# Development of Model Parameters for the Prediction of Methane Production From Paper Industry Landfills

Presented at

The Second
Intercontinental Landfill Research Symposium

Van Maltby, NCASI

Dr. Morton Barlaz, North Carolina State University

October 13-16, 2002

Asheville, North Carolina, USA

# Landfill Gas Emission Research

- Clean Air Act - Title V
  - emission factors based on MSW landfills
  - HAPs linked to emission rate
- Global climate change issues

# First Order EPA Equation (LandGEM)

$$Q_{CH4} = L_0 R(e^{-kc} - e^{-kt});\ m^3/yr$$

where:

$Q_{CH4}$ = methane generation rate

$L_0$ = $m^3$ methane / Mg refuse

R = refuse acceptance rate, Mg/yr

k = decay constant

c = time since closure, yrs

# Typical Paper Industry Wastes

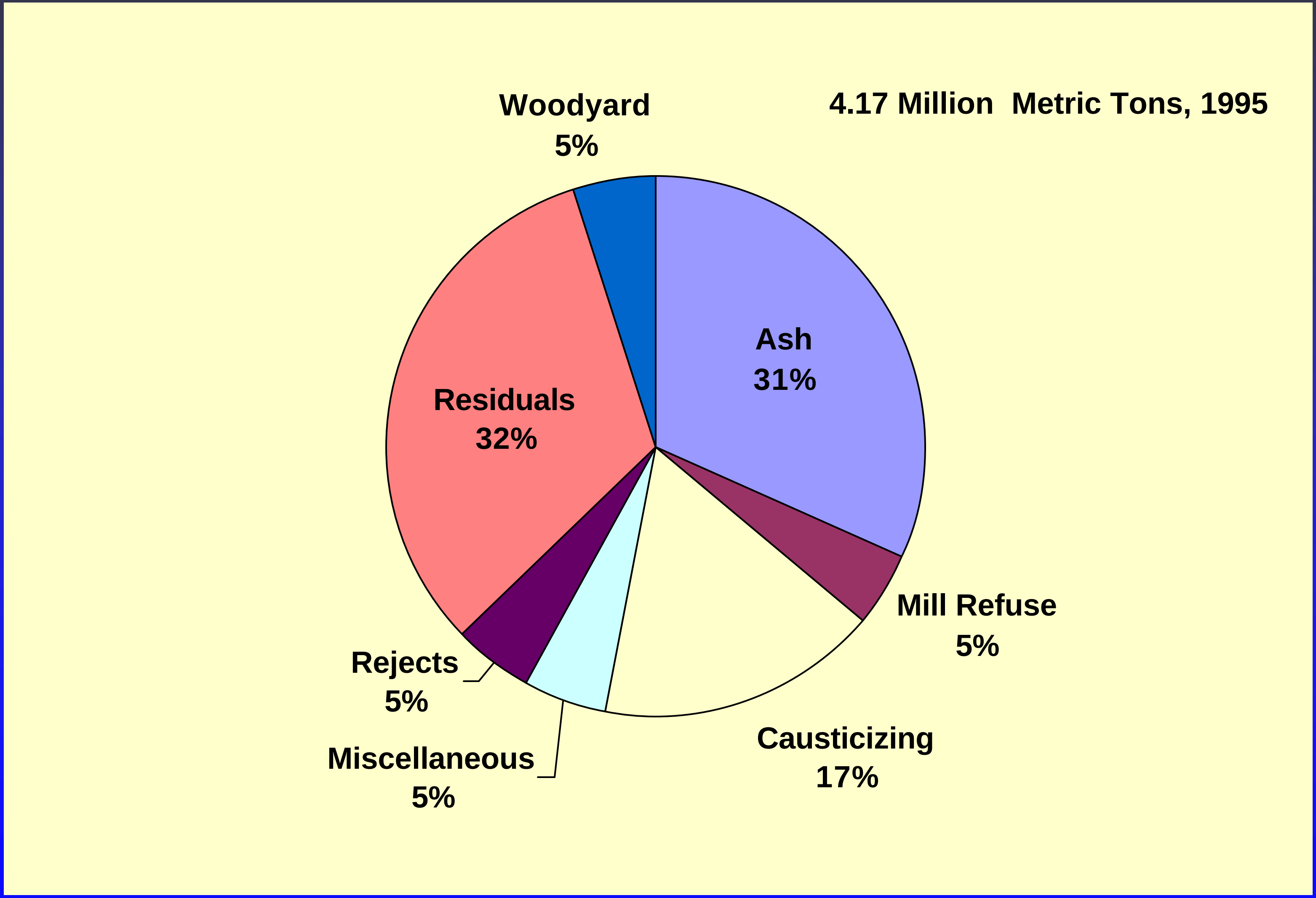
- Residuals: lignocellulosic waste - e.g.,“sludge”
  - cellulose, hemicellulose, lignin
- Combustion ash: fly ash
  - silicates, inert material
- Causticizing wastes: alkaline material

- Woodyard Waste: gravel, bark

# Residuals Terminology

- Primary Residuals:  Primary treatment
  - wood fibers, clay, $CaCO_3$, pigments, inert materials
- Secondary Residuals: Biological treatment
  - microbial biomass
- Combined Residuals:  Mixture of primary and secondary residuals (improved handling)

# Industry-Wide Landfill Contents



# Multi-Phase Project

- Phase 1 - Evaluation of the EPA-recommended approach to predicting air emissions from pulp and paper industry landfills (September 1999)
  - industry landfills emit less methane than MSW
  - need realistic $L_0$ and k values for industry wastes
- Phase 2 - Laboratory development of $L_0$
- Phase 3 - Field development of k

# Phase 2 - $L_0$
## Laboratory Reactors

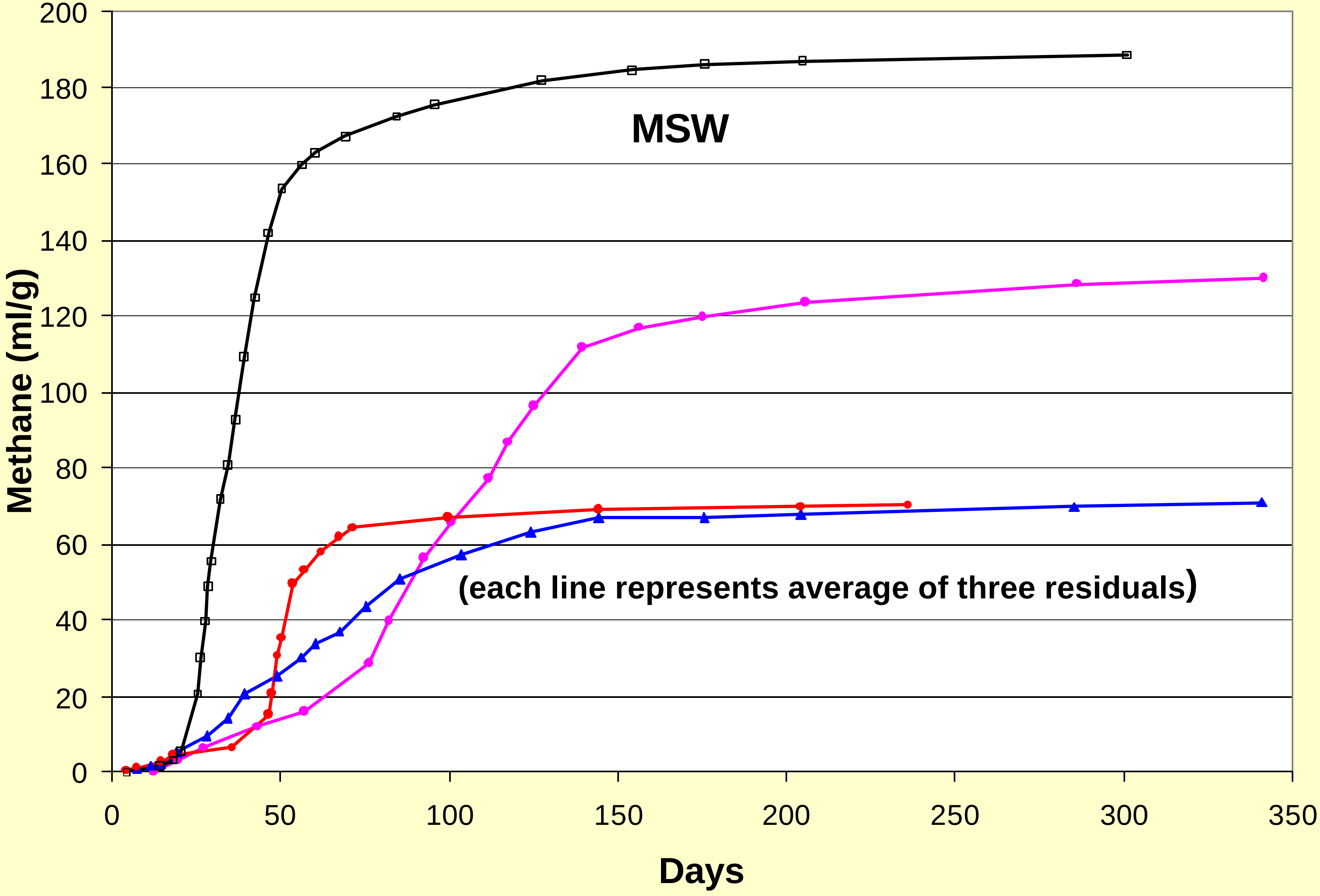
- 6-in. diameter PVC, 4 liter volume
- Anaerobic conditions
- Operated at 38$^{O}$C, long-term
- Intermittent mixing
- pH adjustment

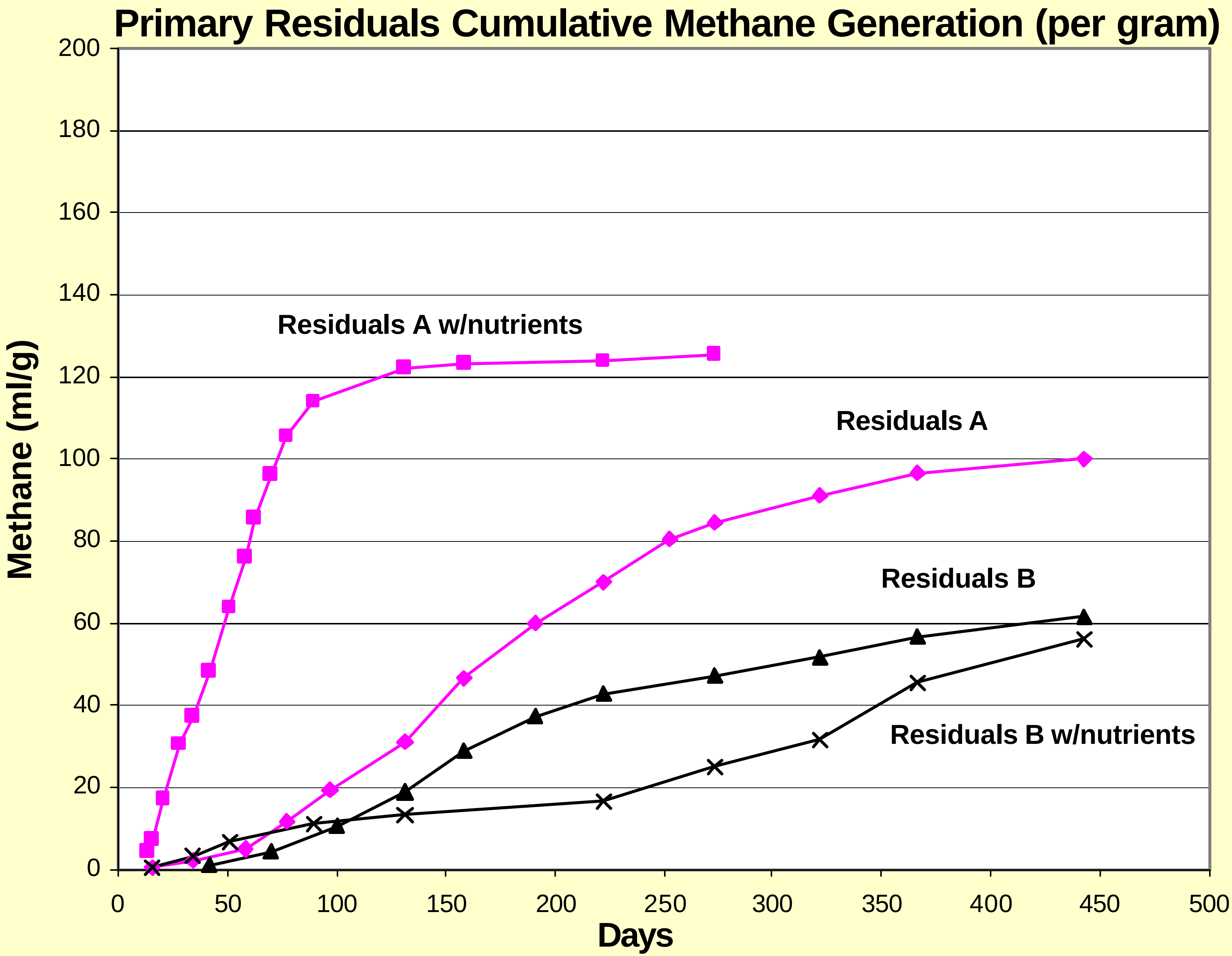
# Experimental Design - Lab Study

- Optimize conditions for $L_0$
  - pH, temperature, moisture
- 5 residuals from various production categories
- Effects of nutrient and seed addition
- Effects of ash and causticizing waste addition
  - blended at “typical” ratios
- $L_0$ for MSW (ground truth)

# Laboratory Reactor Tank
## ($L_0$)

# Combined Residuals Cumulative Methane (per gram)





Primary Residuals Cumulative Methane Generation (per gram)
Methane (ml/g)
Days
0
20
40
60
80
100
120
140
160
180
200
0
50
100
150
200
250
300
350
400
450
500
Residuals A w/nutrients
Residuals A
Residuals B
Residuals B w/nutrients

# Terminal Analyses - Residuals B

## (Combined + Nutrients)

| | Fresh | Decomposed |
|---|---|---|
| **Cellulose** | 21.5% | 5.4% |
| **Lignin** | 14.7% | 18.7% |
| **BMP (ml/g)** | 76.7 | 3.9 |

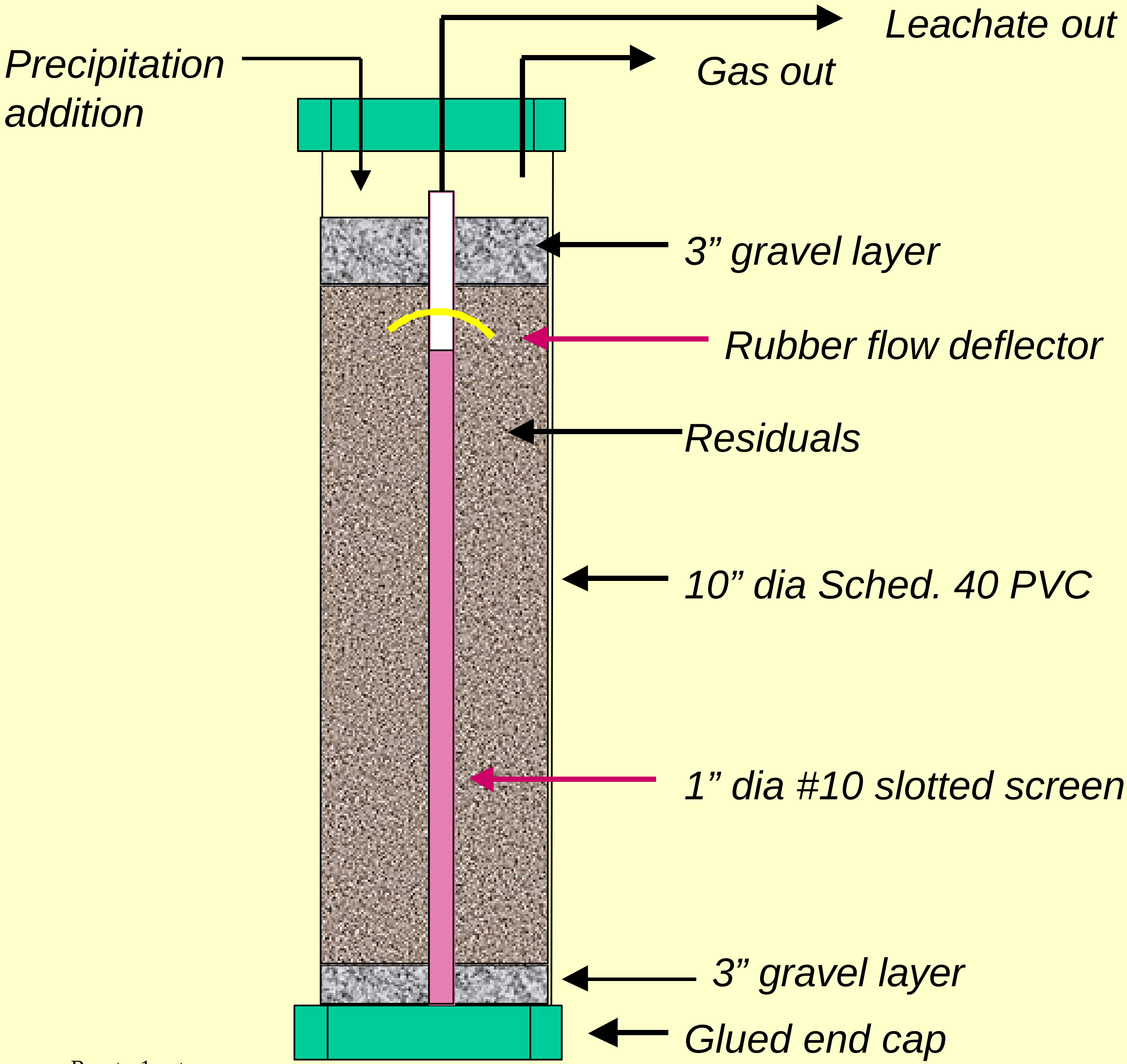
# Terminal Analyses - Residuals C

## (Combined + Nutrients)

| | Fresh | Decomposed |
|---|---|---|
| **Cellulose** | 20.8% | 0.6% |
| **Lignin** | 12.0% | 12.3% |
| **BMP (ml/g)** | 45.9 | 6.3 |

# Phase 3 - k
## Field Study Reactors

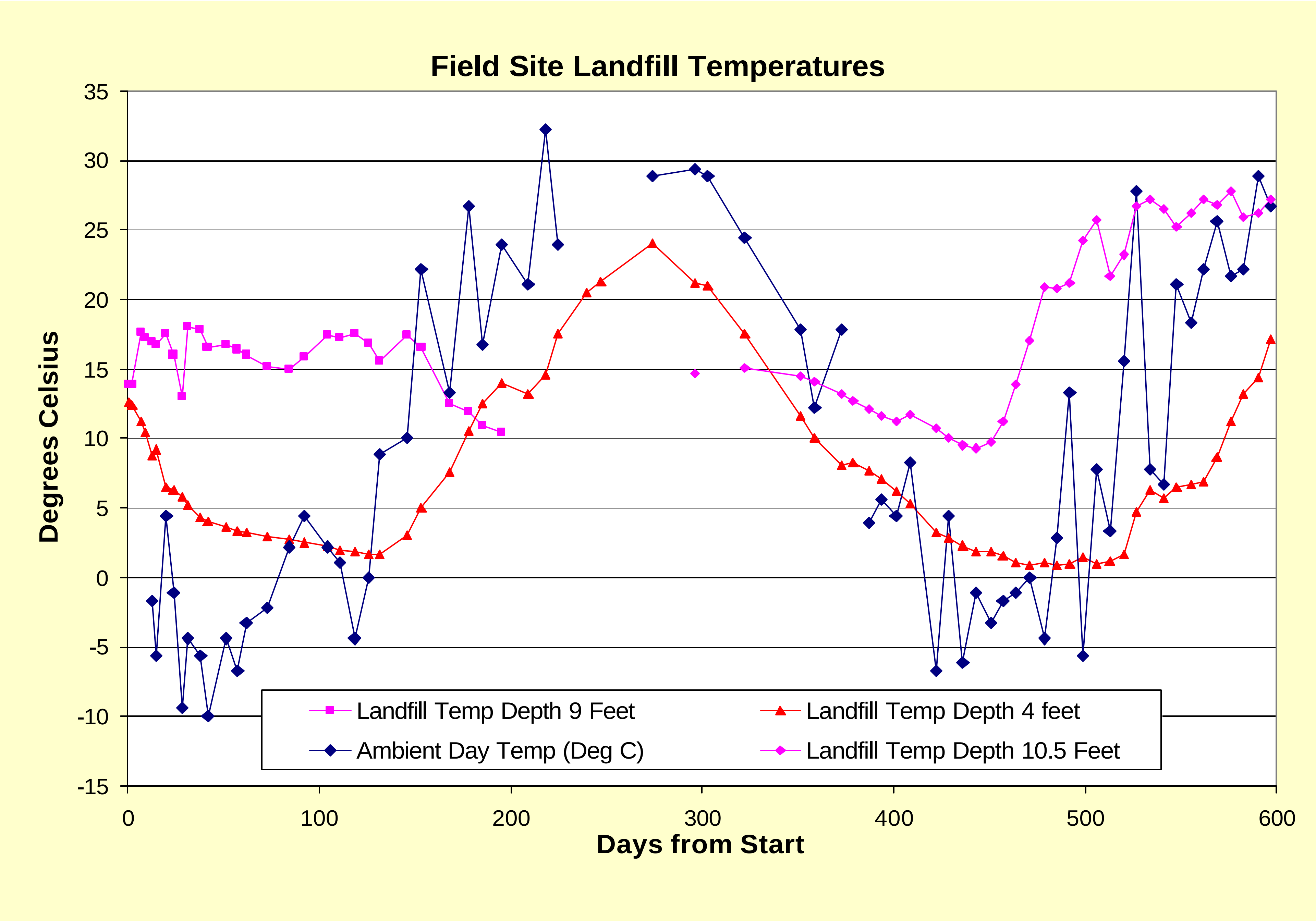
- 10-in dia. PVC, 76-liter volume
- anaerobic conditions
- landfill temperature
- precipitation addition (HELP model)
- leachate removal



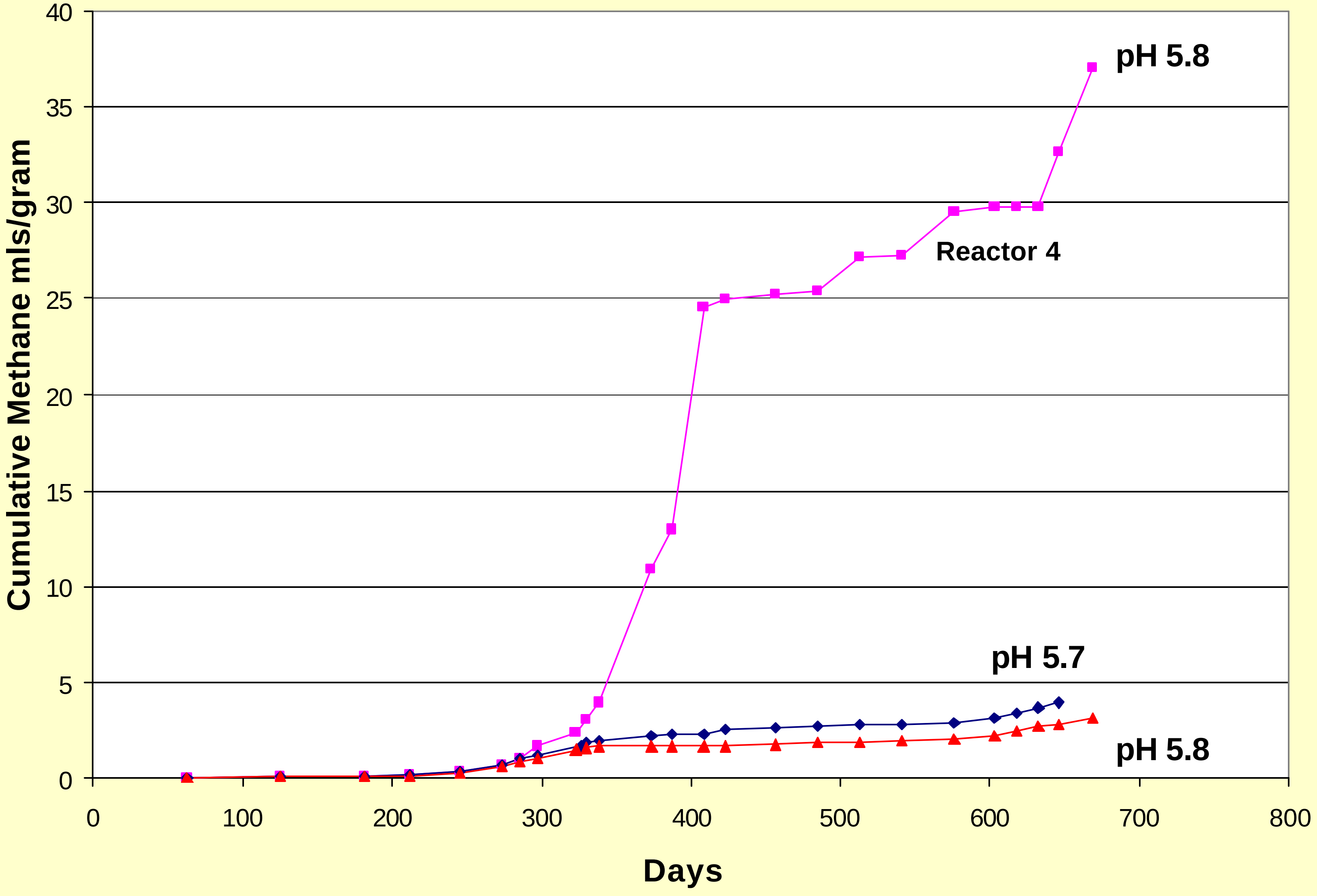

Reactor1.ppt

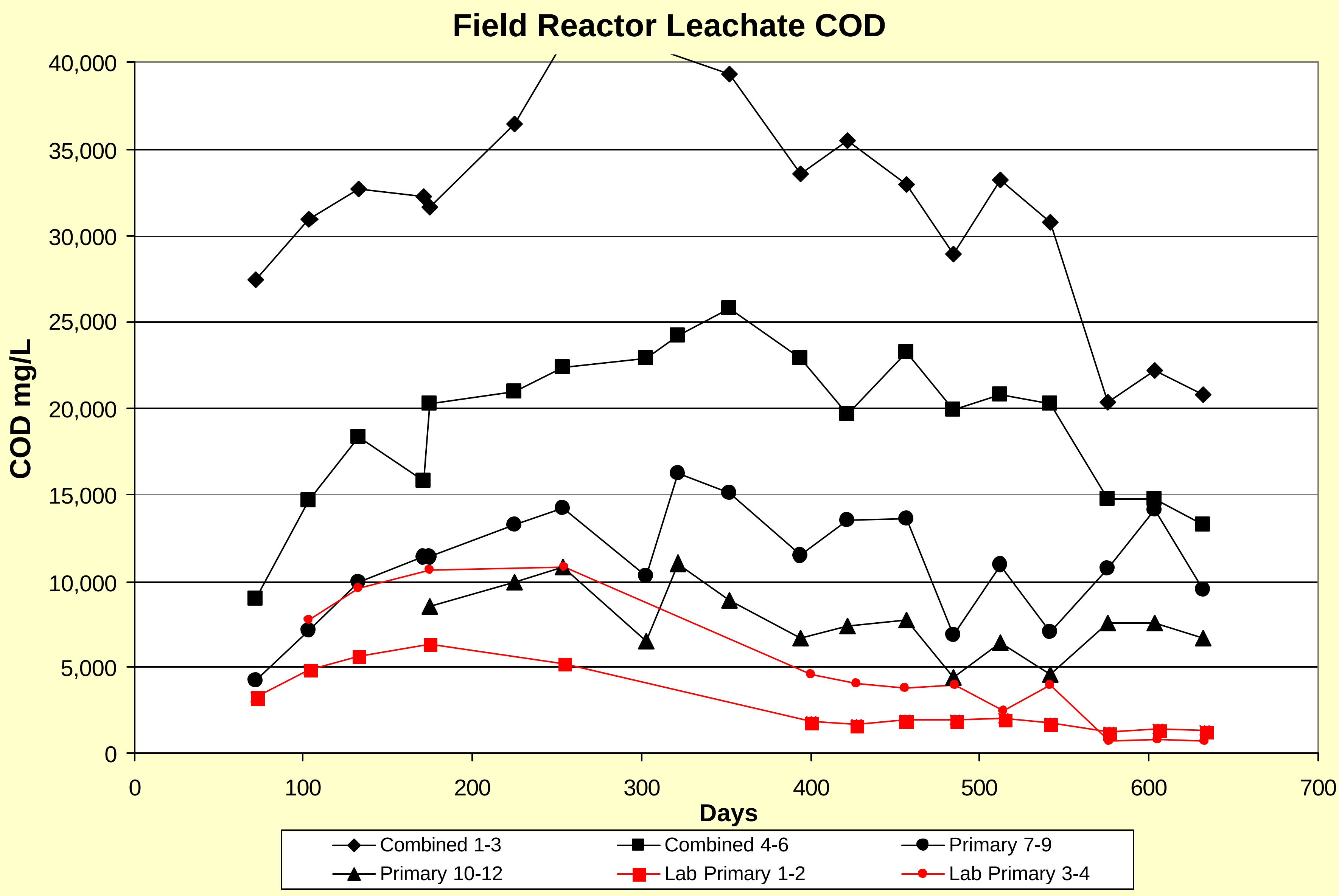
# Construction of Field Site

# Construction of Field Site


Field Site Landfill Temperatures
Degrees Celsius
Days from Start
35
30
25
20
15
10
5
0
-5
-10
-15
0
100
200
300
400
500
600
Landfill Temp Depth 9 Feet
Landfill Temp Depth 4 feet
Ambient Day Temp (Deg C)
Landfill Temp Depth 10.5 Feet

## Field Reactors Cumulative Methane Generation (per gram)
### One Set of Combined Residuals Reactors





Field Reactor Leachate COD
COD mg/L
Days
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
0
100
200
300
400
500
600
700
Combined 1-3
Combined 4-6
Primary 7-9
Primary 10-12
Lab Primary 1-2
Lab Primary 3-4

# Field Reactors' Latest pH Readings

| | |
|---|---|
| Combined 1-3 | 5.65 |
| Combined 4-6 | 5.79 |
| Primary 7-9 | 5.84 |
| Primary 10-12 | 6.23 |
| Lab Primary 1-2 | 6.17 |
| Lab Primary 3-4 | 6.23 |

# Interim Observations

- Methane production rate influenced by pH
- Seed addition not necessary to initiate methane production in residuals reactors
- Causticizing waste inhibited methane production
- Wood ash had no significant effect

# Interim Observations

-continued-

- Nutrient addition had no significant effect on combined residuals $L_0$
- Greatest methane volume and rate in MSW
- Most residuals produced less than half the volume of methane produced by MSW
- Primary residuals - lower k, $L_0$
- Field reactors still in lag phase?