Methyl Bromide and Sulfuryl Fluoride
Gas Leakage Rates from Structures

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Introduction

- During typical structural fumigations, do MB and SF show different gas dynamics (for example leakage rates and gas distribution)?

- Problem – when the two gases are compared, environmental conditions generally are not analyzed in details and sealing quality is assumed the same.

![Comparable leakage rate?]
Introduction

• Research at Purdue University and Kansas State University
  – Fumigation experiments and simulations for the past six years and continuing
  – A number of fumigation experiments in flour mills
  – Computer models of the fumigation process
Fumigation Simulations


Model

• Based on a commercial reference flour mill
• Takes into account leakages created by wind and buoyancy forces
  – Input: weather conditions, type of fumigant, amount released, etc.
  – Output: gas concentration readings
Simulations

- MB and SF fumigation simulations performed with hourly average weather data around the Independence Day and Labor Day of 1996 – 2006
  - 11 MB fumigations on each of Independence and Labor Days
  - 11 SF fumigations on each of Independence and Labor Days

- Fumigation practices were the same
  - Gas introduction and monitoring locations
  - Sealing quality
  - Exposure time
Half-Loss Time

The graph shows the half-loss time (HLT) for two regions, SF and MB, across years from 1996 to 2006. The HLT values are indicated on the y-axis, ranging from 0 to 30 hours. The bars for each year illustrate the HLT for SF (black) and MB (gray). The data suggests variations in HLT across the years, with some peaks and troughs.
Findings

• Leakage rates (i.e., half-loss time) largely depends on weather conditions during fumigation
• Under the same weather and sealing conditions, leakage rates of MB and SF are similar

→ These findings were based on computer simulations
→ Would we obtain similar findings in actual fumigations?
Experiments at Hal Ross Flour Mill

- As many controlled parameters as possible
- Two MB and two SF fumigations in one single building
- Almost identical sealing quality verified by building pressurization tests
- Continuous weather condition and gas concentration monitoring

<table>
<thead>
<tr>
<th>Fumigation #</th>
<th>MB1</th>
<th>SF2</th>
<th>MB3</th>
<th>SF4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting time</td>
<td>6:40 PM May 6th</td>
<td>6:00 PM May 27th</td>
<td>2:50 PM Aug 11th</td>
<td>2:45 PM Aug 19th</td>
</tr>
<tr>
<td>Exposure (hr)</td>
<td>~24</td>
<td>~24</td>
<td>~24</td>
<td>~24</td>
</tr>
</tbody>
</table>
Experimental Setup

- Weather station (temperature, RH, wind, solar radiation, barometric pressure)
- Temp/RH logger (one point on each floor)
Experimental Setup

- Gas concentrations continuously monitored at 6 locations evenly distributed on each floor
Pressurization Test

- Flow rate VS Pressure
  - Good seal → Lower flow rate at any given pressure
Pressurization Test

- Sealing quality of MB1, SF2 and MB3 fumigations was identical.

- Pressure test result of SF4 experiment was adversely affected by strong outdoor wind.

→ Assuming best sealing quality of SF4 experiment, sealing quality of all fumigations was the same.
Gas Concentration: MB1

- HLT \approx 111 \text{ hr}
- HLT \approx 16.4 \text{ hr}
- HLT \approx 10.2 \text{ hr}
Gas Concentration: SF2

HLT ≈ 19.7 hr
Gas Concentration: MB3

HLT $\approx 26$ hr
Gas Concentration: SF4

**HLT ≈ 26.1 hr**

**HLT ≈ 9.9 hr**
Discussion

- Both MB and SF were evenly distributed throughout the building
- Both MB and SF fumigations showed varying HLTs
- Sealing quality was the same, but different HLTs were observed

→ What caused these differences?
→ Can the weather data explain this?
Gas Concentration: MB1

111hr HLT
Avg spd = 1.65

16.4hr HLT
Avg spd = 3.52

10.2hr HLT
Avg spd = 7.12
Gas Concentration: SF2

19.7hr HLT
Avg spd = 3.67
Gas Concentration: MB3

26hr HLT
Avg spd = 2.16
Gas Concentration: SF4

- 9.9hr HLT Avg spd = 6.9
- 26.1hr HLT Avg spd = 3.0
Discussion

• Wind speed data are consistent with the observed HTLs
• Small fluctuations of wind could not be picked up by gas monitoring
  → How about buoyancy and barometric pressure pumping forces?
Barometric Pressure

Graph showing barometric pressure (mbar) over elapsed time (hr) for different locations: MB1, SF2, MB3, and SF4.
Temperatures

MB1

SF2

MB3

SF4
Solar Radiation
Discussion

• Clear-cut correlations between buoyancy and pressure pumping forces and HLTs could not be established
  – Their effects might be overshadowed by the wind effect
  – More data analyses will be conducted after the final set of experiments
• Despite variations in outside temperature, RH and solar radiation, inside temperatures and RHs were relatively stable
  – Relatively airtight building
  – The heat transfer, generation and accumulation rates were balanced
  – Similar observations can be expected for buildings with the similar airtightness level
<table>
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<tr>
<td><strong>Exposure (hr)</strong></td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td><strong>Total gas used (kg)</strong></td>
<td>181 (400 lb)</td>
<td>567 (1250 lb)</td>
<td>159 (350 lb)</td>
<td>511 (1125 lb)</td>
</tr>
<tr>
<td><strong>Inside temp (C)</strong></td>
<td>22 - 23</td>
<td>23 - 26</td>
<td>27 - 31</td>
<td>28 - 32</td>
</tr>
<tr>
<td><strong>Outside temp (C)</strong></td>
<td>15 - 29</td>
<td>14 - 26</td>
<td>19 - 34</td>
<td>16 - 27</td>
</tr>
<tr>
<td><strong>Inside RH (%)</strong></td>
<td>39 - 50</td>
<td>34 - 44</td>
<td>40 - 60</td>
<td>40 - 55</td>
</tr>
<tr>
<td><strong>Outside RH (%)</strong></td>
<td>37 - 91</td>
<td>25 - 88</td>
<td>30 - 90</td>
<td>45 - 95</td>
</tr>
<tr>
<td><strong>Avg wind spd (m/s)</strong></td>
<td>1.65, 3.52, 7.12</td>
<td>3.67</td>
<td>2.16</td>
<td>3.0, 6.9</td>
</tr>
<tr>
<td><strong>HLT (hr)</strong></td>
<td>111, 16.4, 10.2</td>
<td>19.7</td>
<td>26</td>
<td>26.1, 9.9</td>
</tr>
<tr>
<td><strong>Ct product (g-hr/m(^3))</strong></td>
<td>283 - 327</td>
<td>923 - 1191</td>
<td>268 - 318</td>
<td>663 - 1003</td>
</tr>
</tbody>
</table>
Findings

• Fumigation experiments at Hal Ross Mill confirmed the previous findings
• SF and MB showed similar gas distribution and leakage characteristics
  – Inside gas distributions were dominated by circulation fans
  – Leakage rates were influenced by environmental conditions
  – For these particular experiments, wind was the dominating factor
Findings

• Sealing effectiveness can be determined by pressurization testing ahead of a fumigation
  – By itself, it cannot predict HLT
  – It can differentiate a "well" vs "poorly" sealed facility

→ How can we use the pressurization test to predict HLT more accurately?
Superposition

- Quadratic superposition method
- Used by the HVAC industry to quantify air infiltration in houses for energy saving and in-door air quality purposes

\[ Q = \sqrt{Q_s^2 + Q_w^2} = \frac{A_L}{1000} \sqrt{C_s \Delta t + C_w U^2} \]

\[ HLT = \frac{V \ ln(2)}{Q \ 3600} \]
Superposition

Leakage due to stack effect

Total leakage rate

Leakage due to wind effect

Equivalent leakage area

Stack coefficient

Wind coefficient

Temperature difference

Wind velocity

Could be estimated by pressurization test and computer simulation
Thank You