# No Smoke, No Fire, No Hazard

## *Firefighters Perspective on the Hazards of Fire Overhaul and How to Protect Against Them*

Dawn Bolstad-Johnson, MPH, CIH, CSP

# Overview

- The insults of smoke and fire are well known.
- There are many carcinogenic hazards that remain after the fire is extinguished.

# Introduction

- Fire Suppression
  - Firefighters are in a defensive mode.
  - Firefighting is accomplished with large amounts of water and foam.
- Fire Overhaul
  - Fire is under control and/or extinguished.
  - Firefighters are in the structure looking for hidden fire above ceilings, in between walls or in other obscure areas.

# Current types of respiratory protection for each fire phase

- **Fire Suppression**
  - Self Contained Breathing Apparatus (SCBA)
- **Fire Overhaul**
  - Much of fire overhaul is done without respiratory protection.
  - Previously, CO levels were measured.
  - 35 ppm CO firefighters considered atmosphere to be “safe”.
  - SCBA units were removed

# Carbon Monoxide Metering

- Why 35 ppm?
  - NIOSH = 35 PPM
  - OSHA = 50 PPM
  - ACGIH = 25 PPM

- These are all **8 HOUR AVERAGE EXPOSURES**
- Ceiling value for CO = 200 ppm
- Overhaul lasts about 60 minutes

- 60 min x 150 ppm/ 480 minutes

= 18.75 ppm

# Objectives of 1998 Phoenix Fire Study

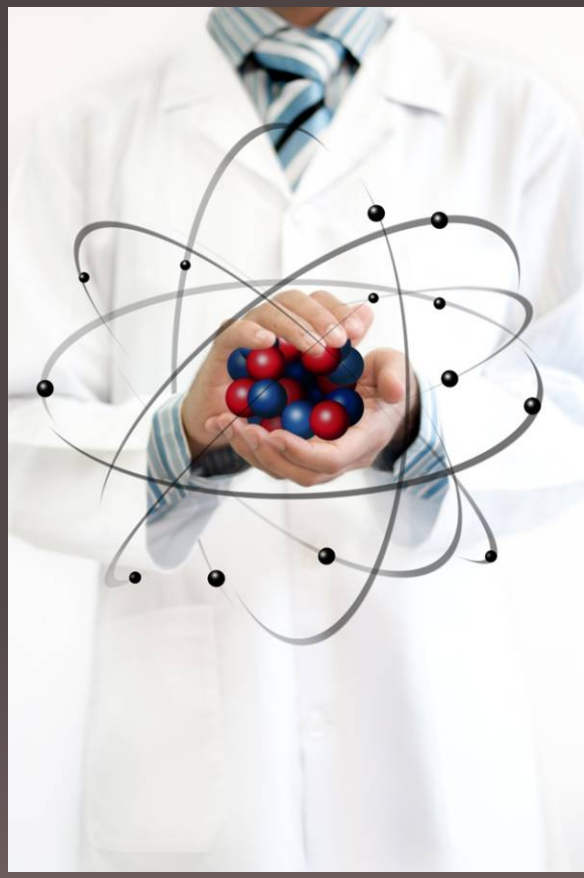
- Characterization of the fire overhaul environment to select appropriate Respiratory Protection.
- Determine if CO can be used as an indicator for other contaminants in the fire overhaul environmental.

# Contaminants of Concern Personal Sampling

- Aldehyde Profile
- BTEX
- Hydrochloric Acid
- Polynuclear Aromatic Hydrocarbons (PAH)
- Respirable Dust
- CO, HCN, $NO_2$ and $SO_2$

# Contaminants of Concern Area Sampling

- Asbestos
- Total Dust
- Metals
  - Cadmium
  - Chromium
  - Lead



# Methods

- Development of Sampling Scheme
  - Minimum number of pumps
  - Determination of how firefighters are going to wear all of the sampling equipment
  - Minimum sampling time.
- Training of  Firefighters to become IH assistants
- Simplification of IH sampling train.
- Development of sampling protocols and procedures.

# Methods

- Logistics
  - Arrival at an incident within 10-20 minutes.
  - Notification of fire incidents
  - Available personnel
    - to be monitored
    - to implement monitoring
- Determine how to manage IH sampling trains at a fire incident
  - power issues for area pumps
  - overall time limitations onc at the scene
  - Overhaul typically lasts in duration about 20 minutes or so.

# Results

- Monitoring was accomplished at 26 fires from June 13 - September 25, 1998.
- Four individuals were monitored at each fire.
  - Area of origin
  - Other adjacent area

# Results

- The following analytes were not determined in concentrations above LOD
  - ethyl benzene
  - toluene
  - xylene
  - cadmium
  - chromium

# Results

- The following analytes were determined in concentrations above STEL/Ceiling values
  - Acrolein
  - Benzene
  - Carbon Monoxide
  - Formaldehyde
  - Glutaraldehyde
  - $NO_2$ and $SO_2$

# Results

- The following analytes were determined in low concentrations
  - Respirable Dust
  - Hydrochloric Acid
  - HCN (NIOSH Method)
  - Asbestos

## TABLE IV

## Summary Data For Non-Particulate Samples

| Analyte | Number of Samples Collected | Number of Samples above LOD | Ave Sample Conc. | STD DEV | MIN | MAX |
|---|---|---|---|---|---|---|
| Acetaldehyde | 96 | 71 | **0.34[1] ppm** | 0.41 | 0.041 ppm | **1.75[1] ppm** |
| Acrolein | 96 | 7 | **0.123[2] ppm** | 0.133 | 0.013 ppm | **0.3[2] ppm** |
| Benzaldehyde | 96 | 18 | 0.057 ppm | 0.031 | 0.016 ppm | 0.13 ppm |
| Formaldehyde | 96 | 86 | **0.25[3] ppm** | 0.252 | 0.016 ppm | **1.18[3] ppm** |
| Glutaraldehyde | 96 | 24 | 0.046 ppm | 0.04 | 0.005 ppm | **0.15[4] ppm** |
| Isovaleraldehyde | 96 | 18 | 0.07 ppm | 0.038 | 0.02 ppm | 0.16 ppm |
| Benzene | 95 | 53 | 0.383 ppm | 0.425 | 0.07 ppm | **1.99[5] ppm** |
| Hydrochloric Acid | 95 | 34 | 0.99 $mg/M^3$ | 1.10 | 0.1 $mg/M^3$ | 3.96 $mg/M^3$ |
| Hydrogen Cyanide | 25 | 4* | ---- | ---- | ---- | ---- |

* Above analytical limit of detection but below quantification limit. All samples were less than 1.0 $mg/M^3$.
1. Exceeded NIOSH Lowest Feasible Concentration
2. Exceeded ACGIH CEILING 0.1 ppm
3. Exceeded NIOSH CEILING 0.1 ppm; Exceeded ACGIH CEILING 0.3 ppm
4. Exceeded ACGIH CEILING 0.05 ppm
5. Exceeded NIOSH STEL 1 ppm

## TABLE V

## Summary Data For PNA Samples

| Analyte | Number of Samples above LOD | Ave Sample Conc. Fg/M³ | STD DEV | MIN Fg/M³ | MAX Fg/M³ |
|---|---|---|---|---|---|
| Acenaphthene | 2 | 77.7 | 15.8 | 66.5 | 88.8 |
| Acenaphthylene | 34 | 415.0 | 536 | 88 | 2,440 |
| Anthracene | 1 | 22.2 | --- | --- | --- |
| Benz(a) anthracene | 3 | 24.9 | 4.90 | 19.3 | 27.9 |
| Benzo(a)pyrene | 5 | 33.2 | 13.6 | 18.7 | 50 |
| Benzo(b)fluoranthene | 4 | 22.3 | 10.6 | 9.5 | 34 |
| Benzo(ghi)perylene | 2 | 29.0 | 23.3 | 12.5 | 45.4 |
| Benzo(k)fluoranthene | 2 | 23.8 | 1.67 | 22.6 | 25 |
| Chrysene | 1 | 12.9 | --- | --- | --- |
| Dibenz(a,h)anthracene | 2 | 45.5 | 31.6 | 23.2 | 67.9 |
| Fluoranthene | 4 | 120 | 39.9 | 79.1 | 169 |
| Fluorene | 0 | --- | --- | --- | --- |
| Indeno(1,2,3-cd)pyrene | 3 | 19.5 | 8.35 | 14.3 | 29.1 |
| Naphthalene | 28 | 223.0 | 101 | 73 | 540 |
| Phenanthrene | 13 | 24.3 | 9.19 | 10.8 | 40.5 |
| Pyrene | 4 | 93.1 | 83.8 | 13.8 | 211 |

Total =88 PNA samples collected

# Results

- A logistic regression was performed using the direct read data to test for correlations to other identified products of combustion.
  - Benzene
  - Acetaldehyde
  - Formaldehyde
  - Hydrochloric Acid

# Results

- $SO_2$ concentrations obtained during the first 10 minutes of overhaul explained
  - 54.9 % of the variability of acetaldehyde; and
  - 48.4 % of the variability of formaldehyde

# Results

- HCN was eliminated from the regression analysis.
- **CO was not correlated to any of the contaminants measured.**
- None of the direct read sensors could predict HCL concentrations.

# Discussion

- Due to interference from temperature and humidity extremes, the HCN readings obtained from the direct read instrument were considered to be invalid.
- The results from the NIOSH method for HCN included only four samples which were above the LOD of 1 ug but below the Quantification Limit of 10 ug.

# Discussion

- Based on the findings of  this study, firefighters should use respiratory protection during fire overhaul.

# N95 Mask

- Probably one of the most MISUSED forms of PPE by Emergency Responders.
- Protects against particulates and droplets like TB
- DOES NOTHING for CHEMICAL Exposures

# Where do we go from here?

- This study has not determined the point in time (if any) in which it is safe to enter an after fire environment without any type of respiratory protection.
- Other professionals may be unknowingly exposed.
  - Arson investigators
  - Homocide investigators/Crime Lab technicians
  - Red Cross Personnel

# Where do we go from here?

- Other issues that require further investigation include toxicology studies regarding synergism, potentiation, and cancellation of the identified products of combustion.

# Fire Investigators

- How to protect the arson investigator?
- They are on the fire scene the longest.
- They dig through debris
- What type of respiratory protection is appropriate?

# Background

- No published data exists which identifies toxic exposures of arson investigators.
- This study was conducted as a hazard assessment to determine appropriate respiratory use for fire investigators.

# No support for Fire Investigators

- Once the fire is out and the fire companies pack up and leave, so do all the support trucks.
- If a fire investigator chose to wear an SCBA, there is no resource to refill his bottle.
- This makes the use of SCBA for fire investigators impractical.

# Review of Previous Overhaul Studies

- 1998 Overhaul Study (Bolstad-Johnson, DM *et al*)
  - 26 fires in Phoenix
  - Sampled 17 analytes
- 1999 Overhaul Study (Burgess,JL *et al*)
  - 10 Fires in Phoenix
  - 10 Fires in Tucson
  - Biological Monitoring (pre and post fire)

# 1998 Overhaul Study

- The following analytes exceeded published ceiling values:
  - Acrolein 0.1 ppm (at one fire)
  - CO - 200 ppm (at five fires)
  - Formaldehyde - 0.1 ppm (at twenty-two fires)
  - Glutaraldehyde - 0.05 ppm (at five fires)

# Arson Investigator Study 2009-2010

- January 2009 - May 2010
- 16 independent fire investigations were monitored.
- Focus of sampling was based on previous overhaul study results.
- One investigator wore two personal sampling pumps at each event.
- Analytes included aldehyde profile, respirable dust and HCN.
- Aldehyde sampling media was changed every 30 min.

# Summary of Fires

- The following table summarizes characteristics of each fire as well as time of dispatch and time monitoring began and ended.
- The fire investigator estimated damage to the structure from fire and damage to the structure from smoke damage based on an estimated percentage (%) of the entire structure.
- This was done to look for “predictors” that could be applied to future fire investigations.

# Summary of Fires

| Date | Fire | FD | SD | Structure | SF | DT | MS | ME | Ald | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/9/09 | Fire #1 | 10% | 20% | House | 1800 | 1017 | 1125 | 1230 | | Kitchen fire, smoke damage throughout house, not a lot of contents |
| 1/12/09 | Fire #2 | 10% | 75% | House | 2300 | 1451 | 1840 | 2000 | | Bedroom/Fatality. Burned completely through roof of bedroom, Full contents |
| 1/28/09 | Fire #3 | 5% | 40% | Apartment | 1000 | 1032 | 1137 | 1247 | | Living Room Fire, Contents and carpeting involved. Not a large fire. |
| 4/14/09 | Fire #4 | 20% | 40% | Apartment | 560 | 1304 | 1345 | 1459 | yes | Food on stove fire that extended to kitchen cabinents. Lighting involved plastic covers. |
| 4/15/09 | Fire #5 | 15% | 25% | House | 1700 | 937 | 1027 | 1216 | yes | Laundry room fire. Fire extended to the house/attic. Laundry room, clothes, storage W/D involved. |
| 4/16/09 | Fire #6 | 10% | 25% | House | 1400 | 1810 | 1850 | 2014 | | Back porch extended to house. Digging through back porch. |
| 5/13/09 | Fire #7 | 30% | 75% | Garage/House | 3000 | 1135 | 1457 | 1615 | yes | Garage extened to house. 2 vehicles in garage. Mostly garage contents involved. |
| 5/19/09 | Fire #8 | 50% | 100% | Mobile Home | 400 | 1508 | 1600 | 1755 | yes | Couch, heavy contents . |
| 6/14/09 | Fire #9 | 40% | 100% | Town House | 600 | 923 | 1123 | 1239 | yes | Candle fire, heavy contents . |
| 7/5/09 | Fire #10 | 75% | 90% | House | 7000 | 431 | 1010 | *7/8/09 | yes | Theater room, 20 leather sofa chairs. Heavy contents. House boarded up for several days before investigation. |
| 11/16/09 | Fire #11 | 100% | 100% | Town House | 1500 | 1638 | 1743 | 1852 | | Cigarette in the sofa. Burned sofa chairs, lots of O2 tanks, O2 generating machine |
| 11/24/09 | Fire #12 | 10% | 25% | House | 1000 | 1012 | 1050 | 1203 | | NO CONTENTS. Attic fire. . |
| 11/24/09 | Fire #13 | 25% | 100% | Apartment | 300 | 1343 | 1441 | 1547 | | Candle fire on plastic crate. Clothes closet involved. |
| 1/18/10 | Fire #14 | 15% | 25% | House | 2500 | 1305 | 1418 | 1519 | yes | Electrical fire involved mattress. Total room involvement. |
| 4/2/10 | Fire #15 | 20% | 75% | Apartment | 750 | 1715 | 1808 | 1844 | yes | Bedroom fire, sampled in bedroom total room involvement |
| 4/14/10 | Fire #16 | 20% | 75% | House | 2500 | 1052 | 1325 | 1356 | | Bedroom fire, sampled in bedroom total room involvement |

August 2010

# Exposure Limits

| Chemical | OSHA | ACGIH | NIOSH | STEL | IDLH |
|---|---|---|---|---|---|
| Acetaldehyde | 200 ppm | --- | LF | 25 ppm (C) | 2000 ppm |
| Acrolien | 0.1 ppm | --- | 0.1 ppm | 0.1 ppm (C) | 2 ppm |
| Formaldehyde | 0.75 ppm | -- | 0.016 ppm | 2 ppm<br>0.1 ppm (C) | 20 ppm |
| Glutaraldehyde | --- | --- | --- | 0.05 ppm (C) | --- |
| Hydrogen cyanide | 10 ppm | --- | --- | 4.7 ppm | 50 ppm |
| Isovaleraldehyde | --- | --- | --- | --- | --- |

# Results Summary

- Detectable levels of aldehydes at eight fires.
- Formaldehyde over the ceiling value of 0.1 ppm at two fires.
- Below LOD - HCN and Respirable dust

# Results Summary

| | | |
|---|---|---|
| Fire 4 (1) | Acetaldehyde | 0.097 ppm |
| | Formaldehyde | 0.144 ppm |
| | Glutaraldehyde | 0.020 ppm |
| Fire 4 (2) | Acetaldehyde | 0.173 ppm |
| | Formaldehyde | 0.368 ppm |
| | Glutaraldehyde | 0.044 ppm |
| Fire 5 (1) | Glutaraldehyde | 0.027 ppm |
| | Formaldehyde | 0.144 ppm |
| Fire 5 (2) | Formaldehyde | 0.082 ppm |

# What we know

- Typical house fires are not identified as potential “toxic hazards” by firefighters or by fire investigators.

# All Fires should be treated as HAZMAT Incidents

- Contents of the typical house has changed dramatically since the 1998 and 1999 overhaul studies.
- The “plastic load” in the house has increased dramatically.
- Examples: TV casings, appliances, furniture, carpeting, computers, printers, digital cameras, scanners, home offices, toys

# Challenges for First Responders

- Identifying the hazard allows the responder to select appropriate hazard controls.
- There is not direct read instrumentation available to identify all toxic hazards present on the fire scene.

# Conclusions

- Fire scenes present complicated “toxic soup” type of exposures.
- Formaldehyde again is under estimated in the areas we found it in quantifiable concentrations as the peaks were not identified.

# Conclusions

- SCBA provides the best respiratory protection for all unknown chemical insults on the fire ground. However they are not practical for detailed tasks such as arson investigations.

# Recommendations for Arson Investigators

- SCBA for the first hour of investigation
- Full face cartridge respirators equipped with CBRN canisters should be used for the duration of the investigation.

# Studies going on now

- Breast milk study with City of Phoenix Fire Fighters.
- Dr. Jeff Burgess and Dr. Eric Lutz are repeating the study using biomarkers with CBRN cannisters.

# Contact Information

Dawn Bolstad-Johnson, MPH, CIH, CSP
PHI Air Medical

602-224-3519
623-451-5651 cell

dbolstad@phihelico.com