ABSA 2012, Orlando, Florida: Green gas, dry mists and dense vapours; an overview of independent fumigant testing at the UK Health & Safety Laboratory (HSL)

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About this presentation

• A brief introduction to the Health & Safety Laboratory, UK

• Formaldehyde – a widely used chemical under constant scrutiny

• Summary of some decontamination and simulant work HSL has undertaken:
  - HSE fumigation testing - laboratory sector study
  - UK Gov. Decontam. Service work – biosecurity in brief

• Acknowledgements
HSL: who are we, where are we?

- 320+ staff
- 90+ PhDs
- 80+ MScs
- 550 acre site in the Derbyshire Peak District, UK

A big site for (some) big experiments
But we do small stuff too....!

Widest science base of any equivalent European Laboratory – www.hsl.gov.uk
Let’s talk formaldehyde and fumigation
Formaldehyde exposure – a justifiable concern regardless of context

In the airborne state:

**UK** long and short term exposure limits – currently 2ppm (2.5mg/m³ air)

**OSHA** - 0.75ppm as an 8-hour time-weighted average (TWA) or,
short-term exposure limit - 2ppm during a 15-minute period
Setting the scene: formaldehyde use within the European Union – status as of October 2012

• France – has proposed reclassification of formaldehyde as a mutagen and category 1 carcinogen - currently classified as a category 2 carcinogen, with no mutagenic effects

• Formaldehyde a good candidate for substitution as there are probably safer alternatives. Chemicals with the following characteristics are automatically considered for substitution:
  - Carcinogen,
  - Mutagen,
  - Reprotoxin and
  - Persistent, bio-accumulative, toxic substance

• European Biocidal Products Directive (BPD) discussions planned for formaldehyde later in 2012
HSL asked to consider the efficacy of formaldehyde and alternative fumigants for whole room treatment

- UK: CL3/4 facilities (BSL3/4 equiv.) must be sealable for fumigation -
  - In the UK formaldehyde is still often used but alternative fumigants are available and deserve unbiased assessment

- Formaldehyde is simple to deliver and widely used for decades -
  - How does it compare to more recently developed systems?

- Formaldehyde is highly toxic and is a human carcinogen -
  - do the alternatives have any associated risks in use?

- How do the various systems compare for usability and efficacy when used side by side against substantial microbial challenges?
In labs, what can compete with the wok or hot plate?

$55 from a high street store - boringly simple and inexpensive fumigant delivery – hard to beat?
HSL lab study - other fumigants tested

- $\text{H}_2\text{O}_2$ – Hydrogen peroxide – as vapour & dry mist (3 systems)

- $\text{O}_3$ – Ozone - a true gas

- $\text{ClO}_2$ – Chlorine dioxide - a true gas
Lab study - microbiological challenges

- **Geobacillus stearothermophilus**
- **Clostridium difficile**
- **Mycobacterium fortuitum**
- **Vaccinia virus**
- Spill tests – used 6 well plates
- All microorganisms presented in **broths** in which prepared
- Multiple cycles used to assess each system

**Left:** commercially available *Geobacillus* discs

**Right:** steel discs used for other challenges
The test facilities: a sealable exposure chamber & CL3 lab

Exposure chamber:
• 35m³ & set up as a ‘mock’ lab area for initial equipment testing;
• 40% RH and 23°C starting conditions typically used

HSL’s CL3 facility:
• Real working lab area of 105m³
• Used for scale up equipment testing under ambient conditions
Initial findings (using *Geobacillus*) – what is an effective formaldehyde level for whole rooms?

- 1200ppm to 1500ppm formaldehyde = cabinet type fumigant levels – a blanket bomb approach

- Fair evaluation needed against other systems as these usually try to avoid over-delivery of fumigant

- 600ppm gave 6-log reductions with *Geobacillus* – though not at all room locations

- Literature indicated effective spore kill with as little as 400ppm formaldehyde;

- Later results confirmed that 600ppm was a reasonable choice to work with vs other systems
Lab study findings – overall efficacy

Observed log reduction by fumigation system and organism

Log Reduction

Organism

Geobacillus
C. difficile
M. fortuitum
Vaccinia

Error bars represent interquartile range
Dashed line represents four-log reduction
One of the toughest challenges: efficacy by location for *C. difficile* endospores

Error bars represent interquartile range
Dashed line represents four-log reduction
Overall performance by location – *M. fortuitum*

Error bars represent interquartile range
Dashed line represents four-log reduction
In summary – overall efficacy for lab setting

• Formaldehyde (600ppm) and ClO₂ = consistently best results:
  – 4 to 6-log reduction typical - even with spore forming bacteria and *Mycobacterium* sp.

• H₂O₂ = also capable of 4 to 6-log reductions with some challenges,
  – though performance sometimes variable

• Spill simulations = difficult challenge for some systems, e.g where *Mycobacterium* & *C. difficile* used
  – Formaldehyde and ClO₂ = most consistent with spill test of this type

• All systems showed a good degree of efficacy against *Vaccinia*

Full findings published in: A. J. Beswick *et al.* (2011). Comparison of Multiple Systems for Laboratory Whole Room Fumigation” as published in Applied Biosafety: Journal of the American Biological Safety Association (Volume 16, Number 3; 139-157.)
Laboratory fumigation - lessons learnt?
What do we want from a fumigation system?

Routine decontamination

- Consistent, reproducible and effective kill
- Easily removed from the treated/contained area
- Leave room/laboratory and it’s equipment undamaged

Emergency decontamination (e.g. lab spill or ward outbreak)

- All of the above
- Quick and easy to deploy (ideally without requiring entry into the room if CL3-based)
- Reliable (especially if equipment is to be resident in room)
Consistency

- All systems tested showed efficacy BUT some were variable in performance, e.g.
  - Between target organisms
  - Between identical consecutive cycles
- Formaldehyde and ClO$_2$ = most consistent killers in the lab
- Hydrogen peroxide vapour = frequently gave good results
Removal of fumigant

All systems prone to residual fumigant in excess of exposure limit after room aeration:

- Off-gassing from porous material (e.g. cardboard boxes)
  - Formaldehyde – 20ppm around planted cardboard 24 hrs after fumigant removal
  - $\text{H}_2\text{O}_2$ - 15ppm to 50ppm in room after 3 to 4hr aeration

- Ozone - secondary products & odours may remain after chemical quenching with the system tested.
  - Other systems using UV-based removal might avoid this
Ease of use and reliability

Ease of use varied between systems

- Formaldehyde – not difficult! - correct formalin/water volumes required for treated laboratory area

- H₂O₂ – some systems used ‘smart’ cartridges for source chemical (tricky to insert, storage, shelf life issues etc.)

- User interfaces varied in their simplicity. Many have easy-to-use touch screens

All machines suffered technical problems = aborted decontamination cycles, delays and lost data
Take home messages - fumigation?

To the User:

**VALIDATION, VALIDATION, VALIDATION!**
- Against target organism or representative surrogate
- For each individual containment laboratory or treated area
- Monitor variability between repeat cycles
- *Always* check fumigant levels before re-entry

To the manufacturer:

**RELIABILITY, RELIABILITY, RELIABILITY!**
- All systems tested have efficacy and application
- Consistency between identical cycles a concern
- Inherent technical reliability of the systems poor in some cases
Acknowledgements – in case I need to stop here!!

• Thanks to the UK Health and Safety Executive (HSE) and Home Office/GDS for their funding of this work

• Thanks also to Dr. Jonathan Gawn (HSE) for his contributions to this presentation

• Much of the HSL practical work was performed by Catherine Makison and Jayne Farrant

• Statistics - Gillian Frost, HSL Mathematical Modelling Unit

• We are grateful to several fumigation system suppliers for their support during these studies
In brief:

Use of formaldehyde for biosecurity related whole room fumigation
Reasons for work

• To assess the efficacy of formaldehyde vapour against a range of challenge microorganisms (safe surrogates for microorganisms listed on the ATCSA biosecurity threat list)

• To assess the different methods of available fumigant removal (with or without mechanical ventilation assistance)

• To use information from the above to determine fumigant delivery considerations for environments such as the laboratory, office and domestic setting.
Microbiological challenges

- *Pantoea agglomerans* used as a surrogate for *Yersinia pestis* (plague)

- *Bacillus subtilis* var *globigii* [NCTC 10073] used as a surrogate for *Bacillus anthracis* (anthrax)

- *Vaccinia virus* used as a surrogate for *Variola virus* (smallpox)

- Fumigant efficacy against *Coxiella burnetii*, (Q fever), also evaluated; non-pathogenic strains of *C. burnetii* (NMII-83 Clone 4 and NMII-87 Clone 4; Laboratory of Intracellular Parasites, USA)
Simple room scenarios created

Laboratory

Office

Domestic
Fumigant delivery and removal assessed
Summary findings – in brief

• Overall microbiological reductions > 6-Log were possible - some variation noted depending on microbiological challenge and location

• Formaldehyde was efficiently removed from the room air by mechanical ventilation alone

• Chemical quenching of formaldehyde using vaporised ammonia was rapid, but required additional ventilation to remove by-products of that reaction

• Off gassing from surfaces was observed, with higher levels and longer periods of off gassing detected from soft furnishings

• Conclusion? - Formaldehyde use likely to continue as an effective option for UK bio-security related alerts
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The Health & Safety Laboratory

Thank you for your attention