Priorities to address smoke hazards for wildland firefighters

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Respirable particulate can include crystalline silica, e.g., during “Hand” construction of fireline

Many incomplete combustion toxins are well-correlated in smoke

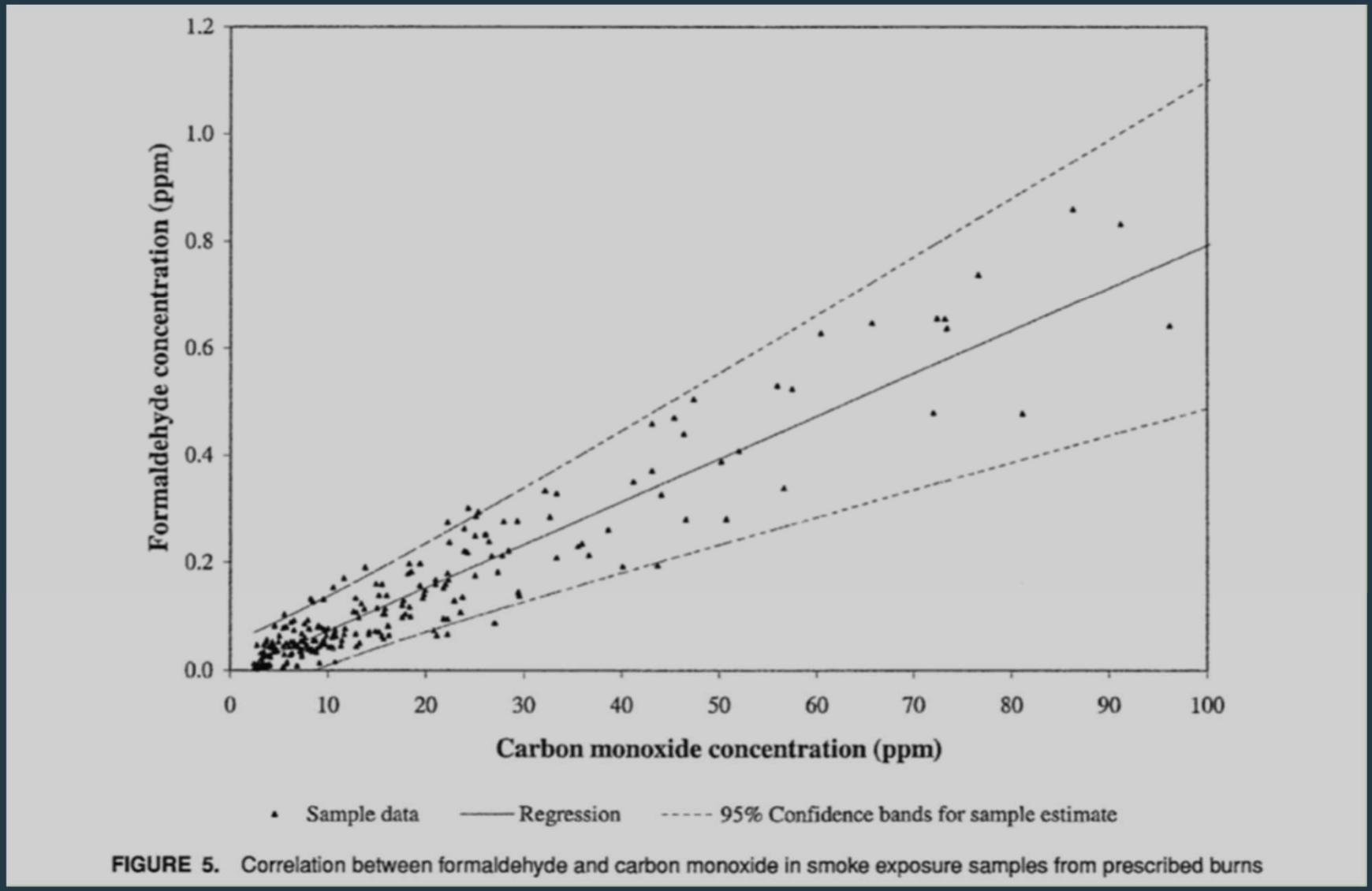

FIGURE 5. Correlation between formaldehyde and carbon monoxide in smoke exposure samples from prescribed burns

Reinhardt and Ottmar, JOEH 2004.

Historically, the Permissible Exposure Limit for nuisance respirable dust (5 mg/m^3) was applied to smoke. Unacceptable. Should it be:

- Like Cellulose (1 mg/m^3)?
- Like Lead or Respirable Crystalline Silica, (0.05 mg/m^3)?
- Like Hexavalent chromium, (0.005 mg/m^3)?
- Like Beryllium (0.0002 mg/m^3)?
- Using the *Pope et al 2011* dose-response for CVD mortality from fine particles (multiple sources) *Navarro et al 2019* found the risk curve is very steep at low concentrations, typical of most smoke exposure
- Major research need, still not met, NIOSH began prospective epi study in 2018

Controls

- Engineering and administrative controls preferred but not yet proven effective.
  - Trying enclosed-cab dozers, but requires maintenance, and operator cooperation. Helps relatively few firefighting personnel
  - Prescribed burn planning is better, more defensible layouts, some pre-wetting of perimeter fuels—huge incentive to endure smoke to prevent escape
  - Reducing standard distance from firelines for 100% mop-up
  - Some pilot use of filtered tents in fire camps
  - Rare to have any CO exposure monitoring, and resulting administrative action taken

Controls: Respirators

- NFPA 1984: 2016 for wildland fire respirators, calls for minimum ½-face N95 with ultra-low breathing resistance, ember resistance, and removal of CO, HCHO, acrolein, plus organics and acid gases
- Half-mask doesn't help the eye irritation, but won't fog
- A full-face PAPR to this standard would be an excellent tool for holding fireline, structure protection, high-smoke situations, but:
  - Costly
  - No one makes one yet
  - No guaranteed market yet
  - Potential critical hindrance to communication
  - Potential deadly loss of situational awareness

Controls: Respirators

- No respirators presently approved, some non-NIOSH-approved bandana-like devices being advertised and sold to the unwitting.
- Clear need for respiratory protection against crystalline silica in soil dust
- But N95 respirator for crystalline silica poses a quandary:
  - If the PM4 is mainly from smoke, then an N95 does not protect against CO, formaldehyde, acrolein and other gases (NO, NO_2, SO_2, benzene, etc.)
  - Scenario of 4% silica in dust, firefighters protected from that by an N95 but encountering the equivalent smoke (to ½ silica limit*) could on average be exposed to:
    - 70 ppm CO (WFF guideline= 12 ppm for 12-hr shifts)
    - 0.55 ppm formaldehyde (PEL is 0.3), and
    - 0.07 ppm acrolein (PEL is 0.01), with an
    - Irritant index of 2.5 for just these two strongly irritant gases
    - Ethical to endure ENT irritation or take as signal to retreat?

*Maximum use concentration for an N95 respirator

Final points

- The best exposure measurement for smoke-derived PM4 must exclude non-smoke PM4. Explore an organic carbon method focusing on PM1, such as a variation of the MSHA diesel particulate matter method
- But as a real-time go/no-go, alarming CO sensors need to be a critical part of the administrative and respiratory protection toolkit
- So far, it isn't.
- A respirator that solves only half the problem invites misuse. If you're enduring smoke, of course you'll don the respirator that you have. Maybe better to evacuate the area.