NEREDA®

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

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

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

\[ \text{COD} + O_2 \rightarrow \text{CO}_2 + H_2O \]
\[ \text{NH}_4 + O_2 \rightarrow \text{NO}_x \]

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

\[ \text{COD} + \text{NO}_x + \text{PO}_4^{3-} \rightarrow \text{N}_2 + \text{CO}_2 + H_2O + \text{poly-P} \]

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.
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

<table>
<thead>
<tr>
<th>CAS</th>
<th>Nereda®</th>
</tr>
</thead>
</table>

energy

<table>
<thead>
<tr>
<th>CAS</th>
<th>Nereda®</th>
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</thead>
</table>

costs

<table>
<thead>
<tr>
<th>CAS</th>
<th>Nereda®</th>
</tr>
</thead>
</table>
## 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>&lt; 6</td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>95%ile, grab</td>
<td>&lt; 15</td>
<td>&lt; 5</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>95%ile, grab</td>
<td>&lt; 1</td>
<td>&lt; 5</td>
<td></td>
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<tr>
<td>TN</td>
<td>Annual average, composite</td>
<td>&lt; 5</td>
<td>&lt; 0.5</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>TP</td>
<td>Annual average, composite</td>
<td>&lt; 1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
History

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

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

1995 Stable granulation in lab

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2005 Start-up industrial launching customer

2006 Industrial units

start Municipal National Nereda Research

2006 / 2008 Design/construction municipal demo units

2010 construction first Dutch full scale municipal plant
Global Nereda® roll-out

- Operational plants
- Plants under construction
- Pilots
- Partners
### 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>
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</thead>
<tbody>
<tr>
<td>Vika, Ede (NL)</td>
<td>50-250</td>
<td>1,500-5,000</td>
<td>2005</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>
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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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<td>STP Epe (NL)</td>
<td>8,000</td>
<td>54,000</td>
<td>2011</td>
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<td>STP Garmerwolde (NL)</td>
<td>30,000</td>
<td>140,000</td>
<td>2013</td>
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<td>STP Vroomshoop (NL)</td>
<td>1,500</td>
<td>12,000</td>
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<td></td>
</tr>
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<td>3,100</td>
<td>11,111</td>
<td>2013</td>
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<td>39,000</td>
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<td>44,444</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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<tr>
<td>Westfort Meatproducts, IJsselstein (NL)</td>
<td>1,400</td>
<td>43,000</td>
<td>2015</td>
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<tr>
<td>STP Clonakilty (IRL)</td>
<td>4,896</td>
<td>23,278</td>
<td>2015</td>
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<tr>
<td>STP Carrigtwohill (IRL)</td>
<td>6,750</td>
<td>41,204</td>
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<td>86,400</td>
<td>480,000</td>
<td></td>
<td>2016</td>
</tr>
<tr>
<td>Plants under construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STP Jardim Novo, Rio Claro (BR)</td>
<td>23,500</td>
<td>152,315</td>
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<td>2016</td>
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<tr>
<td>STP Hartbeestfontein (RSA)</td>
<td>5,000</td>
<td>52,185</td>
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<td>2016</td>
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<tr>
<td>STP Kingaroy (AUS)</td>
<td>2,700</td>
<td>11,000</td>
<td></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>
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<td>2016</td>
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<tr>
<td>STP Highworth (UK)</td>
<td>10,111</td>
<td></td>
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<tr>
<td>STP Cork Lower Harbour (IRL)</td>
<td>18,280</td>
<td>65,000</td>
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<td>2016</td>
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<tr>
<td>STP Sintelpeld (NL)</td>
<td>3,668</td>
<td>11,880</td>
<td></td>
<td>2016</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></td>
<td>2019</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></td>
<td>2017</td>
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<tr>
<td>STP Österröd, Strömstad (S)</td>
<td>3,730</td>
<td>10,400</td>
<td></td>
<td>2016</td>
</tr>
<tr>
<td>STP Tatu, Limeira (BR)</td>
<td>57,024</td>
<td>517,000</td>
<td></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>
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<td>2016</td>
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<tr>
<td>STP Jabotão, Recife (BR)</td>
<td>109,683 (1st fase); 154,483 (2nd fase)</td>
<td>858,333</td>
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<td>2017</td>
</tr>
<tr>
<td>STP Jardim São Paulo, Recife (BR)</td>
<td>19,529 (1st fase); 78,117 (2nd fase)</td>
<td>325,315</td>
<td></td>
<td>2017</td>
</tr>
<tr>
<td>STP Utrecht (NL)</td>
<td>55,000</td>
<td>430,000</td>
<td></td>
<td>2018</td>
</tr>
<tr>
<td>STP Faro – Olhão (PT)</td>
<td>28,149</td>
<td>113,200</td>
<td></td>
<td>2018</td>
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</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 (3Reactors)

influent → N → N → N → effluent

2. GREENFIELD (2Reactors + BUFFER)

influent → B → N → effluent

3. HYBRID EXTENSION

influent → CAS → SC → B → N → excess sludge → effluent

4. RETROFIT CAS OR SBR

influent → CAS → Nereda® → CAS → SC → 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 m$^3$/day (59,000 p.e. inclusive 13,750 p.e. from industrial discharges)
- **Peak flow:** 1,500 m$^3$/hour
- **Pre-treatment:** screening, sand trap and oil & grease removal (to cope with slaughterhouse emissions)
- **Post-treatment:** sand filtration
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_{\text{tot}} ) ( \text{ppm N} )</td>
<td>(&lt; 8)</td>
<td>(&lt; 5)</td>
</tr>
<tr>
<td>( P_{\text{tot}} ) ( \text{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 incorporated 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…
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@rhdhv.com