Feasibility of the Power-to-Protein concept in the circular economy of the city of Amsterdam

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OUR RESEARCH

SUSTAINABLE WATER CYCLE

- Sustainable use of water resources
- Preparing for climate change
- Water technologies for sustainable energy
- Resource recovery
The idea of power-to-protein
Avecom Belgium/ Prof. Dr. Willy Verstraete & Silvio Matassa M.Sc.

May 2015, cover ES&T

“Can direct conversion of used nitrogen to new feed and protein help feed the world?”

Is this how we feed 10 billion people on this planet in 2050?
Power-to-protein concept

Direct upcycling of ammonia as microbial protein

The artificial nitrogen cycle is very inefficient

Haber Bosch → reactive N:
450 million tons/yr enter our biosphere

Only 10% becomes edible protein; 90% is lost to the environment

SOURCE: MATASSA, S. ET AL., ENVIRON. SCI. TECHNOL., 49 (2015), 5247 - 5254
Power-to-protein concept
All sources from the waste water chain

- $\text{NH}_4^+$ from reject water sludge digester
- CO$_2$ from biogas refinery to biomethane or other industrial sources
- CO$_2$/H$_2$ from steam methane reforming of biogas
- H$_2$ from renewable energy on/off site (hydrogen economy)
Power-to-protein concept

Laboratory set up and results

CSTR; 5 liter reactor

*Batch mode*

Enriched mixed culture

$\text{H}_2$ gas conversion eff. 65 %

78 g CDW/m$^3$reactor·h

*Continuous mode*

Monoculture: *Sulfuricurvum spp.*

$\text{H}_2$ gas conversion eff. 81 %

375 g CDW/m$^3$reactor·h

Single cell protein

Crude protein content = 71 %

Nutritional properties:
comparable to high-quality fishmeal

PtP project Amsterdam
The potential of the PtP-concept in the water cycle of Amsterdam

Desk study with following goals:
• Create a link with relevant sources in the urban zone of the city of Amsterdam
• Determine the technological and economic feasibility of the Power-to-Protein concept
• Define relevant research questions that have to be answered

<table>
<thead>
<tr>
<th>Amsterdam Locations WWTP</th>
<th>Number of inhabitants connected</th>
<th>N-load (tons/yr)</th>
<th>ammonia load (tons/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WWTP West</td>
<td>564,113</td>
<td>3,009</td>
<td>3,876</td>
</tr>
<tr>
<td>WWTP Westpoort</td>
<td>265,510</td>
<td>1,416</td>
<td>1,824</td>
</tr>
<tr>
<td>Total</td>
<td>829,623</td>
<td>4,425</td>
<td>5,700</td>
</tr>
</tbody>
</table>
## PtP Project Amsterdam
### Potential and necessary resources

<table>
<thead>
<tr>
<th></th>
<th>Avecom (2014)</th>
<th>Amsterdam-West reject water sludge digestion</th>
<th>WWTP’s Amsterdam influent water</th>
</tr>
</thead>
<tbody>
<tr>
<td>available:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ammonium NH&lt;sub&gt;4&lt;/sub&gt;-N</td>
<td>196 kg</td>
<td>by air stripping</td>
<td>total potential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.235 tons/yr</td>
<td>4.670 tons/yr</td>
</tr>
<tr>
<td>hydrogen H&lt;sub&gt;2&lt;/sub&gt;</td>
<td>786 kg</td>
<td>5.000 tons/yr</td>
<td>18.900 tons/yr</td>
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<tr>
<td>carbon dioxide</td>
<td>3309 kg</td>
<td>21.000 tons/yr</td>
<td>79.400 tons/yr</td>
</tr>
<tr>
<td>oxygen</td>
<td>2924 kg</td>
<td>18.400 tons/yr</td>
<td>69.600 tons/yr</td>
</tr>
<tr>
<td>Production SCP</td>
<td>1,000 kg</td>
<td>6,300 tons/yr</td>
<td>24,000 tons/yr</td>
</tr>
</tbody>
</table>

Based on reaction stoichiometry

\[
21.36 \text{ H}_2 + 6.21 \text{ O}_2 + 4.09 \text{ CO}_2 + 0.76 \text{ NH}_3 \rightarrow C_{4.09}H_{7.13}O_{1.89}N_{0.76} + 18.7 \text{ H}_2\text{O}
\]

Equals 36 % of the net protein demand of the cities population
PtP Project Amsterdam
Costs and revenues (in k€/ton SCP)
Power-to-Protein concept

Conclusions

The potential for production of SCP from sources in the waste water chain is high
There is a good economic potential as well from a broader perspective
There is a need for efficient methods to extract ammonia from the waste water chain

Other relevant aspects:

- Introduction novel food: complex, time consuming and expensive/ focus on animal feed
- Protein characterisation: nutritional value, digestibility, allergenicity
- Public acceptance
Power-to-Protein concept

Follow-up

Follow up research:
- Upscaling of the reactor
- Demonstration on site
- Characterisation of the SCP produced

Project partners:
Waternet, AEB, Waterboard Vechtstromen, Barentz Agri Nutrition, Avecom, KWR.

See [www.powertoprotein.eu](http://www.powertoprotein.eu)
Acknowledgement

Project partners:

Waternet: Jan Peter van der Hoek & Andre Struker
AEB: Sietse Agema
Waterschap Vechtstroom: Mathijs Oosterhuis
Barentz Foods: Mathijs Keij
Avecom: Silvio Matassa & Willy Verstraete
KWR, Laura Snip, Hans Huiting, Luc Palmen, Jos Boere

This activity is co-financed with TKI-funding from the Topconsortia for Knowledge & Innovation (TKI’s) of the Ministry of Economic Affairs.