2. Reverse Osmosis and Nanofiltration Using The Disc-Tube-Module in the Purification of Landfill Leachate

(Dr. Peters, ROCHEM)

REVERSE OSMOSIS AND NANOFILTRATION USING THE DISC-TUBE-MODULE IN THE PURIFICATION OF LANDFILL LEACHATE

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Based on innovative membrane module concepts reverse osmosis and nanofiltration are going to become important instruments in environmental engineering. One example is the Disc-Tube-module and its application for the purification of landfill leachate. Currently over 45 different landfills are using this ROCHEM DT-module, in some cases combined with the high pressure reverse osmosis versions of this module, operating at up to 120 bar and 200 bar. This state of the art membrane technology and the DTF-module for nanofiltration, developed by ROCHEM on the basis of the DT-module and RO-systems for the purification of landfill leachate, make possible in hybrid processes permeate recovery rates of more than 97 % with concentration factors up to 40.

1. Introduction

Due to the ability of modern high rejection membranes to retain with high efficiency in the range of 98% to 99% both organic and inorganic contaminants dissolved in water and particularly due to the availability of open channel membrane modules like the Disc-Tube-module (DT-module, figure 1) reverse osmosis has turned into an important instrument in environmental engineering. Thus reverse osmosis is used as main step in the purification of liquid waste like landfill leachate and contributes to solving growing water pollution problems.

2. Purification of landfill leachate and reverse osmosis

Toxic and hazardous compounds can originate from landfill leachate as a result of the soluble components of solid and

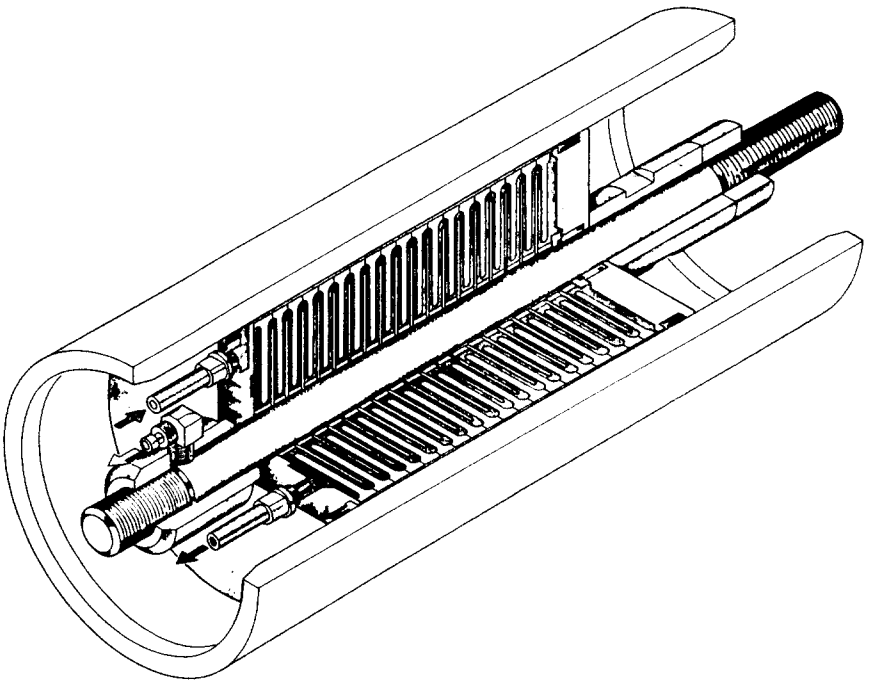

Figure 1: The Disc-Tube-module (DT-module) Source: ROCHEM

liquid wastes being leached into surface and groundwater. Landfill leachate is comparable to complex industrial waste streams which contain both toxic organic and inorganic contaminants [1].

New regulations help to limit the discharge of such complex wastes to municipal sewers since the contaminants are mostly not appropriate for treatment by conventional biological processes. Therefore more effective methods of treatment of this material had to be developed. The use of reverse osmosis as a main step in a landfill leachate treatment chain - composed of different processes - or as single purification step has shown to be a very successful solution.

On one side of the reverse osmosis membrane, the residual organics and dissolved solids are concentrated and the remaining concentrate is recirculated or reduced in volume by further treatment like evaporation and solidification. If these remaining solids are deposited on the landfill site under controlled conditions no further pollution is expected.

On the other side of the membrane, a treated water stream is generated with very low respectively negligeable levels of inorganic and organic contaminants. These meet potable water standards. The discharge of this water to the next river or aquifer contributes to maintain the natural equilibrium, as this leachate was originally mainly clean rain water [2].

3. Reverse osmosis and Disc-Tube-module

After the introduction in 1988 of the DT-module in treatment systems for the purification of landfill leachate, more than half of the reverse osmosis plants installed for landfill leachate purification worldwide up to the end of 1994 have been equipped with this ROCHEM technology.

The high acceptance of the DT-module and the related plants - delivered as standardized fully tested stainless steel profile frame-construction units - is based on product properties like high operation security, process stability and reliability, flexibility against changes of the amount and the contaminants in the landfill leachate, the reproducable high purification efficiency as well as the low energy demand and small need of cleaning chemicals. The use of reverse osmosis is possible in this case with low pretreatment demand like multi media filtration even if the water to be treated has a high Silt Density Index respectively high turbidity because of the combination of an open channel design with the narrow gap technology and an optimized membrane cushion concept realized in the DT-module.

4. DT-module for high pressure reverse osmosis

The steady improvement of the DT-module has resulted in a high pressure reverse osmosis system with operating pressures in the range of 120 bar. With this development the limits for the recovery rate in landfill leachate have been overcome and the concentration factor for the organic and inorganic matter dissolved in the landfill leachate was doubled. This means an

increase of the permeate recovery rate from about 80% - related to a concentration factor of 5, considered as the limit of usual reverse osmosis - to 90% recovery with a concentration factor of 10 for the contaminants in the retentate.

The concentrate produced in this system can directly be fed into a dryer or a solidification device avoiding evaporation.

The result of further development was a DT-module for an operating pressure of 200 bar and more, that can be used under certain circumstances to improve the permeate recovery rate up to 95 % with a concentration factor up to 20.

5. Examples for leachate treatment with high pressure DT-module

5.1 Ihlenberg landfill

On the landfill of Ihlenberg a high pressure reverse osmosis stage for 120 bar (figure 2) is working since January 1992 with

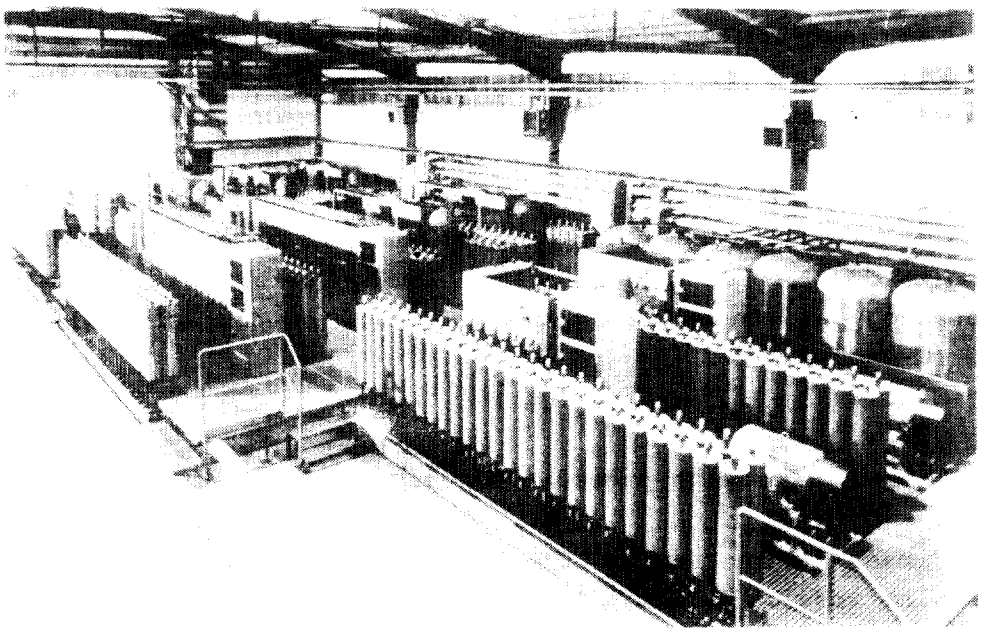

Figure 2: ROCHEM reverse osmosis landfill purification unit with leachate stage, permeate stage and concentrate stage (120 bar) at Ihlenberg using DT-modules with a capacity of up to 50 m^3/h Source: DMG/ROCHEM

a salt rejection of more than 99% (e.g. from 73,280 µS/cm in the feed to 434 µS/cm in the permeate). The average specific energy demand for this concentrate stage is 14 kWh per m^3 permeate (the leachate stage with 80% recovery in front of this system is consuming 5 kWh/m^3 permeate). The concentrate is processed in a solidification plant, were after the dosing of certain compounds a solid is produced that meets the environmental discharge requirements (figure 3, source: DMG/ROCHEM).

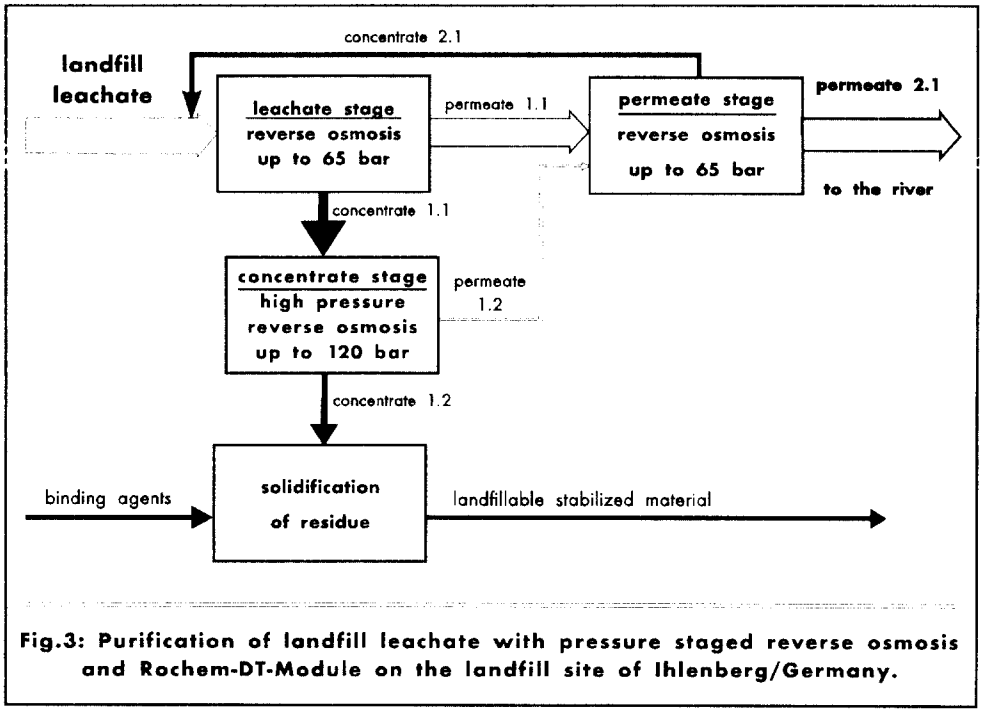

Fig.3: Purification of landfill leachate with pressure staged reverse osmosis and Rochem-DT-Module on the landfill site of Ihlenberg/Germany.

5.2 Halle-Lochau landfill

Since February 1993 a plant is in continuous operation at the landfill site of Halle-Lochau with a reliability of more than 95% and salt rejection rates of the same quality like reported above. Despite the very high electrical conductivity in the landfill leachate of 40,000 µS/cm in this case a overall recovery rate up to 90% is achieved with high pressure reverse osmosis respectively concentrate stages operating at 120 bar and at 200 bar (figure 4).

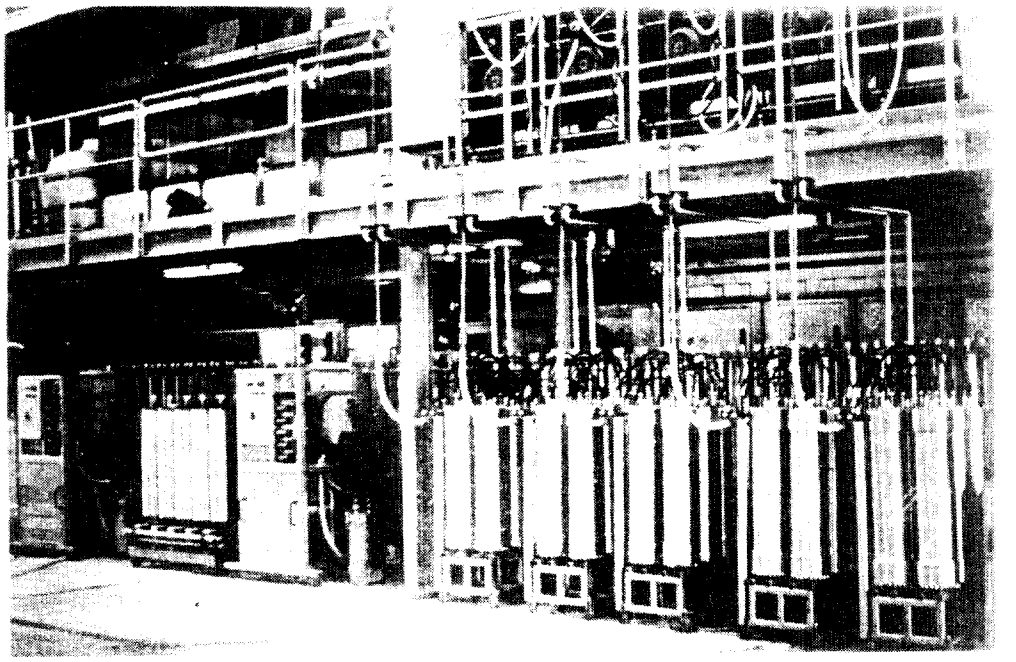

Figure 4: high pressure reverse osmosis concentrate stages with DT-modules for 120 and 200 bar operating pressure at the landfill site of Halle-Lochau Source: ROCHEM

Similar good results are obtained with reverse osmosis plants from ROCHEM and the DT-module meanwhile on more than 45 other landfill sites worldwide, whereby 17 are equipped with high pressure stages.

6. High pressure reverse osmosis and nanofiltration

Reverse osmosis together with high pressure reverse osmosis opens new perspectives for different kinds of separation problems in chemical engineering related to process fluids and waste water. Regarding the purification of landfill leachate a further improvement of the permeate recovery has been obtained by the combination of reverse osmosis operating at a pressure of 120 bar and/or 200 bar with the reduction of the concentration of certain salt fractions by controlled precipitation - the "fractionated removal of solids from RO-concentrates" [3] - and the nanofiltration, as shown in figure 5.

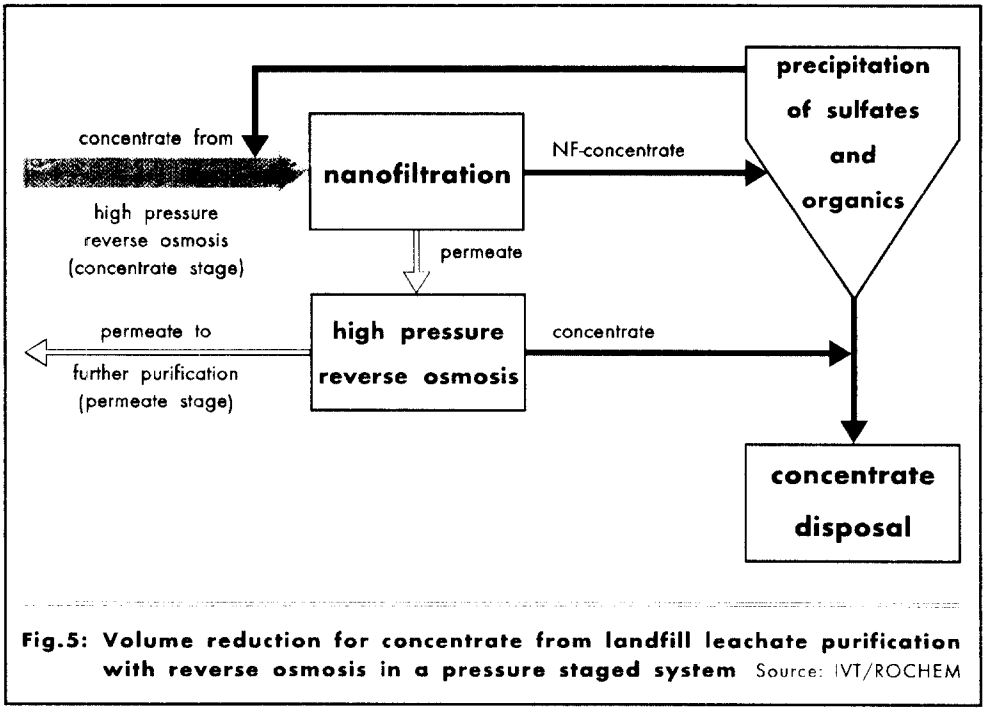

Fig.5: Volume reduction for concentrate from landfill leachate purification with reverse osmosis in a pressure staged system Source: IVT/ROCHEM

Using nanofiltration, material dissolved in water can be separated into monovalent and bivalent ions. Thus the high rejection rate for sulphate ions and dissolved organic matter together with very low rejection of chloride and sodium ions can also be used for the treatment of concentrates resulting from the purification of landfill leachate by reverse osmosis. When this nanofiltration stage is combined with controlled precipitation of salt fractions a further reduction of the concentrate waste volume can be achieved. For example, at one landfill a recovery rate of 97,5% with a concentration factor of 40 is now the operating standard [4].

7. Nanofiltration and the DTF-module

In order to use nanofiltration membranes effectively on heavy loaded waste water such as leachate two requirements must be met. Firstly, the membrane must be selected for suitability to the specific separation problem. Secondly, the module supporting the membrane must be suitably designed to optimize the interaction of flow parameters such as feed flow velocity, pressure drop, efficient membrane cleaning, insensitivity to particles in the µm-range, and finally a good cost/performance ratio.

These requirements for successful and continuous separation of heavily loaded waste water as described above are met by the ROCHEM DTF-module (figure 6).

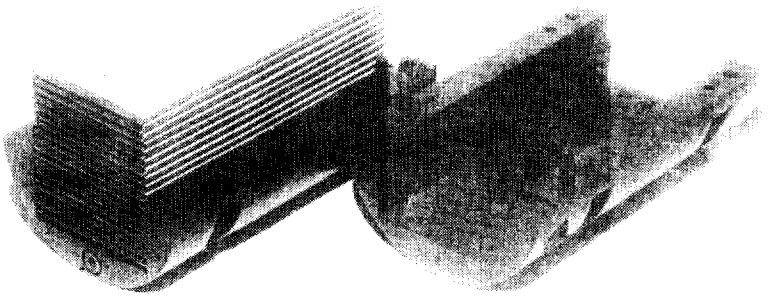

Figure 6: The DTF-module for nanofiltration Source: ROCHEM

This is a flat-channel module consisting of only a few components in which the advantages of an open-channel construction are combined with the benefits of the narrow gap technique. In the individual segments of the DTF-module rectangular hydraulic discs and ultrasonically welded membrane cushions are stacked alternately together and assembled in a multifunctional covering device. The module, a pressure vessel containing several of this segments, is delivered with a membrane area between 1 and 5 m^2.

A nanofiltration plant with the DTF- module with 180 m^2 installed membrane area for a permeate production between 3.6 and 5.5 m^3/h is shown in figure 7.

8. Purification of Landfill leachate as service

Based on the technology explained above a special service was installed by the plant manufacturer, the purification of

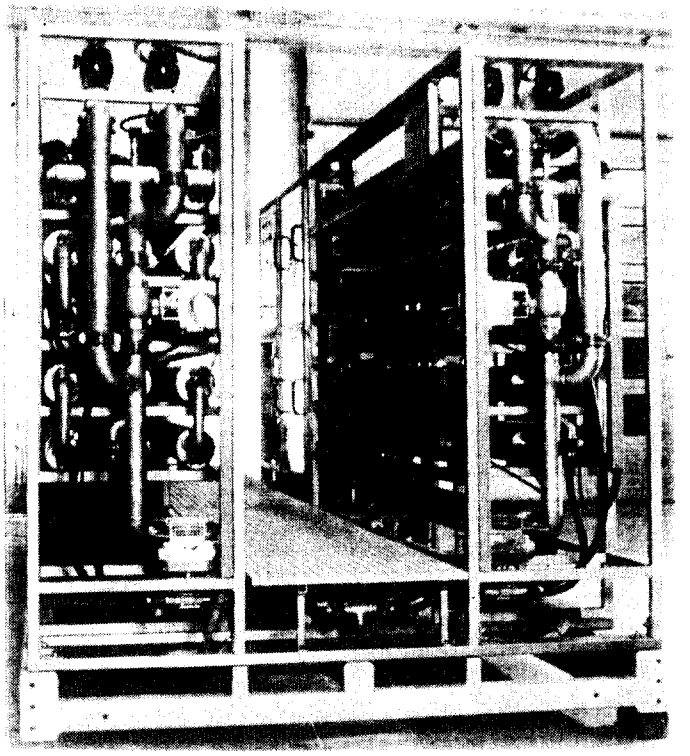

Figure 7: Nanofiltration plant with the DTF-module ROCHEM

landfill leachate on an "own and operate" basis. In 1992 and 1993, over 600,000 m^3 of raw leachate was treated by ROCHEM "owned and operated" plants. The clients simply paid a price per m^3 of leachate treated without capital risk and with minimal operational involvement.

This has been increased in 1994 due to new start up locations and ROCHEM's decision to operate its equipment for short term emergency situations caused by heavy precipitation and capacity bottle-necks.

One example for the quality: at a former disposal facility for liquid waste from the petroleum industry, near Houston, in the leachate of the bioremediated sludge of this superfund site - processed with two ROCHEM-DT-systems with 27 m^3/h feed capacity each - for example the TDS is reduced in single pass from 2,500 to 8 mg/l, TOC from 1,750 to 4 mg/l and TOX from 155 to 0.002 mg/l. The permeate, meeting National Pollution Discharge Environmental Standards, is discharged directly to a river.

9. Conclusions

The results obtained during the operation of an increasing number of plants under very different conditions prove that reverse osmosis is a very effective instrument for the purification of landfill leachate, if all design criteria and requirements specific for leachate have been taken into consideration and an adapted system like the DT-module as well as correlated technologies are used.

A further improvement was obtained through the development of modules for the high pressure reverse osmosis (120/200 bar) and of a open channel module for nanofiltration (DTF-module) that in combination with a controlled crystallisation process allows permeate recovery rates up to 98% - depending on the contaminants in the raw leachate. Advantages of this hybrid-process and reverse osmosis plants as well as nanofiltration plants from ROCHEM are the simplicity of this particular membrane technology, the high reliability, the significantly low energy consumption, and the ellimination of the negative impact of landfill leachate on the environment due to the dramatic minimization of residual waste to be processed or immobilized and due to the high quality of the purified water discharged back to nature.

10. Literature

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