S.C.E.N.A. PROCESS FOR LOW ENERGY NITROGEN REMOVAL WITHOUT EXTERNAL CARBON SOURCE

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SMART-Plant partners

- 8 Research Organisations
- 11+1 Technology/Service Providers
- 6 Water utilities

Project Total Max Cost: €9,768,806.09
Max EU Contribution: €7,536,300.02
Max Swiss contribution: €536,365
Alto Trevigiano Servizi profile

**ALTO TREVIGIANO SERVIZI**

Water utility company

Municipalities: 53

Area: 1’375 km²

Citizens: 500’000

Staff units: 240
Outline

• Dynamic effect of the nutrients return from the sidestream sludge treatment;

• Upgrade of the existing sludge line for energy and sludge reduction;

• Short-cut Enhanced Nutrients Abatement (S.C.E.N.A) for the via-nitrite anaerobic supernatant treatment;

• Key Performances Indicators and Economical analyses;

• Ongoing activities: Environmental Technology Verification.
Carbonera WWTP (40,000 P.E.)

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**WATER LINE**

<table>
<thead>
<tr>
<th>N. LINES</th>
<th>TREATMENT</th>
<th>DIMENSIONAL DATA</th>
<th>CHARACTERISTICS AND FLOWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PUMPING STATION</td>
<td>131 m³</td>
<td>WASTE WATER IN FLOW 15,000 mc/d</td>
</tr>
<tr>
<td>2</td>
<td>SCREENING</td>
<td>FREE PASSAGE</td>
<td>OF 5 mm</td>
</tr>
<tr>
<td>2</td>
<td>SCREENING</td>
<td>120 m³</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PRIMARY CLARIFIER</td>
<td>1,600 m³</td>
<td>225 m³/d OF I° + II° SLUDGE OUTFLOW</td>
</tr>
<tr>
<td>4</td>
<td>PRIMARY CLARIFIER</td>
<td>452 m²</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>BIO-REACTOR</td>
<td>4,571 m³</td>
<td>400 m³/d OF II° SLUDGE PRODUCTION</td>
</tr>
<tr>
<td>1</td>
<td>BIO-REACTOR</td>
<td>207 m²</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>SECONDARY CLARIFIER</td>
<td>2,260 m³</td>
<td>600 m³/h OF SECONDARY SLUDGE RICIRCULATION</td>
</tr>
<tr>
<td>4</td>
<td>SECONDARY CLARIFIER</td>
<td>904 m²</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>DISINFECTION</td>
<td>180 m³</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TERTIARY FILTRATION</td>
<td>114 m²</td>
<td></td>
</tr>
</tbody>
</table>

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**DECEMBER 2017**

**DYNAMIC THICKENING**

**SECONDARY CLARIFICATION**

**ANAEROBIC DIGESTION**

**FINAL FILTRATION & DISINFECTION**

**BIOLOGICAL REACTOR (SCHREIBER PROCESS) + chemical P removal**

**PRIMARY CLARIFICATION**

**PUMPING & PRE-TREATMENTS**

**DEWATERING**
Conventional WWTP scheme

- Raw wastewater influent
- Preliminary Treatment
- Primary Sedimentation
- Primary Sludge
- Biological Reactor
- Secondary Sedimentation
- Secondary Sludge
- Anaerobic Supernatant TN >20%
- Anaerobic Digesters
- Biogas
- Disinfection
- Effluent
Characterization of supernatants - 2016

10h for dewatering operations (from 9:00 am to 7:00 pm)
21% of TN And supernatants
23% of TP And supernatants
Dynamic thickening

- Flowrate: around 20 m$^3$/h
- Around 40 m$^3$/d of mixed sludge concentration: 4.5-5.0%

Opposite valves V3/V4, controlled based on level sensors

- around 30 m$^3$/d fed to the anaerobic digestor;
- around 10 m$^3$/d fed to the fermentation unit;
Centrifuge

Flowrate: 8 – 10 m$^3$/h;

Anaerobic supernatant: 1000 – 1300 mgN/L

Currently, the peak of nitrogen loading (per hour) from the anaerobic supernatant represents up to 50% of the total nitrogen influent (per hour).

-50% ENERGY SAVING DEW.LINE

-15% SLUDGE DISPOSAL

+20% BIOGAS PRODUCTION

Energy consumption for sludge dewatering

Biogas production

Flowrate (m$^3$/d)

El. Energy (kWh/d)

Weeks

0 200 400 600 800

0 1 3 5 7 9 11 13 15 17 19 21 23 25

02/01/2018 01/02/2018 03/03/2018
Characterization of reject water - first results 2018

Carbonera Nitrogen flow with/without anaerobic supernatant

- 5h for dewatering operations (from 9:00 am to 2:00 pm)
- 5% of TN from DT Supernatants
- 5% of TP from DT Supernatants
- 50% of TN from AnD Supernatants
- 10% of TP from AnD Supernatants

5% of TN from DT Supernatants
5% of TP from DT Supernatants

Co-funded by the Horizon 2020 programme of the European Union
Integration of S.C.E.N.A. process in sidestream of AnD (Smartech 4a)
S.C.E.N.A. SBR cycle

1- Filling (5 min)
2- Anaerobic (60 min) Carbon source addition
3- Aerobic (180 - 200 min)
4- Anoxic (45 min) Carbon source addition
5- Settling (40 min)
6- Discharge (10 min)

Nitrogen & Phosphorus
Biological removal

VFAs

Co-funded by the Horizon 2020 programme of the European Union
A key issue: the carbon source

- **Phosphorus Accumulating Organism**
  - **Acetic Acid** (50% - 60%)
  - **Propionic Acid** (25% - 30%)
  - **Butyric Acid** (5% - 15%)
  - **Other SCFA**
  - **Glycogen Accumulating Organism**

- **Fermentation promotes production of acetate and propionate as primary by-products**

- **PHOSPHOROUS REMOVAL**
  - **CH₃COOH**
  - **CH₃CH₂COOH**
  - **CH₃CH₂CH₂COOH**
  - **CH₃CH₂CH₂…COOH**

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Implementation of the first full scale S.C.E.N.A. system

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume</th>
<th>Tank</th>
</tr>
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<tbody>
<tr>
<td>Storage/Equalization Supernatant</td>
<td>90 m³</td>
<td>Ex Storage of Liquid Waste</td>
</tr>
<tr>
<td>VIA NITRITE scSBR</td>
<td>70 m³</td>
<td>Ex Storage of Liquid Waste</td>
</tr>
<tr>
<td>Fermentation Unit</td>
<td>50 m³</td>
<td>External tank</td>
</tr>
<tr>
<td>VFAs Storage</td>
<td>20 m³</td>
<td>External tank</td>
</tr>
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</table>
START-UP NOVEMBER 2017

**FERMENTER**

**VFAs STORAGE**

**DYNAMIC THICKENER**

**SCREW-PRESS S/L SEPARATION**

**SUPERNATANT TREATING ON S.C.E.N.A. FULL - SCALE**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowrate [m3/d]</td>
<td>35 - 40</td>
</tr>
<tr>
<td>N load [kgN / d]</td>
<td>35 - 42</td>
</tr>
<tr>
<td>P load [Kg P / d]</td>
<td>1 - 2</td>
</tr>
</tbody>
</table>
S.C.E.N.A. efficiency

S.C.E.N.A. next targets:
✓ 5 kWh/kgNrem;
✓ 85% TN removed;
✓ 80% TP removed.
Suitable carbon source with low energy consumption

0.2 kWh/kgCOD_{VFA}
S.C.E.N.A. management: simple or not?

### SCREW PRESS

<table>
<thead>
<tr>
<th></th>
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<th>h</th>
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</thead>
<tbody>
<tr>
<td>START-UP</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>REGIME CONDITIONS</td>
<td>0.15</td>
<td></td>
</tr>
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</table>

### SBR

<table>
<thead>
<tr>
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<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>START-UP</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>REGIME CONDITIONS</td>
<td>0.15</td>
<td></td>
</tr>
</tbody>
</table>

**NOW**

15' - 30' min/day at regime conditions
S.C.E.N.A. OPEX after 4 months

<table>
<thead>
<tr>
<th>Nitrogen Removed</th>
<th>36 kgN/d</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Component</th>
<th>kWh/d</th>
<th>€/kgN rem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage Supernatant</td>
<td>3,2</td>
<td>0,02</td>
</tr>
<tr>
<td>SBR</td>
<td>123,2</td>
<td>0,59</td>
</tr>
<tr>
<td>Fermenter</td>
<td>9,0</td>
<td>0,04</td>
</tr>
<tr>
<td>S/L Separator</td>
<td>23,0</td>
<td>0,11</td>
</tr>
<tr>
<td>Total Energy</td>
<td>158,4</td>
<td>0,75</td>
</tr>
<tr>
<td>Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyelectrolyte</td>
<td>9,2</td>
<td>0,36</td>
</tr>
<tr>
<td>Dosage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sludge Production</td>
<td>54,0</td>
<td>0,15</td>
</tr>
<tr>
<td>Personnel</td>
<td>4,9</td>
<td>0,14</td>
</tr>
<tr>
<td>Maintenance</td>
<td>0,10</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>1,50</td>
<td></td>
</tr>
</tbody>
</table>

Carbonera WWTP
Around 5,4 €/kgN rem
OPEX reduction the treatment of An. Supernatant: around 70%
Specific OPEX for treating supernatant after 4 months operations

- Total Energy Consumption: 50%
- Polyelectrolyte Dosage: 24%
- Sludge Production: 10%
- Personnel: 9%
- Maintenance: 7%
External carbon source VS carbon source from sewage sludge fermentation

External Carbon Source (eg. Acetic Acid)

- Stable N removal in denitrification
- Instable BIO P removal
- Higher Carbon Footprint
- Commercial product
- Cost €1.69/kg N rem + extra cost for sludge disposal

Carbon source from sewage sludge fermentation

- Stable N removal in denitrification
- Stable and linear BIO P removal
- Lower Carbon Footprint
- Homemade Product
- Cost €0.51/kg N rem...+ P rem

Carbon source from sewage sludge fermentation cost vs. Acetic Acid cost – 69%
Carbonera WWTP energy scenario

- **BIOLOGICAL REACTOR AND CLARIFIERS**: 53%
- **PUMPING STATION AND PRETREATMENTS**: 15%
- **AIR TREATMENT**: 13%
- **SLUDGE LINE (AnD - DT - CF)**: 15%
- **S.C.E.N.A.**: 4%
- **OTHERS**: 1%

**Energy consumption in Carbonera WWTP around 5000 kWh/d**
Verification procedure for S.C.E.N.A.

Timeline

✓ Contact phase with Verification Body
✓ Quick-Scan (QS) eligibility assessment
✓ Verification proposal
✓ Offer and contractual agreement
✓ Specific verification protocol phase (starting)

→ Testing
→ Verification
→ Reporting and publication
Conclusions

The point of view of the water utility

- Dynamic thickening of the sewage sludge increased the efficiency of the sludge treatment line...but careful to the pick of nutrient loadings during sludge dewatering!!!

- The S.C.E.N.A. process allows an autonomous management of the bioprocesses and simplicity of the operations.

- Short period for the start-up operations, very stable under transient conditions;

- The fermentation liquid is a cheap source of VFAs, which allows an effective biological removal of Nitrogen and Phosphorus (for sidestream and mainstream)

- Alto Trevigiano Servizi took this decision mainly to achieve better quality of the effluent (N & P) and to reduce the energy consumption for nitrogen removal.
THANK YOU!

www.smart-plant.eu
Supporting informations
scSBR via nitrite optimization logic control

DATA CYCLE

IDENTIFICATION OF FAULTS

PROFILES SIGNAL PROCESSED

INTELLIGENT CONTROL SYSTEM

ELECTRICAL CONDUCTIVITY

DISSOLVED OXYGEN

pH

RESULTS: CONTROL POINTS OF IDENTIFICATION

MOVE TO THE NEXT STEP
S.C.E.N.A. Nitrogen kinetics

The carbon source is automatically dosed during ANAEROBIC phase and than during ANOXIC phase: the denitrification phase of the scSBR operation to remove nitrite and in the same time phosphorus.

<table>
<thead>
<tr>
<th>CARBONERA S.C.E.N.A. SBR</th>
<th>CARBONERA WWTP MAIN LINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIFIC NUTRIENTS REMOVAL RATES - (T = 20 °C)</td>
<td>SPECIFIC NUTRIENTS REMOVAL RATES - (T = 20 °C)</td>
</tr>
<tr>
<td>sAUR (mgN/gVSS*h)</td>
<td>sAUR (mgN/gVSS*h)</td>
</tr>
<tr>
<td>12 - 15</td>
<td>1.5 – 2.5</td>
</tr>
<tr>
<td>sNUR_{BACS} (mgN/gVSS*h)</td>
<td>sNUR (mgN/gVSS*h)</td>
</tr>
<tr>
<td>35 - 40</td>
<td>5 - 6</td>
</tr>
</tbody>
</table>
✓ After 10 days → Complete Via-Nitrite pathway (NOB inhibition)
✓ After 15 days → Start with VFAs dosage
✓ After 20 days → No N-NO₃ in discharge
✓ After 245 days → start dosing both anaerobic and anoxic phases
## Footprint S.C.E.N.A. VS conventional

How much VOLUME of Biological Reactor to treat the same Load?

<table>
<thead>
<tr>
<th></th>
<th>It Reactor/P.E.</th>
<th>OTHERS/S.C.E.N.A.</th>
<th>VOLUME (mc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional MLE</td>
<td>180</td>
<td>12</td>
<td>840</td>
</tr>
<tr>
<td>Intermittent Aeration</td>
<td>150</td>
<td>10</td>
<td>700</td>
</tr>
<tr>
<td>Carbonera WWTP Main line</td>
<td>114</td>
<td>7.6</td>
<td>533</td>
</tr>
<tr>
<td>Carbonera S.C.E.N.A. SBR</td>
<td>15</td>
<td>1</td>
<td>70</td>
</tr>
</tbody>
</table>

- ✓ Less impact on the landscape
- ✓ Lower costs of construction
Comparison between mainstream and sidestream nitrogen removal

<table>
<thead>
<tr>
<th></th>
<th>Carbonera WWTP (Mainstream)</th>
<th>S.C.E.N.A. process (Sidestream)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy consumption</strong></td>
<td>2,3€/kg N rem</td>
<td>0,75 €/kg N rem</td>
</tr>
<tr>
<td><strong>Sludge production</strong></td>
<td>0,78 €/kg N rem</td>
<td>0,15 €/kg N rem</td>
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</tbody>
</table>