Modern reverse osmosis system with retentate treatment

Households in Baden-Baden, Germany, have been supplied with softer, largely PFC-free drinking water since August 2018. To make this possible, a low-pressure reverse osmosis system (**Fig. 1**) with retentate treatment was installed in the Oberwald groundwater plant after a complete renovation and extension. Activated carbon filtration eliminates PFC from the concentrated retentate before the retentate is fed into the discharge system. This is probably the first time that this process technology has been used in such a configuration in Germany and probably also in Europe.

Water demand

When the spring water supply is sufficient, up to 80% of water requirements for the city's approx. 55,000 inhabitants are covered by soft spring water. In summer, flows from springs are greatly reduced, so harder groundwater is needed to cover up to 90% of water requirements. The possibility of a complete loss of spring water was also taken into account when the Oberwald groundwater plant treatment system was newly conceived. As a result, the groundwater plant must be able to cover the entire water demand. The use of spring waters and groundwaters with different hardness levels means there are two supply zones: one where only spring water is used and a mixed water zone where the hardness fluctuates between 1,5 and 2,2 mmol/L depending on the time of year. When the Oberwald waterworks in Sandweier was renovated due to ageing, the project also aimed to treat groundwater in such way that the water hardness would be reduced to between 1,5 and 2,2 mmol/L.

PFC problem

In summer 2013, a study was carried out into per- or polyfluoroalkyl chemicals (PFCs) drinking water treatment plants in response to a directive from the Rastatt and Baden-Baden Public Health Department. During the study, PFC was detected in different deep groundwater catchment wells while spring waters were found to be free of these compounds. Treatment measures became essential due to the steadily increasing contamination levels in the drinking water wells and the newly adapted requirements imposed by the responsible Public Health Department in spring 2017.
The municipal utility company needed to expand its existing concept plan for a groundwater softening facility to include a low-pressure reverse osmosis system to reduce PFCs. This required a significant increase in treatment capacity and, consequently, filter performance to ensure that drinking water supply would be available even if there was a breakdown.


Source: HydroGroup®

Fig. 1 *LPRO system*

Source: HydroGroup

Fig. 2 Retentate discharge

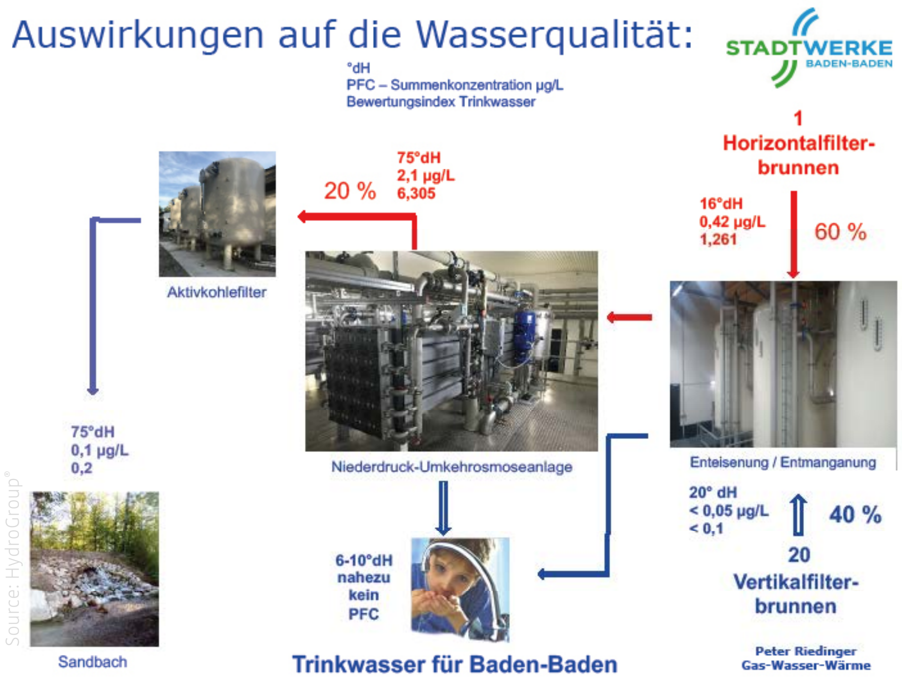
Source: Baden-Baden public utilities

Fig. 3 Pressure filter system

Retentate disposal posed a particular problem. In a normal situation, retentate was discarded into a receiving water course via a direct discharge. In Sandweier, the Sandbach brook, about 1.8 km away, was the only option in this case. Discharge of this type was not possible or was not approved for PFC-contaminated retentate. After a highly complex approval procedure under water resources law, a retentate treatment process was defined based on activated carbon in the reverse osmosis downstream. This needed to be taken into account as another factor in plans. Two parallel pipelines were provided to ensure that the retentate discharge could continue to operate in the event of a malfunction and repairs (**Fig. 2**) .

Process engineering implementation

The existing pre-aeration and deacidification system and the technically outdated open sand filter system were gradually taken out of operation during 2014 and 2015. They were replaced by an additional, fully automatic, closed pressure filter system (**Fig. 3**) with six filter vessels in a newly constructed section of the building. These six filter vessels plus the existing four deferrization and demanganization pressure filters form a ten-filter system, which delivers a maximum treatment capacity of 1,500 m^3/h. The existing four pressure filters were also fully automated as part of this construction stage. Due to the PFC problem that is now known, a separate raw water feed was installed from the vertical springs and the horizontal spring in such a way that the PFC-contaminated water can be treated separately via directly assigned filter lines. The total of ten filter vessels can treat the horizontal filter spring waters and/or the vertical filter springs separately in partial load operation, depending on the water catchment situation. As a result, a PFC-contaminated volume flow can be fed directly into the low-pressure reverse osmosis system while the second non-contaminated volume flow can be fed directly onto the downstream flatbed aerator (**Fig. 4**). Instead of the open aeration, the oxygen enrichment required before filtration for oxidation is provided by regulated compressed aeration into the raw water feed pipe to the pressure filter concerned. The elimination of open aeration means that excess carbon dioxide is no longer discharged. The compressed aeration in the pressure system thus produces pure water with a significantly higher CO$_2$ content or lower pH value. As a result, measures to adjust pH levels or stabilise chemical corrosion were implemented in the form of regulated downstream flatbed aerators when the process engineering system was replaced. A total of three downstream flatbed aerators (**Fig. 5**) were installed with



Source: HydroGroup®

Fig. 4 Treatment system diagram

Fig. 5 *Flatbed aerator*

Fig. 6 *Open filter system*

Fig. 7 *Pipe basement*

an overall throughput rate of 1,350 m^3/hour. The filter systems feed the two-chamber pure water tanks with a total capacity of 1,200 m^3, from which water is conveyed to the central Tannenweg and Annaberg elevated tanks. The water quantity required per flushing process is also taken from the pure water tank. The backwash water ends up in a sedimentation tank.

Low-pressure reverse osmosis system (LPRO system)

The public utilities' plan envisaged that the existing buildings would be reused to a large extent since they were in good condition. The largest building contained the open filter system, which was taken out of service once the new pressure filters had been commissioned. The space above the filters, partially recessed into the floor, was more than enough (**Fig. 6**) to house both the deacidification systems and the nanofiltration systems. Demolition of the solid concrete walls was deemed infeasible for reasons of cost. These walls were obviously buttressed since one filter was converted into a pipe basement (**Fig. 7**). Holes needed to be drilled in or cut out of concrete walls about 1.5 m thick, which involved not inconsiderable effort. An end-to-end bearing structure made of structurally dimensioned steel girders was installed over the filter walls to house the system components. The old system's waste pumps and blowers were demolished to make way for retentate treatment piping, the CIP system (**Fig. 8**) and the anti-scalant dosing system.

Treatment in the nanofiltration system has been designed to achieve a hardness within a range between 1,5 and 2 mmol/L after processing and complete PFC removal downstream from the system with a permeate treatment capacity of 600 m^3/h. Variations in volumes of up to about 20% also needed to be taken into account. The treatment capacity was divided between six racks, each with a permeate capacity of 100 m^3/h and a maximum feed of 125 m^3/h. Toray TMH20A-440 modules were used, proving themselves to be an eminently suitable solution for this problem. A maximum yield of 80% was determined due to the downstream retentate treatment and the long discharge pipe to minimise the risk of efflorescence on the activated carbon.

No factory pre-assembled membrane racks could be used due to the need to house the systems in the existing building with its highly restrictive access openings. This is why Knappe Composites' innovative system pressure pipes were selected since they could be used to create highly space-saving module racks assembled on site. The racks are highly accessible all the way round and thus operator- and maintenance-friendly thanks to

Fig. 8 CIP station

Fig. 9 LPRO rack with switchgear assembly

Photos: HydroGroup®

Fig. 10 Activated carbon filter to treat retentate

the raw water feed to the systems beneath the bearing structure and the pipelines for permeate, retentate and CIP above. Optimally efficient vertical centrifugal pumps have been fitted and operate via frequency converters.

Switchgear assembly

The power distribution and switchgear assembly for the LPRO racks (**Fig. 9**) have also been installed in the filter room. The power distribution and switchgear assembly for the deacidification and pressure filter systems have been installed in an intermediate building. Both switchgear assemblies communicate with one another via a glass fibre cable and can be fully monitored and controlled on the 15” touch panel built into each switchgear assembly. A remote client is also installed in the control room to establish communication to the public utilities’ network control centre, thus guaranteeing remote monitoring.

Retentate treatment

The activated carbon filters for retentate treatment have been installed outdoors (**Fig. 10**). The approval under water resources law for retentate discharge requires strict compliance with the discharge levels. This also applies to the mandatory anti-scalant and its concentration.

Three activated carbon filters have been installed, although a maximum of two are operated at the same time. The third filter is not switched on until one filter is no longer effective. The water volumes channelled via the filters are measured and recorded on a continuous basis as are the retentate volumes released into the Sandbach brook. The filters feature thermal insulation and are equipped with connections to flush out used activated carbon and jet in the new carbon.

Costs

The investment costs for the entire low-pressure reverse osmosis system with retentate treatment came to around €3,250,000. This amount includes the costs for systems engineering, the building conversion, all pipeline construction work and the retentate treatment. The city of Baden-Baden’s water catchment systems are now state-of-the-art after this latest major investment.

It is known that PFCs entered extensively into the environment due to agricultural land use. There is concrete evidence that contaminated compost mix was applied to the majority of polluted surfaces.

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