Carbon Monoxide Surveillance, Education and Response: Findings from Baltimore City

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Carbon Monoxide: A Healthy Homes Issue

- Carbon Monoxide is an odorless, colorless, tasteless gas that is produced as a byproduct of incomplete combustion.
Sources of Carbon Monoxide in Homes

- Boilers and furnaces
- Gas stoves & ovens
- Fireplaces
- Tobacco smoke
- Space heaters/portable generators
Carbon Monoxide Poisoning: Why?

- Malfunction and improper use of indoor combustion appliances are the most common causes of CO exposure in the home
- To be continued…
Health Effects of Carbon Monoxide Exposure

- Death
  - ~500 deaths every year
- Variety of health impacts due to chronic exposure
  - ~20,000 non-fatal ED visits each year
    - Under-reported
- Elderly, pregnant women, fetuses, young infants and those with pre-existing medical conditions are most susceptible
Non-fatal Carbon Monoxide Exposure

- 20,636 ED visits for non-fatal, unintentional CO exposure*
  - 73% of these exposures occurred in the home
  - 41% occurred during winter months (December - February)

*Morbidity Mortality Weekly, August 22, 2008 / 57(33); 896-899
Chronic Exposure to CO

- No clear definition of “low level” exposure
- Associations between chronic exposure and low birth weight, increased chest pain in individuals w/ coronary artery disease, hospitalization for COPD, asthma exacerbation*

*Note: the asterisk (*) typically indicates a footnote or additional information that is not visible in the image.
Carbon Monoxide Poisoning: Why?

- Malfunction and improper use of indoor combustion appliances are the most common causes of CO exposure in the home

- Continued...
NHANES II Study (1988-1994)*

- 7.7% of US adults with gas stove or oven reported using their stove/oven to heat their home at least 1 time in past year
- More common for low-income, rural and African American adults

*Use of Unvented Residential Heating Appliances—United States, 1988-1994
JMAM. 1998;279:423-424
In the News: Environmental Disasters

- Use of portable generators, charcoal grills or camp stoves *indoors* during power outages
  - Hurricane Katrina: 51 cases of carbon monoxide poisoning, including 5 deaths
  - Hurricane Ike: 1 death due to CO (4 year old boy)
Hurricane Katrina Aftermath

FIGURE. Number of carbon monoxide poisoning cases reported by hyperbaric oxygen facilities after Hurricane Katrina — Alabama, Louisiana, and Mississippi, August 29–September 24, 2005
Carbon Monoxide Exposure in Baltimore

- August 2008: at least 6 residents of Baltimore City have been sent to the hospital due to CO exposure in the home
  - In at least one case, family used stove to heat their home due to a non-functioning furnace
- 2000-2006: 20 deaths
CO Exposure in Baltimore

- The risk of malfunctioning appliances is greater in older homes, which are more likely to have older appliances and/or lack central air conditioning.
- In Baltimore, half of the housing stock was built before 1940*

An Equation for Carbon Monoxide Exposure

Old housing stock + lack of knowledge of CO risks + improper use of appliances + economic instability + no regulation requiring CO detectors

= High risk for CO exposure
BCHD: Surveillance, Education and Response

- CO surveillance, education and response conducted since November 2007 in high-risk, underserved homes
- Part of comprehensive healthy homes inspection conducted by a trained environmental sanitarian
- Ambient levels in each room; testing of high-risk appliances
- EDUCATION and REFERRALS
Surveillance: The Basics

- 6 environmental sanitarians (trained in lead poisoning prevention)
- All day training (use of Toxipro, CO risks)
- Bump testing and calibration (conducted by dedicated Healthy Homes Resources Manager)
Surveillance: The Equipment
Surveillance

- Obtain reading outside
- Walk through to monitor ambient readings - record the highest level
- Risk assessment of appliances
  - Test appliance if risk found
- Education, education, education
  - Do you use stove to heat your home?
  - Cleanliness of stove top; importance of ventilation
Results

- 90% Homes with gas range/oven
- 10% Families reporting use of oven to heat home
- 17% Gas stoves with CO levels >34ppm
- 14% Gas ovens with readings > 34
CO Surveillance, Education & Response: Opportunity for Impact

- Boilers and furnaces → Homeowners vs. Renters
- Gas stoves/ovens → Education and linkage to service
- Gas space heaters → Education and linkage to service
- Fireplaces → Not as relevant in Baltimore
- Tobacco smoke → Education and linkage to service
Results: Surveillance

- Ambient levels low (average ~ 2 ppm)
  - Average level in homes w/o gas stoves range from .5 to 5 ppm (EPA)
- ~14-17% of homes had stoves/ranges w/ readings over 34 ppm
  - Levels near properly adjusted gas stoves are often 5 to 15 ppm and those near poorly adjusted stoves may be 30 ppm or higher (EPA)
Results: Education

- Hands-on educational opportunity
  - Teachable moment
- Advise on the importance of CO detectors
- Homeowners vs. Renters
Education: Homeowners vs. Renters

- Homeowners
  - Annual appliance check-ups
  - CO detectors

- Renters
  - CO Detectors
  - Tenant’s rights/ 311 calls
  - Ventilation/keeping stove tops clean
  - May not have access to furnaces, hot water heaters etc.
Results: Response

- 5 referrals to Baltimore City Fire Department for CO risks
  - On-the-Spot action
  - 1 case - the stove was shut down
- 4 referrals to 311 for CO risks
- Referrals to energy assistance programs, smoking cessation
Future Directions

- Linkage to Baltimore City Weatherization Program
- Resources for stove replacement?
- Provide carbon monoxide detectors as part of regular package of services
- Baltimore City’s carbon monoxide detector bill
Acknowledgments

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- Madeleine Shea- Assistant Commissioner Healthy Homes
BUILDING A FRAMEWORK
FOR HEALTHY HOUSING

Combustion Appliances
and IAQ

Paul W. Francisco
Building Research Council
University of Illinois

2008 National Healthy Homes Conference • September 15-17, 2008 in Baltimore, MD
Overview

- IAQ standards/guidelines for combustion gases
- Measured combustion gas concentrations
- Venting
- Measurement strategies
Combustion Gases

- Produce CO, CO₂, NOₓ (NO + NO₂), water
- Deplete oxygen
- Standards/guidelines for indoor concentrations vary, or don’t exist
## Threshold Values

<table>
<thead>
<tr>
<th>Combustion Product</th>
<th>Threshold Value</th>
<th>Source</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>9 ppm – 8 hr avg</td>
<td>US EPA</td>
<td>9 ppm WHO</td>
</tr>
<tr>
<td></td>
<td>35 ppm – 1 hr avg</td>
<td>US EPA</td>
<td>25 ppm WHO</td>
</tr>
<tr>
<td>NO₂</td>
<td>250 ppb – 1 hr avg</td>
<td>Health Canada</td>
<td>No US standard</td>
</tr>
<tr>
<td></td>
<td>110 ppb - 1 hr avg</td>
<td>WHO</td>
<td></td>
</tr>
<tr>
<td>H₂O</td>
<td>60% RH</td>
<td>ASHRAE 55-92</td>
<td>Obsolete, for comfort</td>
</tr>
</tbody>
</table>
Combustion Gases in the Home

- Generation
- Dilution
  - By directly venting
  - By using exhaust ventilation
  - Infiltration (?)
Venting?

- Always vent furnaces/water heaters
- Gas Ranges? Gas Fireplaces?
Two studies in Puget Sound region

- Both focused on duct leakage, also did safety checks
  - Study #1: utility leakage retrofit program
    Measured CO in furnaces, water heaters, gas fireplaces, gas ranges
    Recruitment via newspaper column
  - Source: Davis et al. 1999 – *Duct Sealing Pilot Program Results*: final report
Two studies in Puget Sound region

- Study #2: duct leakage measurement technique research
  - Measured CO in furnaces only
  - Most homes through utility employees
Study #1: Furnaces

- 166 natural gas furnaces
  - > 10 ppm CO in exhaust: 80 (48%)
  - 11-49 ppm CO in exhaust: 38 (23%)
  - 50-99 ppm CO in exhaust: 10 (6%)
  - 100-999 ppm CO in exhaust: 10 (6%)
  - Over 1000 ppm CO in exhaust: 22 (13%)

- > 3 ppm CO in supply air: 4 (2%)
Study #1: Other Combustion

- Water heaters (n=144):
  - More than 10 ppm CO in exhaust: 9 (6%)
  - More than 100 ppm CO in exhaust: 4 (3%)
- Gas fireplaces (n=17):
  - More than 100 ppm CO: 3 (18%)
  - Average CO for all 17: 85 ppm
- Gas ranges/ovens
  - More than 100 ppm CO: 2
Study #2: Furnaces

![Diagram showing carbon monoxide readings for different draft conditions: Condensing, Induced draft, Natural draft.](image)

- Condensing
- Induced draft
- Natural draft

Carbon Monoxide reading, ppm

\( n = 37 \)
Study #2: Furnaces

- Condensing
- Induced draft
- Natural draft

Carbon Monoxide reading, ppm
Study #2: Furnaces

- 37 natural gas furnaces
  - > 10 ppm CO in exhaust: 37 (100%)
  - 11-49 ppm CO in exhaust: 29 (78%)
  - 50-99 ppm CO in exhaust: 4 (11%)
  - 100-999 ppm CO in exhaust: 2 (5%)
  - Over 1000 ppm CO in exhaust: 2 (5%)
Study in Minneapolis-St. Paul

- Part of Sound Insulation Program for homes around MSP airport
- Measured CO in all combustion appliances
- Source: Center for Energy and Environment, 2002 – Ventilation and Depressurization Information for Houses Undergoing Remodeling
MSP results

- 25% of gas ovens exceeded 150 ppm CO (n=2,891)
- 3.5% of gas water heaters exceeded 100 ppm CO (n=1,356)
- 7.7% of gas furnaces exceeded 100 ppm CO (n=548)
Unvented fireplace study

- 30 homes in Central Illinois
- Healthy Homes Technical Study
- Measured room air CO, CO$_2$, NO$_x$ (NO + NO$_2$), oxygen, and water at 1-minute intervals for 3-4 days
- Measured CO and NO$_x$ at fireplace with combustion analyzer
Unvented fireplace study
Unvented fireplace study

![Graph showing Carbon Monoxide 8-hr average, ppm vs. Site ID. The data points are scattered, with some sites having higher concentrations than others. The x-axis represents Site ID, ranging from 1 to 31, and the y-axis represents Carbon Monoxide concentration, ranging from 0 to 15 ppm.]
Unvented fireplace study

Nitrogen Dioxide 1-hr average, ppb

Site ID

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Unvented fireplace study
Unvented fireplace study

\[ \text{Temperature at Mantel, } \text{C} \]

\[ \text{Carbon Monoxide, ppm} \]

\[ \text{Hour of Day} \]

- Carbon Monoxide
- Temperature at Mantel
Unvented fireplace study
Unvented fireplace study

The graph shows the concentration of Carbon Monoxide (CO) and Nitrogen Dioxide (NO2) over the period from 02 February 2006 to 06 February 2006. The concentrations are measured in parts per million (ppm).

- Carbon Monoxide (CO) concentrations range from 0 to 15 ppm.
- Nitrogen Dioxide (NO2) concentrations range from 0 to 0.5 ppm.

Key dates and notable peaks in concentrations are marked.

Legend:
- • Carbon Monoxide
- • Nitrogen Dioxide
Venting

- Study #1 (Davis et al.) identified 15 furnaces as having a venting problem
  - Low draft pressure in vent
  - Extensive soot/corrosion on vent
  - Undersized vent
  - Poorly connected or disconnected vent
  - Insufficient amount of double-wall “B”-vent
Venting

- MSP study (CEE)
  - Evaluated “worst-case” house depressurization (WC) and spillage
  - Of 1,827 homes:
    - 86.2% had WC between 0-3 Pa
    - 9.4% had WC between 3-5 Pa
    - 4.3% had WC greater than 5 Pa
Venting

- MSP study (CEE)
  - For water heaters:
    - 5% had spillage if WC between 0-3 Pa
    - 24% had spillage if WC between 3-5 Pa
    - 82% had spillage if WC greater than 5 Pa
  - Some evidence that common vent size impacted results
  - “B”-vent had lowest failure rate
  - About half of failures due to excessive depressurization rather than vent problems
Measurement - Generation

- Hand-held analyzers are designed for flue gas measurement, not room air
- Accuracy not sufficient to assess moderate levels in room air
  - Often ± 10 ppm for CO
- Averaging period of standards/guidelines makes in-room comparison measurement impractical
Measurement - Generation

- Best to measure combustion gas directly with combustion analyzer.
- For concern about room air levels of CO can as easily use CO alarms.
Natural Draft Furnaces

- One port for each burner
- Should measure each

220 2100 380 64

Site 51 from Study #2
Measurement - Venting

- Both “worst-case” tests and spillage tests important
- Failure can be either poor venting or excessive depressurization
Conclusions/Recommendations

- Many appliances have low levels of CO, but some are very high – need to measure
- Room air CO levels troublesome to measure in general inspections – use CO alarms to identify extreme cases (and put one in every house regardless of appliances present)
Conclusions/Recommendations

- Substantial relationship between WC reading and spillage – measure both and correct when necessary
- Use “B”-vent, especially for flues outside of conditioned space
Conclusions/Recommendations

- Automobiles can result in noticeable levels of CO in the home – consider venting garages
- Ventilation should always go to outside – no recirculating range hoods