Innovative technology for cost-effective, energy efficient, sustainable and profitable wastewater treatment

andrew.thompson@rhdhv.com
Wastewater treatment with Nereda®

- Natural way of treating wastewater using aerobic granular sludge with excellent settling properties

Flocs
4 g/l
$SVI_5 > SVI_{30}$

Granules
8 g/l or more
$SVI_5 \approx SVI_{30}$
Aerobic Granular Biomass

Activated Sludge

- Excellent settling properties
- Pure biomass
- No support media
- High MLSS levels (up to 15 g/L)
- Reliable and stable operation
- No bulking sludge

Aerobic Granules
Three important selection mechanisms

- Hydraulic selection for fast settling particles
- Biotech selection of EPS forming microorganisms
  - like phosphate or glycogen accumulating organisms (PAO / GAO’s)
- Suppression of filamentous growth
**Oxygen gradient in granule**

**Anaerobic zone:**
- Nitrate reduction to nitrogen gas
- Phosphate removal

\[ \text{COD} + \text{NO}_x + \text{PO}_4^{3-} \rightarrow \text{N}_2 + \text{CO}_2 + \text{H}_2\text{O} + \text{poly-P} \]

**Aerobic zone:**
- Biological oxidation
- Ammonium oxidation to nitrate

\[ \text{COD} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

\[ \text{NH}_4 + \text{O}_2 \rightarrow \text{NO}_x \]

Heterotrophic organisms

Ammonium oxidising organisms

*Transport by diffusion, not by pumping*
Microorganisms in the granule

Activated sludge

Aerobic granular sludge

- Nitrifiers
- Denitrifiers
- Phosphate Accumulating Organisms (PAO’s)
- Glycogen Accumulating Organisms (GAO’s)
Nereda® compared with conventional

- Biological nutrient removal in activated sludge requires many compartments and circulation flows
Nereda® compared with conventional

- Biological nutrient removal in activated sludge requires many compartments and circulation flows.

C2 - Nitrogen and phosphorus removal in UCT configuration

- Raw sewage
- Influent
- Aeration
- "r"-recycle
- "a"-recycle
- Mixed liquor
- Final Settler
- Effluent
- Biogas
- Sludge Digester
- Digested sludge
- Supernatant
- Return sludge
- Excess sludge (Secondary sludge)
- Thickened excess sludge
High process robustness

- Continuous suppression of filamentous growth
- Robust during less favourable conditions, like:
  - salt fluctuations
  - chemical spikes
  - pH fluctuations
  - T fluctuations
  - load variations

Activated sludge and granular sludge with shock addition of 5,000 ppm NaCl after 5 min settling
Nereda® process cycle

- Simple one-tank concept
- No clarifiers
- No moving decanter
- No mixers
- Extensive biological COD, N- and P-removal
- Low energy consumption
- Easy operation
- Low totex
Key advantages of Nereda®

- Small footprint
- Sustainable & energy efficient
- Cost-effective
- Easy to operate
- Flexible & future proof

footprint

energy

costs

CAS   Nereda®   CAS   Nereda®   CAS   Nereda®

A product of Royal HaskoningDHV
## Typical effluent quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Consent type</th>
<th>Nereda only</th>
<th>+Tertiary solids removal</th>
<th>+top-up chemical dosing</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>95%ile, grab</td>
<td>&lt; 12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>95%ile, grab</td>
<td>&lt; 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>95%ile, grab</td>
<td>&lt; 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TN</td>
<td>Annual average, composite</td>
<td>&lt; 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP</td>
<td>Annual average, composite</td>
<td>&lt; 1.0</td>
<td></td>
<td>&lt; 0.5</td>
</tr>
</tbody>
</table>
History

It all started with a good discussion and collaboration between two professors at an October Fest.

Prof. Peter Wilderer
TU Munich

Prof. Mark van Loosdrecht
TU Delft
History

1995 Stable granulation in lab

2000 close co-operation DUT / DHV

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2002 Feasibility study showed great potential

2002 Stable granulation, extensive N- en P-removal in DUT lab

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1995 Stable granulation in lab

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2002 Feasibility study showed great potential

2003 – 2005 Large pilot-research at Ede STP

2005 Start-up industrial launching customer

2006 Industrial units
History

- Mid ‘90’s Research by Delft University of Technology (DUT)
- 1995 Stable granulation in lab
- 2000 close co-operation DUT / DHV
- 2002 Stable granulation, extensive N- en P-removal in DUT lab
- 2002 Feasibility study showed great potential
- 2003 – 2005 Large pilot-research at Ede STP
- 2005 Start-up industrial launching customer
- 2006 Industrial units
- 2006 / 2008 Design/construction municipal demo units
- 2010 construction first Dutch full scale municipal plant

Nereda®
A product of Royal HaskoningDHV
Global Nereda® roll-out

- Operational plants
- Plants under construction
- Pilots
- Partners

United Kingdom & Ireland

The Netherlands

Nereda®
## Operational plants

<table>
<thead>
<tr>
<th>Operational plants</th>
<th>Daily average flow (m³/day)</th>
<th>Peak flow (m³/h)</th>
<th>Person Equivalent (Calculated for p.e. a 54 g. BOD)</th>
<th>Start-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vika, Ede (NL)</td>
<td>50-250</td>
<td>1,500-5,000</td>
<td>2005</td>
<td></td>
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<tr>
<td>Cargill, Rotterdam (NL)</td>
<td>700</td>
<td>10,000-30,000</td>
<td>2006</td>
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<tr>
<td>Fano Fine Foods, Oldenzaal (NL)</td>
<td>360</td>
<td>5,000-10,000</td>
<td>2006</td>
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<tr>
<td>Smilde, Oosterwolde (NL)</td>
<td>500</td>
<td>5,000</td>
<td>2009</td>
<td></td>
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<tr>
<td>STP Gansbaai (RSA)</td>
<td>5,000</td>
<td>63,000</td>
<td>2009</td>
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<tr>
<td>STP Epe (NL)</td>
<td>8,000</td>
<td>54,000</td>
<td>2011</td>
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<td>140,000</td>
<td>2013</td>
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<tr>
<td>STP Vroomshoop (NL)</td>
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<td>12,000</td>
<td>2013</td>
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<tr>
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<td>3,100</td>
<td>11,111</td>
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<tr>
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<tr>
<td>STP Frielas, Lisbon (PT)</td>
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<tr>
<td>STP Ryki (PL)</td>
<td>5,300</td>
<td>42,889</td>
<td>2015</td>
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<td>Westfort Meatproducts, IJsselstein (NL)</td>
<td>1,400</td>
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<tr>
<td>STP Clonakilty (IRL)</td>
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<td>STP Deodoro, Rio de Janeiro (BR)</td>
<td>86,400</td>
<td>480,000</td>
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<td>STP Dinxperlo (NL)</td>
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<td>11,111</td>
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<td>STP Wemmershoek (RSA)</td>
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<td>STP Friesland, Lisbon (PT)</td>
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<td>41,204</td>
<td>2015</td>
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<td>STP Deodoro, Rio de Janeiro (BR)</td>
<td>86,400</td>
<td>480,000</td>
<td>2016</td>
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<tr>
<td>Plants under construction</td>
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<td></td>
<td></td>
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<tr>
<td>STP Jardim Novo, Rio Claro (BR)</td>
<td>23,500</td>
<td>152,315</td>
<td>2016</td>
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<tr>
<td>STP Hartebeestfontein (RSA)</td>
<td>5,000</td>
<td>52,185</td>
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<td>STP Kingaroy (AUS)</td>
<td>450</td>
<td>11,000</td>
<td>2016</td>
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<tr>
<td>STP Ringsend SBR Retrofit 1 Cell, Dublin (IRL)</td>
<td>82,000</td>
<td>94,000</td>
<td>2016</td>
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<tr>
<td>STP Highworth (UK)</td>
<td>675</td>
<td>23,278</td>
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<tr>
<td>STP Cork Lower Harbour (IRL)</td>
<td>18,280</td>
<td>65,000</td>
<td>2016</td>
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<tr>
<td>STP Selmelveld (NL)</td>
<td>3,668</td>
<td>11,880</td>
<td>2016</td>
<td></td>
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<tr>
<td>STP Ringsend Capacity Upgrade, Dublin (IRL) part of the upgrade project to 2,4 million p.e.</td>
<td>117,000</td>
<td>400,000</td>
<td>2019</td>
<td></td>
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<tr>
<td>Plants under design</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>STP Alpnach (CH)</td>
<td>14,000</td>
<td>49,000</td>
<td>2017</td>
<td></td>
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<tr>
<td>STP Österröd, Strömstad (S)</td>
<td>3,730</td>
<td>10,400</td>
<td>2017</td>
<td></td>
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<tr>
<td>STP Tatu, Limeira (BR)</td>
<td>57,024</td>
<td>517,000</td>
<td>2016</td>
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<tr>
<td>STP São Lourenço, Recife (BR)</td>
<td>19,093 (1st fase); 25,123 (2nd fase)</td>
<td>139,574</td>
<td>2016</td>
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<tr>
<td>STP Jaboatão, Recife (BR)</td>
<td>109,683 (1st fase); 154,483 (2nd fase)</td>
<td>858,333</td>
<td>2024</td>
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<tr>
<td>STP Jardim São Paulo, Recife (BR)</td>
<td>19,529 (1st fase); 78,117 (2nd fase)</td>
<td>325,315</td>
<td>2025</td>
<td></td>
</tr>
<tr>
<td>STP Utrecht (NL)</td>
<td>55,000</td>
<td>430,000</td>
<td>2018</td>
<td></td>
</tr>
<tr>
<td>STP Faro – Olhão (PT)</td>
<td>28,149</td>
<td>113,200</td>
<td>2018</td>
<td></td>
</tr>
</tbody>
</table>
Current status of Nereda®
**UK Status - Pilots**

- Number of Pilot studies completed:
  - Crewe, Davyhulme (United Utilities)
  - Daldowie, Dalmarnock (Scottish Water)

- Two pilot studies starting up:
  - Newmarket (Anglian Water)
  - Macclesfield (United Utilities)

- Extensive interest from water companies across UK
  - Scottish, UU, Severn Trent, Anglian, Welsh, Thames, Wessex, Yorkshire
Pilots – proof of technology

- Extensive trials by United Utilities and Scottish
  - Pushed to extremes (temperature and load variation)

Scottish Water: “During the time spent below 5°C the effluent ammonia was below 1mg/l and soluble reactive phosphorus remained below 0.2mg/l”

- Pilot plant phosphorus studies – “how low can we go…?”
  - Newmarket (Anglian Water)
  - Macclesfield (United Utilities)
UK Status – Design/Construction

- Demonstration Plant – Thames Water
  - Highworth 10,000 PE Commission January 2017

- Full scale plants in Detailed Design
  - Inverurie Scottish 30,000 PE 20 mg/l ammonia, 2 mg/l TP
  - Kendal UU 93,000 PE 5 mg/l ammonia, 0.8 mg/l TP
  - Barston Severn Trent 76,000 PE 1 mg/l ammonia, 0.14 mg/l TP

- Contract negotiation
  - ~5 more plants expected to be awarded within 2016
Aerobic granular biomass technology

Applications
Nereda system configurations

1. GREENFIELD (3 REACTORS)

influent → influent

2. GREENFIELD (2 REACTORS + BUFFER)

influent → B → effluent

3. HYBRID EXTENSION

influent → excess sludge → effluent

4. RETROFIT CAS OR SBR

influent → Nereda® → effluent
Nereda® Ringsend
Ireland, 2016

- **Client:** Irish Water
- **Wastewater type:** Municipal
- **Capacity Upgrade:** 400,000 pe
- **SBR Retrofit:** 2,000,000 pe
- **Total:** 2,400,000 pe
## Retrofit SBR: Ringsend STP, Ireland

Significantly more biological treatment capacity by retrofit existing SBR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current SBR’s</th>
<th>Retrofitted SBR’s into Nereda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (PE)</td>
<td>1,700,000</td>
<td>1,950,000</td>
</tr>
<tr>
<td>MLSS (g/l)</td>
<td>2.5</td>
<td>8</td>
</tr>
<tr>
<td>NTotal (annual average)</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>TSS (annual average)</td>
<td>35</td>
<td>10-15</td>
</tr>
<tr>
<td>Bio-P</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>
Nereda® Epe
The Netherlands, 2011

- **Client**: Water Board Veluwe
- **Wastewater type**: Municipal & Industrial
- **Capacity**: 8,000 m³/day (59,000 p.e. inclusive 13,750 p.e. from industrial discharges)
- **Peak flow**: 1,500 m³/hour
- **Pre-treatment**: screening, sand trap and oil & grease removal (to cope with slaughterhouse emissions)
- **Post-treatment**: sand filtration
Epe STP

Replacement existing STP by Nereda

- On-line: Q3 2011
- 59,000 p.e. including 13,750 from slaughterhouses

<table>
<thead>
<tr>
<th></th>
<th>Limit</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{tot}$ ppm N</td>
<td>&lt; 8</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>$P_{tot}$ ppm P</td>
<td>&lt; 0.3</td>
<td>&lt; 0.2</td>
</tr>
</tbody>
</table>
Epe power consumption

<table>
<thead>
<tr>
<th>Period</th>
<th>Energy consumption per removed pollution equivalents (of 150 g Total Oxygen Demand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guaranteed value</td>
<td>≤ 22.7 kWh/(PE.annum) @ full load</td>
</tr>
<tr>
<td>Actual</td>
<td>16.3 kWh/(PE.annum) @ full load</td>
</tr>
<tr>
<td></td>
<td>22.2 kWh/(PE.annum) @ actual load</td>
</tr>
<tr>
<td>Bench mark similar Dutch treatment plants with post treatment (Union of Dutch Water Boards 2009)</td>
<td>37.5 kWh/(PE.annum) @ actual load</td>
</tr>
<tr>
<td>Bench mark all STP’s (Union of Dutch Water Boards, 2009)</td>
<td>33.4 kWh/(PE.annum) @ actual load</td>
</tr>
</tbody>
</table>

Energy consumption: 40% less than other Dutch STP’s with polishing filter while 2 m additional water head was incorporate to enable retrofit to conventional CAS
Profitable wastewater treatment
Opportunities – Power/Biogas

- Power self sufficiency
  - Reduce power demand
    - 30-50% reduction by using Nereda

- Combine with advanced digestion
  - THP, EEH, HPH, Ephyra®
  - Increased biogas production

- Options for profitability
  - CHP for power production
    - Less power needed for Nereda, less biogas needed for CHP
  - Gas clean-up and injection to gas network
    - More gas available, more profitable
Energy balance (worked example – 59,000PE)

- Power consumption
  - Inlet works (Pumping, screens, FOGG)
  - Nereda
  - Sand filter, top-up chemical dosing
  - Sludge thickening
    - Power usage: 22.2 kWh / PE.annum

- Power production
  - Sludge production 80g/PE/d (crude, bio-P, yield 1.15)
    - 29.2 kg/PE.annum
  - Typical THP: 0.98 MWH/tds (typical: 0.9-1.1 MWH/tds gross)
    - Allow 15% for advanced digestion power requirements
  - Power production: 24.3 kWh / PE.annum

- Produce 110% of required power
  - Settled sewage could be even better…

(ref: Epe WWTP, 59,000 PE)
Opportunity - Biorefinery

- Bio-P sludge – phosphorus recovery
  - Struvite or similar

- Biopolymer from waste granules
  - Granules contain 15-25% of structural gel, mainly alginate like polysaccharides

- Easy to harvest
- High market value
- Recover biopolymer and upgrade into non-food applications
- First commercial installation in construction (Holland)
Contact

- www.nereda.net
- nereda@rhdv.com