Physical Characterization and Methane Potential Measurements of Lethbridge Landfill Drill Samples

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Bio-Processing Group

Alberta Innovates – Technology Futures

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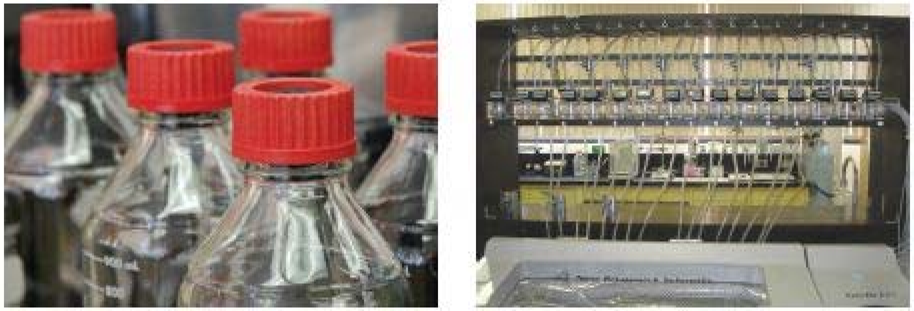
Freedom To Create. Spirit To Achieve.

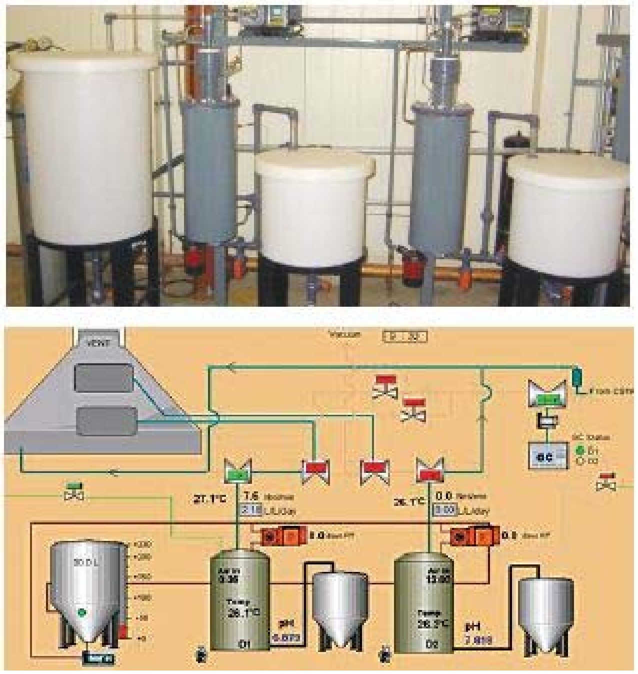
AITF Bio-Processing Group: - Capabilities



Completely automated BMP batch culture system, with unique individual flow meters

Continuous stirred tank AD reactor pilot plant

Analytical Laboratory



High Rate Anaerobic Digestion Pilot System

Dry Batch Digestion Pilot Plant
(for non-flowing/stackable dry material)

http://www.albertatechfutures.ca/OurTeams/BioProcessing/BiogasInnovation.aspx

AITF Bio-Processing Group: Services Offered

- Feedstock evaluation
  - Chemical and physical analysis
  - BMP evaluation

- Pilot plants for process simulation
  - High Rate AD for low (<1%) particulate wastewaters
  - CSTR AD for pumpable wastes
  - Dry batch digestion for stackable wastes
  - Aerobic activated sludge system for liquid wastes

- Integration studies
  - System style and configuration
  - System integration into existing facilities
  - Mass energy balance
  - Process economic analysis

- Specialized pilot plant construction and training

Waste Management

- In 2012, 25 million tons of non-hazardous waste was sent to Canadian waste disposal facilities
- ~77% of MSW landfilled
- National average waste disposal per capita: 720 kg/ person
- Alberta highest per capita waste disposal: ~ 1 ton/person
- Alberta waste: ~75% non-residential, 25% residential

Methane as GHG

- CH_4, a major GHG, global warming potential > 25 times the CO_2 eq.
- Biologically derived CH_4 mainly from microbial degradation of organic material in anaerobic environments such as wetlands, rice paddies, digestive tracts of ruminants and landfills
- Landfills are the second largest contributor of global anthropogenic methane
- In Canada, CH_4 accounts for approximately 13% of GHG emission, 20% of which is derived from landfills
- Quantification of landfill CH_4 emission is therefore imperative for the determination of landfill GHG emission rates to evaluate and improve on mitigation strategies (i.e. prevention, diversion, c-sequestration & c-credit allocation programs)

Estimating GHG emission from landfills

- LandGEM:

$$Q_n = kB_0 \sum_{i=0}^{n} \sum_{j=0.0}^{0.9} \frac{M_i}{10} e^{-kt_{i,j}}$$

Most commonly used in North America

Q_n: CH_4 generated ($m^3\ yr^{-1}$)
n: nth year of assessment
k : waste degradation rate (yr^{-1})
B_0: CH_4 generation potential ($m^3\ Mg^{-1}$ wet waste);
M_i the waste mass deposited in year i (Mg);
j : 0.1 year time increment used to calculate CH_4 generation;
t: time (yr)

Based on the IPCC Model with default k of 0.02 yr^{-1} for Alberta, classified as semi-arid climate

- The Alberta Landfill Gas Quantification Model (ALGQM):

$$k = 0.00003 \times (PCPN + AL) + 0.01$$

$$B_0 = MCF \times DOC \times DOC_F \times F \times \left(\frac{4}{3}\right)$$

k: waste degradation rate (yr^{-1})
$PCPN$: precipitation in the year of calculation ($mm\ yr^{-1}$),
AL: additional liquids deposited in the landfill in the year of calculation ($mm\ yr^{-1}$),
B_0: the CH4 yield (ton CH4/ wet ton MSW)
MCF: methane correction factor
DOC: total degradable organic carbon in MSW (ton, wet weight),
$DOCF$: fraction of non-lignin based degradable organic carbon,
F: volume fraction of CH4 in generated landfill gas
$\left(\frac{4}{3}\right)$: the CH4/Carbon molecular weight ratio

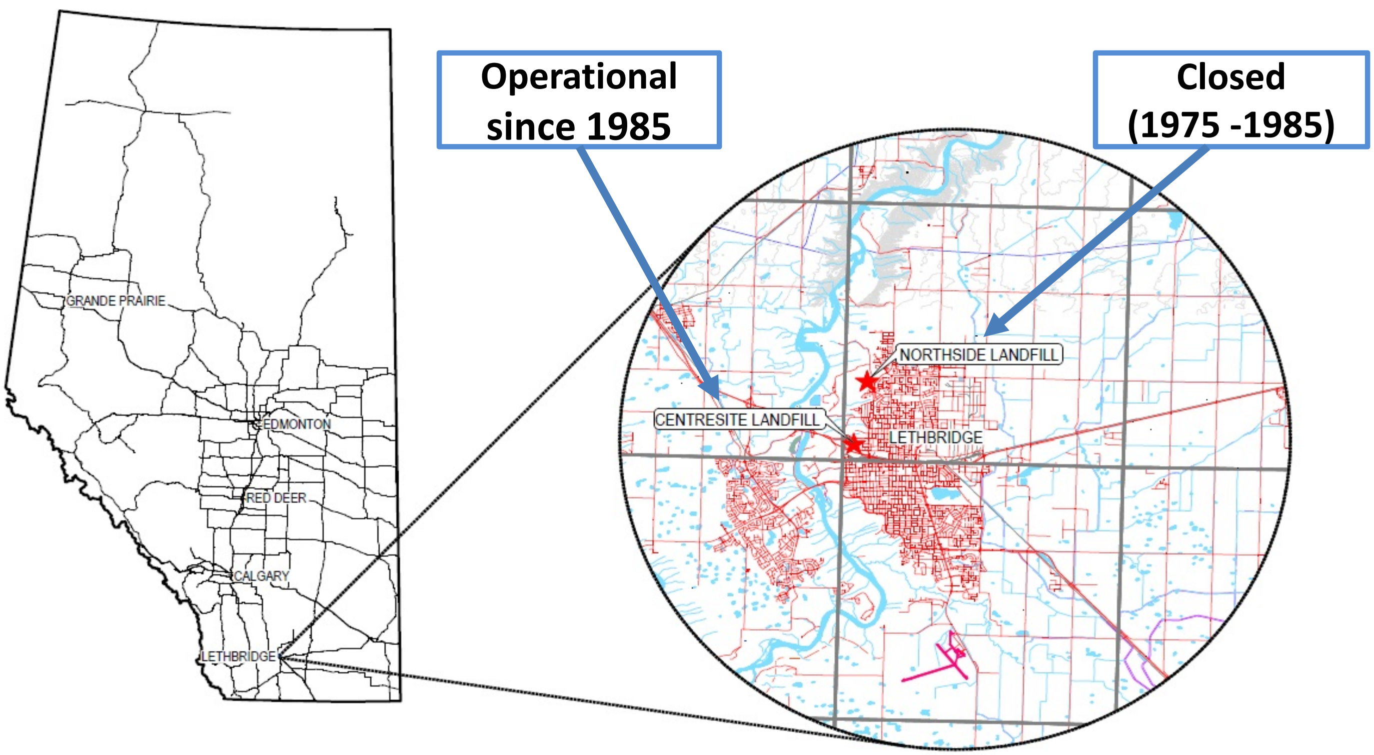
Key Limitations of IPCC-based ALGQ Model

- IPCC Model is not based on Alberta-specific experimental data
- IPCC Model designed but for larger geographic entities such as nations or regions in similar climatic zone, and not for individual landfills
- Alberta has 4 distinct climatic sub-regions, IPCC default *k* may not apply to all
- Landfill-specific benefits or liabilities related to GHG emission (e.g. carbon credit allocation or levying of fines, respectively) must be based on landfill-specific emission data
- The ALGQM requires several inputs, some to be determined experimentally
- Alberta-specific experimental data required to support/fine-tune AB landfill gas offset protocol and to validation the ALGQM

Project Background

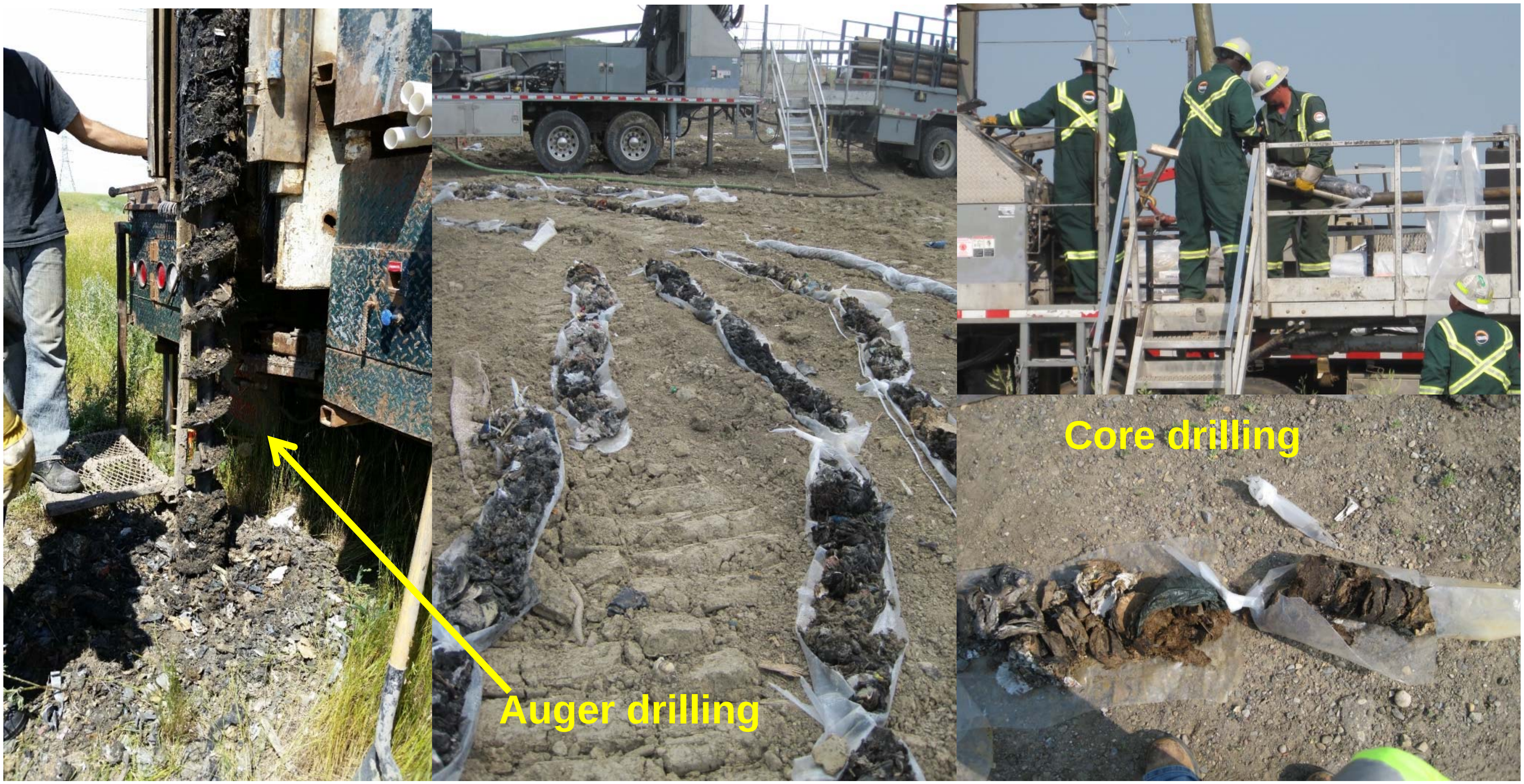
- Baro-pneumatic testing & modelling of experimental site-specific *k* for the City of Lethbridge landfills for comparison with provincial Model value and IPCC default

- The City of Lethbridge, in the Prairie region of Southern Alberta, has a fairly cool, semi-arid climate, annual average precipitation ~ 15 inches



City of Lethbridge, AB – courtesy of the City of Lethbridge

Drilling operation



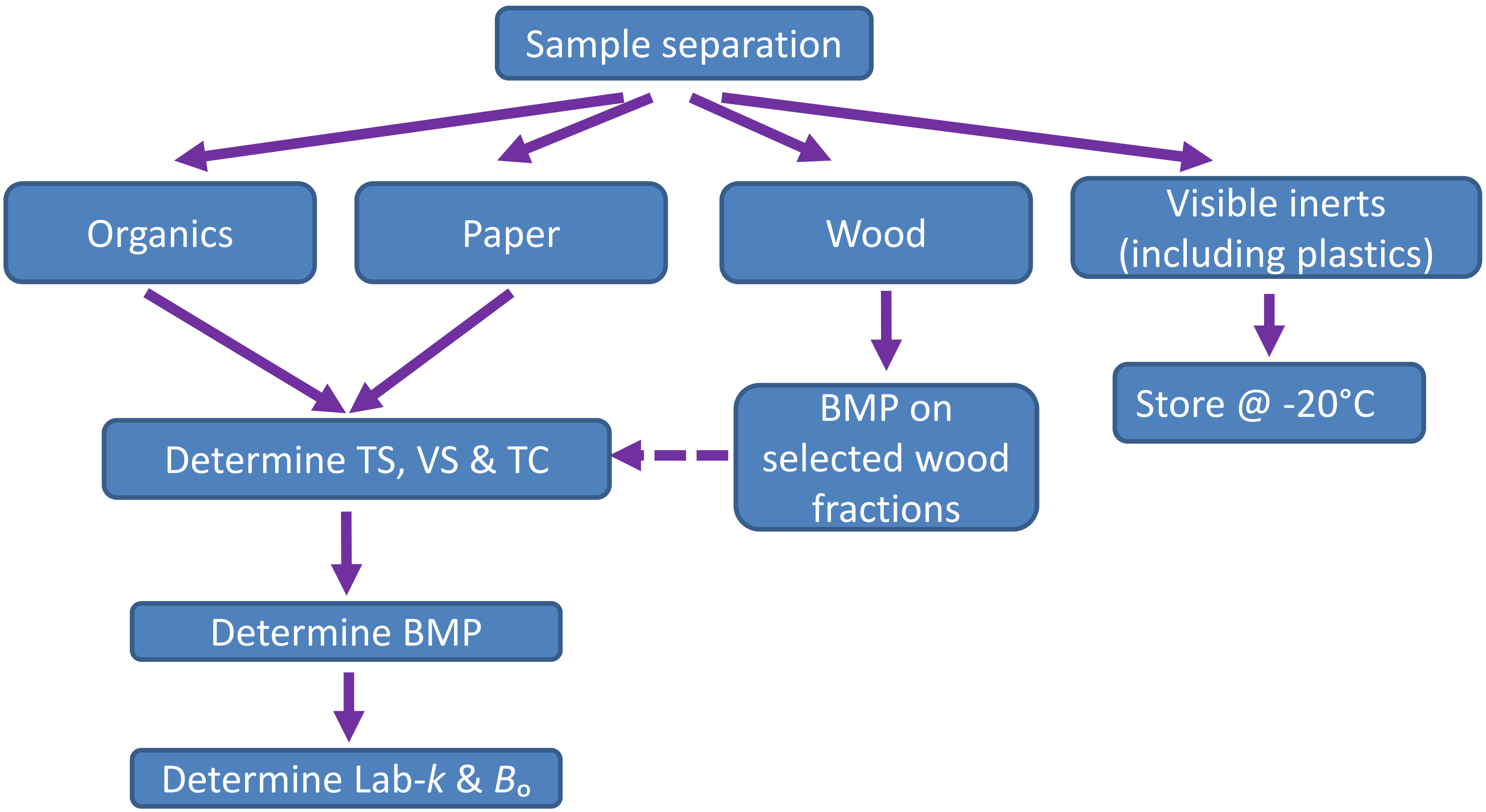
City of Lethbridge, AB – courtesy of the City of Lethbridge

Spent waste Characterization and BMP Analysis

Objective

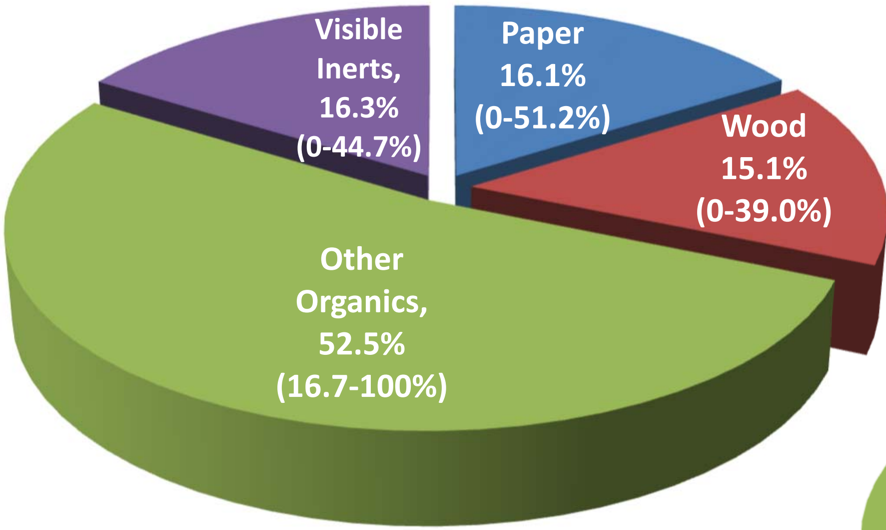
- Physical characterization of 45 landfill drill samples + 5 wood samples
- BMP evaluation
- Evaluate effects of physical characteristics on k_{lab} and B_0
  - Moisture content,
  - Water activity
  - Metabolizable energy content
  - Age
  - Depth
  - Total carbon

Methodology



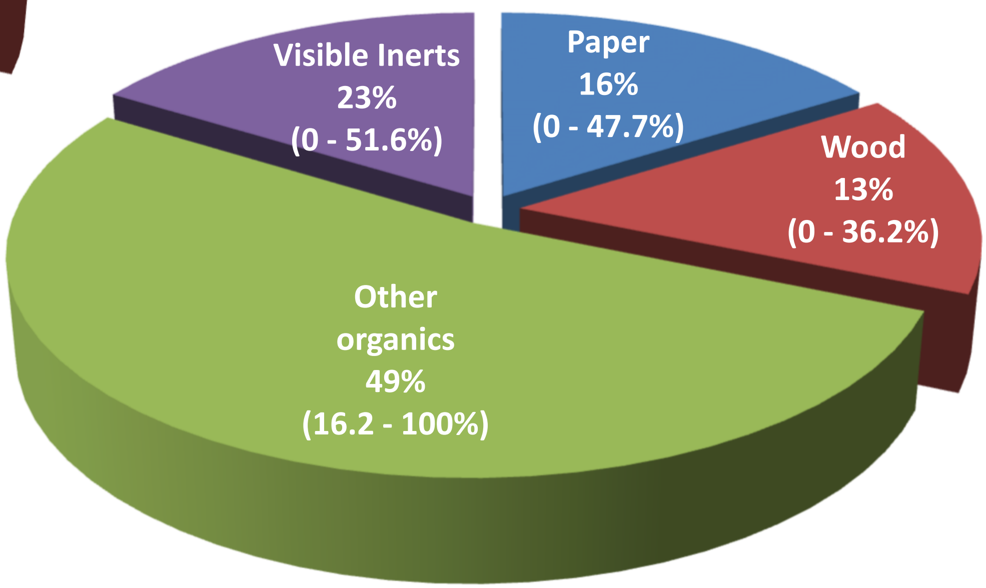
Results – Compositional

Material composition was heterogeneous with varying amounts of 'other organics', Paper, Wood and Visible inerts

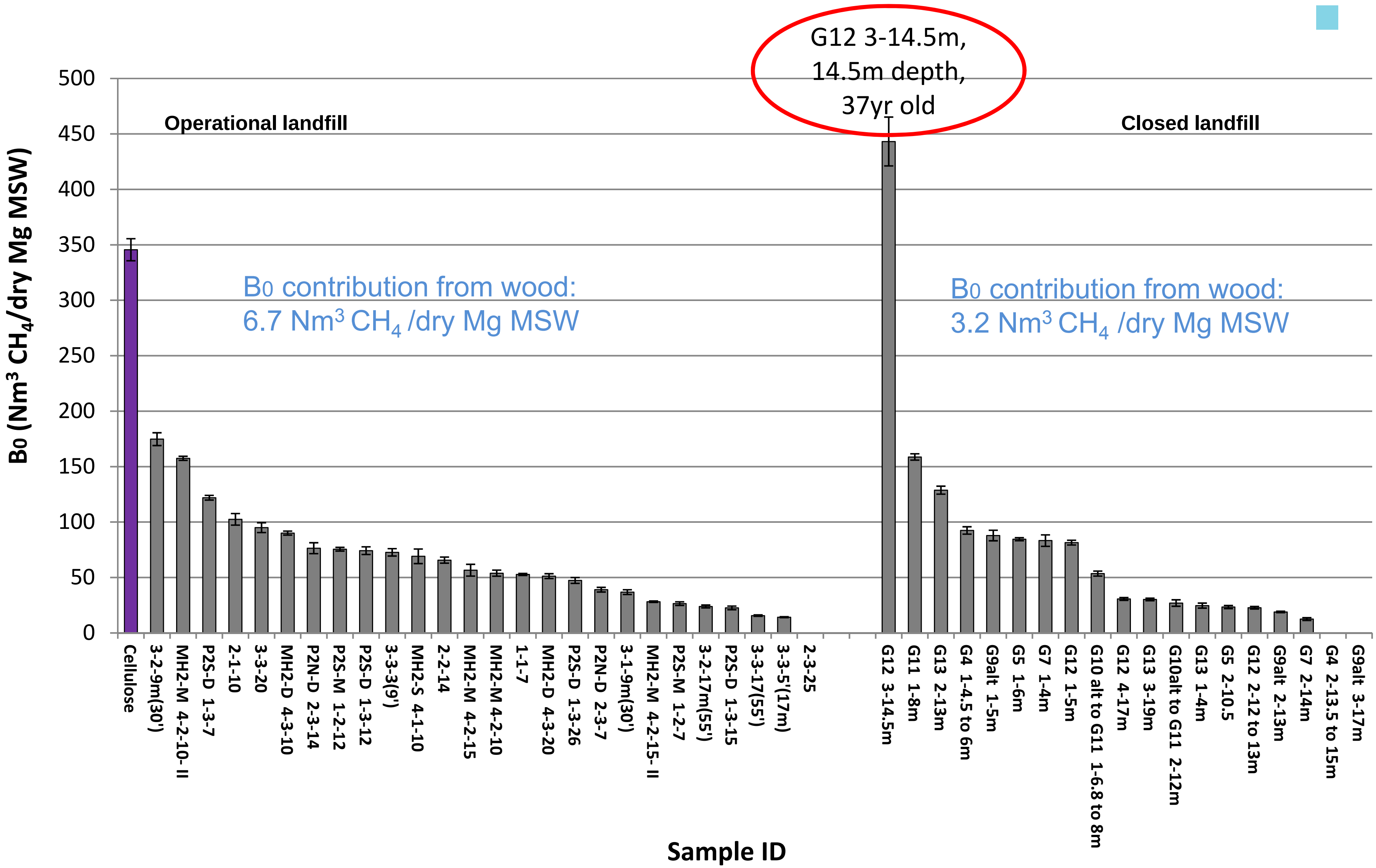


Wet weight basis

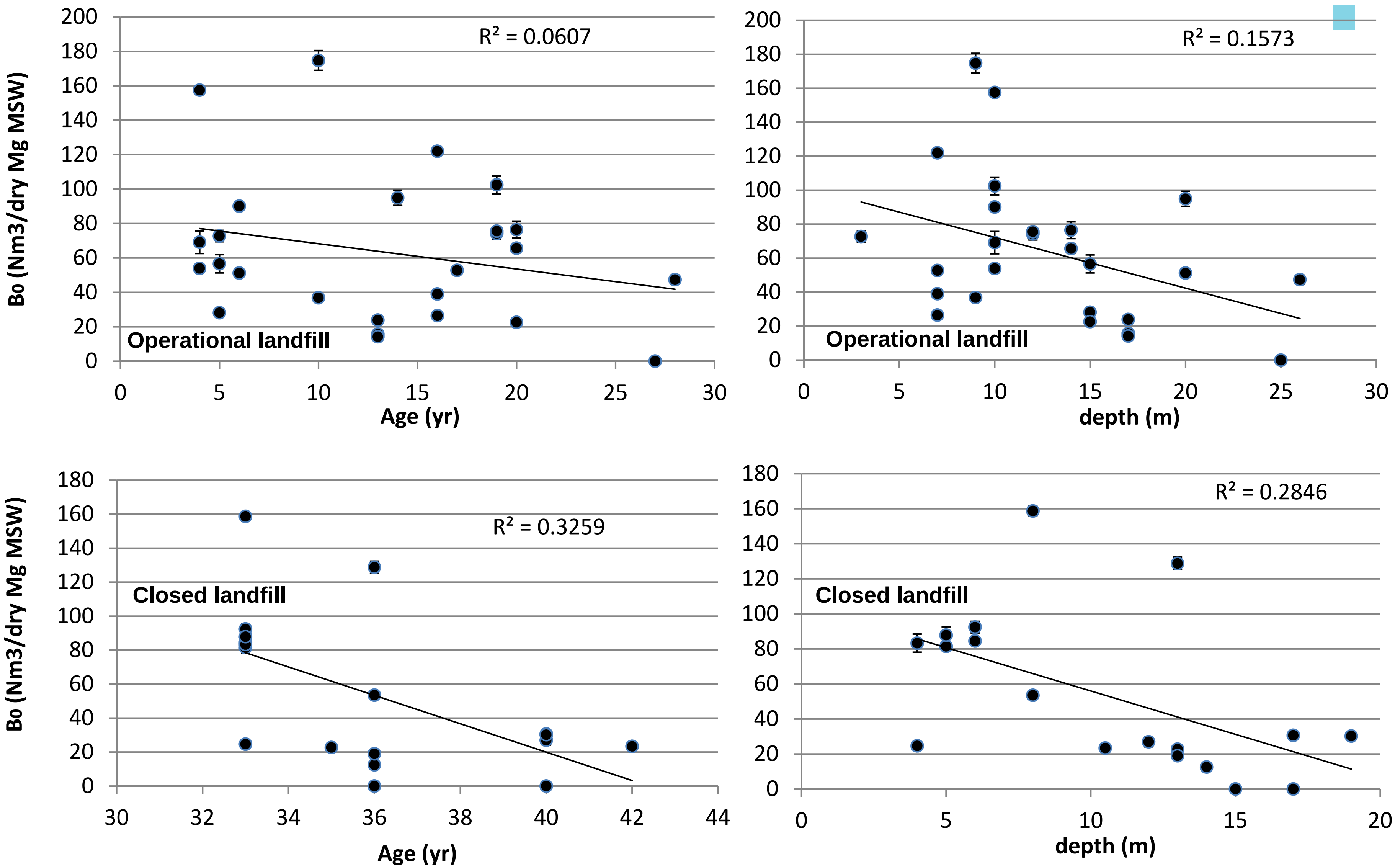
Dry weight basis



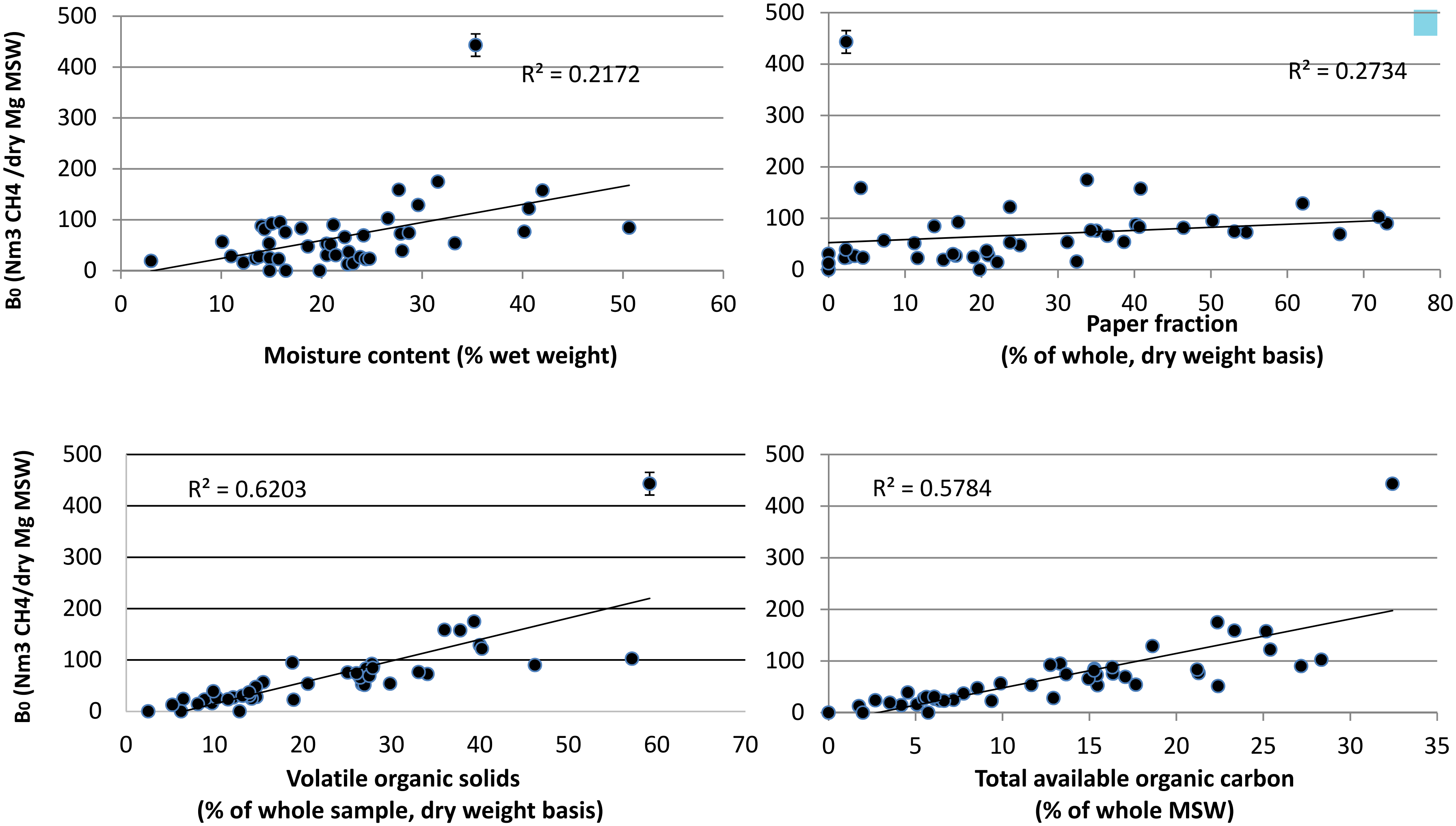
Maximum Methane Yield, Bo



B0 vs age and Depth

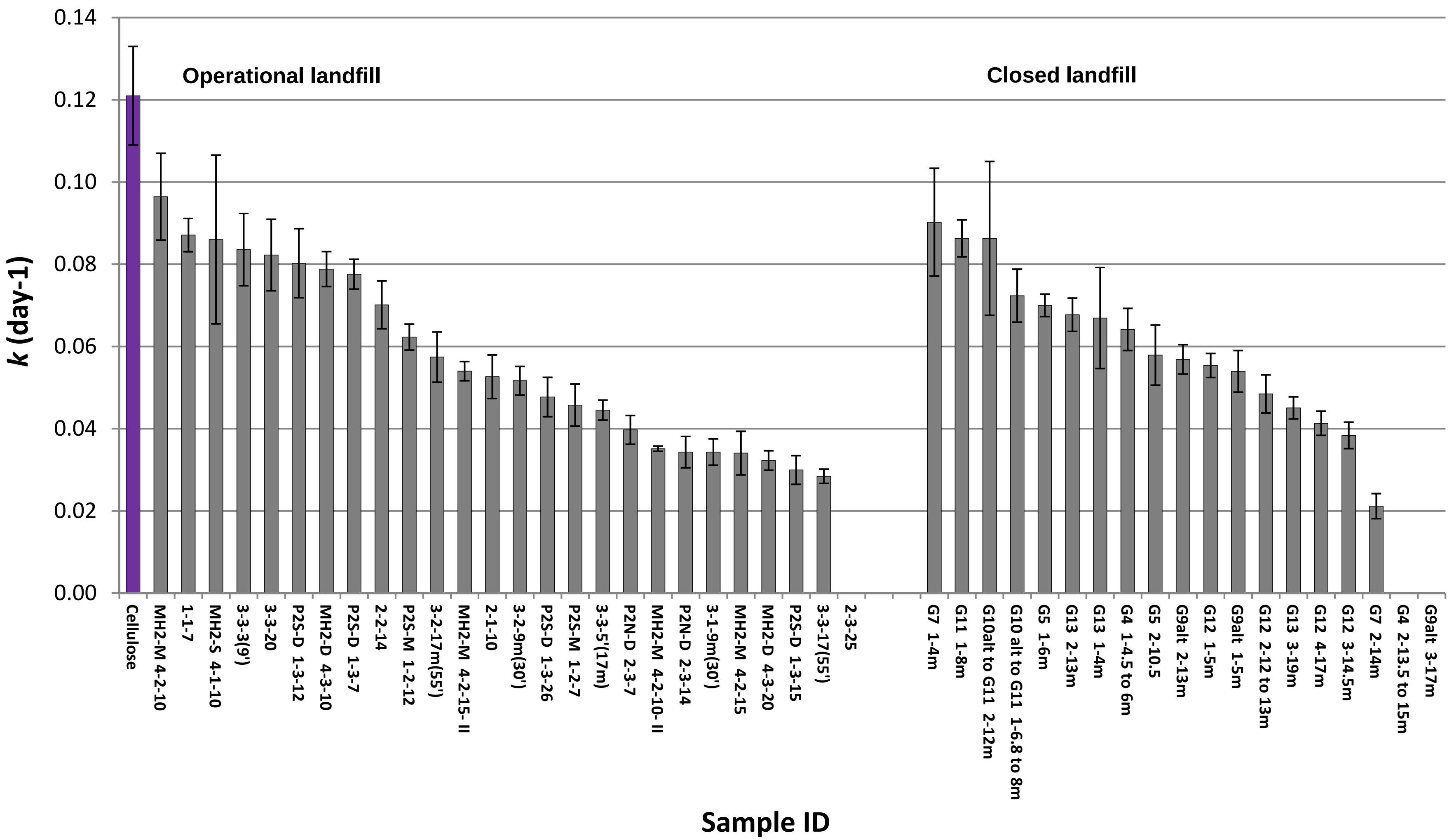


Substrate characteristics vs B_0

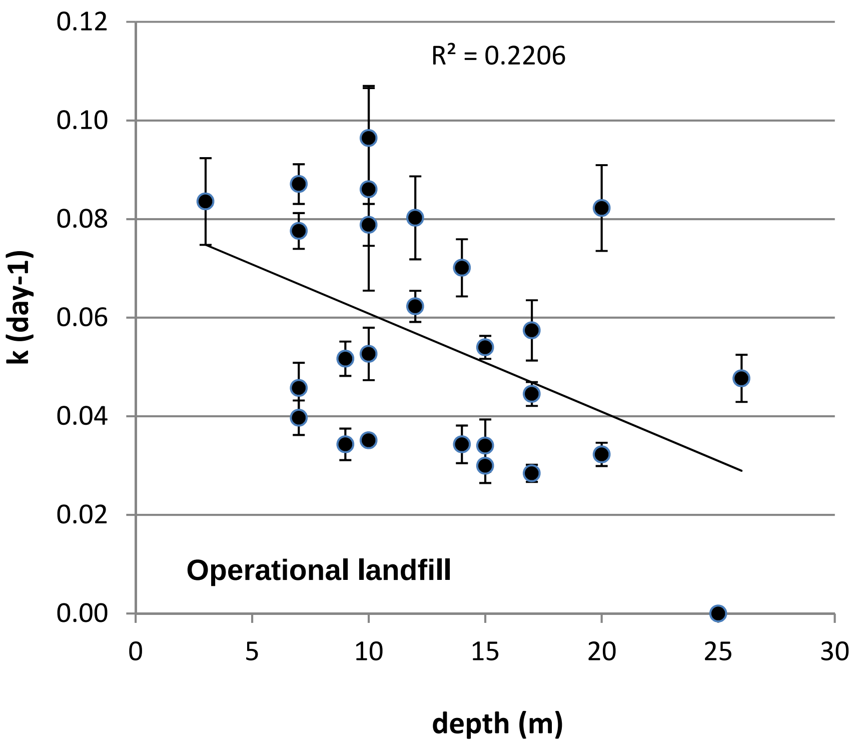


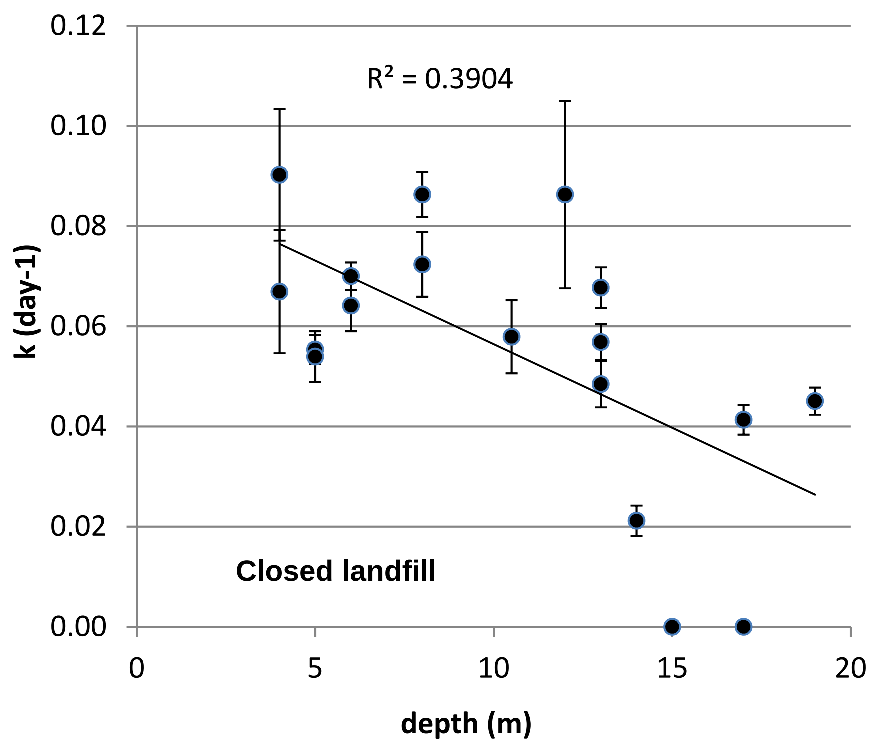
Other organics, wood, visible inerts and a_w did not affect B_0

Degradation rate, k_{lab}



Degradation rate with age and Depth

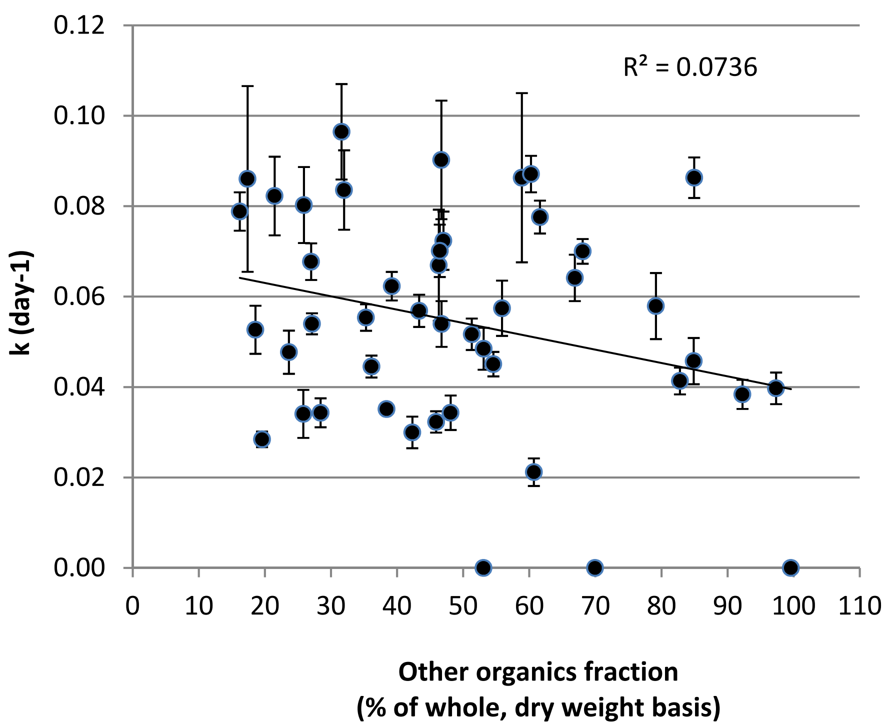


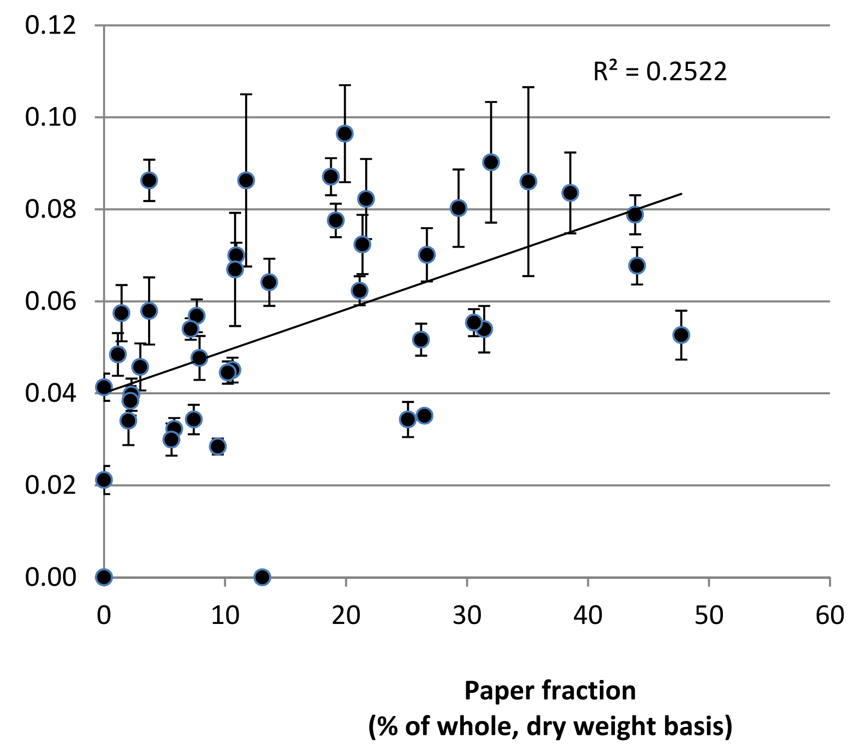


Sample age did not affect k_{lab}

Substrate characteristics vs degradation rate

Moisture and water activity did not affect *k_lab*





Wood, Visible inerts, volatile organic matter, total carbon, Moisture and a_w did not affect k_{lab}

Summary of chemical and biological characteristics

Parameter (Average)	Landfill	
	Operational	Closed
Dry matter (% wet weight)	76.3 ± 8.8	80.2 ± 11.9
Total carbon (% dry weight)	25.5 ± 12.0	15.5 ± 9.3
Methane yield, B_0 (Nm^3 CH_4/dry Mg MSW)	63.2 ± 42.4	53.4 ± 45.4
MSW degradation rate, k_{lab} (day^{-1})	0.055 ± 0.024	0.054 ± 0.026
MSW degradation rate, k_{lab} (yr^{-1})	20.0 ± 1.9	19.6 ± 2.0
Average Wood from landfill B_0 (Nm^3 CH_4/dry Mg wood)	42.3 ± 1.0	41.3 ± 1.1
Fresh soft wood B_0 (Nm^3 CH_4/dry Mg wood)	42.1 ± 1.5	
Average Wood from landfill k_{lab} (day^{-1})	0.034 ± 0.002	
Average Wood from landfill k_{lab} (yr^{-1})	12.41 ± 0.73	
Fresh soft wood k_{lab} (day^{-1})	0.023 ± 0.001	
Fresh soft wood k_{lab} (yr^{-1})	8.40 ± 0.37	

Moving Forward: Relating *k_{lab}* to *k_{field}*

$$k_{field,MSW} = f \times \sum k_{lab,i} \times (weighted\ fraction)_i$$

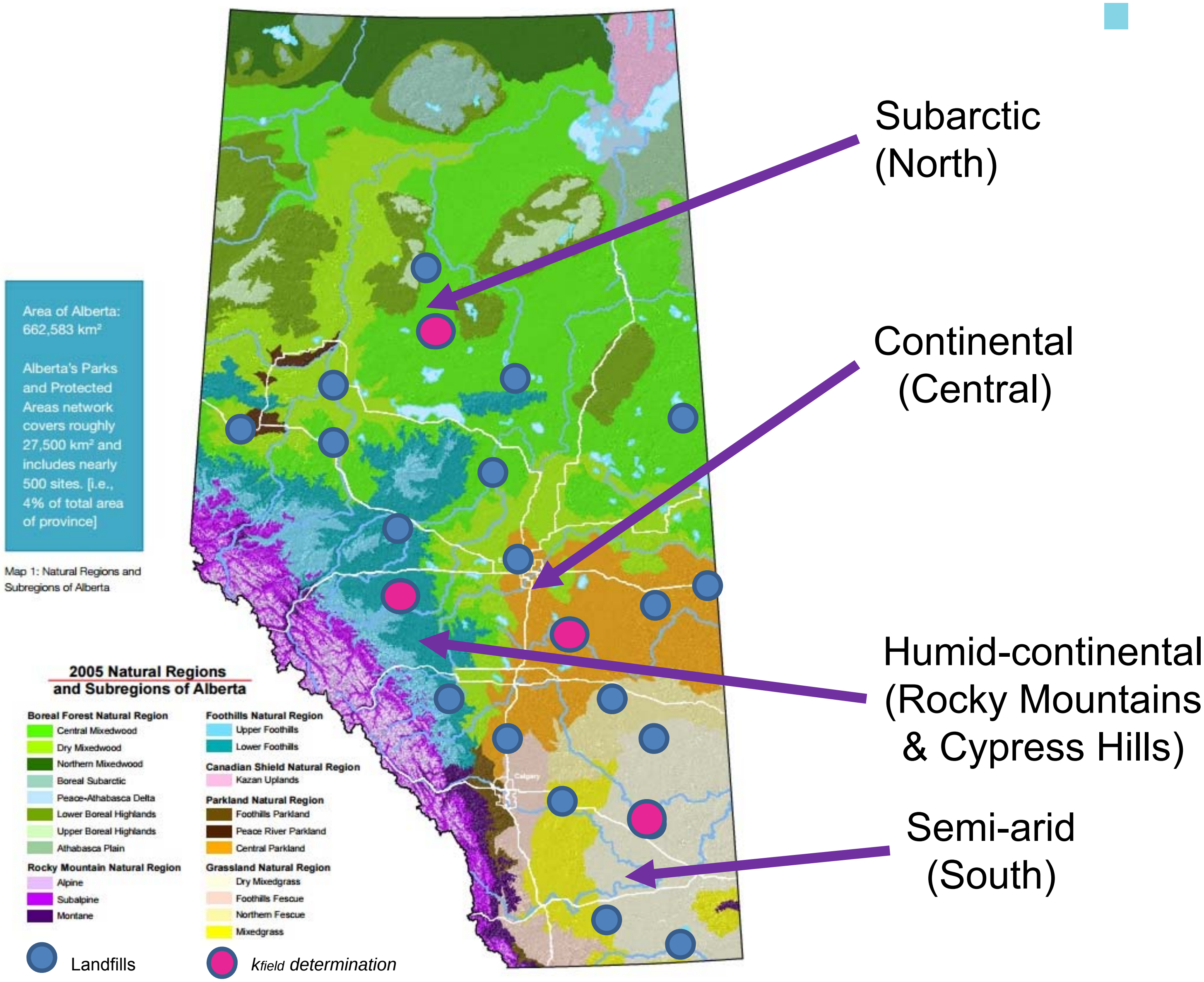
where *i* is the *i*th waste component and *f* is a correction factor.

Key Assumptions:

- Lab samples should be a reasonably true representative of the MSW composition in the landfill
- Average k_{lab} for weighted components = k_{lab} for bulk MSW
- K_{field} for landfill must be known
- No interaction which can influence *k* occurs between the waste components used in separate BMP assays.

De la Cruz FB, Barlaz MA, (2010). *Environmental Science and Technology*, 44(12):4722-4728

Determine k_{field} in each climatic subregion



http://www.albertaparks.ca/

Concluding Remarks

- Experimental data on landfill waste characteristics and B_0 for landfills in the semi-arid region of Lethbridge
- No significant difference was observed between the two landfills with respect to waste characteristics, B_0 and *k*
- B_0 and *k* showed positive linear correlation with paper content and available carbon in the waste.
- Sample depth in landfill had a negative effect on *k* and B_0
- Very low *k* and B_0 were observed for wood, which favour carbon sequestration
- Data generated will be valuable in establishing a lab-to-field *k* conversion factor for the semi-arid region of Alberta for landfill gas quantification model validation.
- Similar studies are required in other climatic sub-regions of AB for a comprehensive province-wide validation of the Alberta landfill gas quantification model

Research Team

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