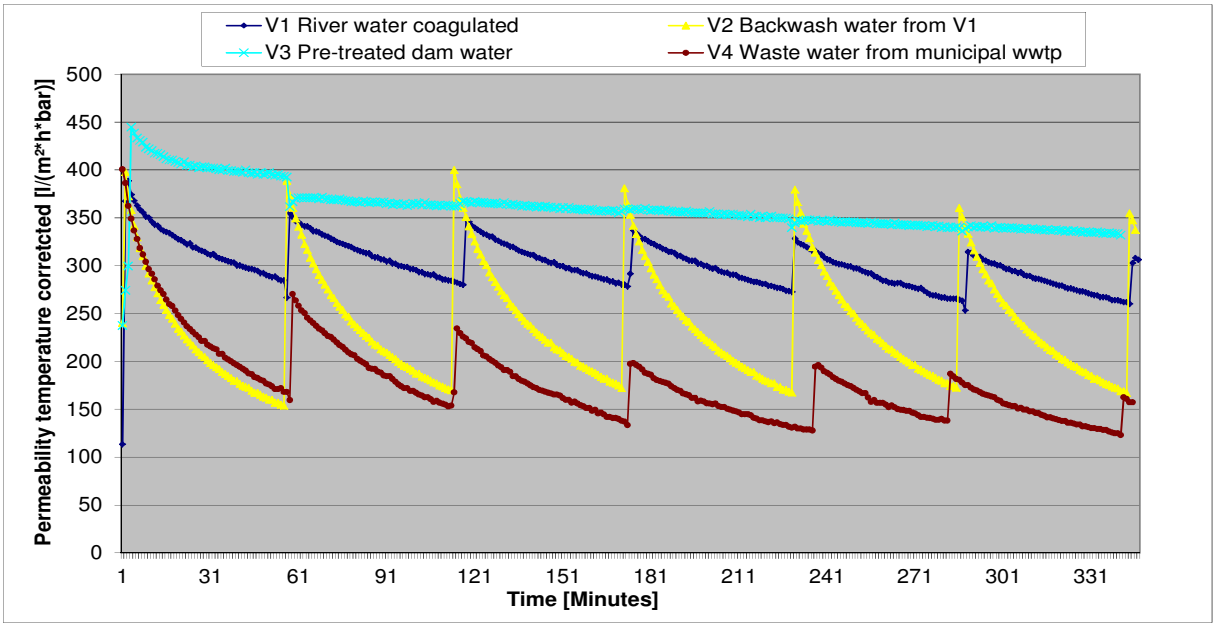

Figure 2: UF Pre-Test with different feed water qualities at a tmp of 0.3 bar; backwash @ 1bar

In sample V1, the river water coagulated with Polyaluminiumchloride, showed a relatively high permeability with a low decrease over time. In sample V2, using the backwash water from sample V1, results showed a high loss of permeability in each filtration interval, which is explained by the high solid content. However, V2 showed very good recovery after each backwash compared to sample V4 where the tertiary waste water from the municipal WWTP had a strong decrease of permeability and relative low recovery after backwash. Comparatively, the pre-filtered dam water in sample V3 from the company's water system showed a low decrease of permeability over time. Solid content was negligible, so a slower decrease overall was expected.

It was observed that the backwash in the small system was operating well, as recovery was on the same relative scale as a larger module system with 75m² membrane area.

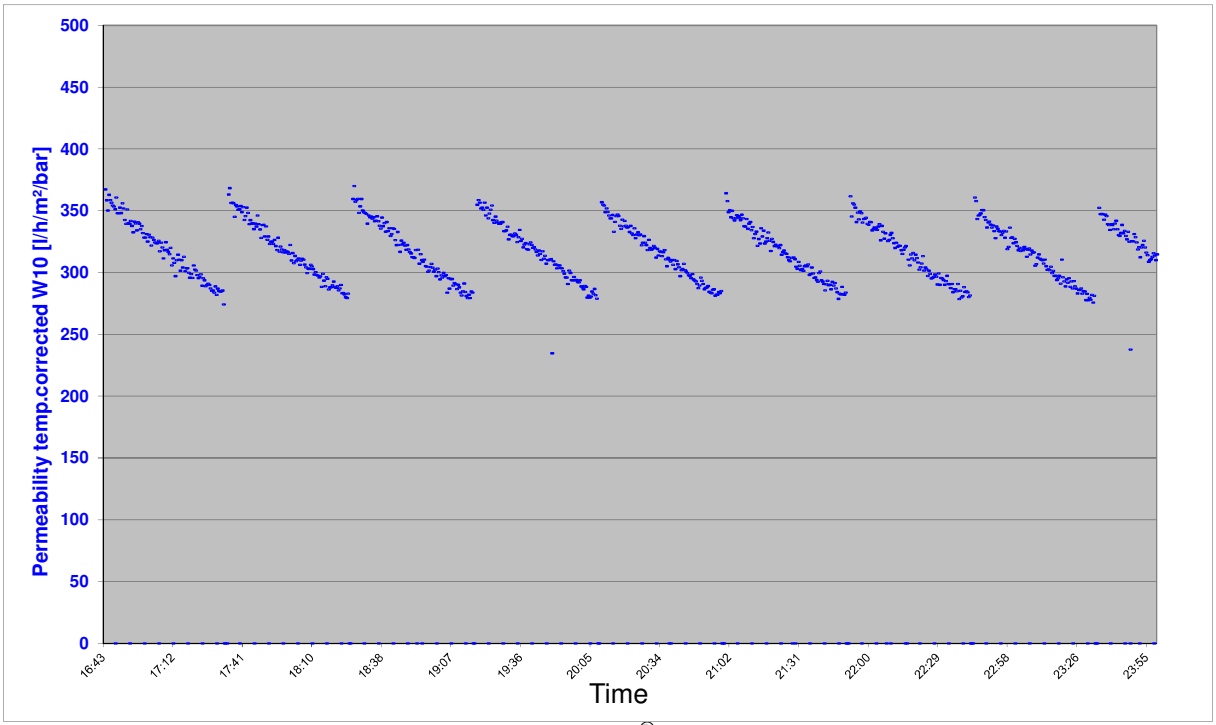

Figure 3: Part of a graph from a 75m² Liqui-Flux® W10 module for comparison; Wupper river water filtration at 89 lmh; backwash every 50 minutes

These first results were encouraging as different water qualities showed characteristic courses in permeability depending on the composition of the water. Also the fourth water source (V4) using the treated water from the municipal waste water treatment plant, showed behaviour that was very similar to what had been observed with the large scale module.

Comparing the data collected from the trials with large scale pilot systems provided confidence that tests with the UFPT module will be able to reflect results very similar to operating a large scale module.

4. Optimization & further tests

While the first results were encouraging it was recognized that a filtration time of 6 hours was not sufficient for all water sources to clearly show differences in the Ultrafiltration Pre-Test (UFPT), such as water quality, the test itself or a combination of both. Therefore, a more sensitive test was devised in order to verify its usefulness as an indicator of a large-scale

system. Modifications were introduced to generate more stress for the test module. In addition the influence of the coagulation was to be tested.

The following parameters were tested:

- Influence of coagulation (general test to verify the function)
- Test time (12h instead of 6h to have a longer test time and more fouling on the membrane)
- Feed pressure of 0.5 bar instead of 0.3 bar
- Preloading the membrane by doing no backwash during the first 5 hours
- Test of modules with shorter length

Results:

Influence of coagulation

Figure 4 shows the difference between river water (Wupper) with coagulation with PACl and without. The change is significant and shows a much better performance with 0.4 ppm Al/l Polyaluminiumchloride.

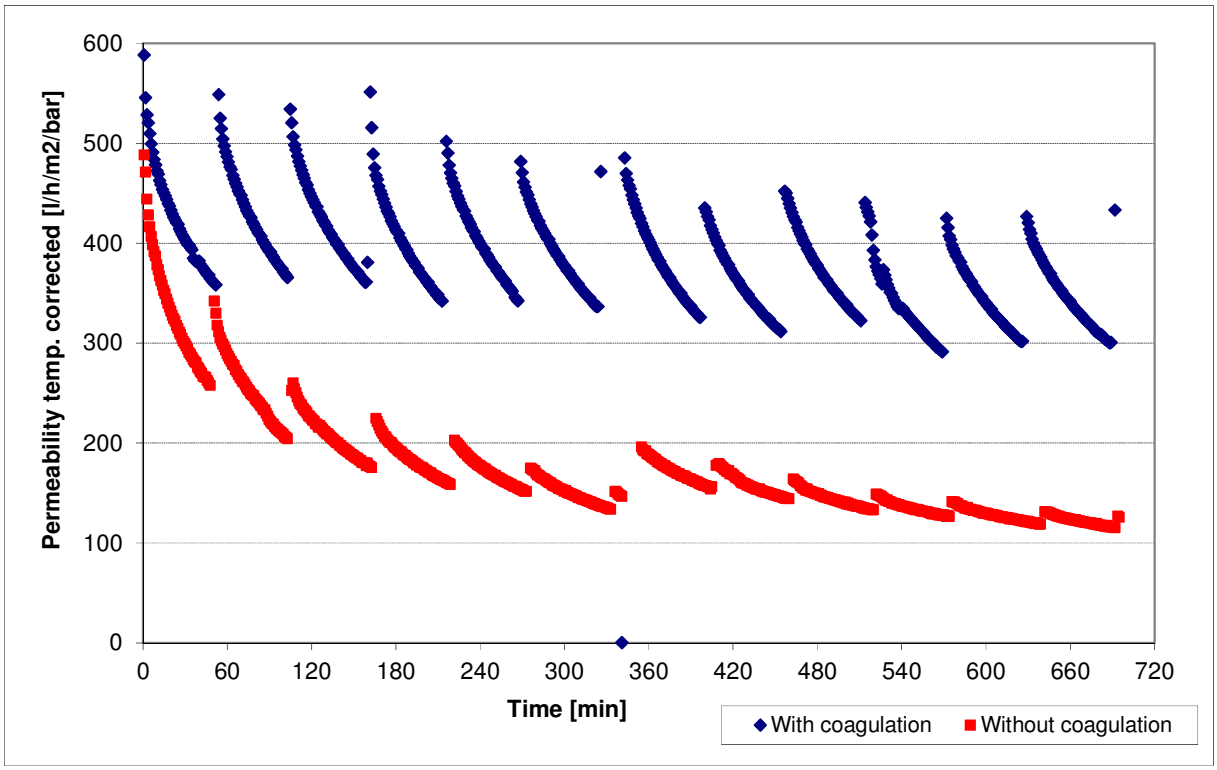

Figure 4: UF Pre-Test of river water (Wupper) with and without PACl coagulation (1000mm module length at 0.54 bar tmp)

Similar behaviour was observed in tests using Liqui-Flux® W10 modules with 75m^2 membrane area for filtering Wupper river water when coagulation was used. After several hours of filtration without coagulation the tmp of the W10 module increased from 0.3 bar to more than 1.2 bar.

The test shown in figure 4 ran for six hours on the first day and additional 6 hours the next day. For logistic reasons there was a break of approximately 15 h between the first and second set of six-hour periods of filtration. This test shows that with coagulation permeability

stabilized after the 8th filtration interval. Without coagulation permeability continuously decreased, only during the 15 hour break a small recovery was observed.

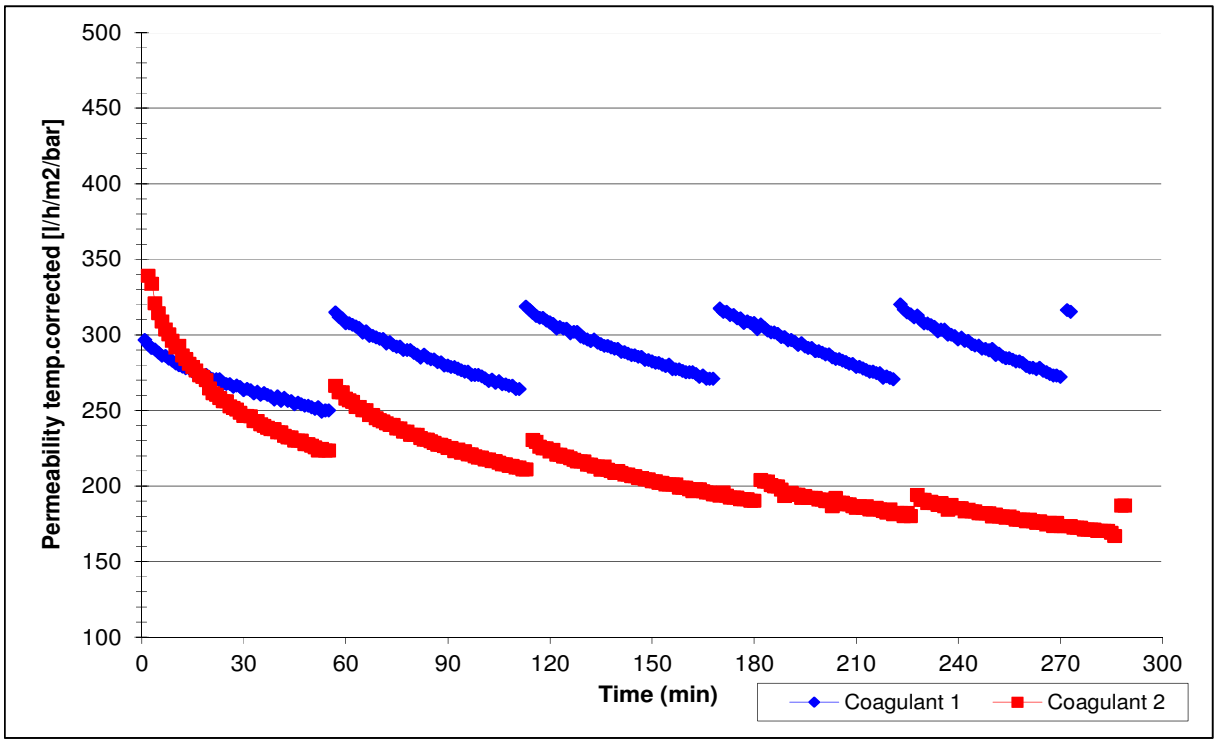

Figure 5: UF Pre-Test of well water with two different kind of PACl coagulation (1000mm module length and 0.54 bar tmp)

In another experiment we compared two different coagulants. As shown in figure 5 a big difference between the two Polyaluminiumchlorides is obvious. However, the relatively low starting point of coagulant 1 could not be explained.

Test time & feed pressure

Looking at figure 4 it is clear that a longer test is more conclusive. In this case, stability was reached after 8 hours using water with coagulation. Without coagulation a stable flux was not even reached after 12 hours of filtration, but the high loss in permeability during the first 6 hours provides a good indication about the inadequate filterability of this water.

In general a 12 hour test is recommended compared to a 6 h test. In most cases a break will be required.

Preloading by doing no backwash during the first 5 hours

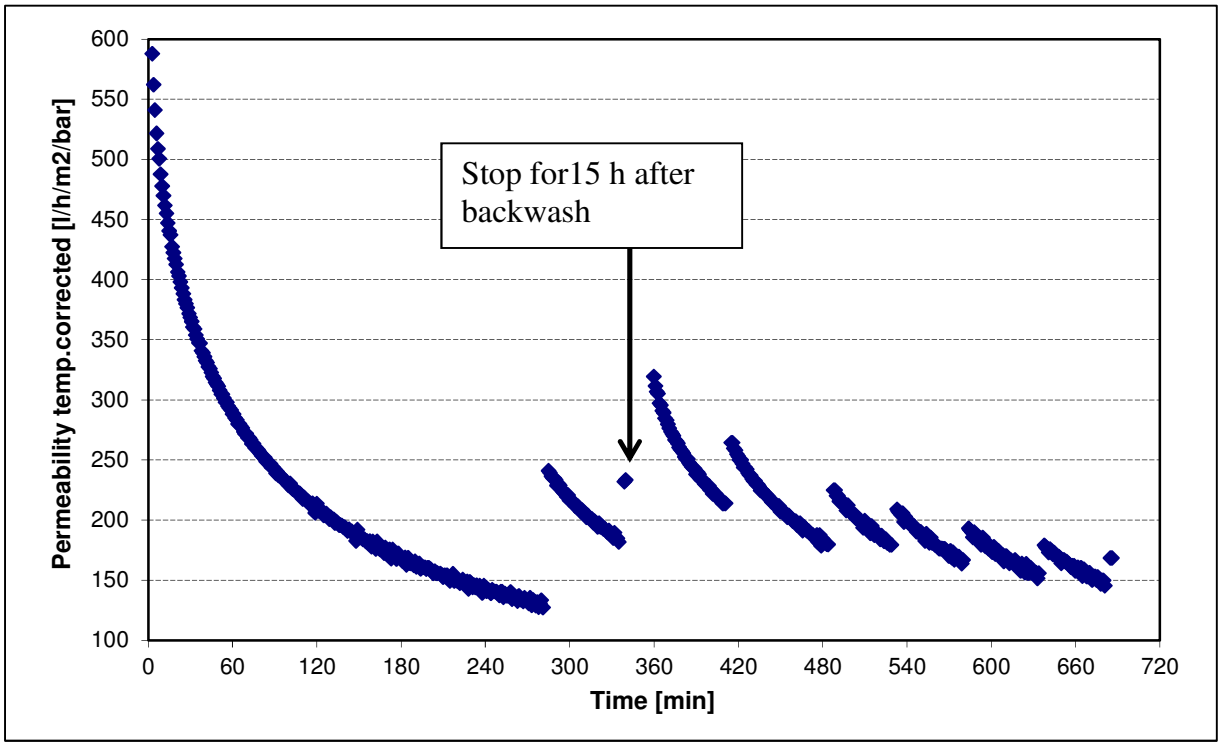

Figure 6: River water (Wupper);TMP=0.54 bar; module length=350mm; no coagulation; after 360 min. stop for 15 h

The UF Pre-Test shown in figure 6 was done with a shorter module (350mm length instead of 1000mm) at 0.54 bar tmp without coagulation. No backwash was performed during the first 280 minutes. During this time period the permeability decreased from approximately 600 to 130 lmh/bar. Comparing this result with the graph of the coagulated water in figure 4 a reduction of the permeability to about 150 lmh/bar after 5 h can be observed in both trials.

Therefore it seems that the shorter module in combination with doing no backwash for the first 5 hours will not lead to significantly more stress in the form of more fouling or lower permeability with the Wupper river water.

Based on these observations, it was decided that a length of 1000mm was sufficient. In this case there is a larger volume in the lumen of the fibers to accumulate solids, which is an advantage in the presence of higher solid content in the feed water and the dimensions are closer to the industrial scale module length of 1250mm.

5. Estimation of flux, filtration interval and CEB interval for a design proposal

Using the results from an Ultrafiltration Pre-Test of course need to be evaluated carefully, as the test only reflects a short period of time. However, the experiments show that the permeability with the examined water sources normally stabilizes after several hours.

To deduce a design flux from the UFPT results one may be able to use permeability after stabilization. For example, taking the average permeability of the 11th filtration interval with coagulation (figure 4), at a tmp of 0.54 bar, could be multiplied with a “standard” tmp of 0.3 bar to obtain the design flux value. 0.3 bar was chosen as this value normally generates a stable filtration.

Alternatively the average flux of the sixth hour could be used to estimate the design flux value, multiplied by a safety factor of 0.7-0.8 to account for the possibility that the permeability has not reached a stable level.

The filtration interval should be chosen based on the obtained data. If the data indicate a stable permeability at the end of the test, the 60 minute filtration interval used in the test might be useful for the design proposal. If permeability did not stabilize during the test an additional safety factor may be reasonable.

The determination of the CEB interval is also a challenge. In general the higher the permeability loss in 6 or 12 h is observed the more often a CEB might be necessary.

6. Discussion

The UF Pre-Test is easy to use and shows comparable results to field data with industrial scale modules, when applied to different water sources by using a tmp of about 0.5 bar. Also the backwash and the coagulation are working properly and are comparable to what has been observed in our large pilot system.

The testing time should be at least 6 h with 12 h being recommended.

Interruptions of the test seem only to have a negligible influence.

Given the results, potential UF users are able to perform the test within 1-2 days and generate data that is suitable to use when making decisions how to proceed with the planning of an UF-System. In many cases the data can be used for a first design proposal and to calculate a budget price.

Some work is still needed to set up algorithms for estimating the flux, filtration interval and CEB interval to improve the safety of a calculation for a design proposal.

Nevertheless the test can be done in quite a short time frame, and it is suitable for water sources that do not show wide variations over weeks or months. In case the variations are bigger the UFPT needs to be repeated several times or pilot testing for a longer time period should be considered.

Turbidity, SDI or other parameters can be determined with the UFPT in order to evaluate the filtrate quality and to complete the design proposal.

References

Bachelor Thesis of Jan Pagel: “Entwicklung und Erprobung eines Wasserschnelltests zur Beurteilung von Wasserproben hinsichtlich ihrer Filtrierbarkeit mittel UltraPES™ Hohlfasermembranen“, Bergische Universität, Wuppertal, 2011