BIO-TARP: DEVELOPING A METHANOTROPHIC ALTERNATIVE DAILY COVER (ADC) TO MINIMIZE LANDFILL METHANE EMISSIONS

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Why use alternative daily cover (ADC) ?

Thin or removable ADC minimizes
loss of airspace volume to non-waste materials

Tarping (removable/reusable daily OR biodegradable films) is one type of ADC that has become standard commercial practice

Why develop a methanotropic ADC?

To mitigate early CH_4 emissions: CH_4 generation begins early in the life of a landfill cell (daily cover over fresh refuse : measured CH_4 emissions up to 10-100 g m^{-2} day^{-1})

Background:

•Three year project funded by the U.S. Dept of Energy: collaboration between University of North Carolina-Charlotte, Landfills +, Inc. , and Ten Cate Nicolon to develop a "bio-tarp" ADC that can effectively oxidize early methane emissions by exploiting immobilized methanotrophs.

•Project goal: develop and field test one or more prototype bio-tarps to replace traditional soil cover or other ADC.

•Overall strategy: Exploit methanotrophic methane oxidation as a biological strategy to effectively reduce early methane emissions

•This paper: focuses on laboratory tests that were conducted during Year 1 to immobilize methanotrophs using a variety of candidate tarp materials and immobilization techniques.

Some Important Technical Issues:

- A bio-tarp cannot be "impermeable": need to maintain a high gas-filled porosity to promote counter-current diffusion of O_2 from the atmosphere and CH_4 from landfill gas.

- Optimum levels of methanotrophic activity require critical ranges of temperature and moisture that may be difficult to maintain in field settings.

- A bio-tarp requires immobilized methanotrophs that can maintain high levels of methane-oxidizing activity either overnight (for ADC applications) or for longer periods of time (for intermediate cover applications).

Methanotroph Isolation – Soil Enrichment

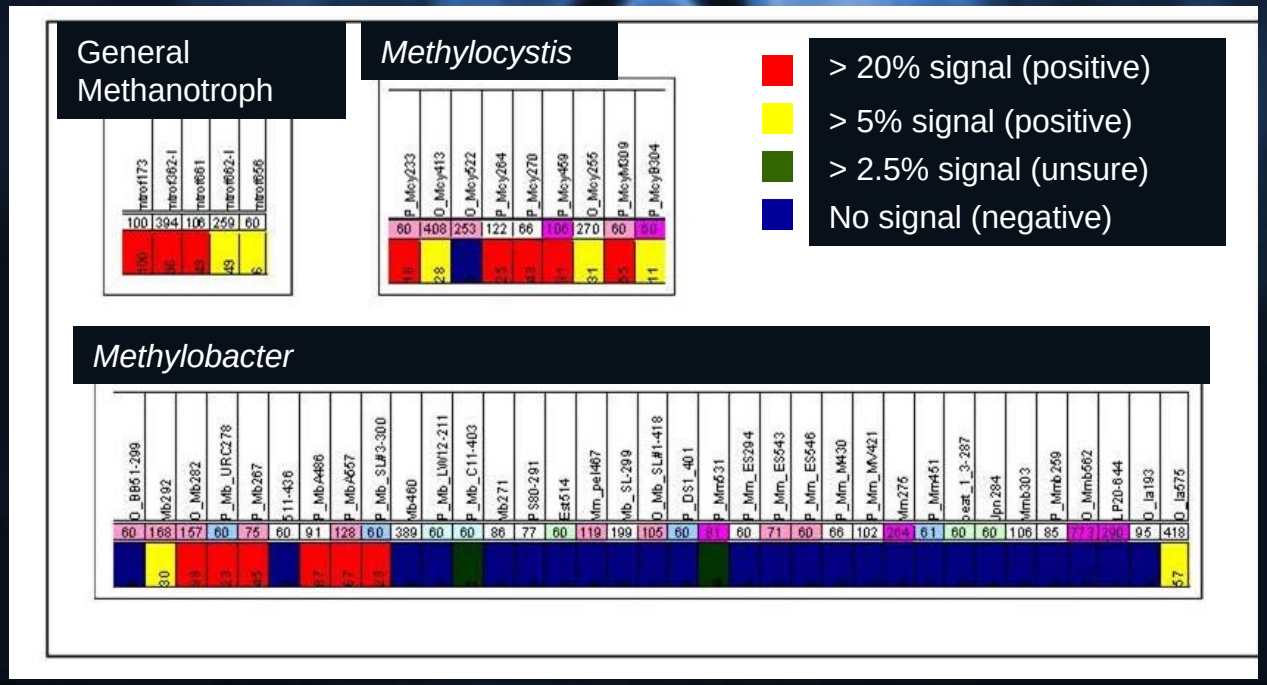
- Soil enrichment from landfill cover soil
- 50% methane: air headspace and monitored for methane oxidation
- Soil samples serially diluted in liquid media to further enrich under 10% methane:air headspace

Methanotroph Isolation – Soil Enrichment

- A mixed methanotroph population was developed
- Plating on nutrient-rich media revealed the presence of at least one heterotroph in co-culture
- Identified as *Acinetobacter* genomospecies III by 16s rRNA sequencing

Mixed Methanotroph Population

- Headspace analysis indicated that the cell population consumed methane and oxygen and produced carbon dioxide
- Microarray analysis by Lev Bodrossy [Austria] found the dominant genera to be *Methylocystis*, *Methylosinus,* and *Methylobacter*

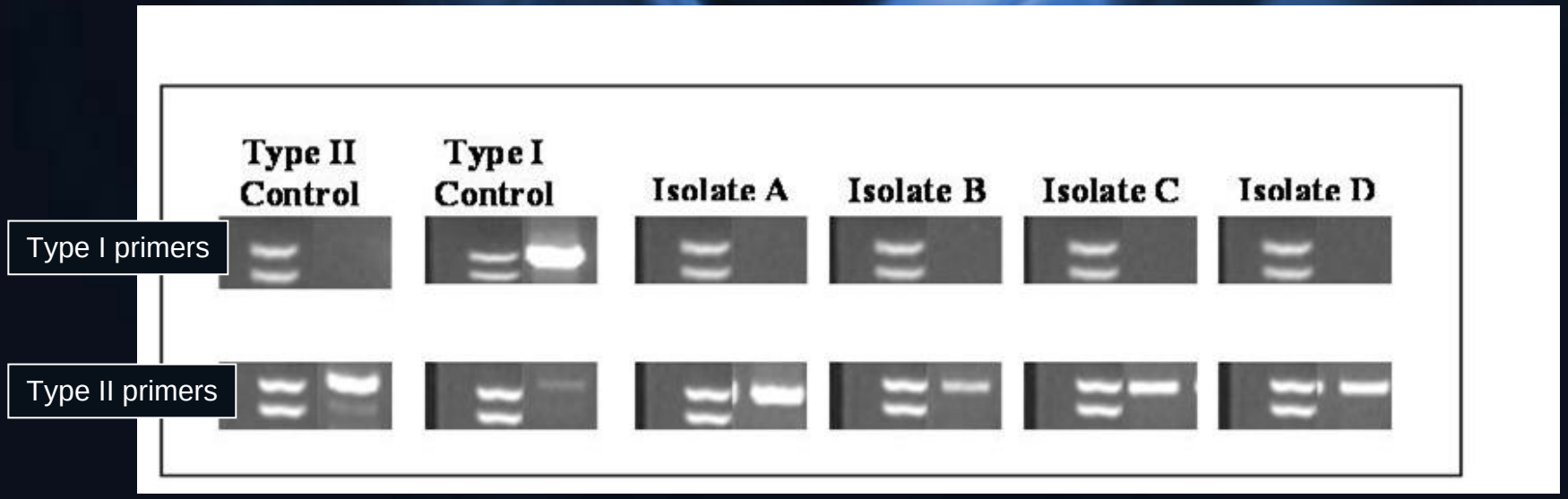


Methanotroph Isolation - Membrane

- Method described by Svenning et al. (2003).
- Landfill cover soil spread on a polycarbonate filter atop an agricultural soil slurry
- Colonies form on membrane

Methanotroph Isolation - Membrane

- Colonies were selected and isolated by streak plating on NMS agar plates
- Isolates were confirmed as methanotrophs and typed by PCR using 16s rRNA specific primers
- All were found to be Type II methanotrophs



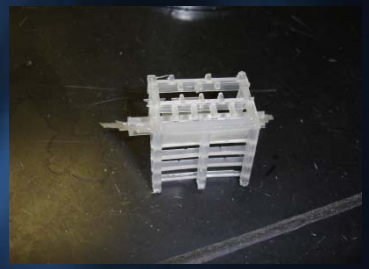
Bacterial Cell Immobilization

Of several general types of immobilization methods, two were applicable for a biotarp and investigated:

- Adsorption
  - Simple adsorption to various supports
- Entrapment/Encapsulation
  - Alginate beads
  - Liquid core gel capsules

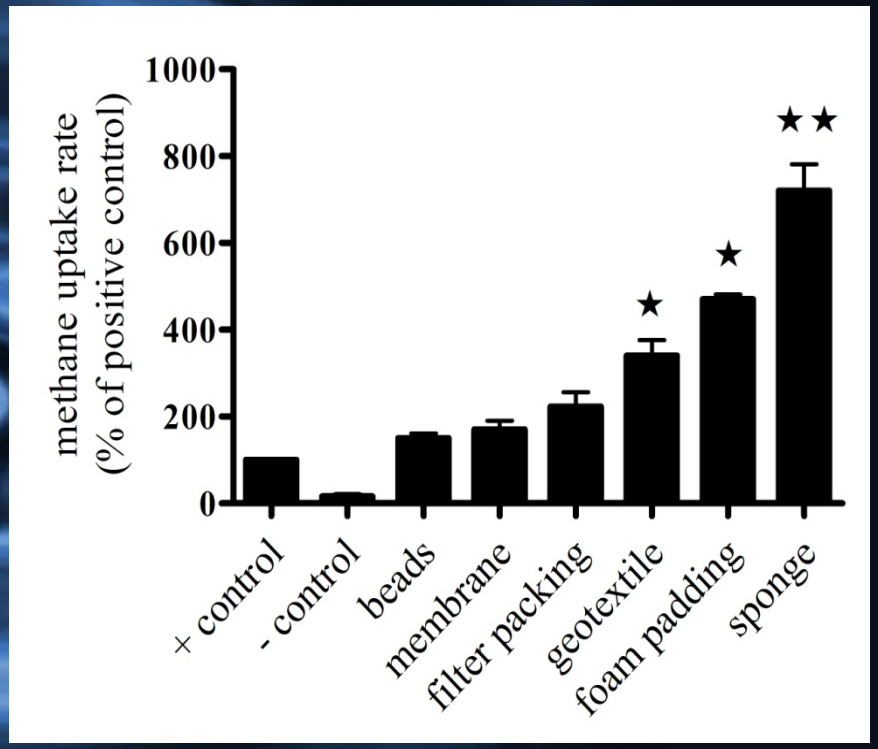
Adsorption

- Involves nonspecific, physio-chemical binding and cellular attachments between cells and the surface of a support material
- Adsorbed cells to a natural sponge, foam padding, nonwoven geotextile, plastic filter packing media, polycarbonate membrane filter, and glass beads



Adsorption

- Cells adsorbed to the sponge had the highest methane uptake rate, followed by the foam padding and non-woven geotextile
- Plastic filter packing, glass beads, and polycarbonate membrane filter showed no difference in uptake compared to controls

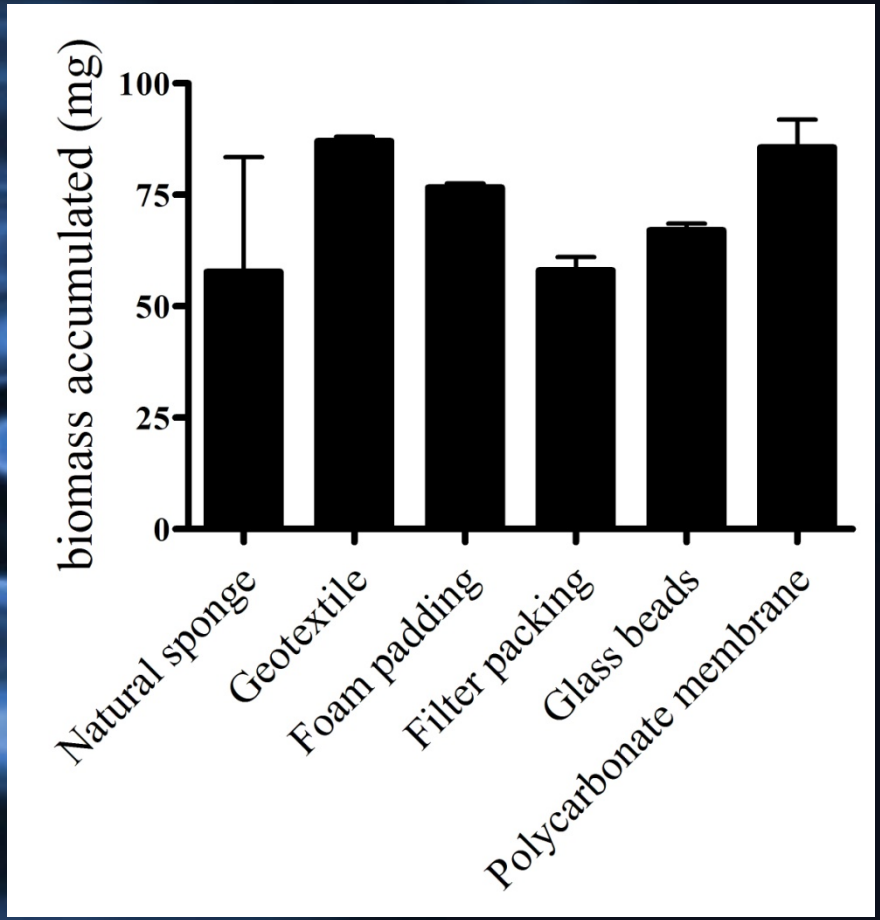


★indicates a statistically significant difference from the positive control (P<0.001)
★★ indicate a statistically significant difference from the positive control, geotextile, and foam padding (P<0.001).

Adsorption

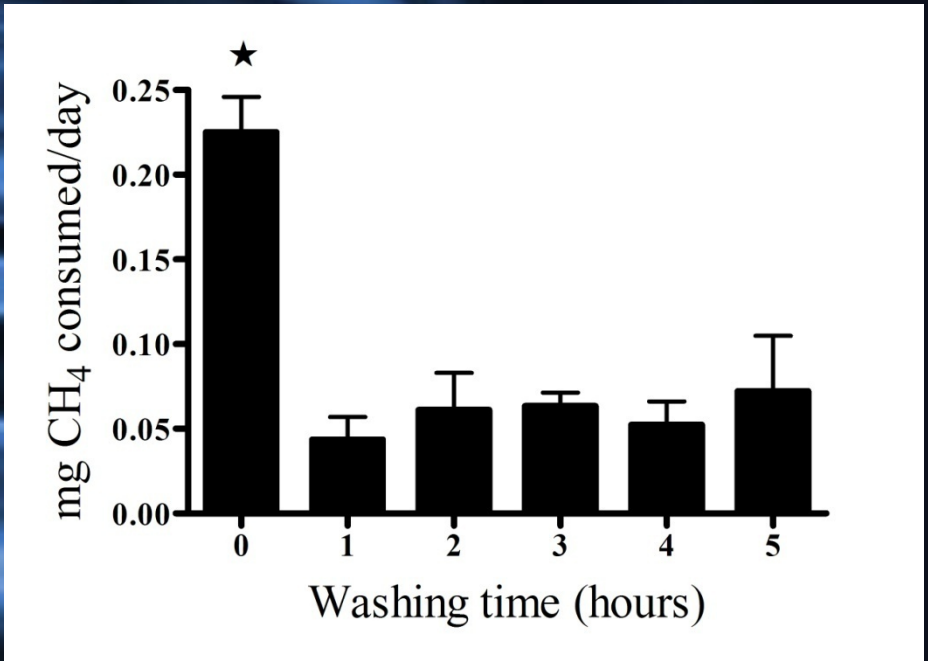
- Examined the biomass accumulated on each support after three weeks to determine the ability of cells to adsorb to the surfaces

- Although large differences in methane oxidation were observed, the biomass accumulation was similar on all supports.



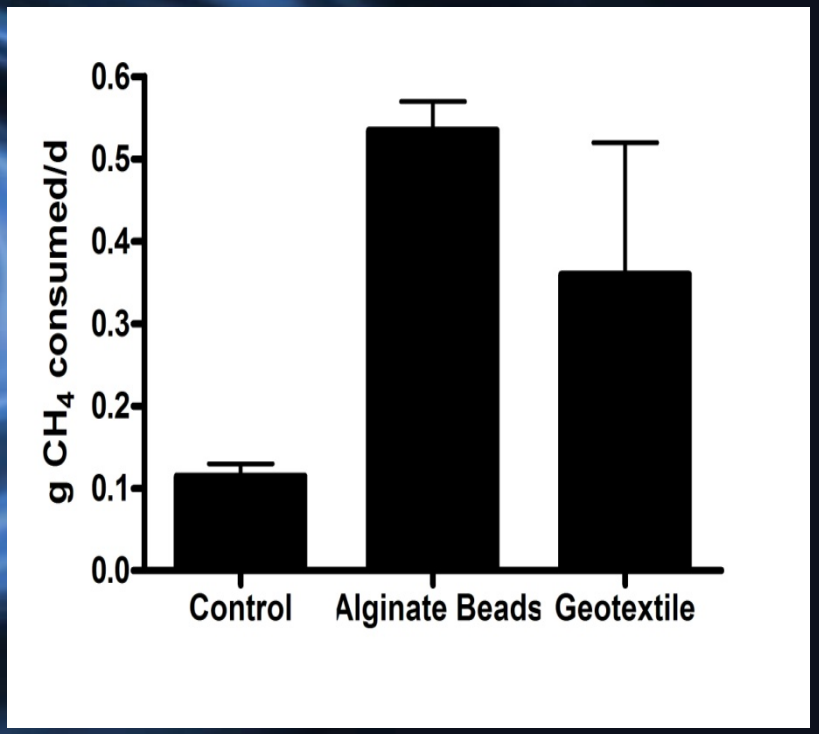
Adsorption

- Based on methane oxidation studies and the feasibility of use in field application, only the non-woven geotextile was included for further consideration.
- A stability assay was used to assess the strength of cell attachment by shaking samples for up to 5 hours and examining the methane uptake after 24 hours in a methane headspace.
- A 70% decrease in activity relative to controls was observed after 1 hour of washing.
- No further loss of activity was detected after 1 hour.



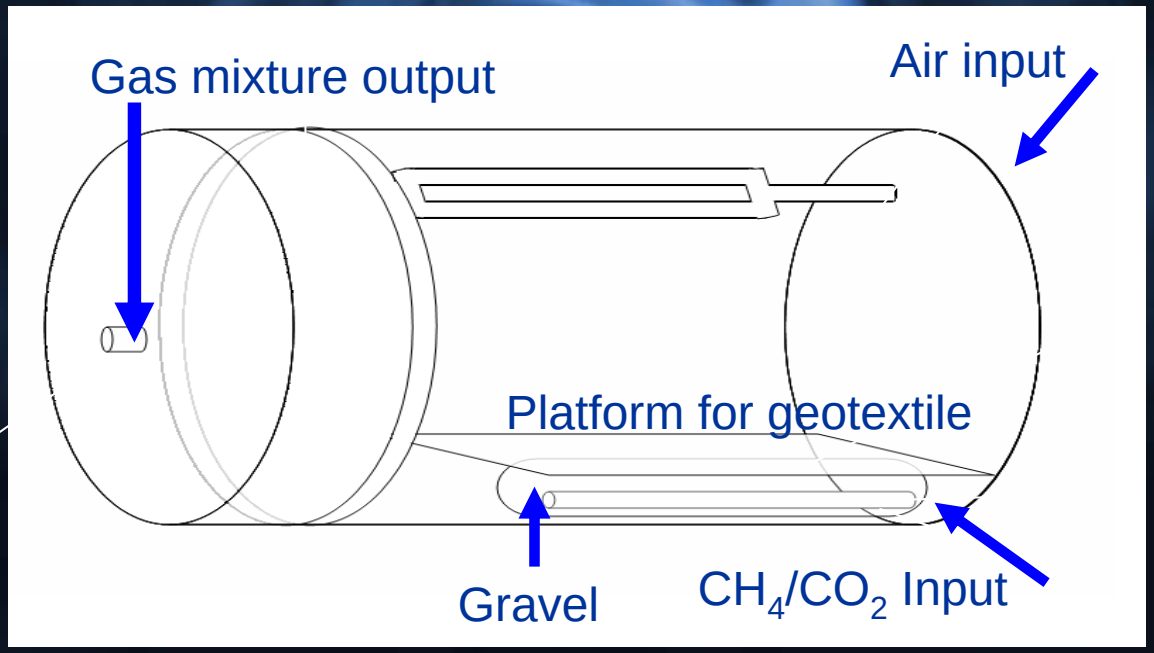
Encapsulation

- Alginate beads: 10% mixed methanotrophic cell beads had a methane oxidation rate similar to cells adsorbed to the geotextile
- Liquid core gel capsules: Much lower methane oxidation rate than alginate beads or adsorbed cells
- Both encapsulation products were highly susceptible to dehydration and were resistant to re-hydration.



Continuous Flow Chambers

- Used to simulate the movement of landfill gas under laboratory conditions



Continuous Flow Chambers

Biotarp Prototype

- Using the continuous flow chamber, testing of several prototypes is in progress.
- Thickness "goal" is less than 2 cm.

Project timing:

Year 1 (this paper): screening of prospective materials, development of techniques to embed methanotrophs, static and dynamic laboratory testing

Year 2: field trials of one or two prototype bio-tarps with complementary laboratory testing, modeling

Year 3: complete field and laboratory testing of prototype(s), recommendations for future work and commercial development

Questions?

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