Experience from start-up and operation of ANITA™ Mox plants and development of a new Hybas™ ANITA™ Mox process

Nitrogen Removal Technologies

15th May Leeds

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Principle – **ANITA™ Mox**

1-stage Deammonification

-60% O$_2$

-100% COD

**Aerobic**

- Half Nitritation

AOB

55% O$_2$ (40%)

**Anoxic**

NH$_4^+$

45%

Aerobic

COD (0%)

NH$_4^+$

45%

Anammox

O$_2$

COD

N$_2$ + NO$_3^-$

89%

11%

Denitrification

COD

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ANITA™ Mox – MBBR process

- High sludge retention time (SRT) needed
- Necessity to protect anammox bacteria (O₂ / NO₂ → Biofilm
- Necessity to keep bacteria into the system (avoid washout)
- Maximum robustness and stability desired
ANITA™ Mox – Sjölunda WWTP, Malmö (Sweden)

4 x 50m³ = 200m³

- Sjölunda WWTP reject water
- Capacity = 200 kgN/d
- 800-1200 mgN-NH₄/L
- 1st ANITA™ Mox reference
- Flexibility for fullscale testing
ANITA™ Mox – Different Media tested

K3  
500 m²/m³

K5  
800 m²/m³

BiofilmChip M  
1200 m²/m³

MBBR = Media + Grid ➔ No risk of losing Anammox biomass
ANITA™ Mox – BioFarm concept

→ **BioFarm concept** = Providing seeded carriers for rapid start-up of future full-scale ANITA™ Mox units
\(1.1 \text{ kgN-NH}_4/\text{m}^3.\text{d}\) in 4 months with only 3% seeding
BioFarm – Performance

- 90% NH$_4$ removal and 80% TN removal
- Patented DO control strategy reduce NO$_3$ production <11%
- 1.4 – 1.7 kWh/kgN-NH$_4$ removed
ANITA™ Mox – Sundets WWTP, Växjö (Sweden)

- 350 kgN/d → 430 kgN/d reject water
- Existing 350m³ SBR → MBBR
- K5 carrier (AnoxKaldnes)
- Quick seeding (13% from BioFarm)
- Started in January 2012

3.5m depth
Fine bubble aeration
Växjö – N-load / NH₄-rem

- Treating all reject water after only 30 days (with 13% seeding)
- 0.4-0.5 kgN/m³.d → ½ design N-load expected → Co-digestion 2013
Växjö – Performance

90% NH₄ removal and 80% TN removal
DO control strategy reduce NO₃ production <11%
Växjö – N-load vs NH$_4$-removal

$y = 0.88x$

$R^2 = 0.97$

$\Rightarrow 88\% \text{ NH}_4 \text{ removal since start-up}$
ANITA™ Mox – Holbæk (DK)

- 120 kgN/d (reject water + leachate)
- Retrofitting 600m³ existing tank
- Quick seeding (BioFarm)
- Commissioning June 2012
Holbæk – Performance

- N-removal %
- % N-NH4
- % NO3-N produced to NH4-N removed
- Temperature

DO regulation “Off”

- 80% NH₄ removal even at 15° C
- Patented DO control strategy very efficient to keep NO₃ <11%
ANITA™ Mox – Grindsted, Denmark

50,000 tons/year to BioPasteur® digester:
- 45% of DS from wastewater sludge
- 35% of DS from organic household waste
- 20% of DS from organic industrial waste

- 110 kgN/d reject from co-digester
- 140 m³ (new tank)
- Quick Seeding (BioFarm)
- Start-up May 2013
ANITA™ Mox – James River WWTP, Newport News, VA US

• 250 kgN/d reject water
• Retrofit of existing tank
• Quick seeding (BioFarm)
• Start-up Q3 2013
• Existing Hybas™ system 60,200m³/d
ANITA™ Mox – South Durham, North Carolina US

- 333 kgN/d reject water
- Retrofit of existing tank
- Quick seeding (BioFarm)
- Start-up Q1 2014
- 3 years payback
- US based BioFarm
New Development – IFAS configuration

**MBBR**

- Liquid
- **NH\(_4^+\)**
- **NO\(_2^-\)**
- **N\(_2\)**
- Biofilm
- Media
- Anoxic
- **Aerobic**
- **Nitritation**
- **AOB**
- **Anammox**

**IFAS**

- Liquid
- **NH\(_4^+\)**
- **NO\(_2^-\)**
- **N\(_2\)**
- **AOB**
- Flocs (1-3 g/L)
- **Nitritation**
- **Anoxic**
- Biofilm
- Media

AOB in biofilm = NO\(_2^-\) limitation

AOB in flocs = less NO\(_2^-\) limitation

\[O_2 = 0.5-1.5 \text{ mg/L}\]
Bench-scale trial – IFAS and MBBR

**A  Influent**
- AD Sidestream
- $\text{NH}_4 = 900 \text{ mgN/L}$
- $\text{tCOD} = 400 \text{ mg/L}$
- $\text{BOD} = 30 \text{ mg/L}$
- $\text{tCOD/N} = 0.4$
- $\text{sbCOD/N} = 0.25$

**B  Conditions**
- $30 \, ^\circ\text{C}$
- 43 % K5 carrier
- Volume reactor = 7 L
- $\text{D.O. IFAS} = 0.2 \, \text{mg O}_2/\text{L}$
- $\text{D.O. MBBR} = 1.0 \, \text{mg O}_2/\text{L}$
Hybas™ ANITA™ Mox – Bench-scale

Stage I
- R1: MBBR
- R2: MBBR
(150mg/L NH₄-N)

Stage II
- R1: MBBR
- R2: IFAS
(150mg/L NH₄-N)

Stage III
- R1: MBBR
- R2: IFAS
(70mg/L NH₄-N)

Stage IV
- R1: MBBR
- R2: IFAS
(30mg/L NH₄-N)

Stage V
- R1: MBBR
- R2: IFAS
(10mg/L NH₄-N)
Stage I
- R1: MBBR
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→ Expected IFAS design = 2-3 kgN/m³.d (x2-x3 pure MBBR)
Higher NO₂ concentrations in IFAS
Higher N-removal rates with higher NO₂ concentrations
Optimum NO₂ level depends of hydrodynamics condition
Hybas™ ANITA™Mox – Bench-scale

- **qPCR**: Evolution (Anammox, AOB, NOB and total Bacteria)

**Suspended solids composition (MLSS)**

1. Stable SS composition in MBBR
2. Augmentation of Biomass in IFAS
3. Higher increase of AOB in IFAS (x1000!)
### Hybas™ ANITA™ Mox – Bench-scale

#### qPCR: Evolution (Anammox, AOB, NOB and total bacteria)

**Biomass repartition IFAS vs MBBR**

<table>
<thead>
<tr>
<th></th>
<th>Biofilm</th>
<th>MLSS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anammox</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode MBBR</td>
<td>99%</td>
<td>1%</td>
</tr>
<tr>
<td>Mode IFAS</td>
<td>96%</td>
<td>4%</td>
</tr>
</tbody>
</table>

|                |         |      |
| **AOB**        | 99%     | 1%   |
| Mode MBBR      | 99%     | 1%   |
| Mode IFAS      | 7%      | 93%  |

|                |         |      |
| **Total biomass** | 92%     | 8%   |
| Mode MBBR      | 92%     | 8%   |
| Mode IFAS      | 52%     | 48%  |

x 1 000 in IFAS
Hybas™ ANITA™ Mox – IFAS configuration

Hybas™ ANITA™ Mox = Higher N-removal with combination of carriers and suspended biomass
New Development – Mainstream N-removal

- ANITA™ Mox Pilot trial on BOD-treated WW:
  - After BOD AS (Sweden)
  - After UASB (Middle East)

- 3 different systems tested:
  - Pure MBBR
  - IFAS
  - Sequenced treatment of reject water and BOD-treated WW
ANITA™ Mox – Applications (MBBR & IFAS)

- **Municipal** :
  - **Sidestreams:**
    - Anaerobic Digested Sludge centrate validated
    - Thermal Hydrolysis* + AD centrate validated
  - **Mainstream:** *(IFAS = easy retro fit)*
    - Post anaerobic (UASB) under evaluation
    - Post high-rate BOD-stage under evaluation

- **Industrial** :
  - Landfill Leachates (old) validated
  - Post anaerobic from Bio-composting (COD/N=2) validated
  - Micro-electronic / Semi-cond validated
  - Other Post anaerobic effluent (slaughterhouse, F&B) under evaluation

* *(Biothelys™, Exelys™, Cambi™)*
ANITA™ Mox – Conclusion

- **Stable and robust**

- **Low OPEX + C-footprint :**
  - - 60% O_2 / no COD dosing / 1.4-1.7 kWh/kgN_{rem} / N_2O < 0.5%

- **Efficient aeration control**
  - Continuous aeration $\rightarrow$ no mixer / low N_2O
  - Keep NO_3 < 11% $\rightarrow$ no NOB (MBBR & IFAS)

- **N-removal performances :**
  - MBBR = >1 kgN_{rem}/m^3.d (Sidestream)
  - IFAS = 2-3 kgN_{rem}/m^3.d (Sidestream)

- **BioFarm seeding strategy = Quicker Start-up**

- **6 references :**
  - Malmö WWTP (Sweden) $\rightarrow$ 200 kgN/d reject water 2010
  - Växjö WWTP (Sweden) $\rightarrow$ 430 kgN/d reject water 2012
  - Holbæk WWTP (DK) $\rightarrow$ 120 kgN/d reject water + leachate 2012
  - Grindsted WWTP (DK) $\rightarrow$ 110 kgN/d co-dig. sludge + food waste May 2013
  - James River WWTP (USA) $\rightarrow$ 253 kgN/d reject water Aug 2013
  - South Durham WWTP (USA) $\rightarrow$ 333 kgN/d reject water late 2013
THANK YOU !!