Algae beads: a ‘round’ way to remove nutrient and recover energy

Dr Raffaella Villa
Microalgal wastewater treatment: is it possible in the UK?

- Wastewater
- Residual N and P
- Algal treatment
- Clarified Water
- Raceway Algae Pond
- Harvesting unit
- Pre-treatment
- Anaerobic Digestion
- Energy generation
- Double the size in winter to accommodate reduced hours of light
- Potentially high energy input
- Possible energy recovery?

- Possible energy recovery?
Do they work for low nutrient remediation?
Low energy harvesting system: BDAF

BDAF - Ballasted Dissolved Air Flotation (0.04 kWh m⁻³)

- Sludge scraper
- Floc & bead aggregate
- Hydrocyclone to separate floc and bead
- Separated beads leave from top & are recycled
- Flocculated material sinks to be removed from the base
- Micro beads
- New bead added to make up for any loss during recycle
- Recycled bead are introduced at base of flocculation zone
- Bead pump
- Bead recycle line
- Clarified water

60-80% less energy compare to traditional DAF
Low energy harvesting system

BDAF

DAF vs BDAF performance

S. obliquus cultivated in Jaworski Media

40% reduction on coagulant addition

Energy recovery from the waste

- Strong resistance to bacteria degradation
- Limited biogas production
- Residual intact cell after digestion (40d)

Pre-treatments to improve biogas production

**Biogas potential**

- WW sludge
- S. obliquus

**Pre-treatments**

- **TEMPERATURE**
  - Thermal: 120°C, 2 bar, 30min

- **PRESSURE**
  - Commercial enzymes: 50°C, 24h

**Residual cell**
Pre-treatments

- **Thermal**
  - 105°, 1 bar
  - 120°, 2 bar
  - 145°, 3 bar
  - 155°, 5 bar
  - 165°, 7 bar

- **Enzymatic**
  - Cellulase + Endogalactour.
  - Alpha amylase
  - Esterase + Protease
  - Pectinase
  - Esterase
  - Mixture

Biogas improvement: thermal treatment

![Graph showing biogas improvement with and without thermal treatment over time.](image)

The graph illustrates the biogas production (m$^3$ kg Vs$^{-1}$) over time (d) for untreated and treated samples. The treated samples exhibit a significant increase in biogas production compared to the untreated samples. The time axis is labeled as 'time (d)' and the biogas production axis is labeled as 'Biogas (m$^3$ kg Vs$^{-1}$)'.

- Untreated cells
- Treated (cellulase) DP40
- Treated (lipase) LP957
- Treated Mix enzymes

The treated samples show a distinct upward trend, indicating improved biogas production, while the untreated samples remain relatively flat.
Microalgal wastewater treatment: is it possible in the UK?

What is immobilisation?

- Centrifuged algal suspension
- Resin
- Algae-resin solution
- Peristaltic pump
- Curing solution
Methodology

Batch trials

Continuous trials

Algem™ Environment Modelling Labscale Photobioreactor
**Microalgal wastewater treatment: nitrogen and phosphorous removal**

**Synthetic Wastewater**

**Real Wastewater**

$NH_4^+$ and $PO_4^{3-}$ (N:P 5) removal by algae beads ($\blacktriangledown$), blank beads ($\blacktriangle$) and suspended cells ($\bullet$). Wastewater only was used as control ($\times$) to evaluate losses by volatilisation.

Microalgal wastewater treatment: nitrogen and phosphorous removal

<table>
<thead>
<tr>
<th>Removal rates (mg·L⁻¹·h⁻¹)</th>
<th>Immobilised algae</th>
<th>Suspended cells</th>
<th>Blank beads</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Synthetic wastewater</strong></td>
<td></td>
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<tr>
<td>Ammonium</td>
<td>0.42</td>
<td>0.24</td>
<td>0.29</td>
<td>0.13</td>
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<tr>
<td>Orthophosphate</td>
<td>0.056</td>
<td>0.108</td>
<td>0.019</td>
<td>0.007</td>
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<tr>
<td><strong>Real wastewater</strong></td>
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<tr>
<td>Ammonium</td>
<td>0.37</td>
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<tr>
<td>Orthophosphate</td>
<td>0.025</td>
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<td>0.018</td>
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</tbody>
</table>
Can we re-use the beads?

Graph showing NH₄⁺-N concentration (mg/L) over time (h) for Cycle 1, Cycle 2, and Cycle 3, with points indicating degradation over time.
Removal improvement in continuous (real wastewater)

- **20 h**: 0.03 mg.L\(^{-1}\)
- **12 h**: 0.17 mg.L\(^{-1}\)
- **6 h**: 0.10 mg.L\(^{-1}\)
- **3 h**: 0.43 mg.L\(^{-1}\)
...what do we do with the algal beads waste?
Do the systems compare?

**Untreated cells**
- Digested sludge control (S)
- S. Obliquus (cells)

**Pre-treated cells**
- Digested sludge control (S)
- Thermally treated cells
- E1 Depol 40
- E2 Lipomod 957
- E1+E2 MIX

**Untreated beads**
- Digested Sludge Control (S)
- Blank Beads (BB)
- Clean Algae Beads (CA)
- 6 days Used Algae Beads (6-UA)
- 10 days Used Algae Beads (10-UA)
- Algal Sludge Residue (AS)

**Pre-treated beads**
- Digested Sludge Control (S)
- Blank Beads (BB) E1
- Clean Algae Beads (CA) E1
- Algae 6 days Used Beads (6-UA) E1
- 10 days Used Algae Beads (10-UA) E1
- 6 days Used Algae Beads (6-UA) E2
What is the action of the pre-treatments do to the beads?

- Enzymes
- Thermal
How do the systems compare in terms of energy?

WWTP with a 2,000 PE and represent sites which do not currently utilise chemical dosing and include coagulation followed by either algal pond or an immobilised algal bioreactor.

BDAF

IBR with AD (no-pretreatment)

HRAP with AD (pre-treatment)

HRAP with AD (no-pretreatment)

% energy change compared to standard works

Better than standard works

The team

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With gratitude...