Integration of Microalgal Biofuel Production with Phytoremediation Using Algal Turf Scrubber®

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Concept of Integrated Technology for Biofuel Production with Phytoremediation
## Contaminated Water as Source of Nutrients for Algae Production

Wastewater treatment facilities in U.S.\(^A\)

<table>
<thead>
<tr>
<th>Number of facilities</th>
<th>Total flow (mgd)</th>
<th>N, ton/year</th>
<th>P, ton/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,774</td>
<td>32,345</td>
<td>1,340,709</td>
<td>223,451</td>
</tr>
</tbody>
</table>

Assuming nutrient content in WW: 30 mg/L of N and 6 mg/L of P

Assuming algal biomass composition: 6% N, 1% P and 25% lipids

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Algal biomass, ton/year</td>
<td>22 x 10^6</td>
</tr>
<tr>
<td>Lipid, gal/yr</td>
<td>1.6 x 10^9</td>
</tr>
<tr>
<td>Percent from US liquid fuel consumption, %</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Other sources of nutrients may include storm water or polluted streams

<table>
<thead>
<tr>
<th>River Basin</th>
<th>N, ton/year (^B)</th>
<th>P, ton/year (^B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippi</td>
<td>1,104,000</td>
<td>86,900</td>
</tr>
<tr>
<td>Atchafalaya</td>
<td>357,000</td>
<td>30,600</td>
</tr>
</tbody>
</table>

(A): commercial ATS® facility treating stormwater in Vero Beach, FL produces more than 2-3 dt per week;  (B): Rake-harvesting generates biomass with 10wt% solid content. [1]

- natural, attached, filamentous algae;
- poly-culture of many genera & species;
- grows well in low-nutrient media;
- extremely robust in various wastewater;
- easy/cheap to harvest and dewater;
- productivity up to 25-60 dt/acre-yr.

Nutrient Removal Efficiency

**Mean RE$_p$ 22%**

**Mean RE$_N$ 6%**

**Mean RE$_{BOD}$ 21%**

[2] Bohutskyi et al. (in preparation) Assessment of integrated technology for biofuel production with phytoremediation using ATS®
Low FAME content – 1-2% dw;
High ash content – 20-50% dw.

Anaerobic Digestion (AD) of ATS® Biomass

Semi-continuous AD system:
- Bioreactor - 8 L spinner flasks at 35°C;
- Biogas flow - wet-tip gas meter;
- Methane - Shimadzu GC-TCD, Hayes Q 80/100 column.
- Effluent nutrients - filtered (0.45 µm), N & P Hach TNTplus kits, other by ICP-MS

Operational parameters

<table>
<thead>
<tr>
<th>Run</th>
<th>HRT, days</th>
<th>OLR, gVS/L-day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>5</td>
</tr>
</tbody>
</table>
Average specific biogas production \(~0.38\) L per gVS of biomass with methane content \(\sim 56\%\).
Nutrient Recovery from ATS® Biomass
(as concentration in AD effluent)
Nutrient Recovery from WFA
(as % of nutrient in the AD feed)
Nutrient Recovery from WFA
(as % of nutrient in the AD feed)
Testing of Algal Cultivation in the Diluted AD Effluent

150 ml flasks, 100 µmol photon / m²-s, 14/10 h L/D
Algal Cultivation in the Diluted AD Effluent

- *Chlorella sorokiniana*
- 5% dilution of AD effluent after OLR 3 and 4 g/L-day
- 3L spinner flask bioreactors at 22.5°C;
- 0.2 LMP air flow per flask;
- Fluorescent Grow Light System (~120 µmol photon / m²-s, 14/10 h L/D).

### Table: FAME content of algal biomass

<table>
<thead>
<tr>
<th>Specie</th>
<th>AD effluent</th>
<th>FAME, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCTCC M209220</td>
<td>OLR 3</td>
<td>14.8</td>
</tr>
<tr>
<td>CCTCC M209220</td>
<td>OLR 4</td>
<td>12.5</td>
</tr>
<tr>
<td>UTEX 1230</td>
<td>OLR 3</td>
<td>15.6</td>
</tr>
<tr>
<td>UTEX 1230</td>
<td>OLR 4</td>
<td>11.5</td>
</tr>
</tbody>
</table>

![Graph showing culture density over cultivation time.](image)
**Proposed Process**

1. **Nutrient removal by ATS system from wastewater or contaminated streams**

2. **Biomass anaerobic digestion to biogas (methane)**
   - Solids as fertilizer
   - Nutrient-rich liquid fraction
   - Biogas (methane)

3. **Combined heat and power generation**
   - Exhaust gases with CO₂
   - Turbine and generator
   - Nutrient-containing liquid fraction

4. **Production of high-quality microalgal biomass**
   - Lipids for biodiesel
   - Hexane lipid extraction
   - Lipid-rich microalgae
   - Electricity (hot water)
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