Screening approach for landfill gas migration

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Landfill/ground/mine gas in Scotland

- Gas in the ground is a major issue in Scotland at the moment
- Gorebridge in Midlothian
- Houses on the site prior to redevelopment for 50 years
- New houses present for four years before the incident, when grouting occurred nearby
- A risk based approach to ground gas from all sources is still appropriate
- Use of GSVs to assess existing buildings in this scenario, Part IIa, etc is not appropriate – too conservative
- NHS Scotland calls for membranes in all coal areas misguided
Screening for landfill gas migration

- A method developed for Aberdeenshire Council to reduce the 250m planning consultation zone around landfill sites
- Developed further to assess old landfill sites for other Local Authorities in England - allows targeted site investigation and monitoring
- Used to help assess the risk of gas migration if old gas extraction and flare systems are turned off
- Used to help assess risk of landfill gas migration to new developments and whether cut off trenches are required
- The principles can be applied to many other gas scenarios, eg Part IIA and assessments for Environmental Permits
The conceptual site model (again!)

- It is important to develop a robust conceptual site model
- Two example sites - similar sites in terms of landfill and the volume of gas being generated
- Two very different levels of risk
- Most important driver of landfill gas migration risk is the geology outside the landfill site and the construction of the development
- For gas migration to pose a significant risk outside the landfill site open pathways are necessary along with a suitable reservoir for gas to accumulate close to the building
- One site required very little gas monitoring, the other required numerous wells, multi level wells and lots of monitoring and testing including isotope testing, etc
Examples of two landfill sites
Simplified CSM for each site

- High gas migration risk

Scenario 1

Groundwater
Clay
Dry

Older Volcanics - basalt with columnar structure - pathway for gas migration
Extremely complex geology and hydrogeology

Recent domestic waste in peak phase of gas generation
Daily cover layers clay - perched
Poorly performing gas extraction
Simplified CSM for each site

- No gas migration risk

Scenario 2

- Recent domestic waste in peak phase of gas generation
- Limited or no daily cover
- Waste flooded
- Passive vent wells
Screening approach

- Based on international guidance from New Zealand and Canada
- Assess level of risk associated with three components
  - Hazard (ie the source of gas)
  - Pathway
  - Receptor
- Standard risk assessment procedure
Hazard component

- The type of landfill waste accepted and its biodegradable content
- The age of the landfill (time since filling was completed)
- The volume of material placed in the landfill and whether it is a wet or dry landfill
- The presence of engineering measures that could reduce the risk of gas migration (liners, gas extraction) or increase the risk (simple capping layer)
Hazard component

- Landfill gas generation uses up the source
- Old landfills – pre 1975 are generally not a problem with respect to off site migration
Hazard component

- The greater the volume of waste material the greater the volume of gas that can be generated.
- Landfills with a higher moisture content generate more gas than one that is dry.
- Only a worst case approximation of the volume is required, based on estimates of the plan area of the landfill and the likely depth.
Pathway component

- Two parts to the pathway component

1. Nature of the soils/rock surrounding the landfill and the likely permeability. This is determined from geological maps (solid and drift geology). Soils with lower permeability (e.g., clayey soils) will limit the risk of gas migration and soils/rocks with a higher permeability (e.g., highly fractured rock or sand and gravel deposits) will increase the risk.

2. Likely presence of preferential pathways such as faults or large services.
Receptor component

- Look at sensitivity of receptor
- Consider
  - Use of building
  - Type of building
  - Floor construction
  - Basement construction
  - Building ventilation
  - Any gas protection systems
  - Services and drainage
Scoring system

- Following factors are scored from 0 to 1
- 0 is lowest risk and 1 is highest risk

- Type of landfill
- Age of landfill
- Volume of material and whether wet or dry
- Engineering measures
- Pathway permeability
- Preferential pathways
- Is there evidence of gas migration
- Receptor sensitivity
Scoring system examples

- **Type of landfill**
  - Domestic/Sanitary landfill – High – Score = 1
  - Commercial/Industrial – Moderate – Score = 0.6
  - Inert landfill – Low – Score = 0.1

- **Pathway permeability**
  - High risk – Open or high permeability preferential pathway – Score = 1
  - Moderate risk – Permeable soils such as sand and gravel - Score = 0.6
  - Low risk – Low permeability soils or rock – Score = 0.1
Overall risk

- The overall risk of gas migration determined by multiplying the individual scores together
- The overall level of risk is based on the following assumptions:
  - Low risk – Individual scores comprise 4 low, 2 moderate and 2 high \((0.1^4 \times 0.6^2 \times 1^2 = <3.6 \times 10^{-5})\)
  - Low/moderate risk - Individual scores comprise 3 low, 4 moderate and 1 high \((0.1^3 \times 0.6^4 \times 1 = <1.3 \times 10^{-4})\)
  - Moderate risk - Individual scores comprise 8 moderate \((0.6^8 = <0.017)\)
  - High risk - > 0.017.
Decision and judgement time

- Does the result of the assessment seem sensible?
- Does it agree with the CSM?
- What is the level of uncertainty?

- This is a tool to help with decision making
- It helps with consistency between sites
- It cannot be applied without careful thought and consideration
Pathway preliminary modelling

- Migration modelling uses a one dimensional convective – dispersive solute transport equation
- Used in the GASSIM programme
- The general form of the equation is:

\[
R \frac{\partial C}{\partial t} = \frac{\partial^2 C}{\partial x^2} - V \frac{\partial C}{\partial x}
\]

- Where \( C \) = gas concentration, \( x \) = distance along pathway, \( t \) = time, \( D \) = diffusion coefficient, \( V \) = flow velocity and \( R \) = retardation factor
Example 1

- Cross sections – we can obtain a lot of information on levels from historical maps
Example 1

- Type of landfill: Domestic refuse, high = 1
- Age of landfill: Filled by 1969, > 40 years, low = 0.1
- Volume of material: Conservative estimate is 41,000m³, wet area, Low = 0.1
- Engineering measures: unlined and uncapped, moderate = 0.6
- Pathway permeability: Bedrock is Old Red Sandstone with superficial of sands and gravel, high permeability, high = 1
- Preferential pathways: potential culvert, moderate = 0.6
- Is there evidence of gas migration: historic gas monitoring indicates no evidence, low = 0.1
- Receptor sensitivity: Housing, high = 1
Overall risk rating

- Overall risk score is 0.00036
- Low to moderate risk
- Maximum likely gas migration distance is 115m
- Use this for planning consultation zone around the landfill site
Consider future - Impact of flooding

- Recent evidence review of landfill gas migration and flooding
- The literature review did not find any publicly documented case where surface flooding has caused landfill gas migration into buildings
- It did find evidence of potential risks that need to be assessed
- Three key issues concerning gas risk and flood waters:
  - Effect of groundwater flooding and rising groundwater levels;
  - Effect of flood water on surface sealing;
  - Effect of flood water or rising groundwater sealing existing migration pathways and causing migration elsewhere.
Flooding changes gas migration pathways

Gas migrates via new route because old one is closed off.

Gas migration route sealed by flood water.

Flooding saturates ground and prevents gas migration out of surface.

Gas pushed out of ground by rising groundwater. Rate of rise determines significance of risk.

Gas can become trapped below impermeable layers and migrate sideways - would require large volumes of gas to be a significant risk.

New gas migration route in deeper unsaturated and permeable layer.
Flooding – eg groundwater flooding

- The evidence review found that in relation to groundwater:
  - Rising groundwater can in theory push gas out of the ground.
  - If the groundwater rise is slow, displacement of gas from soil or rock pores is not likely to cause sufficient emissions at the ground surface to pose a risk in normally ventilated buildings (assuming it is not concentrated at a fault, shaft or similar feature)
  - Any rise in groundwater that causes groundwater flooding is also unlikely to be fast enough or sustained enough to cause appreciable gas emissions at the surface (the same applies on many sites that are affected by tidal variations)
Other information

• A paper to accompany this presentation will be available at www.epg-ltd.co.uk as Ground Gas Information Sheet No 3
• Using ternary plots for interpretation of ground gas monitoring results - Ground Gas Information Sheet No 1
• Dissolved Methane Monitoring for Ground Gas Risk Assessment – Ground Gas Information Sheet No 2
• Piled Foundations and Pathways for Ground Gas Migration in the UK - Environmental Geotechnics
• CL:AIRE TB16 Complete Continuous Monitoring in Underfloor Voids
• CLAIRE TB17 Ground Gas Monitoring and ‘Worst-Case’ Conditions
Thank You

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