Employee Exposure Review

Health Hazards of Smoke Conference, Missoula, MT April 8, 1997

Tim Reinhardt, Radian International
Roger Ottmar, USDA Forest Service,
PNW Research Station

This presentation aims to summarize work done to assess firefighter exposure to smoke. The assessment is important to define where we stand in terms of compliance with occupational exposure limits, but also to provide data for a risk assessment to determine the significance of the health risks.

Occupational Exposure Limits

Limit	CO (ppm)	PM3.5 (mg/m^3)	Formal-dehyde (ppm)	Acrolein (ppm)	Benzene (ppm)
OSHA PEL	50	5	0.75 (2.0)	0.1 (0.3)	1 (5)
ACGIH TLV	25	3	0.3	0.1 (0.3)	0.5 (2.5)
NIOSH REL	35 (200)	n/a	0.016 (0.1)	0.1 (0.3)	0.1 (1)

A variety of occupational exposure limits exist, ranging from the OSHA Permissible Exposure Limits to the ACGIH Threshold Limit Values and the NIOSH Recommended Exposure Limits. These are shown above for comparison. Short-term Exposure Limits (STELs) and ceiling limits (instantaneous upper limits) designed to control peak exposures to fast-acting toxins are shown in parentheses.

Note that OSHA revised the PELs for CO and many other contaminants in the 1980s to be consistent with the NIOSH RELs, but after several years a legal challenge forced them to withdraw the more stringent standards. Because the original revision was undertaken in response to scientific evidence demonstrating the 50 ppm standard was inadequate, many industrial hygienists consider compliance with OSHA limits to be insufficient to avoid adverse health effects.

Exposure Limits

- Adjust for extended workshifts:

CO PEL = 50 x 8/(hours worked)--for 14-hour shift, the adjusted PEL is 29 ppm

- Account for multiple pollutants:

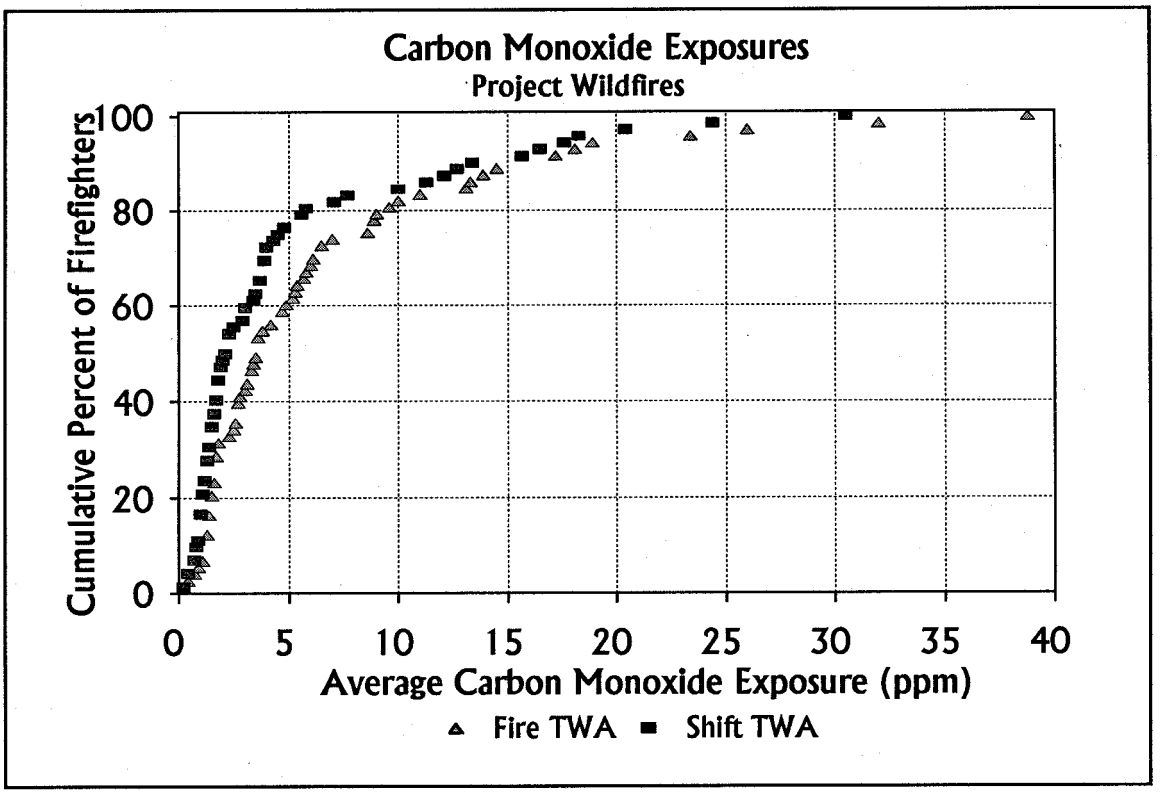
Sum the respiratory irritants--PM3.5, acrolein and formaldehyde

Because occupational exposure limits are based on avoiding adverse health effects during a career of standard 8-hour workshifts, adjustment of the basic exposure limits is recommended to account for the increased uptake of contaminants during a longer workshift. One common formula for doing so is given above.

As well, the total impact of multiple contaminants that affect the same target organ(s) should be considered when evaluating a workplace. A recommended way to do this is to sum each contaminant divided by its respective exposure limit. In smoke, respirable particulate (PM3.5), acrolein and formaldehyde all affect the eyes and respiratory system--primarily through irritation. Thus the formula would be:

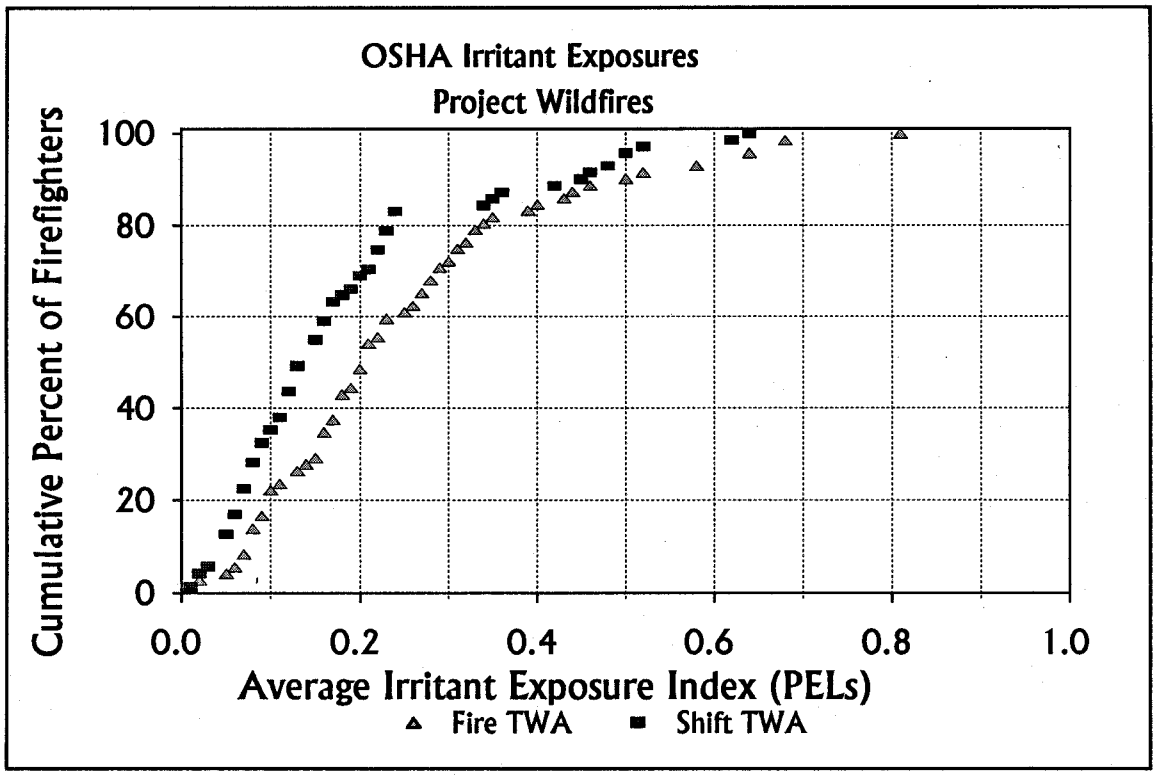
> PM3.5 exposure/PM3.5 exposure limit + acrolein exposure/acrolein exposure limit + formaldehyde exposure/formaldehyde exposure limit

This calculates a unitless "irritant exposure index". There are other respiratory irritants in smoke that have not been measured, so this formula underrepresents the true respiratory irritant exposure.

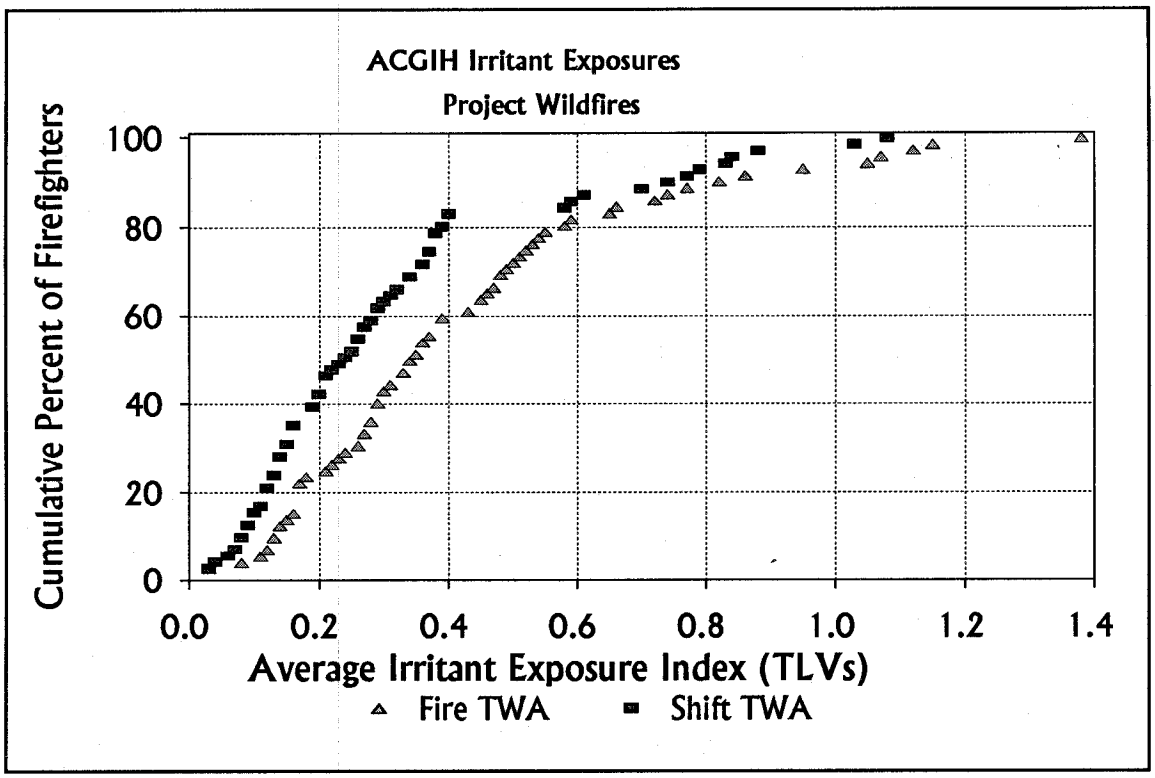


Shown above is an example of the exposure to CO among firefighters at project (extended) wildfires. The CO concentration is on the x-axis, and the percent of firefighters studied is on the y-axis. Both shift-average (Shift TWA) and fireline-average (Fire TWA) exposures are shown.

It is apparent that about 81% of the firefighters at project fires had fireline-average CO exposures that were at or below 10 ppm CO. Only a very small percentage of firefighters had shift-average exposures above the PEL adjusted for a 14-hour workshift (29 ppm). Thus shift-average overexposure to smoke is a limited problem at project wildfires. Note that the Shift TWA exposures are less than the Fire TWAs because of unexposed time traveling to and from the fire.

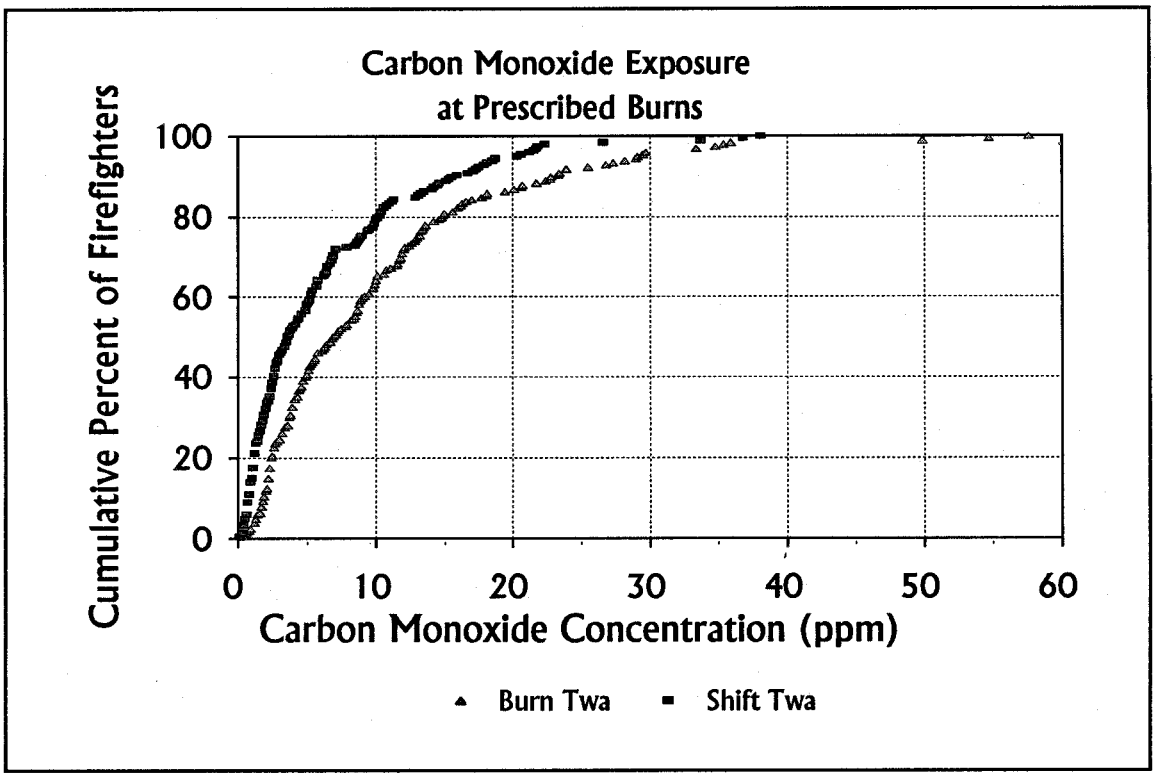


Exposure to respiratory irritants is similar to CO, but none of the irritant exposures exceed the index based on the current OSHA PELs. A shift-average overexposure would be any that exceeded 1.0 on the unitless irritant index scale. No adjustment for the extended workshift is recommended because the irritant effects are thought to be independent of the number of hours worked.



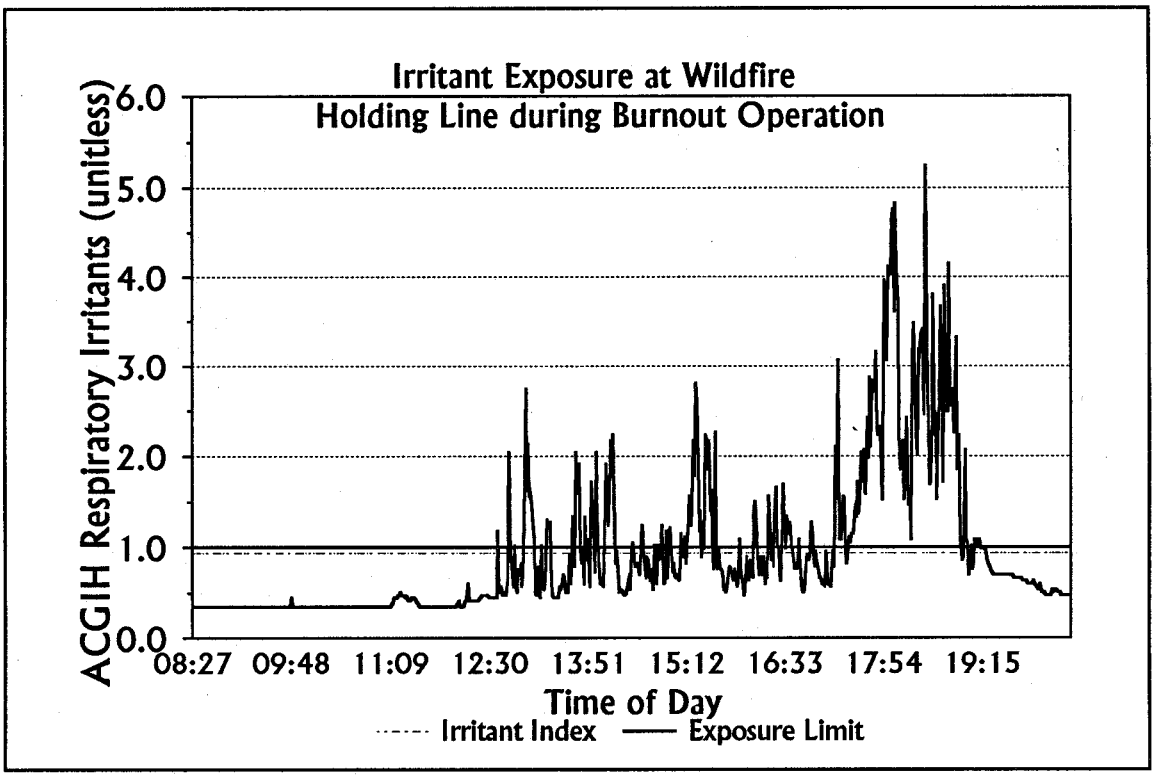
Using the ACGIH TLVs as the occupational exposure limits results in a different interpretation, in that about 3% of the firefighters monitored had exposures that exceeded an irritant index of 1.0 calculated with the TLVs. This is important because the TLVs are well-regarded as incorporating the latest scientific evidence.

Based on this view, the exposure to respiratory irritants is significant, but may be manageable because it only occurs in a minority of cases.

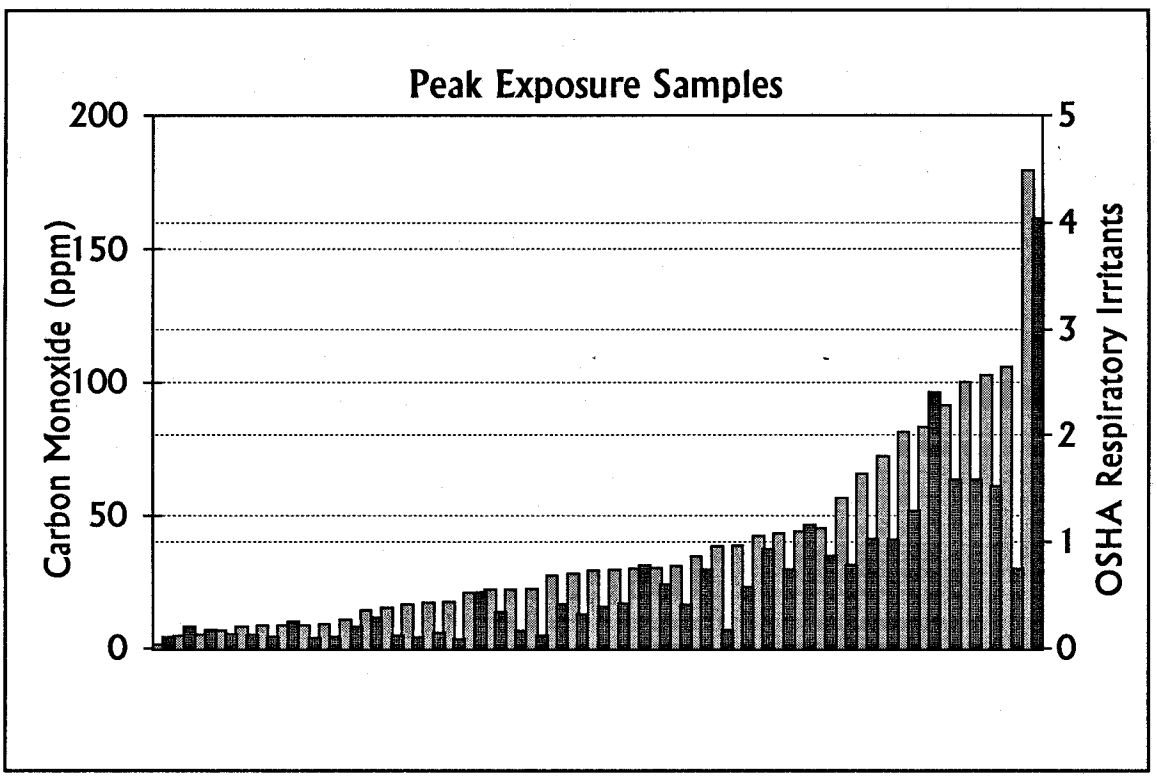


Smoke exposure has been found to be worse at prescribed burns than at wildfires. The data above are from prescribed burns in the Pacific Northwest. Note there are a larger percentage of exposures that exceeded a 25 ppm TLV than there were at the project wildfires monitored.

We believe that smoke exposure is more of a problem at prescribed burns because the firefighters feel that they must control the fire within the prescribed boundaries at all costs. At wildfires, firefighters can often pull back to a more feasible fireline location. The increasing problem of residential influx to wildland areas may cause more overexposure to smoke as firefighters feel compelled to protect structures despite heavy smoke situations.



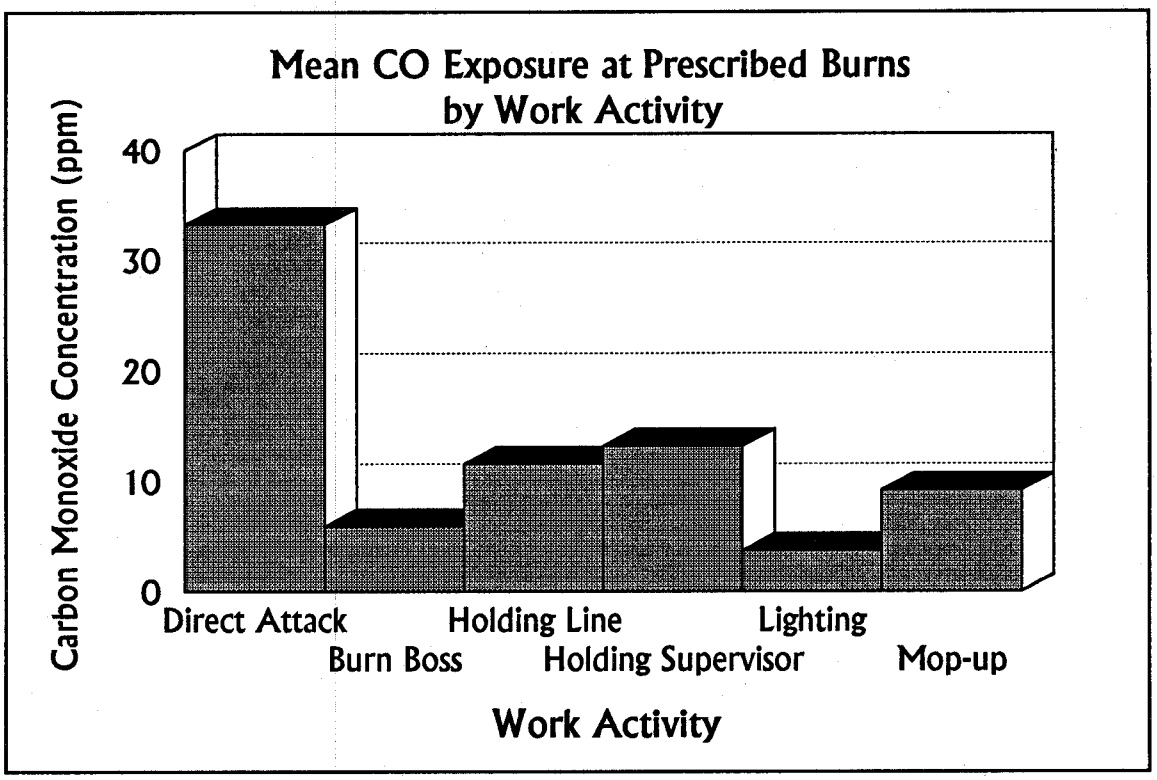
During initial attack, peak exposures to CO and respiratory irritants can exceed short-term exposure limits; CO levels can exceed 200 ppm for short periods. Peak exposure situations also occur during fireline holding actions, with peak exposures to respiratory irritants easily exceeding an irritant exposure limit of 1.0 calculated based on the ACGIH TLVs. Here is an example of respiratory irritant exposure at a project wildfire where the crew was assigned to hold fireline during a burnout in the afternoon. The wind increased during the afternoon, causing significant smoke exposure.



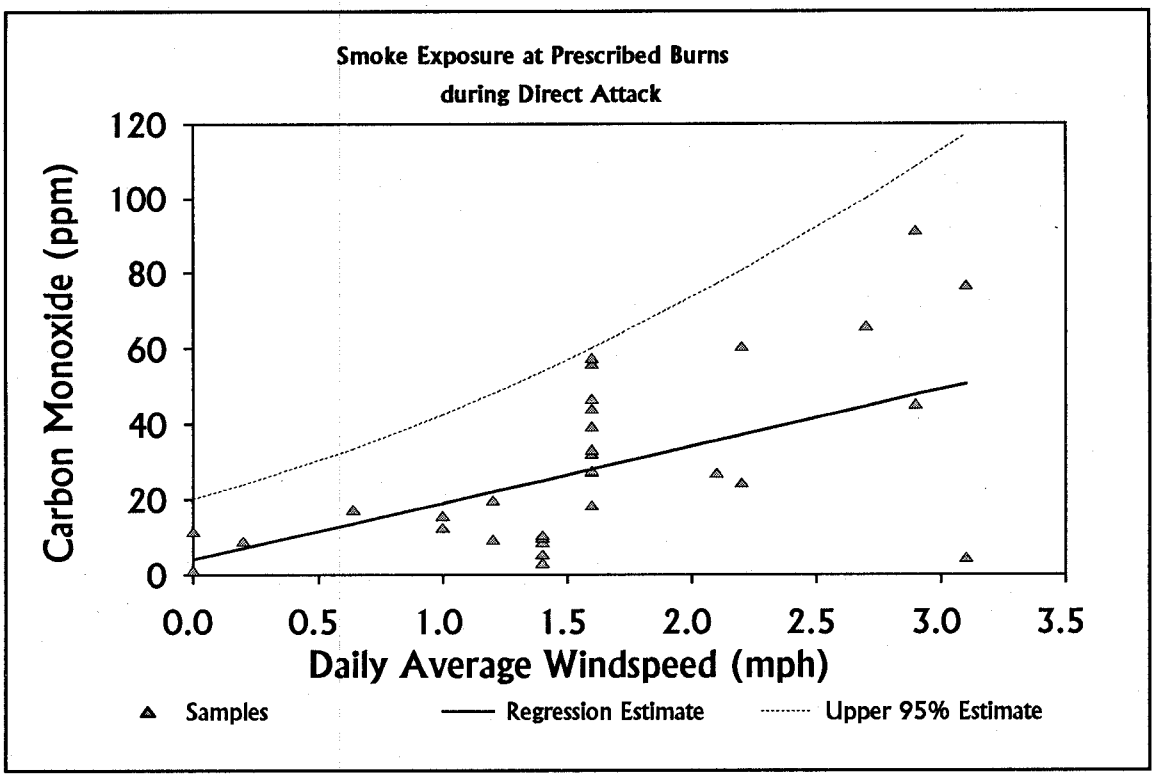
Initial attack is not the only place that peak exposure situations occur. The data above are peak exposure samples obtained from firefighters during initial attack, project wildfires and prescribed burns. These samples are typically 15 minutes in duration to meet minimum sample quantity requirements to enable measurement of the irritants. The scale for the carbon monoxide level during each peak sample period is on the left, and the scale for the respiratory irritant exposure (using the OSHA PELs as the divisor) is on the right. The STELs for acrolein and formaldehyde were used along with a STEL for PM3.5 based on a recommended excursion limit of 3 times the shift-average PEL.

Note that nearly 1/3 of the peak irritant exposures were above the STEL of 1.0, with some as much as 4 times the STEL. Using the ACGIH TLVs as the divisors in the respiratory irritant index resulted in the highest samples to be over 10 times the STELs. The CO levels averaged over the 15-minutes were not as high, but probably did exceed the former 200 ppm ceiling limit for brief periods during the 15-minute samples.

The point here is that a high proportion of firefighters' peak exposures exceed short-term exposure limits, much more than exceed shift-average exposures.



There appear to be differences in smoke exposure potential among various work activities on the firelines. Benzene is unusual in that gasoline is a major source of exposure in addition to smoke, thus the highest benzene exposures (which were well below TLVs) were among sawyers, lighters and portable pump operators. For the other components of smoke (including respiratory irritants), the smoke exposure differed by work activities as shown above, which are data from prescribed burns in the Pacific Northwest. Direct attack of spot-fires and holding firelines were higher-exposure activities than lighting or mop-up. Windspeed and position relative to the fire are also factors that control smoke exposure.



One consistent observation at fires is that the ambient windspeed contributes to smoke exposure potential, if firefighters must be downwind of the fire. This graph of data from prescribed burns demonstrates this point, but it is somewhat misleading in that the "daily average windspeed" was measured at a single point near the fireline, and averaged over an entire workshift, thus it is an insensitive measurement dampened by periods with little or no wind. There were periods in the day when the windspeed was well over 10 miles per hour, and those periods were associated with the individual CO exposures denoted by the triangles.

Wind measurements that were averaged over the same period as the CO samples would be a more meaningful scale. At initial attack fires, such measurements showed that the CO exposure was approximately 3 times the windspeed minus 10. So a 20 mile-per-hour wind would be associated with CO levels of about 50 ppm for those firefighters working downwind edges of the fire.

It should be noted that the other extreme are inversion conditions which trap smoke in valleys. These situations can cause exposures on the fireline and in fire camps to exceed 50 ppm CO.

Summary

- Most Smoke Exposure is well below guidelines--only 1-10% are above limits.
- Overexposures are observed for carbon monoxide and respiratory irritants (aldehydes and PM3.5).
- Overexposures are obvious to trained observers.
- Most overexposures related to "must" situations.

Summary (cont.)

- Higher exposures during direct attack, mobile attack, holding line in adverse situations such as windy conditions.
- Peak exposure situations exceed STELs and cause most of the shift-average overexposures.
- Manage peak exposures and we'll control all exposures.