APPENDIX D

DETAILS OF LEACHATE TECHNOLOGY

Norit Membrane Technology BV

Norit
leading in purification

General Information

Norit "The Purification Company", founded in 1918, offers world wide total solutions and projects for the water, wastewater, beverage, food, dairy and pharmaceutical industries. Norit uses its innovated treatment technologies in products, systems and technological solutions.

With over 1200 employees and a turnover in excess of € 300 million they are a recognised leader in their field.

Description of Products & Services

Norit Membrane Technology is specialised in membrane technology for the production of drink and process water in the application of treatment of groundwater, surface water and for the treatment of (domestic) wastewater for discharge and/or reuse. Norit supports this all with mature scale and pilot plants, process engineering, training and service contracts.

X-Flow, also part of Norit, offers a complete membrane and module program for treatment of any water - potable, industrial, process, waste and landfill leachate.

Depending on the influent specs of the leachate water, Norit will design a plant around its Airlift MBR™ or Crossflow MBR™ technology, using post treatment technologies, such as Reverse Osmosis or Activated Carbon to deliver a water quality within effluent discharge limits.

Norit operates a ISO 9001:2000 quality system and adheres to drinking water standards KIWA-ATA, KTW/DVGW & ANSI/NSF61.

USP's

- Turnkey project management
- In-house Membrane manufacturing
- Lowest CAPEX/OPEX

Export Markets

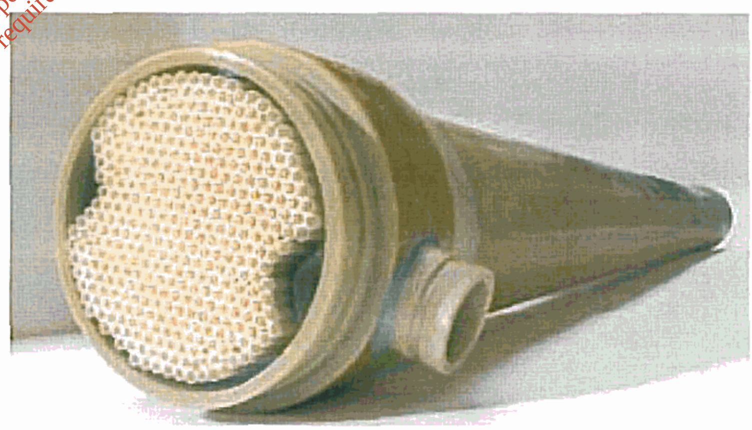
Norit exports to more than 150 countries and has European references in the Netherlands, UK, Portugal, Norway, Slovenia, Ireland, Russia, Croatia, Ukraine, Romania and France.

References

Norit has recently completed Leachate Water Treatment installations at 2 of Europe's largest landfill sites in Turkey.

Norit at IRWM 2008

Norit welcomes contact with waste organisations (both private and government) seeking solutions for treating landfill leachate water before discharge.



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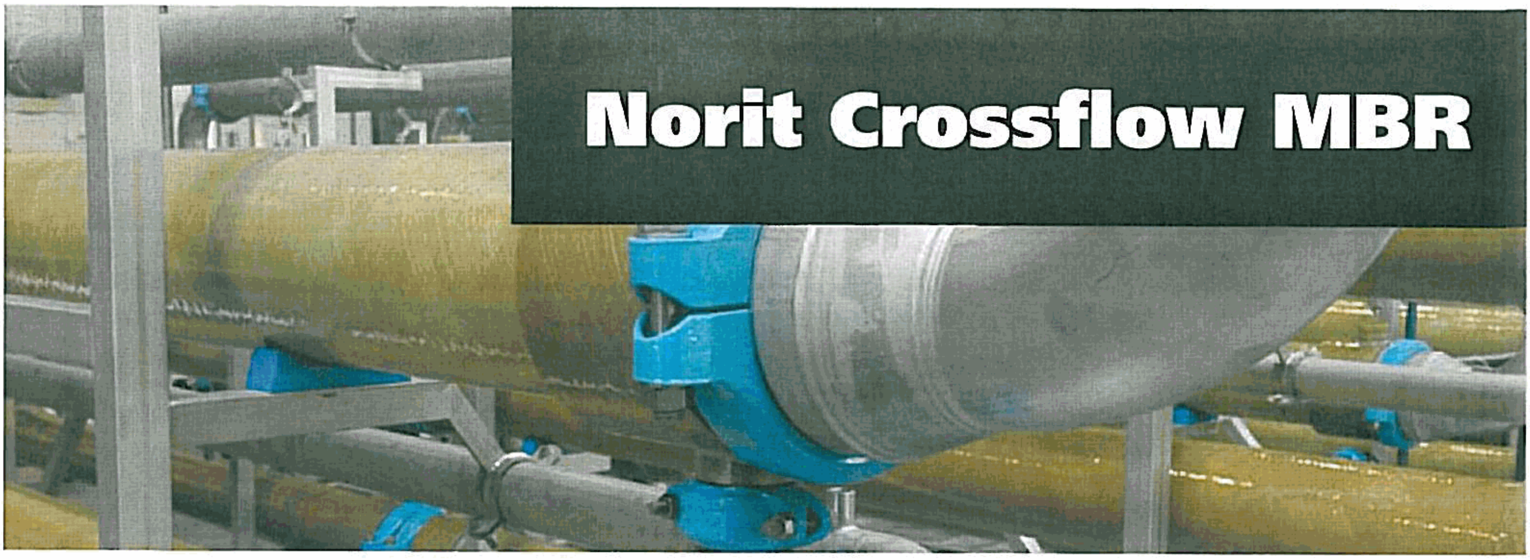

Industrial wastewater

Challenge

Due to more stringent international and governmental legislation, in terms of wastewater discharge consents, the disposal cost of municipal wastewater is increasing. Traditional wastewater treatment is primarily done using biological degradation in reactors followed by a clarification step which is typically a sedimentation process. These tend to be large footprint plants which do not produce water of a re-usable quality. For more efficient wastewater treatment and to provide high quality water for re-use, the Membrane BioReactor (MBR) has been developed.

Solution

The Norit Crossflow MBR is a compact purification system combining the biological degradation step with a membrane separation step. The influent is fed to the aerated bioreactor where the organic components are oxidized by the activated sludge. Next, the aqueous activated sludge solution passes through a membrane filtration unit separating the water from the sludge. The latter returns to the bioreactor, while permeate is discharged or re-used as particle-free effluent.
The membranes are configured in a unique side stream set-up outside of the bioreactor; this offers a compact footprint in combination with a simple and easily maintainable stand alone Norit Crossflow MBR system.
Norit X-Flow's ultrafiltration (UF) membrane will provide a robust purification solution. The water can either be re-used directly or further treated as required, e.g. through reverse osmosis, activated carbon or UV.

Norit Crossflow MBR is applied in areas such as:

- Leachate, effluent coming from landfill sites
- Beverage industry, where high COD loads need to be reduced, e.g. breweries, malteries, dairy factories
- Other industries, e.g. chemical and textile

The Norit X-Flow membrane modules are being produced with ISO 9000 certification.

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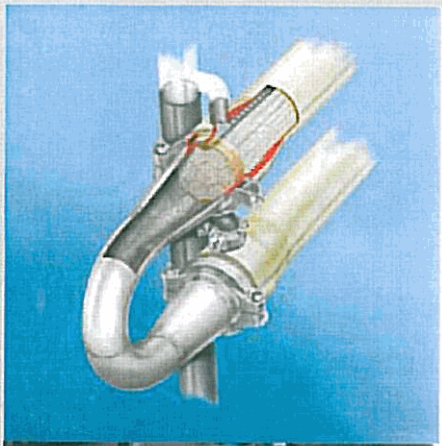
Norit Crossflow MBR



Features and benefits

Tight UF membrane	Turbidity < 0.1 NTU
	SDI < 3
Norit Crossflow filtration	Limited energy consumption
	Simple lay -out
	High flux rates
Cleaning In Place	Fully automated cleanings
	Use of low cost chemicals
Fully automatic operation	Logging of operating parameters
Pressurized system	Fully enclosed
	No operator exposure to fumes or aerosols
	Small footprint

Examples

Norit X-Flow provides membranes for MBRs for hundreds of plants world-wide. Capacity ranges from less than 240 m³/day (0.06 MGD) to more than 3,000 m³/day (0.8 MGD).

Hooge Maay – Belgium	Leachate
Capacity	600 m³/day (0.16 MGD)
Year of start up	2002
Technology	Norit Crossflow MBR
Holland Malt – The Netherlands	Maltery waste recycle
Capacity	1,500 m³/day (0.4 MGD)
Year of start up	2006
Technology	Norit Crossflow MBR
Geest salad factory – UK	Salad factory
Capacity	1,200 m³/day (0.32 MGD)
Year of start up	2004
Technology	Norit Crossflow MBR
AFM – The Netherlands	Chemical waste treatment
Capacity	3,600 m³/day (0.95 MGD)
Year of start up	1999
Technology	Norit Crossflow MBR
Pieter Bon – The Netherlands	Tank cleaning facility
Capacity	240 m³/day (0.63 MGD)
Year of start up	2003
Technology	Norit Crossflow MBR
Glasgow – Scotland	Chemical plant
Capacity	1,400 m³/day (0.37 MGD)
Year of start up	2006
Technology	Norit Crossflow MBR
Istaç – Turkey	Leachate
Capacity	2,000 + 3,000 m³/day (1.32 MGD)
Year of start up	2007
Technology	Norit Crossflow MBR

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Norit Membrane Technology BV reserves the right to make changes in the technical specifications at any time.

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Maria Holmes

From: Edel Brennan [EBrennan@response-group.ie]
Sent: 22 April 2008 16:25
To: Maria Holmes
Cc: Salvador McNamara
Subject: RE: 1908 210408 E Brennan 16.04 - leachate treatment

Maria,
Please find attached details of appropriate equipment for the leachate treatment plant at Derrinumera Landfill. What I have included should ensure that all of the proposed discharge standards are met. I have also attached a copy of a similar project that is currently under construction in Wexford. And the details from Balleally
If you require more information just give me a call.
Regards,

Edel Brennan
O&M Manager

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Email: ebrennan@response-group.ie Web: www.response-group.ie Location map
Incorporated in Ireland Company No. 292095

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Derrinumera Leachate Treatment Facility

Introduction
The detail below outlines a proposed leachate treatment plant at Durrinumera landfill Co. Mayo.
This is indicative of the type of process and plant available to treat the leachate to the proposed discharge standards.

Design Issues

1. COD/BOD
The ratio of these two parameters is vital to the design of the plant. The analysis supplied on the current leachate indicates that the biological portion of the COD is quite low. For this reason an activated carbon filter has been included to remove this portion prior to discharge.

2. Low BOD
Some of the BOD results are very low. There may be a requirement to add additional carbon in the form of acetic acid or methanol. However Nitrate is not included in the current proposed discharge standards. If complete denitrification is required, additional carbon may need to be dosed.

3. Faecal Coliforms
To insure that the complete die/kill off of Faecal coliforms disinfection in the form of Chlorination or Ozone is included. Another option would be a constructed wetland. This would be dependent on the availability of land etc.

4. Heavy Metals PCB and VOC
These are removed by the activated carbon filter.

Proposed leachate treatment plant at Derrinumera landfill

1. Balancing and Storage
1. Feed equalisation and homogenisation
2. Addition of carbon source
3. Storage. 2-3 days.

Plant Required
Holding tank with:
Mixer
pH correction with pH probe
Acid and base dosing pumps
Additional carbon source (Methanol/Acetic Acid) and dosing pump
TOC NH4 SS Turbidity analyser
DO Probe

2. Biological Treatment
1. COD, BOD removal
2. Nitrification
3. Denitrification
4. TP elimination by chemical addition (if required)

Plant Required
1. SBR x 2 set up in series with the option to run in parallel with:
DO Probe
MLSS probe
Variable speed drive blower DO controlled
Mixer
Option to add ferric or other flocculent

2. Tidal Tank- (filter feed tank)
pH correction with pH probe
Acid and base dosing pumps
TOC, NH4, SS and Turbidity analyser
DO Probe
Return pump to back to the holding tank

Proposed leachate treatment plant at Derrinumera landfill

3. Tertiary Treatment
1. Hydrocarbon removal
2. PCB removal
3. Dissolved metal removal
4. VOC removal
5. Disinfection

Plant required
1. Sand Filter or Constructed Wetland (depending on the available space)

2. Carbon Filter

3. Disinfection
Ozone/chlorination (the location dependent on type chosen)

4. Sludge storage and thickening

Plant required
Picket Fence thickener

5. Automation

Plant required
SCADA system

Maria Holmes

From: Marjorie_La_grange@keppelseghers.com
Sent: 04 August 2005 10:48
To: Maria Holmes
Subject: RE: Leachate treatment

MStore_2C_en_004_A - FUJI Neth... MStore_2C_en_003_A - Cova Da B...

Dear Maria,

Based on the information you sent us, we'd suggest a combination of MBR and RO.

With RO one can achieve very high removal efficiency. It is often said that removal efficiency of an RO for salts, minerals, metals, organic matter ... can go up to 99%. Of course this depends on molecular size and weight of the molecules to be removed, but on average efficiency is very high indeed (definitely 95%).

We did a similar project on leachate at Cova de Beira in Portugal. You'll find the case study for that project in attachment. The treated water is used for irrigation, while the brine is sent back to the landfill. Cova was designed with an external MBR. Because of the low biological load in your case, we should be able to work with an internal MBR (submerged
membranes) which represents a much lower energy cost.
To give you an idea of our internal MBRs, I also added the case study of Fuji. The application is totally different and not really relevant here, as the objective was to regain silver from the waste water. The treated water was reused as process water in the factory. The brine was discharged to sewage.

I can't give you figures on recovery for your case right now, as we haven't gotten into dimensioning the MBR or the RO. I suggest to wait for dimensioning until the project has gotten into a further stage.

I hope the above answers your questions. Please feel free to contact us for additional information or if you still have any question. I suggest to get in touch again anyway, when the project has evolved to a phase where a more concrete design is required.

Best regards,
Marjorie

(See attached file: MStore_2C_en_004_A - FUJI Netherlands English.pdf)(See attached file: MStore_2C_en_003_A - Cova Da Beira Portugal English.pdf)

"Maria Holmes" <Maria.Holmes@tobin.ie>
04/08/2005 10:10

To: <Marjorie_La_grange@keppelseghers.com>
cc:
Subject: RE: Leachate treatment

APPENDIX E

CASE STUDIES FOR LEACHATE TREATMENT

BALLEALLY LEACHATE TREATMENT PLANT

DESIGN & BUILD CONTRACT
OPERATE CONTACT

The Contract provides for the Design and Build of new leachate treatment plant at Balleally Landfill, Fingal, Co. Dublin. The plant is designed to treat the following influent loads:-

- BOD:- 1500Kg/day
- COD:- 1800Kg/day
- SS:- 300Kg/day
- Ammonia:- 180Kg/day

The leachate treatment plant is designed to treat a flow of 150 m^3/day, the treatment process selected was Sequencing Batch Reactors followed by AFM Filtration. The process incorporates Balance Tank, 2 No. SBR Tanks, Tertiary Treatment, Backwash System, Sludge Pumping, Storage and dewatering via a centrifuge decanter

The plant consists of the following:-

- Raw leachate balance tank with a capacity of 1043m^3 capacity.
- 2 No. SBR tanks (operated in series) each with a capacity of 1674m^3.
- Fine Bubble Diffused Aeration System c/w by 3 no. 45kW air blowers. Submersible mixers are provided in the Tanks to keep the contents of the tank in suspension.
- Sludge Return & Recycle pumping
- Tertiary Filtration
- Sludge Thickening & Dewatering

The system is set-up with SBR Tank 1 utilised only for nitrification and SBR Tank 2 for denitrification. The system was optimised during the commissioning stage to achieve the required effluent discharge standards. A commissioning period of a year was necessary to allow the plant to develop and operate as designed.

Response Engineering fulfilled the role of PSCS on this project and has responsibility for civil works as follows:-

- Excavation and backfilling of tanks, etc.
- Reinforced concrete bases for glass lined steel tanks
- Construction of SBR tanks (25.0m x 5.5m) & Balance Tanks
- Interconnecting pipework & ducting
- Plinths, manholes and site services
- Access road

Response Engineering have been Operating the plant successfully since March 2006

RESPONSE ENGINEERING

Client:
Fingal County Council,
Swords,
Co. Dublin.

Client Representative:
RPS,
Westpier Business Campus,
Dun Laoghaire,
Co Dublin.

Design Flow:
150 m^3/day

Value:
Capital Works
€ 1,300,000

Year of Commencement:
2004

Status:
D&B:- Complete
O&M:- Ongoing

Project Involvement:
Plant Designer
Principal Contractor

Process:
- **Balancing Tank**
- **Forward Feed Pumps**
- **SBR Tanks (2 No.)**
- **Sludge Pumping**
- **Sludge Thickening**
- **Recycling System**
- **Sludge Dewatering**

Discharge Standard:
25mg/l BOD
35mg/l SS
125mg/l COD

HOLMESTOWN WASTE MANAGEMENT FACILITY & LEACHATE TREATMENT PLANT

DESIGN BUILD OPERATE CONTRACT

The contract consists of the design and build of all instrumentation, mechanical, electrical, and associated civil works in compliance with the waste licence and planning conditions of the Holmestown Waste Management Facility. There shall be a 5 year operation and maintenance period for the works.

The two main elements of the works are as follows:-

1. Leachate Treatment Plant

Turnkey Design & Build Contract of new leachate treatment plant at Holmestown, Co. Wexford and comprises the detailed design and construction of the plant followed by a 5 yr operation & maintenance period of the works.

The plant is designed to treat the following design loads:-

- BOD:- 10,000mg/l
- COD:- 20,000mg/l
- Ammonia:- 3,500mg/l
- Total Nitrogen:- 4,500mg/l

The plant consists of the following:-

- Leachate Balance Tank
- Balance Tank (Hardstanding Area)
- 2 No. SBR Tanks each with a capacity of $1200m^3$.
- Fine Bubble Diffused Aeration System
- Sludge Return & Recycle pumping
- Biological Trickling Filter
- Sludge Thickening & Dewatering

2. Mechanical and Electrical Works

The scope for the Mechanical and Electrical Works include the supply, installation, commissioning and servicing of the following:-

• Site Services and Operations inc. 2 No. Weighbridges, Traffic barriers, Truck wheel wash, Landfill gas collection and flaring & Standby diesel generator

• Building Services for Administration, Weighbridge, Civic Amenity and Maintenance Buildings incorporating alternative power and heat sources (i.e. Photovoltaic panels, wood pellet boiler, wind turbine & Rainwater harvesting)

• Surface Water Management Infrastructure

– Surface water pumping.

– Continuous surface water monitoring (TOC, pH, Conductivity) & flow measurement.

• Other Instrumentation (Weather station, PLC & SCADA)

RESPONSE ENGINEERING

Client:
Wexford County Council, Spawell Rd, Wexford.

Client Representative:
Fehily Timoney, Core House, Pouladuff Rd, Cork.

Design Flow:
90 m^3/day

Value:
Capital Works
€ 3,750,000

Year of Commencement:
2007

Status:
Under Construction

Project Involvement:
Plant Designer
Principal Contractor

Process:
- **Balancing Tanks**
- **SBR Tanks (2 No.)**
- **Biological Trickling Filter**
- **Sludge Pumping**
- **Sludge Thickening & Dewatering**
- **Recycling System**

Discharge Standard:
200mg/l BOD
750mg/l COD
10mg/l NH4-N
1500mg/l NO3-N

Leachate Treatment
Intercommunale Hooge Maey

Cross Flow MBR Leachate treatment
Capacity: 20 m^3/h

Location

Background

Intercommunale Hooge Maey (Antwerpen – Belgium) is a company which manages the distribution of municipal litter over the landfill.
Rain water will dissolve organic compounds, heavy metals and salt while penetrating through the landfill in the direction of the groundwater.
To prevent pollution of the ground water, the polluted water (leachate) is collected under the landfill.
Due to high COD load and high values of nitrogen the leachate has to be treated before it can be discharged to the municipal WWTP. Typical leachate water quality data are given in the following table:

Source	Leachate water
pH	7 – 8
TSS [mg/l]	100
Temperature [°C]	10 – 20
COD [mgO_2/l]	7000
NH_4-N [mg/l]	655
NKj [mg/l]	750
Ptot [mg/l]	7,5

Because of the extreme high loads of COD and Nitrogen the conventional biological treatment is not sufficient to reduce these values till acceptable levels. Therefore, IHM has chosen for a membrane bioreactor (MBR) because of the fact that a MBR can operate at a much higher Mixed Liquor Suspended Solids (MLSS) level enabling a high sludge age and the growth of specific bacteria. These specific bacteria are able to reduce difficult components like humic acids and PAC's resulting in a high removal rate of COD and nitrogen. The membrane will retain all bacteria/sludge keeping the specific biomass in the bioreactor. The high MLSS and the total sludge retention by the membranes result in a compact installation design.

Decision Criteria

Prior to the construction of the full scale, tests were carried out to confirm feasibility of a bioreactor combined with UF. Pilot trails with the COMPACT 8.0 mm UF membranes were performed successfully, proving that UF membrane technology is an appropriate and cost-effective solution to achieve the objectives.

NORIT Cross Flow MBR

Although the MBR technology was originally developed thirty years ago, MBRs have only recently become accepted and utilized on large-scale systems. Moreover, the number of published researches and case studies on industrial and municipal MBR applications in the past ten years indicates that the rate of acceptance is rapidly increasing. Main drivers are the MBR's ability to sustain high biomass concentrations and sludge retention times allowing it to treat widely varying influents of high organic loading and recalcitrant compounds while still producing a high quality.

The MBR process provides quantifiable benefits over conventional activated sludge systems including a small footprint; low effluent suspended solids even if the waste water does not settle well; reduced waste streams and lower sludge production rate; a robust system performance; and improved biological degradation.

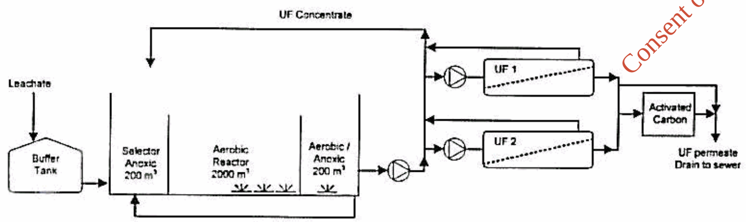
The NORIT CrossFlow MBR Ultrafiltration is a membrane filtration process that was developed by NORIT specifically for treating water with high concentrations of suspended solids in the range of 10,000 – 40,000 mg/l. It uses proprietary NORIT X-Flow tubular membranes encased in a standard 8 inch module. The membrane modules are positioned horizontal in a UF unit. The membranes have an internal diameter of either 5.2 or 8.0 mm, with an average pore size of 30 nm (0.03 µm). This means an absolute removal of particulate matter, including colloids, solids and micro-organisms such as Cryptosporidium and Giardia, ensuring the production of superior water quality.

Tubular UF membrane module

During cross-flow operation the Trans Membrane Pressure over the individual modules can vary between 0.1 – 5.0 bar (1.5 – 73 PSI), depending on the system design and operation. The feed water passes through the membranes from the inside-out, which means that the substances are retained at the inner membrane surface. The retained substances are removed by means of a continuous bleed of concentrate during cross-flow operation. Occasionally the membranes are chemically cleaned by performing a Cleaning In Place (CIP), thereby restoring the membranes to their original clean state.

Project Description

Location	Antwerpen - Belgium
Contractor	Belgroma / Norit Membrane Technology
End-user	Intercommunale Hooge Maey
MBR plant operational since	August 2002



Flow diagram MBR plant

Leachate water from the landfill is pretreated by a drum screen (1 mm) before entering the buffer tank. From the buffer tank the leachate is controlled dosed to the selector where (pre)denitrification takes place. Together with fresh leachate, the concentrate from the UF enters here the bioreactor. The NO_3^- becomes with a carbon source (present in the feed) $CO_2(g)$ and $N_2(g)$. From the selector tank the biomass flows to the aeration tank. The aeration tank is an aerobic/anoxic carrousel in which most of the COD will be broken down and NH_4 is converted to NO_3^- (nitrification). From here, part of the sludge flow enters the post nitrification tank. This tank can be aerated periodically as an option to achieve a high N-reduction.

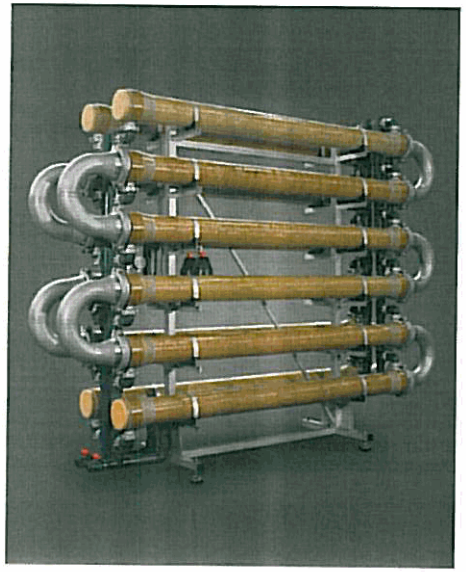
From the post-nitrification tank the sludge flows through the membranes and the concentrate re-enters the (pre)denitrification tank. Permeate from the UF is free from suspended solids and may, if necessary, partly be lead over activated carbon filters to remove the last COD residue to meet the requirements for discharge.

Denitrification (R), Nitrification (L) and carrousel (in front)

NORIT MEMBRANE TECHNOLOGY

Configuration Cross-flow UF

Number of UF units	2
Modules per UF unit	6
Membrane area per module	27 m^2
Total installed membrane area	324 m^2



Cross Flow MBR skid (2 units)

Plant operation

Operating parameters UF

Flux	150 l/m^2h
Capacity	2 x 24 m^3/h feed
CIP1 interval (Citric Acid)	every 2 months
CIP2 interval (NaOCl+caustic)	every 2 months

Typical permeate quality

BOD5 [mgO_2/l)	< 3.0 mg/l
COD [mgO_2/l)	< 700 mg/l < 300 mg/l after AC
NH4-N [mg/l]	0.23 mg/l
Nkj [mg/l]	20 mg/l
Nitrate + Nitrite [mg/l]	2.21 mg/l
P-tot [mg/l]	0.20 mg/l

Seghers Keppel

UNIBRANE® *External Membrane Bioreactor*
Cova Da Beira
Portugal (2003)

The Cova da Beira (Central Compostagem) plant in Fundão is a municipal waste dump and composting facility .

The produced waste water is collected in lagoons and then treated by a MBR and then further polished by an RO treatment.

Description of waste water treatment plant

The UNIBRANE® process combines advanced biological treatment with membrane filtration to achieve a high degree of treatment and to produce a high quality effluent. For the removal of nitrogen and COD from the leachate, a 4-stage UNIBRANE® reactor was built.

Table Overview of the raw water characteristics

Parameter	Value	Unit
Flow	3.75	m^3/h
COD	15000	mg/l
BOD	7500	mg/l
SS	1000	mg/l
Total N	1000	mg/l
NH4-N	660	mg/l
pH	5-10	Sör
temperature	20-30	°C
conductivity	30000	S/cm

Table overview of the dimensioning parameters

Parameter	Dimensioning value	Unit
COD load	1350	kg/day
BOD load	675	kg/day
SS load	90	kg/day
N load	90	kg/day
flow	3,75	m^3/h
	90	m^3/d
COD vol.load	3,33	$kg/m^3.day$
N vol.load	0,22	$kg/m^3.day$

Table Overview of the effluent quality

Parameter	Limit	Performance	Unit
COD	150	150	mg/l
BOD	40	40	mg/l
SS	60	60	mg/l
Total N	15	15	mg/l
NH4-N	7,8	7,8	mg/l
NO3-N	11,3	11,3	mg/l
pH	6-9	6-9	Sör
temperature	20-30	20-30	°C
conductivity	30000	150	S/cm

This comparison and also the results of official measuring campaigns clearly illustrate the outstanding and continuous performance of the waste water treatment plant.

The UNIBRANE® process combines advanced biological treatment with membrane filtration to achieve a high degree of treatment and to produce a high quality effluent. For the removal of nitrogen and COD from the leachate, a 4-stage UNIBRANE® reactor is required, consisting of :

- Equalisation tank
- Pre-denitrification reactor
- Nitrification reactor with aeration system and re-circulation loop
- Post-denitrification reactor
- Re-aeration reactor, containing a tubular ultra-filtration unit for separation of biomass (sludge) and treated water.
- R-O filtration system

Raw leachate is fed to the leachate treatment plant. The flow to the plant can be selected by the operator and is controlled by means of a magnetic flow measurement and a regulating valve.

The pre-denitrification receives the equalised raw leachate and also a recycle of nitrified water from the nitrification tank. Sludge is recycled from the re-aeration reactor.

Nitrate from the nitrification tank is reduced to nitrogen gas by means of the organic material present in the raw leachate, with some additional methanol. Denitrification requires absence of oxygen so no aeration but only mixing is provided. From the pre-de-nitrification basin, the activated sludge flows by gravity to the nitrification basin.

In the nitrification basin, organic compounds and ammonia nitrogen are oxidised to carbon dioxide + water and nitrate. Air is introduced through a fine bubble aeration system fed with pressurised air by two blowers. A large part of the nitrified water is recycled to the pre-de-nitrification tank for the removal of nitrate. The fine bubble aeration systems consist a number of diffuser discs installed on the bottom of the nitrification reactors. This aeration system provides high aeration efficiency, does not produce aerosols and does not cool down the water. From the nitrification tank the activated sludge flows by gravity to the post-de-nitrification unit.

This second de-nitrification unit removes all remaining nitrates, with the internal reserves of the bio-mass being used as carbon source in the reduction process (endogenous de-nitrification). In case of low BOD/N ratios in the raw leachate, addition of an external carbon source acetic acid is also used.

The use of the post-denitrification unit reduces the required recycles in the systems, optimises the hydraulics of the treatment plant and optimises reaction rates through an increase of substrate levels.

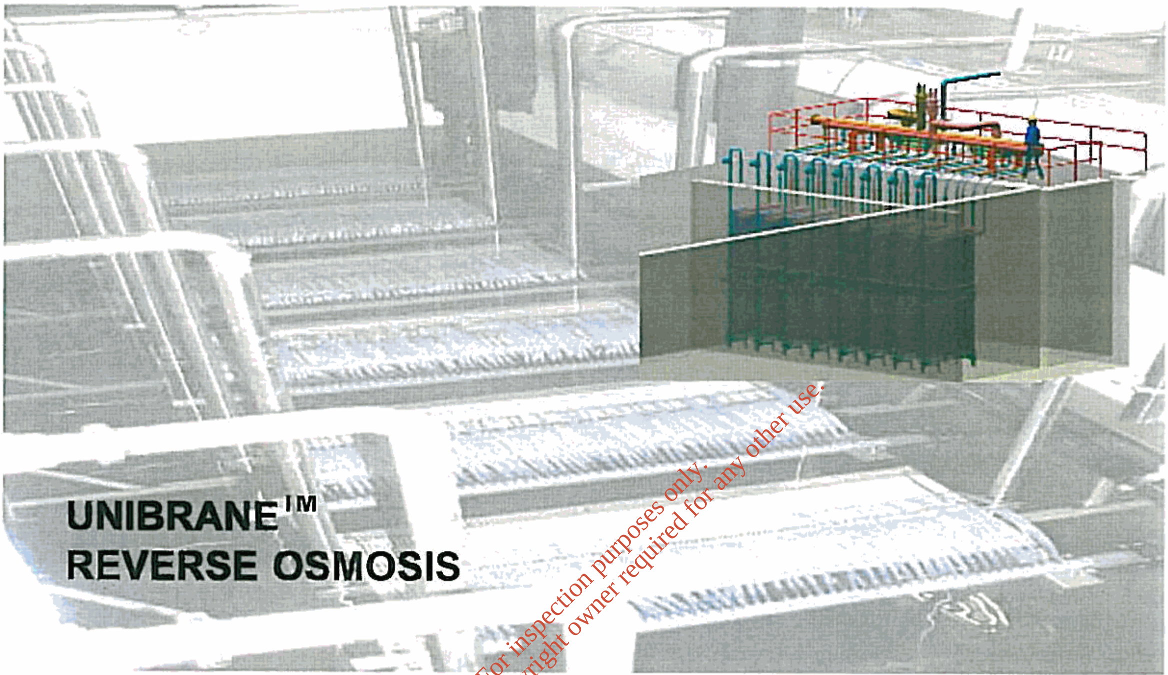
From the denitrification tank the activated sludge flows by gravity to the re-aeration tank, where water is re-aerated to guarantee a high quality effluent. In the re-aeration tank a ultra-filtration system is installed.

The ultra-filtration separates water from the biomass mixture. The retained biomass is returned to the pre-denitrification reactor, hence increasing the sludge level of the biological system. The ultra-filtration unit consists of three tubular membranes. For occasional cleaning of the membranes, a CIP (cleaning in Place) unit is included. The CIP unit consists of a separate CIP tank, with a CIP chemical storage and dosing facility. Chemicals will be fed into the CIP tank, by chemical pump. The UF filtration unit has all the necessary valves and piping included.

Permeate from the ultra-filtration unit is discharged to a storage tank, before the Reversed Osmosis filtration.

Seghers Keppel

UNIBRANE® - REVERSE OSMOSIS
Fuji The Netherlands (2003)



Fuji in Tilburg the Netherlands is a production facility with focus on :

- Steady production of Colour Paper, Colour Negative Film and Presensitized Plates
- Quality assurance products
- Teamwork, involvement

Description of waste water treatment plant

.The UNIBRANE® process combines advanced biological treatment with membrane filtration to produce a high quality effluent.

By means of a RO system, the effluent is treated so far that it can be reused in the production process.

The waste sludge which contains silver, will be dewatered and sent to an extern silver reuse installation.

The installation is also equipped with a heat pump for optimal use of the energy balance.

Table : Overview influent characteristics

PARAMETER	Unit	design
Flow (day) flow (hour) flow (peak)	m^3/day m^3/h m^3/h	840 35 45
Temperature	°C	37
PH	Sör	7 - 8
COD concentration	mg/l	1800
BOD concentration	mg/l	850
BOD / COD	-	0,47
TSS concentration	mg/l	48
Total Nitrogen Concentration	mg/l	94
Kjeldahl-N	mg/l	35
NO_3^--N	mg/l	30
NO_2^--N	mg/l	25
BOD/N	-	9,4
Total Phosphor concentration	mg/l	5
Total Phosphor concentration		5

Table overview of the Effluent quality

PARAMETER	UNIT	GARANTUEED
COD COD (av. Removal)	mg/l %	< 51 > 97
Ss	mg/l	0
Total-N	mg/l	< 5
Ag non soluble	mg/l	0

The waste water is collected in a buffer tank. From there it is pumped through a curved screen.
Through a middle buffer tank the water is then pumped to the denitrification tank of the biology.
Here the nitrates formed in the aerobic compartment are denitrified. The sludge – water mixture streams further to the aerobic compartment where nitrification takes place and BOD/COD are assimilated and dissimilated. From this tank the sludge/water mixture is pumped towards the membrane compartment, where the permeate from the membranes is extracted. The thickened sludge/water mixture flows over into the aerobic tank, and a part of it is extracted towards the decant centrifuge for dewatering and further drained off for treatment .
The permeate is fed to the permeate tank and pumped through a reversed osmosis membrane to remove salts in order to achieve process water quality, suitable for reuse in the plant.

FULL SCALE LEACHATE TREATMENT BY NANOFILTRATION IN TURKEY AND THE NETHERLANDS

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SUMMARY:

1. INTRODUCTION

Recently three major leachate treatment plants with the use of nanofiltration have been implemented in Turkey and the Netherlands. This paper has been prepared by the landfill owners ISTAÇ and ESSENT and the supplier NMT and deals with the aims of the treatment, pilot plant research and the first results of the full scale plant.

ISTAÇ is one of the Economic Enterprises of Istanbul Metropolitan Municipality operating landfills, composting plants and several other recycling plants..

ESSENT is a Dutch multi-utility company with, as its core activities, energy production and distribution by network systems and waste management. ESSENT is operating 8 landfills including the Wijster Landfill with an extended leachate treatment and LFG-utilization.

NORIT Membrane Technology (NMT) is in the Netherlands leading company for turnkey projects based on membrane technology and world wide one of the leading companies in this field. X-Flow, also part of the NORIT Group offers a complete membrane and module program for all the processes as mentioned above. The capillary NF modules are produced by X-Flow.

2. LEACHATE TREATMENT AND THE ROLE OF NANOFILTRATION

The choice of the leachate treatment system depends on the standards to meet for the receiving surface water. In general, the self-purification capacity is insufficient for concentrated discharges and therefore treatment in a WWTP or biological leachate treatment plant has to reduce oxygen consumption of the leachate (BOD removal and nitrification). In case of discharge of to more critical receiving water denitrification and phosphorous removal is necessary.

The next step is removal of color, heavy metals and organic micro pollutants (PAH, EOX etc.) by oxidation (peroxide, ozone), activated carbon systems, coagulation or NANOFILTRATION. If the receiving water cannot dilute the salt content in a proper way and is used for agricultural purposes (cattle water, irrigation) or is a source for potable water, desalination of the leachate is necessary by reverse osmosis, electro-dialysis or evaporation.

Nanofiltration is a promising complementary treatment technique for leachate treatment. Full scale experiences with so called plate modules have been reported from two German landfills. In these cases the goal was reduction of residue in combination with reverse osmosis systems. Full scale results with direct spiral wound nanofiltration treating raw methanogenic leachate are known. Due to a low bio-fouling potential of the untreated leachate this German plant operates under stable conditions. From the moment there is a biological pre-treatment in front of the nanofiltration bio-fouling becomes a serious problem. The experiences with direct capillary nanofiltration (The Netherlands) and spiral wound nanofiltration membranes with a MBR pretreatment including ultrafiltration (Turkey) will be demonstrated.

3. GENERAL ASPECTS OF MEMBRANE FILTRATION

With membrane filtration one fluid stream (the feed) is divided into two or more fractional streams, one of them more concentrated in certain components (the concentrate) and the other one more diluted (the permeate). The membrane acts as a selective barrier enabling some components to pass and others not. The driving force for this process in water treatment is usually restricted to a pressure difference.

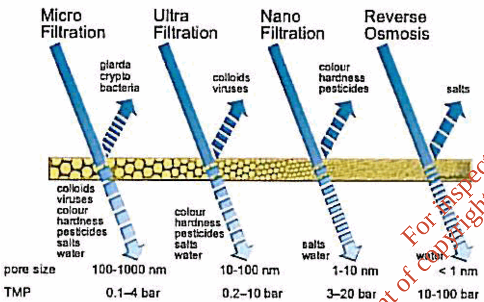


Figure 1: Pressure-driven membrane processes.

Figure 1 presents the main properties of the pressure-driven membrane processes. Going from microfiltration through ultrafiltration to reverse osmosis, the particle size of the molecules to be separated decreases, and, consequently, the pore size in the membrane becomes smaller. This implies that the resistance of the membranes to mass transfer increases and hence the applied pressure, also called the transmembrane pressure (TMP), has to be increased to obtain the same flux. However, no sharp distinction can be drawn between the various processes.
In waste water treatment microfiltration and ultrafiltration are generally applied in MBR concepts or as first step in polishing the effluent, because their separation characteristics are well enough to fulfill the effluent requirements. Nanofiltration and/or reverse osmosis

can be used as second step to upgrade the ultra filtered water to process or potable water quality.

3.1 Membrane characteristics

Individual membranes are placed into modules which are available in several configurations:

- plate-&-frame: a flat membrane is mounted on a supporting plate and several plates are fixed together into a frame;
- spiral wound: a flat membrane is wounded around a central pipe given from the side a spiral effect;
- tubular and capillaries: many tubular or capillary membranes are placed in a housing and sealed at the ends by means of an epoxy resin.

Microfiltration and ultrafiltration membrane modules applied in water treatment are usually capillary or tubular modules, while plate-&-frame modules are also used for waste water treatment. Nanofiltration and reverse osmosis membranes are usually spiral wound modules. Figure 2 shows several commercially available modules, from which the tubular ultrafiltration modules (Figure 2b) are used in the applications described later in this paper.

(a) (b) (c) (d)

Figure 2: Module configuration: (a) capillary ultrafiltration module; (b) tubular ultrafiltration module; (c) plate-&-frame ultrafiltration module; (d) spiral wound nanofiltration or reverse osmosis module.

3.2 Membrane Bioreactor

A membrane bioreactor (MBR) is a compact-built purification system combining the biological degradation step with a membrane separation step instead of with a clarification tank. The influent is fed to the aerated bioreactor where the organic components are oxidized by the activated sludge. Next, the aqueous activated sludge solution passes through a micro- or ultrafiltration membrane filtration unit separating the water from the sludge. The latter returns to the bioreactor, while the permeate is discharged or re-used as particle-free effluent.

Presently, two basic MBR systems can be distinguished using these principles (Figure 3): Side-stream: the membranes are placed outside the bioreactor. The membranes are horizontally or vertically placed tubular membranes and fed at the inside. Depending on the driving forces the following concept can be distinguished:

the system operates under overpressure in cross-flow mode (horizontal); or
the system operates under underpressure in airlift mode (vertical);
Submerged: the membranes are submerged in (a separate part of the) the bioreactor. The membranes are either horizontally or vertically placed fibers, or vertically placed flat sheets. All systems are aerated at the bottom side, while the permeate is withdrawn by means of suction at the permeate side.

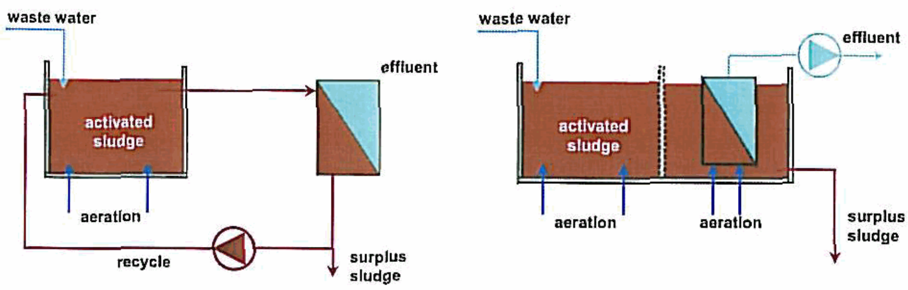


Figure 3: Membrane Bio-Reactor system: (a) side-stream; (b) submerged.

2.4. (Direct) Nanofiltration

A nanofiltration (NF) membrane removes bacteria and viruses, for example, as well as pesticides, organic matter, heavy metals, and to some degree also salts. The permeate is therefore of a high quality, reliable and can be used as process water for industry (e.g. for producing ultra-pure water, boiler supply water or water for the process industry, etc.) or for discharge on surface water.

Membranes in current NF installations are usually designed as spiral-wound elements and placed in pressure vessels. A membrane element consists of sealed envelopes that are bonded to a central product tube. The envelopes are wrapped spirally around the product tube. The envelopes have spacers fitted between them, enabling input water and permeate to flow through and along the envelopes. Fig.1a shows an 8 inch Spiral Wound NF module.
The advantage of a spiral-wound membrane element is the large surface area of the membrane (per m3) and therefore the large production volume that can be achieved per element. The disadvantage is, however, the limited space between the envelopes through which the input water flows. The small height of the feed spacers (approximately 0.8 mm) makes the spiral-wound membrane extremely susceptible to floating matter.
In order to use spiral-wound NF membrane elements pre-treatment is necessary before the water can be treated. In practice, membrane filtration is part of a (long) series of treatment steps, such as
flocculation/sedimentation + rapid sand-filtration + NF;
(sandfiltration) + ultafiltration + NF;
making membrane filtration not always economically viable to produce process water out of lower quality sources.

In order to improve the economical attractiveness for the production of process water out of the fore-mentioned sources NORIT has recently developed low-pressure NF capillary membranes. These NF capillaries should bridge the cap between the bulky, but robust tube-sized NF membranes at one side and the compact, but fouling-sensitive spiral-wound NF membranes at the other side.
The background of this new product is based on the use of capillary ultrafiltration (UF) as pre-treatment before spiral-wound NF. Since the mid-nineties of the last century UF is being used successfully as a new pre-treatment step for spiral-wound modules creating an effective barrier to suspended matter. A capillary NF membrane combines the favourable properties of the capillary UF membranes in terms of ease of cleaning with the favourable properties of the NF membrane in terms of the removal of bacteria, viruses, pesticides, organic matters and heavy metals. Fig.1a shows an 8 inch NF module with 20 m2 of membrane area.

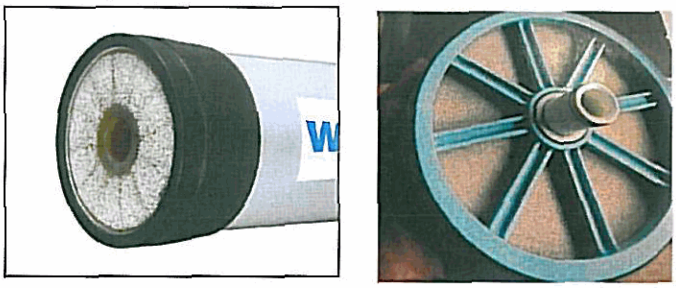


Figure 4: NF module: (a) capillary; (b) spiral wound.

4. NANOFILTRATION ESSENT LANDFILL WIJSTER (NL)

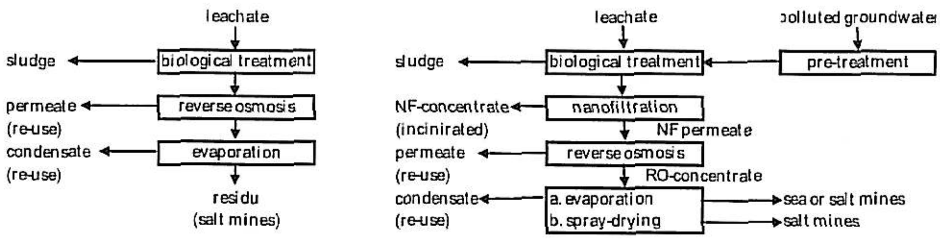
4.1 Introduction

The leachate treatment system at the Wijster Landfill consisted from 1994 until 2006 of:

- Biological pre-treatment (activated sludge system/ nitrification-denitrification)
- Reverse-osmosis (tubular membranes and spiral-wound membranes)
- Evaporation plant (multi-stage flash) treating the RO-concentrate
- Discharge of the residue to former salt-mines after solidification.

Desalination by reverse osmosis has been installed in 1986 caused by the stringent effluent criteria (chloride 200 ppm, total nitrogen 10 ppm) for the receiving surface water. The former treatment system (250,000 m3/a) needed an upgrading, while:

- The system was expensive (all-in €15/ m3 leachate)
- The tubular RO-system was technically spoken no more "state of the art"
- The high amount of residue (7,000 tons/a) made the system not sustainable.



A. B.

Figure 5 : Former leachate treatment system (A.) and the new system (B.)

Since 1999 ESSENT and NORIT Membrane Technology studied on pilot plant scale the possibilities of tubular nanofiltration and capillary nanofiltration. Additional research has been done with spiral wound membranes.
The objectives of nanofiltration are:

- Reducing the amount of residue by separating the mono-valent salts (chloride, potassium and sodium) from the other components in the leachate
- Concentrating the organic compounds with heavy metals and organic micro pollutants.

The concentrate of the nanofiltration (concentration factor, CF, is 10 or higher) can be incinerated or spray-dried by the MSW incineration plant (see Figure 1). The permeate of the nanofiltration (with mono-valent salts) is concentrated by RO and spray-dried.

4.2 Pilot plant research

The research included:

- Research with tubular modules (trans membrane pressure 20 bar, cross flow operation)
- Research with capillary modules (TMP 6 bar, semi-dead end and cross-flow operation)
- Research with spiral wound membranes (TMP 5 till 40 bar, cross flow operation)

Tubular nanofiltration membranes:
In 1999 the research started with tubular nanofiltration modules (diameter 15 mm). With a trans membrane pressure of 20 bar, a (recirculation) velocity of 3 m/sec and a concentration of 10 times. Fluxes were obtained of approx. 25 l/m2 hr and also a good quality permeate was obtained.
That time the capillary nanofiltration was introduced (on the basis of capillary ultrafiltration membranes with a polyamide layer) with several advantages.

Capillary nanofiltration membranes:
Potential advantages of capillary membranes:

- Less energy consumption due to TMP of 6 bar and a lower velocity of 2 m/sec; reducing the energy consumption from 6 to 3.5 kWh/m3 permeate.
- Less chemical consumption for cleaning because of the lower volume to surface ratio of the capillary membranes.

- The potential use of air-flush cleaning.
- The potential use of back flush cleaning.

In 2001 the research with the capillary nanofiltration membranes started (see Figure 3) with testing the optimal operation procedure: semi-dead operation (and additional air-flush cleaning) or continuous operation (feed and bleed) with a recirculation flow. The semi-dead operation gave relative bad flux results and there wasn't any advantage of air-flush cleaning. Due to the bio-fouling potential of the pretreated leachate continuous operation with a recirculation flow gave the best performance. In this paper the results of the continuous (cross-flow) operation are presented.
During all test-runs the biologically pretreated leachate has been mechanically screened (200 µm), pH adjusted (range 7 to 7.2) and supplied with anti-scalant. First step was testing the optimal recirculation velocity (between 1 and 2.5 m/sec); optimal velocity of approx. 2 m/sec was determined and used during the proceeding tests.

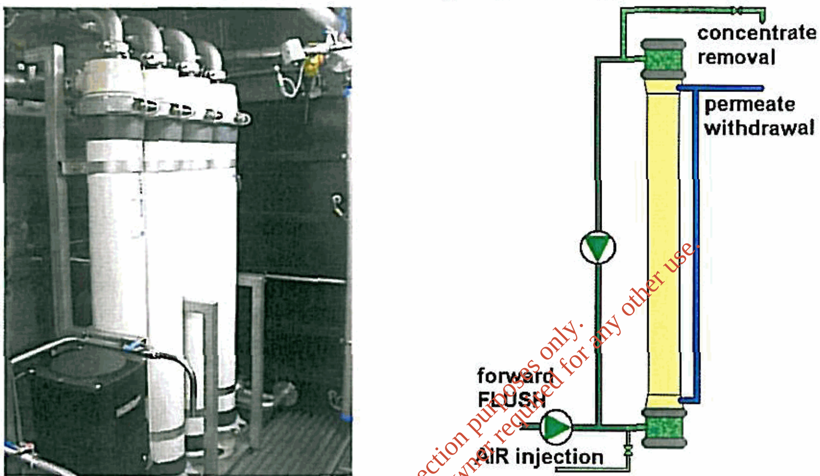


Figure 6. Pilot plant with four capillary membrane modules and flow diagram.

The results of different test runs of 100 hours are presented in Table 1. The temperature increases due to mechanical (pump) input. The trans membrane pressure increases from the start to the end of a test-run (manual adjusted).
With these results a multi-stage plant can be designed with an average flux of 22 l/ m2 hr.

Table 1. Flux and trans membrane pressure for different concentration factors.

CF	Temperature (^{0}C)	TMP (bar)	Flux: start-end (l/m2,hr)
2	15-17	2.8-4.2	31-25
4	32-35	2.7-5	26-22
10	32-38	2.2-6	21-18

Table 2. Water qualities.

parameter	unit	raw leachate	influent NF	permeate NF
COD	mg/l	2500	1500	105
BOD	mg/l	150	5	1
NKj	mg/l	1200	60	4
NO3-N	mg/l	0	20	20
Cl	mg/l	3000	3000	3050
SO4	mg/l	240	220	60
Cd	µg/l	5	2	0.2
Hg	µg/l	0.15	0.1	0.01
PAH (16 EPA)	µg/l	0.5	0.095	0.025
EOX	µg/l	0.6	0.4	0.1
Color		black	black	transparant

In Table 2 the water quality is given of the raw leachate, effluent of the biological treatment (influent of the nanofiltration) and the permeate of the nanofiltration operated with a concentration factor of 10 times (recovery of 90%). The retention of COD is 93%, the average of heavy metal removal is 90% and for organic micro pollutant 75%. No retention of mono-valent ions could be measured.

After every test-run the membranes have been cleaned with an alkaline solution (pH about 11) to remove organic pollution; periodically an additional cleaning with acid and oxidation with peroxide is necessary as well as an enzymatic (detergent) cleaning. The cleaned membranes are controlled by measuring the "clean-water-flux" (approx 20 l/m2 hr bar).

Spiral wound nanofiltration membranes:
In 2003 a full scale plant with spiral wound nanofiltration in Germany had been visited with good treatment results on raw leachate from an old methanogenic landfill. These good results were the motive to start a pilot plant research in 2004 for the ESSENT leachate. The biological pretreated leachate was mechanically screened (20 µm), pH adjusted to 6.7 and anti-scalant had been supplied.
The preliminary results with the spiral wound membrane have been promising: high retention, fluxes of 17 l/m2,hr and runtimes of 7 to 10 days before cleaning. After one month of operating the cleaning intervals have been reduced to one day! In one day the trans membrane pressure increased from 4 to 40 bar. Strong oxidation agents have to be used (peroxide solutions) to get a maximum runtime of 3 days. Due to the high biological potential of the leachate, bio-fouling on the membranes have been built up in a very fast way. On the membrane a layer of extra cellular sugars form the glue for the colloidal humic acids (a typical leachate product) and dispersed micro-organisms. The intensified usage of peroxide will reduce the life time of the membrane drastically. Direct nanofiltration with spiral wound membranes will result in intensified cleaning procedures and relative short run times.

4.3 Full scale plant: description and performance

In 2005 the existing groundwater treatment plant has been partly destroyed by a fire. Groundwater has been polluted by leachate in former days and is nowadays controlled by an extraction and treatment system. The former groundwater treatment system existed of a pretreatment followed by ultrafiltration and reverse osmosis. So the scheduled upgrading of the leachate system was combined with the groundwater treatment. The extracted groundwater is pretreated by aeration and sedimentation to remove methane, hydrogen sulfide and iron. The pretreated groundwater and leachate are combined and biologically treated and than enter the new nanofiltration and reverse osmosis plant (see figure ...). In table ... the pre-treated groundwater and biological treated leachate are presented (design values) as well as the actual input of the plant in 2006/2007.

The maximum capacity of the new plant is 50 m3/hr (375,000 m3/a). The plant exists of a pre-treatment, nanofiltration, reverse-osmosis and CIP (cleaning in place) device.
The **pretreatment** exist of a screening, pH adjustment to 7 by sulfuric acid, heating up to 25 ^{0}C by a CHP and a supply of an anti-scalant.
The **nanofiltration** unit exists of four similar sections in series. Each section is cleaned separately. Each section has 30 capillary membrane modules (design flux 20 l/m2) with a recirculation pump to get a horizontal velocity of 1.5 m/sec along the membrane. The central feed pump keeps the total pressure on a maximum of 6 bar. Each day there is short back flush (60 sec) to remove a (part) of the fouling. Twice a week there is a chemical cleaning with two main steps an alkaline cleaning followed by an oxidizing (hydrogen peroxide) cleaning.

Figure 7: Overview of the nanofiltration plant ESSENT and a capillary module.

The **reverse osmosis** unit exists of three parallel operating sections each with 6 spiral wound modules.

Table 3: Performance of the NF and RO plant

parameter	unit	influent NF	permeate NF (influent RO)	concentrate NF	concentrate RO	permeate RO
Flow	m3/hr	50	45	5	7.5	37.5
COD	mg/l	320	43	2700	114	16
BOD	mg/l	<3	<3	11	<3	<3
NKj	mg/l	18	3	154	5.5	0.7
NO3-N	mg/l	1.9	2.1	2.2	6.2	0.05
Cl	mg/l	1500	1500	1700	4500	18
SO4	mg/l	110	35	1300	320	<2
Color		dark	transparent	black	yellow	clear

5. THE ISTANBUL LANDFILLS OF ISTAC

İSTAÇ Co., Istanbul Metropolitan Municipality Environmental Protection and Waste Materials Valuation Industry and Trade Co., is one of the Economic Enterprises of Istanbul Metropolitan Municipality.

As the name denotes, İSTAÇ Co. within the scope of Solid Waste Project of Istanbul Metropolitan Municipality, provides services for transportation of solid wastes, production of compost fertilizer, recycling of wastes, disposal of them via regulated storing, electric energy generation from landfills, transportation of medical waste and their disposal via incineration.

On the European side 8 thousand tons of garbage is being collected daily in the Landfill Area established on 75 hectares in Odayeri/Göktürk'teki. Nowadays 2000 m3 of leachate daily is produced and in the future this will be 3000 m3.

On the Anatolian side 4 thousand tons of garbage is being collected daily in Landfill Area in Kömürcüoda/Karakiraz Village, and a area of 100 hectares is used for this work. Nowadays 1200 m3 of leachate daily is produced and in the future this will be 2000 m3.

5.1 The leachate treatment project.

In 2006 the project for the treatment of leachate for the two Istanbul landfills was awarded to Norit Membrane Technology. In 2007 the leachate treatment plants from the two main landfills in Istanbul, one at the European (Kömüorcüoda) and one at the Asian (Oyaderi) side of the city, will be executed with a membrane bioreactor system (MBR) followed by a nanofiltration system (NF) with post treatment by activated carbon (AC). The concentrate of the nanofiltration system will be treated on the landfill site and the salty permeate will be discharged in the seawater of the Bosporus.

The waste water treatment plants in Istanbul will use a combination of several different Norit Group purification solutions: a biological process applied in conjunction with ultrafiltration, followed by nano-filtration and activated carbon filtration. Norit Membrane Technology has developed this turnkey project in cooperation with a civilian partner in Turkey. In addition, Norit will be responsible for plant operation during the initial years.

The Leachate treament plant consists of the following process stages:

Leachate intake
Membrane Bio Reactor (Norit Crossflow MBR), consisting of:
Oxic/Anoxic bioreactor
Norit Crossflow Ultrafiltration installation
Sludge treatment
NORIT Nanofiltration installation
NORIT Activated Carbon filtration
Effluent discharge

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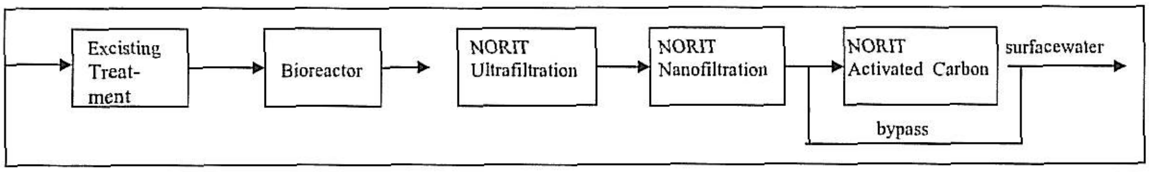


Basic Process Flow Diagram

Essent Landfill Wijster (NL)

In 2006 the leachate treatment plant of Essent (45 m3/hr) has been upgraded from a two stage reverse osmosis system to a combined nanofiltration and reverse osmosis plant. Pre-treatment by an existing activated sludge system with a settling tank causes a biofouling potential that high that a capillary nanofiltration system was necessary. Due to sensitive receiving waters a post treatment by reverse osmosis has been included. The concentrates of both systems are treated in the nearby incineration plant.

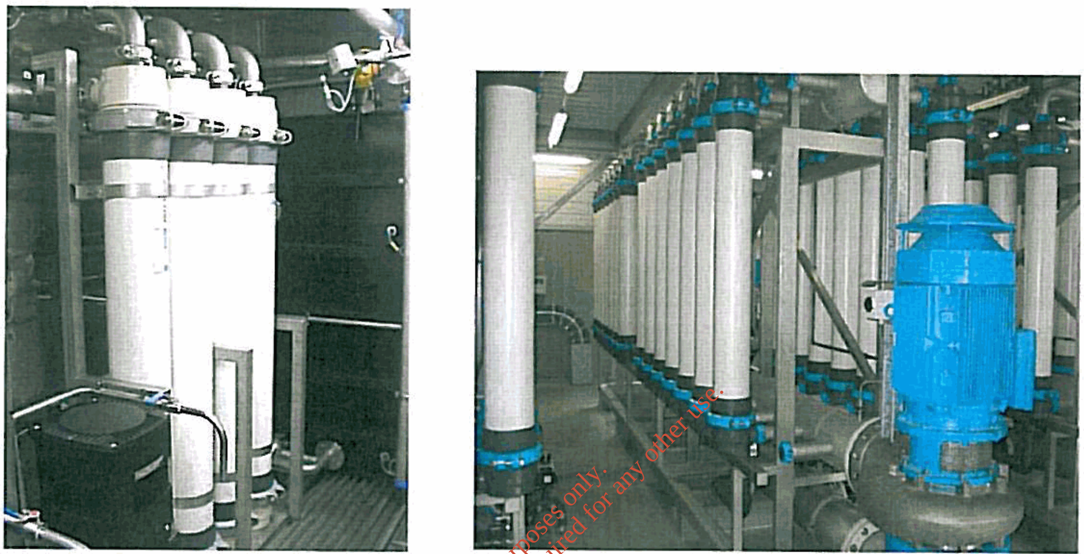


Figure 1. Pilot plant and full scale plant with capillary nanofiltration in the Netherlands..

The Istanbul landfills of ISTAC

In 2007 the leachate treatment plants (125 and 85 m3/hr) of the two main landfills in Istanbul will be extended with a membrane bioreactor system (MBR) followed by a nanolfiltration system (NF) with post treatment by activated carbon (AC). The pretreatment exists of pre-settling and a anaerobic system. The concentrate of the nanofiltration system will be treated on the landfill site and the salty permeate will be discharged in the seawater of the Bosporus.

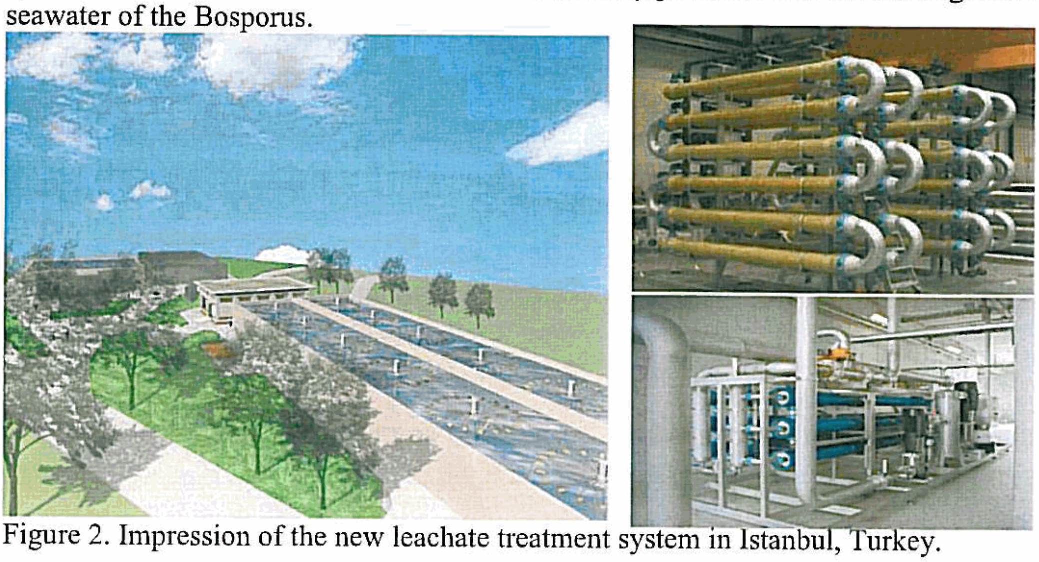


Figure 2. Impression of the new leachate treatment system in Istanbul, Turkey.

APPENDIX D

DETAILS OF LEACHATE TECHNOLOGY

Norit Membrane Technology BV

Norit
leading in purification

General Information

Norit "The Purification Company", founded in 1918, offers world wide total solutions and projects for the water, wastewater, beverage, food, dairy and pharmaceutical industries. Norit uses its innovated treatment technologies in products, systems and technological solutions.

With over 1200 employees and a turnover in excess of € 300 million they are a recognised leader in their field.

Description of Products & Services

Norit Membrane Technology is specialised in membrane technology for the production of drink and process water in the application of treatment of groundwater, surface water and for the treatment of (domestic) wastewater for discharge and/or reuse. Norit supports this all with mature scale and pilot plants, process engineering, training and service contracts.

X-Flow, also part of Norit, offers a complete membrane and module program for treatment of any water - potable, industrial, process, waste and landfill leachate.

Depending on the influent specs of the leachate water, Norit will design a plant around its Airlift MBR™ or Crossflow MBR™ technology, using post treatment technologies, such as Reverse Osmosis or Activated Carbon to deliver a water quality within effluent discharge limits.

Norit operates a ISO 9001:2000 quality system and adheres to drinking water standards KIWA-ATA, KTW/DVGW & ANSI/NSF61.

USP's

- Turnkey project management
- In-house Membrane manufacturing
- Lowest CAPEX/OPEX

Export Markets

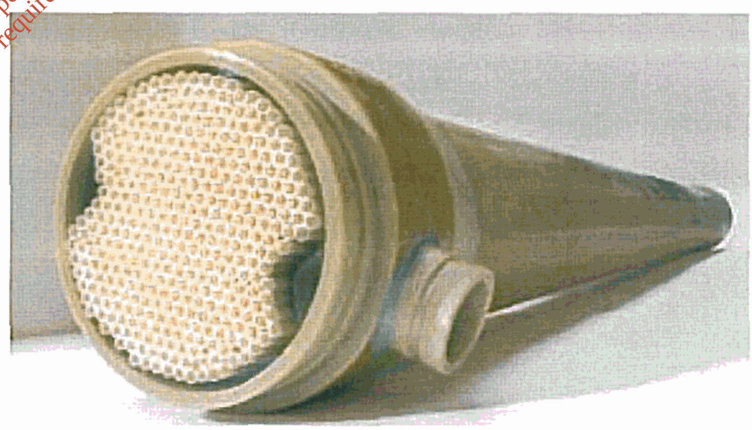
Norit exports to more than 150 countries and has European references in the Netherlands, UK, Portugal, Norway, Slovenia, Ireland, Russia, Croatia, Ukraine, Romania and France.

References

Norit has recently completed Leachate Water Treatment installations at 2 of Europe's largest landfill sites in Turkey.

Norit at IRWM 2008

Norit welcomes contact with waste organisations (both private and government) seeking solutions for treating landfill leachate water before discharge.



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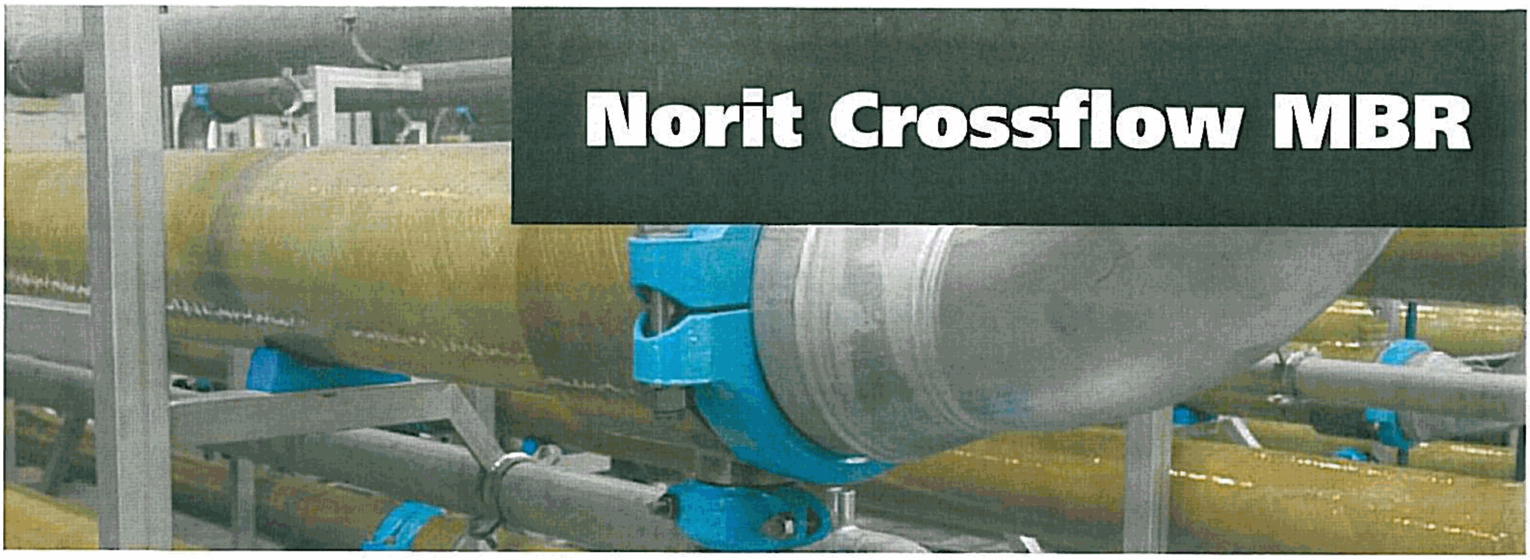


Norit Crossflow MBR

Industrial wastewater

Challenge

Due to more stringent international and governmental legislation, in terms of wastewater discharge consents, the disposal cost of municipal wastewater is increasing. Traditional wastewater treatment is primarily done using biological degradation in reactors followed by a clarification step which is typically a sedimentation process. These tend to be large footprint plants which do not produce water of a re-usable quality. For more efficient wastewater treatment and to provide high quality water for re-use, the Membrane BioReactor (MBR) has been developed.

Solution

The Norit Crossflow MBR is a compact purification system combining the biological degradation step with a membrane separation step. The influent is fed to the aerated bioreactor where the organic components are oxidized by the activated sludge. Next, the aqueous activated sludge solution passes through a membrane filtration unit separating the water from the sludge. The latter returns to the bioreactor, while permeate is discharged or re-used as particle-free effluent.

The membranes are configured in a unique side stream set-up outside of the bioreactor; this offers a compact footprint in combination with a simple and easily maintainable stand alone Norit Crossflow MBR system.

Norit X-Flow's ultrafiltration (UF) membrane will provide a robust purification solution. The water can either be re-used directly or further treated as required, e.g. through reverse osmosis, activated carbon or UV.

Norit Crossflow MBR is applied in areas such as:

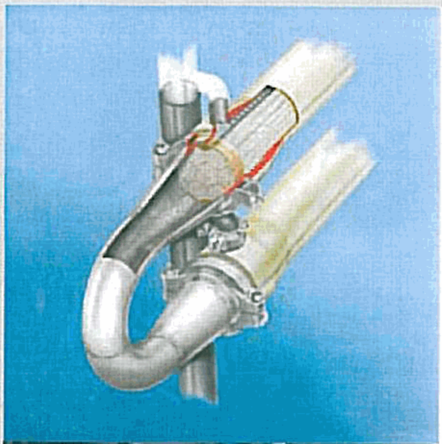
- Leachate, effluent coming from landfill sites
- Beverage industry, where high COD loads need to be reduced, e.g. breweries, malteries, dairy factories
- Other industries, e.g. chemical and textile

The Norit X-Flow membrane modules are being produced with ISO 9000 certification.

Norit

leading in purification

Norit Crossflow MBR



Features and benefits

Tight UF membrane	Turbidity < 0.1 NTU
	SDI < 3
Norit Crossflow filtration	Limited energy consumption
	Simple lay -out
	High flux rates
Cleaning In Place	Fully automated cleanings
	Use of low cost chemicals
Fully automatic operation	Logging of operating parameters
Pressurized system	Fully enclosed
	No operator exposure to fumes or aerosols
	Small footprint

Examples

Norit X-Flow provides membranes for MBRs for hundreds of plants world-wide. Capacity ranges from less than 240 m³/day (0.06 MGD) to more than 3,000 m³/day (0.8 MGD).

Hooge Maay – Belgium	Leachate
Capacity	600 m³/day (0.16 MGD)
Year of start up	2002
Technology	Norit Crossflow MBR
Holland Malt – The Netherlands	Maltery waste recycle
Capacity	1,500 m³/day (0.4 MGD)
Year of start up	2006
Technology	Norit Crossflow MBR
Geest salad factory – UK	Salad factory
Capacity	1,200 m³/day (0.32 MGD)
Year of start up	2004
Technology	Norit Crossflow MBR
ATM – The Netherlands	Chemical waste treatment
Capacity	3,600 m³/day (0.95 MGD)
Year of start up	1999
Technology	Norit Crossflow MBR
Pieter Bon – The Netherlands	Tank cleaning facility
Capacity	240 m³/day (0.63 MGD)
Year of start up	2003
Technology	Norit Crossflow MBR
Glasgow – Scotland	Chemical plant
Capacity	1,400 m³/day (0.37 MGD)
Year of start up	2006
Technology	Norit Crossflow MBR
Istaç – Turkey	Leachate
Capacity	2,000 + 3,000 m³/day (1.32 MGD)
Year of start up	2007
Technology	Norit Crossflow MBR

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Norit Membrane Technology BV reserves the right to make changes in the technical specifications at any time.

Norit
leading in purification

Maria Holmes

From: Edel Brennan [EBrennan@response-group.ie]
Sent: 22 April 2008 16:25
To: Maria Holmes
Cc: Salvador McNamara
Subject: RE: 1908 210408 E Brennan 16.04 - leachate treatment

Maria,
Please find attached details of appropriate equipment for the leachate treatment plant at Derrinumera Landfill. What I have included should ensure that all of the proposed discharge standards are met. I have also attached a copy of a similar project that is currently under construction in Wexford. And the details from Balleally
If you require more information just give me a call.
Regards,

response group

Edel Brennan
O&M Manager

Response Engineering Ltd – a Response Group Company
Railway Rd, Charleville, Co Cork, Ireland (registered office)
Tel: +353 (0)63 33400 Fax: +353 (0)63 33401
Email: ebrennan@response-group.ie Web: www.response-group.ie Location map
Incorporated in Ireland Company No. 292095

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Derrinumera Leachate Treatment Facility

Introduction
The detail below outlines a proposed leachate treatment plant at Durrinumera landfill Co. Mayo.
This is indicative of the type of process and plant available to treat the leachate to the proposed discharge standards.

Design Issues

1. COD/BOD
The ratio of these two parameters is vital to the design of the plant. The analysis supplied on the current leachate indicates that the biological portion of the COD is quite low. For this reason an activated carbon filter has been included to remove this portion prior to discharge.

2. Low BOD
Some of the BOD results are very low. There may be a requirement to add additional carbon in the form of acetic acid or methanol. However Nitrate is not included in the current proposed discharge standards. If complete denitrification is required, additional carbon may need to be dosed.

3. Faecal Coliforms
To insure that the complete die/kill off of Faecal coliforms disinfection in the form of Chlorination or Ozone is included. Another option would be a constructed wetland. This would be dependent on the availability of land etc.

4. Heavy Metals PCB and VOC
These are removed by the activated carbon filter.

Proposed leachate treatment plant at Derrinumera landfill

1. Balancing and Storage
1. Feed equalisation and homogenisation
2. Addition of carbon source
3. Storage. 2-3 days.

Plant Required
Holding tank with:
Mixer
pH correction with pH probe
Acid and base dosing pumps
Additional carbon source (Methanol/Acetic Acid) and dosing pump
TOC NH4 SS Turbidity analyser
DO Probe

2. Biological Treatment
1. COD, BOD removal
2. Nitrification
3. Denitrification
4. TP elimination by chemical addition (if required)

Plant Required
1. SBR x 2 set up in series with the option to run in parallel with:
DO Probe
MLSS probe
Variable speed drive blower DO controlled
Mixer
Option to add ferric or other flocculent

2. Tidal Tank- (filter feed tank)
pH correction with pH probe
Acid and base dosing pumps
TOC, NH4, SS and Turbidity analyser
DO Probe
Return pump to back to the holding tank

Proposed leachate treatment plant at Derrinumera landfill

3. Tertiary Treatment
1. Hydrocarbon removal
2. PCB removal
3. Dissolved metal removal
4. VOC removal
5. Disinfection

Plant required
1. Sand Filter or Constructed Wetland (depending on the available space)

2. Carbon Filter

3. Disinfection
Ozone/chlorination (the location dependent on type chosen)

4. Sludge storage and thickening

Plant required
Picket Fence thickener

5. Automation

Plant required
SCADA system

Maria Holmes

From: Marjorie_La_grange@keppelseghers.com
Sent: 04 August 2005 10:48
To: Maria Holmes
Subject: RE: Leachate treatment

MStore_2C_en_004_A - FUJI Neth... MStore_2C_en_003_A - Cova Da B...

Dear Maria,

Based on the information you sent us, we'd suggest a combination of MBR and RO.

With RO one can achieve very high removal efficiency. It is often said that removal efficiency of an RO for salts, minerals, metals, organic matter ... can go up to 99%. Of course this depends on molecular size and weight of the molecules to be removed, but on average efficiency is very high indeed (definitely 95%).

We did a similar project on leachate at Cova de Beira in Portugal. You'll find the case study for that project in attachment. The treated water is used for irrigation, while the brine is sent back to the landfill. Cova was designed with an external MBR. Because of the low biological load in your case, we should be able to work with an internal MBR (submerged
membranes) which represents a much lower energy cost.
To give you an idea of our internal MBRs, I also added the case study of Fuji. The application is totally different and not really relevant here, as the objective was to regain silver from the waste water. The treated water was reused as process water in the factory. The brine was discharged to sewage.

I can't give you figures on recovery for your case right now, as we haven't gotten into dimensioning the MBR or the RO. I suggest to wait for dimensioning until the project has gotten into a further stage.

I hope the above answers your questions. Please feel free to contact us for additional information or if you still have any question. I suggest to get in touch again anyway, when the project has evolved to a phase where a more concrete design is required.

Best regards,
Marjorie

(See attached file: MStore_2C_en_004_A - FUJI Netherlands English.pdf)(See attached file: MStore_2C_en_003_A - Cova Da Beira Portugal English.pdf)

"Maria Holmes" <Maria.Holmes@tobin.ie> 04/08/2005 10:10

To: <Marjorie_La_grange@keppelseghers.com>
cc:
Subject: RE: Leachate treatment

APPENDIX E

CASE STUDIES FOR LEACHATE TREATMENT

BALLEALLY LEACHATE TREATMENT PLANT

DESIGN & BUILD CONTRACT
OPERATE CONTACT

The Contract provides for the Design and Build of new leachate treatment plant at Balleally Landfill, Fingal, Co. Dublin. The plant is designed to treat the following influent loads:-

- BOD:- 1500Kg/day
- COD:- 1800Kg/day
- SS:- 300Kg/day
- Ammonia:- 180Kg/day

The leachate treatment plant is designed to treat a flow of 150 m^3/day, the treatment process selected was Sequencing Batch Reactors followed by AFM Filtration. The process incorporates Balance Tank, 2 No. SBR Tanks, Tertiary Treatment, Backwash System, Sludge Pumping, Storage and dewatering via a centrifuge decanter

The plant consists of the following:-

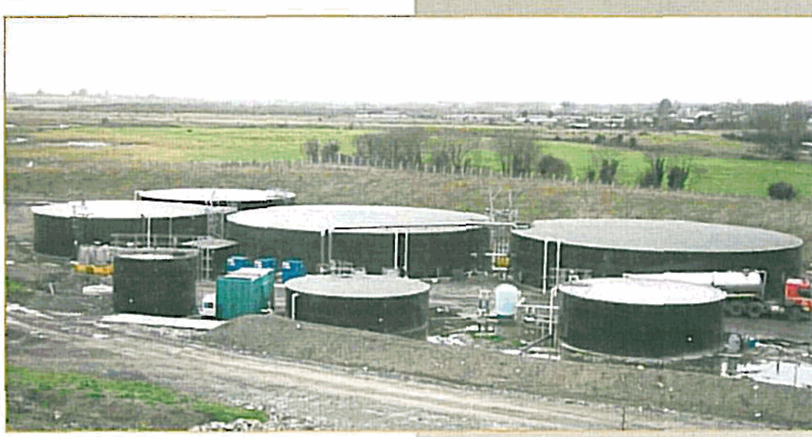
- Raw leachate balance tank with a capacity of 1043m^3 capacity.
- 2 No. SBR tanks (operated in series) each with a capacity of 1674m^3.
- Fine Bubble Diffused Aeration System c/w by 3 no. 45kW air blowers. Submersible mixers are provided in the Tanks to keep the contents of the tank in suspension.
- Sludge Return & Recycle pumping
- Tertiary Filtration
- Sludge Thickening & Dewatering

The system is set-up with SBR Tank 1 utilised only for nitrification and SBR Tank 2 for denitrification. The system was optimised during the commissioning stage to achieve the required effluent discharge standards. A commissioning period of a year was necessary to allow the plant to develop and operate as designed.

Response Engineering fulfilled the role of PSCS on this project and has responsibility for civil works as follows:-

- Excavation and backfilling of tanks, etc.
- Reinforced concrete bases for glass lined steel tanks
- Construction of SBR tanks (25.0m x 5.5m) & Balance Tanks
- Interconnecting pipework & ducting
- Plinths, manholes and site services
- Access road

Response Engineering have been Operating the plant successfully since March 2006



RESPONSE ENGINEERING

Client:
Fingal County Council,
Swords,
Co. Dublin.

Client Representative:
RPS,
Westpier Business Campus,
Dun Laoghaire,
Co Dublin.

Design Flow:
150 m^3/day

Value:
Capital Works
€ 1,300,000

Year of Commencement:
2004

Status:
D&B:- Complete
O&M:- Ongoing

Project Involvement:
Plant Designer
Principal Contractor

Process:

- **Balancing Tank**
- **Forward Feed Pumps**
- **SBR Tanks (2 No.)**
- **Sludge Pumping**
- **Sludge Thickening**
- **Recycling System**
- **Sludge Dewatering**

Discharge Standard:
25mg/l BOD
35mg/l SS
125mg/l COD

HOLMESTOWN WASTE MANAGEMENT FACILITY & LEACHATE TREATMENT PLANT

DESIGN BUILD OPERATE CONTRACT

The contract consists of the design and build of all instrumentation, mechanical, electrical, and associated civil works in compliance with the waste licence and planning conditions of the Holmestown Waste Management Facility. There shall be a 5 year operation and maintenance period for the works.

The two main elements of the works are as follows:-

1. Leachate Treatment Plant

Turnkey Design & Build Contract of new leachate treatment plant at Holmestown, Co. Wexford and comprises the detailed design and construction of the plant followed by a 5 yr operation & maintenance period of the works.

The plant is designed to treat the following design loads:-

- BOD:- 10,000mg/l
- COD:- 20,000mg/l
- Ammonia:- 3,500mg/l
- Total Nitrogen:- 4,500mg/l

The plant consists of the following:-

- Leachate Balance Tank
- Balance Tank (Hardstanding Area)
- 2 No. SBR Tanks each with a capacity of 1200m^3.
- Fine Bubble Diffused Aeration System
- Sludge Return & Recycle pumping
- Biological Trickling Filter
- Sludge Thickening & Dewatering

2. Mechanical and Electrical Works

The scope for the Mechanical and Electrical Works include the supply, installation, commissioning and servicing of the following:-
• Site Services and Operations inc. 2 No. Weighbridges, Traffic barriers, Truck wheel wash, Landfill gas collection and flaring & Standby diesel generator
• Building Services for Administration, Weighbridge, Civic Amenity and Maintenance Buildings incorporating alternative power and heat sources (i.e. Photovoltaic panels, wood pellet boiler, wind turbine & Rainwater harvesting)
• Surface Water Management Infrastructure
– Surface water pumping.
– Continuous surface water monitoring (TOC, pH, Conductivity) & flow measurement.
• Other Instrumentation (Weather station, PLC & SCADA)

RESPONSE ENGINEERING

Client:
Wexford County Council, Spawell Rd, Wexford.

Client Representative:
Fehily Timoney, Core House, Pouladuff Rd, Cork.

Design Flow:
90 m^3/day

Value:
Capital Works
€ 3,750,000

Year of Commencement:
2007

Status:
Under Construction

Project Involvement:
Plant Designer
Principal Contractor

Process:
- Balancing Tanks
- SBR Tanks (2 No.)
- Biological Trickling Filter
- Sludge Pumping
- Sludge Thickening & Dewatering
- Recycling System

Discharge Standard:
200mg/l BOD
750mg/l COD
10mg/l NH4-N
1500mg/l NO3-N

![NORIT Membrane Technology]

Leachate Treatment
Intercommunale Hooge Maey
Cross Flow MBR Leachate treatment
Capacity: 20 m^3/h

Location

Background

Intercommunale Hooge Maey (Antwerpen – Belgium) is a company which manages the distribution of municipal litter over the landfill.
Rain water will dissolve organic compounds, heavy metals and salt while penetrating through the landfill in the direction of the groundwater.
To prevent pollution of the ground water, the polluted water (leachate) is collected under the landfill.
Due to high COD load and high values of nitrogen the leachate has to be treated before it can be discharged to the municipal WWTP. Typical leachate water quality data are given in the following table:

Source	Leachate water
pH	7 – 8
TSS [mg/l]	100
Temperature [°C]	10 – 20
COD [mgO_2/l]	7000
NH_4-N [mg/l]	655
NKj [mg/l]	750
Ptot [mg/l]	7,5

Because of the extreme high loads of COD and Nitrogen the conventional biological treatment is not sufficient to reduce these values till acceptable levels. Therefore, IHM has chosen for a membrane bioreactor (MBR) because of the fact that a MBR can operate at a much higher Mixed Liquor Suspended Solids (MLSS) level enabling a high sludge age and the growth of specific bacteria. These specific bacteria are able to reduce difficult components like humic acids and PAC's resulting in a high removal rate of COD and nitrogen. The membrane will retain all bacteria/sludge keeping the specific biomass in the bioreactor. The high MLSS and the total sludge retention by the membranes result in a compact installation design.

Decision Criteria

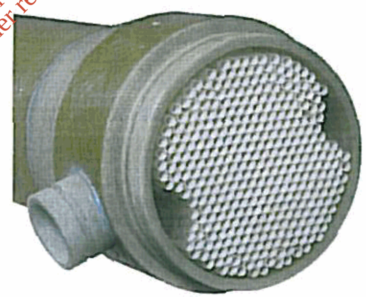
Prior to the construction of the full scale, tests were carried out to confirm feasibility of a bioreactor combined with UF. Pilot trails with the COMPACT 8.0 mm UF membranes were performed successfully, proving that UF membrane technology is an appropriate and cost-effective solution to achieve the objectives.

NORIT Cross Flow MBR

Although the MBR technology was originally developed thirty years ago, MBRs have only recently become accepted and utilized on large-scale systems. Moreover, the number of published researches and case studies on industrial and municipal MBR applications in the past ten years indicates that the rate of acceptance is rapidly increasing. Main drivers are the MBR's ability to sustain high biomass concentrations and sludge retention times allowing it to treat widely varying influents of high organic loading and recalcitrant compounds while still producing a high quality.

The MBR process provides quantifiable benefits over conventional activated sludge systems including a small footprint; low effluent suspended solids even if the waste water does not settle well; reduced waste streams and lower sludge production rate; a robust system performance; and improved biological degradation.

The NORIT CrossFlow MBR Ultrafiltration is a membrane filtration process that was developed by NORIT specifically for treating water with high concentrations of suspended solids in the range of 10,000 – 40,000 mg/l. It uses proprietary NORIT X-Flow tubular membranes encased in a standard 8 inch module. The membrane modules are positioned horizontal in a UF unit. The membranes have an internal diameter of either 5.2 or 8.0 mm, with an average pore size of 30 nm (0.03 μm). This means an absolute removal of particulate matter, including colloids, solids and micro-organisms such as Cryptosporidium and Giardia, ensuring the production of superior water quality.

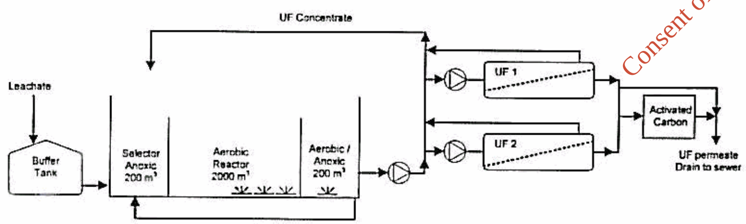


Tubular UF membrane module

During cross-flow operation the Trans Membrane Pressure over the individual modules can vary between 0.1 – 5.0 bar (1.5 – 73 PSI), depending on the system design and operation. The feed water passes through the membranes from the inside-out, which means that the substances are retained at the inner membrane surface. The retained substances are removed by means of a continuous bleed of concentrate during cross-flow operation. Occasionally the membranes are chemically cleaned by performing a Cleaning In Place (CIP), thereby restoring the membranes to their original clean state.

Project Description

Location	Antwerpen - Belgium
Contractor	Belgroma / Norit Membrane Technology
End-user	Intercommunale Hooge Maey
MBR plant operational since	August 2002



Flow diagram MBR plant

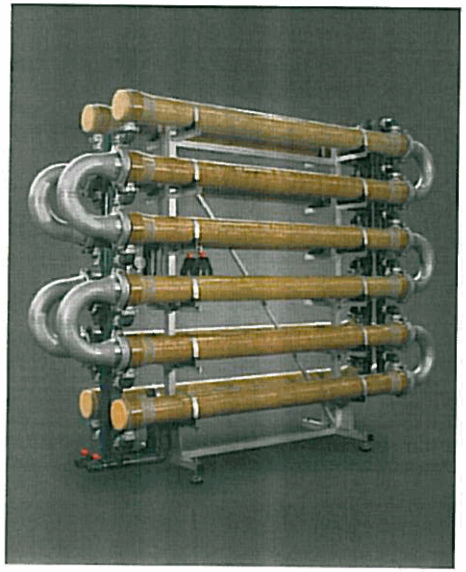
Leachate water from the landfill is pretreated by a drum screen (1 mm) before entering the buffer tank. From the buffer tank the leachate is controlled dosed to the selector where (pre)denitrification takes place. Together with fresh leachate, the concentrate from the UF enters here the bioreactor. The NO_3^- becomes with a carbon source (present in the feed) $CO_2(g)$ and $N_2(g)$. From the selector tank the biomass flows to the aeration tank. The aeration tank is an aerobic/anoxic carrousel in which most of the COD will be broken down and NH_4 is converted to NO_3^- (nitrification). From here, part of the sludge flow enters the post nitrification tank. This tank can be aerated periodically as an option to achieve a high N-reduction.

From the post-nitrification tank the sludge flows through the membranes and the concentrate re-enters the (pre)denitrification tank. Permeate from the UF is free from suspended solids and may, if necessary, partly be lead over activated carbon filters to remove the last COD residue to meet the requirements for discharge.

Denitrification (R), Nitrification (L) and carrousel (in front)

Configuration Cross-flow UF

Number of UF units	2
Modules per UF unit	6
Membrane area per module	27 m^2
Total installed membrane area	324 m^2



Cross Flow MBR skid (2 units)

Plant operation

Operating parameters UF

Flux	150 l/m^2h
Capacity	2 x 24 m^3/h feed
CIP1 interval (Citric Acid)	every 2 months
CIP2 interval (NaOCl+caustic)	every 2 months

Typical permeate quality

BOD5 [mgO_2/l)	< 3.0 mg/l
COD [mgO_2/l)	< 700 mg/l < 300 mg/l after AC
NH4-N [mg/l]	0.23 mg/l
Nkj [mg/l]	20 mg/l
Nitrate + Nitrite [mg/l]	2.21 mg/l
P-tot [mg/l]	0.20 mg/l

Seghers Keppel

UNIBRANE® *External Membrane Bioreactor*
Cova Da Beira
Portugal (2003)

The Cova da Beira (Central Compostagem) plant in Fundão is a municipal waste dump and composting facility .

The produced waste water is collected in lagoons and then treated by a MBR and then further polished by an RO treatment.

Seghers Keppel

Description of waste water treatment plant

The UNIBRANE® process combines advanced biological treatment with membrane filtration to achieve a high degree of treatment and to produce a high quality effluent. For the removal of nitrogen and COD from the leachate, a 4-stage UNIBRANE® reactor was built.

Table Overview of the raw water characteristics

Parameter	Value	Unit
Flow	3.75	m^3/h
COD	15000	mg/l
BOD	7500	mg/l
SS	1000	mg/l
Total N	1000	mg/l
NH4-N	660	mg/l
pH	5-10	Sör
temperature	20-30	°C
conductivity	30000	S/cm

Table overview of the dimensioning parameters

Parameter	Dimensioning value	Unit
COD load	1350	kg/day
BOD load	675	kg/day
SS load	90	kg/day
N load	90	kg/day
flow	3,75	m^3/h
	90	m^3/d
COD vol.load	3,33	$kg/m^3.day$
N vol.load	0,22	$kg/m^3.day$

Seghers Keppel

Table Overview of the effluent quality

Parameter	Limit	Performance	Unit
COD	150	150	mg/l
BOD	40	40	mg/l
SS	60	60	mg/l
Total N	15	15	mg/l
NH4-N	7,8	7,8	mg/l
NO3-N	11,3	11,3	mg/l
pH	6-9	6-9	Sör
temperature	20-30	20-30	°C
conductivity	30000	150	S/cm

This comparison and also the results of official measuring campaigns clearly illustrate the outstanding and continuous performance of the waste water treatment plant.

The UNIBRANE® process combines advanced biological treatment with membrane filtration to achieve a high degree of treatment and to produce a high quality effluent. For the removal of nitrogen and COD from the leachate, a 4-stage UNIBRANE® reactor is required, consisting of :

- Equalisation tank
- Pre-denitrification reactor
- Nitrification reactor with aeration system and re-circulation loop
- Post-denitrification reactor
- Re-aeration reactor, containing a tubular ultra-filtration unit for separation of biomass (sludge) and treated water.
- R-O filtration system

Raw leachate is fed to the leachate treatment plant. The flow to the plant can be selected by the operator and is controlled by means of a magnetic flow measurement and a regulating valve.

The pre-denitrification receives the equalised raw leachate and also a recycle of nitrified water from the nitrification tank. Sludge is recycled from the re-aeration reactor.

Nitrate from the nitrification tank is reduced to nitrogen gas by means of the organic material present in the raw leachate, with some additional methanol. Denitrification requires absence of oxygen so no aeration but only mixing is provided. From the pre-de-nitrification basin, the activated sludge flows by gravity to the nitrification basin.

In the nitrification basin, organic compounds and ammonia nitrogen are oxidised to carbon dioxide + water and nitrate. Air is introduced through a fine bubble aeration system fed with pressurised air by two blowers. A large part of the nitrified water is recycled to the pre-de-nitrification tank for the removal of nitrate. The fine bubble aeration systems consist a number of diffuser discs installed on the bottom of the nitrification reactors. This aeration system provides high aeration efficiency, does not produce aerosols and does not cool down the water. From the nitrification tank the activated sludge flows by gravity to the post-de-nitrification unit.

Seghers Keppel

This second de-nitrification unit removes all remaining nitrates, with the internal reserves of the bio-mass being used as carbon source in the reduction process (endogenous de-nitrification). In case of low BOD/N ratios in the raw leachate, addition of an external carbon source acetic acid is also used.

The use of the post-denitrification unit reduces the required recycles in the systems, optimises the hydraulics of the treatment plant and optimises reaction rates through an increase of substrate levels.

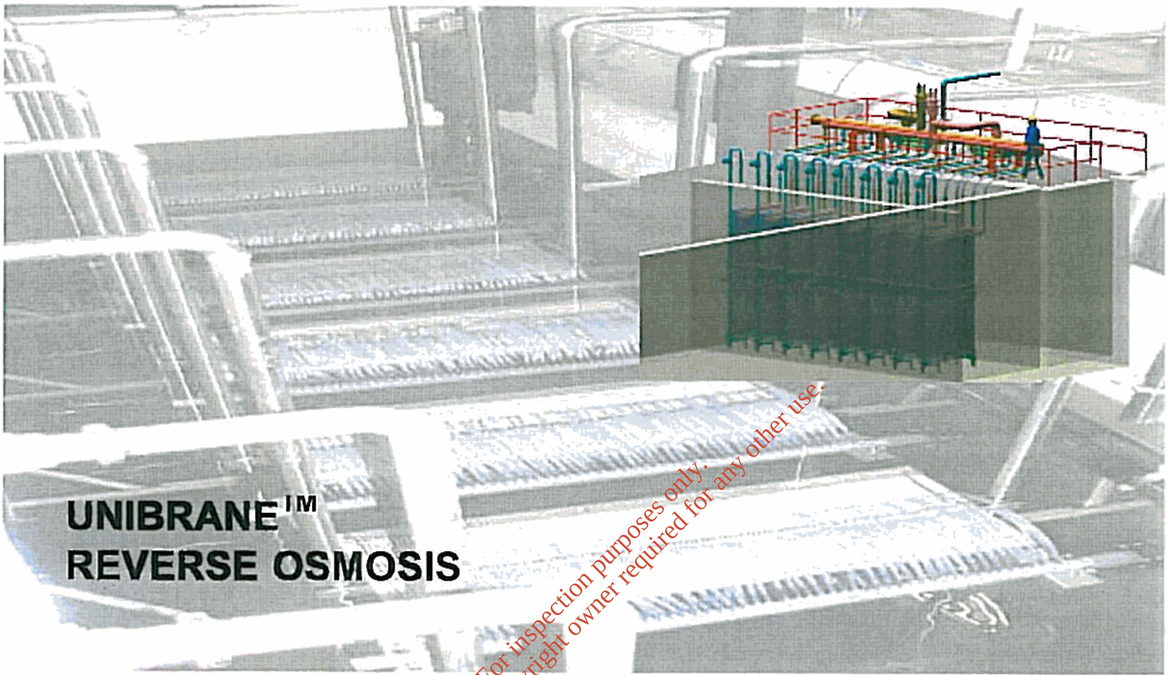
From the denitrification tank the activated sludge flows by gravity to the re-aeration tank, where water is re-aerated to guarantee a high quality effluent. In the re-aeration tank a ultra-filtration system is installed.

The ultra-filtration separates water from the biomass mixture. The retained biomass is returned to the pre-denitrification reactor, hence increasing the sludge level of the biological system. The ultra-filtration unit consists of three tubular membranes. For occasional cleaning of the membranes, a CIP (cleaning in Place) unit is included. The CIP unit consists of a separate CIP tank, with a CIP chemical storage and dosing facility. Chemicals will be fed into the CIP tank, by chemical pump. The UF filtration unit has all the necessary valves and piping included.

Permeate from the ultra-filtration unit is discharged to a storage tank, before the Reversed Osmosis filtration.

Seghers Keppel

UNIBRANE® - REVERSE OSMOSIS
Fuji The Netherlands (2003)



Fuji in Tilburg the Netherlands is a production facility with focus on :

- Steady production of Colour Paper,
  Colour Negative Film and Presensitized Plates
- Quality assurance products
- Teamwork, involvement

Description of waste water treatment plant

.The UNIBRANE® process combines advanced biological treatment with membrane filtration to produce a high quality effluent.

By means of a RO system, the effluent is treated so far that it can be reused in the production process.

The waste sludge which contains silver, will be dewatered and sent to an extern silver reuse installation.

The installation is also equipped with a heat pump for optimal use of the energy balance.

Table : Overview influent characteristics

PARAMETER	Unit	design
Flow (day) flow (hour) flow (peak)	m^3/day m^3/h m^3/h	840 35 45
Temperature	°C	37
PH	Sör	7 - 8
COD concentration	mg/l	1800
BOD concentration	mg/l	850
BOD / COD	-	0,47
TSS concentration	mg/l	48
Total Nitrogen Concentration	mg/l	94
Kjeldahl-N	mg/l	35
NO_3^--N	mg/l	30
NO_2^--N	mg/l	25
BOD/N	-	9,4
Total Phosphor concentration	mg/l	5
Total Phosphor concentration		5

Table overview of the Effluent quality

PARAMETER	UNIT	GARANTUEED
COD COD (av. Removal)	mg/l %	< 51 > 97
Ss	mg/l	0
Total-N	mg/l	< 5
Ag non soluble	mg/l	0

The waste water is collected in a buffer tank. From there it is pumped through a curved screen.
Through a middle buffer tank the water is then pumped to the denitrification tank of the biology.
Here the nitrates formed in the aerobic compartment are denitrified. The sludge – water mixture streams further to the aerobic compartment where nitrification takes place and BOD/COD are assimilated and dissimilated. From this tank the sludge/water mixture is pumped towards the membrane compartment, where the permeate from the membranes is extracted. The thickened sludge/water mixture flows over into the aerobic tank, and a part of it is extracted towards the decant centrifuge for dewatering and further drained off for treatment .
The permeate is fed to the permeate tank and pumped through a reversed osmosis membrane to remove salts in order to achieve process water quality, suitable for reuse in the plant.

FULL SCALE LEACHATE TREATMENT BY NANOFILTRATION IN TURKEY AND THE NETHERLANDS

H. WOELDERS*, Ş. Yildiz**, H. SCHONEWILLE***

** Essent Milieu Wijster, PO Box 5, NL-9418 ZG, Wijster, the Netherlands*
***ISTAÇ, Feriköy, Piyalepaşa Bulvan no. 9, 80250 Şişli-Istanbul, Turkey*
**** NORIT Membrane Technology, P.O. Box 731, 7500 AS Enschede, the Netherlands*

SUMMARY:

1. INTRODUCTION

Recently three major leachate treatment plants with the use of nanofiltration have been implemented in Turkey and the Netherlands. This paper has been prepared by the landfill owners ISTAÇ and ESSENT and the supplier NMT and deals with the aims of the treatment, pilot plant research and the first results of the full scale plant.

ISTAÇ is one of the Economic Enterprises of Istanbul Metropolitan Municipality operating landfills, composting plants and several other recycling plants..

ESSENT is a Dutch multi-utility company with, as its core activities, energy production and distribution by network systems and waste management. ESSENT is operating 8 landfills including the Wijster Landfill with an extended leachate treatment and LFG-utilization.

NORIT Membrane Technology (NMT) is in the Netherlands leading company for turn-key projects based on membrane technology and world wide one of the leading companies in this field. X-Flow, also part of the NORIT Group offers a complete membrane and module program for all the processes as mentioned above. The capillary NF modules are produced by X-Flow.

2. LEACHATE TREATMENT AND THE ROLE OF NANOFILTRATION

The choice of the leachate treatment system depends on the standards to meet for the receiving surface water. In general, the self-purification capacity is insufficient for concentrated discharges and therefore treatment in a WWTP or biological leachate treatment plant has to reduce oxygen consumption of the leachate (BOD removal and nitrification). In case of discharge of to more critical receiving water denitrification and phosphorous removal is necessary.

The next step is removal of color, heavy metals and organic micro pollutants (PAH, EOX etc.) by oxidation (peroxide, ozone), activated carbon systems, coagulation or NANOFILTRATION. If the receiving water cannot dilute the salt content in a proper way and is used for agricultural purposes (cattle water, irrigation) or is a source for potable water, desalination of the leachate is necessary by reverse osmosis, electro-dialysis or evaporation.

Nanofiltration is a promising complementary treatment technique for leachate treatment. Full scale experiences with so called plate modules have been reported from two German landfills. In these cases the goal was reduction of residue in combination with reverse osmosis systems. Full scale results with direct spiral wound nanofiltration treating raw methanogenic leachate are known. Due to a low bio-fouling potential of the untreated leachate this German plant operates under stable conditions. From the moment there is a biological pre-treatment in front of the nanofiltration bio-fouling becomes a serious problem. The experiences with direct capillary nanofiltration (The Netherlands) and spiral wound nanofiltration membranes with a MBR pretreatment including ultrafiltration (Turkey) will be demonstrated.

3. GENERAL ASPECTS OF MEMBRANE FILTRATION

With membrane filtration one fluid stream (the feed) is divided into two or more fractional streams, one of them more concentrated in certain components (the concentrate) and the other one more diluted (the permeate). The membrane acts as a selective barrier enabling some components to pass and others not. The driving force for this process in water treatment is usually restricted to a pressure difference.

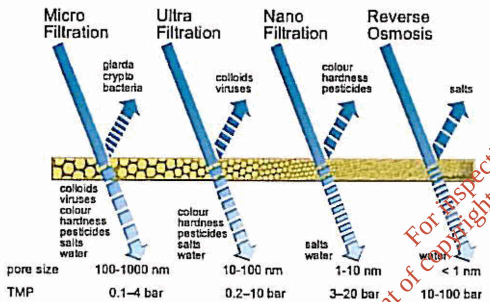


Figure 1: Pressure-driven membrane processes.

Figure 1 presents the main properties of the pressure-driven membrane processes. Going from microfiltration through ultrafiltration to reverse osmosis, the particle size of the molecules to be separated decreases, and, consequently, the pore size in the membrane becomes smaller. This implies that the resistance of the membranes to mass transfer increases and hence the applied pressure, also called the transmembrane pressure (TMP), has to be increased to obtain the same flux. However, no sharp distinction can be drawn between the various processes.

In waste water treatment microfiltration and ultrafiltration are generally applied in MBR concepts or as first step in polishing the effluent, because their separation characteristics are well enough to fulfill the effluent requirements. Nanofiltration and/or reverse osmosis can be used as second step to upgrade the ultra filtered water to process or potable water quality.

3.1 Membrane characteristics

Individual membranes are placed into modules which are available in several configurations:

- plate-&-frame: a flat membrane is mounted on a supporting plate and several plates are fixed together into a frame;
- spiral wound: a flat membrane is wounded around a central pipe given from the side a spiral effect;
- tubular and capillaries: many tubular or capillary membranes are placed in a housing and sealed at the ends by means of an epoxy resin.

Microfiltration and ultrafiltration membrane modules applied in water treatment are usually capillary or tubular modules, while plate-&-frame modules are also used for waste water treatment. Nanofiltration and reverse osmosis membranes are usually spiral wound modules. Figure 2 shows several commercially available modules, from which the tubular ultrafiltration modules (Figure 2b) are used in the applications described later in this paper.

(a) (b) (c) (d)

Figure 2: Module configuration: (a) capillary ultrafiltration module; (b) tubular ultrafiltration module; (c) plate-&-frame ultrafiltration module; (d) spiral wound nanofiltration or reverse osmosis module.

3.2 Membrane Bioreactor

A membrane bioreactor (MBR) is a compact-built purification system combining the biological degradation step with a membrane separation step instead of with a clarification tank. The influent is fed to the aerated bioreactor where the organic components are oxidized by the activated sludge. Next, the aqueous activated sludge solution passes through a micro- or ultrafiltration membrane filtration unit separating the water from the sludge. The latter returns to the bioreactor, while the permeate is discharged or re-used as particle-free effluent.

Presently, two basic MBR systems can be distinguished using these principles (Figure 3): Side-stream: the membranes are placed outside the bioreactor. The membranes are horizontally or vertically placed tubular membranes and fed at the inside. Depending on the driving forces the following concept can be distinguished:

the system operates under overpressure in cross-flow mode (horizontal); or
the system operates under underpressure in airlift mode (vertical);
Submerged: the membranes are submerged in (a separate part of the) the bioreactor. The membranes are either horizontally or vertically placed fibers, or vertically placed flat sheets. All systems are aerated at the bottom side, while the permeate is withdrawn by means of suction at the permeate side.

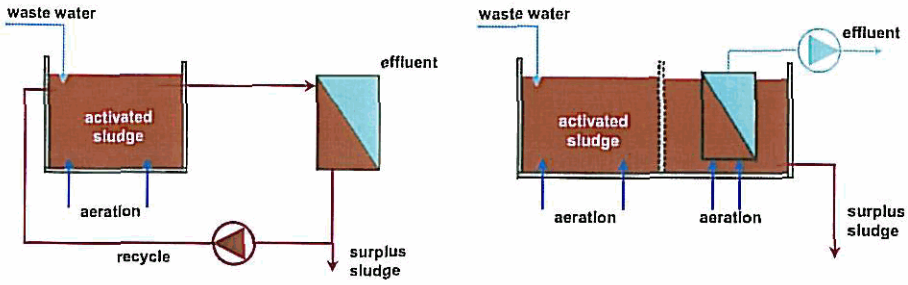


Figure 3: Membrane Bio-Reactor system: (a) side-stream; (b) submerged.

2.4. (Direct) Nanofiltration

A nanofiltration (NF) membrane removes bacteria and viruses, for example, as well as pesticides, organic matter, heavy metals, and to some degree also salts. The permeate is therefore of a high quality, reliable and can be used as process water for industry (e.g. for producing ultra-pure water, boiler supply water or water for the process industry, etc.) or for discharge on surface water.

Membranes in current NF installations are usually designed as spiral-wound elements and placed in pressure vessels. A membrane element consists of sealed envelopes that are bonded to a central product tube. The envelopes are wrapped spirally around the product tube. The envelopes have spacers fitted between them, enabling input water and permeate to flow through and along the envelopes. Fig.1a shows an 8 inch Spiral Wound NF module.
The advantage of a spiral-wound membrane element is the large surface area of the membrane (per m3) and therefore the large production volume that can be achieved per element. The disadvantage is, however, the limited space between the envelopes through which the input water flows. The small height of the feed spacers (approximately 0.8 mm) makes the spiral-wound membrane extremely susceptible to floating matter.
In order to use spiral-wound NF membrane elements pre-treatment is necessary before the water can be treated. In practice, membrane filtration is part of a (long) series of treatment steps, such as
flocculation/sedimentation + rapid sand-filtration + NF;
(sandfiltration) + ultafiltration + NF;
making membrane filtration not always economically viable to produce process water out of lower quality sources.

In order to improve the economical attractiveness for the production of process water out of the fore-mentioned sources NORIT has recently developed low-pressure NF capillary membranes. These NF capillaries should bridge the cap between the bulky, but robust tube-sized NF membranes at one side and the compact, but fouling-sensitive spiral-wound NF membranes at the other side.
The background of this new product is based on the use of capillary ultrafiltration (UF) as pre-treatment before spiral-wound NF. Since the mid-nineties of the last century UF is being used successfully as a new pre-treatment step for spiral-wound modules creating an effective barrier to suspended matter. A capillary NF membrane combines the favourable properties of the capillary UF membranes in terms of ease of cleaning with the favourable properties of the NF membrane in terms of the removal of bacteria, viruses, pesticides, organic matters and heavy metals. Fig.1a shows an 8 inch NF module with 20 m2 of membrane area.

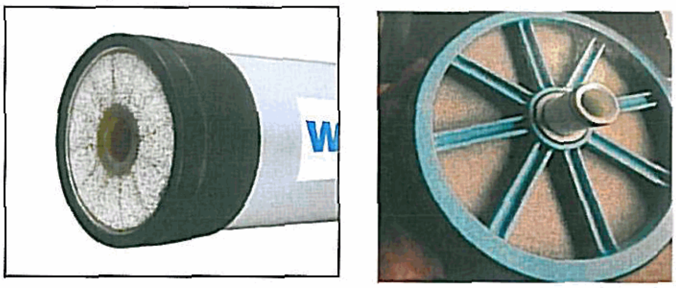


Figure 4: NF module: (a) capillary; (b) spiral wound.

4. NANOFILTRATION ESSENT LANDFILL WIJSTER (NL)

4.1 Introduction

The leachate treatment system at the Wijster Landfill consisted from 1994 until 2006 of:

- Biological pre-treatment (activated sludge system/ nitrification-denitrification)
- Reverse-osmosis (tubular membranes and spiral-wound membranes)
- Evaporation plant (multi-stage flash) treating the RO-concentrate
- Discharge of the residue to former salt-mines after solidification.

Desalination by reverse osmosis has been installed in 1986 caused by the stringent effluent criteria (chloride 200 ppm, total nitrogen 10 ppm) for the receiving surface water. The former treatment system (250,000 m3/a) needed an upgrading, while:

- The system was expensive (all-in €15/ m3 leachate)
- The tubular RO-system was technically spoken no more “state of the art”
- The high amount of residue (7,000 tons/a) made the system not sustainable.

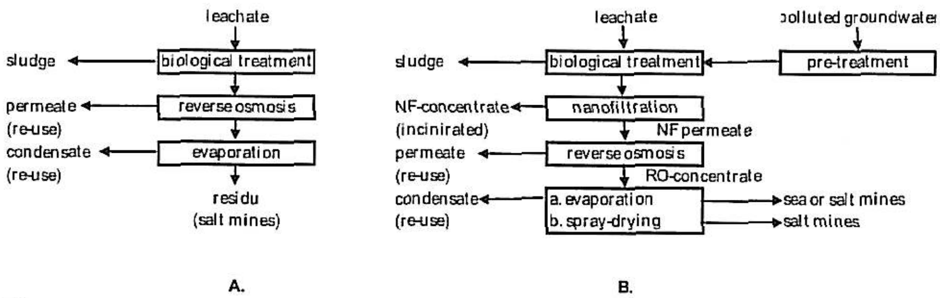


Figure 5 : Former leachate treatment system (A.) and the new system (B.)

Since 1999 ESSENT and NORIT Membrane Technology studied on pilot plant scale the possibilities of tubular nanofiltration and capillary nanofiltration. Additional research has been done with spiral wound membranes.
The objectives of nanofiltration are:

- Reducing the amount of residue by separating the mono-valent salts (chloride, potassium and sodium) from the other components in the leachate
- Concentrating the organic compounds with heavy metals and organic micro pollutants.

The concentrate of the nanofiltration (concentration factor, CF, is 10 or higher) can be incinerated or spray-dried by the MSW incineration plant (see Figure 1). The permeate of the nanofiltration (with mono-valent salts) is concentrated by RO and spray-dried.

4.2 Pilot plant research

The research included:

- Research with tubular modules (trans membrane pressure 20 bar, cross flow operation)
- Research with capillary modules (TMP 6 bar, semi-dead end and cross-flow operation)
- Research with spiral wound membranes (TMP 5 till 40 bar, cross flow operation)

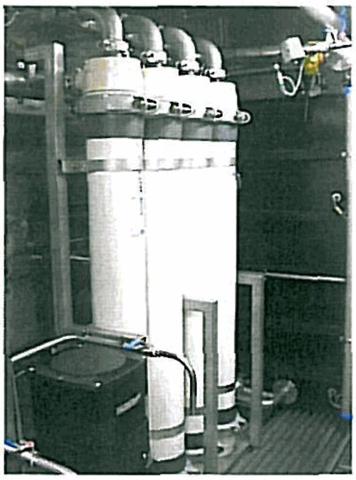
Tubular nanofiltration membranes:
In 1999 the research started with tubular nanofiltration modules (diameter 15 mm). With a trans membrane pressure of 20 bar, a (recirculation) velocity of 3 m/sec and a concentration of 10 times. Fluxes were obtained of approx. 25 l/m2 hr and also a good quality permeate was obtained.
That time the capillary nanofiltration was introduced (on the basis of capillary ultrafiltration membranes with a polyamide layer) with several advantages.

Capillary nanofiltration membranes:
Potential advantages of capillary membranes:

- Less energy consumption due to TMP of 6 bar and a lower velocity of 2 m/sec; reducing the energy consumption from 6 to 3.5 kWh/m3 permeate.
- Less chemical consumption for cleaning because of the lower volume to surface ratio of the capillary membranes.

- The potential use of air-flush cleaning.
- The potential use of back flush cleaning.

In 2001 the research with the capillary nanofiltration membranes started (see Figure 3) with testing the optimal operation procedure: semi-dead operation (and additional air-flush cleaning) or continuous operation (feed and bleed) with a recirculation flow. The semi-dead operation gave relative bad flux results and there wasn't any advantage of air-flush cleaning. Due to the bio-fouling potential of the pretreated leachate continuous operation with a recirculation flow gave the best performance. In this paper the results of the continuous (cross-flow) operation are presented.
During all test-runs the biologically pretreated leachate has been mechanically screened (200 µm), pH adjusted (range 7 to 7.2) and supplied with anti-scalant. First step was testing the optimal recirculation velocity (between 1 and 2.5 m/sec); optimal velocity of approx. 2 m/sec was determined and used during the proceeding tests.



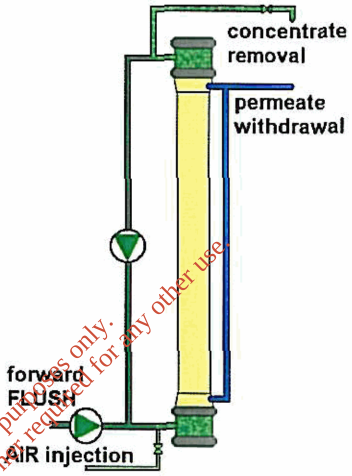


Figure 6. Pilot plant with four capillary membrane modules and flow diagram.

The results of different test runs of 100 hours are presented in Table 1. The temperature increases due to mechanical (pump) input. The trans membrane pressure increases from the start to the end of a test-run (manual adjusted).
With these results a multi-stage plant can be designed with an average flux of 22 l/ m2 hr.

Table 1. Flux and trans membrane pressure for different concentration factors.

CF	Temperature (^{0}C)	TMP (bar)	Flux: start-end (l/m2,hr)
2	15-17	2.8-4.2	31-25
4	32-35	2.7-5	26-22
10	32-38	2.2-6	21-18

Table 2. Water qualities.

parameter	unit	raw leachate	influent NF	permeate NF
COD	mg/l	2500	1500	105
BOD	mg/l	150	5	1
NKj	mg/l	1200	60	4
NO3-N	mg/l	0	20	20
Cl	mg/l	3000	3000	3050
SO4	mg/l	240	220	60
Cd	μg/l	5	2	0.2
Hg	μg/l	0.15	0.1	0.01
PAH (16 EPA)	μg/l	0.5	0.095	0.025
EOX	μg/l	0.6	0.4	0.1
Color		black	black	transparant

In Table 2 the water quality is given of the raw leachate, effluent of the biological treatment (influent of the nanofiltration) and the permeate of the nanofiltration operated with a concentration factor of 10 times (recovery of 90%). The retention of COD is 93%, the average of heavy metal removal is 90% and for organic micro pollutant 75%. No retention of mono-valent ions could be measured.

After every test-run the membranes have been cleaned with an alkaline solution (pH about 11) to remove organic pollution; periodically an additional cleaning with acid and oxidation with peroxide is necessary as well as an enzymatic (detergent) cleaning. The cleaned membranes are controlled by measuring the "clean-water-flux" (approx 20 l/m2 hr bar).

Spiral wound nanofiltration membranes:
In 2003 a full scale plant with spiral wound nanofiltration in Germany had been visited with good treatment results on raw leachate from an old methanogenic landfill. These good results were the motive to start a pilot plant research in 2004 for the ESSENT leachate. The biological pretreated leachate was mechanically screened (20 μm), pH adjusted to 6.7 and anti-scalant had been supplied.
The preliminary results with the spiral wound membrane have been promising: high retention, fluxes of 17 l/m2,hr and runtimes of 7 to 10 days before cleaning. After one month of operating the cleaning intervals have been reduced to one day! In one day the trans membrane pressure increased from 4 to 40 bar. Strong oxidation agents have to be used (peroxide solutions) to get a maximum runtime of 3 days. Due to the high biological potential of the leachate, bio-fouling on the membranes have been built up in a very fast way. On the membrane a layer of extra cellular sugars form the glue for the colloidal humic acids (a typical leachate product) and dispersed micro-organisms. The intensified usage of peroxide will reduce the life time of the membrane drastically. Direct nanofiltration with spiral wound membranes will result in intensified cleaning procedures and relative short run times.

4.3 Full scale plant: description and performance

In 2005 the existing groundwater treatment plant has been partly destroyed by a fire. Groundwater has been polluted by leachate in former days and is nowadays controlled by an extraction and treatment system. The former groundwater treatment system existed of a pretreatment followed by ultrafiltration and reverse osmosis. So the scheduled upgrading of the leachate system was combined with the groundwater treatment. The extracted groundwater is pretreated by aeration and sedimentation to remove methane, hydrogen sulfide and iron. The pretreated groundwater and leachate are combined and biologically treated and than enter the new nanofiltration and reverse osmosis plant (see figure …). In table … the pre-treated groundwater and biological treated leachate are presented (design values) as well as the actual input of the plant in 2006/2007.

The maximum capacity of the new plant is 50 m3/hr (375,000 m3/a). The plant exists of a pre-treatment, nanofiltration, reverse-osmosis and CIP (cleaning in place) device.
The **pretreatment** exist of a screening, pH adjustment to 7 by sulfuric acid, heating up to 25 ^{0}C by a CHP and a supply of an anti-scalant.
The **nanofiltration** unit exists of four similar sections in series. Each section is cleaned separately. Each section has 30 capillary membrane modules (design flux 20 l/m2) with a recirculation pump to get a horizontal velocity of 1.5 m/sec along the membrane. The central feed pump keeps the total pressure on a maximum of 6 bar. Each day there is short back flush (60 sec) to remove a (part) of the fouling. Twice a week there is a chemical cleaning with two main steps an alkaline cleaning followed by an oxidizing (hydrogen peroxide) cleaning.

Figure 7: Overview of the nanofiltration plant ESSENT and a capillary module.

The **reverse osmosis** unit exists of three parallel operating sections each with 6 spiral wound modules.

Table 3: Performance of the NF and RO plant

parameter	unit	influent NF	permeate NF (influent RO)	concentrate NF	concentrate RO	permeate RO
Flow	m3/hr	50	45	5	7.5	37.5
COD	mg/l	320	43	2700	114	16
BOD	mg/l	<3	<3	11	<3	<3
NKj	mg/l	18	3	154	5.5	0.7
NO3-N	mg/l	1.9	2.1	2.2	6.2	0.05
Cl	mg/l	1500	1500	1700	4500	18
SO4	mg/l	110	35	1300	320	<2
Color		dark	transparent	black	yellow	clear

5. THE ISTANBUL LANDFILLS OF ISTAC

İSTAÇ Co., Istanbul Metropolitan Municipality Environmental Protection and Waste Materials Valuation Industry and Trade Co., is one of the Economic Enterprises of Istanbul Metropolitan Municipality.
As the name denotes, İSTAÇ Co. within the scope of Solid Waste Project of Istanbul Metropolitan Municipality, provides services for transportation of solid wastes, production of compost fertilizer, recycling of wastes, disposal of them via regulated storing, electric energy generation from landfills, transportation of medical waste and their disposal via incineration.
On the European side 8 thousand tons of garbage is being collected daily in the Landfill Area established on 75 hectares in Odayeri/Göktürk'teki. Nowadays 2000 m3 of leachate daily is produced and in the future this will be 3000 m3.
On the Anatolian side 4 thousand tons of garbage is being collected daily in Landfill Area in Kömürcüoda/Karakiraz Village, and a area of 100 hectares is used for this work. Nowadays 1200 m3 of leachate daily is produced and in the future this will be 2000 m3.

5.1 The leachate treatment project.

In 2006 the project for the treatment of leachate for the two Istanbul landfills was awarded to Norit Membrane Technology. In 2007 the leachate treatment plants from the two main landfills in Istanbul, one at the European (Kömüorcüoda) and one at the Asian (Oyaderi) side of the city, will be executed with a membrane bioreactor system (MBR) followed by a nanofiltration system (NF) with post treatment by activated carbon (AC). The concentrate of the nanofiltration system will be treated on the landfill site and the salty permeate will be discharged in the seawater of the Bosporus.
The waste water treatment plants in Istanbul will use a combination of several different Norit Group purification solutions: a biological process applied in conjunction with ultrafiltration, followed by nano-filtration and activated carbon filtration. Norit Membrane Technology has developed this turnkey project in cooperation with a civilian partner in Turkey. In addition, Norit will be responsible for plant operation during the initial years.

The Leachate treament plant consists of the following process stages:

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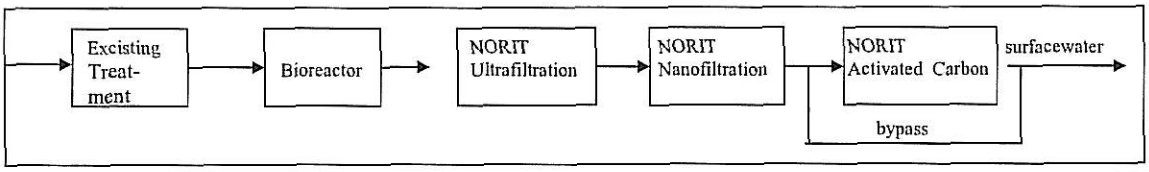
Leachate intake
Membrane Bio Reactor (Norit Crossflow MBR), consisting of:
Oxic/Anoxic bioreactor
Norit Crossflow Ultrafiltration installation
Sludge treatment
NORIT Nanofiltration installation
NORIT Activated Carbon filtration
Effluent discharge



Basic Process Flow Diagram

Essent Landfill Wijster (NL)

In 2006 the leachate treatment plant of Essent (45 m3/hr) has been upgraded from a two stage reverse osmosis system to a combined nanofiltration and reverse osmosis plant. Pre-treatment by an existing activated sludge system with a settling tank causes a biofouling potential that high that a capillary nanofiltration system was necessary. Due to sensitive receiving waters a post treatment by reverse osmosis has been included. The concentrates of both systems are treated in the nearby incineration plant.

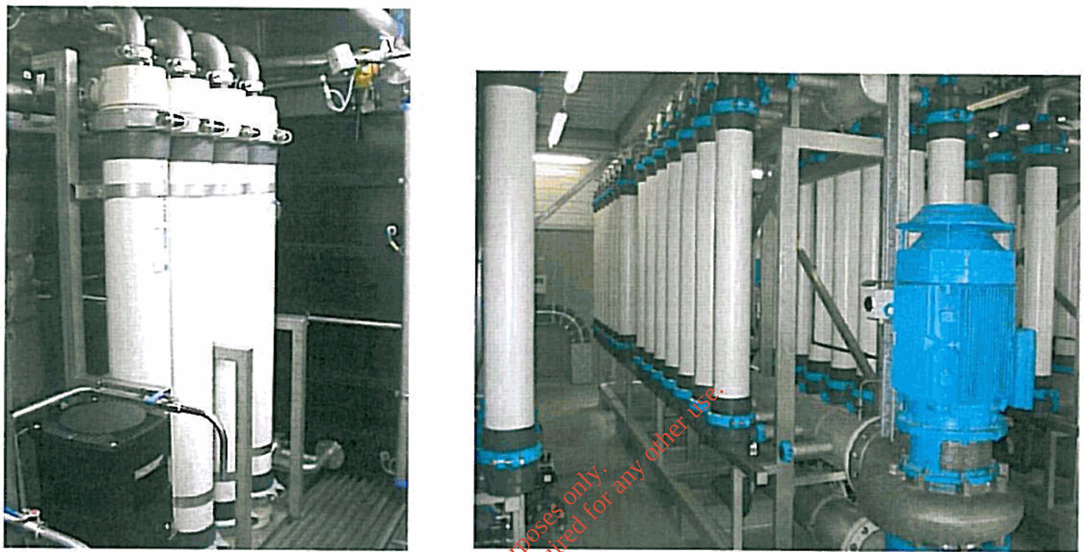


Figure 1. Pilot plant and full scale plant with capillary nanofiltration in the Netherlands..

The Istanbul landfills of ISTAC

In 2007 the leachate treatment plants (125 and 85 m3/hr) of the two main landfills in Istanbul will be extended with a membrane bioreactor system (MBR) followed by a nanolfiltration system (NF) with post treatment by activated carbon (AC). The pretreatment exists of pre-settling and a anaerobic system. The concentrate of the nanofiltration system will be treated on the landfill site and the salty permeate will be discharged in the seawater of the Bosporus.

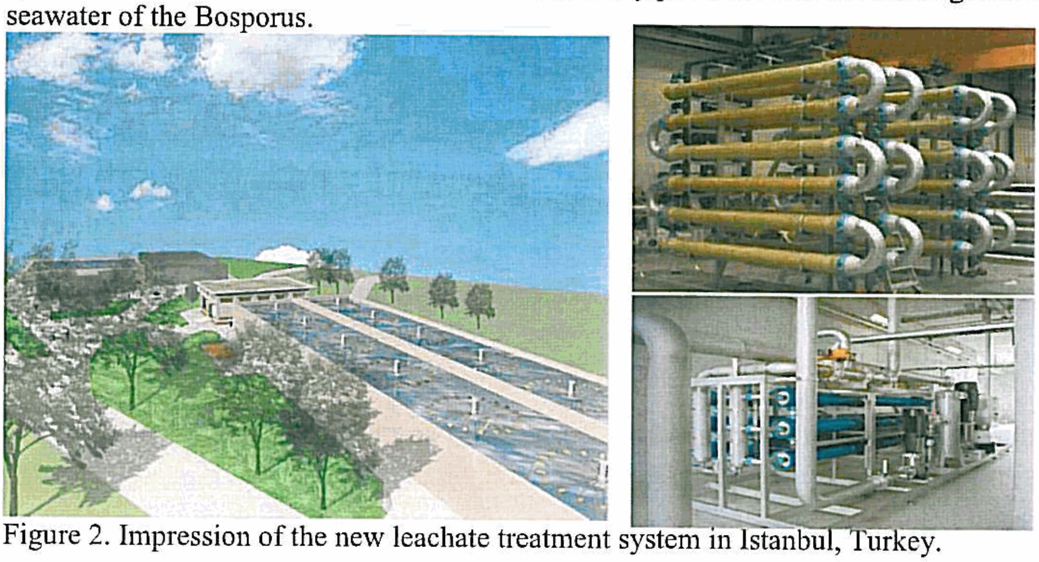


Figure 2. Impression of the new leachate treatment system in Istanbul, Turkey.