Methane from Leaking Abandoned Wells: Health and Safety Issues

Summary and Key Risk Management Considerations

- Methane toxicity is minimal, physical hazards of flammability/explosiveness are greater concern.
- Methane is only likely to reach concentrations approaching flammability levels while traveling under pressure to a confined space. Dispersion to general atmosphere is likely to be rapid.
- Best practice for risk mitigation is increased air circulation and ventilation of confined spaces, and positive pressurization of buildings, where possible
- Occupational Health and Safety and Landfill Management guidelines provide relevant information for action levels and best practices.

BACKGROUND

Health Risks

The most important health risks of methane are not associated with an internal toxic mechanism of action, but with the physical hazards of flammability/explosiveness, and of oxygen replacement in air that leads to simple asphyxiation.

Physical Hazards

Flammability/Explosiveness

Methane is flammable in concentrations from 5% to 15 %. Vapour accumulation to these levels is unlikely in the outdoors, but can occur in confined spaces, such as mine shafts, underneath buildings and in basements or rooms with poor air circulation. Methane concentrations in this range, and a source of ignition, can lead to flash fires or explosions powerful enough to destroy wooden or brick buildings.

Alberta Occupational Health and Safety Code Explanation Guide, Part 10 has information about the explosive limits of methane and other flammable gases, as well as suggestions for management.

Simple Asphyxiation

Simple asphyxiation is the process where a gas replaces enough oxygen in breathing air space to cause suffocation. It is not a toxic response to the gas in question, but a lack of oxygen, or hypoxia, that is lethal. Concentrations of methane of 33% to 52% would correspond to 14%-16% oxygen, where respiratory distress is typically observed. At concentrations of 52% to 60% methane (8%-10% oxygen) collapse, nausea and vomiting are common. Oxygen depletion to 8.5% over 30 minutes is considered lethal. Due to the high concentrations involved, methane related fatalities are rare, with most recorded incidents happening in coal mines.

Toxicity

Reviews of literature on methane toxicity conclude that it does not, upon ingestion or inhalation, operate through any systemic or cellular mechanisms but is essentially inert in the body. Extrapolations from studies with similar lower-molecular weight alkane gases (butane, propane) suggests that some methane toxicity to the central nervous system, causing drowsiness and perturbed sense of balance, might exist at concentrations above 1000 ppm in air (0.1%). The American Conference of Governmental Industrial Hygienists (ACGIH) has proposed a threshold limit value (TLV) of 1000 ppm for worker exposure. Studies of methane mutagenicity have found no evidence that it is a mutagen, there is no evidence that it is a teratogen or a reproductive toxicant 0.1% or at any concentration below the onset of hypoxia. The health effects at low doses (at or near the TLV) are understood to be reversible when the exposure ceases.

Toxicity information is mostly available for the inhalation route. Due to the volatility of methane, ingestion and dermal absorption will be minimal. Methane is not an irritant, and unless it is naturally or commercially combined with a sulphur containing compound, it has no odour or taste.

Fate and Transport and Exposure Pathways

The critical issue is for health and safety is whether methane is traveling under pressure towards a confined space where it can accumulate. Methane is a buoyant gas at standard temperature and pressure, and will rise and dissipate in the open air. In the subsurface, methane will follow the path of least resistance towards the surface; cracks and leaks in the gas well casings, but also include fractures in bedrock or pore space in sandy soil and gravel, which may be natural substrate or the fill around utility installations or under building foundations. Transport of subsurface vapours solely due to diffusion and dispersion is generally thought to be an issue when the source is located within 5 m of the foundation. Transport of vapours under pressure can be significant over much greater distances, 30m or more. Alberta's Guidance on managing methane from landfills recommends that soil gas pressure above 0.249 kPA are indicative of sufficient transport in the subsurface that vapour transport is an issue. Methane could accumulate under a building, or enter a building through cracks or holes in the foundation (made to accommodate utilities or sump pumps). Methane is more likely to enter the building if there is a pressure gradient between the building interior and the subsurface, which is often the case when homes are heated with forced air systems. Commercial buildings may have less of an issue if they have a positive pressure ventilation system. Once indoors, the extent of mixing will depend on the building configuration and ventilation. Vapour accumulation could occur in basements if they are poorly ventilated, or if there is a room (such as a small utility room) in a basement that is poorly ventilated

Methane can also be transported in groundwater/well water. Methane in well water may exist naturally, or be the result of leaking gas well passing through groundwater aquifers. Most of the methane is likely to volatilize to air when the groundwater is brought to surface. Tap water, and groundwater seeps in the foundation can contain methane and contribute to indoor air concentrations. Methane concentrations in groundwater associated with gas wells (with 1 km) were found to have an average value of 19.2 mg of methane/litre, and a maximum value of 64mg/l. These values were reported in Pennsylvania and may be the combined product of abandoned gas wells, high natural levels of methane in the subsurface, and ongoing hydraulic fracturing in the area. The same researchers found concentrations in groundwater wells in Pennsylvania to have an average concentration of 1.1 mg/L when they were more than 1 km away from any known wellhead. U.S. Dept of Interior gives 28mg/l as the limit of acceptable concentration of methane in well water for indoor use. This limit is based on the possible contribution to methane levels in indoor air concentrations, and the risk of reaching the explosive limit. Flammable tap water is another hazard associated with methane concentrations in well water, though at concentrations considered supersaturation, made possible only when pressure from methane generation or flow in the subsurface is very high. The 28mg/l threshold would assure water concentrations were below the level where flammable tap water would be a possibility. Though ingestion of small amounts of methane through groundwater is possible, due to its volatility, the airborne methane and resulting physical hazards is the predominant concern. Health risks of ingesting the small amounts of methane that would remain in tap water are minimal.

Transport through ambient air into a building would depend on the flow from the leaking well head, the proximity to a building, and whether some type of intake or draft existed that would draw air into the building.

Selected Action Levels for Indoor Air

The MSDS for methane recommends that ventilation should exist to prevent buildings from accumulating vapours above 1%, and that buildings be evacuated at this concentration, which is 20% of the Lower Explosive Limit. Evacuation levels for methane in buildings usually range from 20% to 25% the Lower explosive limit, or 1% to 1.25 %.

AGGIH TLV Possible short term health effects 0.1% or 1000ppm. Most guidance recommends increase monitoring and improved ventilation.

Alberta Guideline for Landfill in off-site buildings: 0.01% to 0.05% or 100-500ppm –Indicative of possible methane migration and that regular monitoring (quarterly or more) is advisable.

References

AirGas. Material Data Safety Sheet. Methane. Prepared to Canadian WHIMS Standards. http://www.pge.com/includes/docs/pdfs/shared/environment/pge/cleanair/methane1033.pdf

Alberta Occupational Health and Safety Code. Part 10: Fire and Explosion Hazards. https://work.alberta.ca/documents/WHS-LEG_ohsc_p10.pdf

CG& S for Alberta Environmental Protection. Guidance Document on Management of Methane Gas Adjacent to Landfills. Dec 1999. http://environment.gov.ab.ca/info/library/5847.pdf

Duncan, Ian J. Does methane pose significant health and public safety hazards? Environmental Geosciences, v. 22, no. 3 (September 2015), pp. 85–96 85

National Institute for Occupational Safety and Health, International Chemical Safety Cards. Methane. July 1, 2014. http://www.cdc.gov/niosh/ipcsneng/neng0291.html

Osborna, SG, Vengosh, A, Warner, NR, Jackson RB. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences. vol. 108 no. 20 http://www.pnas.org/content/108/20/8172.full.pdf+

Prasad, S., L. Zhao, and J. Gomes, 2011, Methane and natural gas exposure limits: Epidemiology, v. 22, no. 1, p. S251. doi: