Developing Bioplastics from Wastewater Treatment

by

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and

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ifm
Over the coming 10 years, wastewater treatment plants (WWTP) will undergo profound changes.
Talk Outline

1. Description of two problems.
2. A solution for both.
3. A case study.
4. Description of the process.
5. Implementation.
Talk Outline

1. Description of two problems.
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Here's one problem.
Here's another.
Bottled Water - A Package of Both Problems

→ $10 per gallon.

→ Tap water is distributed through an energy-efficient infrastructure; bottled water is transported over long distances (~1/4 crosses national borders).

→ Packaged in plastic made from polyethylene terephthalate, which is derived from crude oil.

→ The plastic bottle must be disposed of (in the US 86% become garbage or litter; incineration produces toxic byproducts; buried water bottles can take up to 1,000 years to degrade).

→ Water tables that farmers, fishers, and others depend on water can drop rapidly from concentrated water extraction.
2. A solution to both problems

Use microorganisms to
- remediate the water
- make bioplastic.

Polyhydroxyalkanoate (PHA) = bioplastic made by microorganisms.
PHA made by bacteria . . .

. . . can be broken down by bacteria.
Microorganisms make PHA as an energy reserve (like fat in people).

There are approximately 150 different kinds of PHAs naturally made.

Different PHAs have different properties:

- flexibility.
- gas permeability.
- temperature tolerance.

Photo: http://www.polyfermcanada.com/
PHA produced by microorganisms is being used in medicine.

Important properties:
- It can be broken down in the human body.
- It is not rejected.

TephaFLEX Surgical Mesh made from knitted filaments of TephaFLEX biopolymer.

FDA gives nod to absorbable suture created from nature plastic

Gautam | Feb 17 2007

FDA has given the green signal to a new type of absorbable suture created from material which has been isolated from bacteria modified by recombinant DNA technology. Called as TephaFLEX Absorbable Suture, it has been developed by Tepha and has been made from designer biomaterials.

These sutures are based on a technology which is based on natural materials called polyhydroxyalkanoates or PHA polymers and have been synthesized by various microorganisms. When compared with other polymers these polymers are thermoplastic and hence can be processed like the plastic used as of now.

The biomaterials have been developed through proprietary transgenic fermentation process which is similar to one used for producing biopharmaceuticals but results in a very high yield. The company is also looking to incorporate polyhydroxyalkanoates in various implantable medical devices such as vascular grafts and artificial cardiac valves.
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1. Description of two problems.
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4. Description of the process.
5. Stages of development.
Anaerobic wastewater treatments

methane
Anaerobic wastewater treatments

STAGE 1
hydrogen, VFAs

STAGE 2
methane
Kinds of Living Organisms

Eukaryotes have a special compartment for their DNA
- Plants
- Animals
- Microbial Eukaryotes

STAGE 1

Prokaryotes do not have the special compartment
- Bacteria
- Archaea

STAGE 2
Anaerobic wastewater treatments

**STAGE 1**

Eukaryotes and Bacteria

hydrogen, VFAs

**STAGE 2**

Archaea

methane
VFAs
- acidify the water.
- can feed harmful microorganisms.
- are a potential source of $$.
Natural gas is abundant and is widely used for home heating and industrial processes. It is easily transported through pipelines and costs about the same or slightly less than gasoline. Compressed natural gas (CNG) vehicles emit low levels of toxics and ozone-forming hydrocarbons. But CNG fuel must be stored under pressure in heavy tanks, and the cost of accommodating these tanks must be considered. There are significant tradeoffs for CNG vehicles among emissions, vehicle power, efficiency, and range; however, natural gas is already used in some fleet vehicles and appears to have a bright future as a motor vehicle fuel.

http://www.epa.gov/oms/consumer/06-clean.pdf
Anaerobic wastewater treatments

**STAGE 1**
- Eukaryotes and Bacteria

**STAGE 2**
- Archaea
- Other Bacteria

- hydrogen, VFAs
- methane
- hydrogen, PHA, other products
Major VFAs in POME: Acetate, Propionate, Butyrate
TN1: the right microbe to do the job

- Can use VFAs as food.
- Makes LOTS of hydrogen and PHA.
- Can grow aerobically and anaerobically.
H₂ production by TN1 using POME as food under anaerobic conditions

<table>
<thead>
<tr>
<th>POME dilution</th>
<th>H₂ (ml/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undiluted</td>
<td>826</td>
</tr>
<tr>
<td>1/10</td>
<td>865</td>
</tr>
<tr>
<td>1/20</td>
<td>781</td>
</tr>
<tr>
<td>1/60</td>
<td>656</td>
</tr>
<tr>
<td>1/100</td>
<td>29</td>
</tr>
</tbody>
</table>

83 l of H₂/ 100 l of POME
### PHA production by TN1 using POME as food under anaerobic conditions

<table>
<thead>
<tr>
<th>POME dilution</th>
<th>BOD (g/l)</th>
<th>VFA consumed (%)</th>
<th>PHA (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undiluted</td>
<td>38.74</td>
<td>27.8</td>
<td>400</td>
</tr>
<tr>
<td>1/10</td>
<td>3.87</td>
<td>87.5</td>
<td>68</td>
</tr>
<tr>
<td>1/20</td>
<td>1.94</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>1/60</td>
<td>0.65</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>1/100</td>
<td>0.39</td>
<td>100</td>
<td>2</td>
</tr>
</tbody>
</table>

40 g of PHA/100 l of POME

POME without TN1

POME with TN1

1 1/10 1/20 1/60 1/100
We discovered that our microbial worker TN1 is a new isolate of *Rhodopseudomonas palustris*.

<table>
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<tr>
<th>Useful features of <em>R. palustris</em></th>
<th>Special features of TN1</th>
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<td>• Produces hydrogen.</td>
<td>• No vitamin requirements.</td>
</tr>
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<td>• Makes PHA.</td>
<td>• Produces high purity hydrogen (99%).</td>
</tr>
<tr>
<td>• Can grow with and without oxygen.</td>
<td>• Maintains pH at 7.</td>
</tr>
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<td>• Can use light as an energy source.</td>
<td>• Stores PHA inside the cells.</td>
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<td>• Degrades aromatic compounds:</td>
<td>• No net carbon dioxide produced when making hydrogen</td>
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<td>- benzenes, toluene, xylene (petroleum waste)</td>
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<td>- lignin (the woody tissues of plants)</td>
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**Useful features of *R. palustris***

- Produces hydrogen.
- Makes PHA.
- Can grow with and without oxygen.
- Can use light as an energy source.
- Degrades aromatic compounds:
  - benzenes, toluene, xylene (petroleum waste)
  - lignin (the woody tissues of plants)

**Special features of TN1**

- No vitamin requirements.
- Produces high purity hydrogen (99%).
- Maintains pH at 7.
- Stores PHA inside the cells.
- No net carbon dioxide produced when making hydrogen.
Lignin (the woody tissues of plants) can also be used as a food source for PHA production.
Closer to home:

PAPER MILL WASTEWATER IN OHIO TO PLASTICS
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Producing cells with PHA from sludge

Bioplastics
(Polyhydroxyalkanoates)
From cells with PHA to PHA powder

1. Organic Solvent to Release PHA from Cells
2. Centrifugation to separate PHA from Bacterial Cell
3. Evaporator
4. PHA Powder
5. Palletizer
6. Bagging Machine
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Steps to First Generation Practical Implementation

- AnoxKaldnes with VERI are implementing transportable pilot scale commercial prototypes of the technology (2011):
  - Industrial WWT with PHA Production (SE)
  - Municipal WWT with PHA Production (BE)
  - Prototype field testing at a production level enabling realistic practical evaluation on the process and specific products (2012)

- Setting sights on first commercial projects to be established in 2012

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Funding for Case Study

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