

# Personal Exposure of Fire Fighters to Air Toxics

**Dr Steve Brown**  
**Bushfire CRC/CSIRO Air**  
**Quality Control Sciences**

# CRC Air Toxics Team

**Dr Fabienne Reisen**  
(CRC Post-Doc,  
toxicologist)



**Min Cheng** (air quality  
chemist)



**John Mahoney** (mech  
engineer)



**Dr Bill Tiganis**  
(chemist,  
occupational  
hygiene)



# Objective s



Measure, evaluate and control the personal exposures of Australian bushfire fighters to air toxics

- Identify key air toxics in bushfire smoke
- Select personal sampling devices
- Field sampling on bushfire fighters
- Occupational exposure goals

# What we've achieved to date

- Review report of air toxics exposure studies in other countries (mainly USA)
- A chamber burn procedure for measuring air toxics from different fuel types (Darwin sorghum grass, WA banksia scrub, Wombat SF eucalyptus litter, Vic pine forest litter)
- Assessment of sampling methods for bushfire smoke environments → methods selection
- **2005 SAMPLING ON FIRE FIGHTERS**



# Key Toxic Air Pollutants Selected for Measurement on Fire Fighters

1. **Carbon monoxide**
2. **Volatile Organic Compounds (VOCs)**  
Benzene, toluene, xylenes, phenol
3. **Aldehydes**  
Formaldehyde, acrolein, acetaldehyde
4. **Respirable particles**
5. **Polycyclic Aromatic Hydrocarbons (PAHs)**
6. **Dioxins (under reconsideration)**

# Air Toxics Health Effects

KEY AIR TOXICS	POTENTIAL HEALTH EFFECTS
Carbon monoxide	Headaches, nausea, impaired exercise capability, exacerbate respiratory & cardiac disease
Volatile Organic Compounds (VOCs) <i>Ex: benzene</i>	Headache, irritation of eyes/nose/throat, dizziness, fatigue <i>Human carcinogen</i>
Aldehydes	Eye/nose/throat irritation, aggravation of existing respiratory conditions
Respirable particles	Impaired lung function, exacerbate cardiac and respiratory illnesses
Polycyclic aromatic hydrocarbons (PAHs) & Dioxins	Probable human carcinogens; dioxin accumulates in fatty tissue over lifetime



# Air Toxics Levels in Bushfires – What Do We Know?

KEY AIR TOXICS	POTENTIAL LEVELS
Carbon monoxide	Estimates from early 1990s ~ 20ppm but limited to small numbers
Volatile Organic Compounds (VOCs)	<b>Unknown</b> , preliminary CRC room burns of forest litters show benzene is a dominant VOC in
Aldehydes	<b>Unknown</b> , CRC room burns of forest litters show formaldehyde and acetaldehyde (carcinogens)
Respirable particles	<b>Unknown</b> , the quantity and composition of particles is needed
Polycyclic aromatic hydrocarbons (PAHs) & Dioxins	<b>Unknown</b> , but recent CSIRO research showed Dioxin levels in smoke less than expected; Dioxin levels in blood now available for

Aust popn.

# Results of CRC Chamber Burns

Litter types	Pollutant Yields (mg/g)				
	Gravimetric particles	CO	Formaldehyde	Acrolein	Benzen e
Cheltenham Pine	39	115	0.32	0.29	0.42
Darwin Sorghum	1.0	30	0.06	0.05	0.06
Mt Dandenong	5.6	63	0.07	0.09	0.22
Wombat S.F. Eucalyptus	10.9	70	0.05	0.11	0.16
W.A. Coastal Scrub	7.8	64	0.10	0.11	0.20



# VOCs released from forest litters in chamber burns

Litter types	Pollutant Yields (mg/g)					
	Benzen e	Toluene	3-Furald- ehyde	Xylenes	Pheno l	TVOC
Cheltenham Pine	0.33	0.30	0.40	0.13	0.35	7.0
Darwin Sorghum	0.06	0.03	0.015	0.015	0.038	0.38
Mt Dandenong Eucalyptus	0.22	0.13	0.055	0.088	0.08	1.6
Wombat S.F. Eucalyptus	0.18	0.10	0.1	0.06	0.09	1.9
W.A. Coastal Scrub	0.21	0.11	0.076	0.045	0.1	1.5



# **Occupational and Environmental Exposure Standards for Air Toxics**

- **Worksafe Australia - Occupational Exposure Standards (OES)**
- **Environment Australia – National Environmental Protection Measures (NEPM for CO, PM<sub>2.5</sub>, ozone, nitrogen dioxide, benzene/toluene/xylene)**
- **World Health Organisation – Air Quality Guidelines (health-based)**

# Occupational Exposure Limits (Australia; future limits)

Limit	CO (ppm)	Resp Particle (mg/m <sup>3</sup> )	Formal- dehyde (ppm)	Acrolei n (ppm)	Benzene (ppm)
Full shift	30	1-10	1 (0.3)	0.1	1 (0.5)
Short term	60- 200	-	2 (0.6)	0.3	1 (0.5)
Envir NEPM	9	~ 0.025	0.04	-	0.01



# Personal Sampling Devices

# Examples of Personal Monitoring Devices

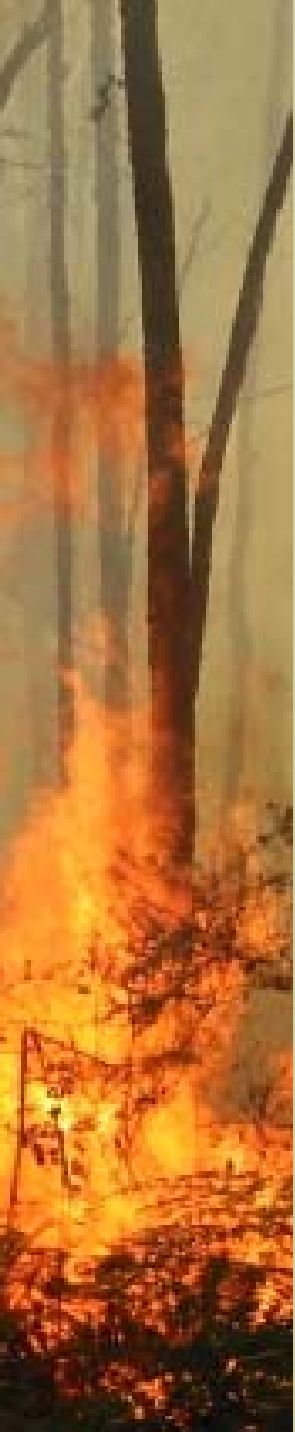
## 1. Carbon Monoxide

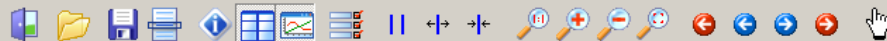
Dräger Pac III data-logging sensor measuring up to 2000 ppm CO in real time



GASTEC Colour Dosimeter Tubes  
Concentration range: 1.0-2000 ppm-hrs

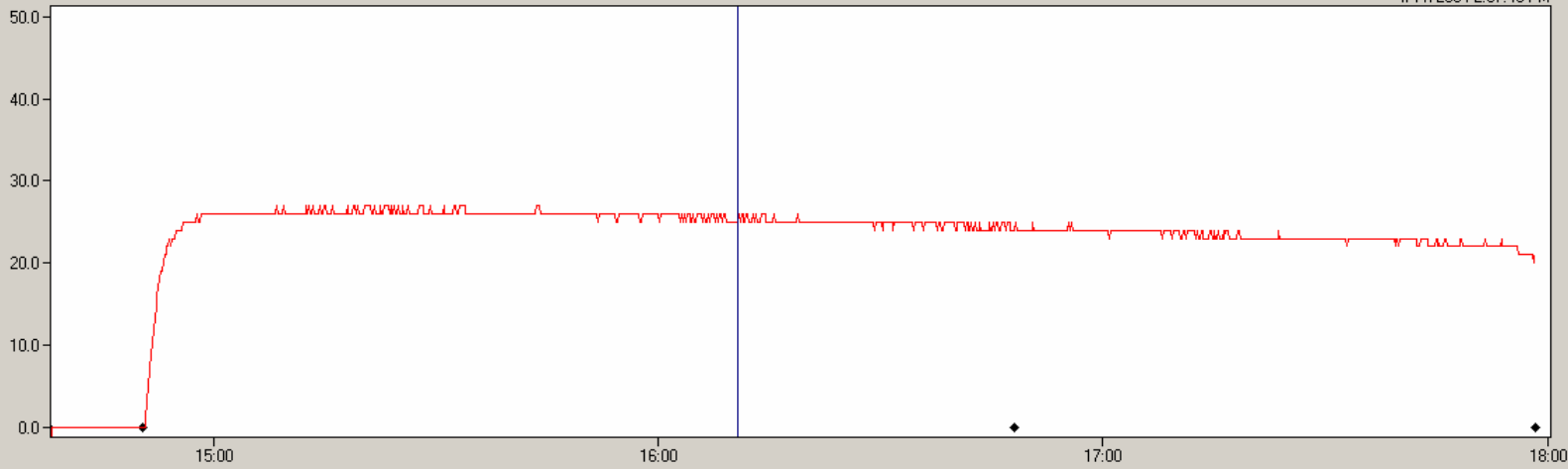
# CARBON MONOXIDE





CO 2000.00 ppm

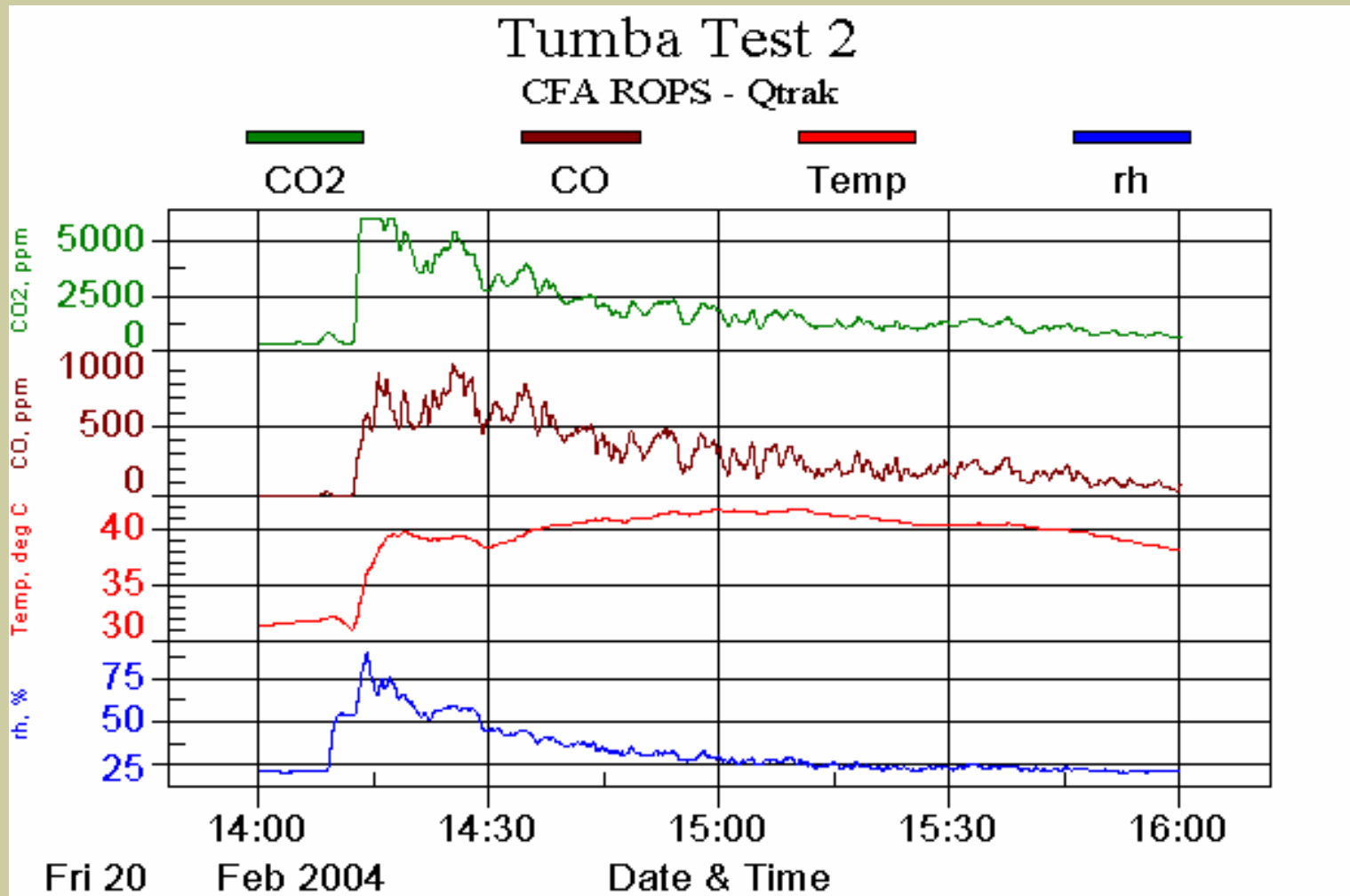
4/11/2004 2:37:46 PM



Type	Aver. [10s]	Gas	CO				
Location	00000000	Unit	ppm				
Pers. ID	00000000	A1 Setting	0.00				
		A2 Setting	500.00				

Date/Time	CO [ppm]				
4/11/2004 4:06:36 PM	25.00				
4/11/2004 4:06:46 PM	26.00				
4/11/2004 4:06:56 PM	25.00				
4/11/2004 4:07:06 PM	26.00				
4/11/2004 4:07:16 PM	26.00				
4/11/2004 4:07:26 PM	26.00				
4/11/2004 4:07:36 PM	26.00				
4/11/2004 4:07:46 PM	25.00				
4/11/2004 4:07:56 PM	26.00				
4/11/2004 4:08:06 PM	25.00				
4/11/2004 4:08:16 PM	26.00				
4/11/2004 4:08:26 PM	26.00				
4/11/2004 4:08:36 PM	25.00				
4/11/2004 4:08:46 PM	25.00				
4/11/2004 4:08:56 PM	26.00				
4/11/2004 4:09:06 PM	26.00				
4/11/2004 4:09:16 PM	25.00				
4/11/2004 4:09:26 PM	25.00				
4/11/2004 4:09:36 PM	25.00				
4/11/2004 4:09:46 PM	25.00				
4/11/2004 4:09:56 PM	25.00				
4/11/2004 4:10:06 PM	25.00				
4/11/2004 4:10:16 PM	25.00				
4/11/2004 4:10:26 PM	25.00				
4/11/2004 4:10:36 PM	25.00				
4/11/2004 4:10:46 PM	25.00				
4/11/2004 4:10:56 PM	26.00				

# CO Measurements in Tumberumba Experimental Fire (1<sup>st</sup> hour ave 450ppm; 2<sup>nd</sup> hour ave 200ppm)





# Examples of Personal Monitoring Devices

## 2. **VOCs** Benzene, toluene, xylenes, phenol

➤ Perkin Elmer sorbent tubes operated by micropumps (active sampling)

➤ passive samplers for organics vapors



# VOCs

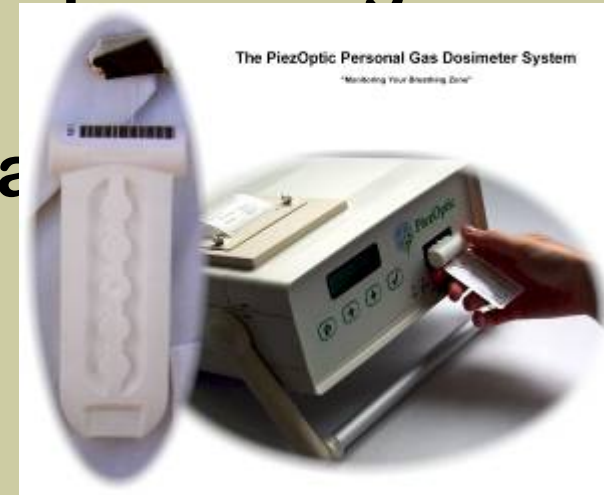
**Benzene,  
Toluene, Phenol**



# Examples of Personal Monitoring Devices

## 3. **Aldehydes** – passive sampler badges

- PiezOptic passive personal dosimeters



- GASTEC Colour Dosimeter Tubes



- UMEx100 passive sampler for total aldehydes (DNPH adduct analysis)



**ALDEHYDES**  
**Formaldehdye,**  
**acrolein,**  
**acetaldehyde**



# Aldehydes released from forest litters in chamber burns

Litter types	Pollutant Yields (mg/g)		
	Formaldehyd	Acetaldehyd	Acrolei
Cheltenham Pine	0.036	0.080	0.040
Darwin Sorghum	0.052	0.055	0.047
Mt Dandenong Eucalyptus	0.063	0.18	0.09
Wombat S.F. Eucalyptus	0.059	0.17	0.09
W.A. Coastal	0.095	0.24	0.11

Scrub

# Examples of Personal Monitoring Devices

## 4. **Respirable particles**

- in real time by laser light scattering TSI SidePak (up to 20 mg/m<sup>3</sup>)



- averaged by gravimetric filter sampling

## 5. **PAH** analysis on gravimetric filters



# RESPIRABLE PARTICLES





# Health Hazards from Bushfire Smoke Particles

Exposure standards don't specify bushfire smoke but....

## Worksafe Occupational Exposure Stds:

Coal dust      3 mg/m<sup>3</sup>

Graphite dust 3 mg/m<sup>3</sup>

Wood dust (hardwood) 1 mg/m<sup>3</sup>

Silica fume      2 mg/m<sup>3</sup>

**An exposure limit of 3 mg/m<sup>3</sup>  
appears reasonable**



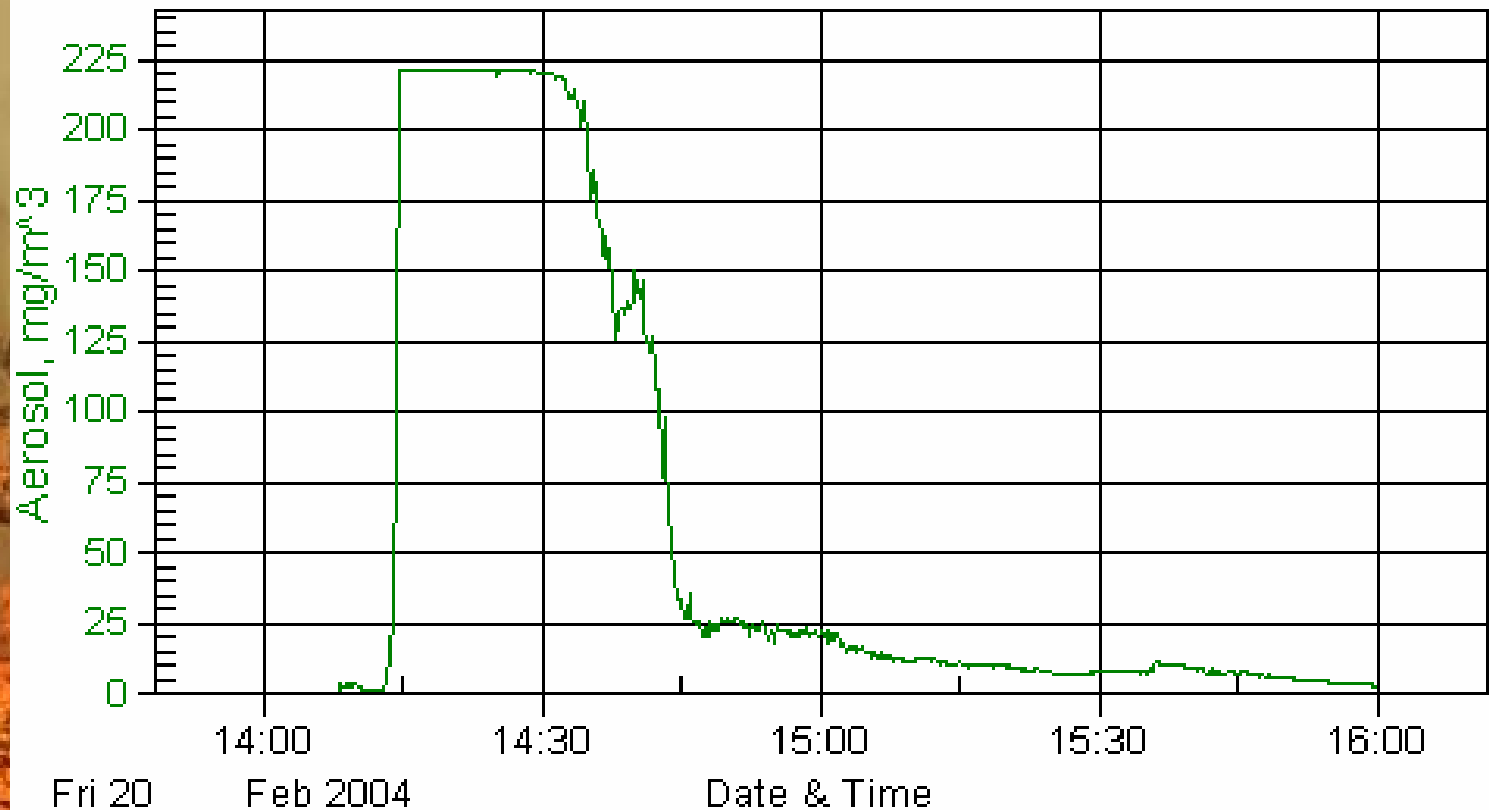
# Community Exposure Limits for Bushfire Smoke – less than 0.5

Category	PM <sub>2.5</sub> or PM <sub>10</sub> Levels (µg/m <sup>3</sup> , 1- to 3-hr avg.)	Visibility - Arid Conditions (miles)	Recommended Actions
Good	0 - 40	≥ 10	If smoke event forecast, implement communication plan
Moderate	41 - 80	6 - 9	<ul style="list-style-type: none"> <li>- Issue public service announcements (PSAs) advising public about health effects/symptoms and ways to reduce exposure</li> <li>- Distribute information about exposure avoidance</li> </ul>
Unhealthy for Sensitive Groups	81 - 175	3 - 5	<ul style="list-style-type: none"> <li>- If smoke event projected to be prolonged, evaluate and notify possible sites for clean air shelters</li> <li>- If smoke event projected to be prolonged, prepare evacuation plans</li> </ul>
Unhealthy	176 - 300	1.5 - 2.5	<ul style="list-style-type: none"> <li>- Consider "Smoke Day" for schools (i.e., no school that day), possibly based on school environment and travel considerations</li> <li>- Consider canceling public events, based on public health and travel considerations</li> </ul>
Very Unhealthy	301 - 500	1 - 1.25	<ul style="list-style-type: none"> <li>- Consider closing some or all schools (However, newer schools with a central air cleaning filter may be more protective than older, leakier homes. See "Closures", below)</li> <li>- Cancel outdoor events (e.g., concerts and competitive sports)</li> </ul>
Hazardous	> 500	< 0.75	<ul style="list-style-type: none"> <li>- Close Schools</li> <li>- Cancel outdoor events (e.g., concerts and competitive sports)</li> <li>- Consider closing workplaces not essential to public health</li> <li>- If PM level projected to continue to remain high for a prolonged time, consider evacuation of sensitive populations</li> </ul>

# Smoke Particle Measurements in Tumberumba Experimental Fire

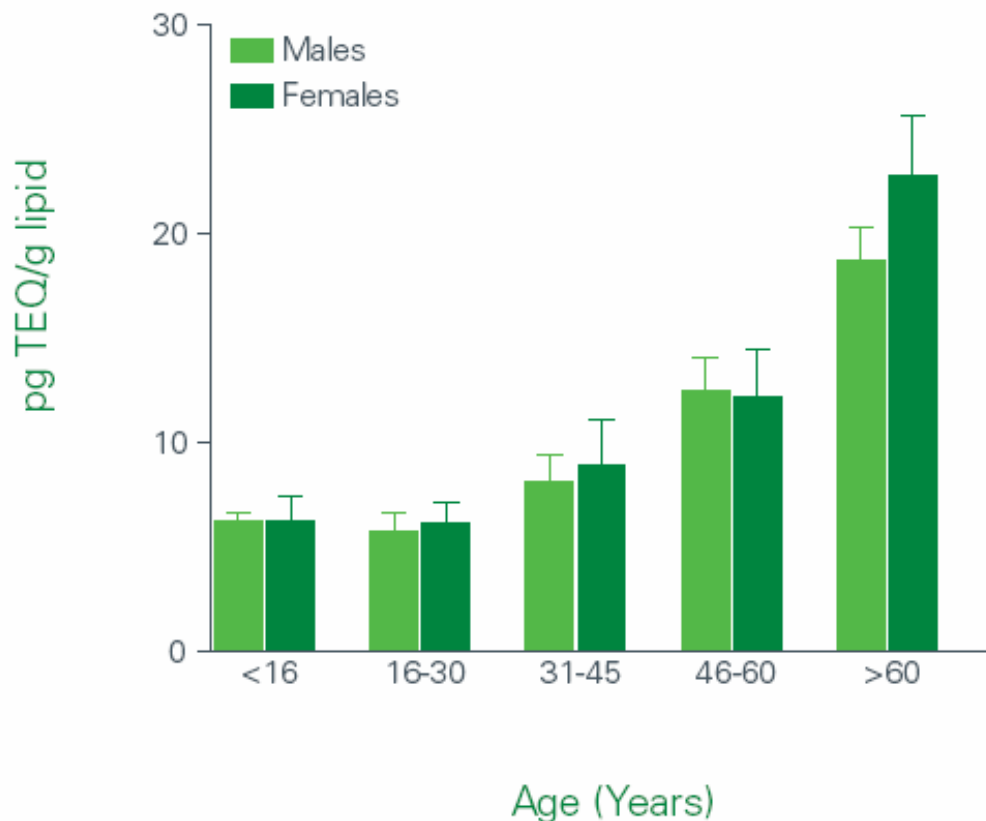
## Tumba Test 2

CFA Cabin - Dustrak



6. **Dioxin** measurements by blood analysis - blood samples outside of the fire season – compare with national levels; **calculations**→**may not detect significant difference** (dioxin uptake is

Levels of dioxins in different age groups



b1

b2

b3

# PRESCRIBED BURNS VIC 2005



We thank the following agencies for their participation in the monitoring process: DSE (VIC), CFS (SA), DEH

(SA), CSIRO (FFP).

 bushfire CRC

**Slide 28**

---

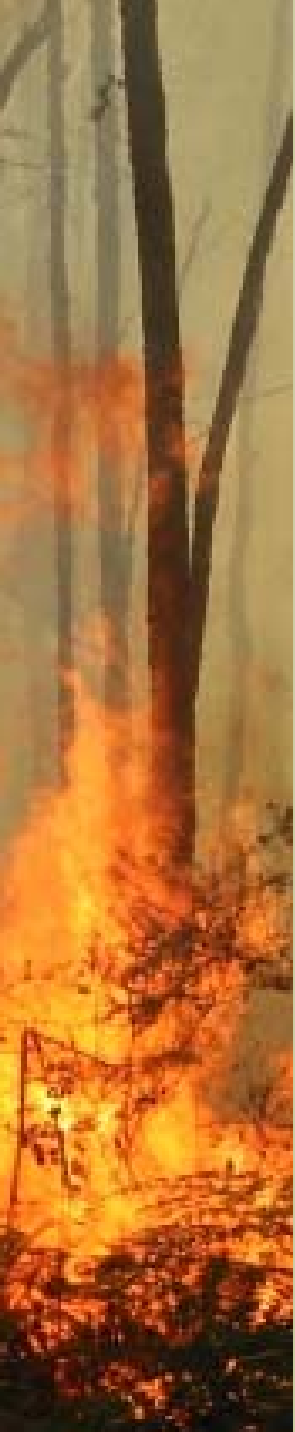
**b1**      bro447, 2/06/2005

**b2**      bro447, 2/06/2005

**b3**      bro447, 2/06/2005

# Personal Sampling

- sampling within breathing zone
- sampling over ½ to full shift
- activity diary of fire fighters (tasks, duration, symptoms)
- individual air sampling record
- fire description (environmental conditions, fuel type and density, fire classification)





# Interview Questions

General Description of Your Main Tasks (please tick 1 or more):

- Fire suppression - hose
- Fire suppression – physical tools (back hoe, etc)
- Fire suppression – power tools (chainsaw, etc)
- Driving fire trucks at suppression sites
- Driving car at suppression sites
- Supervising fire suppression crews at fire site
- Supervising fire suppression crews away from fire site
- Bulldozer driver immediately post-fire
- Fire mop-up (same day fire suppressed)
- Fire mop-up (day or more after suppression)
- Other (specify .....)

Which of the above was the main task and for how many hours was it done?

- task .....
- duration of task .....

Percentage of shift at fire front (tick): <10% ( ) 10-50% ( ) >50% ( )

Which task exposed you to the most smoke?

- task .....

Did any task cause you eye watering or coughing?

Yes  No

- tasks .....



# What happens to air sampling and interview results?

- All data/results at the individual firefighter level will be unknown to us – records will be linked to a pin code which we supply each firefighter for them to access their own results by writing/emailing us
- After 3-4 fire seasons, we will aggregate results to determine exposure levels and key factors to exposure (fuel, fire type, task, etc)
- We will recommend control strategies to manage exposures within occupational exposure standards

# Personal Exposures in Prescribed Burns 2005

Sample	Workshift [min]	average CO [ppm]	max CO [ppm]	average respirable particles [mg/m3]	max respirable particles [mg/m3]	Formaldehyde [ppb]	Acetaldehyde [ppb]
PE-140405-1	35	8.3	118			326	179-207
PE-140405-2	35	7.4	75	2.3	19.1	326	179-207
PE-140405-3	35	26.0	301	> 2.7	> 20	896	298-345
PE-200405-1	140	14.3	1005	1.0	19.1	489	60-69
PE-200405-2	130	10.6	740	> 1.0	> 20	132	0
PE-200405-3	120	4.0	402			73	54-62
PE-220405-1	90	0.8	37			107	ND
PE-220405-2	90	0.2	28	0.2	8.1	95	ND
PE-220405-3	90	1.1	182	0.3	14.2	103	ND
PE-220405-4	90	1.8	230			235	74-85
PE-220405-5	50	20.2	297	4.0	19.7	342	167-193
PE-220405-6	50	14.9	187	4.3	17.5	513	167-193
PE-030505-1	120	4.4	271	0.6	19.9		
PE-030505-2	120	4.5	154	> 0.9	> 20		
PE-030505-3	120	3.2	198	0.6	18.1		
PE-240505-1	380	53.2	1225	> 6.2	> 20		
PE-240505-2	395	29.6	288	> 6.0	> 20		
PE-240505-3	60	16.6	238	3.8	18.5		
PE-240505-4	60	24.1	230	4.1	19.5		
Worksafe Std		30(8hour) 100(30min) 200(15min)	never>400	3		300	25,000

# VOCs in Prescribed Burn Smokes 2005

Sample	Benzene [ $\mu\text{g}/\text{m}^3$ ]	Acetic acid [ $\mu\text{g}/\text{m}^3$ ]	Toluene [ $\mu\text{g}/\text{m}^3$ ]	2- furaldehyde [ $\mu\text{g}/\text{m}^3$ ]	phenol [ $\mu\text{g}/\text{m}^3$ ]
CE-130405	5		9		
DW-140405	180	329	43	418	275
DW-200405-1	10	107.5	16.45	71.5	37.5
DW-220405	439	833.5	215.5	463.5	522
CE-030505	205	383	130	77	257
DW-030505	788	1899	373	527	1120
Worksafe Std	1600	25,000	380,000	7,900	4000
CRC Chamber BurnsEucalypts (xylenes150- 250)	720-770	n.a.	420-620	310-800	400-600

# Downwind Communities

- Prescribed burns
- Indoor and/or outdoor measurements of --- particulate matter
  - O<sub>3</sub> measurements
  - VOCs and aldehydes





# What we need to progress to personal sampling on fire fighters

- CRC Air Toxics: rapid response to **wildfire** events (on site within hours)
- CRC/Fire agencies: agreed procedures/ protocols for
  - notifying CRC Air Toxics of fire events
  - getting CRC Air Toxics to sites (directions, access onto sites)
  - CRC Air Toxics actions on sites (we expect to be restricted to Staging Areas)
  - CRC Air Toxics interactions with fire fighters

Program D Roadshows: Hobart, Adelaide, Sydney, Melbourne.