

**Waste Management Association  
of Australia  
NSW Branch**

**Passive Drainage and Biofiltration of  
Landfill Gas: Findings of Australian Research**

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# Acknowledgements

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# Outline

- ✿ Background
- ✿ Methane oxidation
- ✿ Passive drainage and biofiltration of landfill gas concept
- ✿ Research activities
  - ✿ Kelso Landfill field scale trial
  - ✿ Horsley Park field scale trial
  - ✿ Horsley Park pilot scale field trial
- ✿ Results
- ✿ Conclusions and recommendations
- ✿ Future activities

# Background

- ✿ In 2004/05 there were ~ 400 active landfills in NSW
- ✿ 287 of these receive < 5,000 t/yr
- ✿ Only 14 receive > 100,000 /yr  
(receive ~65% of all waste landfilled)
- ✿ 25 receive > 60,000 t/yr  
(receive ~ 75% of all waste landfilled)

# Background

- ✿ WMAA National Landfill Survey 2005
- ✿ Only 30 – 40% of landfills > 100,000 t/yr have active gas collection and flaring or energy recovery
- ✿ Only 6% of landfills < 50,000t/yr have active gas extraction and flaring
- ✿ Many (most) landfills do nothing to capture and treat landfill gas
- ✿ In 2003 landfill gas emissions were estimated to be 8 Mt (CO<sub>2</sub>-equiv) or 1.5% of Australia's total greenhouse gas emissions

# Background

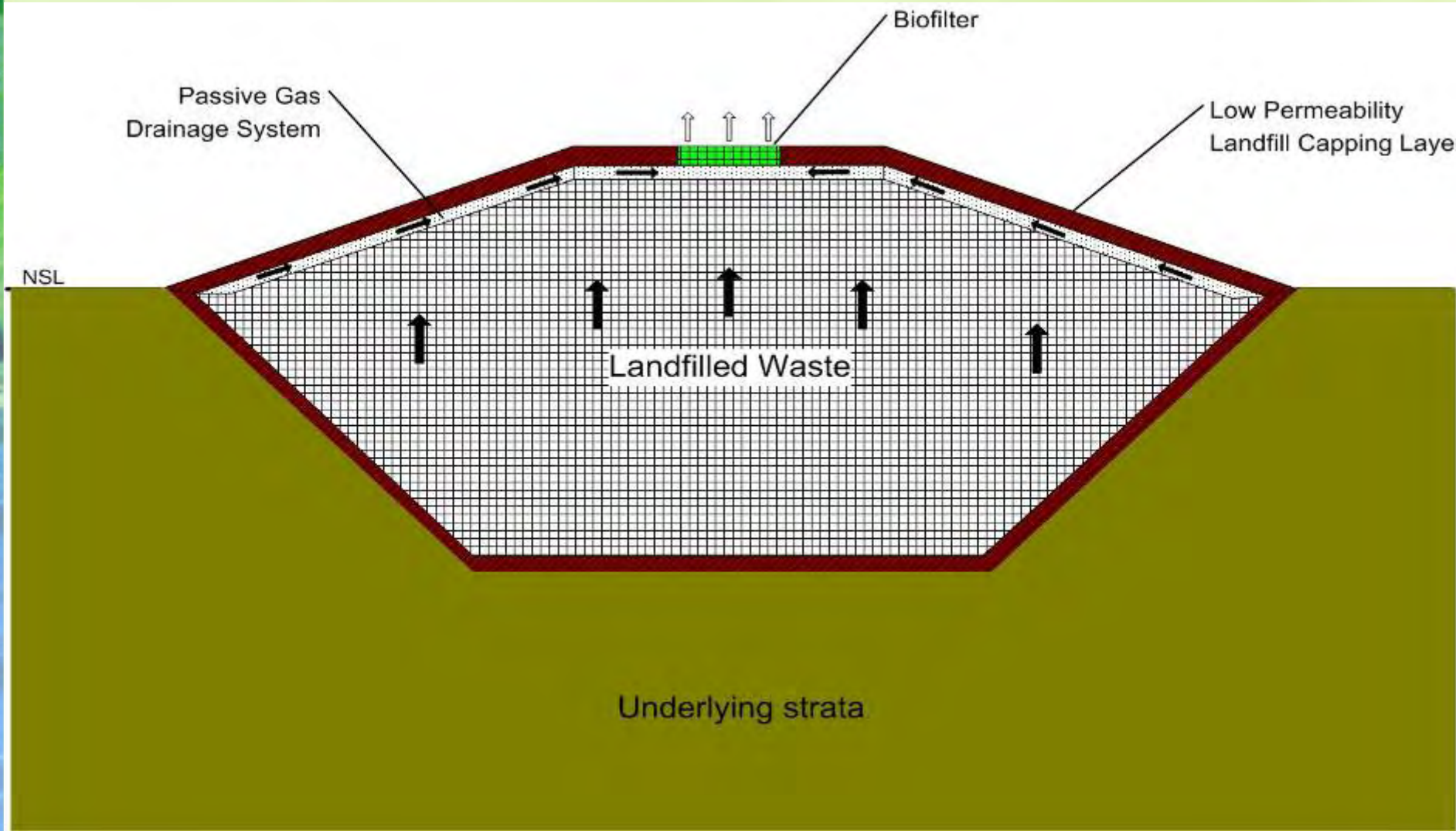
- ✿ Landfill gas emissions have not been considered an environmental issue
- ✿ Active extraction and flaring of landfill gas is costly (capital and operating costs) and ongoing after landfilling revenues have ceased
- ✿ Active extraction of landfill gas energy recovery (electricity generation) is only commercially viable at large landfills (typically >100,000t/yr)
- ✿ Until recently, there have been few other options for treating landfill gas

# Research Goal

- ✿ Identify, evaluate and develop an alternative, cost effective approach for reducing methane emissions at low to moderate gas generating landfills:
  - ✿ Small to medium size putrescible waste landfills  
eg. rural / regional landfills
  - ✿ Non-putrescible waste landfills
  - ✿ Inert waste landfills
  - ✿ Old / closed landfills



# Passive Landfill Gas Drainage and Biofiltration Concept






# Microbial Oxidation of Landfill Gas

- ✿ Methane is readily consumed by microbes (methanotrophs) in the presence of oxygen, under favourable conditions
- ✿ Methane is oxidised:  
$$\text{CH}_4 + \text{O}_2 + \text{nutrients} \Rightarrow \text{Biomass} + \text{CO}_2 + \text{H}_2\text{O}$$
- ✿ Methanotrophs - commonly found throughout the natural environment
- ✿ Process dependent on many factors eg. methane and oxygen supply, temperature, moisture content, nutrient supply

# Other Approaches Involving Microbial Methane Oxidation

## Biocovers

-  Daily cover
-  Intermediate cover
-  Final cover

## Biotarp

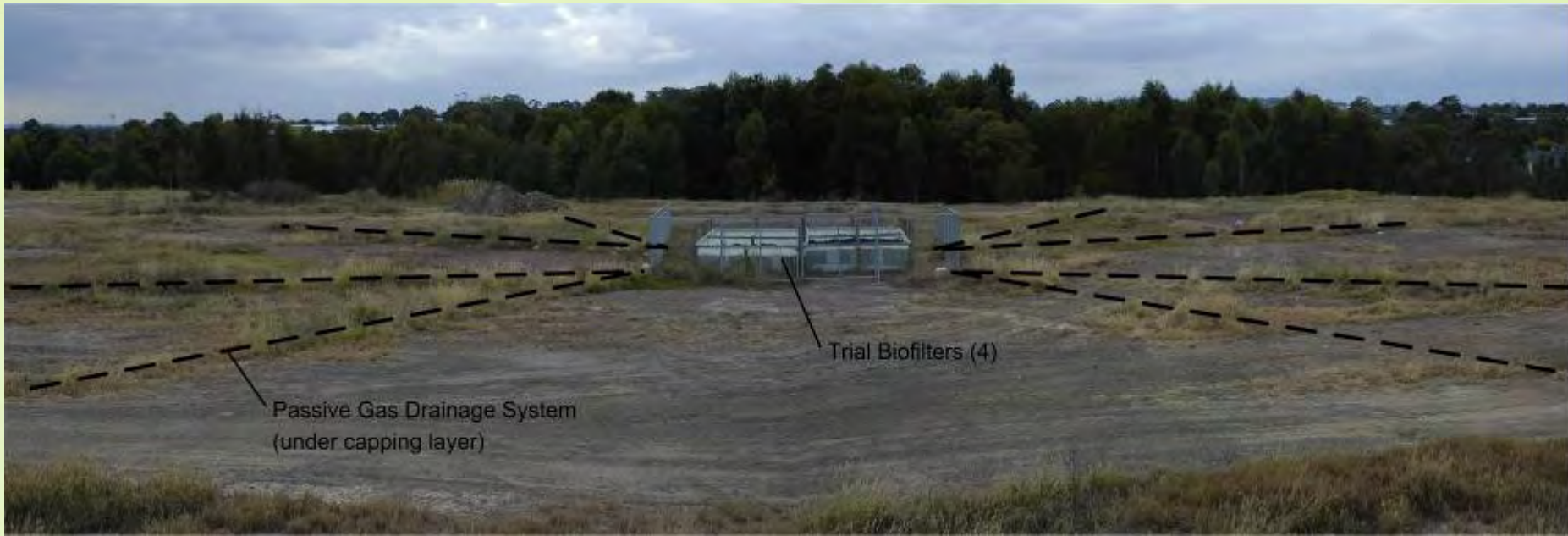
## Active gas extraction and biofiltration

# Australian Field Trials

- ✿ Kelso Landfill passive gas drainage and biofiltration trial (Sept 2004 - ongoing)
- ✿ Horsley Park landfill gas interception and biofiltration wall trial (2005/06)
- ✿ Horsley Park landfill gas loading trial (Jul 2006 – ongoing)

# Kelso Landfill Trial

- ✿ 4 separate passive drainage and biofiltration systems
- ✿ 4 different organic media (composted garden organics, MSW, and shredded wood)
- ✿ Recycled concrete and brick aggregate used in gas drainage system
- ✿ Constructed: September 2004
- ✿ Monitored: October 2004 - ongoing



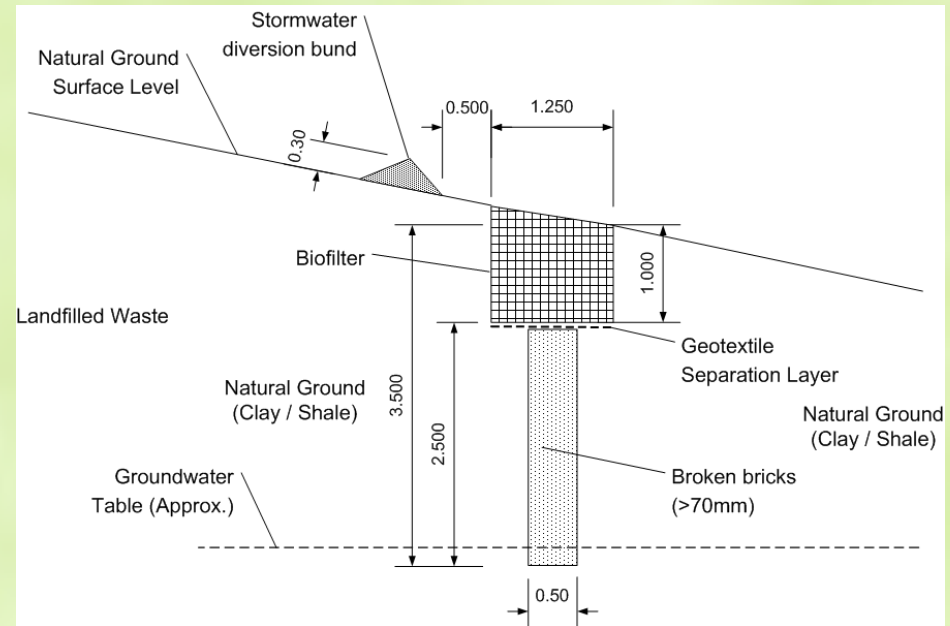


# Kelso Landfill Trial: Completed Trial Biofiltration System



# Horsley Park Trial

- ✿ Passive gas interception trench and biofilter
- ✿ Biofilter media: composted garden organics + shredded wood
- ✿ Recycled bricks and pavers used in gas drainage system
- ✿ Constructed: June 2005
- ✿ Monitored: June 2005 – March 2006



# Horsley Park Trial

- ✿ Full scale system constructed October 2006



# Landfill Gas Loading Trial

## ✿ Project Objectives:

- ✿ Confirm the effect of landfill gas / methane loading on biofilter behaviour and performance
- ✿ Better understand the effect of climatic conditions (temperature and moisture) on biofilter behaviour and performance



# Landfill Gas Loading Trial

- ✿ 4 separate pilot scale biofilters
- ✿ Loaded at different rates (0.5 – 35 g CH<sub>4</sub>/m<sup>2</sup>/hr)
- ✿ Bottled methane and carbon dioxide was used
- ✿ Biofilter media: composted garden organics + shredded wood



# Landfill Gas Loading Trial

- ✿ Constructed: August 2006
- ✿ Monitored: September 2006 – ongoing



# Landfill Gas Loading Trial - Challenges

- ✿ Goats and cows
- ✿ Bird nests in biofilter
- ✿ Snakes !!!



# Monitoring Data

- ✱ Landfill gas loading (flow and composition)
- ✱ Landfill gas pressure
- ✱ Methane concentration profiles
- ✱ Carbon dioxide concentration profiles
- ✱ Methane / carbon dioxide ratio profiles
- ✱ Oxygen concentration profiles
- ✱ Nitrogen concentration profiles
- ✱ Temperature profiles
- ✱ Surface emissions / flux (methane and carbon dioxide)
- ✱ Methane oxidation rate (% of load & g CH<sub>4</sub>/m<sup>2</sup>/hr)
- ✱ Rainfall infiltration and drainage
- ✱ Moisture content profiles
- ✱ Settlement
- ✱ Microbial activity
- ✱ Climatic conditions

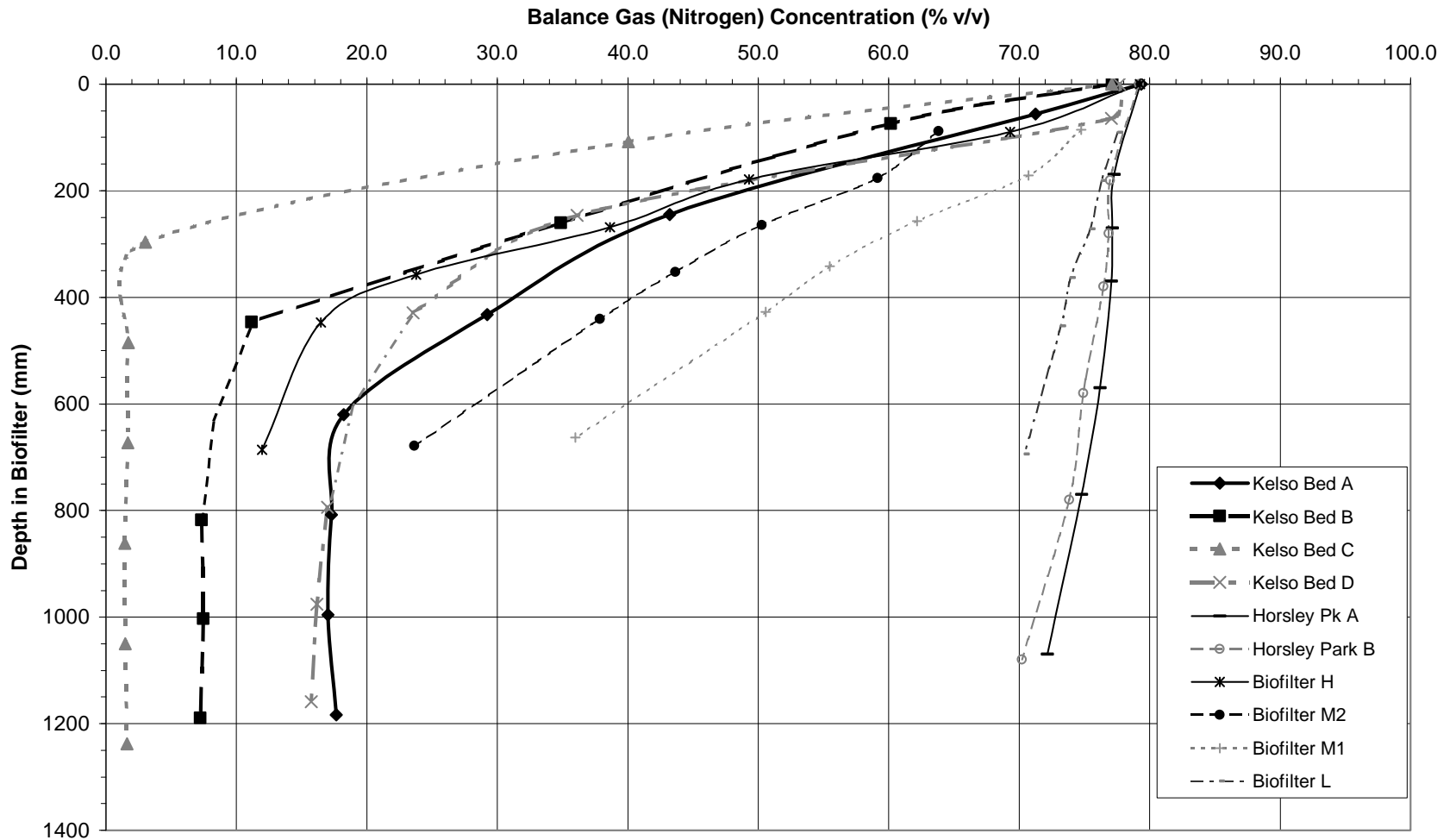
# Data Analysis

- ✱ Effect of landfill gas / methane loading rate:
  - ✿ Gas composition profiles
  - ✿ Biofilter temperature
  - ✿ Microbial activity
  - ✿ Biofilter performance
- ✱ Effect of atmospheric temperature:
  - ✿ Biofilter temperature
  - ✿ Microbial activity
  - ✿ Biofilter performance
- ✱ Effect of microbial activity:
  - ✿ Biofilter temperature
  - ✿ Oxygen concentration profiles
- ✱ Effect of climate on biofilter moisture content
- ✱ Effect of moisture content:
  - ✿ Microbial activity
  - ✿ Biofilter performance

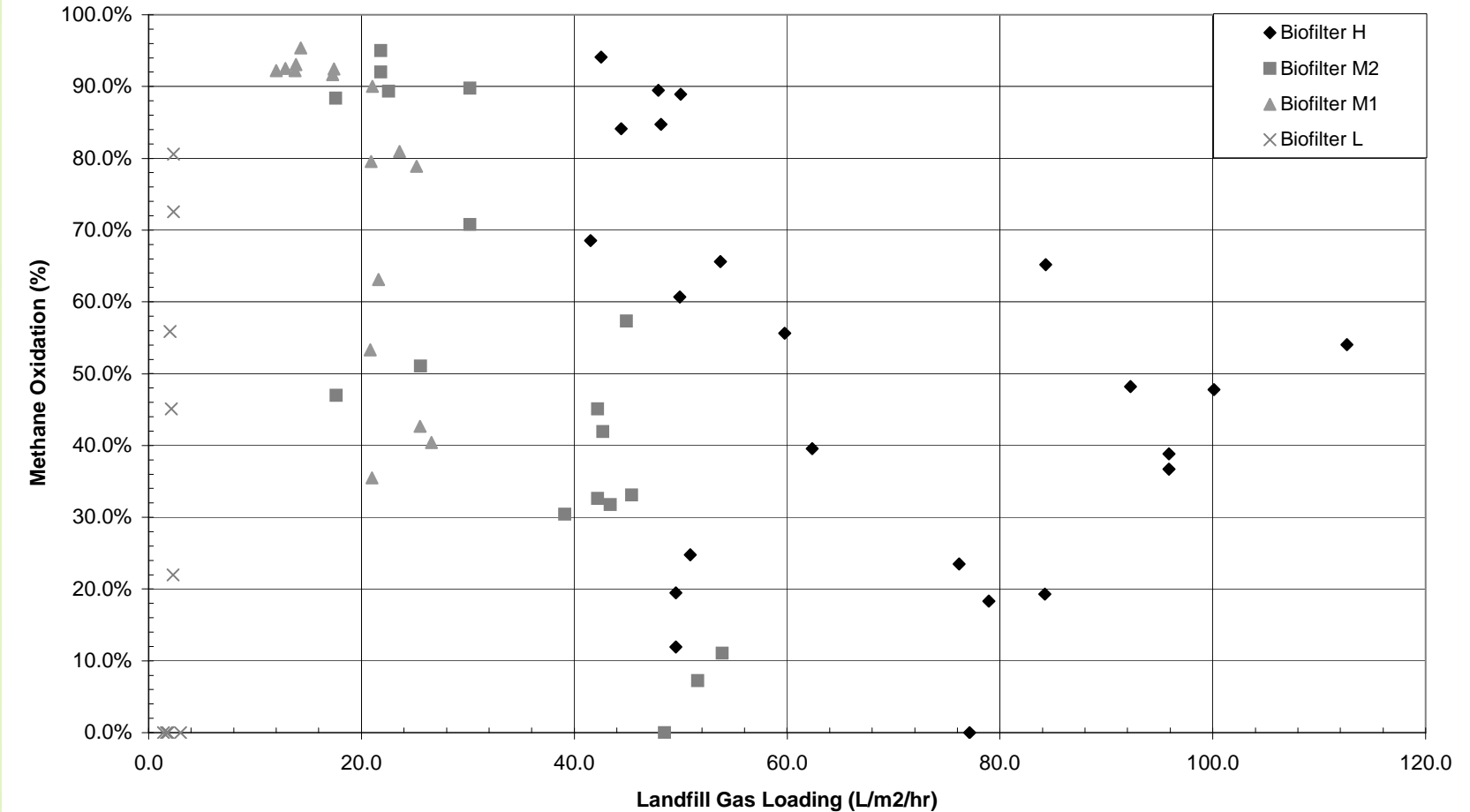
# Overall Findings

- ✿ IT WORKS!!!
- ✿ A passive drainage and biofiltration system can effectively collect and treat landfill gas
- ✿ Methane oxidation rates greater than 90% can be achieved
- ✿ Behaviour and performance of a passive biofilter is dependent on 3 primary factors:
  - ✿ Landfill gas /methane loading rate
  - ✿ Temperature of the biofilter media
  - ✿ Moisture content of the biofilter media

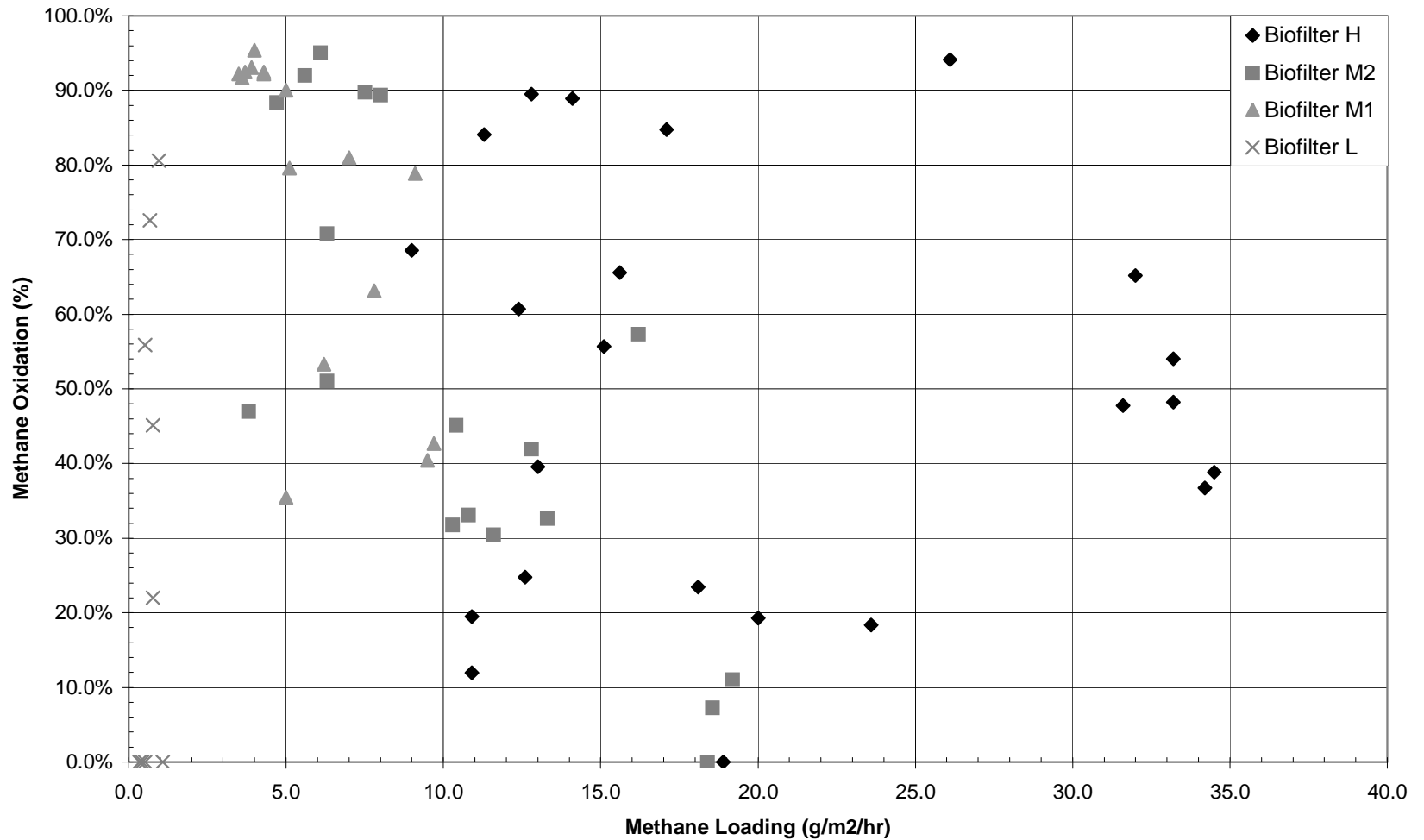
# Effect of Loading Rate on Atmospheric Gas Penetration into a Passive Biofilter



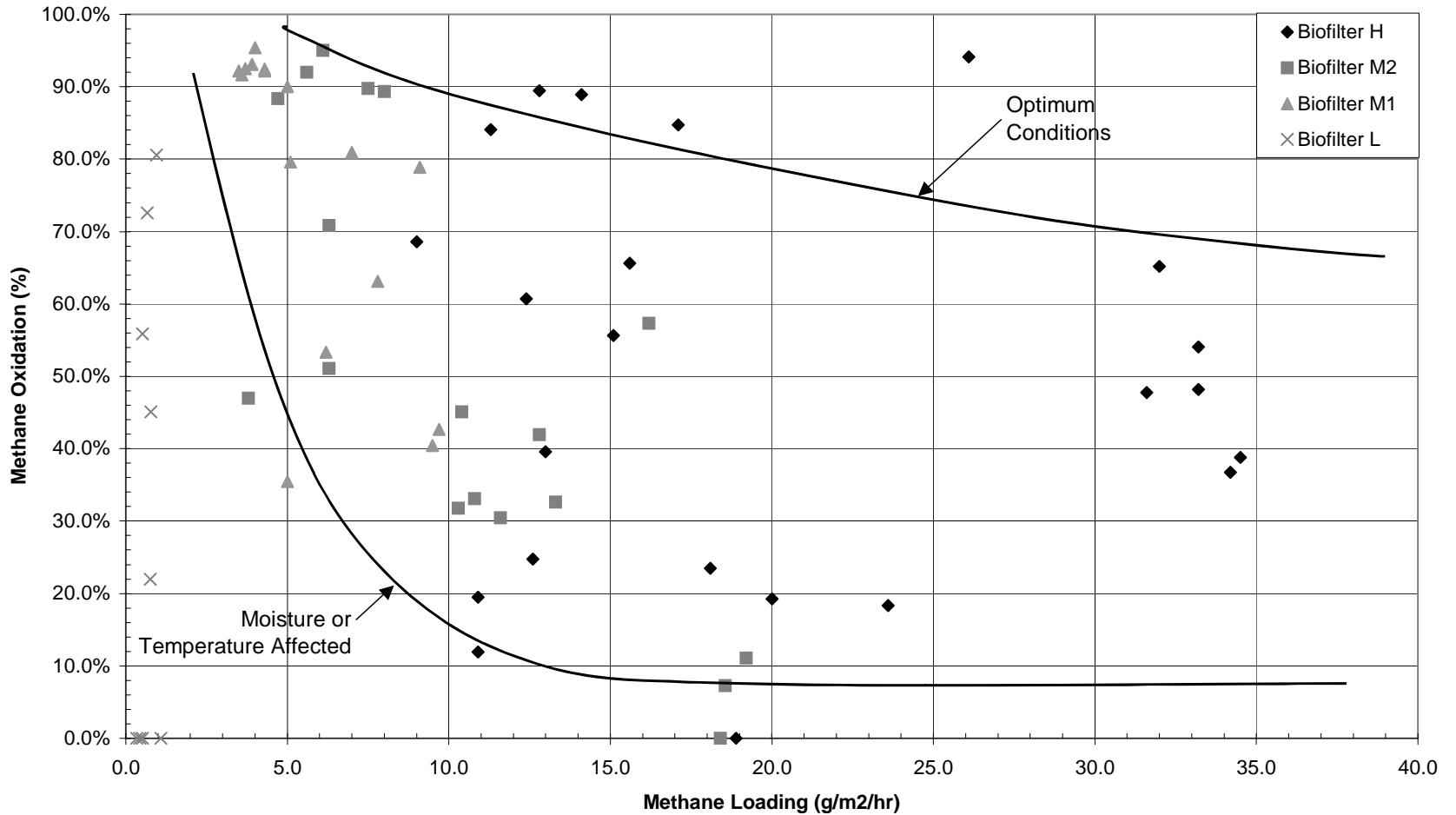
# Effect of Landfill Gas Loading on Biofilter Performance



# Effect of Methane Loading on Biofilter Performance



# Effect of Methane Loading on Biofilter Performance

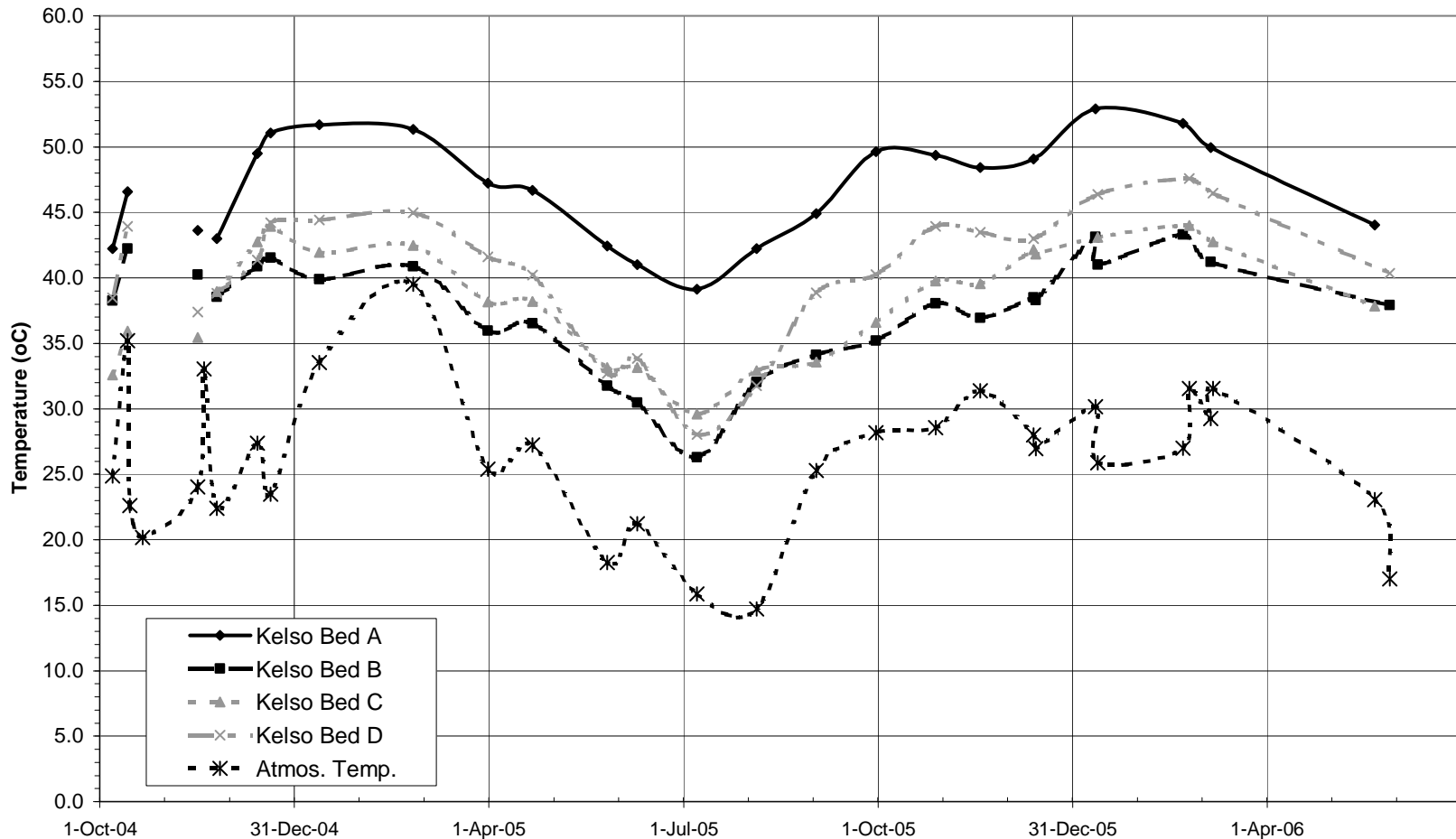




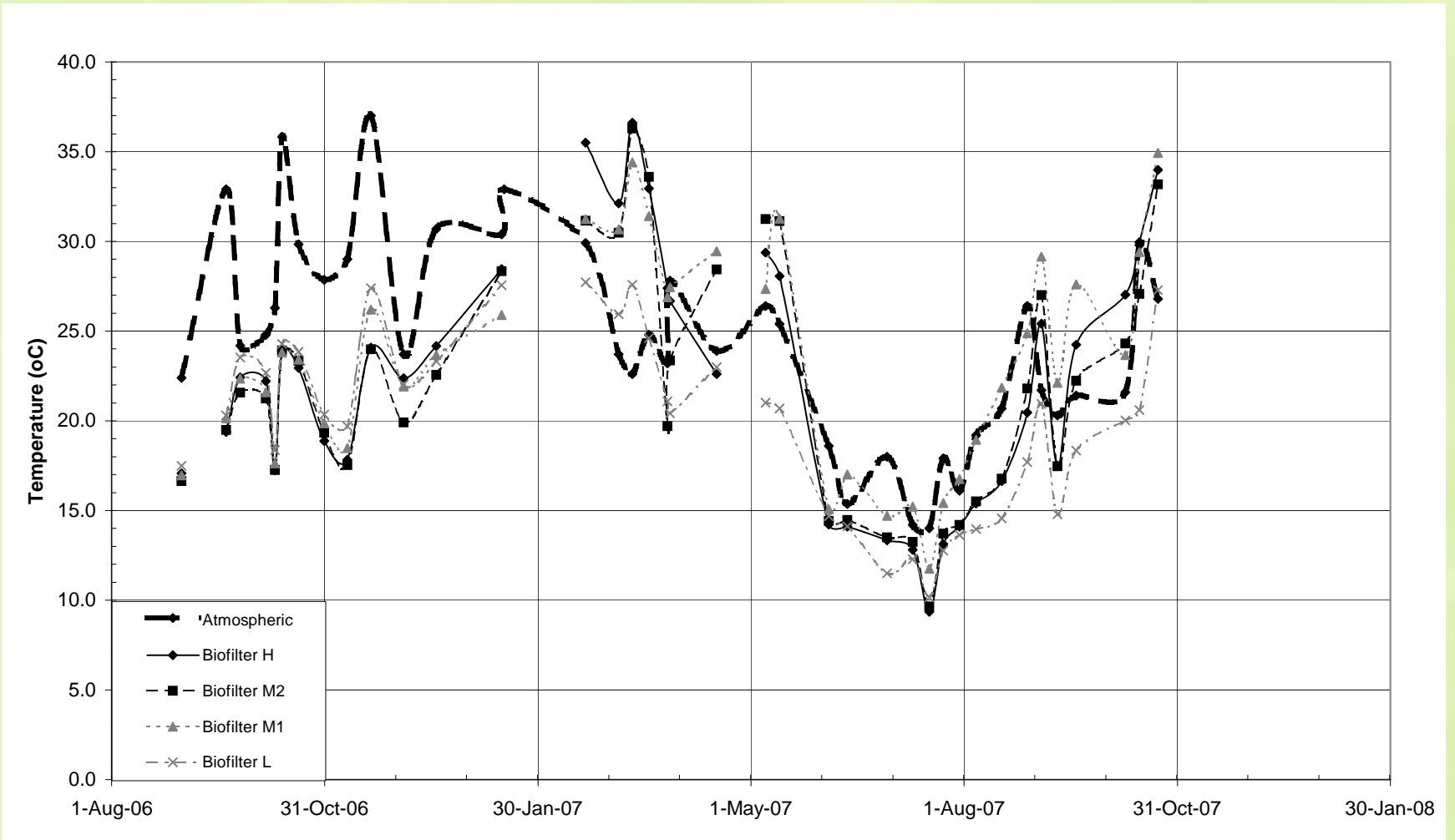
# Factors that Affect Biofilter Media Temperature

- ✿ Atmospheric temperature
- ✿ Landfill gas temperature
- ✿ Microbial activity
- ✿ Thermal properties of the biofilter media

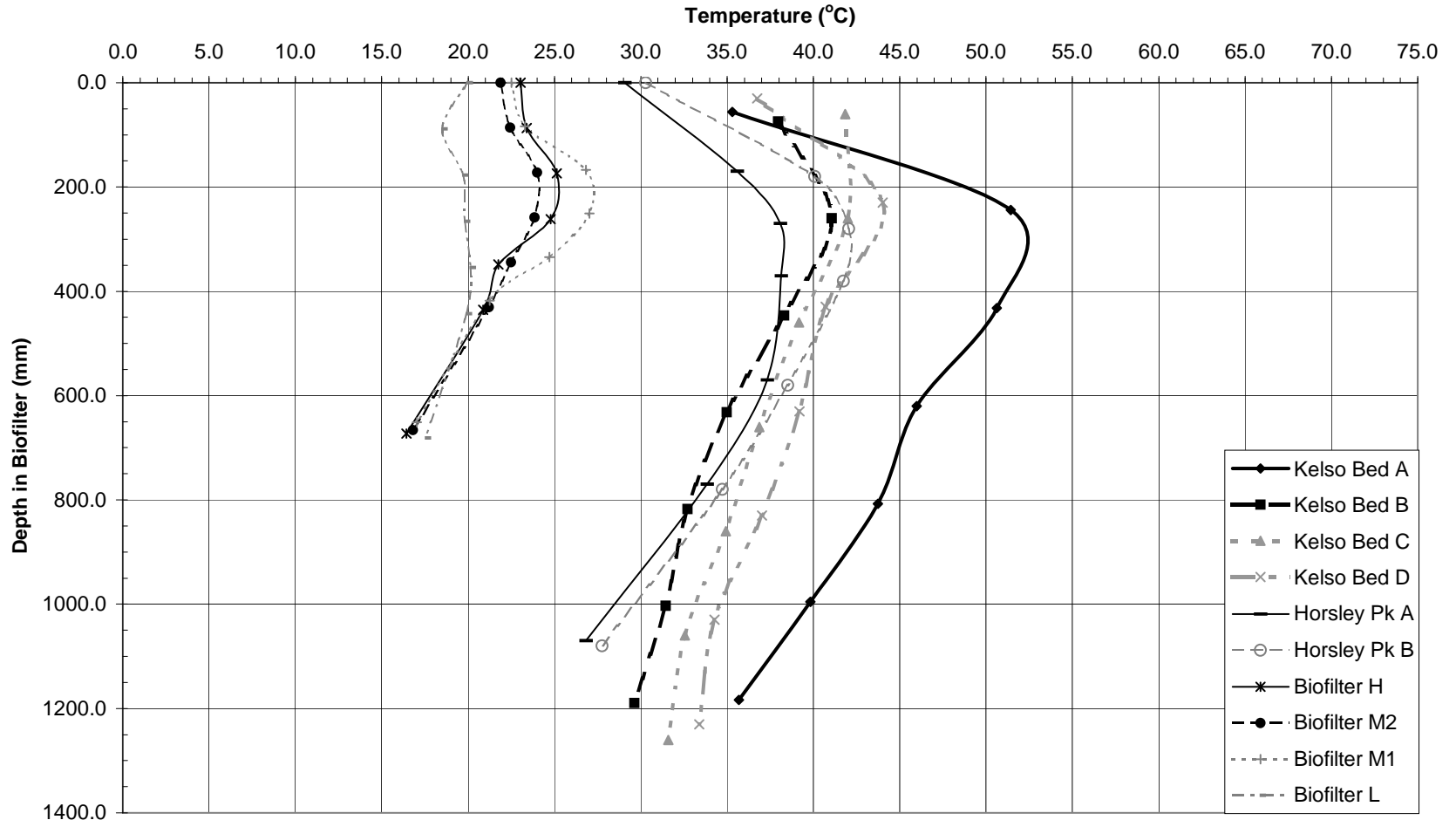
# Effect of Atmospheric Temperature on Kelso Trial Biofilter Temperature



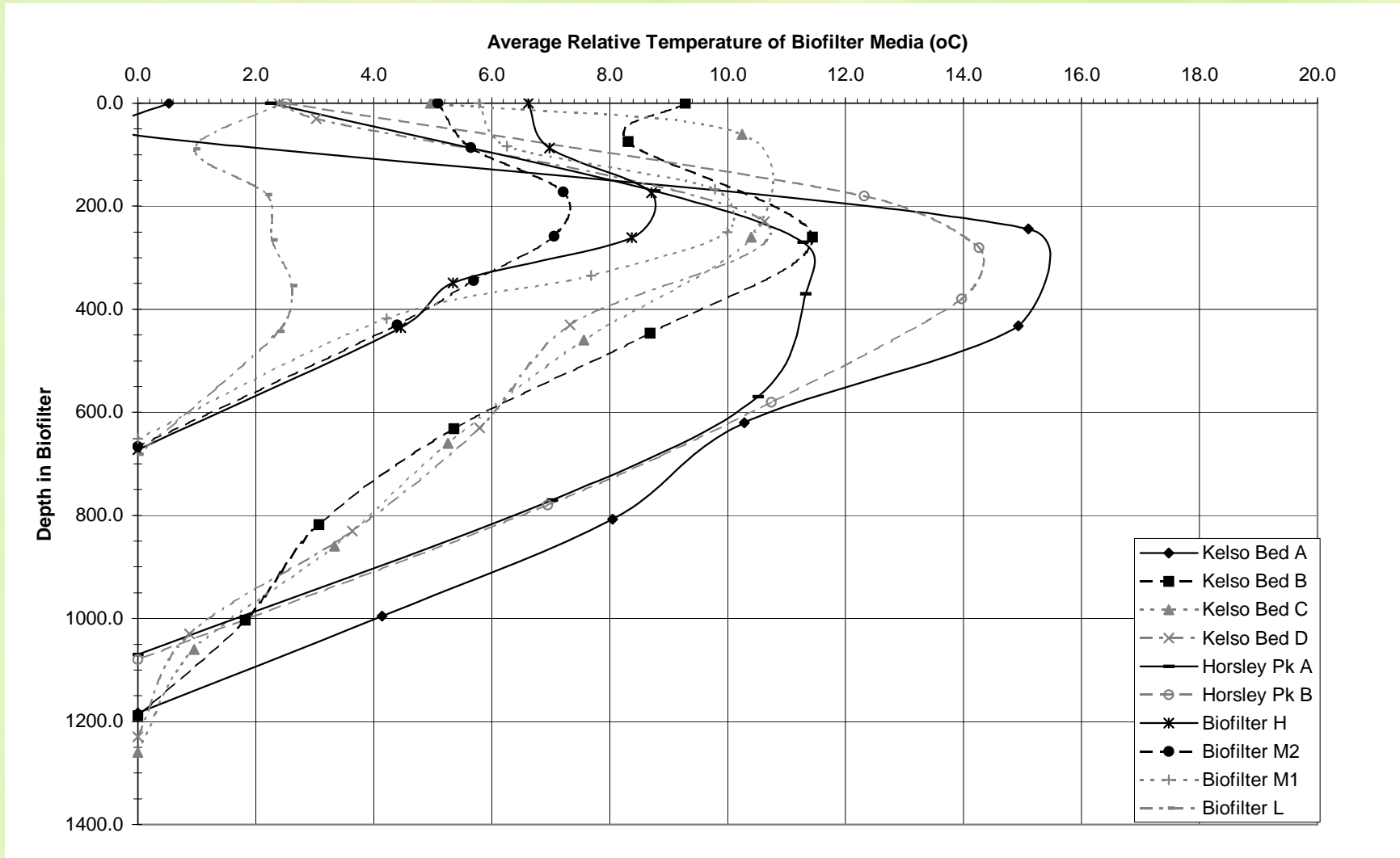
# Effect of Atmospheric Temperature on Landfill Gas Loading Trial Biofilter Temp



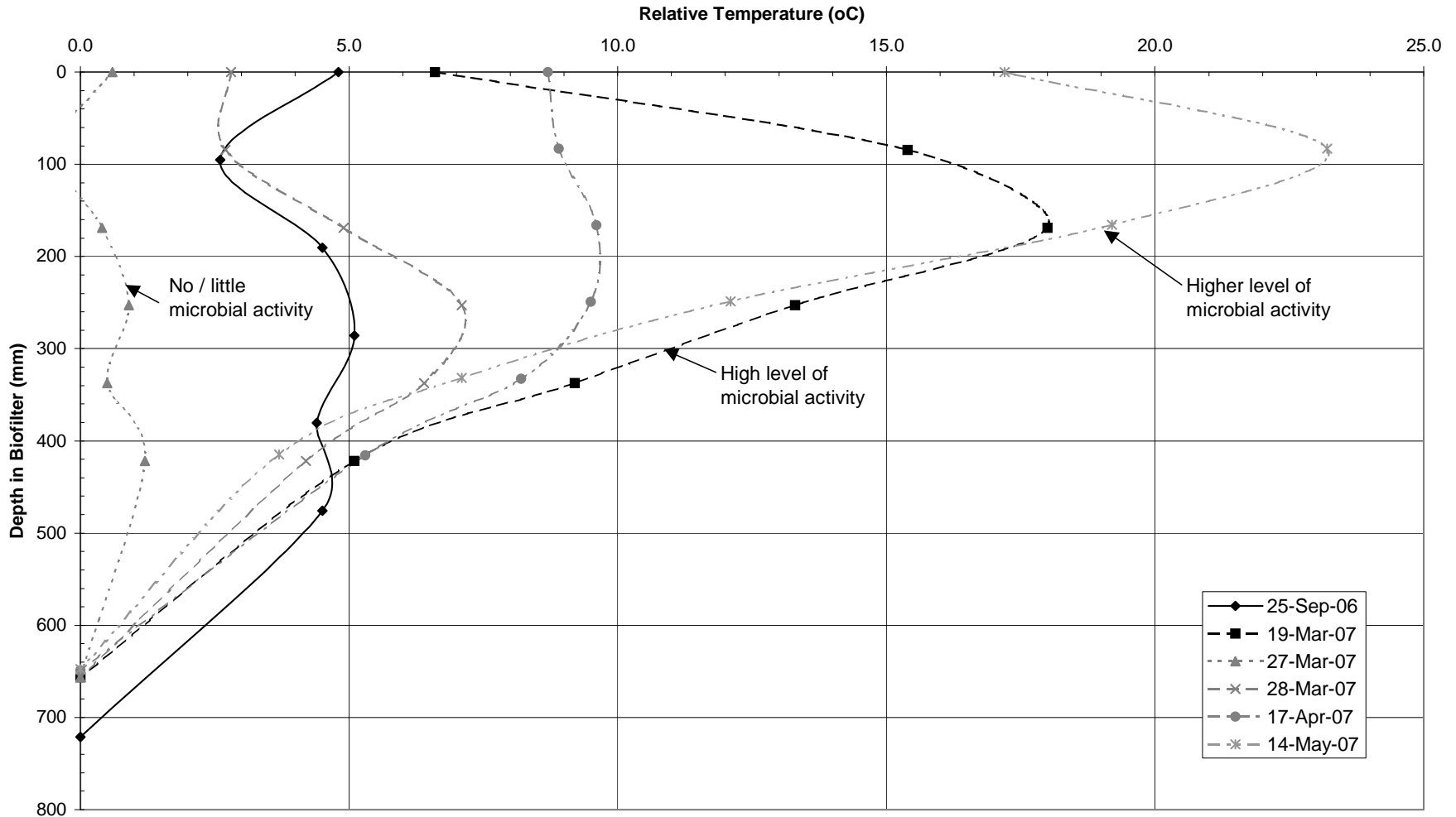
# Average Temperature Profiles of the Trial Biofilters



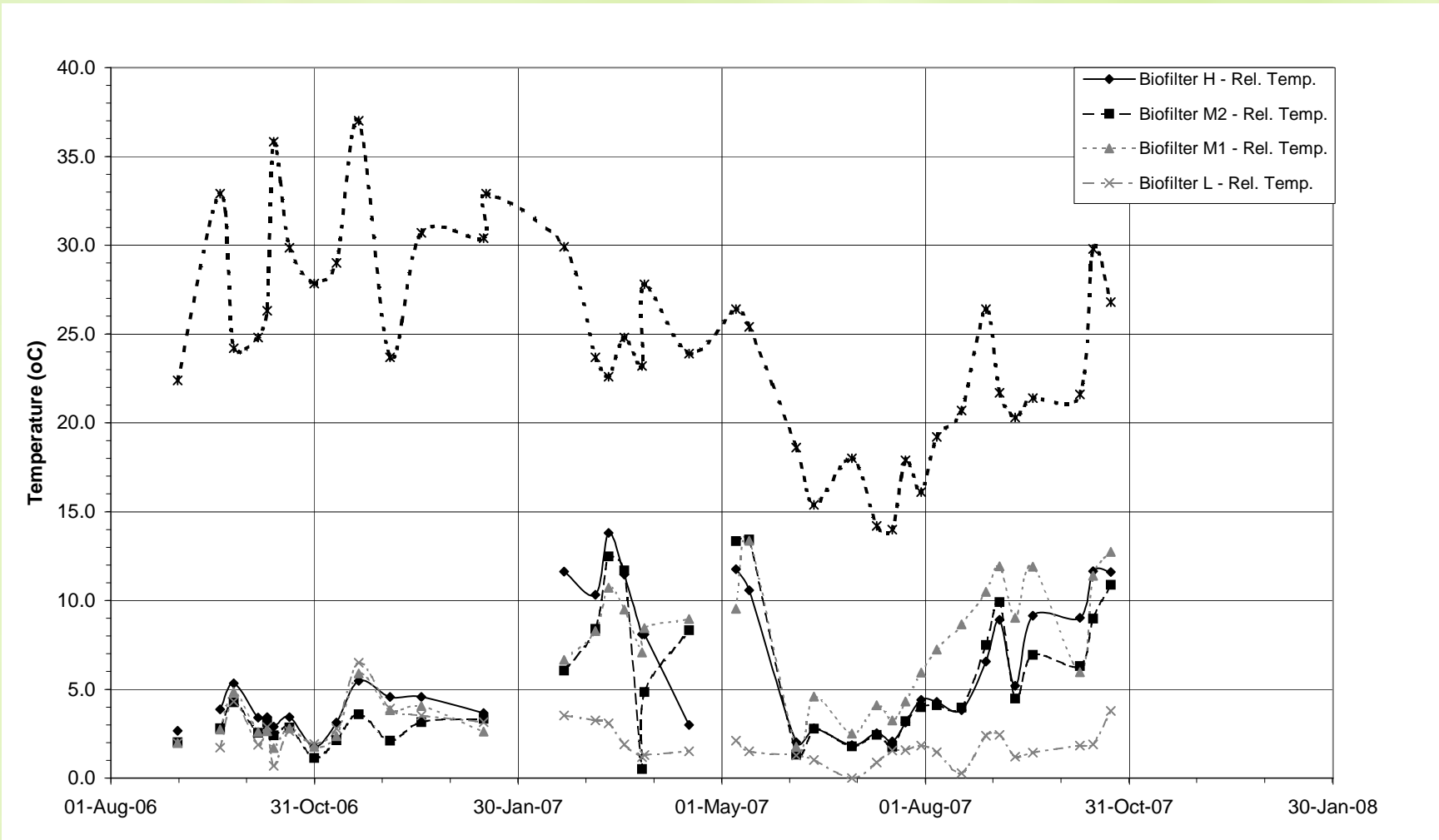
# Average Relative Temperature Profiles of Trial Biofilters



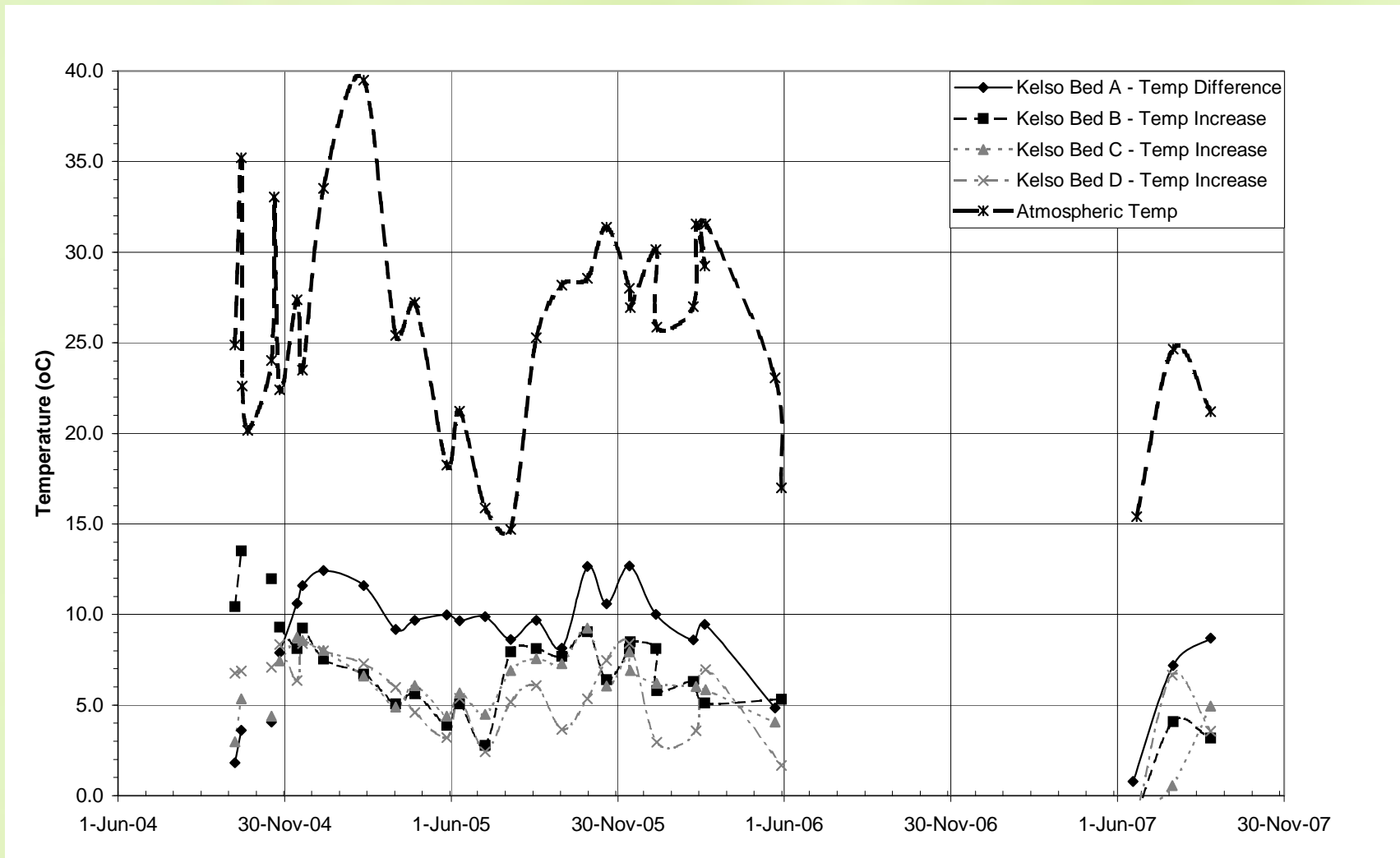
# Effect of Microbial Activity on Biofilter (M2) Temperature



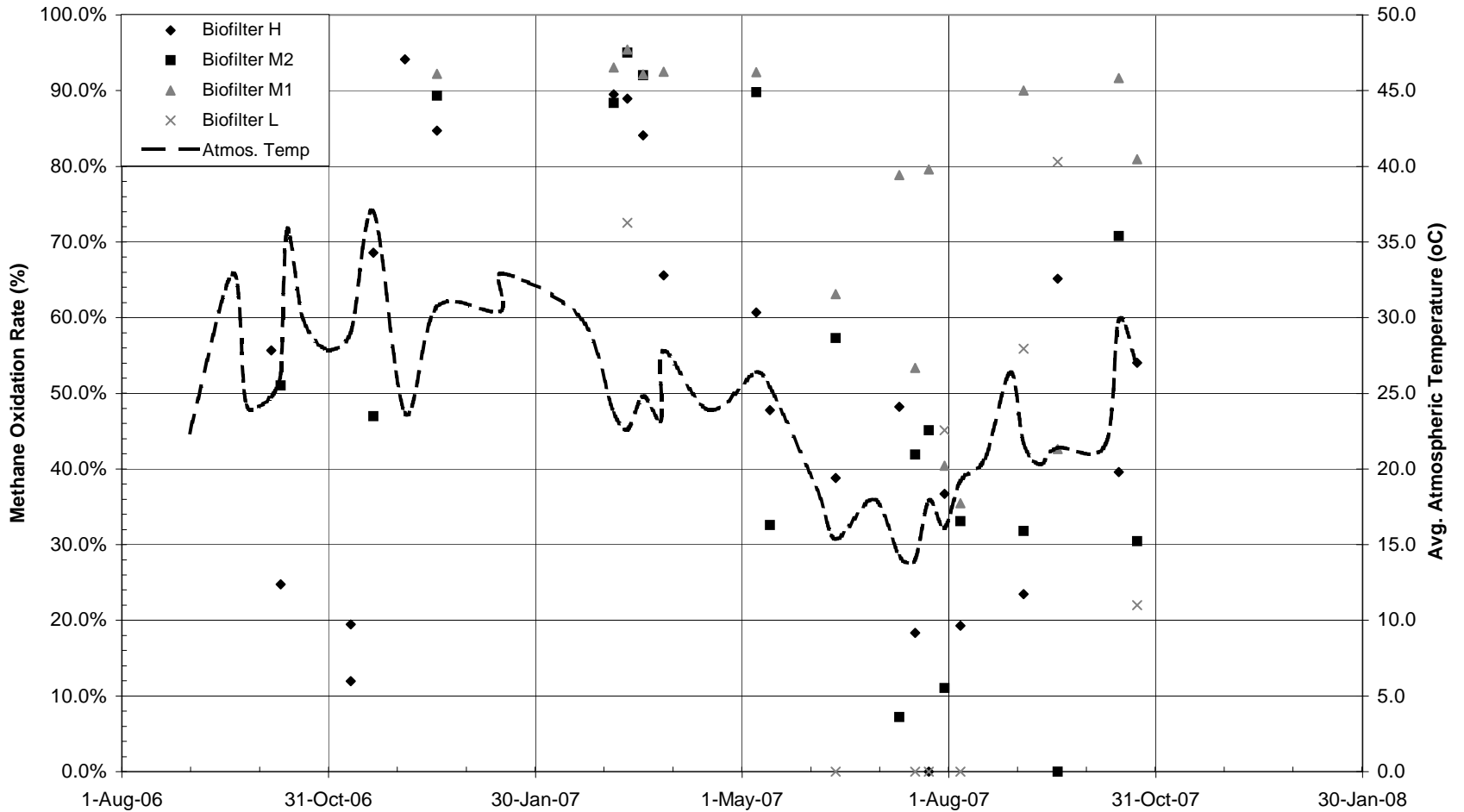
# Effect of Atmospheric Temperature on Microbial Activity



# Effect of Atmospheric Temperature on Microbial Activity in Kelso Trial Biofilters



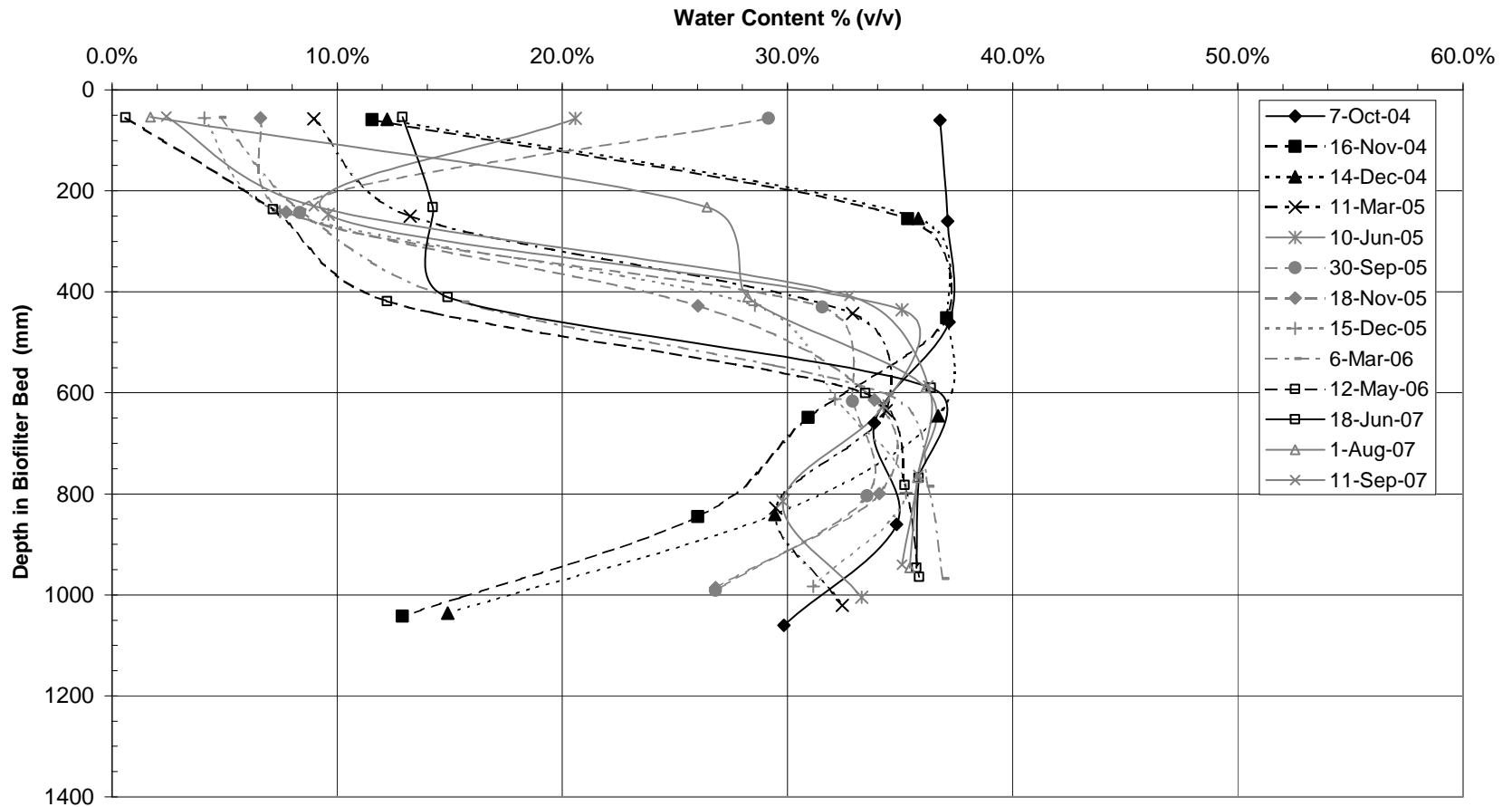
# Effect of Atmospheric Temp. on Methane Oxidation



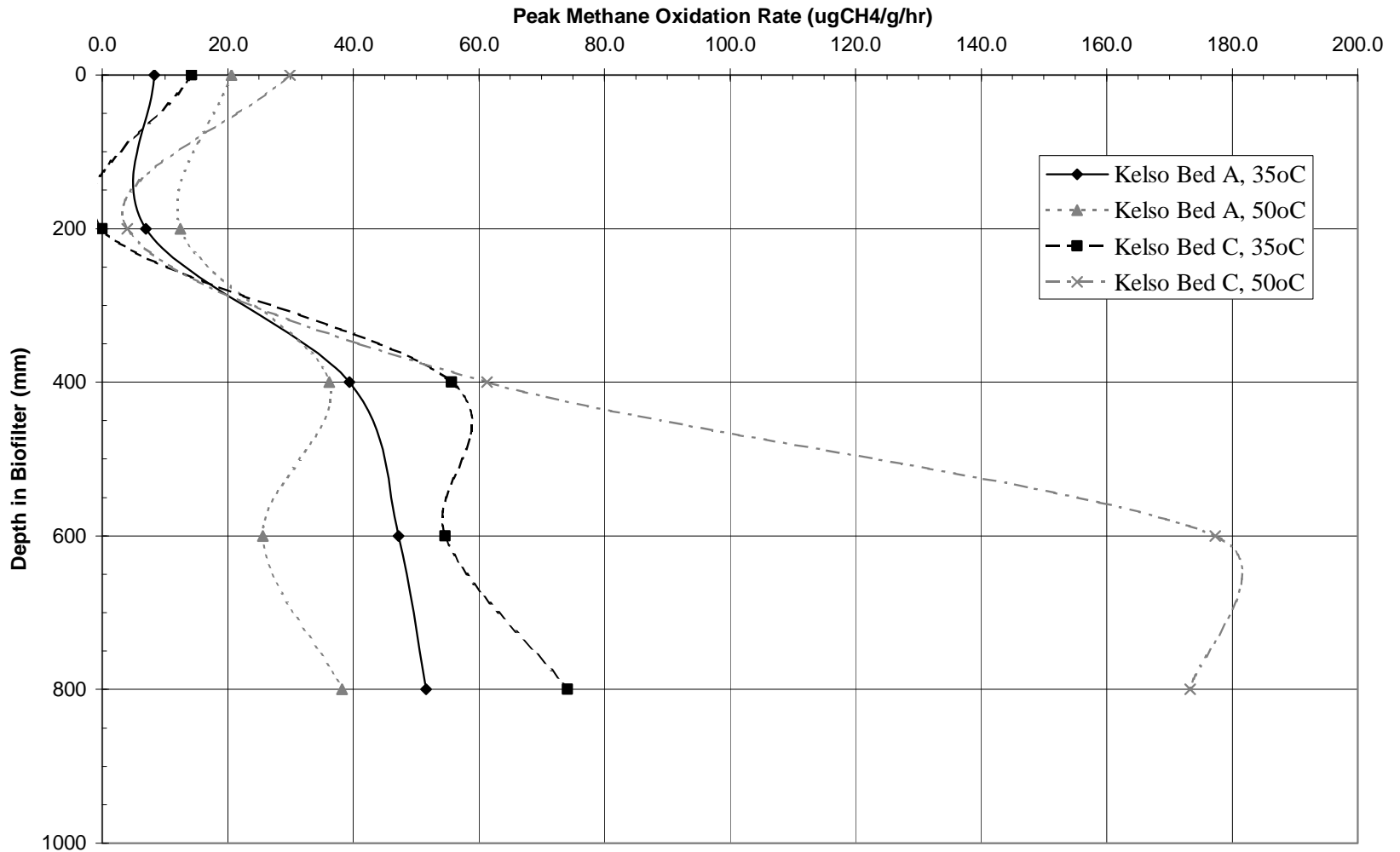


# Moisture Content Profiles of Biofilter Media (Kelso Bed A)

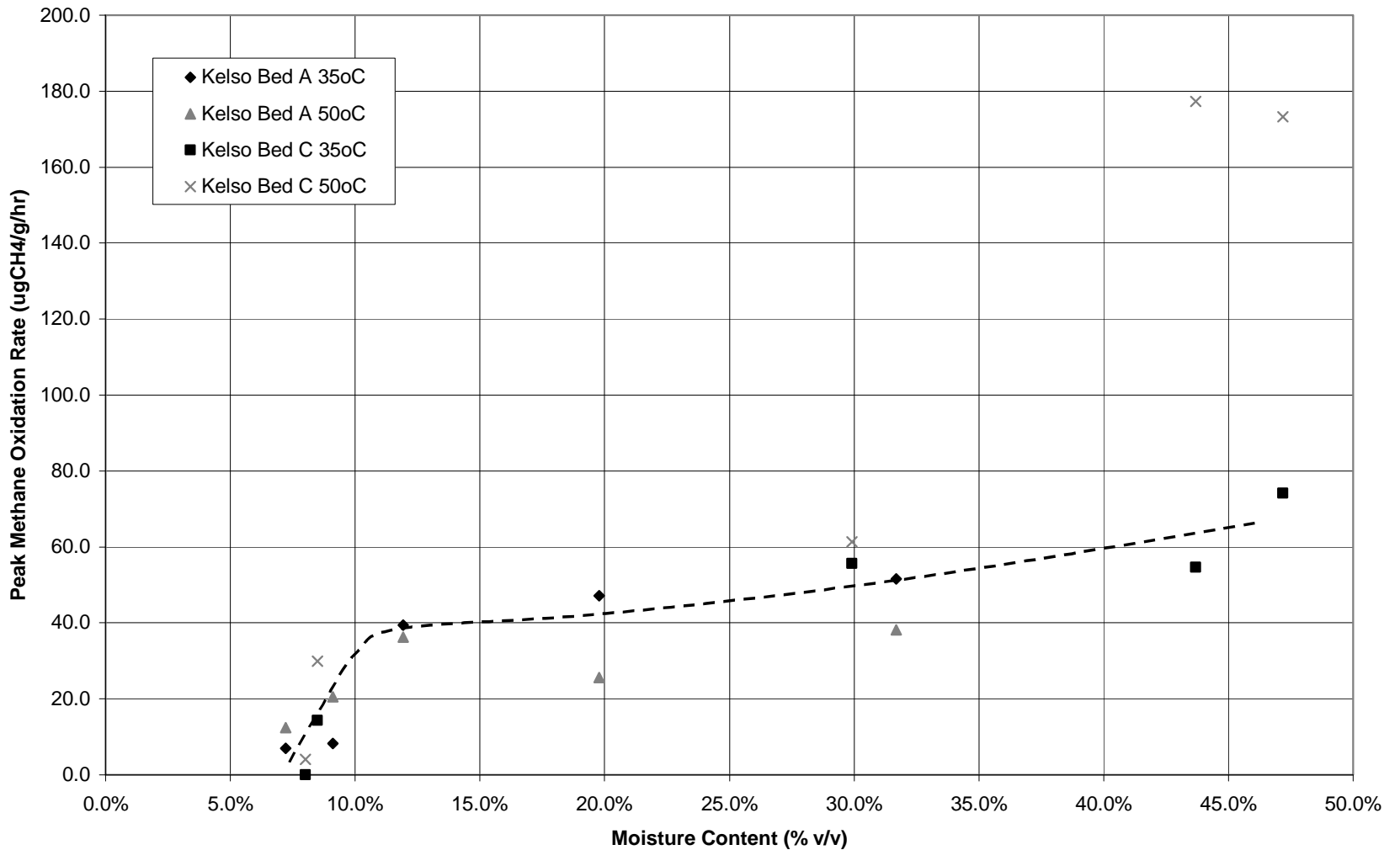
Kelso Bed A (Composted Garden Organics + Shredded Wood)



# Effect of Moisture Content on Methane Oxidation

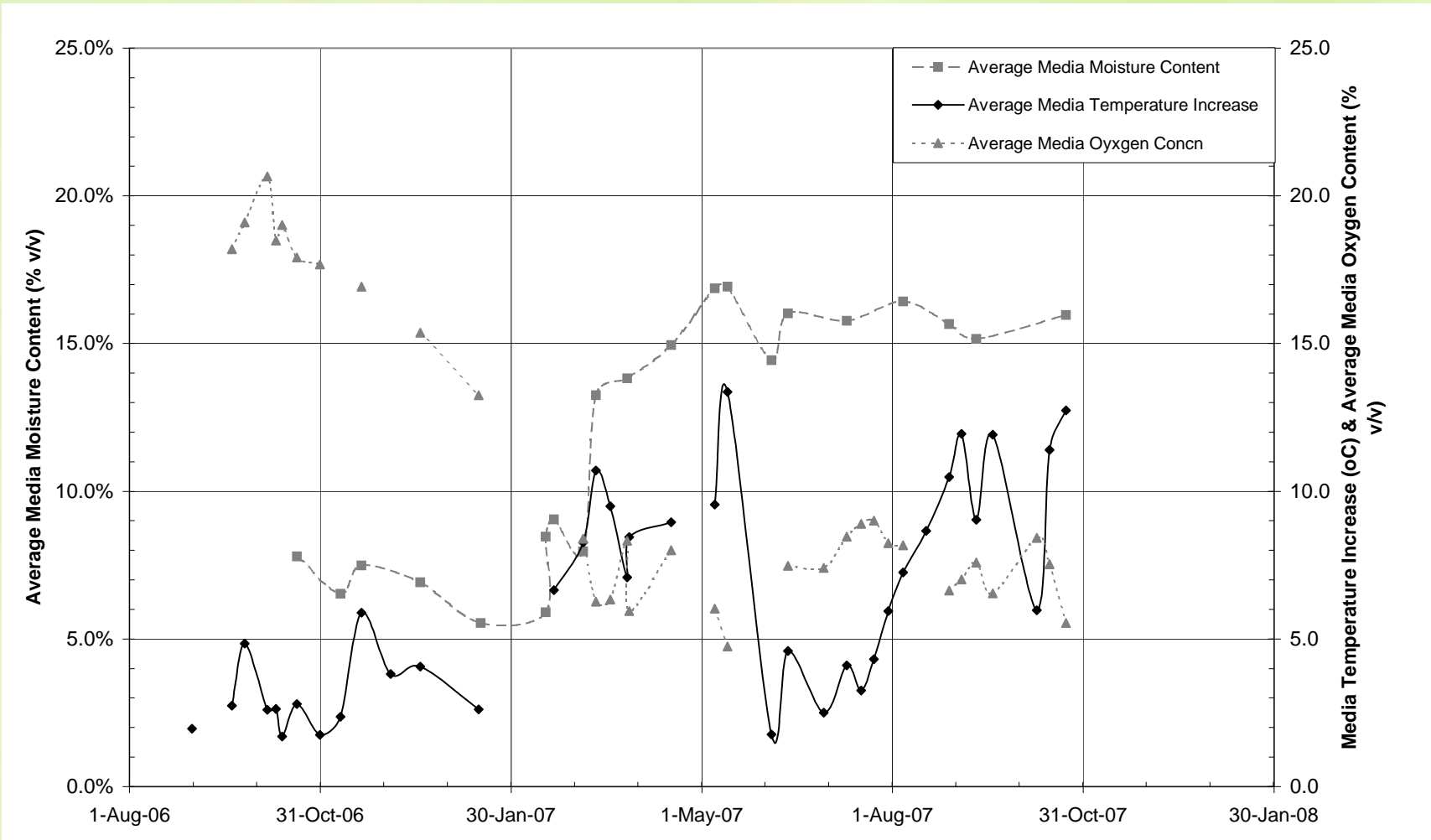


# Effect of Moisture Content on Methane Oxidation





# Effect of Moisture Content on Microbial Activity in Trial Biofilter M1



# Conclusions and Recommendations

- ✿ A passive drainage and biofiltration system can effectively collect and treat landfill gas
- ✿ Methane oxidation rates greater than 90% can be achieved
- ✿ Behaviour and performance of a passive biofilter is dependent on 3 primary factors:
  - ✿ Landfill gas /methane loading rate
  - ✿ Temperature of the biofilter media
  - ✿ Moisture content of the biofilter media

# Conclusions and Recommendations

## ✿ Design factors / criteria:

- ✿ Landfill gas / methane loading rate (minimal management):
  - ✿ Landfill gas loading rate:  $< 20 \text{ L/m}^2/\text{hr}$
  - ✿ Methane loading rate:  $< 5 \text{ gCH}_4/\text{m}^2/\text{hr}$
- ✿ Landfill gas / methane loading rate (active management and warmer climates):
  - ✿ Landfill gas loading rate: up to  $20 - 40 \text{ L/m}^2/\text{hr}$
  - ✿ Methane loading rate: up to  $5 - 10 \text{ gCH}_4/\text{m}^2/\text{hr}$
- ✿ Biofilter media temperature:
  - ✿ Media temperature  $> 20 - 30 \text{ }^\circ\text{C}$
  - ✿ Effect of landfill gas temperature
  - ✿ Effect of climate
  - ✿ Thermal properties of the biofilter media (good thermal insulation in colder climates)
  - ✿ Lower methane loading less affected by temperature

# Conclusions and Recommendations

## ✿ Design factors and criteria continued:

### ✿ Biofilter media moisture content:

- ✿ Media moisture content  $> 10\%$  (v/v) and  $< \text{WHC}$  (cannot be saturated)
- ✿ Effect of climate on biofilter moisture content
- ✿ Active management of biofilter moisture content
- ✿ Characteristics of the biofilter media (good water holding characteristics, good drainage)
- ✿ Lower methane loading less affected by climate

### ✿ Biofilter thickness:

- ✿ Filter media should be 0.5 – 1.0m
- ✿ Effect of climate on biofilter moisture content / active moisture management
- ✿ Effect of climate on biofilter temperature
- ✿ Landfill gas loading
  - High loading – thinner
  - Low loading - thicker

# Conclusions and Recommendations

## ✿ Design factors and criteria continued:

### ✿ Biofilter media characteristics:









- ✿ Low / nil oxygen demand
- ✿ High gas permeability / porosity
- ✿ Media suitable for microbial growth
- ✿ Contain a supply of nutrients for microbial growth
- ✿ Good water holding capacity and drainage
- ✿ Good thermal insulation
- ✿ Structural stability
- ✿ No contaminants that may affect microbial activity / growth e.g. ammonia
- ✿ Mixture of stabilised (mature) recycled organics & shredded wood

# Future Activities

- ✿ Acceptance as effective method for collecting and treating landfill gas:
  - ✿ NSW DEC approval
  - ✿ Incorporation into Landfill Guidelines / Regulations
- ✿ Full scale application
  - ✿ PGH Horsley Park (former Camide Landfill, Horsley Park)
  - ✿ Currently working with a Sydney based landfill operator to incorporate a passive drainage and biofiltration system into their final capping layer
  - ✿ Looking for other suitable landfill sites to a conduct full scale demonstration – ANY INTERESTED PARTIES?

# Future Activities

## Australian Landfill Gas Emissions Project

-  Conduct whole of site landfill gas emissions monitoring
-  Quantify emissions from a range of different type and size landfills
-  Conduct testing at a number of landfill sites across Australia
-  Test a range of methods for measuring landfill gas emissions (surface flux measurements, plume measurements (SPM, DPM) micrometeorological measurements)
-  Still developing the project
-  Working with a number of universities (UNSW)
-  Will be looking for industry partners
-  Will be seeking research funding e.g. ARC



Thankyou  
for your attention

**Questions?**

**Further Information:**

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