hall A2, stand 110

LARGE ULTRAFILTRATION SYSTEM FOR INDUSTRIAL WASTE WATER RE-USE IN TURKEY

In 2006 the Turkish company Arbiogaz from Istanbul received the order for upgrading an existing Waste Water Treatment Plant (WWTP). Arbiogaz with expertise in providing turn-key plants was asked to install a two-stage membrane system, combining ultrafiltration (UF) and reverse-osmosis (RO) with a capacity of 50,000 m³ per day (50 MLD). Membrana GmbH supplied the UF-Modules and conducted the necessary pilot-tests. The WWTP should purify a mixture of different sources, partially pre-cleaned, industrial sewage disposals and rain water. The water quality was subject to seasonal changes.

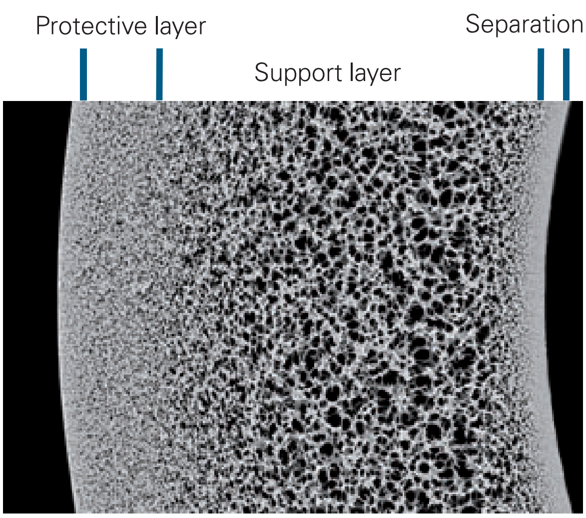
In addition to the already installed mechanical and biological treatment, the system contains a chemical treatment step, in which standard precipitation and flocculation chemicals as well as extra-chemicals for de-coloring are used. The treated waste water should be supplied back to an industrial park. The decision for installing the additional membrane system was made in order to fulfill the water quality requirements of the different industrial clients and to prevent the use of costly potable water for production purpose **(Tab. 1)**.

To reduce the salt, COD and color content from the water after the existing WWTP the installation of a reverse osmosis unit was imperative. Ultrafiltration was chosen as a pretreatment system in order to ensure consistent and efficient performance of the downstream RO-membranes. For an economical operation of the RO-system a small amount of UF-filtrate should be mixed into the RO permeate. However, this was depending on the salt content of the feed to the membrane systems as well as the permeate of the RO-system.

Timing for realization of the whole membrane system was crucial. By the end of 2006 the designing of the system had already started. Commissioning and start-up of the system was scheduled for summer 2007.

The installed ultrafiltration modules

The extremely varying raw water quality required membranes with a low fouling tendency and the ability to be cleaned effectively with cost-efficient chemicals. In addition the expected high cleaning stress requires membranes with mechanical long-term stability. All these properties can be found with UltraPES hollow fiber membranes. Made from polyethersulfone and blended with a co-polymer, it exhibits an extremely hydrophilic characteristic and stability over a wide pH-range (1 - 13). Regarding the membrane structure, UltraPES displays a pronounced asymme-



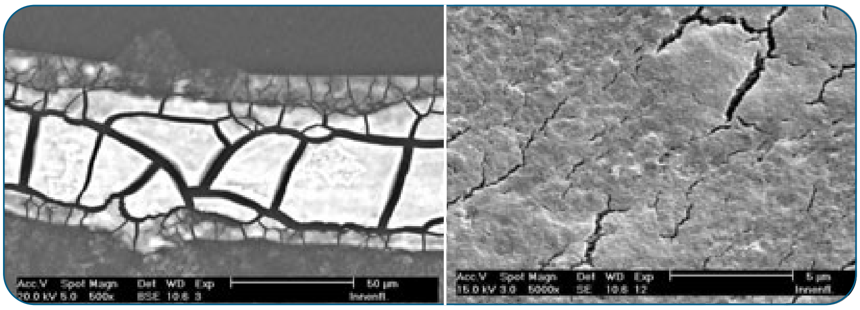
Source: Membrana GmbH

Figure 1: SEM-photo of UltraPES and principle of Multifiber P.E.T.® Technology

Source: Membrana GmbH

◀ Figure 2: Liqui-Flux® W02 with 61 sqm of filtration area

▶ Figure 3: SEM-photos of the scaling layer from the inner membrane surface taken out of the pilot-test module



Source: Membrana GmbH

tric morphology, having a distinctive three layer structure comprising of a retention layer to the inside of the membrane, a support layer providing sufficient mechanical strength through thicker polymer ligaments and a protection layer with reduced pore-size cushioning the overall membrane structure **(Fig. 1)**.

Membrana's PES membranes are known for the well-controlled pore formation process. As a consequence the UltraPES membrane exhibits a narrow pore-size distribution. The combination of such narrow pore-size distribution and asymmetric membrane structure creates an optimized relation between permeability and retention rate, leading to a low pressure drop and reduced energy consumption. Additionally, UltraPES hollow fiber membranes are stabilized by Membrana's Multifiber P.E.T.® Technology. The hollow fibers are entangled with a PET yarn, which is also potted along with the hollow fiber membranes. This technology provides mechanical support for the hollow fiber, in fiber direction as well as during bending, and it improves hydrodynamics during backwash as the yarns act as spacers between discrete bundles of hollow fiber membranes **(Fig. 1)**. UltraPES hollow fiber membranes are integrated in UF-modules of the type Liqui-Flux® W02 with 61 sqm of effective filtration area manufactured by Membrana GmbH **(Fig. 2)**. These pressure-driven inside-out formatted UF-modules feature controlled hydrodynamics in filtration mode as well as during physical cleaning by backwash. The ideal backwash performance is realized by reduced distance from outside to inside of the seven hollow fiber segments (radius <45 mm) and a moderate fiber length of 1,250 mm. Unlike UF-modules equipped with a central tube, Liqui-Flux® W02 does not use any kind of sealing like O-rings for separating the feed and filtrate side. This is an advantage, as O-rings can be seen as a weak point, for example regarding microbiological contamination.

Experience from the pilot phase

From January until August 2007, a pilot system was in operation to obtain reliable data supporting the basic system design and identifying possible interfering influences from the operation of the existing WWTP, especially the chemical treatment. Shortly after start-up of Membrana's mobile pilot-system, it became obvious that an overdosing in the existing chemical treatment step of the WWTP could lead to severe blocking of the test module **(Fig. 3)**. In the chemical laboratory of Membrana, an EDX-analysis (Energy dispersive X-ray) of the blocked membranes was conducted to examine the composition of the layer, clogging the membrane surface **(Fig. 4)**.

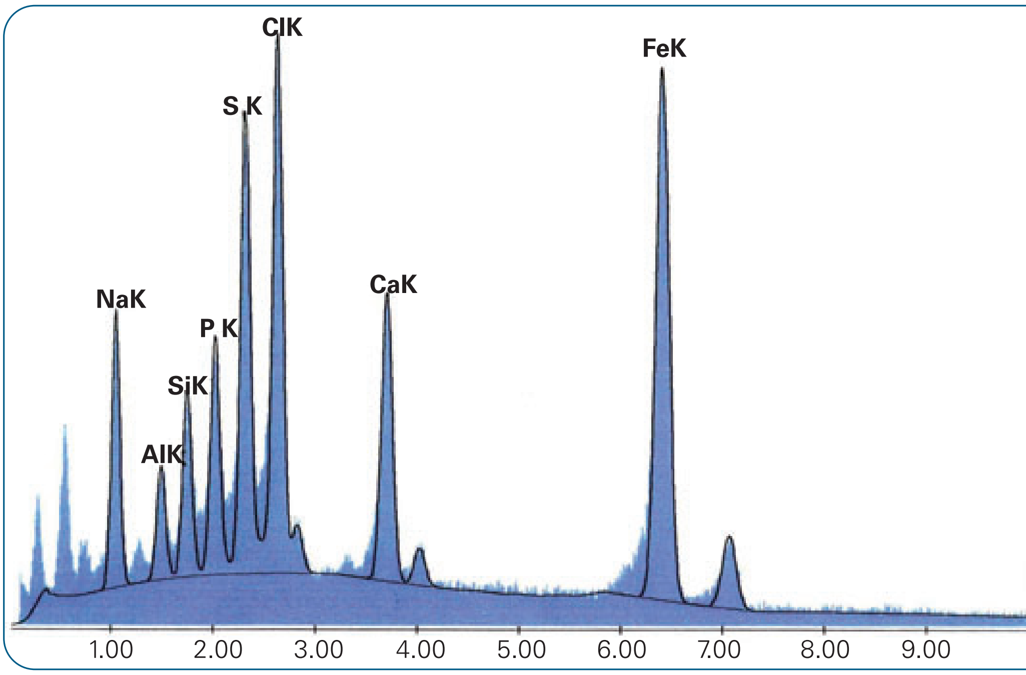


Figure 4: EDX-analysis of the scaling layer

Source: Membrana GmbH

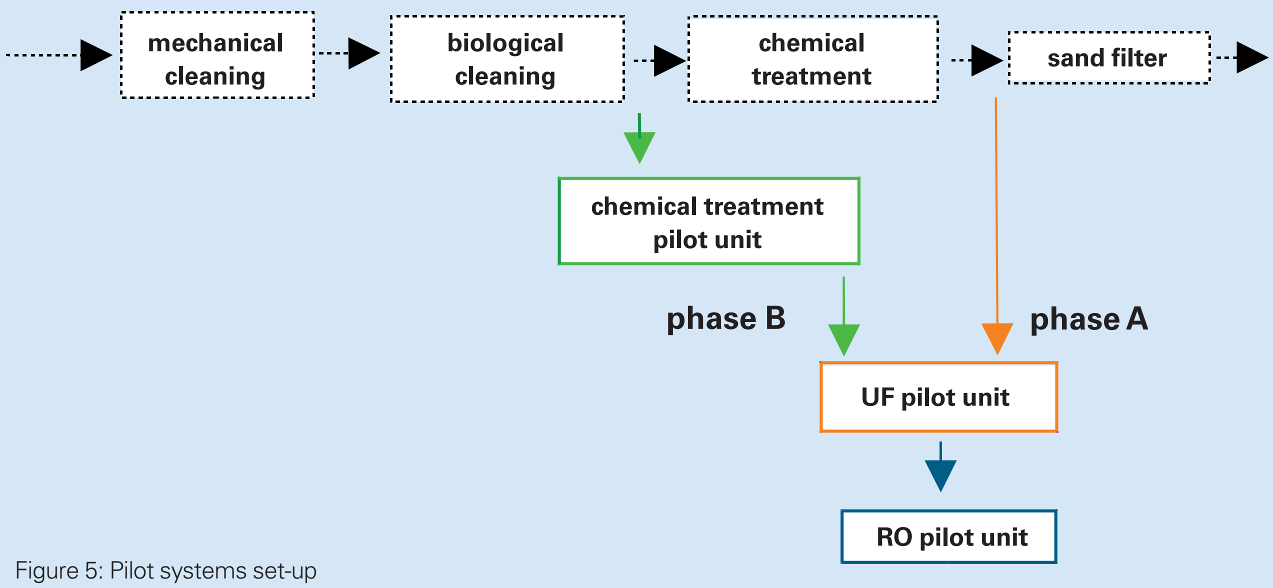


Figure 5: Pilot systems set-up

Source: Membrana GmbH

The EDX-analysis showed several inorganic substances. Cations, like iron and calcium, as well as traces of phosphate and silicates were discovered, which were an indication for a precipitation of the different chemicals in the water before the UF pilot unit. Due to such findings, it was necessary to extend the pilot operation and separate it into two phases **(Fig. 5)**. Phase A: Filtration of the cleaned water from the existing system with a focus on controlling the operation of the UF pilot unit, especially in combination of the existing chemical treatment step. Phase B: Installation of an additional chemical treatment pilot unit to simulate the existing chemical treatment system. Through such installation, it was possible to vary operating parameters of the chemical treatment, which of course could not be done in the WWTP, since a continuous supply of water from the existing WWTP had to be guaranteed.

In Phase A different parameters were checked off, such as flux rate and coagulation concentration. In addition, the operators were trained to prevent overdosing of chemicals in the WWTP. During such Phase A an operation of the pilot-unit was realized that supported the projected membrane system design **(Fig. 6)**. In Phase B the worst case water quality was examined. This took place in parallel to the construction of the new system (UF and RO) until start-up. By variation of process parameters from the chemical treatment pilot unit a worst case feed water quality to the UF pilot unit was created and procedures to cope with such vigorous conditions were developed. The ultrafiltration unit was operating with inline coagulation using polyaluminumchloride (PAC) to optimize its performance.

Plant design

At the beginning of the membrane system design, only limited information about the raw water load and seasonal influence were available. Therefore the system design was arranged to cope with a broad spectrum, ensuring a safe and economical water processing. This also considered a part load operation of one or both membrane stages. **Figure 7** provides an overview of the whole membrane system.

Feed tank and inline-coagulation

To separate the control system from the existing WWTP, and in order to get a buffer in front of the UF-system, a tank was integrated (not visible in Fig. 7), obtaining approximately 30 minutes retention time related to nominal load. To realize a residence time for the coagulation of

Table 1: Water Quality parameters

Parameter	Units	feed to WWTP	after existing WWTP	water quality requirements
Total suspended solids (TSS)	[mg/l]	500 - 750	8 - 30	~0
Chemical oxygen demand (COD)	[mg/l]	400 - 800	20 - 60	< 10
Conductivity	[µS/cm]	1200 - 2800	1200 - 2800	200 - 400
Color	[Co-Pt]	300 - 650	10 - 60	< 5
Temperature [°C]	7 - 30	pH	7,1 - 7,8	7 - 8

Source: Membrana GmbH

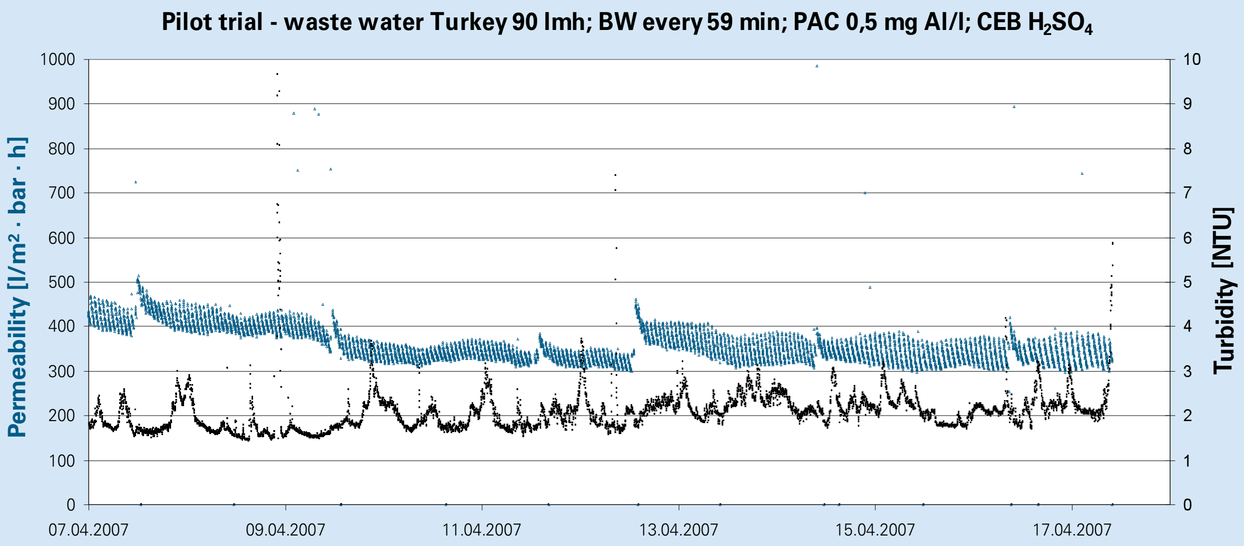


Figure 6: Operating performance of the UF pilot unit (Phase A)

Source: Membrana GmbH

approximately 60 seconds before entering the UF-system, a pipe (DN 600) inside the feed tank was installed. The PAC was mixed by a frequency controlled dynamic mixer before being added to the coagulation line.

Protective filtration

At the downstream side of the existing gravel filters the turbidity of the water was usually low. Occasionally breakthroughs of the gravel filters were detected, which lead to an elevated turbidity and high load of particles in front of the UF. To safeguard the operation of the UF-system, basket filters with a nominal filter mesh size of 200 µm became part of the design **(Fig. 8)**. As they can be backwashed automatically, the backwash cycle of the basket filters were synchronized with the backwash cycle of the continued UF-rack by the programmable logic controller (PLC).

Ultrafiltration unit

The ultrafiltration unit was divided into seven racks analog the RO-unit. Each UF-rack contained 76 Liqui-Flux® W02 modules with a total membrane surface area of 4,636 sqm. A frequency controlled feed pump had been integrated in each rack to feed the UF. The modules were assembled in double rows, directly attached to the foundation **(Fig. 9)**. The Liqui-Flux UF-modules are operated in dead-end mode to minimize energy consumption. By an alternating feed and backwash inflow (to the top and to the bottom) an uneven load and clogging of hollow fibers is prevented.

During the design phase there was a special focus on the pipe manifolds, achieving an equal distribution of the feed and backwash water. Dead zones were eliminated and minimum flow velocities maintained. This way an accumulation of potential nutrients and other fouling agents in the system could be avoided. The optimization of the piping system also led to a safe transfer from the single module pilot system to the final large-scale unit, as the hydraulic system ensured equal conditions for all Liqui-Flux® modules in one rack.

Backwash and cleaning

Basis for an efficient cleaning regime is always a sufficiently dimensioned backwashing. For this UF-system a backwash volume flow of 1,150 m³/h was designed. Periodic fouling should be removed by Chemical Enhanced Backwash (CEB). Dosing pumps for sodium hydroxide, sulfuric acid and sodium hypochlorite are installed for the CEB. Due to the high amount of hydrocarbonate in the treated water, the chemical cleaning of the UF is done by permeate from the RO and not by filtrate from UF to prevent precipitation. In certain cases it is also possible to connect a cleaning in-place system (CIP) from the RO-system to each rack of the ultrafiltration system. While backwashing mode and CEB-mode operate automatically, the CIP should be performed manually by the operator.

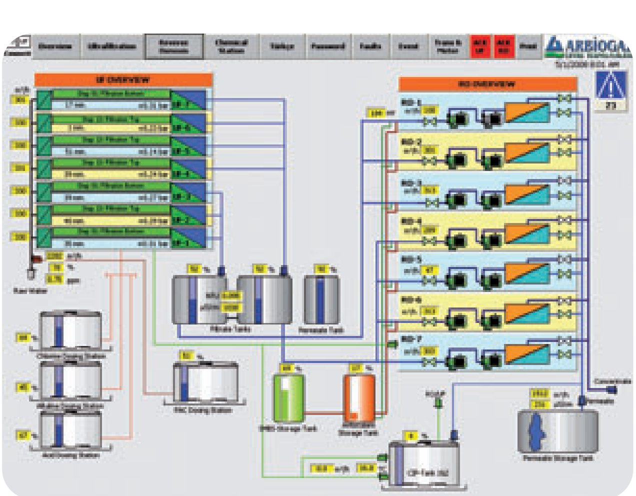


Figure 7: Screen-print of membrane unit control screen

Source: Arbiogaz


Source: Arbiogaz

Figure 8: Protective filters and ultrafiltration unit


Source: Arbiogaz

Figure 9: Ultrafiltration Rack

Operating experience

From August until September 2007 the seven UF- and RO-racks were started sequentially. At that moment a reliable data basis from the pilot trials was available, so that the flux of the UF-units was increased up to the projected value of 75 lmh within a few weeks. Initially the backwash interval was set to every 30 minutes. However, this has been increased in several steps to every 60 minutes, since the transmembrane pressure (TMP) remained below 0.2 bar (2.9 psi) during filtration.

The CEB was adjusted several times to cope with the varying raw water quality. The standard procedure developed, consisted of a first cleaning with NaOH at pH > 12 with the addition of 200 ppm chlorine. After a backwash a second cleaning with acid at pH 2 was conducted to rinse out the caustic residuals. During the start-up phase it was ensured by sampling that all modules receive the same concentration of chemicals. For 3/4 of a year the use of one CEB per day was sufficient. In case of high contamination of the raw water side the operator changed the CEB frequency to every 12 h and in single cases to every 8 h.

Two events within the last three years required special activities: In December 2007 the performance of the biological treatment within the already existing WWTP decreased and some sludge entered into the feed to the UF-system. Within a short time the TMP increased to 0.8 bar and the system was stopped automatically. As a countermeasure several backwashing cycles were performed, with limited success, as the flux rate could only be recovered partially. Therefore, the caustic CEB was executed two times at a pH-value of 12.5 with a soaking time of 20 minutes. Consequently, the permeability increased to > 500 l/h/m²/bar.

About one year later (December 2008) the TMP slowly rose over several weeks, until it reached 0.6 to 0.7 bar. The above-mentioned caustic CEB did not work well, so that an extra water analysis had to be run by the WWTP operating company. In the analytical report, high values of metals (Al, Mn, 0.4-0.5 ppm) became obvious. Consequently, a CIP with citric acid for 1h, at an elevated temperature of 38 °C, recovered the flux to the initial value.

In general the UF-filtrate quality was checked continuously regarding SDI-15 (< 3) and turbidity (< 0.1 NTU). With such reliable water quality the yield of the RO has been raised from 75 percent at the start-up to 85 percent today. The RO-permeate could be maintained during the whole operation time without any restriction.

Summary and outlook

By the combination of inline-coagulation, ultrafiltration and reverse osmosis, a membrane system has been installed, which is working reliable and economical, even under varying conditions in the waste water influenced by different industrial companies. The used Liqui-Flux® ultrafiltration membrane modules are demonstrating their suitability by a low fouling tendency and favourable cleaning properties. In combination with a sophisticated module and system design, and an operation adapted to the local situation, this process scope obtains central importance in industrial waste water recycling. This will be further supported by a continued advancement of the ultrafiltration modules. Membrana GmbH will launch its new Liqui-Flux® modules with 75 sqm filtration area at the IFAT 2010. This module will be the largest pressure-driven inside-out ultrafiltration module of its kind and will be displayed at the Membrana GmbH booth in hall A2.110.

Authors:
Bodo von Harten, Martin König, Norbert Selzer, Martin Rütering

Contact:
Martin Rütering
Membrana GmbH
Öhderstr. 28
D-42289 Wuppertal
tel: +49 (0) 202 6099-950
fax: +49 (0) 202 6099-750
e-mail: martin.ruetering@membrana.de
web: www.membrana.de