FINAL PROGRAM

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LANDFILL LEACHATE

Water is material which by its suitable treatment can close the loop of pluses and minuses of any east European municipal waste management system. Leachate management is one of the most important activities at a landfill facility and needs to be handled properly to avoid unnecessary contamination of the environment. It is a complex waste water that needs to be treated using proper technology that meets the regulatory and local standards. Leachate generation predicted from a mathematic model needs to be calibrated according to the actual leachate quantity collected at the facility. Diffusion of volatile organic compounds through composite landfill liner / system does occur and this aspect will be discussed in this session.

Moderator:
James Law

SESSION - Tuesday / 09:00 - 11:00 / Room 2

WATER IS THE SUBSTANCE WHICH BY ITS SUITABLE TREATMENT CAN CLOSE THE LOOP OF PLUSES AND MINUSES OF ANY EAST EUROPEAN MUNICIPAL WASTE MANAGEMENT SYSTEM
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LEACHATE TREATMENT WITH RCDT REVERSE OSMOSIS
B. Mayr

*** Translation to Serbian and Romanian or Hungarian language will be provided**

Leachate Treatment with RCDT Reverse Osmosis

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Abstract

Today the necessity to purify highly polluted leachate means that the chemical oxygen demand (COD), ammonia and heavy metals with the sum parameter electric conductivity must be reduced by more than 95%. This either asks for a sophisticated combination of several coupled unit processes or can be obtained by reverse osmosis (RO) membranes as simple stand alone solution.

Starting from the late 1980s RO was introduced in Netherlands and Germany and is now the most frequently used system worldwide. It was proven that the reverse osmosis is a very efficient instrument for the purification of leachate. The basis for this is that the presently available reverse osmosis membranes are able to retain more than 98% of organic and inorganic substances with a molecular weight > 100.

As the reverse osmosis membranes function as a barrier, the purification process can be monitored reliably and with high reproducibility by means of the easy and simultaneously precise measurement of electric conductivity. Furthermore, the use of reverse osmosis membranes enables a high reliability, since the start up and shutdowns of plants are initiated by a pressure driven physical separation process and are put into practice within a few minutes. This enables an easy handling of RO-plants in case of shorter or longer standstills. Compared to this relatively simple straight forward process a biological or precipitation plant needs to be steadily adapted to the amount and composition of the leachate.

Caused by the high rejection rate for all pollutants dissolved in leachate, also a large flexibility is given referring to the change of concentration of the individual components. The thereby produced permeate always has a high quality, as this process is based on a reproducible high efficiency.

The modular structure of reverse osmosis systems allows a rapid increase or reduction in purification capacity by extension or reduction of installed membrane surface.

In addition to the fact that highly resistant membranes are necessary for the purification of leachate with reverse osmosis, also the use of modules with open channels is an indispensable condition. Some tests with spiral wound modules failed due to irreversible blocking within the spacers. Open channel modules can be cleaned with a high efficiency to prevent problems with scaling (deposits on the membrane by the precipitation of inorganic components), fouling (formation of deposits on the membranes by organic particulate constituents including colloids) and biofouling (formation of a bio film on the membrane surface). For this purpose the tubular module was used in the first plants. Then in 1988 the disc-tube-module DT was introduced in this market segment successfully.

With the RCDT module a significant improvement was introduced in 2001. The radial channel disc tube module features a special construction where defined open flow channels are formed between hydraulic discs and membrane cushions. Due to its superior hydrodynamic design the RCDT technology yields less pressure drop and consequently the energy demand is up to 30% less compared to common DT products.

A second innovation by the RCDT system is focused on easy maintenance: the Easy-Click system allows the exchange of modules in minimum time and thus helps to save working costs and reduces down time.

Keywords: Reverse osmosis, landfill leachate, RCDT module, EASY CLICK

1 Introduction

Rainwater which is not deflected or evaporated infiltrates the landfill and gets in contact with the waste-body stored in the landfill. A mass balance of rainfall, evaporation, surface drainage and storage in the landfill defines the amount.

Several parameters show a great influence on the formation, amount and concentration of the leachate, among those are

- surface (re-cultivated or open)
- re-infiltration or back-pumping and spraying
- rainfall
- temperature – climate
- composition of waste (household, incinerated, industrial slacks)
- age and design of a landfill

When landfill tops get sealed the amount of leachate will decrease (Schachermayer & Lampert, 2010). It is also important to understand that the landfill is acting as a large storage buffer. In other words a strong and short rainfall will not lead immediately to a strong increase in the effluent, but the amount of leachate will increase over the period of several hours or even days, depending mainly on the altitude and geometry of the landfill.

Due to the fact that leachate contains various types of organic and inorganic contaminants which represent a major risk to natural water resources (Li, et al., 2008), the leachate must be collected and processed with a proper treatment system. The right treatment system process can differ from landfill to landfill because the quality and quantity of leachate is also different for every landfill. The leachate composition mainly depends on biochemical conversion and lixiviation processes in the waste body which is again depended on the type and the amount of waste stored as well as the age of the landfill (Schachermayer & Lampert, 2010, p. 13).

The sum parameters of contaminants which are of great interest in the leachate analysis are next to others: total organic carbon (TOC), chemical oxygen demand (COD), biological oxygen demand (BOD), adsorbable organohalogens (AOX), Ammonia- and Nitrate-Nitrogen (NH_4-N, NO_3-N) and electric conductivity. The necessity to purify highly polluted leachate means that the COD, ammonia and heavy metals with the sum parameter electric conductivity must be reduced by more than 95%.

(Figure 1 here)

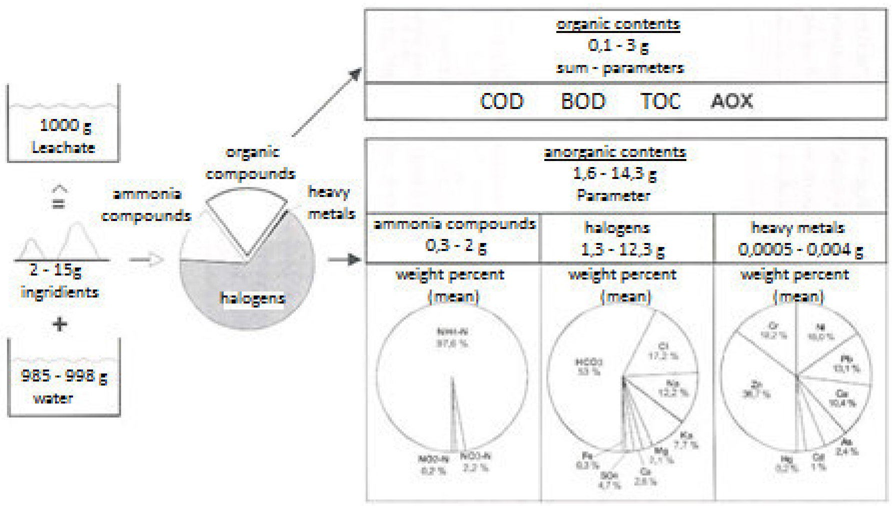

Figure 1: schematic sketch of the ingredients in landfill leachate

In Table 1 a range of concentrations for the most important leachate parameters are given:

(Table 1 here)

Parameter	unit	concentration range (higher values than the stated maxima appear scatered)	required purification performance based on 51. VwV (%)
COD	mg * l^{-1}	100 - 10.000	0 - 95
BOD	mg * l^{-1}	20 - 5.000	0 - 99
NH_4-N	mg * l^{-1}	40 - 2.500	0 - 98
AOX	mg * l^{-1}	0,1 - 5	0 - 90
fish poison	mg * l^{-1}	2 - 100	0 - 98
Cr	µg * l^{-1}	bdl - 500	0
Pb	µg * l^{-1}	bdl - 200	0
Cu	µg * l^{-1}	bdl - 300	0
Ni	µg * l^{-1}	bdl - 400	0
Zn	µg * l^{-1}	bdl - 1.000	0
Hg	µg * l^{-1}	bdl - 200	0
Cd	µg * l^{-1}	bdl - 50	0
el. Conductivity	µS * cm^{-1}	2.000 - 25.000	-
evaporation residue	mg * l^{-1}	1.000 - 15.000	-
ash content	mg * l^{-1}	800 - 10.000	-

bdl: bellow detecion limit

Table 1: range of significant parameters

In some specific cases this ranges might be passed over, for example an Austrian landfill shows COD values up to 40.000 mg/l, NH_4-N = 4.000 mg/l, Cr^{III}=5 mg/l due to dumping significant amounts of waste from leather production.

It can also be stated that the concentrations are higher in arid regions.

We know from experience of several landfills that the amount of leachate is indirectly related to the concentration. In other words the load of ingredients is to some extend quite stable, which is important for the design of a leachate treatment facility.

Some landfill operators use co-treatment or better dilution of leachate within municipal waste water treatment plants (WWTP) as process of decontamination. Regarding increasingly stringent WWTP emission limits and the introduction of organic inhibitory compounds with low biodegradability and heavy metals that may reduce treatment efficiency (Aktaş & Cecen, 2004) co-treatment is under a significant threat in terms of sustainability (Brennan, et al., 2015). This is drawing more interest to on-site leachate treatment.

This either asks for a sophisticated combination of several coupled unit processes or can be obtained by reverse osmosis (RO) membranes as relatively simple stand alone solution (Li, et al., 2008, p. 963). Since enactment of the landfill directive a trend towards higher leachate strength is observed (Brennan, et al., 2015), bringing RO even more into the spotlight as the technology of choice for leachate treatment. RO seems to be one of the most promising and efficient methods among processes for landfill leachate treatment (Renou, et al., 2007, p. 486). This was proven in a broad number of publications – to name a few (Li, et al., 2008), (Baumgarten & Seyfried, 1996), (Kwon, et al., 2007), (Rautenbach, et al., 2000). This paper aims to compare different membrane module designs with regard on contaminant retention, long term stability and specific energy consumption.

2 Materials and Methods

A literature review for publications dealing with landfill leachate treatment by means of reverse osmosis with different module systems was carried out. The literature review was done using online search engines e.g. Science Direct, Elsevier & Google Scholar. The data presented is an extraction of several publications. Obviously not every author gave the same information regarding qualities and process parameters e.g. flux.

Other information was obtained from manufacturing companies through personal communication.

2.1 Reverse osmosis – basic principle

The process of reverse osmosis exploits the natural phenomenon of osmosis. Osmosis takes place if two aqueous solutions with different concentrations are separated by a semi-permeable membrane (Kucera, 2010, p. 15). At a similar pressure on both sides liquid from the weaker solution will permeate the membrane in direction to the stronger solution driven by the force of a concentration difference (diffusion). This process continues until the concentration at both sides is equal.

The reverse osmosis operation reverses this natural process: pressure is applied to a higher concentrated water (leachate) against a "dense" solution diffusion-membrane forcing the water molecules to permeate through it despite the higher osmotic pressure. A clean permeate and a concentrated residual stream is produced. Due to the high rejection rate of the reverse osmosis membrane the permeate is purified water to a defined extent.

2.2 Leachate treatment with reverse osmosis

The necessary far-reaching purification of leachate can be obtained through reverse osmosis membranes, as it is shown by operating results, achieved under several boundary conditions with an increasing number of plants. At the beginning of 1999 more than 140 units were in operation, today several thousand plants are active. The basis for this is also that the presently available reverse osmosis membranes are able to reject all organic and inorganic substances dissolved in water with 98 to 99 % (Mayr, 2000).

With reverse osmosis the leachate is split into a "dense" concentrate and into a purified permeate. This concentrate contains the water components retained by the reverse osmosis membrane. The permeate –mainly the pure water permeating through the membrane -is cleaned to an extent that it can be discharged directly into a receiving water.

Most of the commercially available leachate treatment plants are constructed as two stage plants with contaminant removal rates higher than 99,6 % (Environment & Heritage Service; Environment Agency; Scottish Environment Protection Agency, 2007, p. 44). Molecules with a molecular weight of > 100 kg/kmol can be retained with the presently available reverse osmosis membranes. The desired far-reaching purification from potentially harmful organic compounds or heavy metals can therefore be ensured by reverse osmosis membranes. Therefore the reverse osmosis process is a very efficient unit operation for the purification of leachate.

As the reverse osmosis membranes function as barriers, the purification process can be monitored reliably and with high reproducibility by means of the easy and simultaneously precise measurement of electric conductivity. Furthermore, the use of the pure physical reverse osmosis process enables a high reliability, since the start up and shutdown can be put into practice within a few minutes. The driving force for the process is an operating pressure produced by feed and re-circulation pumps. According to that neither biological lag phases or heating delays nor special instructions have to be observed during start up and shutdown. At the same time this enables an easy handling of plants in case of shorter or longer standstills.

Caused by the high rejection rate for all pollutants dissolved in leachate, also a large flexibility is given referring to the change of concentration of the individual components. The thereby arising permeate always shows a high quality, as this process is based on a reproducible high efficiency during purification.

This technique shows the same flexibility even with considerable changes of leachate to be treated. The modular structure of reverse osmosis systems allows a rapid increase or reduction in purification capacity by extension or reduction of installed membrane surface.

The high flexibility also minimizes the requirement of large balancing tanks/lagoons. Commercial plants are generally containerized modular plants that are fully automated and capable of being monitored and controlled remotely. Standard modules are available with leachate throughput capacities from 20 m³/d up to 200 m³/d housed in single 20" or 40" ISO containers (Environment & Heritage Service; Environment Agency; Scottish Environment Protection Agency, 2007, p. 45).

2.3 Process description

Reverse osmosis plants are very sensitive to incoming particulate matter and fibres. Therefore a tailor-made pre treatment of the leachate has to be designed e.g. sand filtration (separating particles > 50µm) followed by cartridge filtration (separating particles > 10µm) upstream. Also dosing of acid (mostly sulphuric acid) to set the pH to 6.0 – 6.5 is a common make up step before entering the RO-Unit. This helps increasing the solubility of inorganic salts and increases the removal rate of NH_4-N significantly (Li, et al., 2008). The membranes are made of artificial materials (PVDF, polyamid) which is mounted as a thin film composite structure on a supporting layer. Membranes are installed inside of pressure tubes which are interconnected and equipped with recirculation pumps to provide constant overflow over the membrane surface. To avoid concentration polarisation (the build-up of macro molecules next to the membrane which cannot permeate the membrane) and fouling, a sufficient cross flow velocity has to be ascertained. Otherwise the efficiency of the module cannot be maintained.

RO plants do require frequent stoppages to clean the membranes. The membrane cleaning is done with a solution of membrane detergent and permeate produced by the plant. The cleaning cycle is generally managed automatically e.g. by measuring the flux or the electrical conductivity of the permeate.

On many landfill sites the produced concentrate is recirculated over the landfill for reinfiltration (especially at places where there is insufficient precipitation). The applicability of this practice has to be evaluated in each individual case and of course according to country specific governing environmental law.

Most leachate treatment RO plants are built in multi-permeate stage configuration (two to three stages). In Figure 2 a typical process scheme of a 2-stage RO plant is shown.

(Figure 2 here)

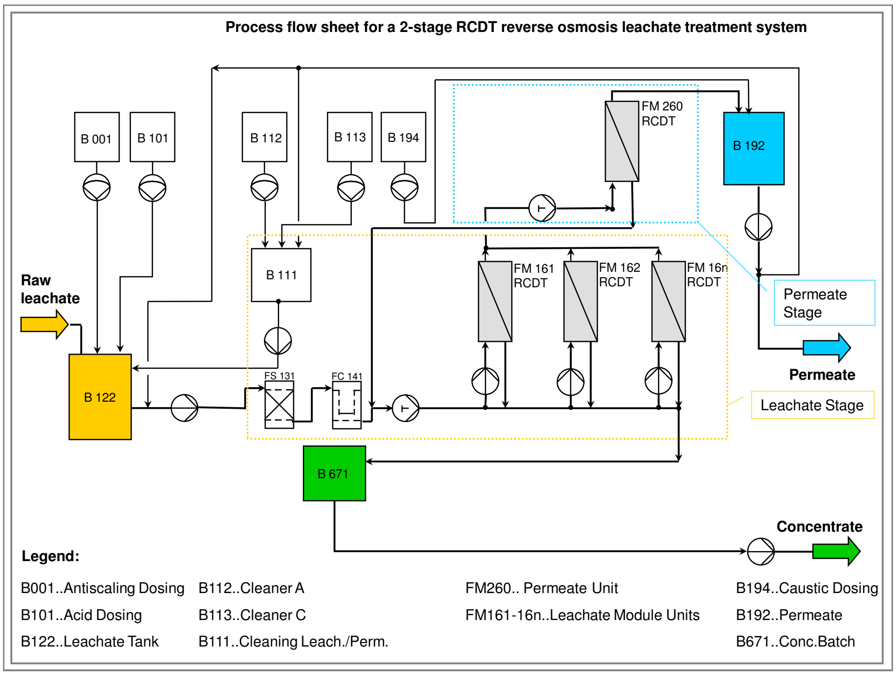

Figure 2: process scheme of a 2-stage RO Plant (ROTREAT Abwasser GmbH)

In the first stage most of the cleaning takes place, while the subsequent stage(s) polish the permeate further. The membranes have high salt rejection and display very high physical and chemical durability.

In the past 20 years considerable improvement of seawater spiral wound elements have been made. The capacity of an 8-inch element has been doubled whereas the salt passage is about three times less (Busch & Mickols, 2004) (Garcia, et al., 2008).

Here it should be emphasized that it is possible to obtain a permeate recovery rate up to 90 % by using the reverse osmosis in combination with high-pressure reverse osmosis (HPRO) developed on the basis of the DT module technique with operating pressures of 120 and 150 bar respectively. Accordingly the concentrate can be reduced to 10 % of the whole volume fed into the plant depending on the input characteristics.

3 Discussion

3.1 Spiral wound modules

In the beginning of the 1990s spiral wound modules started to displace hollow fibre modules (Johnson & Busch, 2009) in the segment of seawater desalination.

The Pros and Cons of spiral wound modules are listed in Table 2:

(Table 2 here)

Pros	Cons
Easy and cheap production	Poor cleaning efficiency
Relative high packing density	Membrane must be weld- and glueable
Good substance exchange due to feedspacer	Partial long flowpath along the permeate side

Table 2: Pros and cons for spiral wound modules (Rautenbach, 1997, p. 74)

Some performance data of spiral wound modules in leachate treatment is presented in Table 3.

(Table 3 here)

	unit	1st-stage inlet	2nd-stage permeate	Removal efficiency	Reference
pH	-	7.9	6.6	-	Li et al. (2008)
Conductivity	$\mu S\ cm^{-1}$	16500	300	98.2	Li et al. (2008)
COD	$mg\ l^{-1}$	3100	15	99.5	Li et al. (2008)
NH_4-N	$mg\ l^{-1}$	1000	11.3	98.9	Li et al. (2008)
NO_2-N	$mg\ l^{-1}$	5	0.15	97	Li et al. (2008)
NO_3-N	$mg\ l^{-1}$	15	2.6	82.7	Li et al. (2008)
Cl	$mg\ l^{-1}$	2850	23.2	99.2	Li et al. (2008)
Al	$mg\ l^{-1}$	0.12	<0.001	>99.2	Li et al. (2008)
Fe	$mg\ l^{-1}$	7.6	<0.001	>99.9	Li et al. (2008)
Pb	$mg\ l^{-1}$	0.37	<0.001	>99.7	Li et al. (2008)
Zn	$mg\ l^{-1}$	0.65	<0.001	99.8	Li et al. (2008)
Cu	$mg\ l^{-1}$	0.26	<0.001	99.6	Li et al. (2008)

Table 3: performance of a spiral wound module

Li et al. (Li, et al., 2008) reported, a average flux in the range of 6.5 – 8.14 l $(m^2\ h)^{-1}$ at a trans-membrane-pressure (TMP) difference of 20 bars initially, rising to 40 bars before chemical membrane cleaning (every 90 h with sodium hypochloride). A Recovery rate of 70 % was achieved. In the work of Li et al the results of other authors that a upstream biological stage enhances the membrane flux, could not be reproduced. With previous biological treatment the flux ranged between 4.23 – 5.53 l $(m^2\ h)^{-1}$.

Anyhow spiral wound modules are successfully used for polishing the effluent of membranebioreactors (MBR) which are used frequently as a first treatment stept to reduce the organic and nitrogen load of the leachate. As long as the micro- or ultrafiltration of the MBR is intact the spiral wound module will not be blocked by filterable solids. The RO-unit will operate stable and not bothered by biofouling, only scaling will have to be controlled (Mayr, 2012) (Mayr, 1998).

The energy demand of a standard 1-stage spiral wound RO plant is roughly in the range of 4 kWh/m³.

3.2 Radial channel disc tube (RCDT) modules

In addition to the fact that highly resistant membranes are necessary for the purification of leachate with reverse osmosis, also the use of modules with open channels is an indispensable condition if no MBR is operated prior to the RO unit. Membranes have to be cleaned with a high efficiency to prevent problems with scaling (deposits on the membrane by the precipitation of inorganic components), fouling (formation of deposits on the membranes by organic particulate constituents including colloids) and bio fouling (formation of a bio film on the membrane surface). For this purpose the tubular module was used in the first plants. In 1988 the disc-tube-module (DT) was introduced in this market segment. At the beginning of 1999 already more than 120 plants were equipped with this module for the purification of leachate, mainly in Europe. Nowadays much more than 1000 units are in operation worldwide. This corresponds to over 90 % of the total capacity of reverse osmosis systems installed on landfills for the purification of leachate.

The Pros and Cons of disk tube modules are listed in Table 4.

(Table 4 here)

Pros	Cons
Few sealings necessary	Relative low packing density (<400 m² m^{-3})
Works in high pressure applications	
Low permeate side pressure loss	
Hardly susceptible to contamination	

Table 4: Pros and cons of disk tube modules (Rautenbach, 1997, p. 76)

Some performance data of disc tube modules is presented in Table 5Table 3.

(Table 5 here)

	unit	1st-stage inlet	1st-stage permeate	2nd-stage permeate	Removal efficiency	Reference
pH	-	6.8 - 7.41	5.9 - 6.3	5.14 - 5.71		Liu et al. (2008)
	-	4.8 - 7.0	-	5.0 - 5.9		Ushikoshi et al (2002)
	-	7.9	-	8.4		Peters (1991)
Conductivity	µS cm^{-1}	7600 - 18610	350 - 728	50.8 -77	99.6	Liu et al. (2008)
	µS cm^{-1}	6360 - 52800	-	29 - 200	99.5 99.7	Ushikoshi et al (2002)
	µS cm^{-1}	13140	-	27	99.7	Peters (1991)
COD	mg l^{-1}	3620 - 11200	79.4 - 197	29.6 - 56	99.2 - 99.7	Liu et al. (2008)
	mg l^{-1}	21.1 - 747	-	<1	98.1 ->99.9	Ushikoshi et al (2002)
	mg l^{-1}	912	-	15	99.9	Peters (1991)
BOD	mg l^{-1}	1300 - 8200	24.1 - 35.5	<10	99.23 - 99.87	Liu et al. (2008)
	mg l^{-1}	5.1 - 197	-	<1 - <5	>90.7 - >98.8	Ushikoshi et al (2002)
	mg l^{-1}	184	-	2.5	98.6	Peters (1991)
SS	mg l^{-1}	340 - 550	0 - 0.25	0		Liu et al. (2008)
TOC	mg l^{-1}	4500	37	0	99.2	Liu et al. (2008)
NH_3-N	mg l^{-1}	229 - 438	26.5 - 125	4.54 - 5.44	>98	Liu et al. (2008)
	mg l^{-1}	3.9 - 53	-	0.29 - 1.53	90.2 - 98.4	Ushikoshi et al (2002)
Cl	mg l^{-1}	2460 - 26900	-	4.5 - 47.4	99.8 - 99.9	Ushikoshi et al (2002)
	mg l^{-1}	3091	-	2.7	99.9	Peters (1991)
Fe	mg l^{-1}	0.2 - 4.1	-	<0.01 - 0.02	98.8 - >99.8	Ushikoshi et al (2002)

Table 5: Performance data of DT modules

In numerous applications disc tube modules have shown very high rejection rates of contaminants as well as long-term process stability in terms of permeate fluxes (Ushikoshi, et al., 2002) (Liu, et al., 2008) (Şchiopu, et al., 2012). The disc tube reverse osmosis module can be regarded as one of the best for leachate purification (Li, et al., 2008).

One significant improvement of the disk tube module is the Radial Channel Disc Tube module (RCDT) – see Figure 3.

Front side Back side

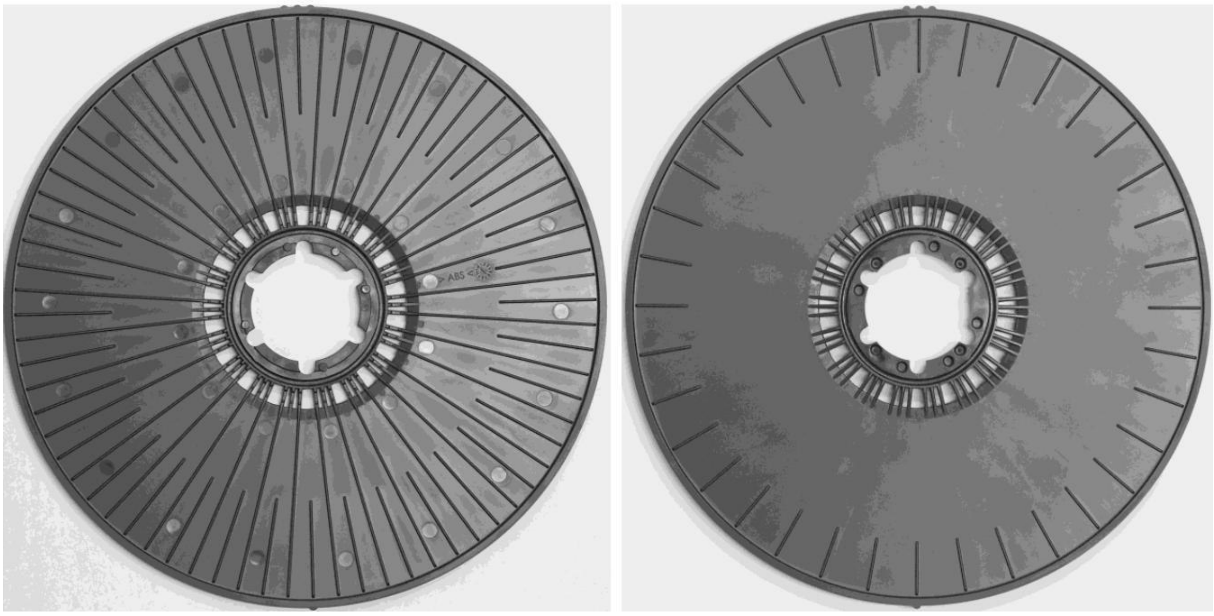

Figure 3: radial channel disc made from ABS © by ROTREAT Abwasserreinigungs GmbH

The RCDT module consists of a pressure tube and hydraulic discs which are held by a central tension rod. Circle- or octagonal shaped membrane cushions lie between every two discs. Owing to this special construction, open flow channels on the raw water side are formed between hydraulic discs and membrane cushions where the raw solution concentrates between in- and outlet. The individual channels are joined together by openings in the discs, which are arranged in annual pattern, so that the feed water flows radial across the membrane cushions, alternately from the inside towards the outside and vice-versa. The clean water that has permeated the RO-membrane flows on the inside of the cushion into the spacer radial inwards to the central permeate collector and is directed along the clamping pin to the connecting flange of the module. The separation of concentrate and permeate happens between the hydraulic disc and the membrane cushion.

Next to the pros of standard disc tube modules stated in Table 4, the innovative pros for the RCDT modules are the hydrodynamic design whereby the module yields less pressure drop due to the formation of laminar flow along the channels with a consequently lower energy demand as well as the maintenance-friendly construction due to the Easy-Click system. This system allows the exchange of modules in minimum time and thus helps to save working costs and reduces down time.

Also the RCDT module is fully compatible with common DT modules. So switching to RCDT modules doesn't imply adaptations of the existing plants. With the development of RCDT 2.0 it is now possible to build circular membrane cushions leading to an increased membrane surface area per module (for size XXL: 12 m² per module). The packing density of the XXL module is 314,6 m²/m³. The RCDT module works up to 90 bar standard operating pressure and modules are available up to 160 bar.

The energy demand for RCDT Modules depends on many parameters like: composition of leachate, capacity of the plant, recovery rate, additional equipment e.g. degasser. For a rough estimate the energy demand can be given as:

- 6,5 kWh m^{-3} for 1-stage RCDT RO without heating or cooling
- 8,5 kWh m^{-3} for 2-stage RCDT RO without heating or cooling
- 11,2 kWh m^{-3} for 3-stage RCDT RO without heating or cooling

3.3 Treatment of the concentrate

Nearly all ingredients of the leachate find their way to the concentrate, in other words they are neither destroyed nor dissolved. Generally there are three options to treat the concentrate of a stand-alone RO unit:

1. drying of concentrate

   This costly process was realized several times in Germany, but failed in practice. The reason was that the dryers were extremely complicated to run and that in the dried product some unforeseen exothermal chemical reactions took place, leading sometimes to fires in the plants

2. incineration of concentrate or treatment as hazardous waste
   This solution is costly but enables a steady and long term operation of the leachate treatment system.
3. reinfiltration of concentrate into the landfill body

   For landfills operated with controlled concentrate infiltration (Peters, 2001) it is possible to give following assessment after an observation of many years: when the system for the controlled infiltration of leachate concentrates were designed considering the characteristics of the corresponding landfill, there were no changes for the concentration of pollutants. This is proved by results, which have been and are achieved on different landfills in various countries, one of these references since 1986.

   Of course it is necessary to monitor certain parameters of the concentrate, also the amount of infiltrated concentrate and rainfall events. Anyhow it has to be noted that several pre-conditions must be met, like the height of the landfill body must sufficient, a suitable re-infiltration system must be installed, the yearly rainfall must not exceed a certain limit and also the kind of waste must be suitable.

4 Conclusion

Today the innovative RCDT-module is the most advanced disc-tube RO. Based on this new and energy efficient design the energy consumption of the open-channel cross-flow plant is nearly as low as the energy demand of a spiral wound RO which is not applicable for the treatment of raw landfill leachate.

The new larger XXL modules allow a significant expansion of the membrane area in existing DT-plants. Due to the lower pressure loss of the newly designed radial feed channels not even pumps have to be changed. Thus the throughput of an existing RO-unit can be increased only by upgrading the existing RO-system to RCDT technology.

Together with the so-called Easy-Click system for changing membrane elements and spacers the RCDT-plant design minimizes time for maintenance and thus saves operating costs.

5 Acknowledgements

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