Costly Mistake 1: The Heavier-Than-Air Myth

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ISSUE

Industrial ventilation systems in some workplaces are designed to remove dense vapours that are thought to collect near the floor. As a result, a costly industrial ventilation system is installed. It does little to reduce toxic exposures and it costs for every hour it is running.

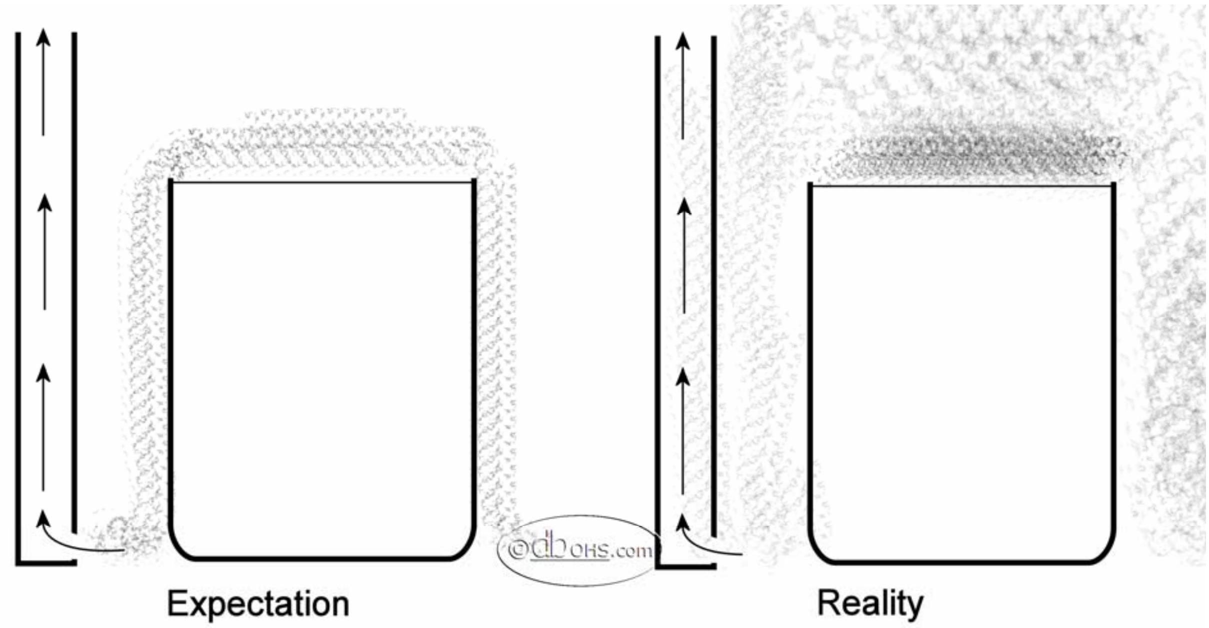

Figure 1 The "Expectation" is that heavier-than-air vapours collect near the ground leads to the wrong design of industrial ventilation to remove the vapours. The "Reality" is an inefficient dilution ventilation system

THEORY

It is not uncommon to find industrial ventilation systems in workplaces designed to remove "heavier-than-air" vapours and gases from near the floor. This can occur at very high concentrations, usually orders of magnitude above occupational exposure limits (see Figure 2 below). If there are no temperature gradients (isothermal) or other air disturbances from moving people or machines, it is possible to achieve a layer of contaminant, such as in the bilge of a boat, but this is very much the exception.

At concentrations likely to support an explosion (30,000 – 50,000 ppm), many solvents are narcotic and a person could become unconscious. Local high zones can occur where explosions or fires could be supported, so ignition sources like welding, electrical equipment or smoking can be a real hazard even when the measured air concentration is low.

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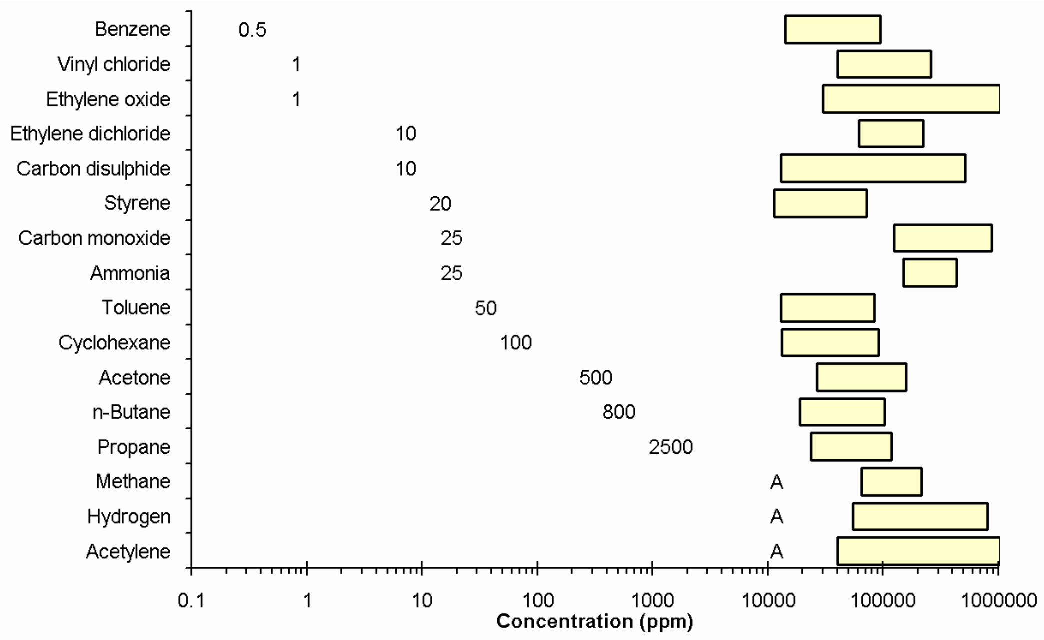

Figure 2 Exposure Limits and Explosive/Flammable Ranges (box) for common chemicals

Data source: 2004 ACGIH TLV® list and Lees (1996).

The concentration is on a logarithmic scale in ppm and most exposure limits are less than 1% of the lower Explosive/Flammable limit. A nominal 15,000 ppm has been plotted for asphyxiants (A) corresponding displacement of oxygen from 21% to 19.5%.

A simple calculations shows that even concentrations of 1000 ppm for a solvent with a vapour density twice that of air are unlikely to sink to the ground:

Imagine a million air molecules with unit density, with 1000 molecules of solvent (10 times the occupational exposure limit for many solvents) with twice the vapour density compared to air. The density of the vapour- air mix is

$$\frac{(999{,}000 \times 1 + 1000 \times 2)}{1{,}000{,}000} = 1.001$$

$$= 0.01\% \text{ increase}$$

Now consider the ideal gas equation, PV = nRT, with the usual symbolic meanings to Pressure, Volume, moles (n), the gas constant R, and absolute Temperature (T) in kelvins (0°C is 273.15°K). The air pressure at the floor and ceiling is effectively the same, ignoring the weight of the air column in the room and the volume of air is constant, so the "nRT" right side of the equation at floor and ceiling is the same, or $n_1T_1 = n_2T_2$. For air temperatures of 20°C at the floor and 21°C at the ceiling gives

T_1 = 20°C = 273 + 20 = 293°K at floor

T_2 = 21°C = 273+ 21 = 294°K at ceiling

giving

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$$\frac{(n_2 - n_1)}{n_2} = 1 - \frac{T_2}{T_1}$$

$$= 0.34\% \text{ change in density}$$

A mere 1°C temperature difference from floor to ceiling is going to produce much greater (34x) convective forces than the density of a vapour at 1000 ppm. This means that in most workplaces, slight air currents will readily mix the air and a blanket of "heavier-than-air" vapour will not form near the floor.

Figure 3 An expensive ventilation system at a paint factory deigned to remove heavier-than-air vapours from the floor. The measured solvent concentration was uniform from the floor to at least 10 m.

A ventilation system designed to remove the solvent vapour from the floor will remove little of the solvent vapour and become an expensive dilution ventilation system.

SOLUTIONS

It is best to control exposures at the source. Investigate whether vessels can be better sealed – including lids on tins. If industrial ventilation is still needed, then a carefully designed hood to remove only fugitive emissions may be the solution. (see **Costly Mistakes 2: Ventilating Process Vessels**).

FURTHER READING

Gately, G. and D. Bromwich (2006). Chapter 4 - Control of Workplace Health Hazards. in Principles of Occupational Health & Hygiene - A Basic Guide for the Occupational Health & Safety Practitioner. Ed C. Tillman. Melbourne, Allen & Unwin: 73-123.

McDermott, H. J. (1976). Handbook of Ventilation for Contaminant Control. Ann Arbor, Ann Arbor Science.

Lees, F. P. (1996). Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control. Oxford, Butterwort-Heinmann.

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