Desalination and Water Treatment
www.deswater.com

31 (2011) 82–87
July

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doi: 10.5004/dwt.2011.2378

Large ultrafiltration system for industrial waste water re-use in Turkey

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Received 15 July 2010; Accepted in revised form 2 February 2011

ABSTRACT

In 2006 a contract for upgrading an existing wastewater treatment system with a capacity of 50,000 m³/d (50 MLD) was awarded to the company ARBIOGAZ from Istanbul. That system was already equipped with mechanical, biological and chemical treatment, but its effluent did not fulfil the quality requirements for process water of the several industrial clients. In order to meet those requirements it was decided to add a membrane filtration system consisting of ultrafiltration followed by reverse osmosis. This paper describes the installed ultrafiltration system, its pilot and design phase, the commissioning and experience from nearly 3 years of operation. Membrana's Liqui-Flux® ultrafiltration modules were selected for the ultrafiltration system. The design of the plant proposed by Membrana was linked to the results of an 8 month pilot trial to determine the optimal operation of the UF system.

Keywords: Ultrafiltration; Reverse osmosis; Wastewater reuse; Turkey

1. Initial position

In the year 2006 the Turkish company Arbiogaz (Istanbul) received the order for upgrading of an existing waste water treatment plant (WWTP). They were asked to install a two-stage membrane system (UF and RO) with a capacity of 50.000 m³/d (50 MLD).

The WWTP cleans a mixture of different, partially pre-cleaned, industrial sewage disposals and rain water. The water quality is changing from season to season.

In addition to the mechanical and biological treatment the system contains a chemical cleaning step, where standard precipitation/flocculation chemicals as well as extra-chemicals for de-coloring are in use. The treated wastewater is supplied to an industrial park.

The decision for installing the additional system was made in order to fulfill the quality requirements (Table 1) for the different industrial clients and to prevent the use of potable water for production purpose.

For the reduction of salts, COD and color a reverse osmosis was essential. Ultrafiltration was planned as pre-treatment system in order to secure consistent and efficient performance of the downstream reverse osmosis membranes. For an economical operation of the RO system a small amount of UF-filtrate, depending on the salt content of the feed to the membrane systems and the permeate of the RO, should be mixed into the RO permeate.

There was little time for the realization of the system. By end of 2006 designing of the system already has started, and commissioning and start-up of the system was scheduled for summer 2007.

Pilot systems were in operation from January 2007 until August 2007 to obtain reliability regarding the basic system design and for the identification of possibly interfering influences from the operation of the existing WWTP.

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Presented at EuroMed 2010 — Desalination for Clean Water and Energy: Cooperation among Mediterranean Countries of Europe and MENA Region, 3–7 October 2010, David Intercontinental Hotel, Tel Aviv, Israel. Organized by the European Desalination Society.

Table 1
Quality parameters

Parameter	Feed to WWTP	After existing WWTP	Quality requirements
TSS, mg/l	500–750	8–30	~0
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

2. Installed ultrafiltration

The extremely varying raw water quality requires membranes which have a low fouling tendency and the ability to be cleaned effectively with cost-efficient chemicals. The expected high cleaning stress requires membranes with strong mechanical long term stability.

All these properties can be found with the UltraPES hollow fiber membranes. They are made by polyethersulfone which is extremely hydrophilic and stable over a wide pH range.

The distinctive three-layer-composition with an inner separation layer and outer protective layer increases the mechanical resistibility of the capillaries. Furthermore the capillaries are entangled with a special spacer yarn, which reinforces the structure and leads to an optimized flow distribution during backwashing.

Another feature of this hollow fiber is the defined retention and high permeability, which results in low pressure drop and therefore leads to low energy consumption.

UltraPES hollow fiber membranes (Fig. 1) are integrated in ultrafiltration modules of the type Liqui-Flux® W02 with 61 m² filtration surface. The optimum backwash capability is realized by short distances from outside to inside of the hollow fiber bundle (radius <45 mm) and a moderate fiber length of 1250 mm. Liqui-Flux® W02 modules do not use any kind of sealing like o-rings etc. for the separation of the feed and filtrate side. This is an advantage, as O-rings can be seen as weak point for example regarding microbiological problems.

3. Pilot phase

Pilot trials with a mobile pilot system started in January 2007 to obtain first performance data from the ultrafiltration with the cleaned water from the WWTP as soon as possible.

Already after a short time during the piloting it became clear that sometimes an overdosing in the chemical step of the WWTP occurred, which in one case led to a blocking (Fig. 2) of the test module.

The analysis of this layer by EDX (energy dispersive X-ray) showed several inorganic substances. Cations like Iron and calcium as well as traces of phosphate and silicates were found (Fig. 3), which is an indication for a precipitation with the different chemicals in the water. Therefore it was necessary to extend the pilot operation and separate it into two phases:

Phase A: Filtration of the cleaned water from the existing system with additional effort for controlling of the existing WWTP, especially the chemical treatment step.

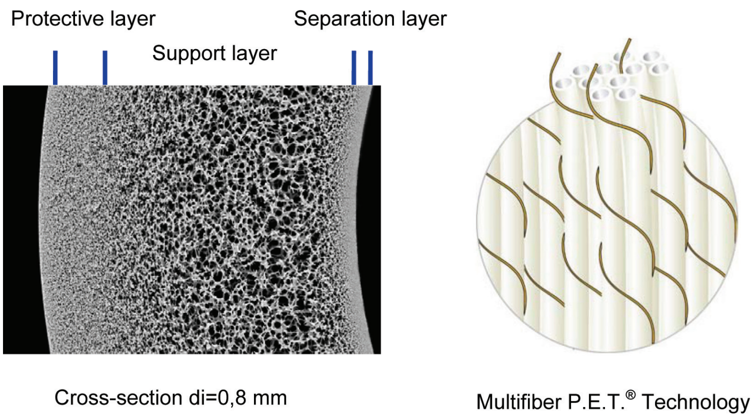

Fig. 1. UltraPES hollow fiber membrane.

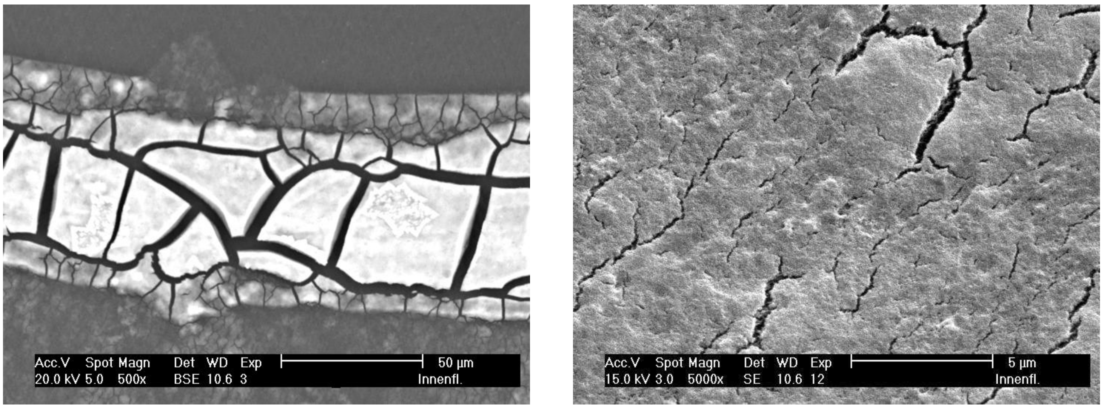

Fig. 2. SEM photos of the scaling layer from the test module.

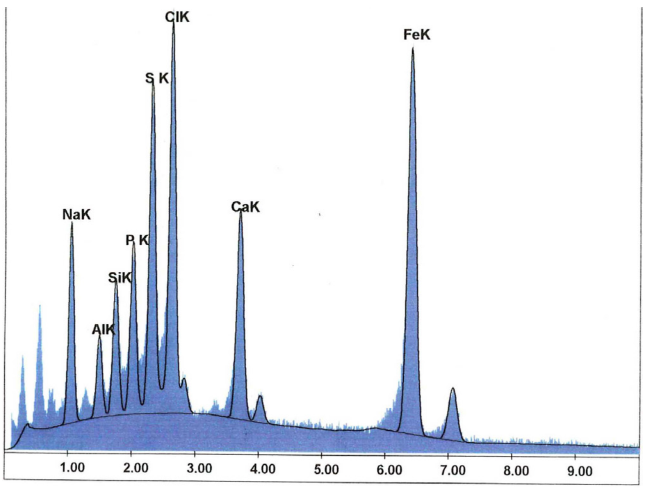

Fig. 3. EDX-analysis of the scaling layer.

Phase B: Installation of an additional pilot system to simulate the existing chemical treatment system. Thereby it is possible to vary the operation parameters, which of course could not be done in the WWTP because a safe supply could not be guaranteed.

In Phase A different parameters were tested like flux, coagulation concentration etc. and the operators were trained to prevent overdosing of chemicals in the WWTP. With that an operation of the pilot UF, which fits to the requirements in respect to the progressing design of the new system, was realized (Fig. 4).

In Phase B (summer 2007), which took place in parallel to the construction of the new system (UF and RO) until start-up, the worst case water quality in combination with different operations of the chemical pilot treatment system was examined.

The ultrafiltration was operating with Inline coagulation using polyaluminiumchloride (PAC) to obtain an optimized performance.

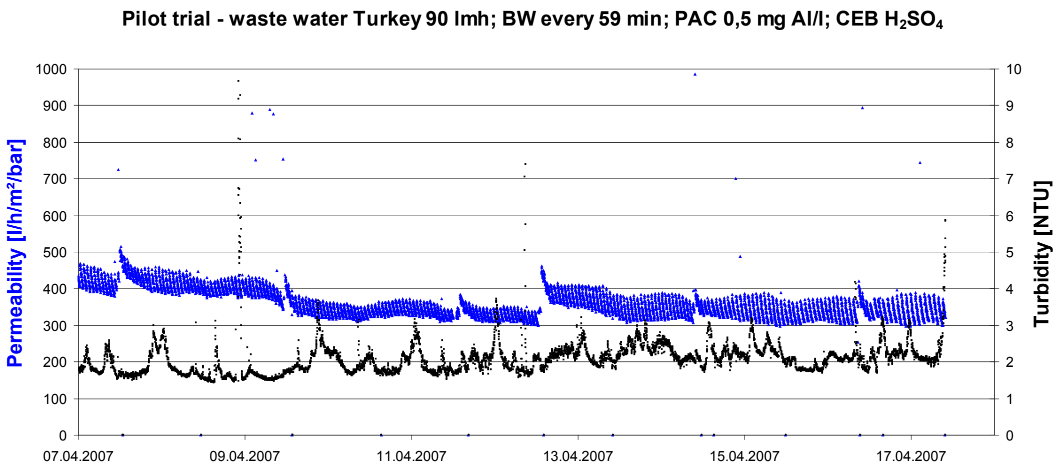

Fig. 4. Operating performance of the pilot UF.

4. Plant design

An overview of the complete membrane system is given in the screen print of the PLC (Programmable logic controller — Fig. 5).

At the beginning of the design phase only limited information about the raw water load for the seasonal differences were available. Therefore the system design was arranged to allow a broad spectrum for processing the water safely and economically. This meant also to consider a part load operation of one or both membrane stages.

4.1. 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 to obtain approximately 30 min retention time related to nominal operation, has been integrated (not visible on the screen print — Fig. 5).

To realize a residence time for the coagulation of approximately 60 s before entering the UF, the best solution was to install a long pipe DN 600 inside the feed tank. Before entering the coagulation line the polyaluminiumchloride was dosed in and mixed by a frequency controlled dynamic mixer.

4.2. Protective filtration

Fig. 5 shows exemplarily the operation of the two membrane stages (UF and RO). Because of the existing gravel filter the turbidity given to the UF normally is relatively low. However, sometimes a breakthrough of the gravel filter may happen, which will lead to high turbidity and high load of particles and even filter material in front of the UF.

For a safe operation of the ultrafiltration sieve basket filters with a nominal filter mesh size of 200 μm are part of the design. They can be backwashed automatically and the backwashing is synchronized with the backwashing of the appropriate UF rack by the PLC.

4.3. Ultrafiltration

The ultrafiltration is divided into 7 racks, like the RO. Each UF-rack contains 76 modules with a total of 4,636 m² membrane surface. A frequency controlled feed pump is working in each rack. The UF modules are assembled in double rows directly at the foundation (Fig. 6).

The UF modules are operated in dead-end mode to minimize energy consumption. By an alternating feed and backwash inflow an unbalanced load and the closure (clogging) of hollow fibers will be prevented safely. Dur-

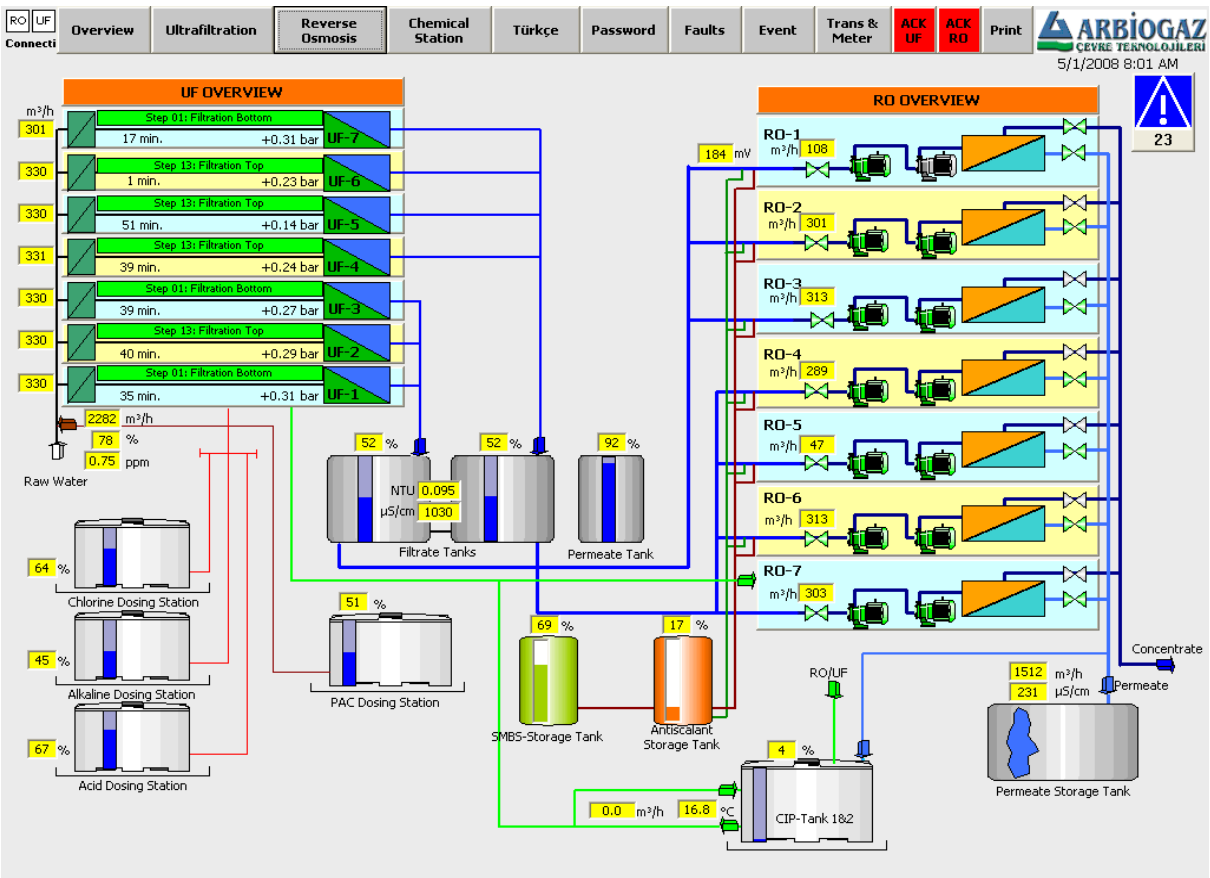

Fig. 5. Screen-print of the membrane stages.

Fig. 6. Ultrafiltration rack.

ing design phase there was a special focus regarding the pipe manifolds to get an equal distribution of the feed and backwash water. Dead zones were eliminated and minimum flow velocities should be maintained.

In so doing the accumulation of potential nutrients and other fouling agents in the system can be prevented.

The optimization of the piping system also led to a safe transfer of the test results from the single module of the pilot system to the final system as the hydraulic system described in Fig. 7 ensures almost equal conditions for all modules in a rack.

Helpful for designing the pipe distributor is the so called Tichelmann distribution, where the flow resistances for each module accumulate to the same order of magnitude. Therefore the distributor pipes do not become too big and deposits of particles are avoided. If in addition the direction of the pipe connection for the racks is chosen in the right way it is guaranteed that each area in the pipe distributor at least once will be flown through with a sufficient flow velocity during two filtration and backwashing cycles.

4.4. Backwash and cleaning

Basis for a good cleaning effect 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, sulphuric acid and sodium hypochlorite are installed for

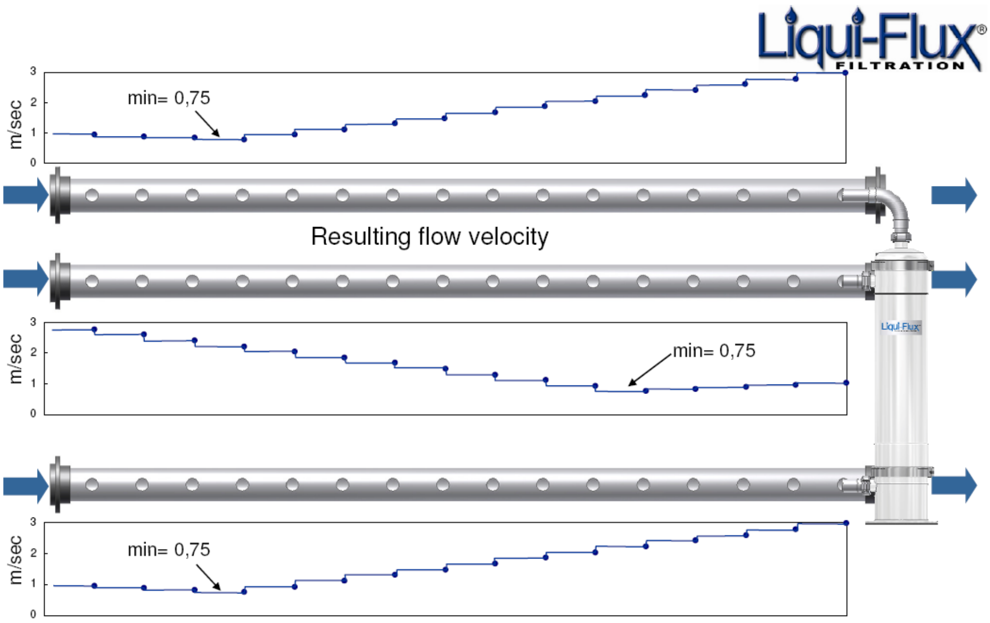

Fig. 7. Resulting distribution of flow velocity in the distributor pipes in a rack during changing incoming flow (top–bottom) for filtration and backwash.

the CEB. Due to the high amount of hydrocarbonate in the water to be treated the chemical cleaning of the UF is done with permeate from RO and not with filtrate from UF to prevent precipitation.

For special events it is also possible to connect the CIP-system (cleaning in place) from the RO system to each rack of the ultrafiltration system. While backwashing mode and CEB mode operate automatically the CIP, if necessary, should be done manually by the operator.

5. Operating experience

From August until September 2007 the 7 UF and RO racks were started one after another, one UF rack then one RO rack and so on.

At this point in time a good basis from the piloting was available to increase the flux of the UF up to the scheduled value of 75 $l/h/m^2$ within a few weeks.

At the beginning the backwash interval was adjusted to 30 min and in several steps increased to 60 min. Transmembrane pressure (tmp) during filtration stayed below 0.2 bar (2.9 psi).

The chemical enhanced backwash was adjusted several times to fit to the raw water quality. The standard procedure now is cleaning with NaOH at pH >12 with addition of 200 ppm chlorine. After a backwash an acid step at pH 2 for rinsing out the caustic follows.

During the start-up it was examined by sampling that all modules get the same concentration of chemicals.

During 9 of 12 month in a year one CEB per day is satisfying. In case of high contamination in the raw water the operator switches the CEB to every 12 h and in single cases to every 8 h.

Two events during the last 3 years required special activities.

In December 2007 the performance of the biological treatment in the WWTP decreased and also a part of sludge came into the feed to the UF. Within a short time the TMP increased to 0.8 bar and the system was stopped automatically. Several backwashing steps could recover the flux only partially. Therefore the caustic CEB was done two times at pH of 12.5 with a soaking time of 20 min, which increased permeability to >500 lmh/bar.

One year later, around new year 2008/2009 an increase of the TMP took place during several weeks until 0.6–0.7 bar were reached. The caustic CEB did not work well. After checking the water analyses from the WWTP, which is done regularly by the operating company, high values of metals (Al, Mn, 0.4–0.5 ppm) were obvious. A CIP with citric acid for 1 h at 38°C recovered the flux to a value in the range of the start value.

The filtrate quality is checked continuously regarding SDI-15 (<3) and turbidity (<0.1 NTU).

With this water quality the yield of the RO could be raised from 75% at the beginning of the operation up to 85% today.

The final quality of product water has been maintained during the whole operation time without any restrictions.

6. Summary and preview

By the combination of Inline-coagulation, ultrafiltration and reverse osmosis a system design has been installed which works safely and economically despite the changing load in the waste water from the different industrial companies.

The used ultrafiltration membranes have been 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 system obtains central importance in industrial waste water recycling.

Alternatively to the pre-treatment from the existing system in this project (sedimentation, gravel filter) for new systems, depending on the load of the water, other process steps like flotation and sieve filter should be tested and considered.