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Seawater intake and partial pre-treatment with Neodren - results from investigation and long-term operation

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ABSTRACT

In the last few years the efforts to improve operation and maintenance of seawater intake systems and of the pre-treatment of seawater for desalination plants have been enforced, especially for those designed on the basis of the membrane process reverse osmosis (RO). Driving forces have been the increasing importance of seawater desalination with RO, the need for the reduction of related costs, and the minimization of the impact of the operation related side effects on the environment. This concerns, e.g., the discharge of water resulting from rinsing and cleaning processes, that are also influenced by agents used in the pre-treatment. Thereby as one very important aspect it has to be considered, that the intake and the pre-treatment of seawater have to be adapted to the specific conditions at the construction site of each plant. These can differ however in a wide range. Beside the influences determining the raw water quality, also items like the geological situation, environmental aspects and details related with infrastructure or logistic are usually different and have to be considered consequently during design, construction and operation of a desalination plant. A successful possibility to reduce these efforts has shown to be the seawater intake and partial pre-treatment system Neodren, that allows for a reliable and long-term operation of desalination plants with nearly no need for chemicals, under certain circumstances even without them. The system is based on porous drains that have been installed with a specially developed horizontal directional drilling technology in about 4–7 m depth in the stratum below the seabed. This is acting as a natural filter and helps to avoid completely usual problems at seawater intakes, like influences on the marine habitat or weather induced contamination peeks. Even if the first system is in trouble-free operation since 1996, and in June 2008 nine systems with a total capacity of about 382,000 m^3 of Neodren-filtrate per day have been installed and are successfully in operation, further investigation is carried out by Catalana de Perforacions and cooperation partners, to take advantage of all benefits of these systems. As one option has been identified to operate them in combination with ultrafiltration. That would allow for increasing the productivity of the RO units, or, if compared to an operation with conventional pre-treatment, for a reduction of the necessary membrane area for the production of the same capacity respectively. Related results from investigation are presented together with an overview of Neodren systems with long-term operation, that confirm the economical and ecological sustainability of the Neodren technology, and details of a new installation.

Keywords: seawater intake; sub-seabed filtration system; pre-treatment for RO; seawater desalination; ultrafiltration

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1. Need for investigation regarding pre-treatment of seawater

The increasing importance of seawater desalination with the membrane process reverse osmosis (RO) and the need for the reduction of related costs, as well as, the minimization of the impact of the operation related side effects on the environment, are driving forces for the intensive investigation of different options for the pre-treatment of seawater [1].

Consistent high-quality pre-treatment of the feed water is one of the most important prerequisites for long-term successful operation of seawater desalination plants [2]. Therefore, the extraction of seawater to feed a RO system is always critical with regards to limitation of suspended solids, variation of seawater temperature, contamination by pollutants and particularly oil, as well as, marine biological matter, which all individual and/or together present a great challenge for the pre-treatment of the RO process with regards to performance and operating cost. There is no doubt, that long-term successful operation of a seawater RO desalination plant is greatly influenced by the kind of intake and pre-treatment [3].

But whereas for the design and the manufacturing of the desalination unit itself well known and approved technical solutions meanwhile are available, the intake and the pre-treatment of the seawater have to be adapted to the specific conditions at the construction site of each plant [3]. These can differ in a wide range, as beside the influences determining the raw water quality, also items like the geological situation, environmental aspects and details related with infrastructure or logistic are usually very different and have to be considered consequently during design, construction and operation of a desalination plant.

Ultrafiltration is considered to be a well-defined barrier with respect to the rejection of particulate matter and microorganism and could help to simplify this design process and to improve the boundary conditions related to the operation of RO-based seawater desalination plants (SWRO).

Facing this background, it has been decided to compare the findings from conventional pre-treatment based on multilayer filtration with those resulting from an innovative module with capillary ultrafiltration membranes.

In one segment of the investigation seawater from an open intake was used, and in the other segment of the investigation seawater extracted with the Neodren system developed by Catalana de Perforacions was chosen as the feed solution. This Neodren technology is based on sub-seabed horizontal drains, consisting of patented high efficient special porous filter pipes, which are acting as horizontal wells with very low filter velocities, e.g. less than 10 m/day, installed with an improved horizontal directional drilling method (HDD) in a depth of 4–7 m in the stratum below the seabed for several hundred meters in lengths [2].

2. Pilot plant for investigation of options for seawater pre-treatment

In this context a containerised pilot plant equipped with a multi layer filter and an innovative ultrafiltration module in industrial scale as main components, followed each by a RO unit has been manufactured. The plant, fully equipped for a self-sufficient function and investigation, has been designed to be operated in combination with the mentioned conventional open seawater intake, or with the sub-seabed seawater intake system Neodren [1].

The pilot plant for the investigation of the pre-treatment of seawater obtained from an open intake and alternatively from the indirect intake system Neodren, on one side consists of a conventional multilayer filter and on the other side of an innovative ultrafiltration module.

The container with this plant has been installed in May 2007 alongside a pumping station for a data sampling Neodren equipment in technical scale with a filtrate rate of up to 100 L/s (8,640 m^3/d) from Catalana de Perforacions, operated on behalf of the local provider for potable water Aguas de Ter y Llobregat from June 2005 till July 2008. The installation, completed by an office container, had been located at the coast of the Mediterranean Sea beside the beach near the airport of Barcelona (Fig. 1).

The plant has been provided with all equipment, measuring devices and analytical instruments that are necessary for a self-sufficient function and investigation. Thereby the comparison of the selectivity of the filtration devices has been based mainly on the measurement of the silt density index (SDI) and on particle counting. Filtrate flux, cleaning intervals, intervals for chemical enhanced backwash of the membrane, etc. and the data for hydraulic parameters of the units have been recorded daily [4].

A unit with an inner diameter of 280 mm and a total length of 2,102 mm, using layer of Hydro Anthrazit N and sand with grain size 0.4–0.8 mm has been selected as sand filter (Fig. 2). This sand filter and the ultrafiltration module (Fig. 3) are the main components of the pilot plant. As ultrafiltration removes turbidity and suspended solids, the modules are ideally suited also as a reliable pre-filtration step for RO in seawater desalination plants, significantly reducing the chemical requirements in operation.

Fig. 1. Pilot plant, Neodren pumping station (right) and office container (left) beside the beach near Barcelona airport. *Source*: Ulbricht / MEMBRANA.

For this kind of application the units are operated usually in dead-end mode and with low transmembrane pressure. Depending on the raw water this could be for example in the range between 0.1 and 0.7 bar (10–70 kPa; 1.45−10.15 psi) [5,6].

3. Operating results

Example for data (particle/mL) obtained during the first segment of trials (Neodren) with this ultrafiltration module and those from the sand filter are shown in Fig. 4.

Fig. 5 shows particulate matter on the surface of the RO membranes that have been operated in line with the test devices for 4 months. The difference between the pre-treatment by a sand filter and by ultrafiltration is very significant.

A similar significant difference between a SWRO desalination plant operated with the seawater intake and partial pre-treatment system Neodren and a twin SWRO desalination plant operated at the same site, but with open intake, has been observed in San Pedro del Pinatar in Spain. There two plants with the same design for the production of 65,000 m^3/day each are in continuous operation. The plant operated with Neodren as intake and a single sand filter as pre-treatment is in operation since 2003 with no need for chemical cleaning of the RO membranes up to now, whereas the membranes in the twin plant, operated with open intake followed by two filter stages with sand/anthracite each, has to be cleaned chemically one or two times per year [7].

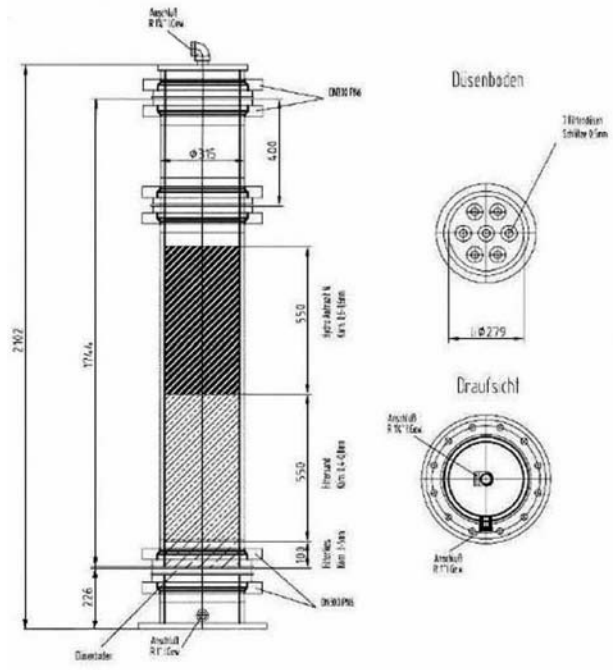

Fig. 2. Sand filter

4. Observation regarding the measurement of the SDI

A comparable picture has been obtained on membranes used for the SDI measurement. But also big differences regarding the value of the SDI have been found for the same water using different membrane materials or membranes supplied by different supplier, respectively, even at the same pH value (Fig. 6). Also differences have been observed for the same material, but different pH value of the feed water. This has to be analysed in deep, as a comparison with other data shall be possible.

It may be mentioned, that similar results have been obtained at a pilot plant equipped with an ultrafiltration unit from PALL using filtrate from a Neodren at another location at the Mediterranean coast [8]. Also there the investigation proved the reliability of the combination of Neodren with ultrafiltration.

5. Long-term operation

The seawater intake and partial pre-treatment system Neodren, installed with a specially developed

Fig. 3. Sand filter and ultrafiltration source: MEMBRANA/WAT module in the container [4,5].

HDD technology, has been installed initially for fish farming. Thereby the first Neodren has been commissioned in 1996 at the Costa Brava (Table 1) and is operated since then successfully.

Since 2003 Neodren systems have been installed mainly at desalination plants using the membrane process RO for the production of drinking water from seawater.

In June 2008 nine commercial systems with a total capacity of about 382,000 m^3 of Neodren-filtrate per day have been installed and are successfully in operation.

Impression of the Neodren system commissioned in Alicante in Spain in 2008 show Figs. 7–9 (source: D. Pintó, Catalana de Perforacions, 2008)

In Fig. 7 appear the end pieces of the Neodren pipelines, equipped with valves, in the excavation pit after having been installed.

The size of the system can be deduced from Figs. 8 and 9. Beside the hand valve that serves for the

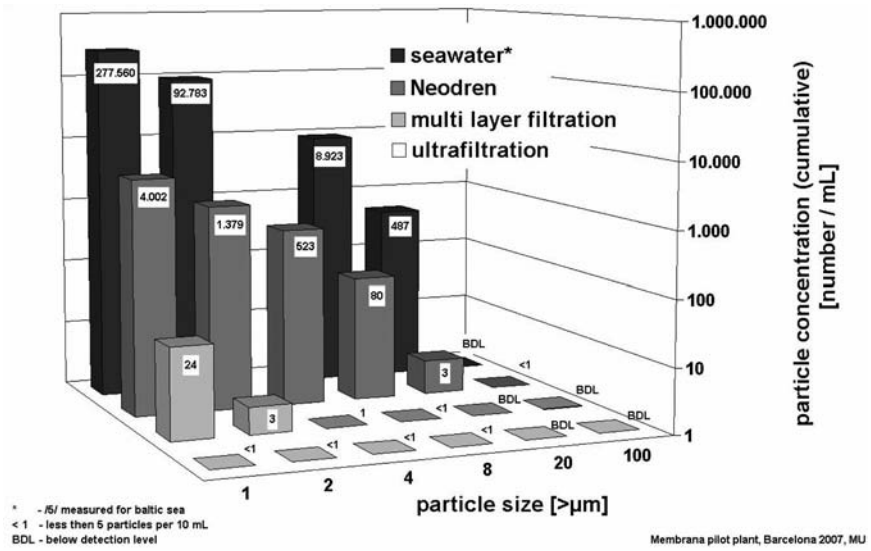

Fig. 4. Particle analysis after sand filter and ultrafiltration [4,6].

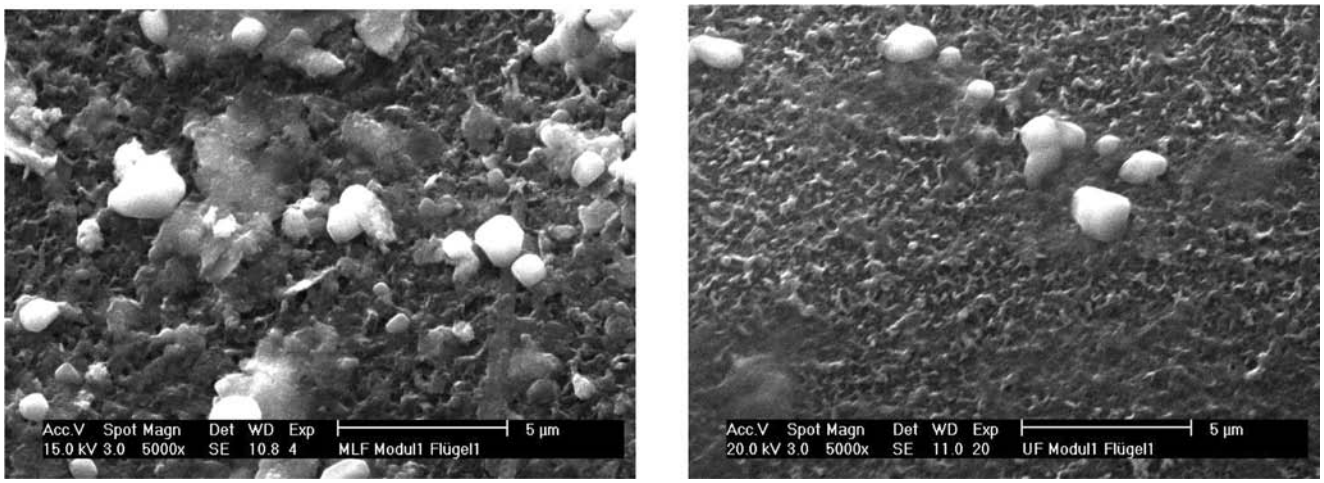

Fig. 5. Particle on RO membrane after sand filter (left) and ultrafiltration (right) [4].

adjustment of the flow, also the flow meter (white device) is to be seen.

Due to a high permeability of the stratum below the seabed in this case the specific flow rate of the individual Neodren pipelines can achieve up to 120 L/s each (10,368 m^3/d). This shows again, that the geological situation can be very different and has to be very well investigated before designing the final installation of a Neodren system.

5. Conclusions

The need for improved pre-treatment for SWRO plants has been and is the driving force for companies involved in the desalination of seawater to investigate this item. In this context Catalana de Perforacions and cooperation partners have initiated the investigation of different options for the pre-treatment, being one first focus the use of the Neodren system in combination with sand filtration or ultrafiltration.

The results of trials with seawater using ultrafiltration and multilayer filtration under real conditions

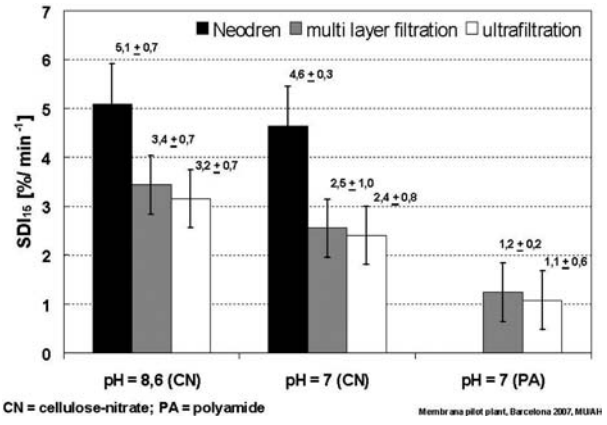

Fig. 6. Results for SDI measurements [1].

Table 1
References for Neodren systems

Start-up	Application and location	Capacity (m^3/d)
1996	Fish-farm in Sant Pere Pescador	4,320
2001	Fish-farm in Sant Pere Pescador (amplification)	8,640
2003	Desalination Plant in San Pedro del Pinatar	172,800
2003	Fish-farm Cabo Cope	8,640
2004	Desalination Plant in Águilas	41,472
2004	Desalination Plant in Alicante, trial	500
2004	Cooling water for biomass plant in Albuixech	10,368
2005–2008	Investigation (data sampling Neodren)	8,640
	For the SWRO in Barcelona, future feed flow	371,520
2006	Desalination Plant, Águilas, Comunidad de Regantes	25,920
2007	Desalination plant in Alicante, first phase	25,920
2007–2008	Investigation (data sampling Neodren)	7,776
	For the SWRO at Blanes, future demand	100,000
2008	Desalination plant in Alicante, second phase	ca. 83,000

Fig. 7. Neodren end pipe.

Fig. 8. View on connection.

show a very high quality of the ultrafiltration filtrate, which is a basis for a reliable long-term operation of SWRO plants.

This reliable and trouble-free long-term operation applies also for the Neodren systems that have been

Fig. 9. Flow control has to be turned by 180°. Domènec should stand, so with the white helmet up.

installed so far, being the first one commissioned in 1996. Whereby the first application has been obtaining clean water for fish farming, since 2003 systems are installed mostly for the seawater intake and partial pre-treatment at seawater desalination plants.

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