Membrane Bioreactors (MBR)

The Irish Experience

Presentation to Engineers Ireland 17th Sept 2007

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Presentation Overview

- Introduction to EPS Bison
- MBR Technology - History & Development
- MBR The Technology
- MBR Applications
- Case Studies
- EPS Bison Clereflo MBR Plants
- Operation & Maintenance
- Capital & Operating Costs
- Conclusions
EPS Bison

- Strategic Business Unit of EPS Group formed March 2002
- Specific Purpose of Design / Supply / Installation / Commissioning & Servicing of Packaged Treatment Solutions
- Product Range:
  - Packaged Treatment Systems
  - Packaged Pumping Stations
  - Attenuation / Storage / Sprinkler Systems
  - Interceptors/Separators / Grease Traps
  - Septic Tank Retrofit Systems
  - Rain Water Harvesting Systems
  - Above Ground Engineered Vessels
EPS Bison

- Full Design & Provision of Turnkey Solutions
- Assistance from initial design stage through planning process to project delivery
- Assistance with all aspects of design for disposal including Assimilative Survey’s and Discharge Licence Applications
MBR Technology History & Development

- First commercialised in 70’s & 80’s
- Small scale applications:
  - On board ships
  - Landfill leachate
  - High strength industrial
MBR Technology History & Development

- Japanese Govt. initiative for initial development
- In Europe First Plant Porlock WWTP 1998 (3800pe)
- Büchel Germany 1999 (1000 pe)
- Rödingen Germany 1999 (3000pe)
- Karst Germany 2004 (80000pe) largest
- In 2005 estimated 10 industrial / 2 municipal in Ireland
MBR Installations By EPS

- As of Sept 2007 EPS Installed / Under construction

**Wastewater**
- Industrial - 4
- Municipal - 11
- Package - 11

**Water**
- Municipal – 2 (UF)
Estimated European Installations (1990-2005)

Figure 1. Development of industrial and municipal MBR markets (402 references in graph).
MBR The Technology

Types Of Membrane

• Flat Sheet
• Hollow Fibre
• Tubular Membranes
• Kubota Submerged Flat Sheet
• Others (39 approx)

Norit x – flow / Berghof / Memos / Zenon
Toray / Kms – Puron etc
The Product

What is MBR Technology?

Membrane filtration is a liquid separation process in conjunction with the activated sludge process that treats and removes pollution from wastewater producing two outputs:

- A highly purified effluent
- A concentrated sludge
Membrane Effluent Treatment

Advantages

• High quality final effluent

• No primary or Secondary Settlement – low land area requirement

• Treatment option for high strength or variable strength effluents

• Lower Sludge production (0.8kg/kgbod)

• Sludge Haulage Costs Reduced

• Retrofittable /Modular
Conventional WwTW

Screening & Grit Removal

Primary Settlement

Secondary Treatment ‘Biological’ Stage

Final Settlement

Sand Filtration

Disinfection

Treated Water
Membrane Bioreactor WwTW

3mm Screen

Membrane Reactor

Permeate (disinfected)
Advantages over conventional plants

GLASTONBURY
(4.5 ha)
Process Principles

In

Screened crude sewage

Waste Sludge (to further treatment)

Air in

Out

Treated & disinfected effluent
Process Principles
Kubota Membrane Units

Basic Product Range

• Includes aeration and filtration sections

• Standard Kubota units: 7 - 200 panels

• Double Deck design: 300 and 400 panel - reduced plan area

• Custom designs to fit application

• Gravity or suction operation

Membrane filtration top section (150 panel)

Diffuser aeration lower section
Membrane Panels
Membrane Filtration

- Air
- Solids
- Virus
- Bacteria
- Treated effluent
- Membrane

- Treated effluent
Membrane Separation

Relative Particle Sizes

- Metal ions
- Aqueous salts
- Virus
- Bacteria
- Cryptosporidium
- Giardia
- Coal dust
- Beach sand
- Ultrafiltration
- Microfiltration

Effective pore size
Nominal pore size

μm (log)

0.001 0.01 0.1 1.0 10 100 1000
Membrane Process

Re-use advantages

- Effluent fully disinfected without chemicals

- Near zero pathogen levels (protozoa, bacteria and virus)
  - > log 6 Bacteria
  - > log 4 Virus

- Consistent high quality effluent
  - SS, BOD, COD
  - NH$_3$, NO$_3$,
  - TP / Ortho P

- Minimal odour
MBR Applications

- Municipal Waste Water
- Domestic/Commercial Waste Water
- Sludge Liquors
- Sludge Thickening
- Industrial Waste Water
- Shipboard Waste Water
MBR Applications

2005 MBR Worldwide Applications

- Household 6%
- Municipal 62%
- Industrial 32%

(COPA MBR)

2005 MBR Installations in Europe

- Industrial 285 units
- Municipal 105 units
- Household 250 units

(B. Lesjean & E. Huisjes: 2007)
EPS References
(installed/under construction)

- Wood Processing 1200M3/d
- Ind. Waste Water 16000pe
- Baileys 200M3/d
- Bweeng 500pe
- Narramore 750pe
- Lismire 500pe
- K Club 500pe
- Cliffs Of Moher 500pe
- Greyabbey 2000pe
- Kircubbin 3000pe
- Drumaness 2000pe
- Aghalee 2000pe
- Aghagallon 2000pe
- Dunloy 2000pe
- Grange 750pe
Case Studies

- Porlock
- Industrial Waste Water
Porlock WwTW

Site data

- Located in Exmoor National Park, with nearby bathing beach
- 3800 population equivalent (summer)
- 1900 m$^3$/d flow to full treatment
- Sewage feed started 12th February 1998
Porlock WwTW
Porlock MBR Building
Porlock BOD Removal

BOD (mgO₂/l)

Feb 98 - Aug 02

Time in Years

- Raw Feed
- Permeate
Porlock NH3 Removal

AmmN (mgN/l)

Time in Days

Raw Feed

Permeate

0 10 20 30 40 50

200 250 300 350 400
Porlock Faecal Coliforms

Faec. Col.
$10^6/100$ ml

Time in Years

Feb 98 - Sept 02

Sampling contamination identified

Raw feed
Permeate
Porlock STW - Compliance Results

**Porlock STW - Compliance Results**

**Kubota Submerged Membrane Process**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>No of samples</th>
<th>Crude Min</th>
<th>Crude Max</th>
<th>Crude Average</th>
<th>Final Min</th>
<th>Final Max</th>
<th>Final Average</th>
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</thead>
<tbody>
<tr>
<td>Total coliforms /100 ml</td>
<td>82</td>
<td>2000000</td>
<td>&gt;3000000000</td>
<td>126000000</td>
<td>2</td>
<td>480</td>
<td>&lt;35</td>
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<td>Faecal coliforms /100 ml</td>
<td>83</td>
<td>300000</td>
<td>160000000</td>
<td>14200000</td>
<td>0</td>
<td>378</td>
<td>&lt;15</td>
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<td>Faecal streptococcus /100 ml</td>
<td>82</td>
<td>26000</td>
<td>9400000</td>
<td>990000</td>
<td>0</td>
<td>20</td>
<td>&lt;9</td>
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<tr>
<td>Clostridium Perfringens /100 ml</td>
<td>74</td>
<td>100</td>
<td>1800000</td>
<td>125000</td>
<td>0</td>
<td>90</td>
<td>&lt;12</td>
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<tr>
<td>Salmonella /10 litres</td>
<td>74</td>
<td>0</td>
<td>1800</td>
<td>52</td>
<td>0</td>
<td>&lt;1</td>
<td>&lt;0.14</td>
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<tr>
<td>Enterovirus /10 litres</td>
<td>74</td>
<td>200</td>
<td>360000</td>
<td>1840</td>
<td>&lt;1</td>
<td>18</td>
<td>&lt;1.5</td>
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<td>F+ coliphage /100 ml</td>
<td>75</td>
<td>1 ?</td>
<td>4350000</td>
<td>154000</td>
<td>0</td>
<td>180</td>
<td>&lt;13</td>
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<tr>
<td>Suspended solids mg/litre</td>
<td>83</td>
<td>20</td>
<td>1030</td>
<td>249</td>
<td>&lt;1</td>
<td>23 ?</td>
<td>&lt;5</td>
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<tr>
<td>Turbidity NTU</td>
<td>32</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.07</td>
<td>1.5</td>
<td>0.23</td>
</tr>
<tr>
<td>BOD₅ mgO₂/litre</td>
<td>35</td>
<td>26</td>
<td>640</td>
<td>290</td>
<td>&lt;2</td>
<td>&lt;8</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

June 1998 – September 2001
Industrial Waste Water

Project Overview

- Enhanced Flow Balancing / Equalisation
- Phosphorus Reduction
- Organic Carbon Reduction (COD/BOD)
- Colour Reduction
- Sludge Treatment
- Blending of Flows
- Process Monitoring
- Control Systems
Industrial Waste Water

- Design Build Project
- Flow rate 600-800 m³/day
- Cod 1200 mg/l
- TP 40mg/l
- Ph 2-12
Industrial Waste Water

Discharge Standard

- Cod 75
- TP 16
- Colour 150 ptCo
- BOD 15
- TN 2
- pH 7.5
Operational Issues

- Varying Flows/loads
- Varying incoming pH (1.5-13.5)
- Varying incoming temp °C (ambient - 85)
- COD range 2500-3500
- Flow 600-800M3/d
EPS Bison Clereflo MBR.
The Packaged Membrane Solution.
Background

2003 EPS Bison Experiencing

- More Stringent Discharge requirements
- Unique Developments in Sensitive areas
- Enhanced implementation of Phos. Regs
- Enhanced implementation of Nitrate Dir
- Local Authorities increased focus on Discharge Licences
- Need for 5:5:5:1 (BOD:SS:NH3:TP)
- Identified MBR Tech
- Developed For Irish market with Conder Products
To develop a process to satisfy EPS Bison client base (residential, hotels, caravan parks)

- Standardised design
- Off the shelf product range
- Domestic/Commercial wastewater only
- No screen/ solids removed by primary settlement
- Maximum acceptable flux of $<0.4 \text{ m}^3/\text{m}^2/\text{d}$
- Quick turnaround
- Low cost design
Design Philosophy

- Standardised plant items
- Only Standby items where essential
- Minimal instrumentation
- Minimal automatic control
- Low specification control panel
- Minimal maintenance requirements
Design Philosophy

- The Clereflo does not have the following as standard but additional requirements can include
  - Inlet Screening
  - Additional Control requirements
  - Monitoring requirements (instrumentation, telemetry)
  - Access
  - UV Disinfection
  - Remote Monitoring
  - Anoxic Stage
Design Philosophy

Standardised Plant Items

- 75 panel full-height membrane unit
- Standard GRP tank diameters
- One bucket lift elevator (BLE) size across range
- Forward Feed Pumping Option
Design Philosophy

Permeate Quality

• 5 mg/l BOD
• 5 mg/l SS
• 5 mg/l NH3 (Potentially lower)
• Disinfection
• Phosphorus reduction - with chemical addition
• Nitrate & Total Nitrogen Reduction
Product Range

- 5:5:5:1: (BOD:SS:NH3:TP)
- 125 pe
- 250pe
- 375 pe
- 500 pe
- 750 pe
- 1000pe

- 2006 - Developed Anoxic Range
- Sites > 1000pe cast in situ concrete
EPS Bison MBR Projects

- Killerig 250pe
- Stamullen 375pe
- Rolestown 375pe
- Dunboy Castle 375pe phase 1 / 250pe phase 2
- Delphi Adven. Centre 500pe phase 1/500pe 2
- Carlton House 500pe Phase 1 / 250pe Phase 2
- Ballyfin House 250pe
- Inchigeelaga 125pe
- Lispole 375pe
- Knackery <2m3/day * 2 sites
Enquiry Requirements

Preliminary Considerations

• Occupancy/shutdowns
• Anticipated future flows and loads
• Disinfectant and chemical usage
• On-site laundries
• Variable water usage
• Use of waste disposal units
• Grease/Fat trap requirement
WHAT CAN GO WRONG

Failure to achieve flow rate

- Plant too small
- Wrong / incorrect flow rates given / used
- Membrane fouling – operation
- Membrane fouling – nature of effluent

Failure to achieve consent

- Plant too small
- Wrong / incorrect loadings given / used
- Operation – Blower failure, Too high MLSS
- Alkalinity > seven times Ammonia for removal
Case Studies

- Killerig
- Rolestown
- Stamullen
Killerig

- Housing Development (Holiday Homes)
- Commissioned Nov 2005
- 250 pe
- Standard Required (5:5:5:50:2)
  (BOD/SS/NH3/COD/TP)
- Standard Achieved (<1.5:<5:<1.5:17:0.7)
- Running Costs / Year (€)
  ESB 6000 / Chemicals 500 / Desludge 6000 / Operate 5600 / Membrane Replacement (10yr) 1200

Total Cost €19,300
Rolestown

- Hotel Development
- Commissioned Feb 07
- 375pe C/w anoxic and UV
- Standard Required (5:5:5:1:5)
  (BOD/SS/NH3/TP/NO3)
- Standard Achieved (<2:<5:<.5:0.6:3.5)
- Running Costs /year (€)
  ESB 9500 / Chemicals 500 / Operate 16900
  Desludge 15000 / Membrane Replacement (10yr) 1800

Total Cost €43,700
Stamullen

- Hotel Development
- Commissioned Nov 06
- 375pe C/w Anoxic
- Standard Required (5:5:5:50:1:5)
  (BOD/SS/NH3/COD/TP/NO3)
- Standard Achieved (<1.7:<5:0.17:22:0.5:<5)
- Running Costs / year (euro)
  ESB 8400 / Chemicals 500 / Operate 24000
  Desludge 15000 / Membrane Replacement (10yr) 1800

Total Cost €49,700
Operation and Maintenance

• To Maintain Permeate Quality
• To Maintain Permeate Flow rate

• Planned Maintenance/Servicing

• Planned maintenance will coincide with either chemical clean or desludge

• Desludge – approx 3 months
• Chemical clean – approx 6 months
O&M Overview

Maintaining Permeate Quality

Two Factors influence permeate quality

• Integrity of membrane panels and permeate pipework

• Biological removal of organic and nutrient pollutants
O&M Overview

Maintaining Permeate Flowrate

Six factors that influence permeate flow rate

- Differential Pressure
- Temperature
- Aeration
- Foulants
- MLSS concentration
- Inter-clogging between membranes
O&M Overview

Typical MBR WwTW Requirements

- Daily automatic sludge-flush of air diffusers (30-60s)
- Daily automatic ‘membrane relaxation’ procedure (30 mins)
- Regular automatic sludge removal
- Site visit once a month
- Two in-situ yearly chemical cleans with either dilute hypo or acid
O&M Overview

Chemical Clean Procedure

- In-situ, semi-automatic procedure
- Requires one operator
- Organic foulants removed with 0.5% NaOCl
- Inorganic precipitants removed with dilute acid
- Spent cleaning solution diluted within the MBR tank
## Cost Comparison Conventional A.S vs. MBR

<table>
<thead>
<tr>
<th>Cost</th>
<th>Conventional 250pe</th>
<th>Conventional 375pe</th>
<th>MBR 250pe</th>
<th>MBR 375pe</th>
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</thead>
<tbody>
<tr>
<td>Capital ( euro net )</td>
<td>160,000</td>
<td>200,000</td>
<td>120,000</td>
<td>220,000</td>
</tr>
<tr>
<td>Mech/Elec only</td>
<td>120,000</td>
<td>146,700</td>
<td>220,000</td>
<td></td>
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<tr>
<td>Chemicals</td>
<td>400</td>
<td>500</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Power</td>
<td>5,200</td>
<td>7,200</td>
<td>6,000</td>
<td>8,400</td>
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<tr>
<td>Desludge</td>
<td>15,960</td>
<td>24,000</td>
<td>13,500</td>
<td>20,000</td>
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<tr>
<td>Labour</td>
<td>5,600</td>
<td>24,000</td>
<td>5,600</td>
<td>24,000</td>
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<tr>
<td>Replacement costs</td>
<td>n/a</td>
<td>n/a</td>
<td>1200</td>
<td>1800</td>
</tr>
<tr>
<td>Total Yr 1</td>
<td>187,160</td>
<td>255,700</td>
<td>146,700</td>
<td>274,700</td>
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<tr>
<td>Total Capital</td>
<td>160,000</td>
<td>200,000</td>
<td>120,000</td>
<td>220,000</td>
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<tr>
<td>Total Operate</td>
<td>27,160</td>
<td>55,700</td>
<td>27,000</td>
<td>54,700</td>
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<td>Disinfection (power/replacement)</td>
<td>4000</td>
<td>6000</td>
<td>n/a</td>
<td>n/a</td>
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<td>Discharge Standard</td>
<td>10:10:5:1</td>
<td></td>
<td>5:5:5:1</td>
<td></td>
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</tbody>
</table>
Membrane Bioreactor Technology

Membrane costs

Membrane cost $ per m²

Year

1991 1993 1995 1997 1999 2001 2003 2005

(Kubota)
Consistent high quality disinfected effluent

Compact, low maintenance, robust

Membrane replacement costs continue to decrease

Lower sludge production & concentrated sludge leading to lower transportation costs

The MBR solution is not the option for all sites
Conclusions

Viable option where:

- Low peak to average flow ratio
- Very tight discharge standards
- Space restrictions
- Re-Use Requirement

EU - Wide Standardisation of Membranes

Enhanced Capital Allowance Scheme (25% / yr on a reducing balance for 10yrs/ re-use 30% treated effluent)
References

- www.epsireland.com
- www.mbr-network.eu
- Survey of European MBR Market, Trends & Perspectives
- Towards Standardisation of MBR Technology
- COPA MBR Tech
- Conder Environmental
Q & A