Landfill Biocell: Cost-effective Technology to Achieve Sustainability of Landfill Operations

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Key message(s)

- Waste landfill cells could be operated **in a "sustainable" manner** (but need a paradigm shift in philosophy, design and operation) – **third "generation" of waste cell operation**

- Some work is needed for **system optimization** and to convince operators and regulators

Background – first generation landfills

- Conversion of Open Dumps to "Sanitary Landfills"
  - First Generation Landfill – operate a cell as a "Dry-tomb waste cell" to control groundwater contamination
    - Keep water away from waste
    - Leachate management

"Dry-tomb waste cell" is a large Anaerobic Bioreactor in which waste degrades very, very slowly

Background: second generation landfill

- Second Generation – Landfill Bioreactor operation
  - Recirculation of leachate
  - Increased amounts of water and recirculation of nutrients and microbes result in rapid waste degradation rates
  - **Landfill gas recovery for production of energy becomes a viable option; both economically and environmentally**

Possible to operate Landfill Bioreactors in both Anaerobic and Aerobic modes

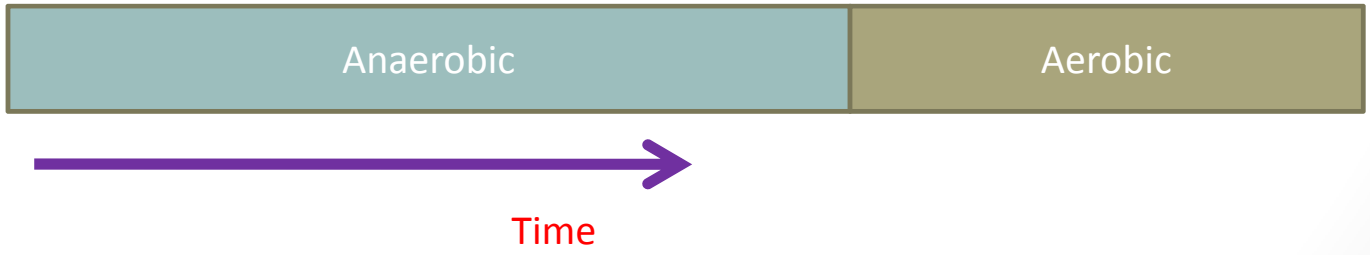
Third Generation – Sustainable Landfills or Biocells

- Rapid degradation and stabilization
- Energy recovery
- Recovery of Resources and Space

These goals are achieved with a combination of Anaerobic and Aerobic Bioreactor Operation and cell Mining

Biocell concept

- Cell operate under **Anaerobic** conditions for few years, when Energy recovery is economically viable
- Then the cell is operated under **Aerobic** conditions for shorter duration to allow faster stabilization
- The Cell is then **Mined** to recover space and materials.
- The Cell converted to an in-ground “waste processing facility” instead of a “perpetual storage facility”.



Some barriers to Biocell implementation

- Technical: Some of the organic materials are not biodegradable (later stages of waste degradation)
  - Presence of Lignin
    - Long-chain organic polymers
    - Increases the difficulty of organic waste degradation
- Regulatory: Lack of accurate method to quantify landfill methane potential (common BMP method may not represent landfill scenario)

Lignin degradation in Biocells

- In nature, white-rot and brown-rot fungi produce enzymes that breakdown lignin
- In Biocells, recirculate leachate could be enhanced with enzymes to degrade lignin that would allow access to entrapped nutrients
  - True lignin degraders
    - Lignin Peroxidase (LiP)
    - Manganese Peroxidase (MnP)

Comparison of enzyme types - Batch Experiments

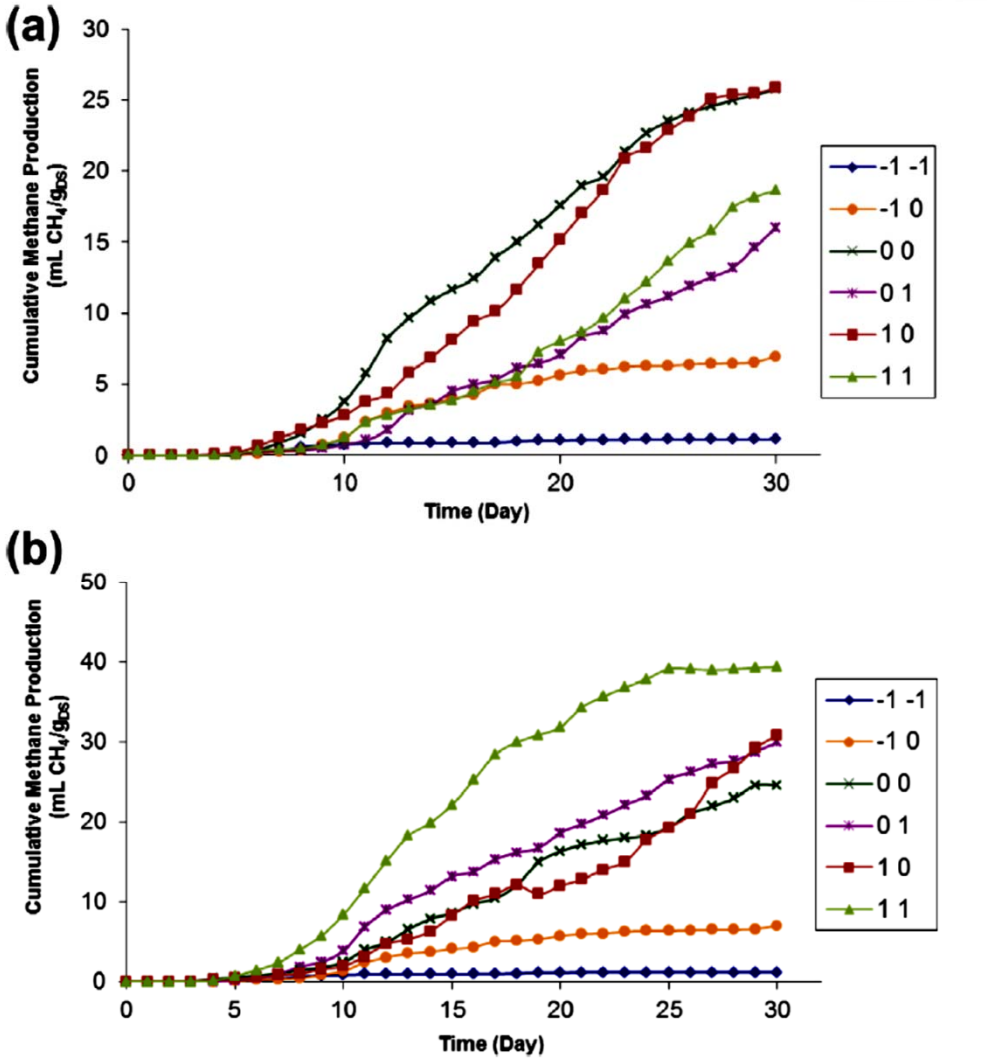
- Factors and Levels
  - Enzyme type
  - Enzyme dose - 3 doses
  - Hydrogen Peroxide (enzyme activator) - 3 doses

- Two enzyme types: LiP and MnP
- Partially degraded waste used in 1 L glass bottle reactors
- Response variable: methane and carbon dioxide gas production

Results - Anaerobic

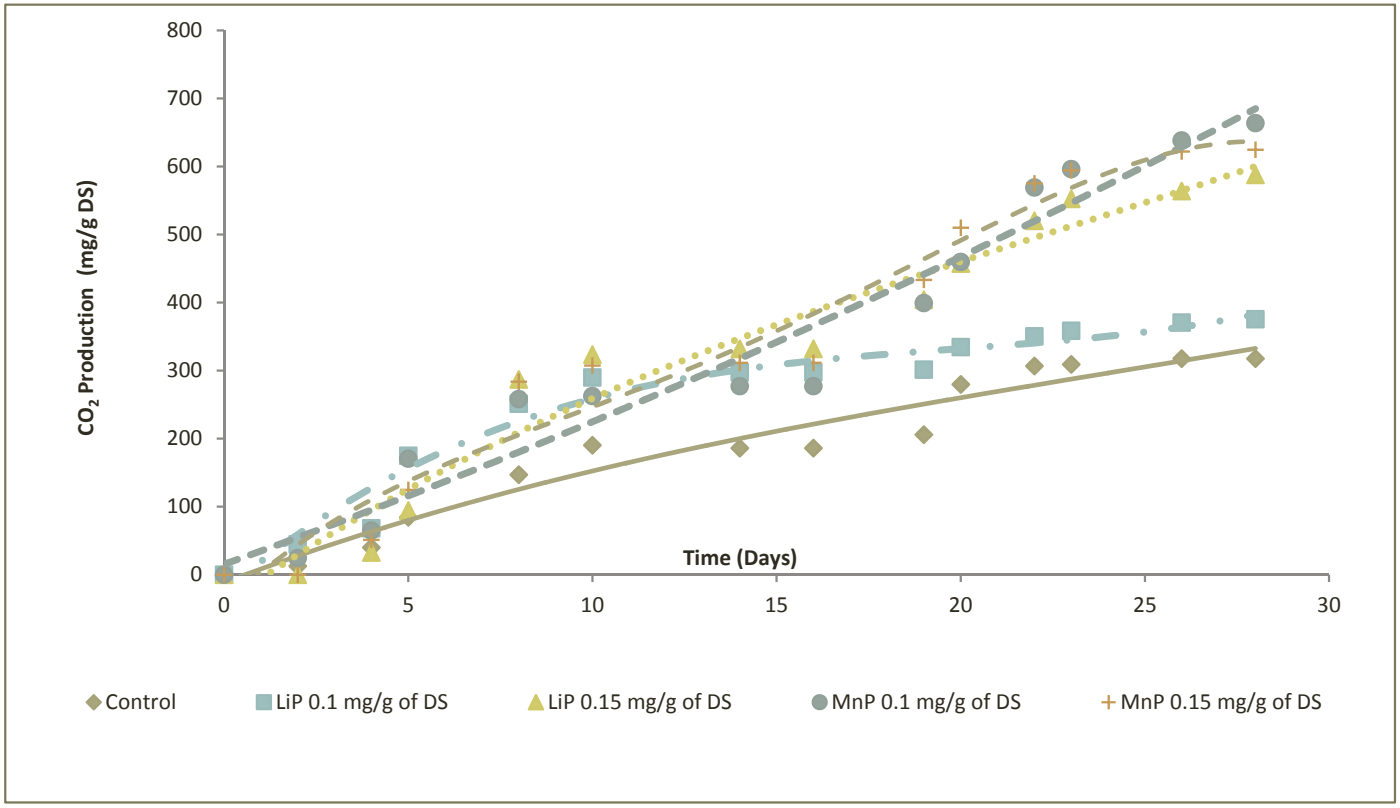
Factors		Treatment Levels		
		-1	0	1
A	Enzyme Dose (mg/g_{DS})	0	0.08	0.16
B	H_2O_2 Dose (mL/g_{DS})	0	0.01	0.02

MnP showed better results



Cumulative CH_4 yield under anaerobic conditions (a) LiP enhancement (b) MnP enhancement.

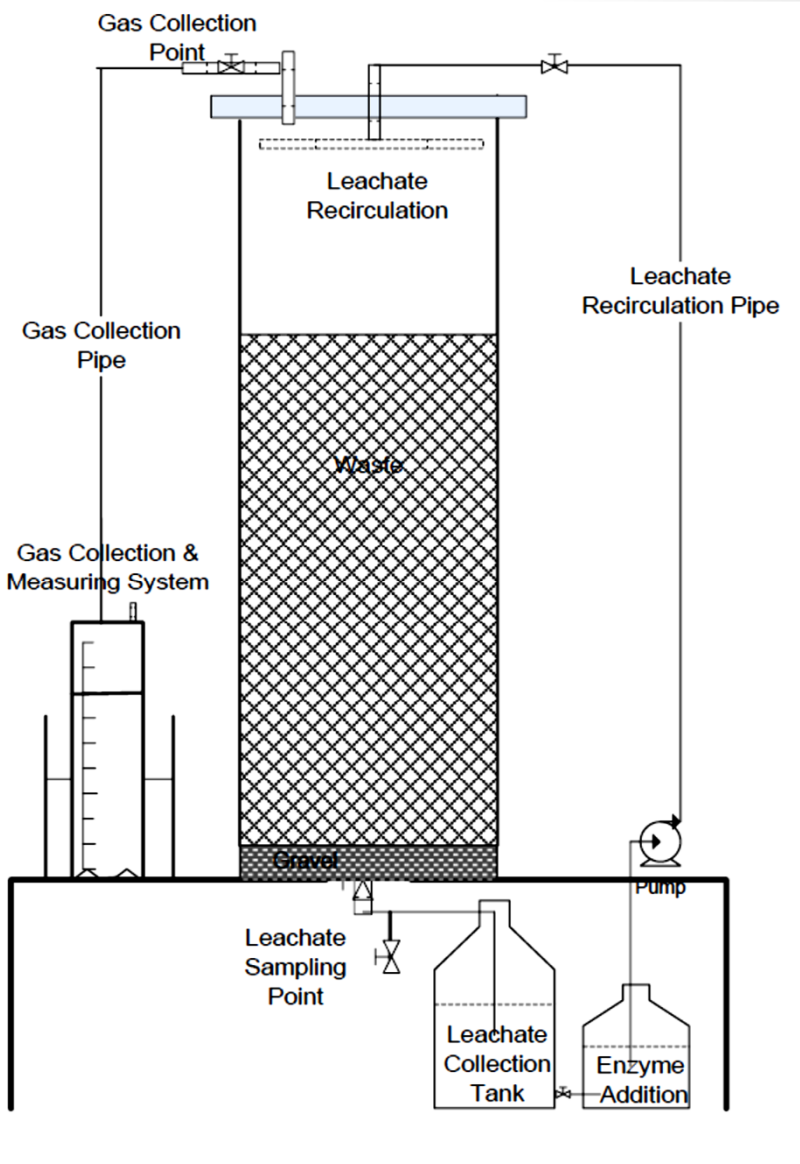
Results – Aerobic



MnP showed better results

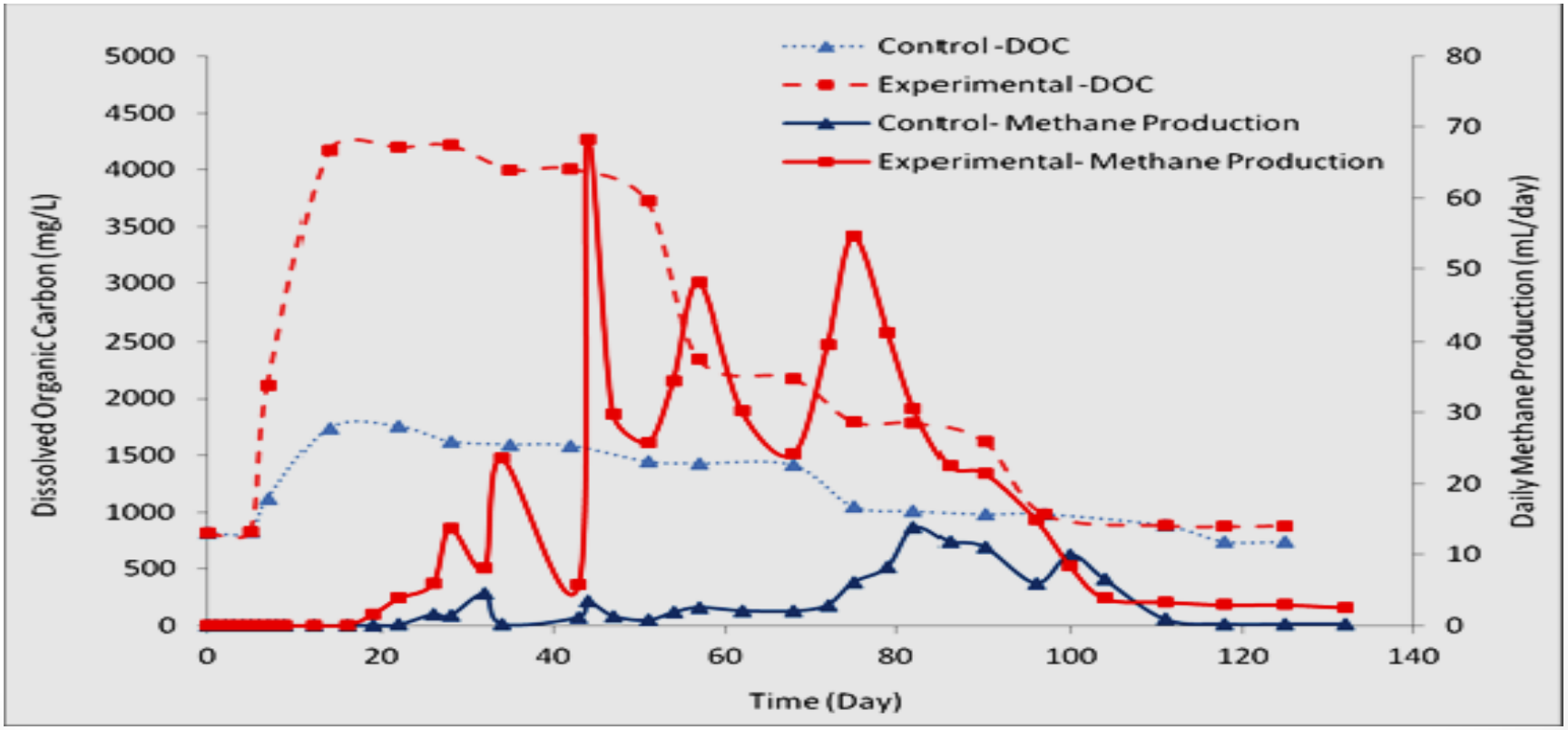
Flow-through column experiments

Anaerobic bioreactor simulation



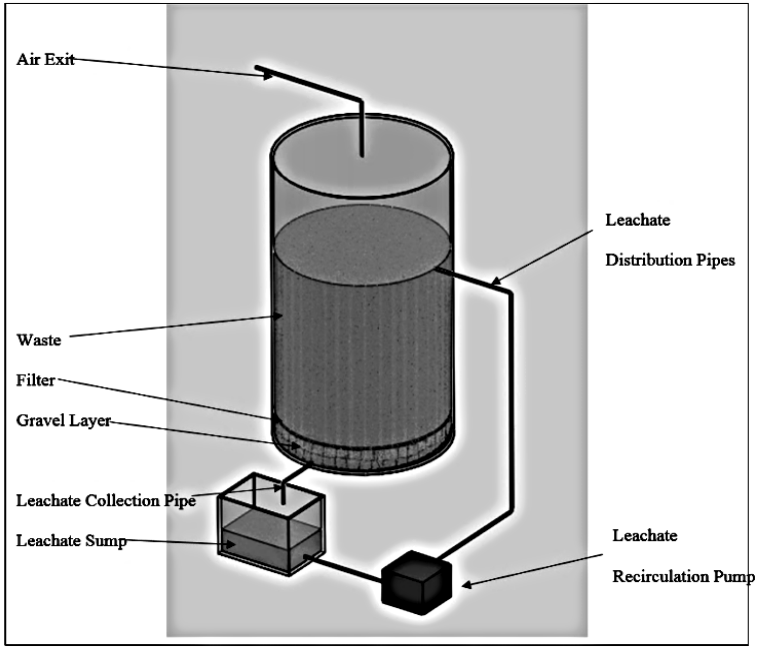
Column experimental results - Anaerobic

- Addition of MnP increased dissolved organic carbon (DOC) levels and daily methane gas production rates



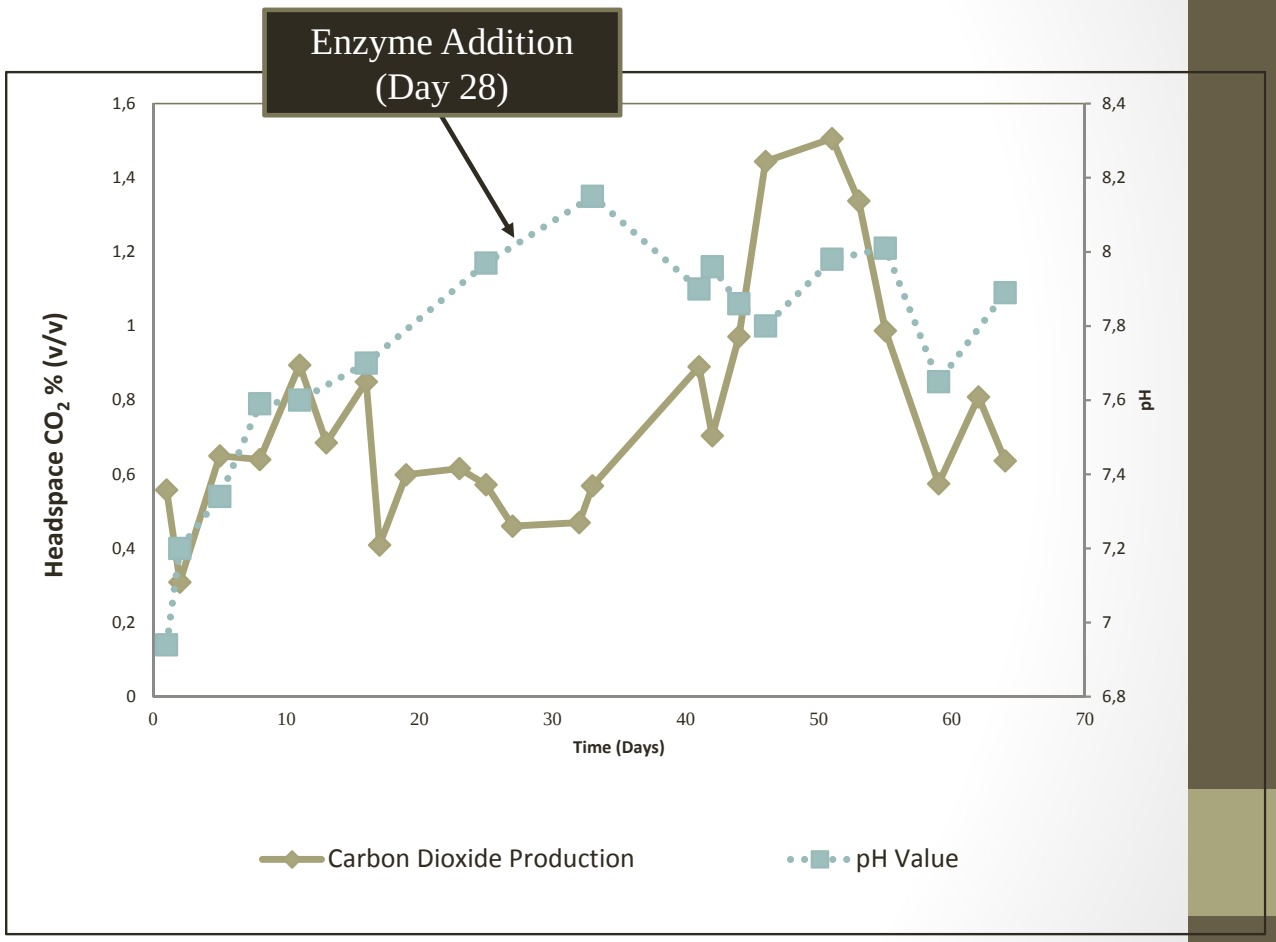
Lysimeter experiments – Aerobic

- Lysimeter experiments (in scaled down version of a waste cell)



Lysimeter experimental results - Aerobic

- Enzyme addition:
  - Increased biodegradability and CO_2 Production
  - Increased rate of hydrolysis

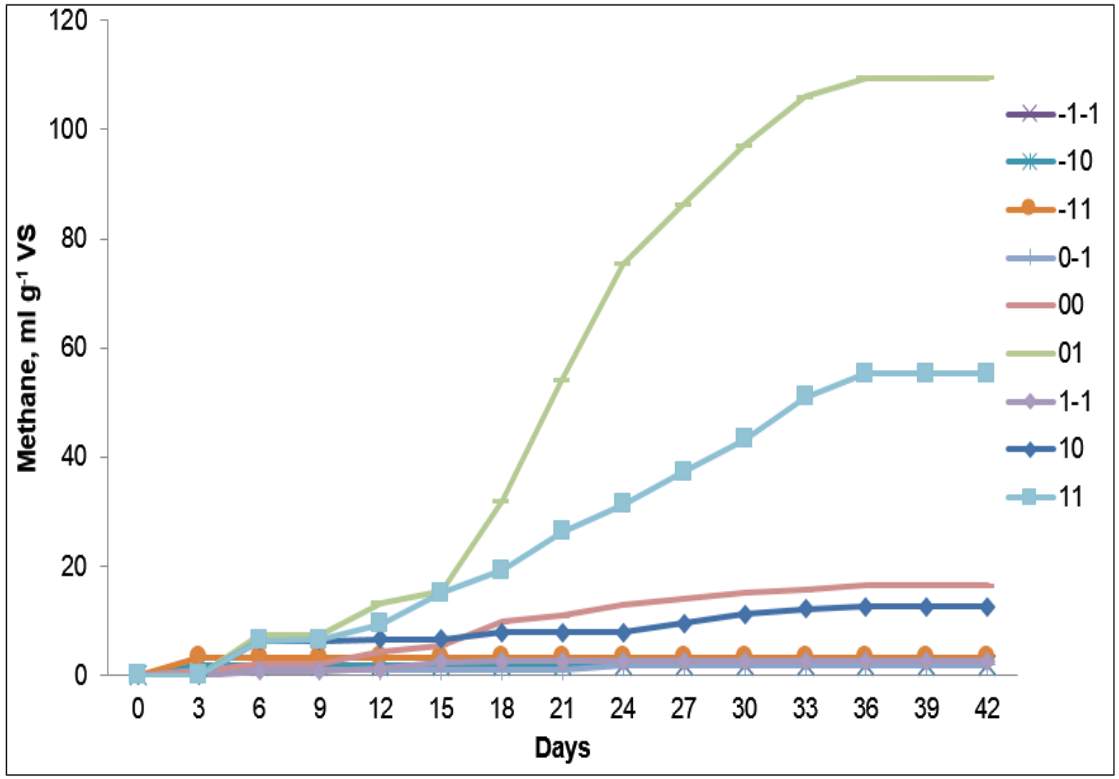


Problems with conventional BMP method

- Bio-methane potential (BMP) method is used as a measure of landfill methane generation potential (ultimate gas generation potential, Lo) because the use of theoretical calculations over-estimate the Lo.
- BMP method uses a batch experimental protocol; results vary due to different experimental conditions; nutrients, inoculum.
- The conventional BMP assay originally developed for anaerobic degradation of wastewater sludge; slurry-phase.
- Not considered: heterogeneous nature of solid waste, non-ideal (low moisture) conditions in a landfill environment.

BMP method development – early results

- Batch experiments conducted to study the effects of:
  - Inoculate to substrate ratio
  - Moisture content



Variables		Levels		
		-1	0	1
A :	Inoculum to substrate ratio (I/S)	1	2	4
B :	Moisture content (%)	100	200	400

BMP method development – early results

- The theoretical ultimate methane potential (Lo_{th}) was estimated as 466 m^3 per tonne of waste volatile solids (WVS), if all the WVS are biodegradable.
- The maximum observed ultimate methane potential (Lo_{exp}) from BMP assay was 113 m^3 per tonne of the WVS.
- Overall, the experimental methane yields were substantially lower than the theoretical values.

Conclusions

- Addition of manganese peroxidase increases waste degradation rates; both under anaerobic and aerobic modes of operation.
  - Increases methane production rates
  - Accelerates waste stabilization during aerobic landfill bioreactor operation
- Theatrical calculations and conventional BMP method overestimate the methane generation potential. Further work required to develop a BMP method applicable in landfill situations.

Overall effect of enzyme enhancement

- Biocell without enhancement

- Biocell with anaerobic enhancement

- Biocell with aerobic enhancement

- Biocell with anaerobic and aerobic enhancement

THANK YOU!