

Workplace Risks from Bacterially Derived Toxic Gases

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Introduction

Risks to human and animal health from bacteria are not only associated with infection, but can be a consequence of exposure to toxic by-products. Natural fermentation of organic materials is likely to involve a complex mixture of bacteria, and if this includes sulphate reducing bacteria (SRB) there is the possibility that hydrogen sulphide (H₂S) will be generated [1].

In the workplace, if this occurs in confined spaces it can lead to oxygen depletion and an asphyxiation hazard for workers, as well as the high toxicity of H₂S. Depending on exposure level, symptoms range from an irritant effect through arrest of cellular respiration to immediate unconsciousness. H₂S has a poisonous effect on all organs, but in particular on the central nervous and pulmonary systems [2]. Health effects, dependent on concentration and duration of exposure, are:

1. At a concentration as low as 0.0047 ppm 50% of humans can detect the characteristic 'rotten egg' odour of H₂S.
2. The UK Workplace Exposure Limit for H₂S is 5 ppm for long-term exposure (8-h Time Weighted Average reference period), or a short-term exposure limit (STEL) of 10 ppm for a 15 min reference period.
3. At 150–250 ppm the olfactory nerve is paralysed after a few inhalations so that the sense of smell disappears, often together with awareness of danger.
4. Exposure to 530–1000 ppm can cause strong stimulation of the central nervous system and rapid breathing, progressing to loss of breathing.
5. 800 ppm is the generally accepted LD₅₀, i.e., the lethal concentration for 50% of an exposed human population after 5 min exposure.
6. Concentrations over 1000 ppm can cause immediate collapse with loss of breathing, even after inhalation of a single breath (UK Health and Safety Executive guidance).

On livestock farms, animal manures and slurry is stored in large tanks or pits. During storage, slurry forms distinct layers when undisturbed and anaerobic biodegradation takes place leading to the production of a number of gases and volatile organic compounds [3]. Efficient mixing is required to return this settled slurry to a homogeneous mixture and allow the slurry to be pumped out of the store and spread as manure. If H₂S produced by SRB in stored animal slurry is emitted into poorly ventilated confined spaces, this can lead to a buildup to concentrations capable of causing asphyxiation. A review of cases in Netherlands revealed that, from 1980 to 2013, 35 accidents involving 56 victims were associated with manure storage. Of those 56, 25 (45%) died at the scene and a further three (11%) died in hospital. As can be seen from these figures, it is not uncommon for multiple

fatalities. Typically, after a first person is overcome, further people succumb during their attempts at rescue.

In the UK, articles in the farmers' trade magazine *Farmers Weekly* ('Farmers risking lives by ignoring deadly slurry gas threat' available at <http://www.fwi.co.uk/news/farmers-risking-lives-by-ignoring-deadly-slurry-gas-threat.htm>) emphasise the need to take precautions to avoid exposure [2]. The Health and Safety Executive of Northern Ireland (HSENI) recognises slurry as one of the four main causes of death and serious injury on Northern Ireland's farms, with serious incidents resulting from farmers being overcome by gas released from slurry during mixing, as well as hundreds of animals being killed in similar circumstances. It is also possible for drowning to occur where people, exposed to the fumes, have fallen through openings into tanks. As a consequence, HSENI has published guidance information to raise awareness in farmers.

It is important to understand factors influencing H₂S emission from slurry, and this is being done in studies conducted by Great Britain's Health and Safety Executive.

Laboratory-based studies

In laboratory-scale experiments, cattle slurry and cattle bedding collected from farms was placed in enclosed 20 liter vessels fitted with mechanical stirrers. H₂S was monitored using a real-time gas detector (GeoTech GA5000) in the head space above the slurry before and after stirring. Before stirring, H₂S levels in head spaces were minimal. After stirring, maximum head space H₂S levels with slurry or bedding ranged from 330 to 1190 ppm. By comparison, the UK STEL is 10 ppm.

A further contributory factor to H₂S generation is that powdered gypsum (hydrated calcium sulphate) may be used as animal bedding. It was hypothesised that if gypsum enters slurry systems, it could be metabolised by SRB and further increase H₂S generation. In laboratory experiments 1% gypsum powder, considered to be a representative proportion, was added to cattle slurry or bedding and H₂S monitoring was continued daily for up to 25 days. Statistically significant increases in H₂S levels were associated with gypsum addition, as high as 1772 ppm with slurry and 3940 ppm with bedding. Emissions peaked at around day 15 with slurry and bedding to which gypsum was freshly added. In samples containing gypsum that had entered the slurry system on the farm emissions peaked within 5 days when further gypsum was added, suggesting a bacterial population already primed for gypsum metabolism.

The results of these laboratory scale studies showed that levels of H₂S produced from stirred slurry could constitute a hazard to anyone exposed to it, with the potential to greatly exceed the STEL in a confined space above stirred slurry and reaching potentially life-threatening levels based on the laboratory simulation. Adding gypsum further increased emission levels. Therefore, if gypsum residues enter

slurry it could increase the risk of H₂S accumulation in confined spaces associated with slurry systems. It is important therefore to take this into account in assessing and managing risk on livestock farms.

Farm-based studies

A series of visits to farms in England is in progress, aiming to improve the knowledge base of the characteristics and spread of H₂S gas generation and dissipation, to understand farmers' knowledge and awareness of H₂S gas and understand farmers' current working practices when working with slurry. The overarching aim of the project is to reduce the number of H₂S and slurry-related deaths and accidents in the UK.

A range of different designs of slurry stores are being assessed. At each farm, real-time measurements of H₂S gas concentration are being taken at points near to and some distance downwind from stirring and agitation of cattle slurry in storage tanks. These are being supported by video footage of the work to provide contextual information that might have an influence on the concentrations of H₂S measured.

Based upon the data collected to date, typically, as may be expected, H₂S gas levels were high near to the stirrer with levels decreasing with distance. However it was possible to detect H₂S at or above the STEL of 10 ppm as far away as 10 m from the stirrer in some instances. Where tanks are under slatted floors in cattle houses, this can lead to high H₂S levels inside the buildings, and it typically takes longer for it to dissipate than outdoors after stirring is stopped. Normal farm practice for slurry stirring is to use a power take-off facility on a tractor to operate the stirrer; with farm staff vacating the area after stirring has started. This showed awareness of the potential hazards and suitable precautions to reduce risk. This was important as high concentrations of H₂S can be detected in the vicinity of the tractor during stirring. Concentrations were lower in enclosed tractor cabs but it would be inadvisable to rely on this protection and remain in the cab.

Many factors are predicted to affect the rate of H₂S gas generation within slurry and subsequent release of the gas during stirring. For example, in some farm visits multiple monitors were placed at the same location at different heights. In the majority of cases H₂S gas levels were higher at the lowest position, particularly at indoor

positions, indicating that during stirring H₂S gas is released from the slurry into the headspace between the top of the slurry and the slatted floor, progressively infiltrating the wider building space, where natural ventilation will affect dissipation. Other factors hypothesised to affect generation include air temperature on the day of stirring and/or on the preceding days, the frequency of stirring to minimise accumulation of gas and the addition of other wastes i.e. dairy chemicals or silage effluent [4]. In general, the data collected to date is varied and multiple factors are likely to affect gas dissipation including natural ventilation, wind direction, individual tank design and position, proximity of nearby buildings, trees etc.

Conclusion

Laboratory-based studies demonstrated the potential for very high levels of H₂S gas to be released from animal slurries when being stirred [5]. Accumulated H₂S gas in confined spaces above the slurry reached levels that would be immediately life-threatening. Initial results from farm-based studies are establishing the circumstances that could lead to H₂S gas release and dispersal with the potential to affect farm workers. This combination of information is vital to further inform farmers and assist them in assessing and controlling risk, and in developing practical measures to mitigate exposure.

References

1. Mooyaart EAQ, Gelderman EAG, Nijsten MW, de Vos R, Hirner JM, et al. (2016) Outcome after hydrogen sulphide intoxication. *Resuscitation* 103: 1–6.
2. Crook B, Stagg S, Bowry A, Frost G (2017) Gypsum in animal slurry systems enhances generation of hydrogen sulphide and increases occupational exposure hazard. *Sci Total Environ* 609: 1381–1389.
3. Reyes M, Borrás L, Seco A, Ferrer J (2015) Identification and quantification of microbial populations in activated sludge and anaerobic digestion processes. *Environ Technol* 36: 45–53.
4. Health and Safety Executive Northern Ireland (HSENI) Slurry gas-mixing slurry safely.
5. UK Health and Safety Executive guidance (2009) Managing Hydrogen Sulphide Offshore.