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Assessment of Ground Gas Sources using Oxygen to Nitrogen Ratios

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Overview

- Carbon Dioxide gas risks and impacts
- Importance to semi-quantitative risk assessment
- Natural sources and subsurface concentrations
- Differentiating between sources
- Oxygen to Nitrogen ratio theory
- Case study

Carbon dioxide acute toxicity risks

- Headaches and shortness of breath at 2% v/v o

Gorebridge development before and after knockdown

In contrast to methane, developments affected solely by carbon dioxide are not perceived as being immediately at risk. This is because even if a high concentration of carbon dioxide accumulates directly beneath a building, it does not pose an immediate risk to occupants, providing it is not allowed ingress.

- CIRIA Report 149

Modified Wilson and Card classification

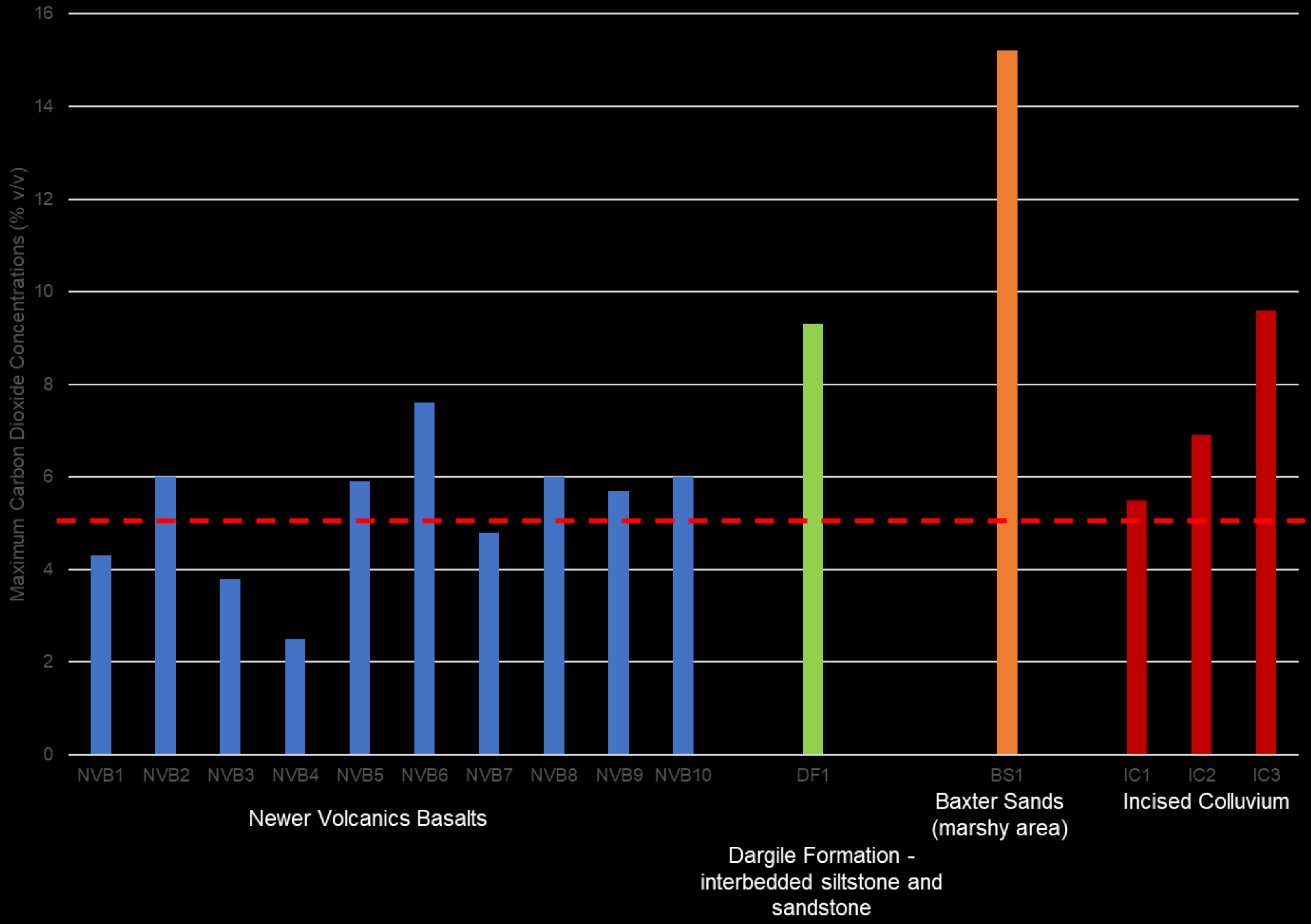
	Characteristic situation (CIRIA R149)	Comparable classification in DETR *et al* (1999)	Risk classification	Gas screening value (GSV) (CH_4 or CO_2) (l/hr)[1] Threshold	Additional factors	Typical source of generation
	1	A	Very low risk	<0.07	Typically methane £1 % and/or carbon dioxide £5 %. Otherwise consider increase to Situation 2	Natural soils with low organic content "Typical" made ground
	2	B	Low risk	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3	Natural soil, high peat/organic content. "Typical" made ground
	3	C	Moderate risk	<3.5		Old landfill, inert waste, mineworking flooded
	4	D	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures.	Mineworking – susceptible to flooding, completed landfill (WMP 26B criteria)
	5	E	High risk	<70		Mineworking unflooded inactive with shallow workings near surface
	6	F	Very high risk	>70		Recent landfill site

Wilson *et al* 2007

Source	Origin	Methane	Carbon dioxide	Other gases
		Typical concentration range (v/v)		
Soil	Physical, chemical and biological weathering	<2 ppm	350 ppm	–
Soil	Oxidation of organic matter		0–10%	–
Swamps and wetlands, waterlogged soils	Anaerobic microbial decay of organic material	10–90%	0–5%	Phosphine (PH_3)
Coal measures strata	Coal seam gas	<1–90%	0–6%	–
Organic shales	Tightly held gas originating from both biogenic and thermogenic processes	60-90%	0-5%	Ethane, H_2S
Carbonate strata, including shelly sands	Dissolution of carbonates by acidic groundwater (e.g. due to oxidation of acid sulfate soils)		1–20%	–
Natural gas traps	Leakage	90–95%	2–8%	–
Granite	Radioactive decay of uranium	N/A	N/A	Radon typically <200 Bq/m^3

NSW EPA 2020

Maximum CO_2 detections from "background bores"



Methods to differentiate between gas sources

- Pre-landfilling/background bore
- Radioisotope analysis
- Isotopic fractionation
- VOC analysis for chlorinated hydrocarbons co-present with the suspected landfill gas.
- Ethane and/or butane content
- **The methane to carbon dioxide and oxygen to balance ratios can provide important information about the source of the gas.**
- Total organic carbon in soil analysis

- EPA Victoria Publication 1684

Oxygen to Nitrogen ratios

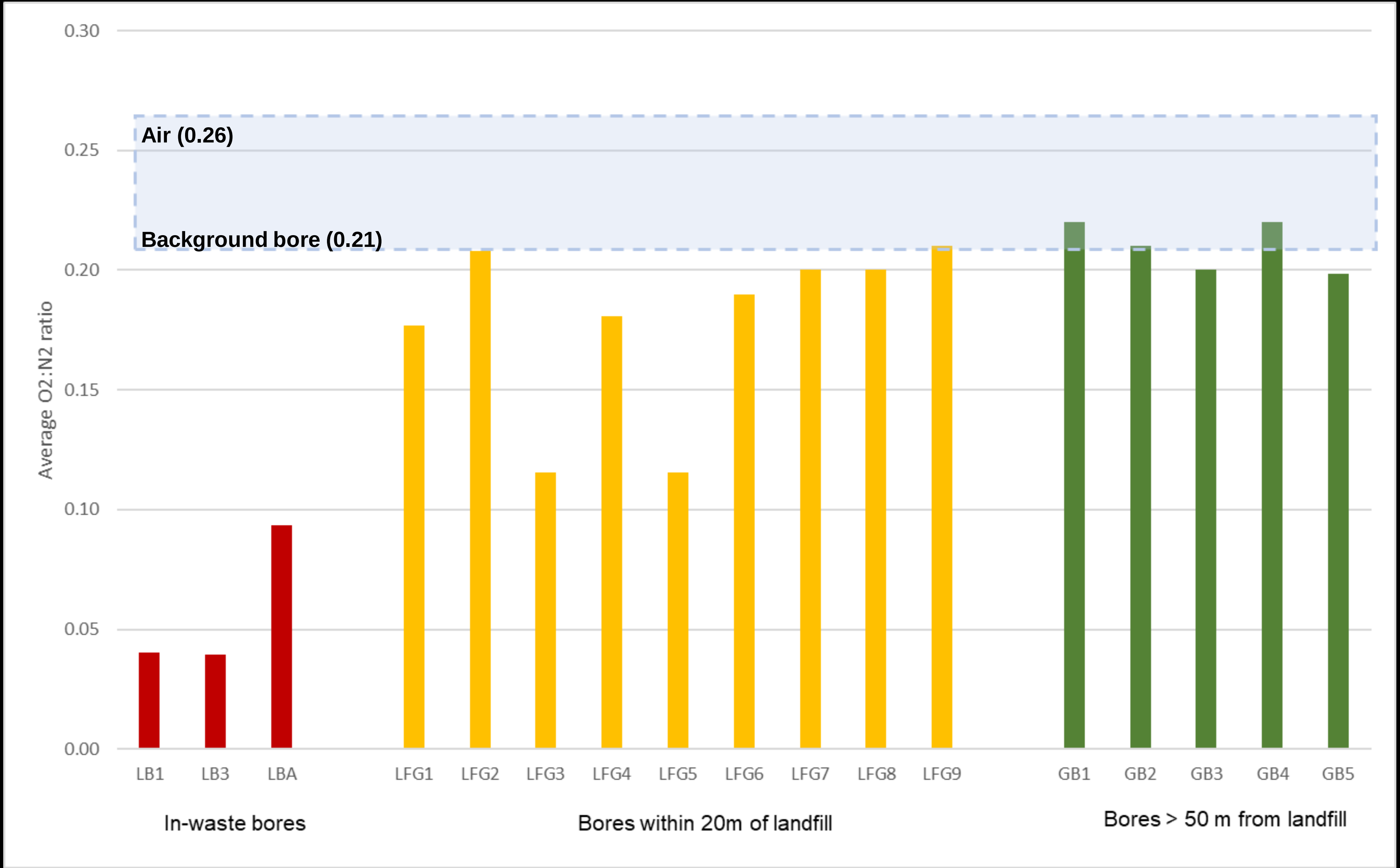
- Show what redox processes are taking place in the ground
- In natural soils, atmospheric gases are typically present at a ratio of 20.95% oxygen to 79% nitrogen (plus argon) unless oxygen consumed by oxidation reactions in ground gas
- Oxygen consumption common near actively gassing landfills
- Background bores can provide information on local ratios
- Ratios between true background and atmospheric gases (21:79 or 0.26) is indicative of background gas ratios. Less is indicative of methane (or other reduced gas) being oxidised
- Monitoring points can show no methane presence if oxidative processes take place faster than landfill gas generation plus migration processes.

Line of evidence to support CSM – do not rely on in isolation

Example case study

- Proposed residential receptor 100 m from closed putrescible landfill – unlined
- Landfill closed 20+ years
- High in-waste gas concentrations, low flow (< 1 L/hr)
- Surrounding geology clayey soils overlying gneiss
- 5+ years of monitoring data
- Landfill perimeter bores showing low CH_4 (0 – 1% v/v), elevated CO_2, decreased O_2
- Receptor bores show no methane but *potentially elevated* (above natural) CO_2
- Background/offsite bore shows CO_2 typically <5% v/v, but some readings up to 7% v/v

Example case study



Oxygen:Nitrogen ratios: Pros and Cons

Pros

- Inexpensive if data is available
- Relatively quick and simple approach
- Trends in ratios can provide indication of extent of LFG migration from a source

Cons

- Requires understanding of “true background” concentration
- Variable geology/backfilling and groundwater in bores can affect results
- Without a robust CSM can be open to scrutiny – e.g. are results representative of range of subsurface conditions, is the “background” ratio representative

SHOULD ONLY BE USED AS A TOOL TO COMPLEMENT A ROBUST CSM

References

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* Thank You

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