Lesson 2b: Modeling Landfill Biogas Generation
Gas Models

- Why model Landfill Biogas
  - Preliminary estimate of methane and energy production
  - Estimate of environmental emissions
  - Initial project capacity and costs
  - Provide a benchmark for project performance

- What a model does not do
  - Guarantee the amount of biogas
  - Guarantee that you can collect all the biogas
The familiar equation

Basic Gas model;
Annual Gas Production = \( L_0 \cdot M \cdot (1 - e^{-k}) \)

where:
- \( k \) = reaction rate constant \((\text{Ln}(2)/t_{1/2})\)
- \( L_0 \) = methane generation potential \((\text{m}^3/\text{tonne})\)
- \( M \) = mass of degradable waste available
Exploring the variable - \( L_0 \)

- **Example**
  - Perfectly degradable organic substrate
  - Perfect digester
  - Ideal conditions

- \( L_0 = \) around 600m\(^3\) / tonne Biogas
- Complete degradation in 3 months
Exploring the variable - $L_0$

- But waste is not 100% degradable
- $L_0$ maybe 300 m$^3$/tonne

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Exploring the variable - $L_0$

- But not all the organic material degrades
  - Particle size too big
- Acid conditions
  - Isolated from bacteria
  - Chemical inhibitors
- Perhaps $L_0$ should be 150m$^3$/tonne
Exploring the variable - k

- In a perfect digester, $k$ is very high.
- In our example, a half-life of 3 months.
Exploring the variable - k

- In a perfect digester k is very high.
- In our example a half life of 3 months
- Landfill is NOT a perfect biodigester
- Perhaps half life = 1 year
Exploring the variable - k

- BUT – all waste is not easily degraded
- Perhaps degradable waste is;
  - 10% Oils, fats & sugars – Rapid (Half life = 1 year?)
  - 10% Proteins, carbohydrates, starches – Moderate (Half life = 2 years?)
  - 30% Paper & Card, green waste – Slow (Half life = 10 years?)
  - 50% Others – very slow (Half Life = 50 years?)

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Exploring the variable - k

- But our 1,000 tonnes was deposited over 1 year!
- Maybe we should allow 6 months to reach full gas production
Are the numbers right?

- Perhaps the Mass is +-10%
Are the numbers right?

- Perhaps the Mass is +-10%?
- Perhaps the $L_0$ is +-10%?
Are the numbers right?

- Perhaps the Mass is +/-10%?
- Perhaps the \( L_0 \) is +/-10%?
- Perhaps the \( k \) is +/-10%
Are the variables right?

- Perhaps the mass is +-10%?
- Perhaps the $L_0$ is +-10%?
- Perhaps the $k$ is +-10%
- Using reasonable assumptions throughout
- With a small error there is almost 100% difference in peak production
Other Waste Considerations

- Is there enough moisture in the waste?
  - Rainfall
  - Capping layer quality

- What is the waste temperature
  - Methanogenic bacteria need heat
Is there something missing?

- Our model indicates the possible baseline
- But we have not yet visited the site!
- So what factors should we look at on the site?
Gas Recovery

Basic IPCC Gas model;
Annual Gas Production = $L_0 \cdot M \cdot (1 - e^{-k})$

Needs a collection efficiency factor;
Annual Gas Recovered = $\eta \cdot L_0 \cdot M \cdot (1 - e^{-k})$
Collection Efficiency

\[ \eta \]

A small factor with a BIG impact

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Is the site full of leachate?
Is the site full of leachate?

- High leachate levels affect the Radius of Influence (ROI) of extraction
- If ROI is estimated at 20m
- A 5% error reduces collection area by 10.7%

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How long is the waste exposed?
Are the gradients too steep?

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Or is the site too shallow?
Are there site operations?
And other factors?

- Air leakage
  - Is the applied vacuum limited by oxygen ingress
- Are all the gas wells performing normally

- APOLOGIES – I know the following slide is hard to read.
Field Measurements
Other issues

- Volume correction for altitude and temperature
  - Are the gas pumps correctly rated?
  - Are flow meters corrected?

- Condensate drainage
  - Flow restrictions can occur

- Pressure drop in pipe work
  - Is there enough suction on the site
Are we collecting all the gas?

\[ \eta \] – Collection Efficiency can’t be modelled

- Reasonable assumptions are needed
- Adjustment based on history is required
Rio Azul Gas Model

Rio Azul Landfill, 6.8 Million Tonnes
70% Collection, 80% Domestic, Wet.
Simeprodeso Gas Model

SIMEPRODESO
70% collection efficiency
Filled from 1991 to 1999
Total 7,698,057 T
Gas Models - Summary

- May not adequately assess;
  - Site Conditions
  - Site Operations
  - Contractual terms

- Do not replace gas pumping trials

- Modelling requires actual and detailed knowledge of the site

- Take 50 gas models
  - On average they may be more or less correct.
  - !Any individual may be an order of magnitude wrong!

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Gas Models - Summary

- In Practice;
  - Gas Models can be quite good
  - Require to have detailed knowledge of the landfill
    - Waste
    - Engineering
    - Management
    - Environment

- CDM landfill gas projects are measured ‘ex-post’
- Often ‘what you get is what you get’ – and with experience that is usually pretty good!