ANITA Mox MBBR
Return on Experience from Start-up of Full Scale Systems and New Developments
European Biosolids Conference and Exhibition, 19-20 November 2013

Context – Sidestream impact on WWTP

- 1-2% of WWTP inlet flow
- 15-25% of N-load
- N-NH$_4$: 500-1500 mg/L
- BOD: < 150mg/L

- Impact mainstream design
- More O$_2$ required
- Lower C/N ratio (C addition?)
- Higher sludge production
Context – Dedicated Sidestream process

- Refuse
- Sand, grease

ANITA™ Mox

Cost- & Energy-efficient Sidestream treatment
Principle – ANITA™ Mox

1-stage Deammonification

-60% O₂

-100% COD

Aerobic

- O₂

Anoxic

Aerobic O₂ (40%)

½ Nitritation

AOB

NH₄⁺

55%

45%

NH₄⁺

Anammox

COD (0%)

N₂ + NO₃⁻

89%

11%

CO₂

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ANITA™ Mox – MBBR process

- High sludge retention time (SRT) needed
- Necessity to protect anammox bacteria (O$_2$ / NO$_2$) → Biofilm
- Necessity to keep bacteria into the system (avoid washout)
- Maximum robustness and stability desired
ANITA™ Mox – Anammox biomass security

MBBR = Media + Grid

⇒ **No risk** of loosing Anammox biomass

⇒ **No impact** of incoming TSS (flow-through)
Anita Mox treating Bio Thelys™ effluent: bench scale trials
Inhibitions and how to address them

Inhibitions from THP effluents
- Inert soluble COD causing immediate toxicity
- Biodegradable COD leading to competitive inhibition

Strategy applied-bench scale
- Reference reactor in parallel (conventional reject water)
- Dilution x4 for THP effluent
- Low initial N-load, careful increase (>1 HRT)

Research questions
- Stable N-removal?
- What type of inhibition?
- 4 times more soluble COD in diluted THP effluent
- 3.5 times more biodegradable soluble COD
- bsCOD/NH$_4$-N = 0.7 in THP against 0.12 in conventional reject water
Results-Bench Scale
30 days of steady increase in N-removal

Stable removal at 1.2gN/m².day (50% of reference reactor)

Cause of this lower removal, toxicity and/or competitive inhibition by heterotrophs?
Increasing heterotrophic activity relatively to autotrophs in test reactor
Results - Visual Analysis

- Dense orange deep layer
- Loose grey outer layer
- Thickening of the outer layer in both reactors, more important in R8

Day 22

Day 49

Day 66
Discussion - Bench Scale
Discussion - Identifying Inhibition

- Negligible physiological/bactericidal toxicity
  - Similar maximum Anammox activity in both reactors for more than 50 days (data not shown)
  - High N-removal efficiency in test reactor (>90%) during 30 days treating THP Bio Thelys™ effluent, indicating good AOB activity
  - Dilution and slow increase of flow rate were effective

- Competitive inhibition by heterotrophs
  - SCOD consumption occurred
    \[ \text{SCOD}_{\text{removed}} / \text{N}_{\text{removed}} < 0.2 \] in reference reactor
    \[ \text{SCOD}_{\text{removed}} / \text{N}_{\text{removed}} > 0.5 \] in test reactor
  - Denitrification occurred
    \[ \text{NO3prod/NH4rem} < 11\% \]
Discussion

Consequences of the high heterotrophic activity in test reactor

- Thick heterotrophic outer layer
  - Lower transport and diffusion of substrates

- Competition for nitrites and oxygen
  - Higher oxygen flux required
  - Lower Anammox activity
Conclusion

Operational performances:

- Anita Mox process applied to Bio Thelys™ effluent provided a stable Nitrogen removal (1.2gN/m².day)
- Lower rate compared to treatment of conventional reject water mainly due to competitive inhibition by heterotrophs
- Dilution and careful load increase prevent toxicity effects from Bio Thelys™ effluent

Recommendations

- BSCOD content should be reduced to a minimum
- Longer residence time in the digester
- High rate aerobic step prior to Anita Mox process
- Anita Mox operated in IFAS mode
BioFarm concept = Providing seeded carriers for rapid start-up of future full-scale ANITA™ Mox units

ANITA™ Mox – Sjölunda WWTP, Malmö (Sweden)

- 4 x 50m³ MBBR (4 x 13,000 gal)
- Capacity = 200 kgN/d – 440 lbN/d
- 800-1200 mgN-NH₄/L
- 1st ANITA™ Mox reference
- Flexibility for fullscale testing
BioFarm – Performance last 2 years

\[
y = 0.89x \\
R^2 = 0.95
\]

\[\text{Empty 85\% carriers for fullscale start-up}\]

\[\Rightarrow 89\% \text{ NH}_4 \text{ removal for the last 2 years}\]
\[\Rightarrow \text{Average } 0.9-1.3 \text{ kgN-NH}_4/\text{m}^3.\text{d}\]
ANITA™ Mox – Sundets WWTP, Växjö (Sweden)

- **350 kgN/d** (700 lb/d) → **430 kgN/d** (950 lb/d) reject water
- Existing **300m³ SBR** → **MBBR**
- **K5 carrier** (AnoxKaldnes)
- Quick seeding *(13% from BioFarm)*
- **Started** in January 2012
Treating all reject water after only 30 days (with 13% seeding)

0.4-0.5 kgN/m³.d → ½ design N-load → Co-digestion + THP 2014
Växjö – Nitrogen species in/out
Växjö – Performance

- 90% NH₄ removal and 80% TN removal
- DO control strategy reduce NO₃ production <11%
ANITA™ Mox – Holbæk (DK)

- 120 kgN/d – 260 lb-N/d (reject water + leachate)
- Retrofitting 600m³ existing tank
- Quick seeding (BioFarm)
- Commissioning June 2012
ANITA™ Mox – Grindsted (DK)

- 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 – 240 lb-N/d Reject Water from co-digester
- 140 m³ - 37,000 gal (new tank)
- Quick Seeding (BioFarm)
- Start-up July 2013
ANITA™Mox – James River WWTP, Newport News, VA US

• 250 kgN/d – 550 lb-N/d (reject water)
• Retrofit of existing tank
• Quick seeding (BioFarm)
• Start-up Oct 2013
• Existing Hybas™ system 60,200 m³/d (16 MGD)
ANITA™ Mox – South Durham, North Carolina US

- 330 kgN/d – 730 lb-N/d (reject water)
- Retrofit of existing tank
- Quick seeding (BioFarm)
- Start-up Q2 2014
- US based BioFarm
**New Development – IFAS configuration**

**MBBR**
- Liquid
- Nitritation $\text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{AOB}$
- Anammox $\text{N}_2$
- Biofilm

**IFAS**
- Flocs (1-3 g/L)
- Nitritation $\text{NH}_4^+ \rightarrow \text{AOB} \rightarrow \text{NO}_2^-$
- Anoxic $\text{N}_2$
- Biofilm
- Media
- Anoxic

**AOB in biofilm = NO}_2^- \text{ limitation**

**AOB in flocs = less NO}_2^- \text{ limitation**
IFAS ANITA™ Mox – Full-scale
Higher NH₄ removal after switch to IFAS (x2-3 MBBR)
IFAS ANITA™ Mox – Full-scale Results (2)

- NH₄ load & removal (kgN/m³.d)
  - NH₄-load
  - NH₄-removal

- SVI (mL/g)
- TSSin & MLSS (mg/L)
- Days

- MBBR ➔ TSS = 2-7 g/L (depending incoming TSS)
- ➔ Good sludge quality (SVI 60-110)

MLSS (mg/L)
TSSin (mg/L)
SVI (mL/g)
Bench-scale trial – IFAS different C/N ratios

4 parallel IFAS reactors

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

B 4 Pilot/Conditions
- 30 °C
- 43 % K5 carrier
- Volume reactor = 7 L
- D.O. IFAS = 0.1- 0.2 mg O$_2$/L
- MLSS = 3g/L
- Regul out N-NH$_4$ = 50 mg/L
- 1) $\text{bCOD/N}=0,05$ (ref)
- 2) $\text{bCOD/N} = 0,5$
- 3) $\text{bCOD/N} = 1,0$
- 4) $\text{bCOD/N}=1,5$
Bench-scale trial – IFAS different C/N ratio

Maximum anammox activity in batch trials

* ➞ Similar removal rates (7 g N/m².d) in batch trials after 50 days
* ➞ No heterotrophic growth in biofilm due to higher C/N ratio
ANITA™ Mox – Applications (MBBR & IFAS)

**Municipal:**

**Sidestreams:**
- Anaerobic Digested Sludge centrate validated
- Thermal Hydrolysis + AD centrate validated
- Different C/N ratio (IFAS) validated

**Mainstream:** *(IFAS = easy retro fit)*
- Post UASB + HRAS (high T°C) under evaluation
- Post Primary + HRAS (low T°C) under evaluation
- Post CEPT + MBBR-C (low T°C) 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) validated
## References

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<td>Sweden</td>
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<td>Municipal AD sidestream</td>
<td>MBBR</td>
<td>2010</td>
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<td>Sundets</td>
<td>Sweden</td>
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<td>Municipal AD sidestream (+ Co-dig. + THP in 2014)</td>
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<td>Holbaek</td>
<td>Denmark</td>
<td>120 kgN/d 260 lb-N/d</td>
<td>Municipal AD sidestream (+ leachate)</td>
<td>MBBR</td>
<td>2012</td>
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<td>Grindsted</td>
<td>Denmark</td>
<td>110 kgN/d 240 lb-N/d</td>
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<td>James River</td>
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<td>South Durham</td>
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<td>Mars Candy</td>
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<td>F&amp;B Industrial sidestream after AnMBR</td>
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<td>Starch</td>
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## ANITA™Mox – Pilot US

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<th>Size</th>
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<tr>
<td>Denver Metro</td>
<td>Municipal AD sidestream</td>
<td>MBBR</td>
<td>3.6m³ (950 gal)</td>
<td>2012 (completed)</td>
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<td>LA County</td>
<td>Municipal AD sidestream</td>
<td>MBBR IFAS</td>
<td>3.6m³ (950 gal)</td>
<td>2013 (on going)</td>
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<td>Cincinnati MSD</td>
<td>Landfill Leachate</td>
<td>MBBR IFAS</td>
<td>7L</td>
<td>2013 (on going)</td>
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ANITA™ Mox – Conclusion

- **Stable and robust**
  - Media + Grid → No risk to loose Anammox
  - Incoming TSS → Limited impact (flow-through syst.)

- **Low OPEX + C-footprint**:
  - - 60% O₂ / no COD dosing / 1.2-1.5 kWh/kgN_{rem}
  - N₂O emission: < 0.5% (MBBR) / < 1-1.5% (IFAS)

- **Efficient aeration control**
  - Continuous aeration → no mixer / no stop-start blower / low N₂O
  - Keep NO₃ < 11% → no NOB (MBBR & IFAS)

- **N-removal performances**:
  - MBBR = 1 kgN_{rem}/m³.d
  - IFAS = 2-3 kgN_{rem}/m³.d

- **BioFarm** seeding strategy = **Quick Start-up** (EU/US)

- 2 configurations: **MBBR or IFAS**
  - Choice based on project specificity → footprint, retrofit...