A Quantification of VOC Emissions from Carpet in a Residence with a High Level of Formaldehyde

Cari L. Gostic¹, Dr. Tom Jobson², Yibo Huangfu²
¹Cornell University, Ithaca, NY, ²Washington State University, Pullman, WA

The Indoor Air Quality [IAQ] Study at Washington State University seeks to better understand the link between IAQ and climate change. Volatile Organic Compounds [VOCs] are common indoor air pollutants that could become more dangerous as building envelopes tighten, for many VOCs are respiratory irritants or carcinogens at high concentrations. A 30 ppbv concentration of formaldehyde was measured in a local residence [H002] as part of WSU’s IAQ study, and carpet is suspected as a major source of this VOC. This project seeks to answer the following questions:

- Is carpet a significant contributor to high formaldehyde levels measured in H002?
- How do VOC emissions from Carpet 1 compare to new, “Green Label Plus” [GLP] certified carpets?
- How do elevated O₃ concentrations and exposure to UV light affect VOC emissions from carpet?

**Methods**

**Samples:**
- Carpet 1: From Room 1 in H002 (Fig 3). Material makeup unknown. Reported as 3 years old.
- Carpet 2: Solution dyed BCF nylon fiber. GLP certified. New.
- Carpet 3: Solution dyed BCF polyester fibers. GLP certified. New.

**Measurements:**
1) Used PTR-MS [Ionicon Analytic] to quantify carpet emissions under 3 treatments (Fig 1) in 148.2 L Teflon chamber with stainless steel rack (Fig 6)
   - Treatment 1: Normal chamber conditions; 10 L/min zero-air inflow, ambient RH and temperature (21°C)
   - Treatment 2: Elevated O₃: 26 ppb achieved in chamber [InDevR 2B Technologies, Inc. Ozone Calibration Source; Model 306]
   - Treatment 3: UV radiation (7.5 mW/cm²) [GE 15W blacklights]
2) Used GC-MS [Agilent Technologies 7890B] to further identify compounds emitted by carpet samples and to verify PTR-MS measurements (Fig 2)

**Equation 1.**

\[
\frac{dC}{dt} = (S + C_{p} n v) - (C n v) - (K C V)
\]

**C₀: Ambient Concentration; K: pollutant decay rate = 0; V: conditioned volume = 0.1482 m³ (chamber); 40.78 m³ (Room) ; n: air change rate = 4.05 hr⁻¹ (chamber); 0.21 hr⁻¹ (Room)

**Figure 1.** Carpet 1 PTR-MS Reading

**Figure 2.** Carpet 1 GC-MS Analysis

**H002 VOC Concentration Calculations:**

Using Equation 1, calculated source rate (S) for each VOC with Carpet 1 steady state mixing ratio (C) chamber measurement. Steady state concentration (C) of each VOC in Room 1 is then estimated using calculated S.

<table>
<thead>
<tr>
<th>m/z</th>
<th>PTR-MS</th>
<th>GC-MS</th>
<th>Carpet 1 Source Rate (µg/m²/hr)</th>
<th>Carpet 2 Source Rate (µg/m²/hr)</th>
<th>Carpet 3 Source Rate (µg/m²/hr)</th>
<th>CRI GLP Standard (µg/m²/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td></td>
<td></td>
<td>0.75</td>
<td>0.15</td>
<td>0.91</td>
<td>250</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td>0.30</td>
<td>0.04</td>
<td>0.15</td>
<td>125</td>
</tr>
<tr>
<td>41</td>
<td></td>
<td></td>
<td>0.35</td>
<td>1.32</td>
<td>1.24</td>
<td>125</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td>7.15</td>
<td>7.14</td>
<td>12.08</td>
<td>125</td>
</tr>
<tr>
<td>47</td>
<td></td>
<td></td>
<td>4.01</td>
<td>7.72</td>
<td>4.06</td>
<td>125</td>
</tr>
<tr>
<td>57</td>
<td></td>
<td></td>
<td>3.44</td>
<td>21.89</td>
<td>23.05</td>
<td>750</td>
</tr>
<tr>
<td>59</td>
<td></td>
<td></td>
<td>2.42</td>
<td>5.24</td>
<td>5.47</td>
<td>125</td>
</tr>
<tr>
<td>61</td>
<td></td>
<td></td>
<td>0.56</td>
<td>18.71</td>
<td>13.09</td>
<td>125</td>
</tr>
<tr>
<td>89</td>
<td></td>
<td></td>
<td>3.07</td>
<td>10.16</td>
<td>11.46</td>
<td>125</td>
</tr>
<tr>
<td>93</td>
<td></td>
<td></td>
<td>0.35</td>
<td>0.17</td>
<td>0.30</td>
<td>125</td>
</tr>
<tr>
<td>113</td>
<td></td>
<td></td>
<td>0.41</td>
<td>0.90</td>
<td>0.90</td>
<td>125</td>
</tr>
<tr>
<td>120</td>
<td></td>
<td></td>
<td>0.13</td>
<td>0.18</td>
<td>0.18</td>
<td>750</td>
</tr>
<tr>
<td>122</td>
<td></td>
<td></td>
<td>0.10</td>
<td>0.19</td>
<td>0.18</td>
<td>125</td>
</tr>
<tr>
<td>123</td>
<td></td>
<td></td>
<td>0.06</td>
<td>0.11</td>
<td>0.11</td>
<td>125</td>
</tr>
</tbody>
</table>

**Results**

Under Normal Chamber Conditions, all 3 carpet samples meet GLP standards. Carpet 3 emits VOCs at the highest overall rate; Carpet 1 emits at the lowest rate.

**Table 1: selected masses and their likely identities, emission rates from each carpet under Treatment 1, and CRI GLP standard emission rates.**

**Figure 4.** Comparison of VOC mixing ratios for the 3 carpet samples obtained for Treatments 1 and 2.

**Figure 5.** Compares concentrations of VOCs under Treatments 1, 2 and 3

UV Radiation caused concentrations of most VOCs to increase. Response could be influenced by temperature: increase from 21°C to 32°C under UV lights.

The table below shows estimated concentrations of selected VOCs in Room 1 compared to guidelines cited by national and international health agencies. Only Formaldehyde exceeds suggested levels. Most identified VOCs are not recognized as indoor air toxics.

**Table 2.** Estimated steady state concentrations of selected VOCs in Room 1 and guidelines cited by national and international health agencies.

**Conclusions**

1. All 3 carpets emit VOCs within GLP standards, though elevated O₃ levels, high temperatures or exposure to UV light increases emissions of some VOCs.
2. Though Carpet 1 emits within GLP standards, emissions from Carpet 1 alone likely cause unhealthy levels of formaldehyde in Room 1 of H002 according to chronic exposure levels cited by the U.S. EPA.
3. The estimated 10.53 µg/m³ (9.67 ppbv) concentration of formaldehyde due to emissions from Carpet 1 account for 32% of the 30 ppbv concentration measured as part of Washington State’s IAQ Study. Carpet likely contributes significantly to unhealthy formaldehyde levels in H002, but is not the only factor.

**References**


This work was supported by the National Science Foundation’s REU program under grant number ACS-1461292