1. **PURPOSE:**

This document establishes best practices for quantitative ambient air quality monitoring and other protective measures to prevent dangerous exposure to carbon monoxide (CO) and hydrogen cyanide (HCN) at working fires of all types. It is primarily intended to provide a means of demonstrating acceptable levels of CO and HCN during and following a working fire before allowing firefighters to doff their self-contained breathing apparatus (SCBA). It also may prompt support sector personnel exposed to significant amounts of smoke, even in an open-air environment, to don an SCBA or retreat to a safe location.

1. **BEST PRACTICE:**
2. CO is a by-product of incomplete combustion. HCN is a by-product of combustion when synthetics and composites are involved. Both CO and HCN are toxic, and the symptoms of overexposure include significant and potentially fatal effects on the central nervous, cardiovascular, and respiratory systems. [*CDC, ATSDR*]
   1. The use of SCBA should be required for personnel engaged in fire suppression or overhaul operations involving any structure or vehicle, or which occur in any enclosed area, until a safe atmosphere can be verified through air monitoring.
   2. Moving to a safer location is the preferred means of exposure control for personnel who are not directly engaged in fire suppression or overhaul operations.
   3. The use of SCBA should not be required for personnel engaged in fire suppression or overhaul operations involving a field, brush, or similar non-enclosed area with only natural materials involved.
3. Transport to a hospital for CO and HCN evaluation (blood analysis) should not be delayed if potentially dangerous exposure is suspected. HCN exposure otherwise may be difficult to determine. HCN poisoning symptoms are similar to those for CO. Low exposure levels may produce headache, nausea, fatigue and dizzy spells, while high levels may produce respiratory problems, unconsciousness, and cardiac arrest. However, HCN is 35 times more toxic than CO and has a metabolic half-life of only one hour. Treatment for carbon monoxide inhalation can revive the patient, however, without a cyanide antidote kit, the lasting effects of hydrogen cyanide poisoning can create enduring medical complications. [*Rochford*]
4. **PERSONAL PROTECTIVE EQUIPMENT (PPE)**
5. SCBA is the best preventive measure because smoke inhalation is the primary route of exposure, and it prevents secondary exposure through the ingestion of soot or contaminated saliva and mucous.
6. Structural turnout gear helps protect personnel from absorbing toxic gases and smoke through the skin, which is a secondary route of exposure, and should be worn by personnel engaged in fire suppression or overhaul operations involving any structure, vehicle, or enclosed area.
7. **AIR MONITORING**
8. CO and HCN meters normally will be located on the first-due structural apparatus. The Incident Commander (IC) is to request a unit with those meters to respond if no on-scene apparatus is equipped with them.
9. Meters should be turned on at a location which is upwind or highly unlikely to be contaminated with CO or HCN and left at the command post to facilitate their usage by the IC, Safety Officer (SO), and/or other designated personnel.
10. Firefighters engaged in fire suppression or overhaul operations should not remove their SCBA until the atmosphere can be monitored and deemed safe.
11. The following conditions should warrant air monitoring for CO and HCN:
12. When active fire suppression or ventilation operations are complete and the removal of SCBA is desired, such as for overhaul operations, especially when smoke is still present.
13. When personnel in the support sector (open air) are exposed to potentially unsafe amounts of smoke during fire suppression or overhaul operations.
14. When personnel are found operating without a SCBA and the atmosphere has not been monitored and deemed safe:
    1. The area where the personnel were found should be immediately monitored.
    2. The CO and HCN levels should be promptly communicated to the IC or SO, and the personnel who were found in the area should be relieved of their assignment, go through rehabilitation as necessary, then report directly to the IC.
    3. The IC and/or SO must determine the potential exposure of each person to the reported CO and/or HCN levels. If the exposure is determined to be potentially dangerous, or if there are signs or symptoms of potentially dangerous exposure, the personnel are to be promptly transported to a hospital for medical evaluation and treatment as necessary. Do not delay this evaluation due to the 1-hour metabolic half-life of HCN.
       1. Symptomatic personnel should receive medical observation for at least 4 to 6 hours. [*ATSDR]*
       2. An acceptable blood cyanide level would be 20 micrograms per decaliter [*Varone et al.]*, beyond which appropriate medical treatment should be immediately provided.
       3. Treatment for carbon monoxide inhalation can revive the patient, however, without a cyanide antidote kit, the lasting effects of hydrogen cyanide poisoning can create enduring medical complications. [*Rochford*]
    4. Disciplinary action may be warranted.
15. Where smoke is reported in adjacent structures or spaces (apartments, suites, etc.).
16. Whenever deemed necessary by the IC or SO.
17. The following conditions typically will not warrant air monitoring for CO and HCN:
18. During active fire suppression or ventilation operations involving a structure or vehicle when a SCBA and turnout gear are being worn.
19. During active fire suppression operations involving a non-enclosed area, such as a field or brush fire, unless otherwise requested by the IC or SO.
20. When a burning odor is detected and there is no visible smoke, i.e. light ballast.
21. **ACTION LEVELS**
22. CO
23. Thirty-five (35) parts per million (ppm) in air, which is the recommended exposure limit (REL) for an 8-hour time-weighted average (TWA) exposure [*NIOSH*], or greater should be the Action Level for which use of a SCBA is required.
24. Two hundred (200) ppm, which is the ceiling limit [*NIOSH*], should never be exceeded.
25. One thousand two hundred (1,200) ppm is an immediately dangerous to life and health (IDLH) concentration [*NIOSH*].
26. HCN
27. Five (5) ppm in air, which is the REL for a short-term (15-minute) TWA exposure limit [*NIOSH*], or greater should be the Action Level for which use of a SCBA and turnout gear is required.
28. Fifty (50) ppm is the IDLH concentration [*NIOSH*].
29. This chemical has a “skin” designation from NIOSH and other agencies, meaning it can be absorbed through the skin and eyes; inhalation is not the only route of exposure.
30. **SIGNS AND SYMPTOMS OF EXPOSURE**
31. CO
32. The signs and symptoms are often variable and non-specific, with the most common being headache, dizziness, weakness, nausea, vomiting, chest pain, and altered mental status. [*CDC*]
33. Severe symptoms include malaise, shortness of breath, headache, nausea, chest pain, irritability, ataxia, altered mental status and other neurologic symptoms, loss of consciousness, coma, and death. [*CDC*]
34. Severe signs include tachycardia, tachypnea, hypotension, various neurologic findings including impaired memory, cognitive and sensory disturbances, metabolic acidosis, arrhythmias, myocardial ischemia or infarction, and non-cardiogenic pulmonary edema, although any organ system might be involved. [*CDC*]
35. HCN
36. Exposure to lower concentrations (or initial exposure to higher concentrations) may result in:
    1. Stupor, confusion, flushing, anxiety, perspiration, headache, drowsiness, and tachycardia (greater than 100 beats per minute in an adult). [*Rochford*]
    2. Eye irritation, headache, confusion, nausea, and vomiting followed in some cases by coma and death. [*ATSDR*]
37. Exposures to higher concentrations may result in:
38. Prostration, tremors, cardiac arrhythmia (in which can be delayed 2 to 3 weeks post-fire exposure), coma, respiratory depression, respiratory arrest, and cardiovascular collapse. [*Rochford*]
39. Abrupt onset of profound central nervous system (CNS), cardiovascular, and respiratory effects leading to death within minutes. [*ATSDR*]
40. **DECONTAMINATION**
41. Personnel who were performing fire suppression or overhaul operations, or who were exposed to substantial amounts of smoke from those operations, should practice good personal hygiene by washing the hands and face with soap and water before eating or drinking.
42. If turnout gear is soiled, decontaminate the gear while on scene.
43. A PPV fan and/or a soft bristle brush can be used to remove large particulates.
44. If a fan or brush is not available, briefly rinse with a soft fog pattern while trying to prevent saturation (HCN skin absorption).
45. Turnout gear should be washed as soon as possible.
46. Turnout gear, flash hood, and gloves should be washed and dried in accordance with the manufacturer’s instructions, or in an extractor per NFPA 1851 if possible.
47. Boots and helmet should be washed with a brush, soap, and water.
48. **REPORTING**
49. The IC and/or SO should be responsible for recording the CO and/or HCN exposure to any personnel not wearing a SCBA or turnout gear as required during a fire.
50. The incident report (NFIRS, etc.) generated by each department should include the CO and/or HCN exposure to its personnel who were not wearing a SCBA or turnout gear as required during a fire.
51. An Accident Report should be completed and submitted to the authority having jurisdiction by an officer from the department of any firefighter who was exposed above an Action Level for CO and/or HCN while not wearing a SCBA or turnout gear as required during a fire.
52. **METER CALIBRATION AND TESTING**
53. Meter calibration and testing should be performed in accordance with the manufacturer’s instructions.
54. Any meters exposed to a high concentration and registering “out of range” (or equivalent) on its display should be taken out of service until it is calibrated (as soon as possible).
55. **REFERENCES**
    1. US Centers for Disease Control (*CDC*) – Clinical Guidance for Carbon Monoxide Poisoning after a Disaster
    2. Agency for Toxic Substances and Disease Registry (*ATSDR*) – Hydrogen Cyanide Patient Information Sheet
    3. Rochford, Rick – Hydrogen Cyanide: New Generation Concerns Resulting in Firefighting Tactics and Medicine
    4. Varone et al. – “Report of the Investigation Committee into the Cyanide Poisonings of Providence Firefighters,” May 30, 2006
    5. National Institute for Occupational Safety and Health (*NIOSH*) – “Pocket Guide to Chemical Hazards,” September 2007