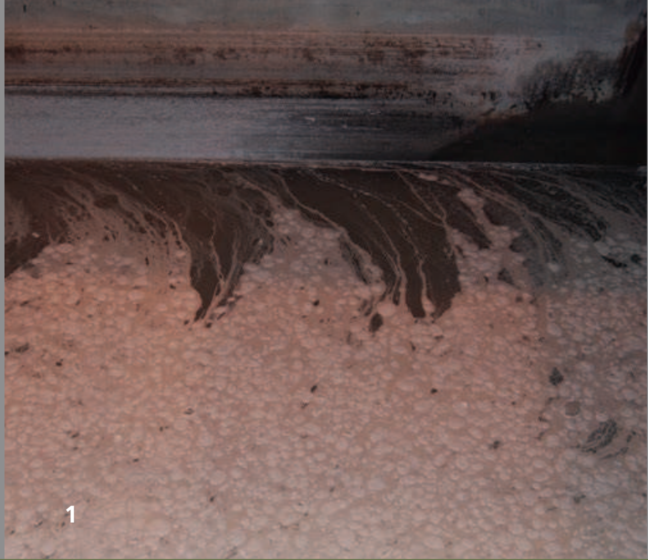

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NF MEMBRANES FOR THE CLEANING OF "RECYCLE WATER" IN OIL SAND EXTRACTIONS

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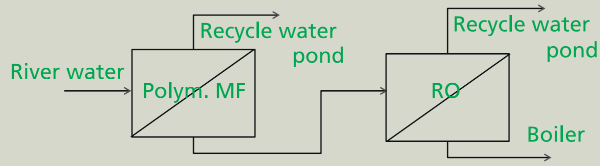
Oil sands, also known as "tar sands" or "bituminous sands", can be either loose sands or partially consolidated sandstone saturated with a highly viscous form of petroleum. Compared with conventional techniques, extraction of oil from tar sands is expensive and hence depends on oil prices and the availability of efficient and sustainable extraction techniques.

Oil extraction from oil sands requires a large amount of water for different processes. Hot water used to reduce the viscosity of the oil makes up the largest share. After oil/water separation, the water is sent to the tailings ponds and can be reused as "recycle water" without any further treatment. River water is primarily used as boiler feed water, but it also finds use as cooling water in the summer. Due to their resistance to organic matter and oil residues, desalination behavior, and thermal stability, ceramic nanofiltration membranes (NF membranes) can contribute to the development of new and more efficient recycling processes, including partial heat recovery.

In a current project started in 2013 together with partners Shell Global Solutions International B.V., Shell Canada Ltd., and Andreas Junghans - Anlagenbau und Edelstahlbearbeitung GmbH & Co. KG, 19-channel elements with ceramic NF membranes are being tested in an oil field in Canada.

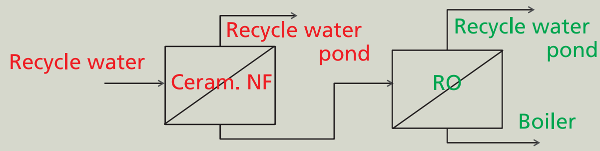
The goal of this project is to make the recycle water usable for other purposes besides the current one (boiler feed water). From an environmental point of view, use of recycle water instead of river water would be beneficial, but this is currently not possible due to the high residual bitumen and solids contents of the tailings.

Current method for preparing boiler feed water: treatment of river water



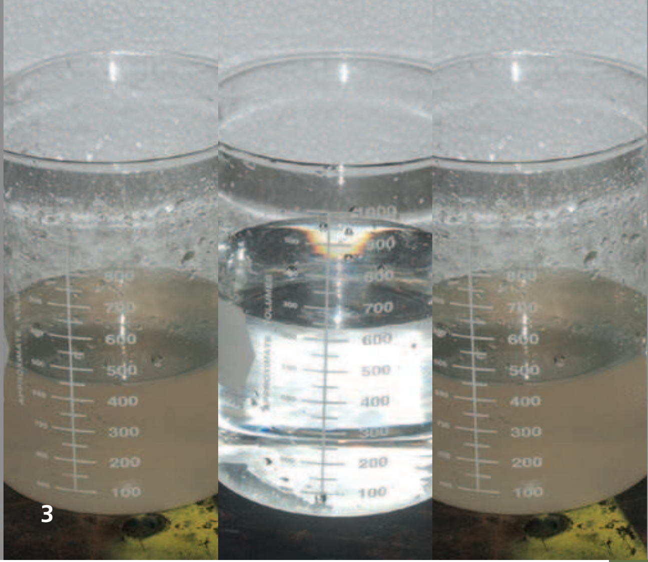
Ceramic NF membranes completely remove suspended solids and residual bitumen and at the same time reject most of the multivalent ions, thereby enabling a much higher yield in the subsequent reverse osmosis process.

New approach for preparing boiler feed water: treatment of "recycle water".



The 19-channel NF membranes showed rejection of alkaline earth metals (Ca and Mg) of up to 80 % and of alkali metals (Na and K) of up to 55 %. The permeate was free of organic matter. Long-term tests performed over several months confirmed the stability of the membranes.

Economically feasible preparation of the large amount of boiler feed water and cooling tower water required is not



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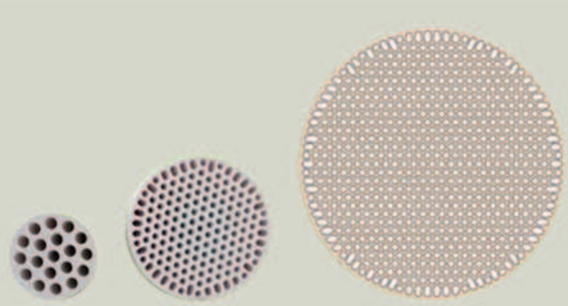
Desalination of "recycle water" using ceramic 19-channel NF membranes

	Feed	Permeate	Retentate
Ca^{2+}	23 ppm	5 ppm	26 ppm
Mg^{2+}	12 ppm	2 ppm	14 ppm
Na^{+}	325 ppm	137 ppm	368 ppm
K^{+}	16 ppm	7 ppm	19 ppm
TOC	44 ppm	1.5 ppm	70 ppm

possible with the 19-channel NF membranes due to the prohibitively high membrane costs. For this reason, Fraunhofer IKTS is looking for ways to reduce the membrane fabrication costs. One approach is to increase the membrane surface area per membrane element and thus reduce handling requirements. The ultimate goal is to use honeycomb substrates with a surface area of up to 20 m² per element instead of 19-channel tubes. In the first scale-up phase, ceramic NF membranes were prepared on 163-channel substrates with a membrane surface area of 1.3 m² per element, five times as high as it originally was. The sol-gel process, on which membrane preparation is based, was adapted to the smaller channel diameter and the reduced suction of the 163-channel substrate.

Scale-up of membrane surface area per element (0.25 m², 1.3 m², 5 m²).



In lab measurements, the membranes showed the same flux and retention behavior as that of 19-channel NF membranes.

Comparison of retention of 19-channel and 163-channel NF membranes determined in lab tests using polyethylene glycol 600

	Flux	Retention
19-channel NF membrane	21 l/(m²hbar)	81 %
19-channel NF membrane	24 l/(m²hbar)	69 %
19-channel NF membrane	25 l/(m²hbar)	71 %
163-channel NF membrane	16 l/(m²hbar)	80 %
163-channel NF membrane	19 l/(m²hbar)	71 %

The next step is to increase the membrane surface area to approx. 5 m² per element. This requires the use of new handling technologies due to the size and weight of the elements. This development work started in 2015.

Acknowledgments

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1 *"Recycle water" from oil sand treatment.*
2 *3.5-m² module for field tests with 19-channel NF membranes.*
3 *Samples for field tests (feed, permeate, and retentate).*
4 *163-channel NF membranes with membrane surface area/element of 1.3 m².*

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