Carbon monoxide exposures in long-term care facilities and hospitals: Developing a monitoring framework

Prabjit Barn and Tom Kosatsky
National Collaborating Centre for Environmental Health & BC Centre for Disease Control

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National Collaborating Centre for Environmental Health
Centre de collaboration nationale en santé environnementale

BC Centre for Disease Control
An agency of the Provincial Health Services Authority

Outline

- Project overview & objectives
- Indoor air guidelines and detectors
- Gaps in research and practice
- Discussion questions

Project Overview

- In 2010, BCCDC was contacted by Saskatoon Health Region to provide guidance on how to monitor CO in LTC facilities after the St. Mary's incident

- BCCDC provided guidance on detector technology, placement, and available indoor air guidelines

Project Objectives

(1) To develop a **health-protective** CO monitoring framework for LTC facilities and hospitals which includes establishing specific values that trigger a) maintenance, b) increased ventilation, and c) evacuation

(2) To suggest **practical** means to support the implementation of the framework

Approach

- **Year 1**: Review health effects related to acute, sub-acute, and chronic CO exposures in healthy and vulnerable populations
- **Year 2**: Conduct toxicokinetic modeling to predict COHb levels based on various CO exposures in vulnerable populations
- **Year 3**: To bring together experts to discuss development of a monitoring framework

Carbon monoxide exposures indoors

- Product of incomplete combustion
- Many indoor and outdoor sources
- Most indoor CO is generated indoors
  - √ Back-drafting furnaces
  - √ Wood and gas stoves
  - √ Underground parking garages
  - √ Smoking

Health effects

- CO reduces the oxygen carrying capacity of blood, leading to tissue hypoxia
- Early symptoms: headache, fatigue, nausea, vomiting, and dizzinesss
- Continued exposure: coma, convulsions, and cardio-respiratory arrest
- Some populations may be particularly vulnerable
  - Those with cardiovascular disease have been considered to be most vulnerable

Other physiologic vulnerabilities

- Not adequately investigated:
  - Persons with **respiratory disease** who may have higher CO uptake due to air trapping
  - **Anaemic persons** who have higher endogenous CO production and lower haemoglobin
  - **Elderly** who may have reduced capacity to respond to lower blood O_2 levels

What the research shows

Healthy individuals

Health outcome	# of studies	Lowest % COHb for measured response	Response
Exercise performance	4	3.95 ± 0.49[1]	Decrease in mean exercise time until exhaustion [from 697.7 s to 662.7s (p<0.001)]
Cardiovascular effects	4	2.4[2]	P-wave changes [in 3/15 participants]
Respiratory effects	6	3.95 ± 1.87[3]	Decrease in inspiratory capacity (p<0.05) and total lung capacity (p<0.02)
Nervous system & behaviour	6	5.1 ± 0.57[4]	Impaired visual manual tracking
Other physiological effects	2	8.5 ± 0.9%[5]	Increase in retinal artery diameter [(by +3.5 ±3.8% (P< 0.01)] Increase in retinal vein diameter [by +4.3± 3.0% (P< 0.01)]

Cardiovascular disease

Health outcome	# of studies	Lowest % COHb for measured response	Response
Exercise-induced angina	9	2.0 ± 0.05[6]	Decrease in time to onset of angina [4.2 % decrease]
Exercise-induced arrhythmias	4	5.91 ± 0.07%[7]	Frequency of single premature ventricular contractions per hr during exercise was significantly higher (p=0.03)
Other CV effects	6	2.38 ± 0.05[8]	Significant decreases in time to development of ischemic ST-segment changes (p = 0.01)
Nervous system and behaviour	1	3.90[9]	No observable response [No significant decrease in visualization test performance]

Other Vulnerable Groups

Health Status	Outcome	# of studies	Lowest % COHb for measured response	Response
Respiratory disease (COPD)	Exercise performance	2	4.08[10]	Decrease in mean exercise time until dyspnea in patients with COPD [from 218.5 to 146.6 seconds ($p<0.001$)
Anaemia	Exercise performance	1	3.38 ± 0.83[11]	Reduction in exercise duration [18% reduction]
Elderly	Neuro-physical function	1	5.0[12]	No observable response [No effects on reaction time and late positive component of visual evoked potential]

Indoor air guidelines and CO detectors

Organization	Population	Avg. period	Guideline/ Limit (ppm)	Comments
Health Canada[13]	General public	1 hour	25	Values are derived from studies of individuals with coronary disease. Values are considered to be protective of the entire population.
		24 hour	10	
World Health Organization (WHO)[14]	General public	15 min	86	Assuming light exercise and that exposure to these levels occurs only once/day.
		1 hour	30	
		8 hour	9	Assuming light to moderate exercise.
		24 hour	6	Assuming exposures occur when people are awake and alert but not exercising.

CO detectors

- Readily available, but their use is not mandatory expect:
  - in provinces that require installation through provincial building codes or,
  - in municipalities that have enacted by-laws requiring their installation
- Saskatchewan is the now the only province that requires CO detectors in health care facilities

Monitoring indoor CO

- Alarms are triggered when specific concentration-duration algorithms are reached

CO concentration	Time period[15]
400 ppm	4-15 min
150 ppm	15-50 min
70 ppm	1-4 hours

Discrepancy between guidelines and detectors

World Health Organization & Health Canada Guidelines	Canadian Standards Association Approved Detectors
2 % COHb	**10 % COHb**
Based on lowest observed COHb level associated with a health outcome in a vulnerable population	Based on efforts to reduce non-emergency calls made to first responders

Gaps in Research and Practice

- Exposure and health effects in those with respiratory disease, anaemia, and the elderly
- Health effects of sub-acute and long-term exposures to low levels
- How best to monitor levels
- Levels that should trigger action

Discussion questions

Are commercially available CO detectors protective of short & medium term exposures in vulnerable persons?

- are current triggers sufficiently protective of all populations?
- are current logging capabilities of detectors sufficient for monitoring purposes?

What is the margin of safety for CO exposures in the short and medium term which would compensate for various conditions related to the monitoring framework, including

- sub-optimal monitor placement
- moderate under-responsiveness
- location of CO source
- multiple sources, etc.

Discussion questions (2)

- What alternate ambient concentration/duration algorithm would optimally protect vulnerable groups?

- How could these health protective measures be implemented in practice?

References

1. Aronow WS, Cassidy J. Effect of carbon monoxide on maximal treadmill exercise. A study in normal persons. Annals of Internal Medicine. 1975 Oct;83(4):496-9.
2. Davies DM, Smith DJ. Electrocardiographic changes in healthy men during continuous low-level carbon monoxide exposure. Environ Res. 1979 Feb;21(1):197-206.
3. Chevalier RB, Krumholz RA, Ross JC. Reaction of nonsmokers to carbon monoxide inhalation. Cardiopulmonary responses at rest and during exercise. JAMA: The Journal of the American Medical Association. 1966;198(10):1061-4.
4. Putz VR. The effects of carbon monoxide on dual-task performance. Hum Factors. 1979 Feb;21(1):13-24.
5. Resch H, Zawinka C, Weigert G, Schmetterer L, Garhofer G. Inhaled carbon monoxide increases retinal and choroidal blood flow in healthy humans. Invest Ophthalmol Vis Sci. 2005 Nov;46(11):4275-80.
6. Allred EN, Bleecker ER, Chaitman BR, Dahms TE, Gottlieb SO, Hackney JD, et al. Short-term effects of carbon monoxide exposure on the exercise performance of subjects with coronary artery disease. N Engl J Med. 1989 Nov 23;321(21):1426-32.
7. Sheps DS, Herbst MC, Hinderliter AL, Adams KF, Ekelund LG, O'Neil JJ, et al. Effects of 4 percent and 6 percent carboxyhemoglobin on arrhythmia production in patients with coronary artery disease. Res Rep Health Eff Inst. 1991 May(41):1-46; discussion 7-58.

8. Allred EN, Bleecker ER, Chaitman BR, Dahms TE, Gottlieb SO, Hackney JD, et al. Effects of carbon monoxide on myocardial ischemia. Environ Health Perspect. 1991 Feb;91:89-132.
9. Aronow WS, Charter R, Seacat G. Effect of 4% carboxyhemoglobin on human performance in cardiac patients. Prev Med. 1979 Sep;8(5):562-6.
10. Aronow WS, Ferlinz J, Glauser F. Effect of carbon monoxide on exercise performance in chronic obstructive pulmonary disease. Am J Med. 1977 Dec;63(6):904-8.
11. Aronow WS, Schlueter WJ, Williams MA, Petratis M, Sketch MH. Aggravation of exercise performance in patients with anemia by 3% carboxyhemoglobin. Environ Res. 1984 Dec;35(2):394-8.
12. Harbin TJ, Benignus VA, Muller KE, Barton CN. The effects of low-level carbon monoxide exposure upon evoked cortical potentials in young and elderly men. Neurotoxicol Teratol. 1988 Mar-Apr;10(2):93-100.
13. Health Canada. Residential indoor air quality guide: Carbon monoxide. Ottawa, ON: Health Canada; 2010 [cited 2011 Jan 18]; Available from: http://www.hc-sc.gc.ca/ewh-semt/pubs/air/carbon_mono/index-eng.php.
14. World Health Organization. WHO guidelines for indoor air quality: selected pollutants. Geneva, Switzerland: WHO; 2010. Available from: http://www.euro.who.int/en/what-we-publish/abstracts/who-guidelines-for-indoor-air-quality-selected-pollutants
15. http://www.msss.gouv.qc.ca/sujets/santepub/environnement/index.php?avertisseur_en&print=1

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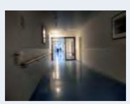
20		http://www.flickr.com/search/?w=42143317@N05&q=hospital	Ralf Heβ	CC BY SA