REUSE OF TREATED MUNICIPAL WASTEWATER AS A SUSTAINABLE APPROACH TO IRRIGATION AND FERTIRRIGATION IN MEDITERRANEAN COUNTRIES: A CASE STUDY

Alfieri Pollice,
Pompilio Vergine,
Antonio Lonigro,
Carlo Salerno,
Giovanni Berardi
1. Water needs in Apulia region
2. Treatment schemes for wastewater reuse
3. Case study description
4. Performance of the pilot scale IFAS MBR
5. Agronomic results
Apulia - Available water and land use

Rainfall (1998)

Apulia: 600-650 mm/year
136 m³/capita per year
absence of permanent rivers/natural lakes

Land use:
- Cultivated: 79%
- Irrigated: 19%
- Other: 21%
Apulia - Potential treated wastewater reuse in irrigation

Water demand in Puglia

10% savings of primary water source

Other advantages:
• Nutrients
• Continuous availability

Municipal wastewater potentially available for reuse in agriculture:
• Total estimate $\rightarrow$ 150 Mm$^3$/year
• Already or almost available (tertiary treatment plants) $\rightarrow$ 90 Mm$^3$/year

Piano di Tutela delle Acque della Regione Puglia (2007) [transl.: Regional Water Protection Plan]
## Treated wastewater reuse for irrigation

### Opportunities
- Continuous water supply;
- Savings on primary sources;
- Nutrients.

### Risks
- Microbiological safety;
- Chronic effects on soils;
- Eutrophication of storage basins.

### Questions
- Is the cost sustainable?
- Are technologies adequate?
- Are limits and regulations representative of local situations?
- How stakeholders and final users can be involved?
How to choose the treatment scheme for agricultural reuse 1/2

Conventional wastewater treatment plant

- Raw sewage
- Pre-treatments
- Primary settling
- Activated sludge
- Clarifier
- Tertiary treatment
- Waterbody
- Discharge standards
- Agricultural reuse standards

or

Tertiary treatments

upgrade
### How to choose the treatment scheme for agricultural reuse 2/2

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Concerns</th>
<th>Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solids</td>
<td>Pipe clogging, Accumul. on soil</td>
<td>Clariflocculation, Filtration (GMF), Membrane filtration</td>
</tr>
<tr>
<td>Microrganisms</td>
<td>Hygienic safety</td>
<td>Disinfection, Membrane filtration</td>
</tr>
<tr>
<td>Toxic compounds (metals/organics)</td>
<td>Accumulation in soil and crops</td>
<td>Act. carbon adsorption, Clariflocculation</td>
</tr>
<tr>
<td>Nutrients (N, P)</td>
<td>Eutrophication of storage basins</td>
<td>Biological treatments, Ammonia stripping, Chemical precipitation</td>
</tr>
</tbody>
</table>
Possible wastewater treatment schemes

Tertiary treatments

a) COAG → FLOC → SED → FILTR → DISINF

b) POND → STABILIZ. POND → DISINF

c) WETLAND → POND → DISINF

d) micro FILTR → DISINF

e) ultra FILTR → DISINF

Application field of IRSA’s pilot tests: surface filtration combined with biological treatment (MBR)

WWTP upgrade:

f) Raw sewage → Pre-treatments → Primary settling → Activated sludge → ultra FILTR → DISINF
The experimental installations

PP) IFAS/MBR + UV
Treatment of pre-screened municipal WW

Test field (3000 m²)
Horticulture irrigated with treated effluents (including the WWTP outlet) and control (well water)
Pilot plant description

Integrated Fixed film-Activated Sludge Membrane BioReactor (IFAS-MBR)

- 0.3-0.8 m³/h
- Reservoir (30 m³)
- UV on demand
- Irrigation

UV disinfection

15 mm
Interruptions (carriers clogging) did not affect COD removal, but affected nitrification. However, nitrification was always recovered in less than one week after each stop.
IFAS-MBR + UV: pathogen indicators removal

- **In IFAS-MBR**: E. Coli (CFU/100mL) 0÷10^1
- **Permeate storage tank**: E. Coli (CFU/100mL) 0÷10^3
- **In UV**: E. Coli (CFU/100mL) 0÷10^1

**Graphs**

- **C. perfringens (CFU/100mL)**
  - IN
  - Out IFAS-MBR
  - Out UV

- **Somatic Coliphages (PFP/100mL)**
  - IN
  - Out IFAS-MBR
  - Out UV

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## Water sources adopted for irrigation (2-years averages)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>WWTP effluent</th>
<th>PP effluent</th>
<th>Local limits for reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EC (µS/cm)</strong></td>
<td>888±420</td>
<td>989±170</td>
<td>764±88</td>
<td>3000</td>
</tr>
<tr>
<td><strong>pH (-)</strong></td>
<td>7.5±0.3</td>
<td>7.7±0.2</td>
<td>7.1±0.5</td>
<td>6.0-9.5</td>
</tr>
<tr>
<td><strong>COD (mgO₂/L)</strong></td>
<td>&lt;15</td>
<td>67.1±55.4</td>
<td>19.5±5.4</td>
<td>100</td>
</tr>
<tr>
<td><strong>NH₄⁺ (mgN/L)</strong></td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>2.6±7.0</td>
<td>2</td>
</tr>
<tr>
<td><strong>NO₃⁻ (mgN/L)</strong></td>
<td>1.5±1.5</td>
<td>6.4±5.6</td>
<td>29.2±17.1</td>
<td>35(*)</td>
</tr>
<tr>
<td><strong>Total Phosphorus (mgP/L)</strong></td>
<td>0.4±0.7</td>
<td>4.2±5.5</td>
<td>8.1±4.3</td>
<td>10</td>
</tr>
<tr>
<td><strong>TSS (mg/L)</strong></td>
<td>&lt;2</td>
<td>4.8±1.0</td>
<td>&lt;2</td>
<td>10</td>
</tr>
<tr>
<td><strong>Free Chlorine (mg/L)</strong></td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>SAR (-)</strong></td>
<td>0.9±0.8</td>
<td>1.1±0.1</td>
<td>0.8±0.1</td>
<td>10</td>
</tr>
<tr>
<td><strong>E. coli (CFU/100mL)</strong></td>
<td>0±0</td>
<td>872±1292</td>
<td>0±1</td>
<td>10(**)</td>
</tr>
<tr>
<td><strong>Salmonella spp</strong></td>
<td>Absent</td>
<td>Absent</td>
<td>Absent</td>
<td>Absent</td>
</tr>
</tbody>
</table>

(*) Limit related to Total Nitrogen.
(**) Limit that has to be respected by 80% of the samples (maximum value=100 CFU /100mL).
Test field

Sept 2013-Jan 2014
Fennel Cv. Archimede - Single rows, 10 plants/m²
Drip irrigation - Irrigation threshold: 16 mm ETc

Apr-Jun 2013
Lettuce Cv. Canasta - Single rows, 6.7 plants/m²
Drip irrigation - Irrigation threshold: 10 mm ETc
Agronomic results - productivity

- Crop yield
- N from fertilization
- N from irrigation
- P from fertilization
- P from irrigation

Crop yield (t/ha)

- lettuce control
- lettuce WWTP
- lettuce PP
- fennel control
- fennel WWTP
- fennel PP

Growing season (d)

- Growing season
- Rainfall
- Irrigation

N and P supply (kg/ha)

- Irrigation
- Rainfall

Growing season:

Salmonella: always **absent** in water, soil and edible parts

<table>
<thead>
<tr>
<th></th>
<th>Water (CFU/100mL)</th>
<th>Soil (CFU/1g)</th>
<th>Edible parts (CFU/1g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fennel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WWTP</td>
<td>$10^2-10^3$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PP</td>
<td>0-10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Lettuce</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WWTP</td>
<td>$10^2-10^3$</td>
<td>&lt;1</td>
<td>4</td>
</tr>
<tr>
<td>PP</td>
<td>0-2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Conclusions

Two treatment schemes applied to the same municipal WW →

Significant differences in terms of suspended solids and faecal indicator removals. The pilot plant, based on ultrafiltration and UV radiation, had better performance for producing water suitable for agricultural reuse (e.g. complying with local laws).

Operating the WW treatment (biological process) for partial nitrogen removal (nitrification) allowed the supply of a consistent fertilization contribution with the irrigation water. →

This had positive effects on yield and growth rate of both lettuce and fennel, without affecting the quality of crops.
Thanks for your attention

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www.water4crops.org  Euro-India collaborative project
www.pon-interra.it    Italian National project
Problems related to the presence of the carriers

→ Clogging in several points of the plant required changes in piping and pumping in the first months after start-up.

→ Steady state conditions for biological processes were reached only some months after start-up.

→ Interruptions of the pilot plant operation caused membrane fouling and a loss of membrane productivity (from 800 L/h to 300 L/h).

→ The biofilm attached to the carriers decreased consistently with the flow rate, indicating that the biofilm growth is significantly limited under very low organic loading rates (0.15 gCOD/gVSS/d).
Agronomic results
Nitrate in crops

NO$_3$ in crops (mg/kg)

standard limit (*)

(*) EU Commission Regulation No 1258/2011 of 2 December 2011