North Carolina Department of Labor
Occupational Safety and Health Division

Raleigh, NC

Field Information System Operational Procedure Notice 148

Subject: Carbon Monoxide Exposure Documentation Guidelines

A. **Purpose.**

This Operational Procedure Notice (OPN) provides the North Carolina Department of Labor (NCDOL) Occupational Safety and Health (OSH) Division guidance on the use of the Coburn Equation to theoretically derive an employee's exposure to carbon monoxide (CO).

B. **Scope.**

This OPN applies to compliance inspections where employees are suspected of being overexposed to CO.

C. **Discussion.**

This OPN describes the use of the Coburn Equation to convert an employee's post-exposure blood carboxyhemoglobin (COHb) level to their airborne CO exposure at the time of exposure. COHb values are obtained by clinics and hospitals for diagnostic purposes when an employee presents symptoms indicative of CO exposure. Industrial hygienists (IHs) must convert COHb to CO time weighted average (TWA) because the Occupational Safety and Health Act (OSHA) regulations have no limits for employee COHb level, but they do have limits for airborne CO exposure. Under 29 CFR 1910.1000—Air Contaminants and 29 CFR 1926.55—Gases, Vapors, Fumes, Dusts and Mists, the permissible exposure limit (PEL) for CO is 50 parts per million (ppm) over an 8 hour TWA. The CO air concentration derived from the Coburn Equation can serve as the basis for citations for CO overexposures under 29 CFR 1910.1000—Air Contaminants and 29 CFR 1926.55—Gases, Vapors, Fumes, Dusts and Mists.

D. **Inspection Guidance.**

Compliance safety and health officers (CSHOs) shall attempt to obtain the information outlined in Appendix B—Coburn Equation-Required Data, to assess the CO exposure situation at the establishment. The CSHOs will request the medical records of employees who are suspected of being overexposed to CO, using the procedures outlined in the Field Operations Manual (FOM) Chapter III—Inspection Procedures, paragraph D.6.a.ii.A., Requesting & Reviewing Medical Records. The CSHOs shall discuss the inspection findings with their district supervisor.

Note: *An employee can have an elevated COHb level that is unrelated to their work activities; such as use of gas ovens and kerosene heaters.*

E. **Documentation.**

The CSHOs shall determine a preliminary CO exposure from the COHb value using the Coburn Equation in Appendix A—Calculations. The CSHOs may utilized the "Coburn Equation Calculator" Excel

spreadsheet, found on the Field Information System (FIS) under Forms, to assist them in calculating the CO exposure. Appendix B lists the data needed for the Coburn Equation. The Coburn Equation alone cannot be utilized for an exact exposure, but it is helpful for identifying situations that should undergo further and costlier analysis due to the high likelihood that the data could show an exposure above a regulatory limit.

Note: *The theoretical concentration derived from the Coburn Equation is an average exposure that has to be converted to an 8-hour TWA before comparison to the PEL.*

If the Coburn Equation indicates the CO exposure is greater than 50 ppm, CSHOs shall obtain the district supervisor's approval to initiate a Salt Lake Technical Center (SLTC) analysis. Due to the high cost per sample, CSHOs must discuss with their supervisor the number of samples to be sent per inspection. Once approval has been obtained from the supervisor (along with Bureau Chief and Staff IH), the CSHOs will send the completed form to SLTC for analysis with their Coburn-Forster-Kane (CFK) model. The CFK model has been extensively tested for reliability. CSHOs shall ensure that the samples cover all potential representative overexposures (that is job titles, departments, and industrial processes) so all significant sources of CO can be addressed in the citation. For a basic exposure scenario (i.e., single source of CO, one work area, no extenuating circumstances), the typical limit on the number of samples would be three. See Appendix C—SLTC Sample Submittal Instructions, for submittal instructions. The cost of the sample includes expert witness testimony from SLTC if the results are challenged in court.

F. **Citation Guidance.**

The CSHOs will calculate the 8-hour TWA and Sampling and Analytical Error (SAE) upon receiving the results from SLTC, following the guidance outlined in the FOM Chapter XV—Industrial Hygiene Compliance, paragraph D.1.j.C, Sampling and Analytical Error (SAE). If the values exceed the PEL, a citation under 1910.1000 or 1926.55 will be issued, provided the other required elements for a citation are present. The CSHOs shall include the following comment on the Air Contaminant Data Sheet: "Employee exposure is based on the result of Coburn-Forster-Kane model to convert the employee's carboxyhemoglobin level in the clinic/hospital to the value of airborne CO in the workplace at the time of employee exposure." CSHOs will determine if there are related violations of the Hazard Communication standard (1910.1200, 1926.59).

G. **Effective Date.**

This OPN is effective on the date of signature. It will remain in effect until revised or canceled by the director.

Signed on Original
John Jaskolka
Health Standards Officer

Signed on Original
Allen McNeely
Director

7/08/2016
Date of Signature

Appendix A: Calculations

Coburn Equation

$$CO = \frac{1316\{[(0.0046)\left(2^{\theta/T}\right)(C)] - [(0.007)(B)] + [(0.007(B) - 2.3(D)(e^{-2.3t/5500B})]\}}{1 - (e^{-2.3t/5500B})}$$

Where:
CO = theoretical concentration of CO in air (ppm)
C = blood COHb in % at the time of blood sampling
B = Activity Factor (sedentary = 0.152, light work = 0.065, heavy work = 0.040)
D = background COHb level (non-smoker = 0.0015, smoker = 0.0100)
t = time of exposure to CO (in minutes)
θ = time between end of CO exposure and blood sampling (in minutes)
T = half-life recovery factor of CO removal from blood (in minutes)

Half-life Recovery Factors*	
Air	320
Oxygen	80
Hyperbaric Chamber	23

Note: *Use only one of these factors when only one method is used for recovery. For mixtures, use equation below to determine half-life recovery factor.*

Calculation for recovery time (mixture)

$$T = \frac{(320)(a) + (80)(o) + (23)(hc)}{(a + o + hc)}$$

Where:
T = recovery time, total, weighted, in minutes
a = recovery time in air
o = recovery time in oxygen
hc = recovery time in hyperbaric chamber

Calculation for 8 hour TWA

$$TWA = \frac{C_1 T_1}{T_1 + T_v}$$

Where:
C_1 = average ppm derived from the Coburn Equation
T_1 = time of exposure to CO (in minutes)
T_v = 480 minutes – T_1

Appendix B: Coburn Equation – Required Data

The data required for Coburn Equation are:

- Blood COHb result (in %)
- Employee activity level (sedentary, light work, or heavy work)
- If the employee is a smoker or non-smoker
- Time of exposure to CO (in minutes)
- Time between end of CO exposure and blood sample (in minutes)
- Type of recovery between end of CO exposure and collection of blood sample (air, oxygen, hyperbaric or mixture)
- If employee recovery was a mixture as defined above, please note the number of minutes in each type of treatment (i.e., number of minutes in air, number of minutes in oxygen, and number of minutes in hyperbaric).

Appendix C: SLTC Sample Submittal Instructions

To obtain the SLTC Application, log on to the OSHA Extranet at https://extranet.osha.gov/remote/login.html

- In the right-hand column, under *OSHA LINKS*, click on *CSHO Resources.*
- Under *Inspection Preparation,* click on *more…*
- Under *Biological Exposure Assessment*, click on *Carbon Monoxide Sheet*.
- In the upper right of the screen, click on *PDF*.

Print the PDF worksheet that is in the SLTC Application. Follow the instructions on the form, and collect the requested information. The SLTC Application is completed by hand. Some of the instructions on the application pertain to only federal compliance officers, so speak to the Staff IH or your supervisor to determine exactly what procedure to follow.

At the OSHA Extranet under *Biological Exposure Assessment* are links to a Catalog of Activity Levels and Medical Access Order Requests. The Catalog of Activity Levels gives activity levels for questions #14 and #16 on the SLTC Application.

For more information on carboxyhemoglobin evaluation, please see OSHA Technical Manual, Section II, Chapter 2 – Surface Contaminants, Skin Exposure, Biological Monitoring and Other Analyses, Subsection IV – Sampling Methodology, Subsubsection C – Biological Monitoring Methodology, Carboxyhemoglobin Evaluation.