BUILDING A FRAMEWORK FOR HEALTHY HOUSING

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

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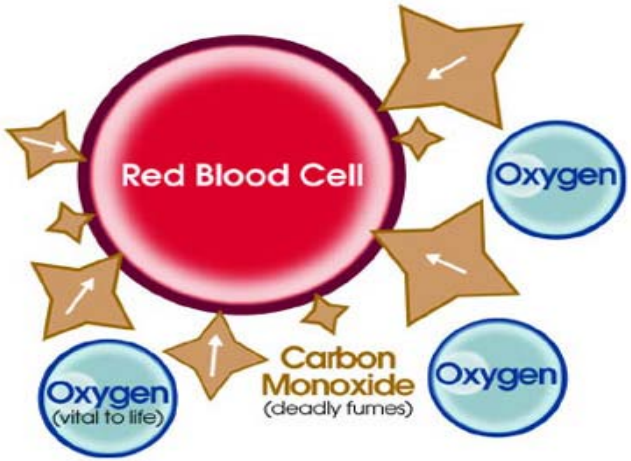
Carbon Monoxide: A Healthy Homes Issue

- Carbon Monoxide is an odorless, colorless, tasteless gas that is produced as a by product 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*

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

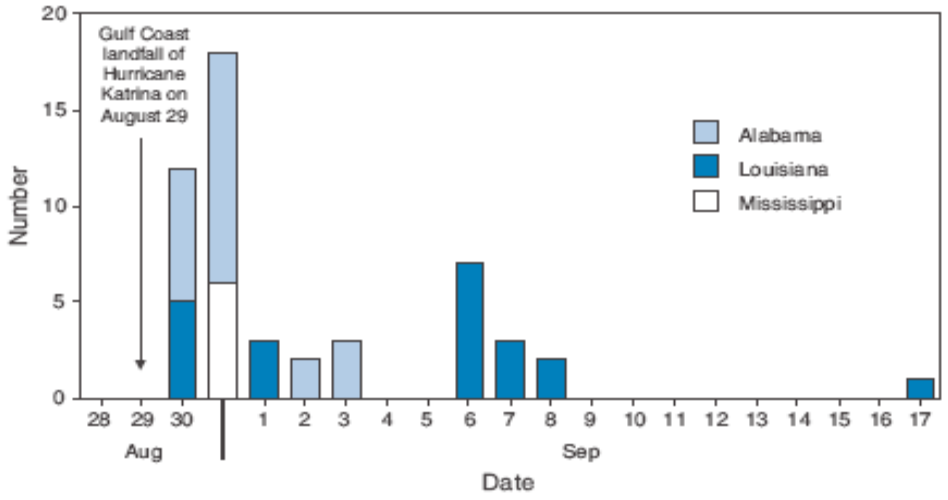
*Use of Unvented Residential Heating Appliances—United States, 1988-1994
JAMA. 1998;279:423-424

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*

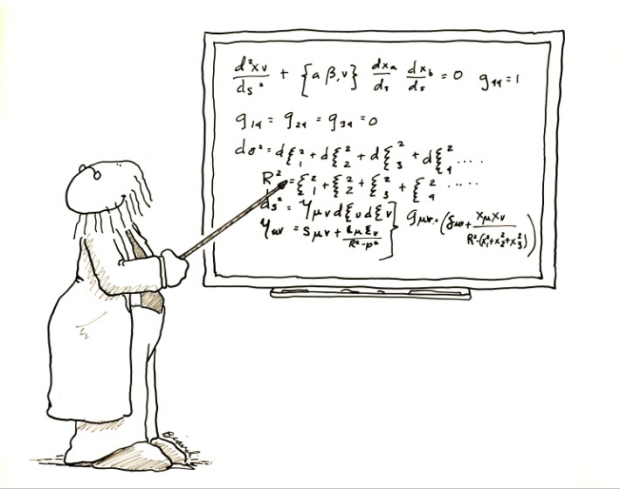
Newman, Sandra J. “Low-End Rental Housing: The Forgotten Story in Baltimore’s Housing Boom.” The Urban Institute: Research Reports. (August 30, 2005). http://www.urban.org/url.cfm?ID=311222

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

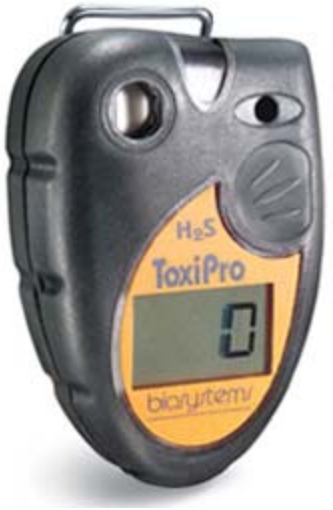
=

High risk for CO exposure



BCHD: Surveillance, Education and Response

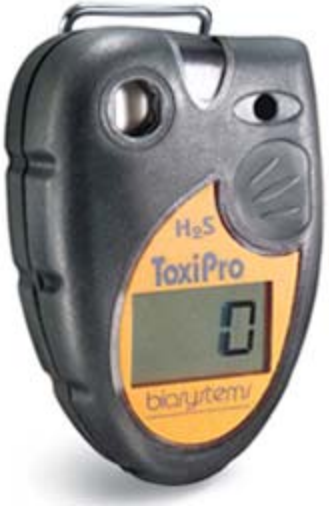
- CO surveillance, education and response conducted since November 2007 in high-risk, underserved homes
- Part of comprehensive healthy homes inspection conducted by a trained environmental sanitarian
- Ambient levels in each room; testing of high-risk appliances
- EDUCATION and REFERRALS



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)

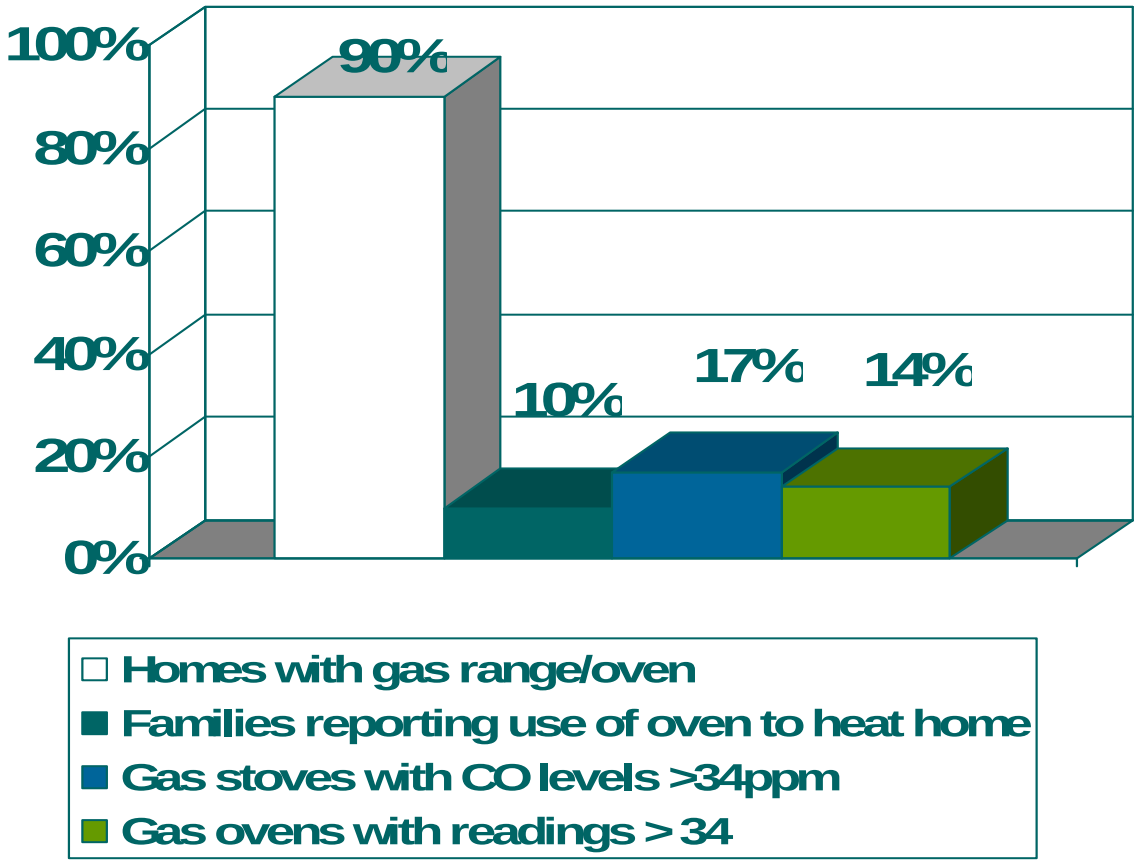
Surveillance: The Equipment



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


100%
80%
60%
40%
20%
0%
90%
10%
17%
14%
Homes with gas range/oven
Families reporting use of oven to heat home
Gas stoves with CO levels >34ppm
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

- Environmental sanitarian staff
- Sarah Norman- Director, Residential Health Services Bureau
- 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, CO_2, NO_x (NO + NO_2), water
- Deplete oxygen
- Standards/guidelines for indoor concentrations vary, or don't exist

Threshold Values

Combustion Product	Threshold Value	Source	Notes
CO	9 ppm – 8 hr avg	US EPA	9 ppm WHO
	35 ppm – 1 hr avg	US EPA	25 ppm WHO
NO_2	250 ppb – 1 hr avg	Health Canada	No US standard
	110 ppb - 1 hr avg	WHO	
H_2O	60% RH	ASHRAE 55-92	Obsolete, for comfort

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
- Source: Francisco et al. 2003 – *Field Evaluation of Improved Methods for Measuring the Air Leakage of Duct Systems Under Normal Operating Conditions in 51 Homes:* final report

Study #1: Furnaces

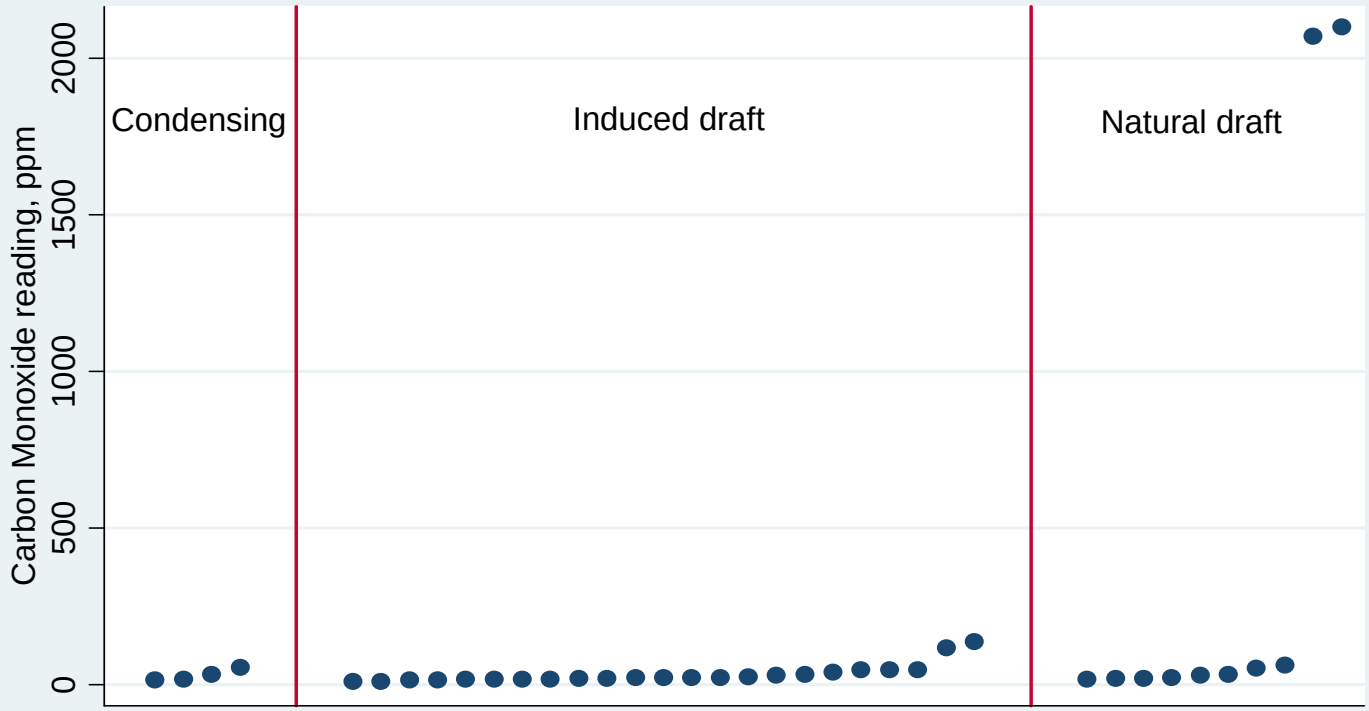
- 166 natural gas furnaces
  - > 10 ppm CO in exhaust: 80 (48%)
  - 11-49 ppm CO in exhaust: 38 (23%)
  - 50-99 ppm CO in exhaust: 10 (6%)
  - 100-999 ppm CO in exhaust: 10 (6%)
  - Over 1000 ppm CO in exhaust: 22 (13%)

  - > 3 ppm CO in supply air: 4 (2%)

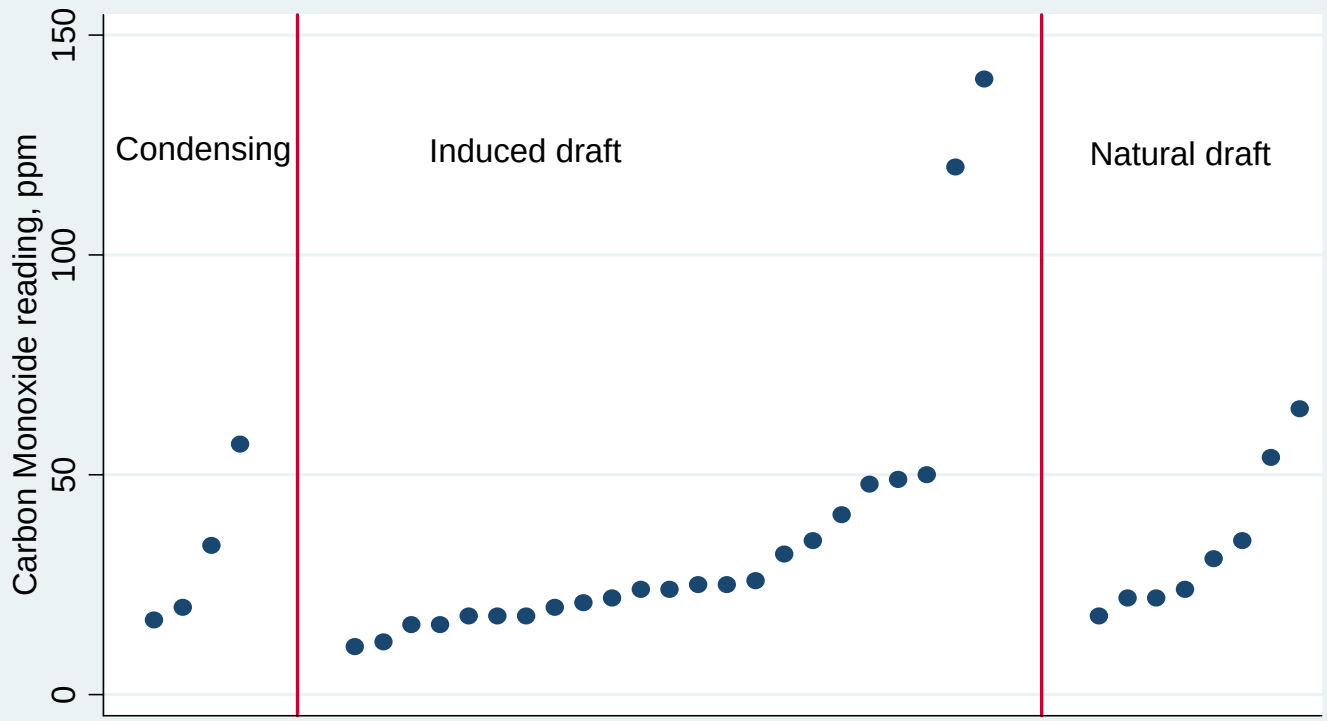
Study #1: Other Combustion

- 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



Study #2: Furnaces



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*

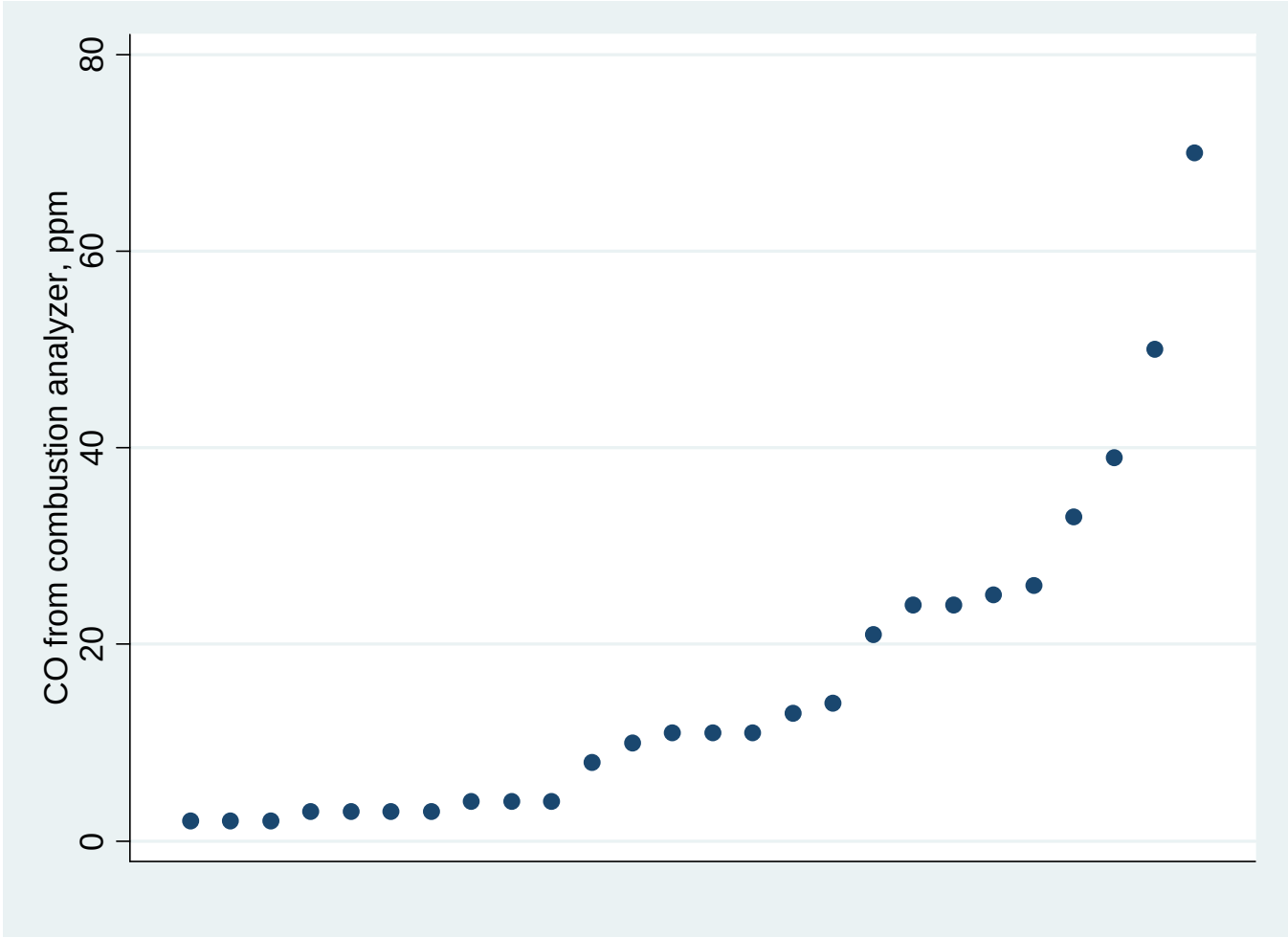
MSP results

- 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



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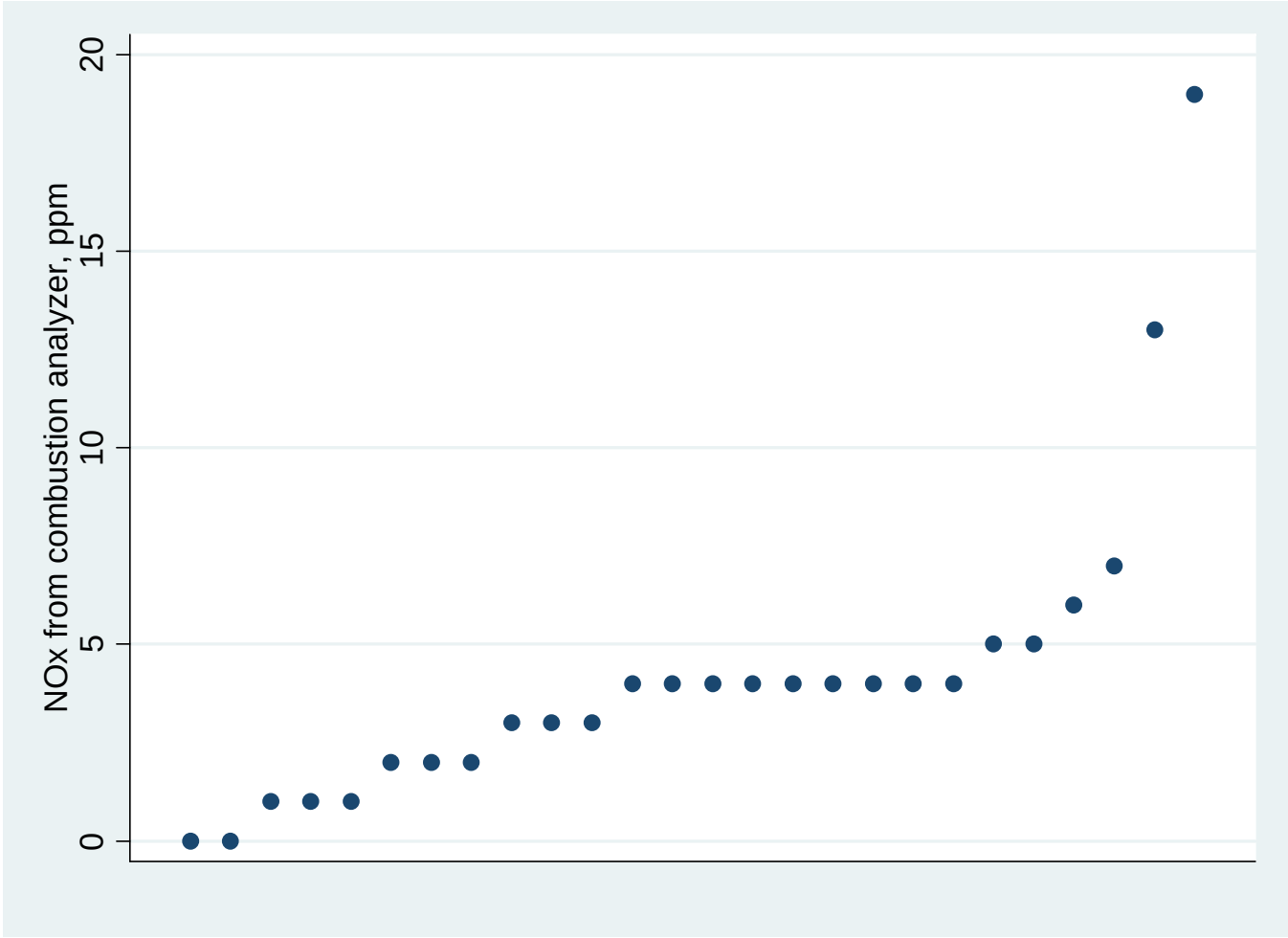

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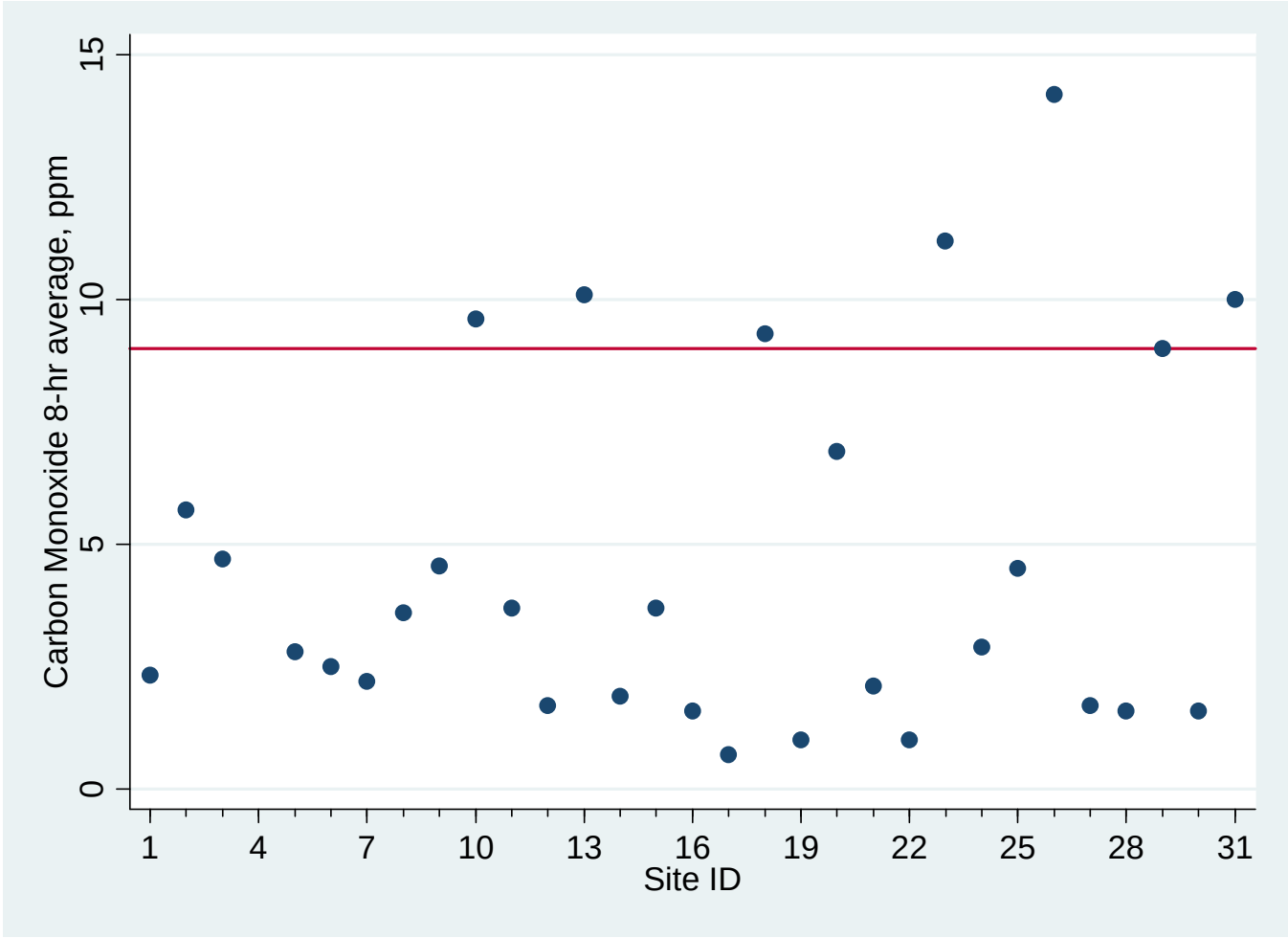

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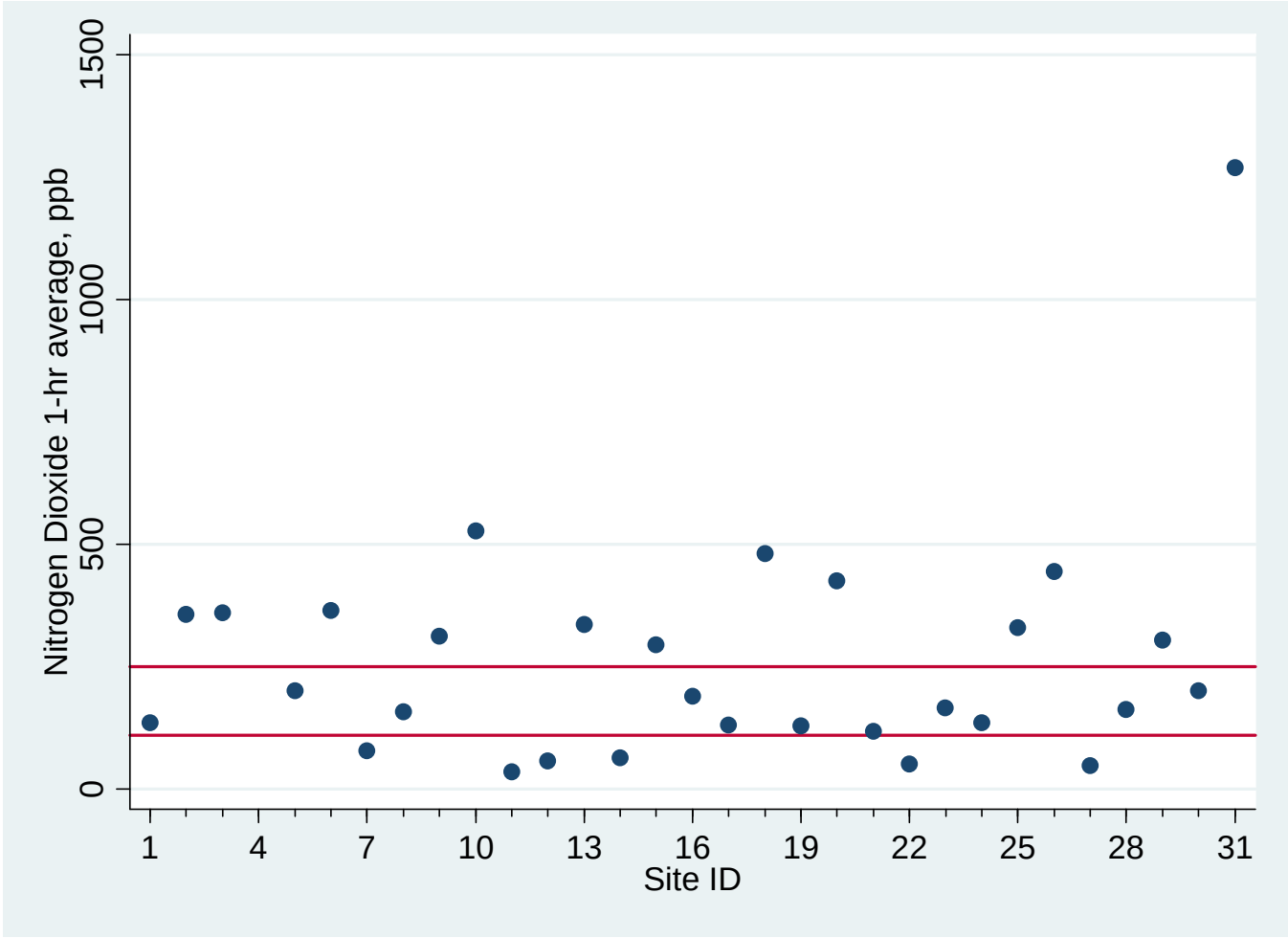

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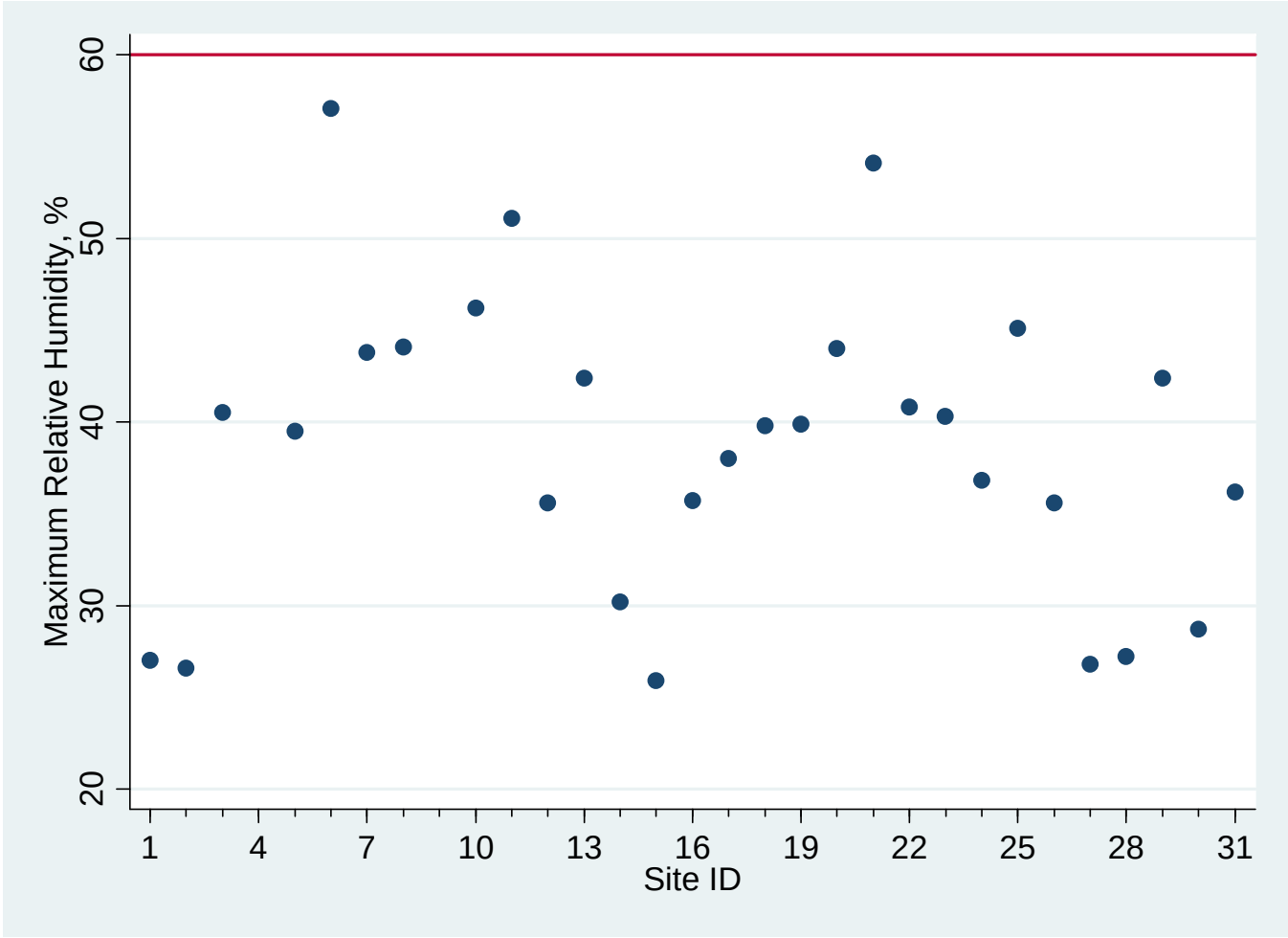

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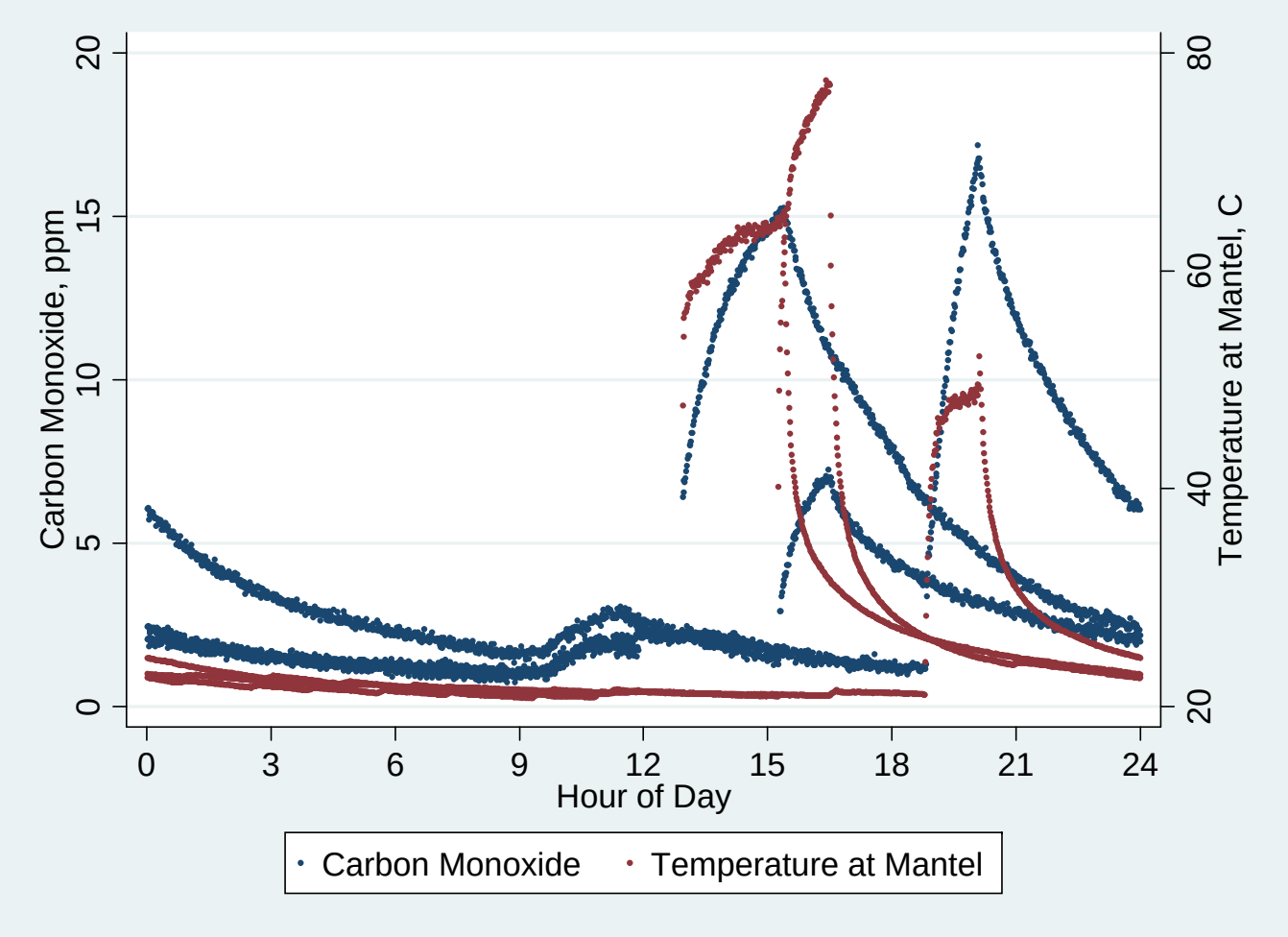

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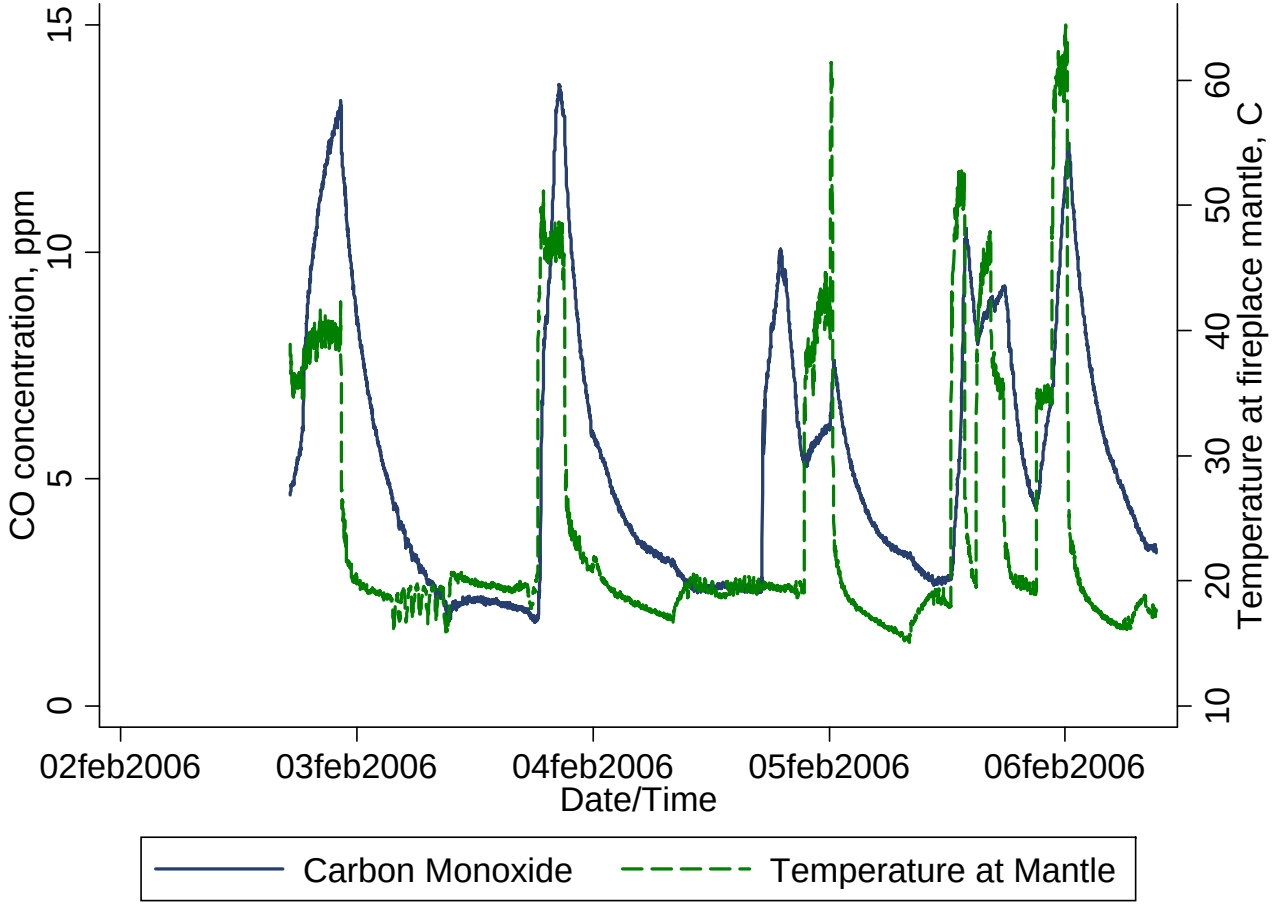

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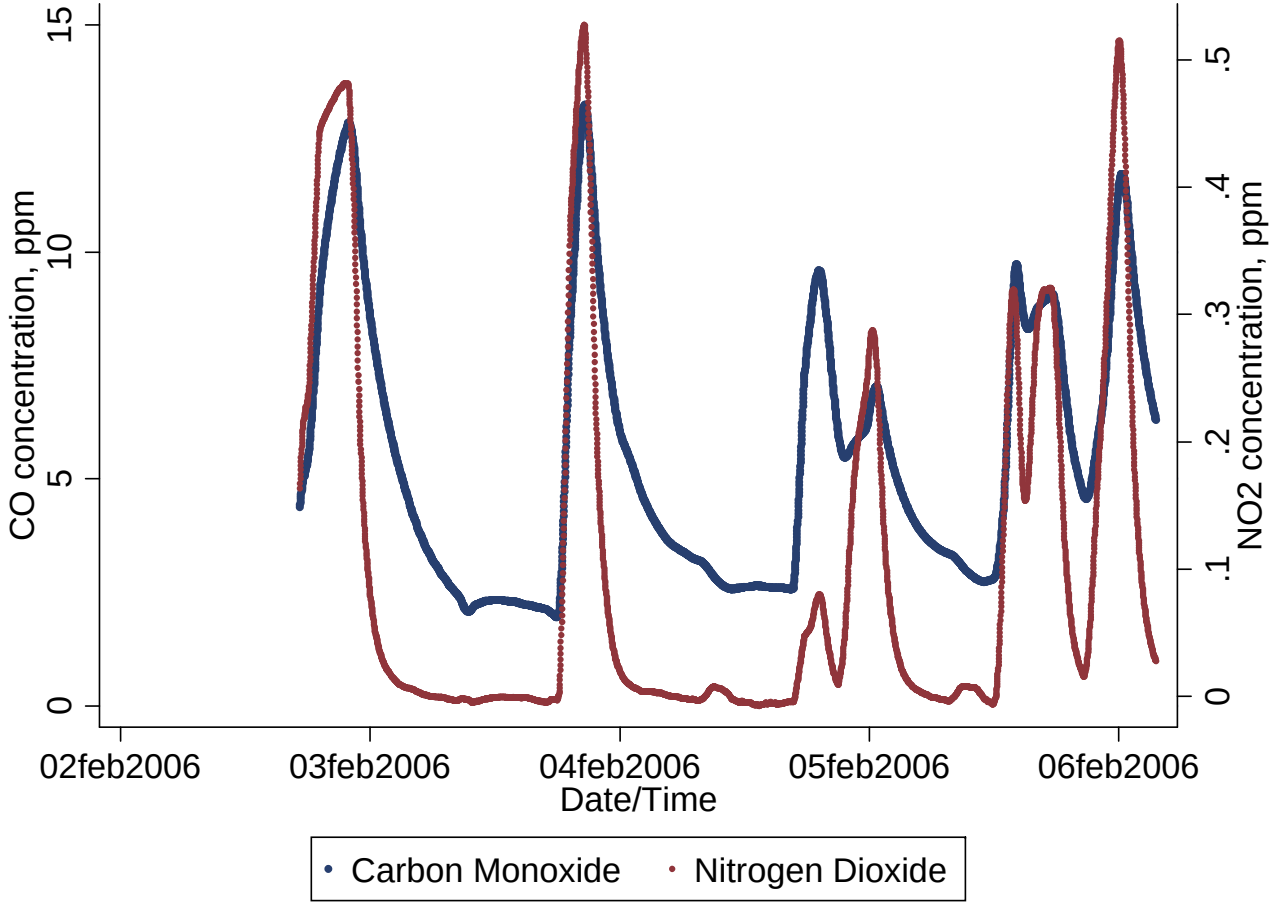

Venting

- 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