Osmodialysis – The Future of Oil Production Water Treatment

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Abstract

With Osmodialysis, the Austrian company fluvicon GmbH has developed a continuously operating, extremely robust membrane process based on forward osmosis that is capable of cleanly separating oil and salt water. Fouling and scaling - the two major problems of membrane separation technology - play no role. That enables extremely long membrane service lives despite high oil loads and water hardness. The range of applications extends from the treatment of produced waters, condensate and seepage water in the oil and gas industry, to the purification of contaminated seawater after tanker accidents, shipwrecks and well disasters.

Keywords: Forward Osmosis, Oil Separation, Produced Waters, Leachate, Condensate

Introduction

Produced waters from the oil and gas industry are among the most difficult to treat of all industries due to their high salinity and residual oil content of usually > 300 mg/L. To date, many expensive treatment steps are required to purify the saline water to less than 30 mg/L residual oil content. For reinjection into the reservoir, the oil content should ideally be < 5 mg/L. Also, for subsurface or marine disposal of such waters, the residual oil content should be separated as completely as possible. Both as the water-to-oil ratio of production increases and as international environmental standards rise, the problem worsens and also becomes a cost factor. Until now, no technology seemed capable of achieving complete separation in a continuous process at a reasonable cost. But that is now changing.

The Austrian company fluvicon is developing membrane separation processes based on forward osmosis. Forward osmosis is the direct biomimetic replication of the natural process of osmosis and, like reverse osmosis, is one of the molecular separation processes used in water treatment. Here, the naturally existing osmotic pressure is utilized as the driving force. In contrast to reverse osmosis, the raw water flows past the membrane without pressure in forward osmosis. On the other side of the membrane is a draw solution, which with its high salt content draws the water molecules from the raw water through the membrane (fluvicon 2021). The hitherto unsolved problem of the technical use of forward osmosis was that the absorbed water must be removed again from the draw solution in order to enable a continuous process, because this is the only way in which the principle can be applied economically. While earlier approaches to the technical use of forward osmosis worked with thermal recycling of the draw solution or partial disposal of the diluted draw solution and subsequent dosing of salt, fluvicon had the idea of combining the osmotic principle as in nature with other principles or process steps to generate continuous processes working at room temperature. The resulting innovative and patented processes include Ionosmosis (Fuhrland/Grießler 2021) and Osmodialysis. While the product of Ionosmosis is pure water, the product of Osmodialysis is pure salt water.

Principle

Osmodialysis is a newly developed process for purifying contaminated salt water (e.g., reservoir water or seawater) in a highly energy-efficient continuous process. The salt water may be loaded with oil, dirt, aromatics, organics and/or solutes. Oil and salt water are separated by an innovative combination of different membrane separation steps including forward osmosis. Pure salt water and a pure oil fraction are obtained as products.

The Osmodialysis process (Fig.1) proceeds as follows:

1. In the dialysis stage, the loaded salt water is divided into two or optionally three partial streams. The first partial stream contains clean water and the salt load. It subsequently serves as the draw solution. The second partial stream contains water, oil and other freight. It is subsequently used as raw water. Optionally, the first partial stream can be separated into a stream with predominantly monovalent ions and a stream with predominantly divalent ions containing the hardness components such as lime. This allows the hardness of the product water to be adjusted.
2. Clean water is drawn in the forward osmosis (FO) module from the dirty raw water side to the saline draw solution side, thereby diluting the draw solution. The oil and other load end up in the concentrate. The diluted draw solution leaves the forward osmosis module as purified salt water. If the hardeners were separated as a partial stream, they can be fed back in here (proportionally, if necessary). Depending on the requirements, the partial flow of the hardness components can also be fed into the concentrate (proportionally, if necessary) or used in some other way.

In very simplified terms, the unique charm of the approach developed is that, after a very short run-in phase to generate an initial draw solution, the overall process can ideally be kept running with minimum effort to compensate for energy losses, because the draw solution is continuously regenerated from the raw water. The concentrate is an oil-containing fraction from which a pure oil fraction is recovered by continuous skimming.

Development status

The Osmodialysis process was successfully developed in the laboratory and then scaled up to the size of a fully automated demonstration plant (Fig. 2) with the support of the German partner MionTec. Depending on the oil content of the raw water, the demonstration plant produces about 100 liters of pure salt water per hour with a residual oil content of < 2 mg/L. Based on this plant, feasibility studies were conducted for various pilot customers. Among others, pure saline water has been successfully extracted from produced waters of oil production and from seepage waters of gas production on a ton scale. Of particular interest to the pilot customers was the fact that the hardness level of the product water is adjustable. Oil contents between 300 mg/L and 50000 mg/L did not cause fouling of the membranes for months. Extremely high lime contents (54° German hardness) in the feed water did not lead to fouling of the membranes for months. With fluvicon's Osmodialysis, these extreme waters can not only be treated economically, but a real recycling of the oil fraction is also conceivable, since the tests with crude oil emulsions have shown that the separated oil has a water content < 1%.

Advantages compared to the state of the art

a) *Separation efficiency and treatability:* The worldwide standard for continuous treatment of produced water is density separation, e.g. by means of parallel plate separators. The separation efficiency achievable on an industrial scale is

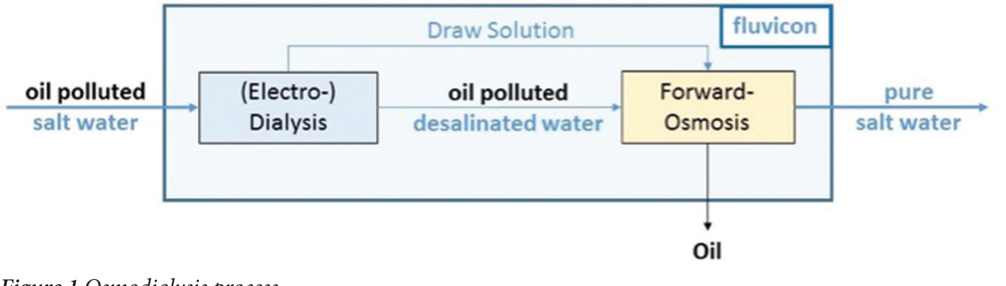

Figure 1 *Osmodialysis process.*

Figure 2 *Demonstration plant for Osmodialysis.*

approx. 300 mg/L residual oil content. The resulting product water thus still meets the criteria for hazardous waste but still contains a lot of valuable oil. Treatment of this product water or even of the original produced water with pressure-driven membrane separation technology (Reverse Osmosis, Nanofiltration) is out of the question, since the membranes would be blocked by the oil within a very short time. In this respect, Osmodialysis has a clear unique selling point in terms of separation efficiency.

b) *Simplification of the process:* According to the published state of the art, an extremely high level of technical and physical effort is required to achieve a separation of oil and salt water on an industrial scale that is even remotely comparable to that of Osmodialysis. Known for this purpose is a complex large-scale process chain consisting of density separation by means of parallel plate separators, coagulation with polymers, flotation, adsorption filters (e.g. nutshell filters) and a downstream multi-stage treatment of process water and flotation sludge (OMV 2018). Osmodialysis promises extreme simplification here, not only by substituting several separation steps at once, but also because no flotate sludge is produced at all. In addition, the offshore suitability of such a process chain (e.g. use on ships of the disaster command) is questionable, whereas Osmodialysis as a membrane process will have no problems here.

c) *Oil recycling:* While chemical-physical treatment produces a sludge as a result of coagulation and flotation that must go into incineration as hazardous waste, Osmodialysis ultimately produces only an oil fraction that can be recycled (see Fig. 3).

d) *Resource requirements:* Osmodialysis has no material resource requirements except for very small amounts of cheap chemicals for occasional cleaning routines. This gives it a clear advantage over material-intensive adsorption processes, such as activated carbon or nutshell filters, cleavage systems with bentonite-based separating agents, or the chemical-physical separation mentioned under b) with its high demand for polymer additives and flotation agents. The cost advantages of Osmodialysis are evident both in the procurement of consumables and in their disposal with the bound oil. Only electrodialysis requires significant energy, while forward osmosis operates without pressure.

All in all, Osmodialysis promises both technologically justified, international compliance with high environmental standards and massive cost advantages compared with the state of the art, thanks to its unprecedented selectivity, simplicity and robustness.

Application potential of Osmodialysis

The major application potential of Osmodialysis is in the field of extraction and processing of crude oil and natural gas on the one hand, and in maritime or offshore transportation of oil on the other. The main applications of the clean separation of oil and salt water are expected to be

1. Treatment of produced waters, from which the oil or aromatics and other hydrocarbons must be separated as completely as possible

Figure 3 *Oil and salt containing produced water before (left side) resp. after (center) Osmodialysis and oil fraction separated from it (right side).*

2. Treatment of process waters, e.g. seawater used for cooling or rinsing in offshore production, or seepage or condensation waters contaminated with aromatics
3. Cleaning of contaminated seawater after tanker accidents, shipwrecks, pipeline leaks and well blowouts
4. Purification of bilge water of arriving ships in ports and purification of port water

Saline produced waters from deep wells for oil and gas production are a huge environmental and economic challenge internationally. Statistics showed a water-to-oil ratio (WOR) of 10:1 as early as 2012 (Produced Waters Society 2012). For the U.S. alone, which has a market share of approximately 13%, this translates to over 21 billion barrels of oil drilling wastewater per year. Most produced waters have higher salinity than seawater. With increasingly depleted and drying reservoirs, WOR will continue to rise, making treatment technologies increasingly urgent. Water online and Transparency Market Research projected the global volume of produced waters to increase to 340 billion barrels by 2020 (Transparency Market Research 2016). Many of these oily saline waters are not economically treatable today. Independent of the problem of residual oil content, the usually high water hardness leads to massive scaling of the plants. A large proportion of the water has to be sunk into depleted reservoirs at great logistical expense, which is becoming increasingly difficult as environmental standards rise. At the same time, however, the wells need water to stimulate the reservoirs and to cool and flush the drills. Fresh water here would lead to further leaching of the reservoir. So recycling the saline produced waters here has a huge economic impact, but requires technologies to remove oil and lime. The Colorado School of Mines estimates that treatment and handling of produced waters can account for more than 10% of the total oil price, depending on the reservoir. The two largest cost drivers for produced water treatment are energy consumption as the clear number 1, and in the number 2 position, the chemical costs of the chemical-physical treatment steps. These two points in particular, along with robustness and selectivity, represent the level of innovation and the unique selling point of Osmodialysis.

The clean separation of oil from seawater is also a standard problem worldwide, for which there is hardly any suitable technology. The chemical-physical processes that can be used onshore are hardly ever used for seawater because it is very complex and expensive. In addition, huge quantities of the above-mentioned process-relevant consumables would be needed in the event of an oil spill. In the past, therefore, an immediate but controversial measure was the use of chemical dispersants, which were spread on the oil spills by airplane and break down the oil into small droplets so that they are pressed under water and become more easily biodegradable. BP used 7 million liters of Corexit for this purpose after the Deepwater Horizon spill. In total, Deepwater Horizon spilled more than 500 million liters of oil into the sea. In 2018, BP put the total cost of the disaster at $65 billion for "cleanup and legal costs" (Reuters 2018). This equates to a cost of $130 per liter of crude oil in the sea. Since the disaster, there has been global awareness of the need for appropriate environmental technology. However, despite various research approaches, a robust separation technology still does not exist. Despite the lack of available offshore technology for large-volume, clean separation of oil from seawater, the requirements for re-injection of depleted mixtures are strictly regulated. According to international environmental guidelines, a purity level of 99.9985 % would be required, i.e. a maximum residual oil content of 15 mg/L – a value that is unlikely to be achieved offshore with the state of the art (Spiegel 2010). Here, a pressureless membrane-based separation technology can finally provide a remedy. With Osmodialysis technology, seawater can be treated cleanly offshore in the future without the use of chemicals.

Conclusions

Fluvicon's Osmodialysis and Ionosmosis technologies open up the possibility of broad technical application of forward osmosis after decades of research. Osmodialysis as a simple process for the clean separation of oil and saltwater that can be applied on a large scale opens up great potential for economically viable solutions to ecological challenges in the oil and gas industry as well as in the oil transportation sector. fluvicon has laid the foundations for this through successful research and development and is now looking for pilot customers and cooperation partners for all types of application fields.

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