

**EXPOSURE TO BUSHFIRE AIR TOXICS
AMONG FIREFIGHTERS AT PRESCRIBED
BURNS DURING AUTUMN 2007**

By

F. Reisen, D. Hansen

June 2007

CSIRO Marine and Atmospheric Research/Bushfire CRC, Aspendale, Victoria

Confidential



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OUTPUT: 18.2. Capabilities for measurement and control of the exposure of firefighters to air toxics

MILESTONES: 18.2.2. Annual reports of exposure measurements and data analysis for each fire season from 2005 to 2008

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ACRONYMS

Ave	Average
CFA	Country Fire Authority
CFS	Country Fire Service
CO	Carbon monoxide
COHb	Carboxyhemoglobin
CP	Conservation Park
DNPH	Dinitrophenylhydrazine
DSE	Department of Sustainability and Environment
E _m	Equivalent Irritant Exposure Index
FF	Firefighters
FRB	Fuel reduction burn
GC/FID/MS	Gas chromatography with flame ionization detection/mass spectrometry
HCHO	Formaldehyde
IMT	Incident Management Team
N/A	Not applicable
ND	Not detected
NIOSH	National Institute for Occupational Safety and Health
NOHSC	National Occupational Health & Safety Commission
NP	National Park
OES	Occupational Exposure Standard
OHS	Occupational Health and Safety
PAHs	Polycyclic aromatic hydrocarbons
PE	Personal exposure measurements
PEL	Permissible exposure limit
PM	Particulate matter
PM _{2.5}	Particulate matter with aerodynamic diameter cut-off of 2.5 µm
PPC	Personal protective clothing
ppb	parts per billion
ppm	parts per million
RH	Relative humidity
RP	Respirable particles
STEL	Short-term exposure limit
TWA	Time-weighted average
USDA	United States Department of Agriculture
VOCs	Volatile Organic Compounds

EXECUTIVE SUMMARY

During autumn 2007, firefighter's exposures to bushfire air toxics were measured at 7 prescribed or slash burns in Victoria.

Prescribed burns that were attended over autumn 2007 included fuel reduction burns, slash burns and heap burns. During fuel reduction burns, measurements were collected on firefighters igniting the burn and crew members patrolling and suppressing spot-fires. On the other hand during slash and heap burns, firefighters were lighting with drip torches only, and working primarily upwind of the smoke. The results have shown that

- Average CO levels ranged from 0.4 up to 120 ppm, exceeding the 8-hour occupational exposure standard of 30 ppm. Maximum CO levels were measured at 1085 ppm and the highest 15-minute average CO concentration was measured at 307 ppm, exceeding the short-term exposure limit of 200 ppm.
- Average concentrations of respirable particles ranged from 0.1 to 16 mg/m³, exceeding the TWA concentration of 3 mg/m³, which for this present project is considered to be appropriate as TWA if the smoke contains no toxic components. Maximum short-term exposures were measured at 174 mg/m³, which largely exceeded 5 times the proposed TWA of 3 mg/m³.
- The major aldehydes present in personal breathing zone samples were formaldehyde, an irritant and known human nasal carcinogen and acetaldehyde, a possible human carcinogen. The formaldehyde levels remained below the proposed occupational exposure standard of 0.3 ppm for approximately 50% of the samples. The formaldehyde concentrations exceeded the capacity of the samplers for 50% of all measurements made and could therefore not be quantified. Using regression parameters from previous data, values of formaldehyde exposures were calculated, and the results have shown that the TWA exposure standard of 1 ppm was exceeded for 7% of samples and the proposed TWA of 0.3 ppm was exceeded for 17% of samples. Acetaldehyde levels remained well below the TWA occupational exposure standard of 20 ppm. None of the samples measured detectable levels of acrolein.
- There was a large variability of air toxics levels among the samples collected. Major factors influencing exposure levels included topography of the burn area, work activities and fire behaviour. Elevated levels of air toxics were measured for firefighters patrolling downwind at the top of a ridge. Exposures at slash burns remained low, with occasional elevated short term peaks.
- Excessive exposures to CO can cause headaches and dizziness, affect work performance and potentially affect safety on the fire ground. Potential health impacts resulting from elevated exposures to other air toxics in bushfire smoke include eye, nose and throat irritation and coughing, which are symptoms commonly reported by firefighters at the end of their shift. Long-term exposure to elevated levels of respirable particles may also reduce lung function and aggravate asthma and respiratory and/or cardiovascular illnesses.

1 Introduction

Bushfire smoke is a complex mixture of gases and particles which when inhaled may impact firefighter's health. Extensive research studies on firefighter's exposures to air toxics in bushfire smoke have been conducted in the United States (Materna *et al.*, 1992; McMahon & Bush, 1992; Reh & Deitchman, 1992; Kelly, 1992a; Kelly, 1992b; Materna *et al.*, 1993; Reh *et al.*, 1994; McCammon & McKenzie, 2000; Reinhardt & Ottmar, 2004), but due to differences in vegetation cover and operations, results from the US studies may not necessarily be applicable within the Australian context. For the last 2 years, the Bushfire CRC project on Air Toxics exposure and management has collected personal exposure measurements at a range of prescribed burns across Australia. The results have shown that work activity is a primary factor influencing exposure levels, and that in general high exposure levels, sometimes exceeding average and short-term occupational exposure standards (OES), were likely for those firefighters involved in patrol and suppression. Therefore future monitoring was targeted towards those particular tasks to assess what potential levels are likely to be expected.

This report presents the findings from a range of prescribed burns attended in Victoria between April and May 2007. The exposure levels were assessed against OES provided in Australia by the Australian Safety and Compensation Council (ASCC) and shown in Table 1.

2 Objective

The aim of the study is to measure, evaluate and control the personal exposure of Australian firefighters to air toxics in bushfire smoke under various conditions. This report presents the findings from samples collected at a range of prescribed burns conducted in autumn 2007. It looks at

- quantifying the personal exposure levels of bushfire firefighters to air toxics (assessing, if possible, both average and peak exposures)
- evaluating exposures by comparing the levels of air toxics to OES and determine under which conditions the standards may be exceeded
- identifying situations which would lead to high exposure levels of air toxics. The exposure levels depend on several factors that may lead to overexposure to smoke and include work activities, fuel and fire characteristics.
- assessing the correlation between air pollutants
- assessing personal versus static sampling

Table 1 Occupational Exposure Standards (NOHSC, 1995)

Air Toxic	TWA¹	STEL²
Carbon monoxide (CO)	30 ppm	200 ppm (15 min) 60 ppm (60 min) 100 ppm (30 min) 400 ppm (0 min)
Formaldehyde (HCHO)	1 ppm (proposed 0.3 ppm)	2 ppm (proposed 0.6 ppm)
Acrolein	0.1 ppm	0.3 ppm
Acetaldehyde	20 ppm	50 ppm
2-furaldehyde	2 ppm or 7.9 mg/m ³	-
Benzene	1 ppm or 3.2 mg/m ³	-
Toluene	50 ppm or 191 mg/m ³	150 ppm or 574 mg/m ³
Phenol	1 ppm or 4 mg/m ³	-
Acetic acid	10 ppm or 25 mg/m ³	15 ppm or 37 mg/m ³
Respirable particles (gravimetric) ³ :		
Respirable coal dust	3 mg/m ³	-
Graphite dust	3 mg/m ³	-
Hardwood dust	1 mg/m ³	-
Softwood dust	5 mg/m ³	10 mg/m ³
Fumed Silica	2 mg/m ³	-

¹ Time-weighted average is the average airborne concentration of a particular substance when calculated over a normal 8-hour working day, for a 5-day working week, for a sedentary activity

² Short-term exposure limit is a 15-minute TWA exposure which should not be exceeded at any time and should not occur more than 4 times per day

³ There is no exposure standard specific to bushfire smoke particles. In the absence of a specific OES, for the present project a TWA of 3 mg/m³ is considered appropriate if the smoke particles do not contain any toxic components.

3 Experimental

3.1 Sites

During autumn 2007, samples were collected at 7 prescribed burns within Victoria. Table 2 lists the dates when smoke exposure was monitored, the burn location and area and the dominant vegetation that was burned at each site. More detailed information on the burns is provided in the appendix of this report.

Table 2 Burns – Site information

Burn #	Date	Burn Name	Burn Location	Burn Area	Fuel species
01	12/04/07	Camp fireline G37	Kurth Kiln Regional Park, VIC	30 ha	Eucalypt forest (red stringy bark, fern)
02	18/04/06	Kyeema D52	Dandenong Ranges NP, VIC	50 ha	Eucalypt forest
03	25/04/06	Aqueduct east R95	Langwarrin Flora & Fauna Reserve, VIC	13 ha	Scrubby forest/heathland
04	26/04/06	Watts Outlet MW13	Yarra Ranges NP, VIC	76 ha	Eucalypt forest
05-07	03/05/07-05/05/07	Pine plantation	NE VIC		Pine windrow burns

3.1.1 Fuel reduction burn at Kurth Kiln Regional Park, VIC

The Kurth Kiln Regional Park is located 65 km east of Melbourne and 7 km north of Gembrook. Its vegetation ranges from Mountain Ash forest and riparian forest to shrubby foothill forest and swamp heathland. The burn area of 30 ha (Figure 1) was characterized by very dense forest and steep gullies, as shown in Figure 2. The burn was conducted by DSE and attended by crews from DSE Gembrook and DSE Ballarat. In total approximately 20 firefighters were involved, working from 2 tankers and 6 slip-on units. Fuel moisture was about 13% in the early afternoon increasing to about 16% in the evening. The burn was ignited at about 13:00 by line burning starting at the southern edge of the burn area. Patrol crews at the edge of the burn area ensured that trees did not cause any embers. The tasks involved hosing down stringy barks and rake-hoeing around the eucalypt trees. The ignition was carried out from 13:00 to 19:00, during which time monitoring of 4 firefighters was conducted. Additionally sampling boxes were positioned on one of the tankers patrolling the eastern edge of the burn area, and on a slip-on unit following bulldozer around the burn area. The smoke was drawn within the plot resulting in minimal smoke exposure to firefighters on patrol along the edge of the burn area. No sampling was done from 20:00 until approximately 22:00, when crews were blacking out.

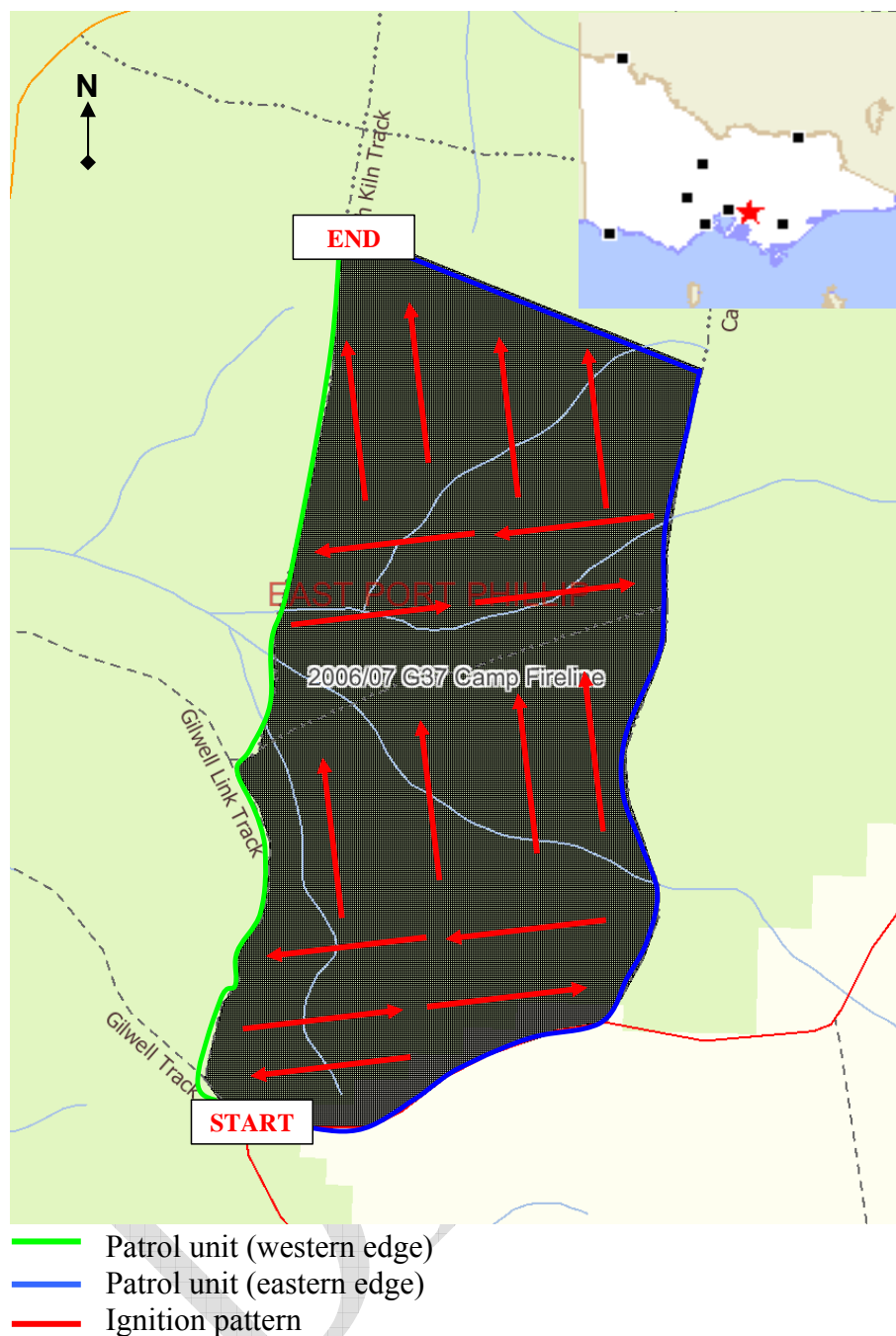


Figure 1 Map of the fuel reduction burn in Kurth Kiln Regional Park, VIC
(Generated at <http://nremap-sc.nre.vic.gov.au/MapShare.v2/>)



Figure 2 Vegetation at FRB in Kurth Kiln Regional Park, VIC

3.1.2 Fuel reduction burn in the Dandenong Ranges National Park, VIC

The 50 ha fuel reduction burn (FRB) in the Dandenong Ranges National Park consists of dry shrubby foothill Eucalypt forest, and is adjacent to private assets (Figure 3). Due to the very high profile of the burn, a full Incident Management Team (IMT) was set-up. The burn was conducted by DSE and attended by approximately 100 crew members including DSE and CFA staff. Two lighting crews started ignition at the top edge on Kyeema track and progressed down the slope. Handline crews were positioned above Kyeema track for any potential spot-overs. The tasks of patrol crews on Kyeema track involved raking around Stringy Bark trees and/or potential problem trees near the edge, patrolling the area for spots and blacking-out as required. They were working downwind of the smoke which was very dense (Figure 4). Monitoring was conducted on 4 patrol crew members along Kyeema track with two additional sampling boxes positioned on tanker and slip-on unit patrolling along Kyeema track. No monitoring was done on handline crews above Kyeema track. CFA crews were on stand-by on Observatory Road to respond to any requests from the public and keep a look out for spots. A sampling box was positioned on a CFA tanker patrolling along Observatory Road.

Even though sampling was not carried out over the entire workshift, which lasted over 12 hours, the sampling time was considered representative of a firefighter's workshift at a prescribed burn.

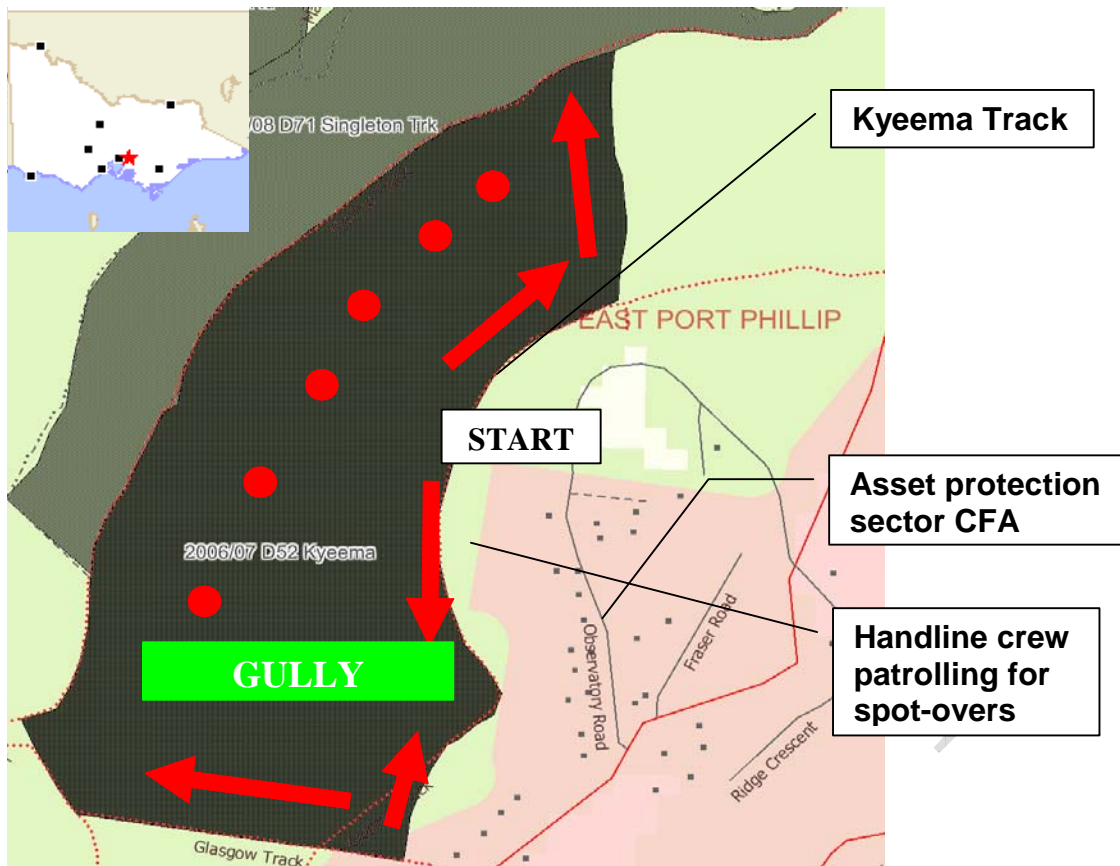


Figure 3 Map of the fuel reduction burn at Mt Dandenong, VIC (Generated at <http://nremap-sc.nre.vic.gov.au/MapShare.v2/>)



Figure 4 Patrol crews on Kyeema Track at the Mt Dandenong FRB, VIC

3.1.3 Fuel reduction burn in the Langwarrin Flora and Fauna Reserve, VIC

The Langwarrin Flora and Fauna Reserve is 42 km southeast of Melbourne and consists of a shrubby eucalypt forest and patches of heathland. The 13 ha burn area was quite flat and fuel moisture ranged between 12-14%. The burn was conducted by DSE and attended by about 25 crew members. Monitoring was conducted on 4 firefighters patrolling the burn area and 1 firefighter supervising the burn. Ignition was done along the edges of the burn (Figure 5) and started at about 12:00 until about 16:30, followed by patrol and blacking out where required. Samples were collected from 12:00 until 18:30.

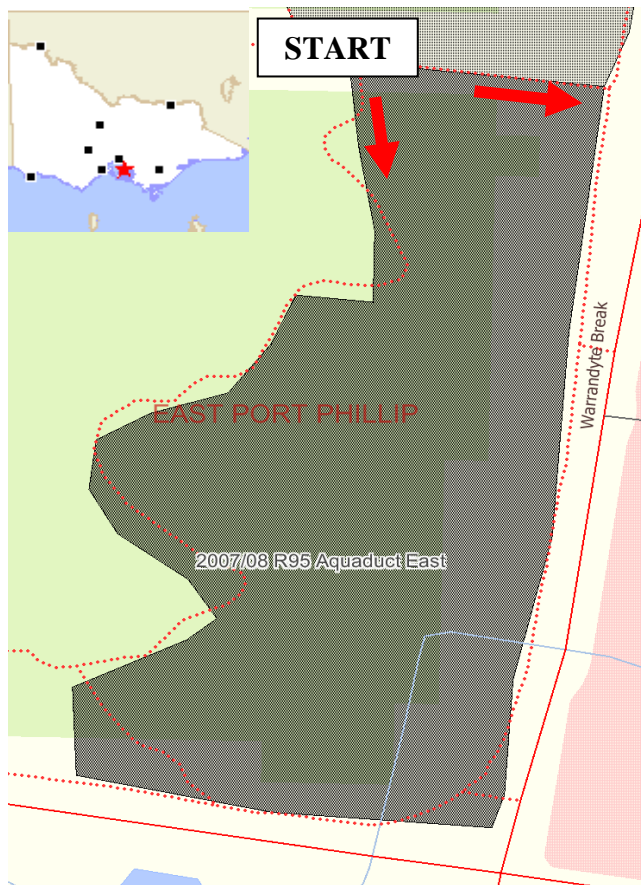


Figure 5 Map of the fuel reduction burn at Langwarrin Flora and Fauna Reserve, VIC (Generated at <http://nremap-sc.nre.vic.gov.au/MapShare.v2/>)



Figure 6 FRB at Langwarrin Flora and Fauna Reserve; patrol crews

3.1.4 Fuel reduction burn in the Yarra Ranges National Park, VIC

The 76 ha burn in the Yarra Ranges National Park Eucalypt forest is located 1.5 km north east of Healesville, adjacent to the Maroondah reservoir in the east and to built assets in the southwest corner. The burn was conducted by DSE and attended by crews from DSE and Melbourne Water. Ignition was started at about 12:00 from the top of mountain until about 17:00. Lighting was done from the centre in a circular motion moving down the slope to the edge of the burn (Figure 7). Minor patrol and black out was done until 19:00. Monitoring was conducted on 2 firefighters on patrol in the Reservoir sector, the bulldozer driver working on a track along the southwest corner (close to built assets) and on one firefighter on patrol with the bulldozer. Sampling boxes were also positioned on DSE tankers patrolling in Reservoir and Weir sectors as well as on a slip-on unit working with the bulldozer in the southwest corner of the burn. Monitoring was done over the entire workshift.

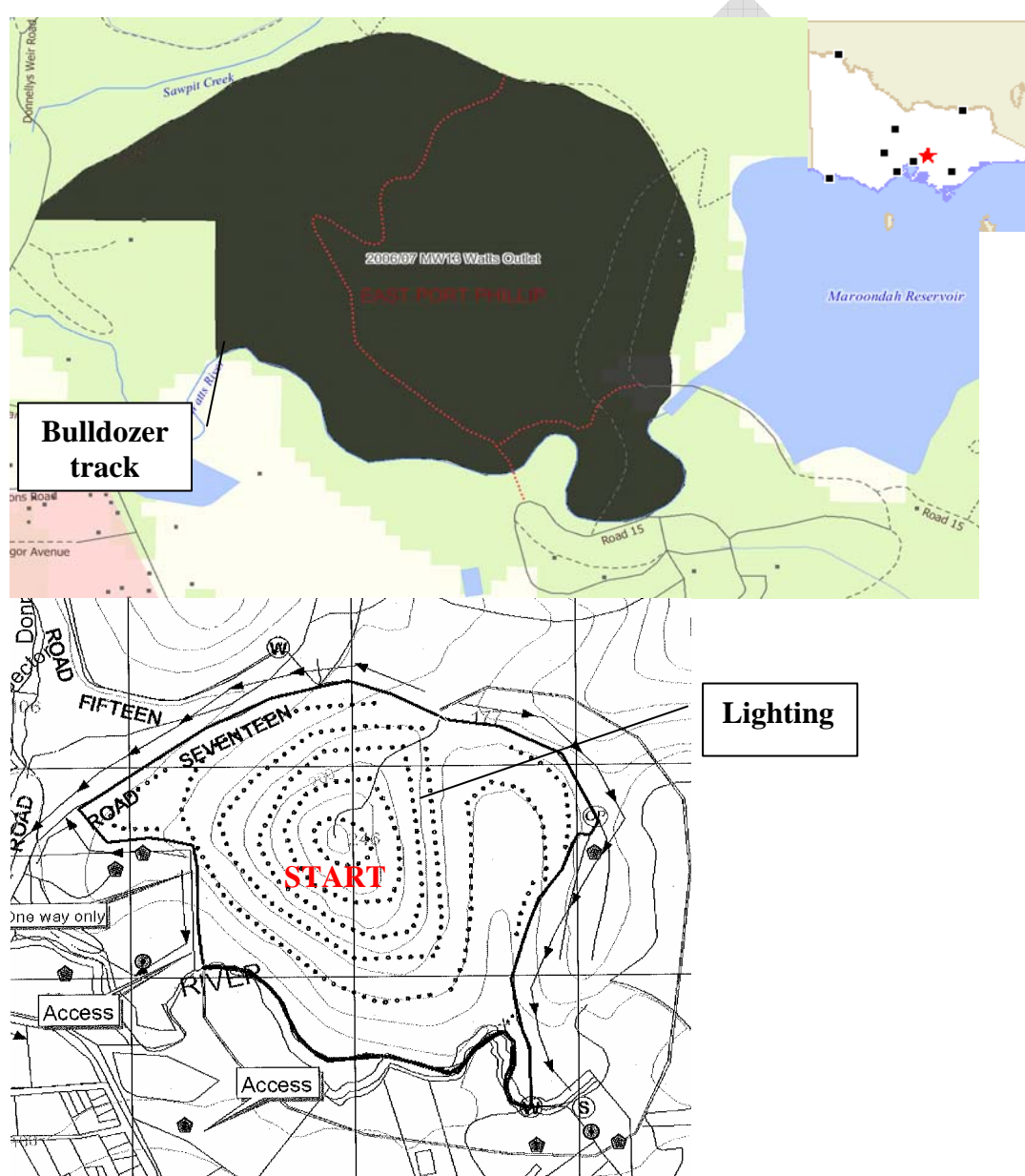


Figure 7 Map of fuel reduction burn at the Yarra Ranges NP, VIC (Generated at <http://nremap-sc.nre.vic.gov.au/MapShare.v2/>; DSE)

3.1.5 Slash/heap burns at pine plantations in Northeast Victoria

Slash burns at Hancock Victorian Plantations in pine forested areas are conducted each year in Northeast Victoria. Crew members are igniting burns with hand-held drip torches and work primarily upwind of smoke, although smoke generated by the burns can be quite dense (Figure 8). Monitoring was conducted on 4 crew members over 3 days. Two sampling boxes were also positioned in dense smoke at each site. Another sample tube was fixed on the Bushfire CRC vehicle while researchers were driving around the burn area. The burns included a 60 ha burn close to Rosewhite, a windrow burn close to Buffalo River and another windrow burn at Meeriyang South, close to Myrtleford.



Figure 8 Smoke generated during windrow burns in pine plantations

3.2 **Personal sampling methods & procedures**

This section contains an overview of the methods and procedures. Detailed information regarding the sampling devices and operating procedures are described elsewhere (Reisen & Brown, 2005).

3.2.1 Personal sampling devices

At each site, the aim was to monitor the personal exposure of 4 firefighters, primarily targeting patrol and suppression crews. The firefighters were asked to wear up to four sampling devices monitoring carbon monoxide (CO), respirable particles (RP), aldehydes and volatile organic compounds (VOCs) within their breathing zone over the duration of their workshift. After their shift, brief interviews were conducted with the firefighters participating in the sampling study.

The CO and VOC monitoring devices were placed in the top pocket of the firefighters personal protective clothing (PPC), while the particle counter and pumps for aldehyde and gravimetric particle collection were carried in a small ‘camelback’ style backpack, with an inlet tube placed on the harness within the breathing zone.

The sampling apparatus (refer to Reisen and Brown, 2005 for more information on the sampling devices and measurement procedures) that the firefighters were asked to wear consisted of:

- an electronic data-logging dosimeter (Draeger PAC IIIE) for continuous CO measurements
- a passive data-logging, light-scattering particle monitor (pDR) for continuous measurement of RP up to 400 mg/m³
- a 25 mm glass fibre filter loaded in a filter cassette and used with a conductive plastic cyclone at 2.2 litre/minute for gravimetric integrated sampling of RP
- a 2,4-dinitrophenylhydrazine (DNPH) impregnated cartridge attached to an air sampling pump at 0.6 L/min for collection and later analysis of total integrated aldehydes
- a PAS-500 Micro Air sampler fitted with a tube holder for Perkin-Elmer prepacked Air Toxics sorbent tubes (Carbograph 1TD/Carboxen 1000) for collection and later analysis of integrated concentrations of VOCs by GS/MS/FID.

3.2.2 Work activities

The various work activities that were covered in the monitoring program included:

- **Supervisor** - responsible for the burn, oversaw the various job activities, including using a drip torch for line burning.
- **Ignition** - using hand-held drip torches to ignite the burn, done as several lines each downwind of the other (line burning) or lighting along the edge of the burn area.
- **Patrol/suppression** - maintaining the fire within the boundaries of the burn area by patrolling the fire line on foot or in a vehicle. The patrolling unit was often involved in extinguishing spot fires that occurred outside the burn area using a hose (wet firefighting) or hand tools such as a rake-hoe (dry firefighting).

Primary focus was on patrol and suppression crews at FRB.

Table 3 lists the work shift duration, sampling time duration, work activities and the air toxics that were monitored at each burn.

Table 3 Personal sampling details

Burn	Work shift (h)	Sampling time (min)	Number of samples	Work activities	Air Toxic monitored
01	9	420	4	Ignition, Patrol, Suppression	CO, RP (pDR)
02	~ 13	400	4	Patrol, Suppression – hose and hand tools	CO, aldehydes, RP (pDR, gravimetric), VOCs
03	~ 7	320	5	Patrol, Suppression, Supervision	CO, aldehydes, RP (pDR, gravimetric), VOCs
04	8	450	3	Patrol	CO, aldehydes, RP (pDR, gravimetric), VOCs
			1	Bulldozer driver	CO, aldehydes, RP (pDR), VOCs
05	~ 4.5	260	4	Ignition	CO, aldehydes, RP (gravimetric)
06	~ 8 h	450	4	Ignition	CO, aldehydes, RP (gravimetric)
07	~ 4 h	220	4	Ignition	CO

3.2.3 Interview

The brief interviews conducted at the end of the sampling period provided information on the task activities of the subject, any adverse health effects they experienced while working in the smoke and which task exposed them to elevated smoke levels. They were also asked whether they were wearing any protective gear such as goggles and dust masks, and if they have any health issues that may be aggravated due to smoke exposure.

3.3 **Area sampling methods and procedures**

Due to the limited amount of sampling devices that firefighters are able to wear without hindering their work activities, additional air monitoring equipment was placed within a sampling box positioned on tankers or slip-on units used by patrol and suppression crews.

3.3.1 Sampling devices

The sampling box included a range of air monitoring devices as follows:

- an electronic data-logging TSI Q-Trak for continuous measurements of CO, CO₂, temperature and relative humidity
- a 2,4-dinitrophenylhydrazine (DNPH) impregnated cartridge attached to an air sampling pump at 0.6 L/min for collection and later analysis of total integrated aldehydes
- an active data-logging, light-scattering real time particle monitor (TSI DustTrak) with a 10 mm nylon Dorr-Oliver cyclone for continuous measurements of RP up to 100 mg/m³ at a flow rate of 1.7 L/min. The flow rate was calibrated before and after each burn.
- a MicroVol 1100 (Ecotech, Knoxfield, Australia) particulate sampler for gravimetric integrated sampling of PM_{2.5} on a 47 mm Teflon filter at a flow rate of 3 L/min
- a 32 mm quartz filter followed by a polyurethane foam within a glass holder attached to an air sampling pump at 2 L/min for collection and later analysis of organic fraction of particles
- a GPS unit to assess the location of firefighters at the burn

3.3.2 Sampling locations

The sampling boxes were attached to the ladders of tankers or put behind the cabin of the slip-on units (Figure 9) during the FRB. During the pine plantation windrow burns, sampling boxes were positioned in dense smoke for a limited amount of time to assess smoke generated from pine plantation burn-offs, and are unlikely to be representative of firefighters' exposures at those types of burn-offs. Additional samples were collected from the Bushfire CRC vehicle that researchers used to drive around the burn area. The air toxics levels are likely to be representative of potential exposures for patrol crews at pine forested areas.



Figure 9 Sampling tube equipped with air toxics monitoring devices set up on slip-on units

3.4 Data analysis

All average concentrations reported in this report are the average concentrations over the actual sampling period. The calculated mean values are represented as arithmetic and geometric means.

Particle measurements – At the FRB, particles were measured using light-scattering devices as well as using filters which were weighed to determine the gravimetric mass of particles. The light-scattering devices are calibrated against a standard dust material (Arizona road dust), but can be recalibrated for bushfire smoke particles by comparing readings with respirable gravimetric measurements. For those samples that used both methods, measurements from light-scattering devices were calibrated against gravimetric measurements. The responses of the light-scattering particle monitors to bushfire smoke were 2.3 for the pDR and Sidepak and 2.6 for the DustTrak. These correction factors will be used for the reporting of all particle concentrations in this report.

Aldehyde measurements – Aldehydes were collected using s10 LpDNPH cartridges, which are air sampling devices designed for sampling carbonyls and which were coated with 1 mg of 2,4-dinitrophenylhydrazine (2,4-DNPH) resulting in a maximum uptake of about 75 µg of formaldehyde. This translates to an ambient concentration of about 0.3 ppm of formaldehyde assuming a 6-hour sampling period at a sampling rate of 0.6 L/min. Due to higher levels of ambient aldehydes, DNPH was all used up for 50% of the personal samples and for 46% of the area samples.

4 Results and discussion

Personal breathing zone samples were collected for 29 firefighters during burns in Victoria between April and May 2007. These samples measured firefighter's exposure to CO (29 samples), RP (7 samples with light-scattering device and 10 samples with gravimetric method), aldehydes (8 samples) and VOCs (3 samples). Additionally sampling boxes equipped with a range of air monitoring devices were put onto tankers

and slip-on units and measured exposure levels on the fire ground during each prescribed burn. During the slash burns in the pine plantations, smoke boxes were positioned in dense smoke and a sampling tube was also fixed on the Bushfire CRC vehicle used to drive around the burn area. Measurements collected on the fire ground included measurements of CO (14 samples), CO₂ (11 samples), RP (17 samples with light-scattering device and 19 samples with gravimetric method), aldehydes (13 samples) and VOCs (4 samples).

The data are summarized in Table 4 and more detailed information is reported in Tables 9-15 in the appendix for each site.

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Table 4 Summary of data collected during prescribed burns over autumn 2007

	Air Toxic	n	Average	Geometric Mean	Range	% Samples detected
Personal	CO ave [ppm]	29	14.6	4.5	0.4 – 120	100
	CO max (10s) [ppm]	29	296	183	18 – 1085	
	CO max (15 min) [ppm]	29	64.3	26.5	3 – 307	
	RP (L) ¹ ave [mg/m ³]	7	0.5	2.2	0.1 – 12.2	100
	RP (L) max [mg/m ³]	7	50	26	2.4 – 174	
	RP (G) ² ave [mg/m ³]	7	3.1	1.3	0.4 - 16	
	Formaldehyde [ppb]	8 ³	> 43	> 38	15 – > 85	100
	Acrolein [ppb]	8	ND	ND		
	Acetaldehyde [ppb]	8 ³	> 23	> 15	9 – > 85	100
	Benzene	3				
	Toluene	3				
	Xylenes	3				
	Total VOCs	3				
Sampling boxes	CO ave [ppm]	14	25.2	9.5	0.7 – 98	100
	CO max [ppm]	14	177	107	20 – 606	
	CO ₂ ave [ppm]	11	657	602	370 – 1215	100
	CO ₂ max [ppm]	11	1933	1454	581 – 5894	
	RP (L) ¹ ave [mg/m ³]	17	2.5	0.6	0.02 – 14.2	100
	RP (L) max [mg/m ³]	17	31	11	0.1 – 121	
	RP (G) ² ave [mg/m ³]	19	2.6	0.8	0.08 - 15	
	Formaldehyde [ppb]	13 ³	> 54	> 34	3 – > 195	100
	Acrolein [ppb]	13			ND – 11	12.5
	Acetaldehyde [ppb]	13 ³	> 17	> 10	2 – > 69	100
	Benzene	4				
	Toluene	4				
	Xylenes	4				
	Total VOCs	4				

¹ RP measured by light-scattering device (TSI SidePak, pDR or DustTrak); The particle concentrations were corrected for the response of the particle monitors to bushfire smoke

² RP measured gravimetrically

³ Cartridges were overloaded for 4 personal samples and 6 smoke signature samples and therefore the mean values are likely to be higher

4.1 Sample distribution

All the samples were collected at prescribed burns within Victoria, with 59% of the personal measurements collected at FRBs. The remaining 41% of the samples were collected at slash burns in pine plantations, where lighting with drip torches was the only task. For the FRBs, all samples were collected in eucalypt forest. The job tasks monitored were primarily patrol and suppression crews (76%), followed by lighting crews (12%), supervisor (6%) and bulldozer driver (6%).

4.2 Workshift assessment

The work shifts ranged from 4 to 13 hours, and sampling times ranged from 3.5 to 8 hours. For 55% of the personal samples, air toxics measurements were collected over the entire workshift. For about 30% of the personal samples, monitoring represented 80% of their workshift and for about 15% of the samples, measurements were collected over a period representing 55% of their workshift (see Table 3). Due to the long workshifts, the exposure standards for conventional work shifts (8 hours per day) may be inappropriate and therefore the 8-hour TWA exposure standard should be reduced by a suitable factor to provide an equivalent degree of protection, as follows (Brief and Scala Model, 1975):

$$\text{Adjusted exposure standard (TWA)} = \frac{8 \times (24 - h) \times \text{OES}}{16 \times h}$$

where h = hours worked per day and OES is the 8-hr TWA OES

The adjusted OES for an altered workshift of 9 hours, 11 hours and 13 hours are shown in Table 5.

Table 5 Occupational exposure standards adjusted for extended work shifts

Air Toxic	Duration of work shift		
	9 hr	11 hr	13 hr
CO [ppm]	25	18	13
Formaldehyde [ppm]	0.8	0.6	0.4
proposed	0.25	0.2	0.13
Acrolein [ppm]	0.08	0.06	0.04
Acetaldehyde [ppm]	17	12	8.5
Benzene [mg/m ³]	2.7	1.9	1.4
Toluene [mg/m ³]	159	113	81
Respirable particles [mg/m ³]	5	3.5	2.5
Respirable particles [mg/m ³]	2.5	1.8	1.3

4.3 Data quality

Samples of various air toxics were collected in the breathing zone of firefighters as well as on vehicles used on the fire ground. Due to various reasons, some of the sample results were questionable.

4.3.1 Personal sampling

The battery life of the light-scattering data-logging particle monitor caused problems at one of the prescribed burns and therefore for 2 samples, data was only recorded for 20-23% of the work shift.

For 50% of the aldehyde samples, the cartridges used for the collection of aldehydes were overloaded and therefore concentrations may have been much higher than reported.

4.3.2 Sampling boxes

A few problems were encountered with the collection of particles. For one sample the data-logging particle monitor recorded only 40% of the workshift and in another instance the cyclone was disconnected during the sampling period.

Gravimetric samples of particles were collected using a MicroVol, which was linked to a datalogger that recorded flow rate over time. In 15% of the samples the flow dropped, which may have been caused by overloading the filter as a result of high particle concentrations in the smoke. In another instance the MicroVol was running only during approximately 20% of the workshift.

As for the personal samples, aldehyde cartridges were overloaded for 46% of the samples and the levels reported here may have been higher.

4.4 **Personal exposure assessment**

4.4.1 Carbon monoxide

Personal exposures to CO were measured for 29 firefighters at 4 FRBs and 3 windrow burns in pine plantations.

Time-weighted average (TWA) CO concentration

Average exposure levels to CO ranged from 0.4 to 120 ppm, with a mean exposure level of 14.3 ppm and median exposure level of 4.4 ppm. The majority of samples (79%) had an average CO exposure below 10 ppm (Figure 10). The TWA exposure standard of 30 ppm was largely exceeded by firefighters patrolling at a FRB. The samples were collected over a 4.5 to 7 hour period. The highest CO exposure level at 120 ppm was measured over a 4 hour sampling period, and may have been lower over the entire workshift. There was an additional average exposure level monitored at 22 ppm sampled over a 5.5 hour period and therefore below the OES.

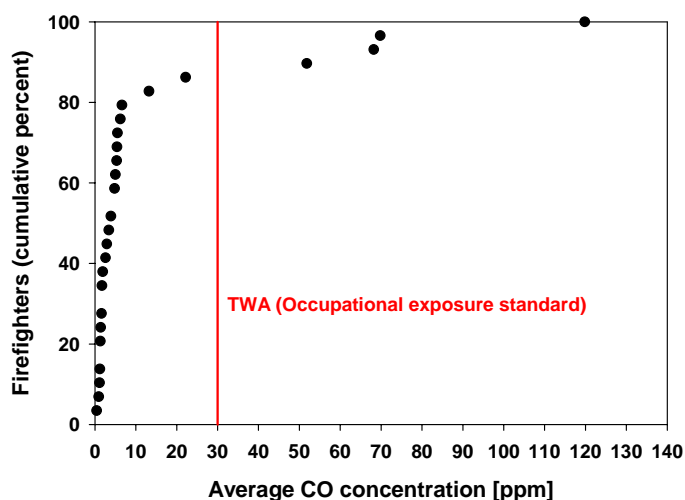


Figure 10 Frequency distribution of personal exposures to CO

Short-term exposure limit (STEL)

The short-term exposure limit (STEL) is a 15-minute average exposure which should not be exceeded at any time during the working day. STEL exposures should not be repeated more than four times per day and should be separated by at least 60 minutes. The STEL of 200 ppm CO was exceeded for 4 firefighters involved in patrol and suppression at a FRB, resulting in maximum 15-minute exposure levels of about 300 ppm. As shown in Figure 11, the 15-minute average CO concentrations exceeded 200 ppm on 2 occasions.

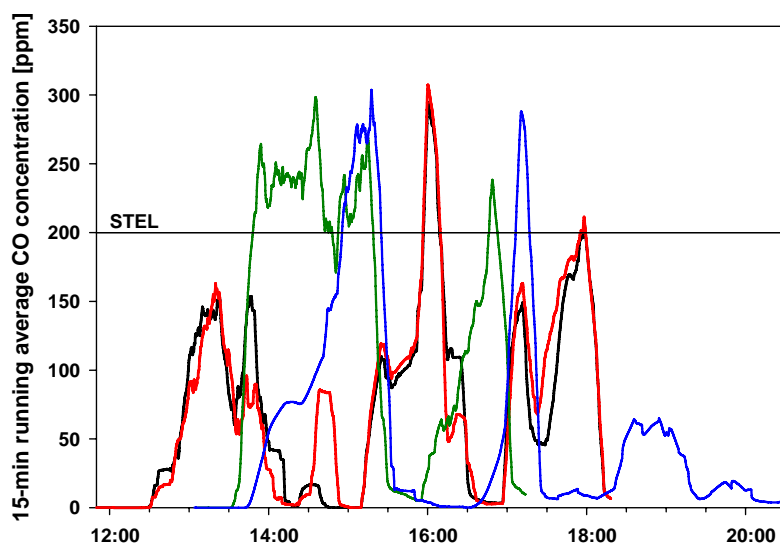


Figure 11 Data-logging records of the 15-minute running average CO concentrations for 3 patrol and suppression crew members at a FRB

Peak limit

Due to the acute adverse health effects of CO, exposures should never exceed 400 ppm. This limit has been exceeded by 7 firefighters, with maximum recorded exposure levels ranging from 594 ppm to 1085 ppm. For 3 firefighters the elevated CO exposure was a one-off excursion, but for 4 firefighters CO levels exceeded 400

ppm over a 4-5 minute exposure time and at several occasions during the duration of the workshift (Figure 12).

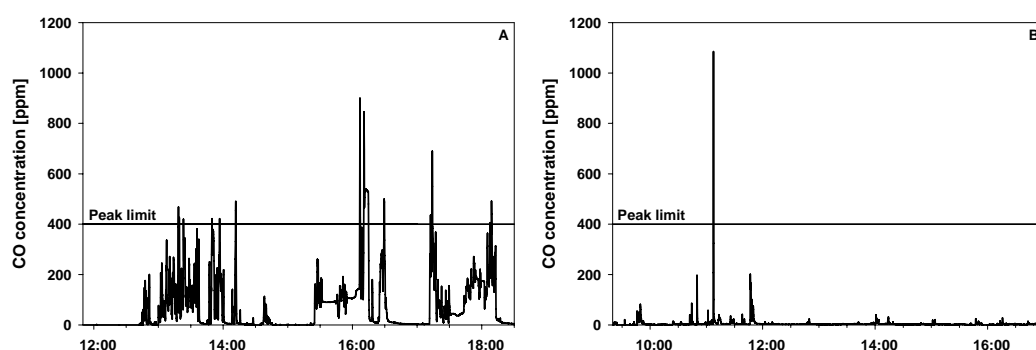


Figure 12 Data-logging records of firefighter's exposures to CO over the duration of their work shift; prolonged exposure to levels above peak limit (A) and brief excursions above peak limit (B)

Potential health impacts

Excessive exposures to CO can cause headaches and dizziness, affect behaviour and reduce work capacity due to increased carboxyhemoglobin (COHb) levels in the blood which reduces oxygen transport to the major organs such as heart and brain.

The Coburn-Foster-Kane (CFK) equation can be used to evaluate COHb levels in blood from external exposures to CO (Coburn et al., 1965). Assuming a moderate work activity over the duration of the workshift (Brotherhood *et al.*, 1997), the firefighters final COHb levels at the end of the sampling period ranged from 0.75 % (background levels) up to 18%. Any levels above 5% are likely to cause CO-induced symptoms as shown in Table 6. Elevated COHb levels were observed for patrol and suppression crews, with an average of 9%. However during the workshift, COHb levels may have been higher, as shown in Figure 13.

Table 6 Potential health effects from exposure to high levels of CO

COHb [%]	SYMPTOMS, EFFECTS
5	Potential for adverse cardiovascular effects
5-10	Effects on performance of tasks requiring vigilance and on reaction time, potential headaches, dizziness, reduced work capacity
10-20	Slight headaches, dizziness, possibly slight breathlessness on exertion
20-30	Slight to moderate headaches, nausea
30-40	Severe headaches, vertigo, nausea

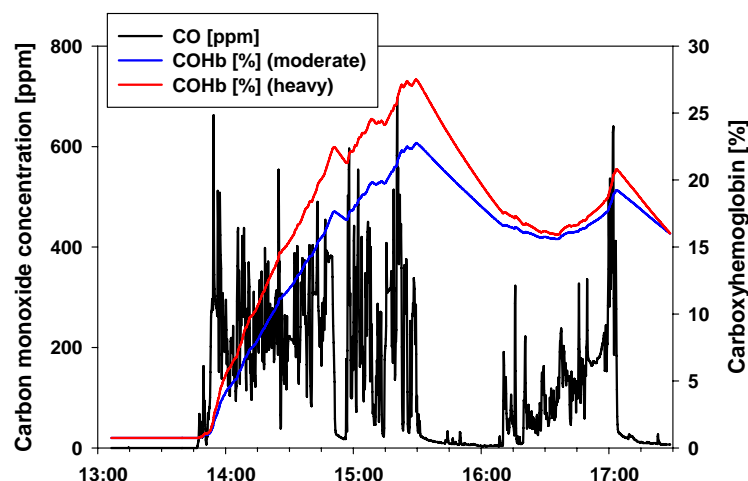


Figure 13 Estimated COHb levels over time derived from the CFK equation

4.4.2 Respirable particles

Both light-scattering data-logging devices and collection of particles onto filters were used to assess personal exposures to RP. Average particle concentrations measured within the breathing zone of firefighters ranged from 0.1 to 16 mg/m³. Out of 14 samples, 2 samples (14%) exceeded 3 mg/m³, which is the TWA concentration considered to be appropriate if the smoke contains no toxic components.

Peak levels of respirable particles determined with the light-scattering devices ranged from 2.4 to 174 mg/m³. The highest particle exposures were measured for patrol and suppression crews.

Since there is no STEL for bushfire smoke particles, exposure levels are considered acceptable if the overall 8-hour TWA is not exceeded, short-term maximum exposure does not exceed 5 times the TWA at any time and short-term exposures exceed 3 times the TWA for no more than 30 minutes in the 8-hour day.

The use of data-logging particle monitors enabled the assessment of short-term excursions. Considering a TWA standard of 3 mg/m³, 71% of the samples recorded excursions above 15 mg/m³, but only 29% recorded 30 minute exposures that exceeded 9 mg/m³.

Similar to CO exposures, we can observe very brief excursions which are due to brief exposure to dense smoke, as well as more prolonged exposures to elevated levels of air toxics, resulting in exceedances of the 30-minute excursion limit of 9 mg/m³ and exceedances of the short-term maximum exposure of 15 mg/m³ (Figure 14).

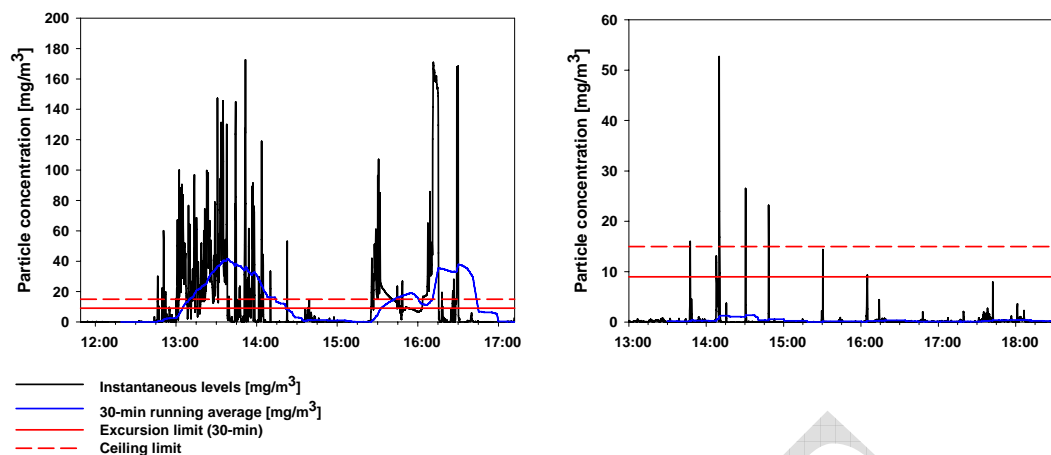


Figure 14 Data-logging records of firefighter's exposure to RP; prolonged exposures to elevated levels of particles (A) and brief excursions (B)

Potential health impacts

RP can cause breathing difficulties, coughing, asthma exacerbation, aggravation of any pre-existing respiratory or cardiovascular illnesses and potential lung dysfunction. Since there is no STEL provided for RP, it is recommended to keep peak levels below 5 times the TWA. This level was largely exceeded by firefighters patrolling at a FRB, as shown on the data-logging record in Figure 14.

4.4.3 Aldehydes

Major aldehydes identified included formaldehyde and acetaldehyde. Other aldehydes identified in the samples included propanal, crotonaldehyde, benzaldehyde, tolualdehyde. Formaldehyde levels ranged from 15 ppb to above 85 ppb and acetaldehyde levels from 8 ppb to above 85 ppb. However since cartridges were overloaded in some samples, aldehyde levels were likely to be much higher than 85 ppb. As shown later, aldehyde concentrations were calculated by using the regression equation parameters obtained from the correlation between CO and HCHO as well as CO and acetaldehyde. This provided a good assessment of the potential exposure to aldehydes. Acrolein was not detected in any of the samples apart from a smoke sample taken during the windrow burns in the pine plantations.

Potential health impacts

Aldehydes are respiratory irritants causing eye, nose and throat irritation if present at elevated levels in the breathing zone. Formaldehyde has recently been classified by the International Agency for Research on Cancer (IARC) as a known human nasal carcinogen and its exposure levels should be kept as low as feasible. The studies have not shown any increased risks of lung cancer among workers exposed to formaldehyde. The Australian National Industrial Chemicals Notification and Assessment Scheme (NICNAS) recommended lowering the current OES for formaldehyde to 0.3 ppm for the 8-hr TWA and 0.6 ppm for the STEL. The new exposure standard is set to provide adequate protection against discomfort of sensory irritation, but also to provide a high level of protection from cancer. Sensory irritation from exposure to formaldehyde is experienced by humans at levels in air of 0.5 ppm and above. For average exposure levels of 0.3 ppm formaldehyde, the occupational risk for respiratory tract cancers after repeated exposure to formaldehyde by inhalation is likely to be low.

4.4.4 Drivers of high smoke exposure

There are a range of factors that may be causing high smoke exposures including work activities, burn conditions, fuel characteristics and meteorology. In this report we are discussing the effect of work activities and burn conditions on personal smoke exposure levels.

Work activity

At prescribed burns, firefighters carry out a range of different work activities, which will influence their time and proximity that they work in dense smoke conditions. Data collected at previous burns has shown that highest exposure levels were observed for patrol and suppression crews compared to lighting crews. The activities monitored during autumn 2007 included patrol crews at FRBs, lighting crews at slash burns in pine plantations, one supervisor and one bulldozer driver.

As shown in Figure 15, highest exposures to CO were measured for patrol and suppression crews resulting in exceedances of average and short-term exposure standards. Average exposure to CO for other work tasks remained well below the OES of 30 ppm. Maximum peak levels were high for lighting crews, primarily those crew members involved in the slash burn at pine plantations. In general the crews work upwind of the smoke, but spend short-time periods in denser smoke. This is in agreement with the measurements from the stationary monitoring equipment which recorded elevated levels of CO and particulate matter.

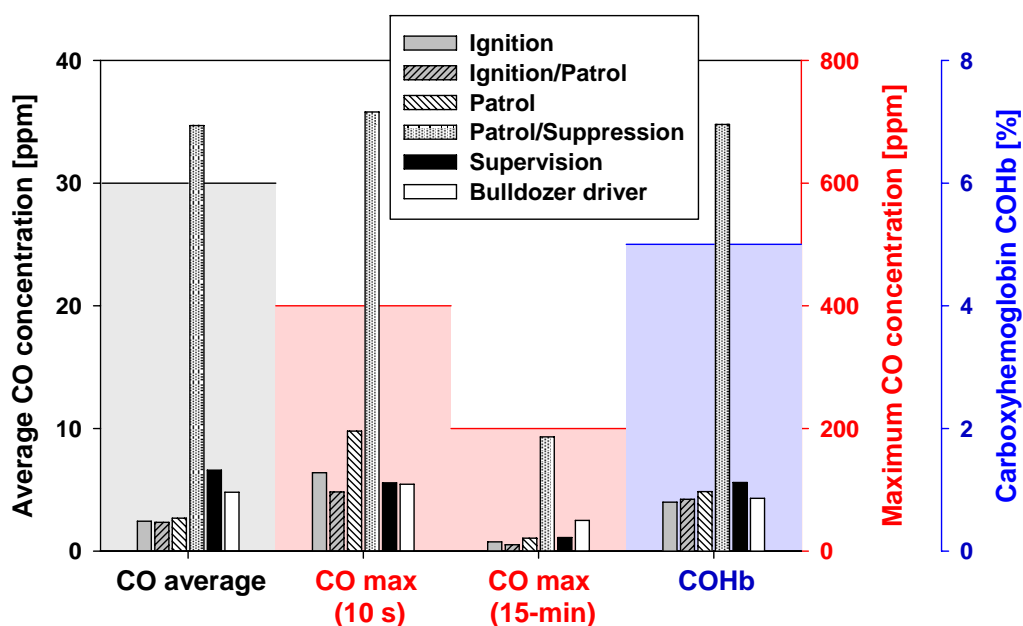


Figure 15 Personal exposures to CO according to work activity

Similar to CO exposures, highest exposure levels for RP were measured for patrol and suppression crews (Table 7). Exposures to HCHO could not be assessed as the sampling media was overloaded in particular for samples collected on patrol and suppression crews. Their exposure levels to HCHO may have been much higher than the values reported in Table 7.

Table 7 Average exposure levels according to work activities

Job activity	CO ave ppm	CO max ppm	RP ave mg/m ³	RP max mg/m ³	HCHO ppm	Benzene mg/m ³	TVOCs mg/m ³
Lighting	1.9	150	-	-	-		
	6.2	76	1.1	30	> 0.085		
	3.4	77	0.7	-	-		
	4.8	183	0.4	-	0.038		
	5.5	248	-	-	-		
	5	139	-	-	-		
	5.4	1085	1.1	-	-		
	2.6	198	1.4	-	0.043		
	1.3	58	-	-	-		
	3.9	173	-	-	-		
	1.2	55	-	-	-		
	1.1	121	-	-	-		
	0.9	18	-	-	-		
	1.4	128	-	-	-		
Average Geomean	3.2	194	1.0				
	2.6	123	0.9				
Patrolling	13.2	292	-	-	-		
	5.3	166	-	-	-		
	0.4	128	0.1	8.4	-		
	1.7	53	-	-	0.015		
	2.9	868	0.5	-	-		
Average Geomean	4.7	301	0.3				
	2.7	196	0.3				
Patrolling, suppression -rake-hoe and hose	1.7	594	0.3	55	-		
	1.6	199	-	-	-		
	1.3	59	0.3	22	-		
	68	900	16	-	-		
	70	750	12	174	> 0.035		
	120	696	-	-	> 0.055		
	60	674	-	-	-		
	22	283	-	-	0.041		
Average Geomean	43	520	7.2	84			
	15	400	2.0	60			
Supervising	6.6	112	1.4		-		
Bulldozer driver	4.8	110	1.1	58	> 0.029		

Burn conditions

Even though work activity is a major factor influencing smoke exposure, low smoke exposures may occur for patrol crews. Figure 16 shows the data-logging records of CO and particle exposures of 2 patrol crew members at 2 different FRBs. There is an approximate 100 fold difference in exposure levels to CO and RP between the 2 firefighters. The primary factor influencing smoke exposure in this case is the topography of the burn area. The high exposure levels were monitored at a FRB which was conducted on a steep terrain with ignition started at the top of the ridge. Due to its proximity to private property, crews were extensively patrolling along the top edge of the burn, which was downwind of the smoke. This resulted in high personal exposure levels. The other measurements were taken from a FRB during which smoke was drawn towards the centre of the burn and therefore resulted in low smoke exposures for patrol crews at the edge of the burn.

Similar windrow burns in the pine plantations resulted in low levels of CO exposures as crew members worked upwind of the smoke, but had occasional elevated smoke exposure.

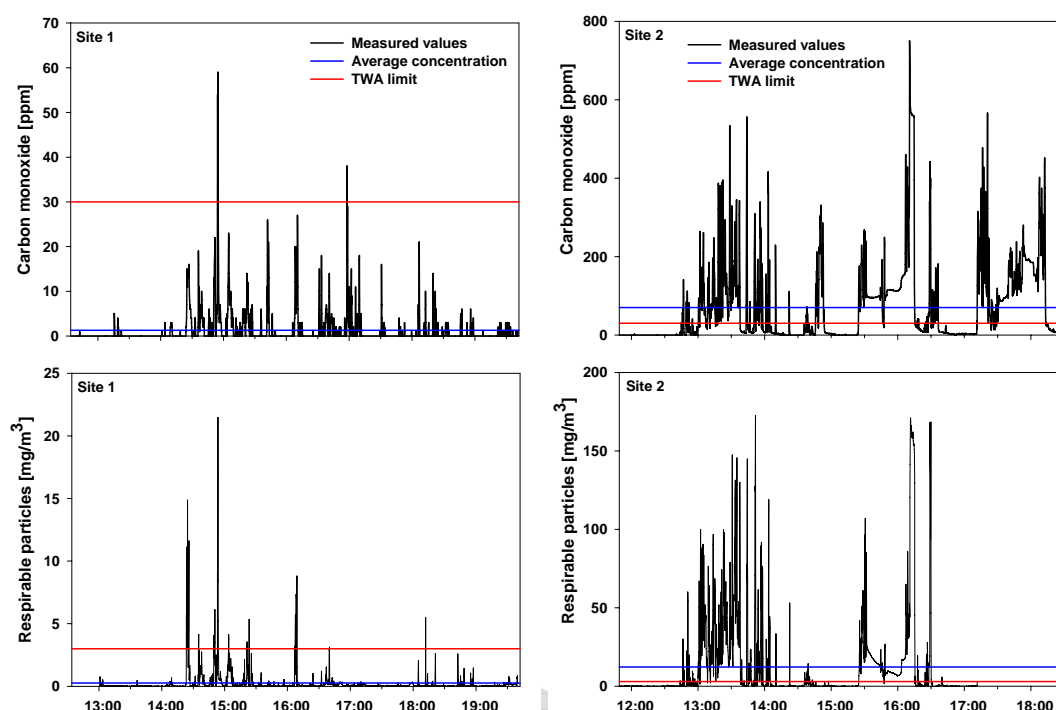


Figure 16 Data-logging records of CO and respirable particle exposures for patrol crews at 2 different FRB

4.5 Smoke signature assessment

Air sampling equipment was set up on vehicles used on the fire ground and measured CO, CO₂, particles and aldehydes.

As can be seen in Figure 17, highest air toxics levels were measured at the Dandenong FRB and at the pine plantations where smoke boxes were specifically positioned within dense smoke. At the FRB at Mt Dandenong, similar to the personal samples, exceedances of the OES were observed for CO average (30 ppm) and peak (400 ppm) concentrations as well as for the PM_{2.5} concentrations which exceeded 3 mg/m³. At the other FRB, air toxics levels remained low.

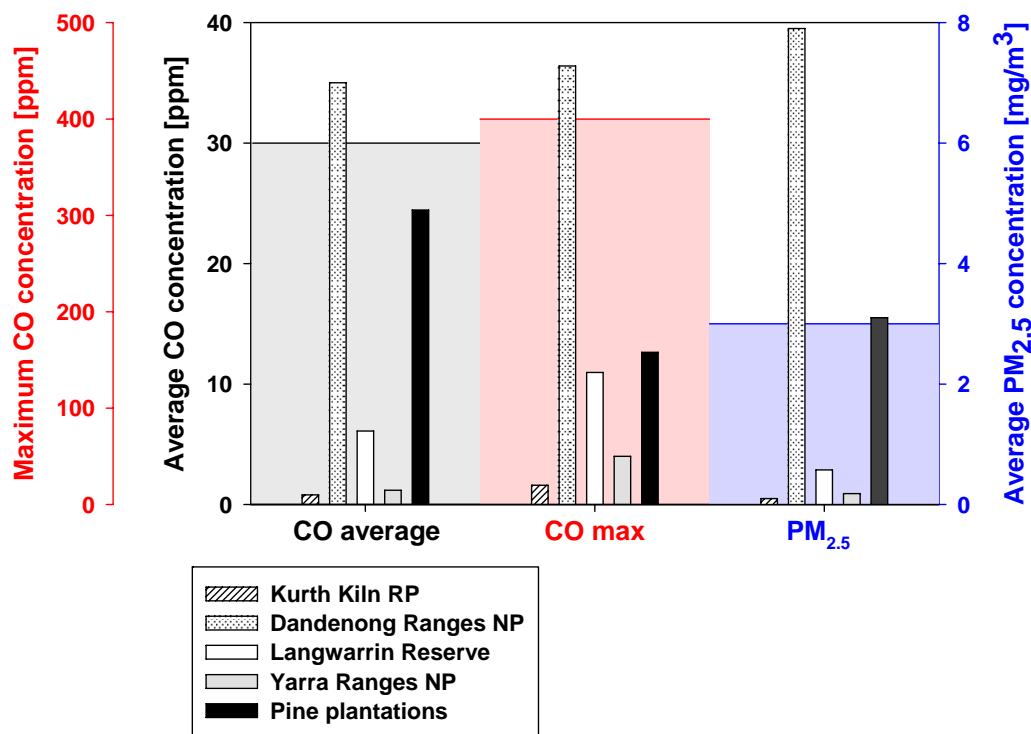


Figure 17 Air toxics levels for sample monitoring

Major aldehydes identified included formaldehyde and acetaldehyde. Other aldehydes identified in the samples included propanal, crotonaldehyde, benzaldehyde, tolualdehyde. Formaldehyde levels ranged from 3 ppb to 195 ppb and acetaldehyde levels from 2 ppb to 69 ppb. However since cartridges were overloaded in some samples, aldehyde levels were likely to be much higher than the values reported. The highest aldehyde levels were measured at the pine plantation windrow burns. Acrolein was not detected in any of the samples apart from a smoke sample taken during the windrow burns in the pine plantations.

4.6 Pollutant correlation

Pollutant correlation was only determined between CO and particles, due to the limited amount of aldehyde samples. The personal and area sampling data collected at prescribed burns in autumn 2007 have shown a strong correlation between CO and RP, as highlighted by the strong correlation of the linear regression (Figure 18) for average exposures to these pollutants ($r^2 = 0.81$, which is significantly different from the null hypothesis (no correlation) at $p=0.001$). This shows that the concentration of RP can be estimated from measurements of the exposure levels to CO.

By separating the data collected at prescribed burns in eucalypt-forested areas from the data collected at the pine windrow burns, the correlation between CO and RP resulted in an r^2 of 0.99 for the eucalypt burns and an r^2 of 0.84 for the windrow burns.

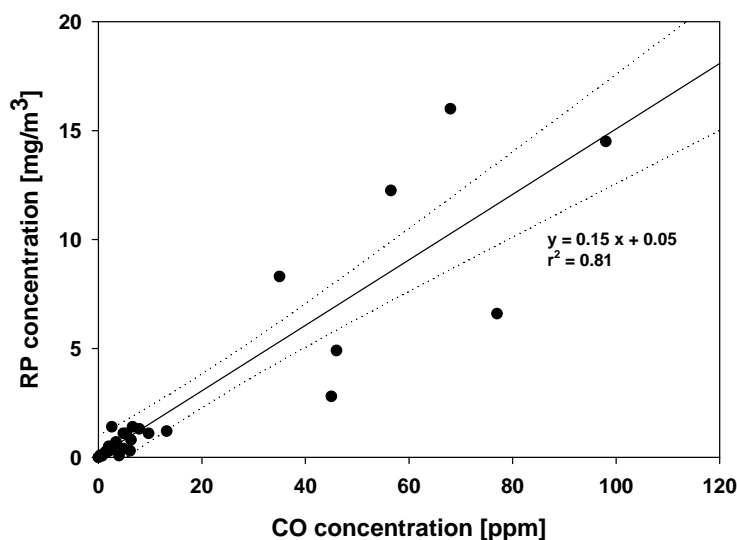


Figure 18 Correlation between RP and CO in personal and smoke signature samples collected during autumn 2007.

Personal exposure data collected over the last 3 years were compiled to determine the regression data which can then be used to assess exposure levels during prescribed burns of autumn 2007 for those pollutants that were not monitored as well as those pollutants where sampling media was overloaded. The regression parameters are displayed in Figure 19 and the measured and calculated values of exposure levels collected in autumn 2007 are shown in Table 8.

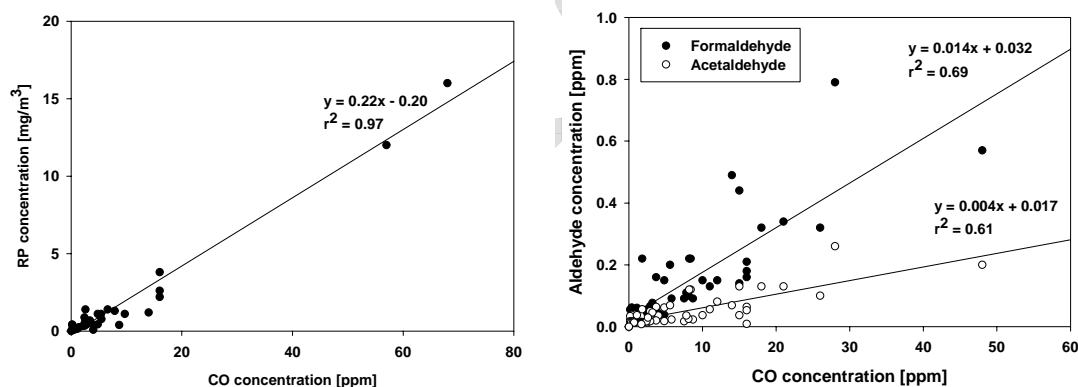


Figure 19 Correlation between RP and CO, aldehydes and CO in personal exposure samples collected at prescribed burns between 2005 and 2007.

Table 8 Measured and calculated values of personal exposure measurements to air toxics in bushfire smoke

Sample	CO [ppm]	RP meas [mg/m ³]	RP calc [mg/m ³]	HCHO meas [ppm]	HCHO calc [ppm]	CH ₃ CHO meas [ppm]	CH ₃ CHO calc [ppm]
PE-120407-1	1.9		0.22		0.059		0.025
PE-120407-2	1.7	0.32	0.17		0.056		0.024
PE-120407-3	1.6		0.15		0.054		0.023
PE-120407-4	1.3	0.25	0.09		0.050		0.022
PE-180407-1	68.2	16.01	14.80		0.987		0.290
PE-180407-2	69.8	12.22	15.16	0.035	1.009	0.005	0.296
PE-180407-3	119.8		26.16	0.055	1.709	0.006	0.496
PE-180407-4	60.3		13.07		0.876		0.258
PE-250407-1	13.2	0.09	2.70		0.217		0.070
PE-250407-2	6.2	1.13	1.16	0.085	0.119	0.009	0.042
PE-250407-3	22.2		4.68	0.041	0.343	0.023	0.106
PE-250407-4	6.6	1.36	1.25		0.124		0.043
PE-250407-5	5.3		0.97		0.106		0.038
PE-260407-1	0.4	0.13	-0.11		0.038		0.019
PE-260407-2	4.8	1.10	0.86	0.029	0.099	0.085	0.036
PE-260407-3	1.7		0.17	0.015	0.056	0.008	0.024
PE-260407-4	2.9	0.51	0.44		0.073		0.029
PE-030507-1	3.4	0.68	0.55		0.080		0.031
PE-030507-2	4.8	0.43	0.86	0.038	0.099	0.018	0.036
PE-030507-3	5.5		1.01		0.109		0.039
PE-030507-4	5		0.90		0.102		0.037
PE-040507-1	5.4	1.14	0.99		0.108		0.039
PE-040507-2	2.6	1.42	0.37	0.043	0.068	0.029	0.027
PE-040507-3	1.3		0.09		0.050		0.022
PE-040507-4	3.9		0.66		0.087		0.033
PE-050507-1	1.2		0.06		0.049		0.022
PE-050507-2	1.1		0.04		0.047		0.021
PE-050507-3	0.9		0.00		0.045		0.021
PE-050507-4	1.4		0.11		0.052		0.023

As can be seen in table 8, overall measured values for RP were in good agreement with calculated values. For formaldehyde and acetaldehyde measured values were much lower for higher exposure samples during which the sorbent for aldehyde collection was overloaded.

Exposure to formaldehyde exceeded 1 ppm in 7% of samples and 0.3 ppm in 17% of samples' whereas acetaldehyde concentrations remained well below the OES of 20 ppm. Like health impacts from exposure to elevated levels of HCHO include eye, nose and throat irritation, which were symptoms commonly reported by firefighters at the end of their shift.

4.7 Personal exposures vs measurements collected in sampling boxes

Due to the limitations of sampling devices that firefighters can comfortably wear without hindering their work, additional sampling equipment was placed on tankers and slip-on units.

As shown in Figure 20, at the FRB both average and peak personal CO exposure levels were higher than those measured on the tankers or slip-on units. Firefighters are likely to work in closer proximity to smoke, which shows that it is essential to monitor firefighter's exposures to air toxics within their breathing zone. Personal CO exposures of the crew members at the pine plantation burns were lower than the

stationary samples and this is due to the fact that the sampling boxes were positioned downwind of the smoke. Firefighters at slash burns are in general not working under those conditions.

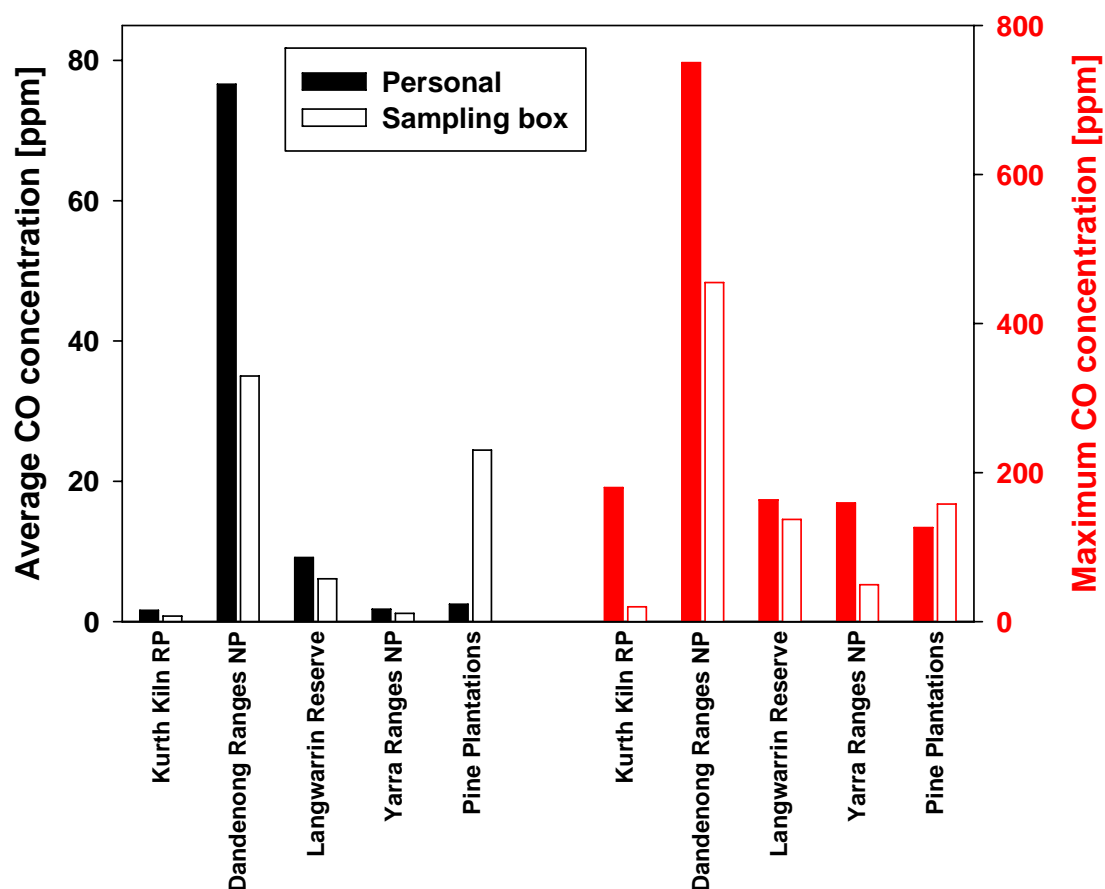


Figure 20 Comparison of CO exposure levels measured within the breathing zone of firefighters and from vehicles used on the fire ground.

5 Acknowledgements

We would like to thank the following agencies for their participation in the study: Department of Sustainability and Environment, Country Fire Authority. This project has been funded by the Bushfire CRC.

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7 Appendix

7.1 Gembrook, Kurth Kiln RP, VIC – 12/04/07

7.1.1 Fire site record

SITE	Gembrook, Kurth Kiln Regional Park; Burn name: G37 Camp Fireline
DATE	12/04/2007
TYPE OF BURN	Prescribed
FUEL DESCRIPTION	Eucalypt forest, red stringy bark, fern, grass
BURN AREA (TOTAL)	30 ha
BURN AREA TODAY	30 ha
DESCRIPTION OF AREA	hilly, steep terrain, thick vegetation
WEATHER DESCRIPTION	Low winds, 21°C, 35-40% RH
FIRE AGENCIES IN ATTENDANCE	DSE Gembrook, Ballarat
NUMBER IN FIRE CREW	approx 20 (6 slip-on units, 2 tankers)
PERSONAL PROTECTIVE EQUIPMENT	-
LENGTH OF DAY SHIFT	approx 9 hours (from 13:00 – 22:00). There was a briefing at 13:00, followed by a drive around burn area. At about 13:30, lighting crew started line burning at the north edge of the burn area (see ignition patterns on map), and worked their way towards the southern end. Patrol crews were patrolling in slip-on units and tankers along the eastern and western edges of the burn area. Ignition was done from 13:30 until approx 19:30; short dinner break; blacking out continued til approx 10 pm (blacking out period not sampled)
NUMBER OF CREW SAMPLED	4 personal; 2 sample boxes (1 on tanker; 1 on slip-on unit)
TASKS OF SAMPLED CREW C.F. REST OF CREW	1 FF was lighting with a drip-torch (line burning through burn area) from 13:30 until approx 19:30. 1 FF was patrolling in slip-on unit (western edge); patrol and suppression with hose 1 FF was on the patrol tanker unit (western edge) (patrol and suppression with hose) until about 17:00. Afterwards, FF was lighting with drip torch (line burning). 1 FF was on a patrol tanker unit (eastern edge) (patrol and suppression with hose); did some ignition with drip torch along edge of burn area
CREW SAMPLE EXPERIENCE	<ul style="list-style-type: none"> - HEADACHE N, N, N, N - IRRITATION N, N, N, N - OTHER (specify) N, N, N, N
SAMPLE BOXES	<ul style="list-style-type: none"> ▪ tanker patrolling eastern edge of burn area ▪ slip-on unit driving around the burn area following bulldozer.

7.1.2 Air sampling results

Table 9 Air sampling results of personal exposure and smoke signature measurements taken at the prescribed burn in Gembrook, VIC on 12/04/07

Sample #	PE-120407-1	PE-120407-2	PE-120407-3	PE-120407-4
Description	7h sample – lighting	7 h sample – patrol (west)	7 h sample – 4 h patrol (west), 2 hr lighting	7 h sample – patrol east
	Smoker	Smoker	Non-smoker	Smoker
Avg CO [ppm]	1.9	1.7	1.6	1.3
Max CO [ppm]	150 (241)	594 (1070)	199 (414)	59 (75)
15-min CO max [ppm]	17	27	6	7.5
Avg RP [mg/m ³]	N/A	0.32	N/A	0.25
Max RP [mg/m ³]	N/A	55	N/A	22
Avg RP (grav) [mg/m ³]	N/A	N/A	N/A	N/A
Formaldehyde [ppb]	N/A	N/A	N/A	N/A
Acetaldehyde [ppb]	N/A	N/A	N/A	N/A
Acrolein [ppb]	N/A	N/A	N/A	N/A
2-Furaldehyde [μg/m ³]	N/A			N/A
Benzene [μg/m ³]	N/A			N/A
Toluene [μg/m ³]	N/A			N/A
Acetic acid [μg/m ³]	N/A			N/A
Phenol [μg/m ³]	N/A			N/A
Xylenes [μg/m ³]	N/A			N/A
TVOCs [μg/m ³]	N/A			N/A

Sample #	SS-120407-1	SS-120407-2
Description	7h sample – tanker	7 h sample – slip-on unit
Avg CO [ppm]	0.8	N/A
Max CO [ppm]	19.8	N/A
Avg CO ₂ [ppm]	429	N/A
Max CO ₂ [ppm]	581	N/A
Avg RP [mg/m ³]	0.12	0.06 (13:15-15:48)
Max RP [mg/m ³]	5.5	4.3
Avg RP (grav) [mg/m ³]	0.08	0.12 (13:20-19:44)
Formaldehyde [ppb]	13	N/A
Acetaldehyde [ppb]	5	N/A
Acrolein [ppb]	ND	N/A

7.1.3 Graphs of personal exposure and area measurements for CO and RP (data logging records)

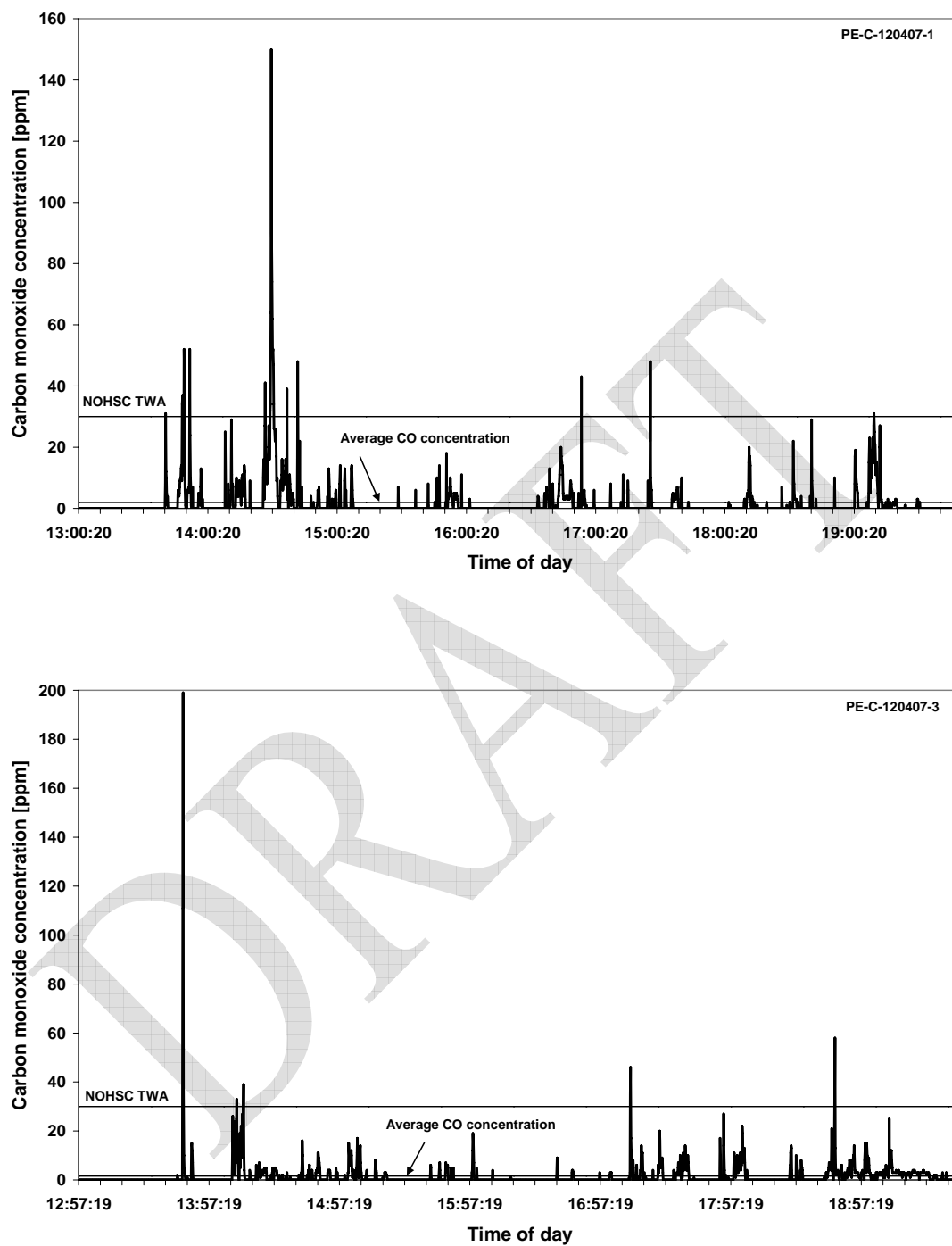


Figure 21 Data-logging records of a firefighters' exposure to CO (Gembrook, VIC)

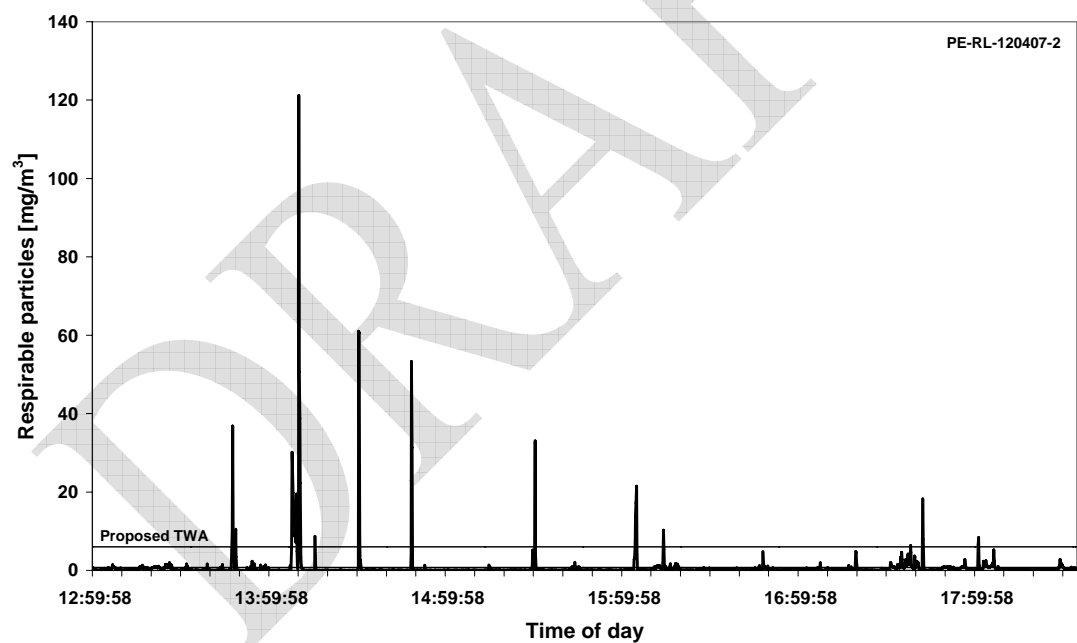
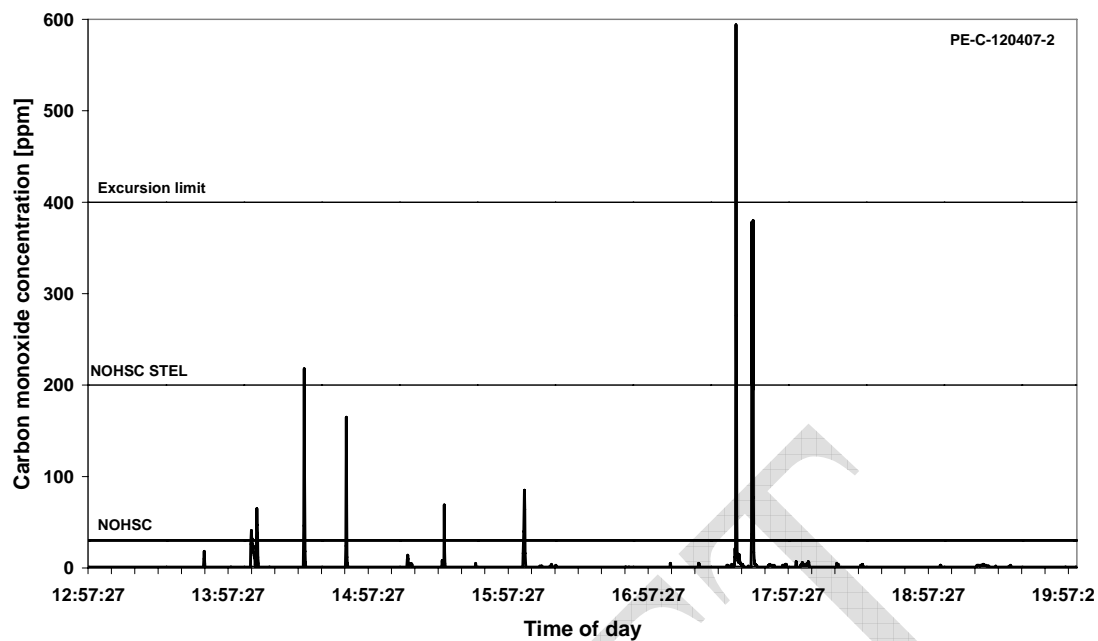


Figure 22 Data-logging record of a firefighter's exposure to CO and RP (Gembrook, VIC)

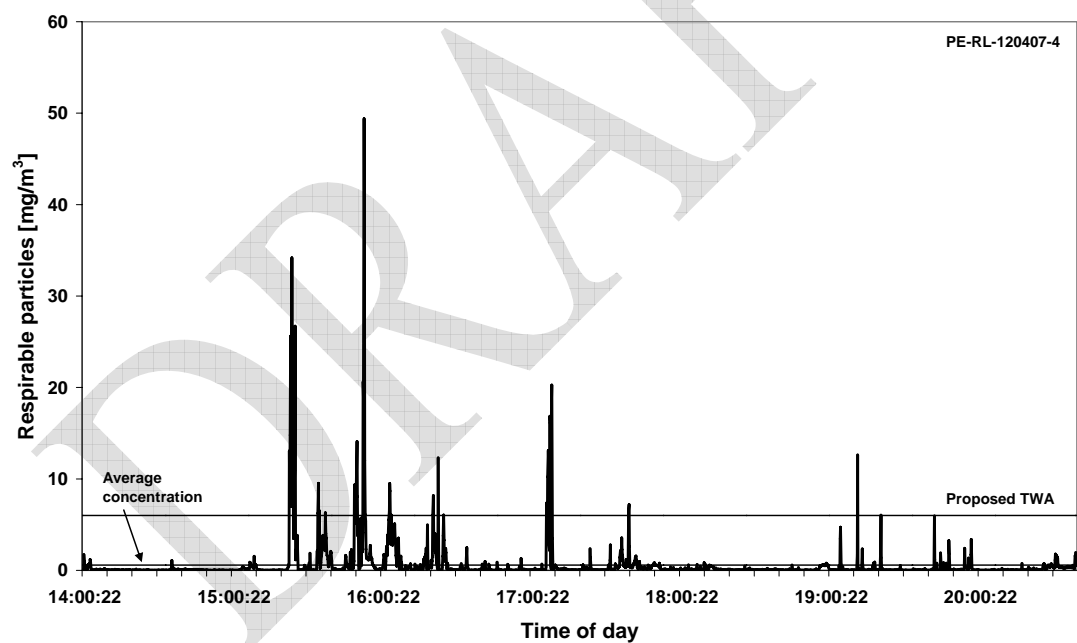
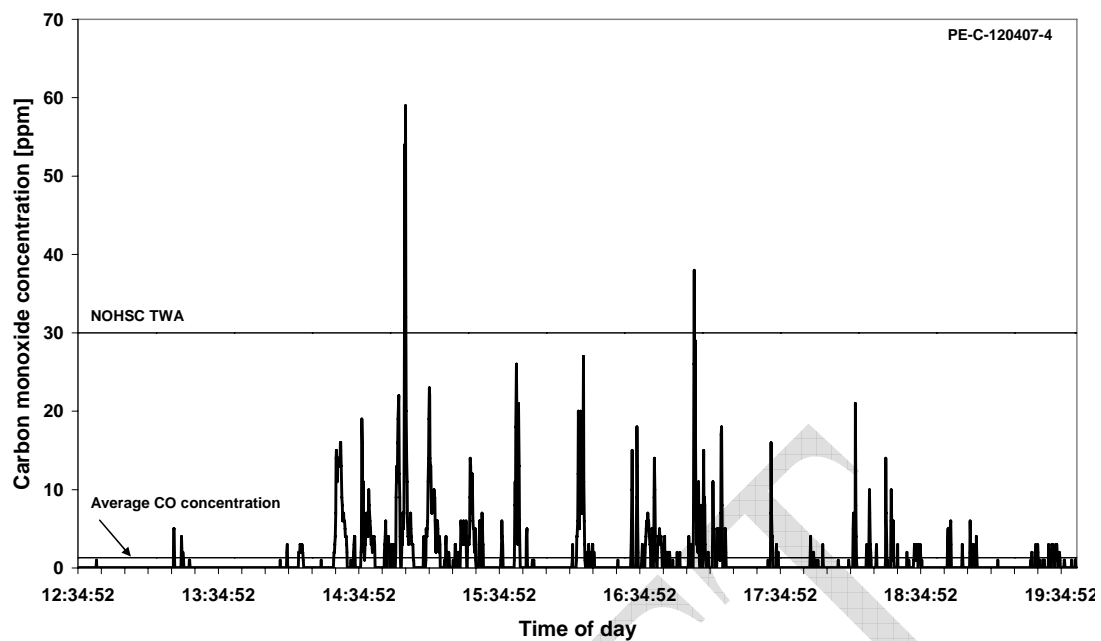


Figure 23 Data-logging record of a firefighter's exposure to CO and RP (Gembrook, VIC)

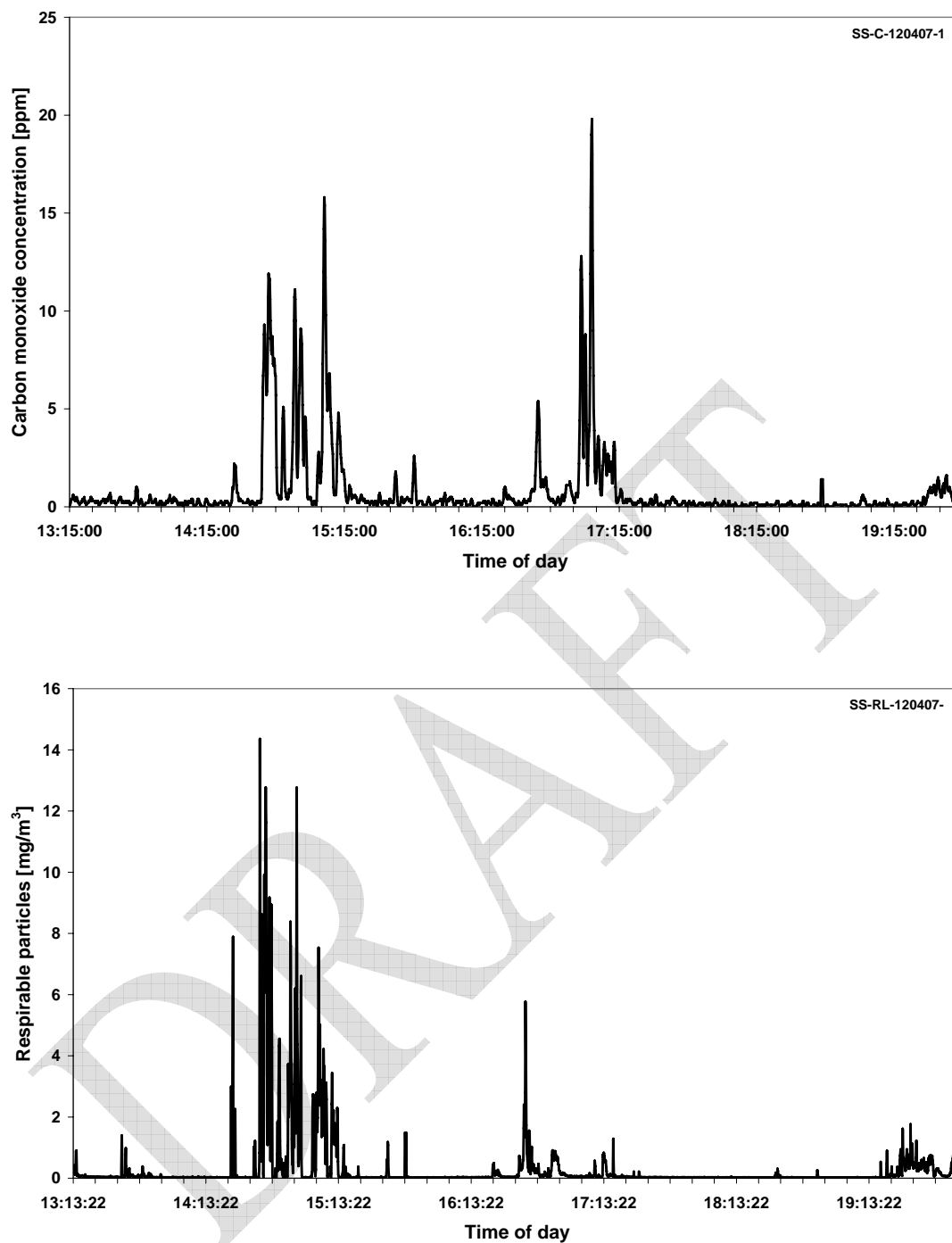


Figure 24 Data-logging record of CO and respirable particle levels at a prescribed burn (Gembrook, VIC)

7.2 Kyeema, Dandenong Ranges NP, VIC – 18/04/07

7.2.1 Fire site record

SITE	Dandenong Ranges NP; Burn name: D52 Kyeema
DATE	18/04/2007
TYPE OF BURN	Prescribed
FUEL DESCRIPTION	Dry shrubby foothill eucalypt forest
BURN AREA (TOTAL)	50 ha
BURN AREA TODAY	50 ha
DESCRIPTION OF AREA	hilly, steep terrain, thick vegetation
WEATHER DESCRIPTION	11:00 17°C, 58.5% RH, 3km/h g 8 km/h 13:00 17°C, 45% RH, 10 km/h g 20 km/h, W-NW 18:00 18°C, 45% RH, 10 km/h g 20 km/h, W Overnight 8°C, 90% RH, 10 km/h g/ 20 km/h S-SW going to 5 km/h g 10 km/h E-SE
FIRE AGENCIES IN ATTENDANCE	DSE Dandenong & Prom (Slip-on units & tankers) CFA tankers
NUMBER IN FIRE CREW	~ 70
PERSONAL PROTECTIVE EQUIPMENT	Yes (goggles, face masks); worn by all patrol crews
LENGTH OF DAY SHIFT	approx 13 hours (from 11:00 – 24:00). Briefing at 11:00 followed by lighting at about 12:00-12:30.
NUMBER OF CREW SAMPLED	4 personal; 3 sample boxes (1 on DSE tanker; 1 on CFA tanker and 1 on slip-on unit)
TASKS OF SAMPLED CREW C.F. REST OF CREW	4 personal samples were all taken on DSE crew members patrolling Kyeema track in slip-on units (involved hosing down area, suppression with hose and rake-hoe) Main tasks at burn: <ul style="list-style-type: none"> - Lighting crew - Patrol crew in vehicles on Kyeema Track - Foot patrol above Kyeema track (rake-hoe) - CFA tanker crew – asset protection
CREW SAMPLE EXPERIENCE	<ul style="list-style-type: none"> - HEADACHE ? - IRRITATION Y, Y, Y, Y - OTHER (specify) N, N, N, N
SAMPLE BOXES	<ul style="list-style-type: none"> ▪ tanker patrolling Kyeema track ▪ slip-on unit patrolling Kyeema track (personal samples) ▪ CFA tanker on asset protection patrol on Observatory Road

7.2.2 Air sampling results

Table 10 Air sampling results of personal exposure and smoke signature measurements taken at the prescribed burn in Dandenong Ranges NP, VIC on 18/04/07

Sample #	PE-180407-1	PE-180407-2	PE-180407-3	PE-180407-4
Description	6.5 h sample – patrol		4.5 h sample – patrol	7 h sample – patrol
	Non-smoker	Smoker	Non-smoker	Non-smoker
Avg CO [ppm]	68	70	120	60
Max CO [ppm]	900 (976)	750 (804)	696 (760)	674 (1795)
Avg RP [mg/m ³]	N/A	12.2	N/A	N/A
Max RP [mg/m ³]	N/A	174	N/A	N/A
Avg RP (grav) [mg/m ³]	16	N/A	N/A	-
Formaldehyde [ppb]	N/A	> 35	> 55	N/A
Acetaldehyde [ppb]	N/A	> 5	> 6	N/A
Acrolein [ppb]	N/A	ND	ND	N/A
2-Furaldehyde [μg/m ³]				
Benzene [μg/m ³]				
Toluene [μg/m ³]				
Acetic acid [μg/m ³]				
Phenol [μg/m ³]				
Xylenes [μg/m ³]				
TVOCs [μg/m ³]				

Sample #	SS-180407-1	SS-180407-2	SS-180407-3
Description	6h sample – DSE tanker	7 h sample – CFA tanker	7 h sample – Slip-on unit
Avg CO [ppm]	35	1.6	N/A
Max CO [ppm]	455	23	N/A
Avg CO ₂ [ppm]	593	426	N/A
Max CO ₂ [ppm]	3700	710	N/A
Avg RP [mg/m ³]	8.8	0.3	> 10
Max RP [mg/m ³]	93	5.4	
Avg RP (grav) [mg/m ³]	7.9	0.2	
Formaldehyde [ppb]	> 33	20	N/A
Acetaldehyde [ppb]	> 6	8	NA
Acrolein [ppb]	ND	ND	N/A

7.2.3 Graphs of personal exposure and area measurements for CO and RP (data logging records)

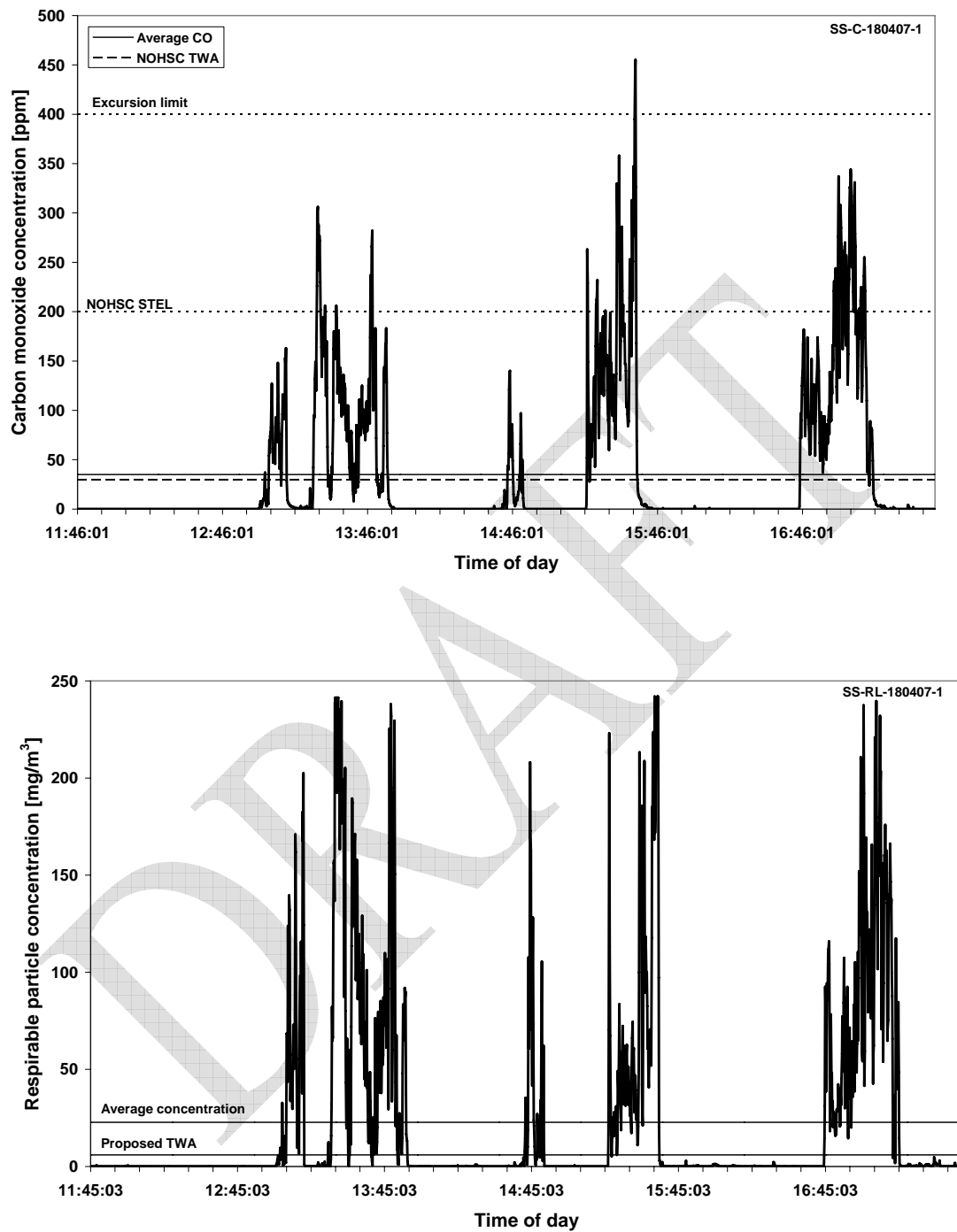


Figure 25 Data-logging record of CO and respirable particle levels at a prescribed burn (Dandenong Ranges NP, VIC)

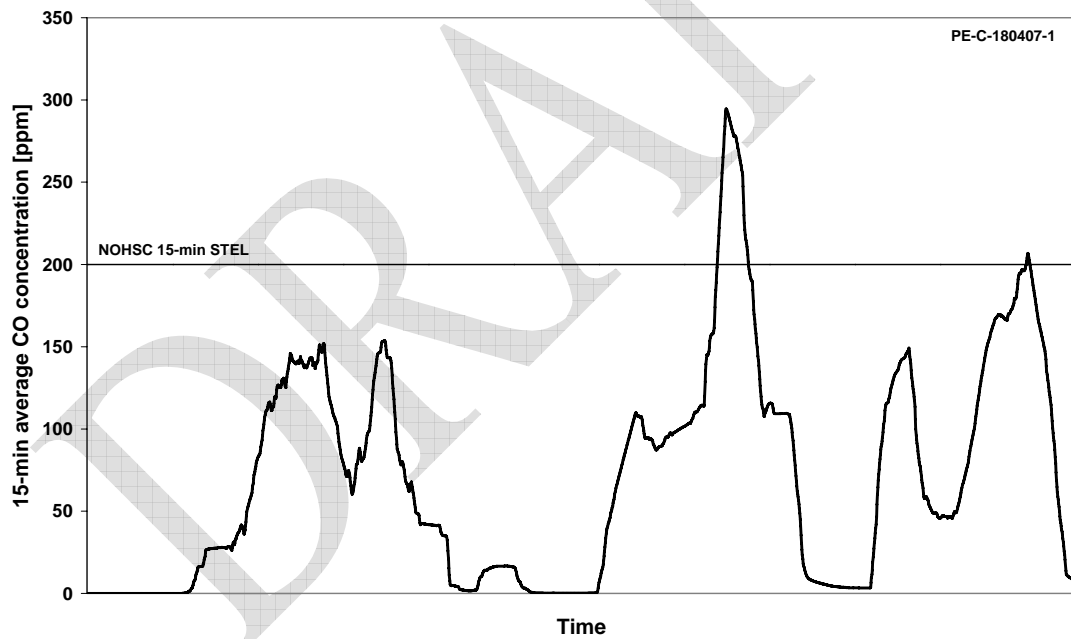
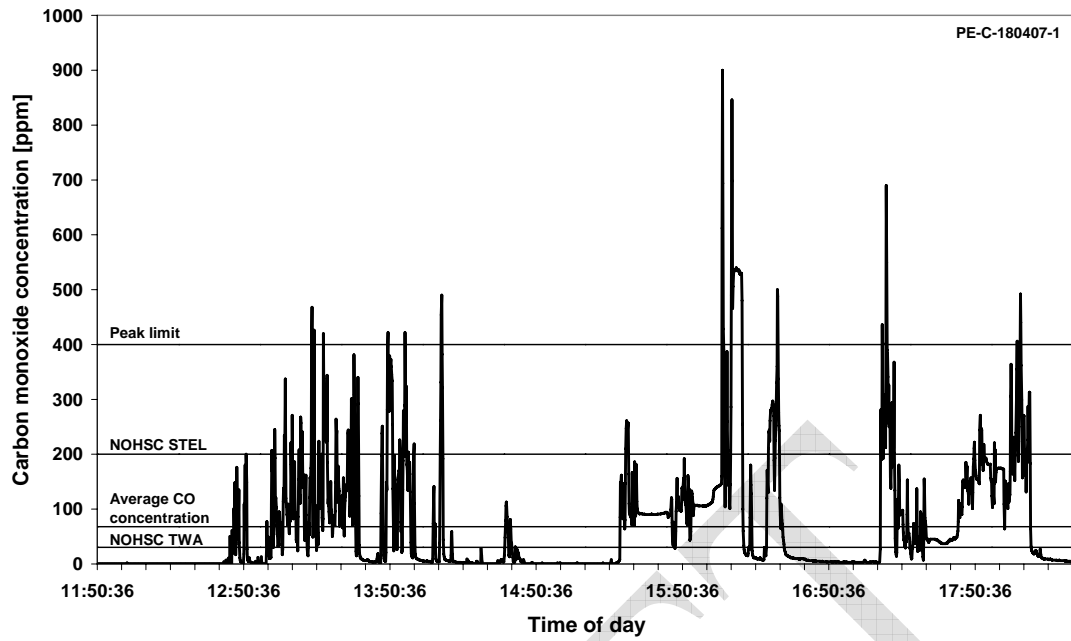


Figure 26 Data-logging record of a firefighter's exposure to CO: (a) 10-seconds running average CO concentrations and (b) 15-minute running average CO concentrations (Dandenong Ranges NP, VIC)

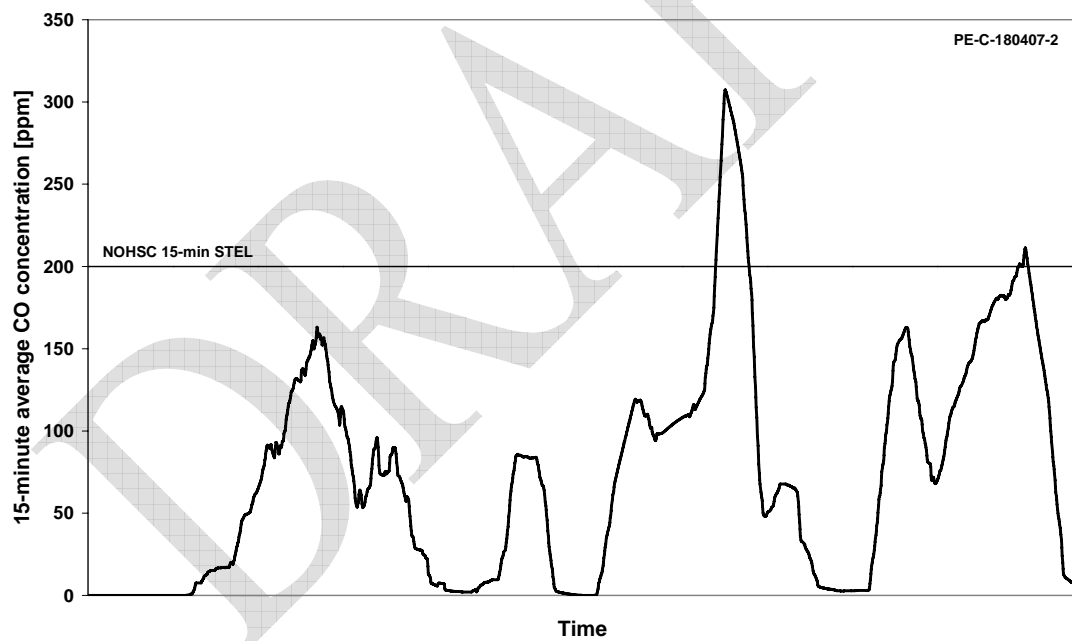
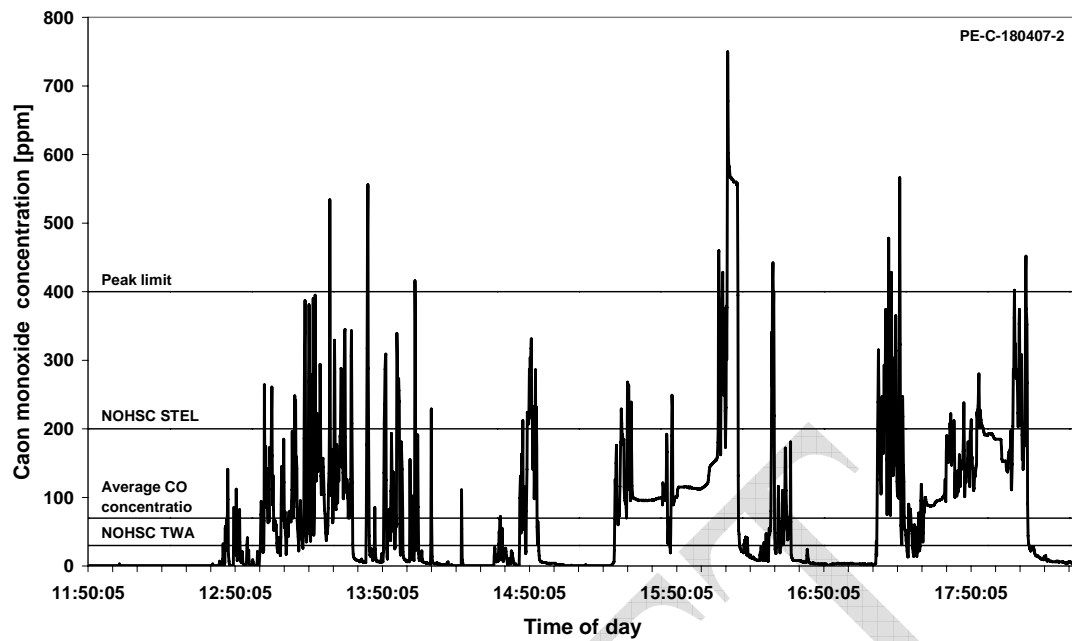


Figure 27 Data-logging record of a firefighter's exposure to CO: (a) 10-seconds running average CO concentrations and (b) 15-minute running average CO concentrations (Dandenong Ranges NP, VIC)

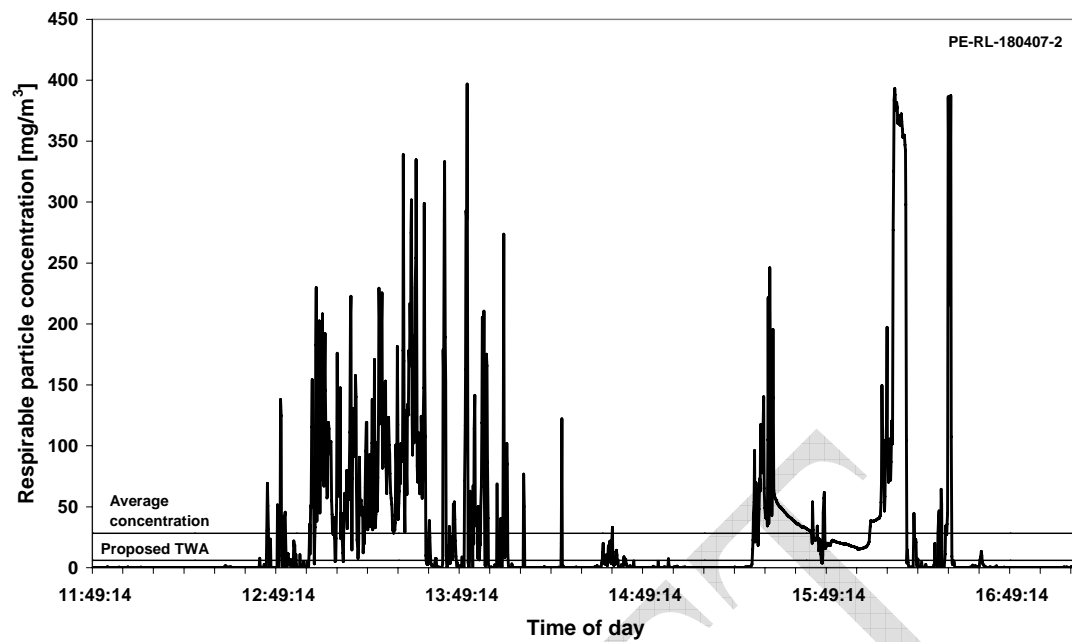


Figure 28 Data-logging record of a firefighter's exposure to RP (Dandenong Ranges NP, VIC)

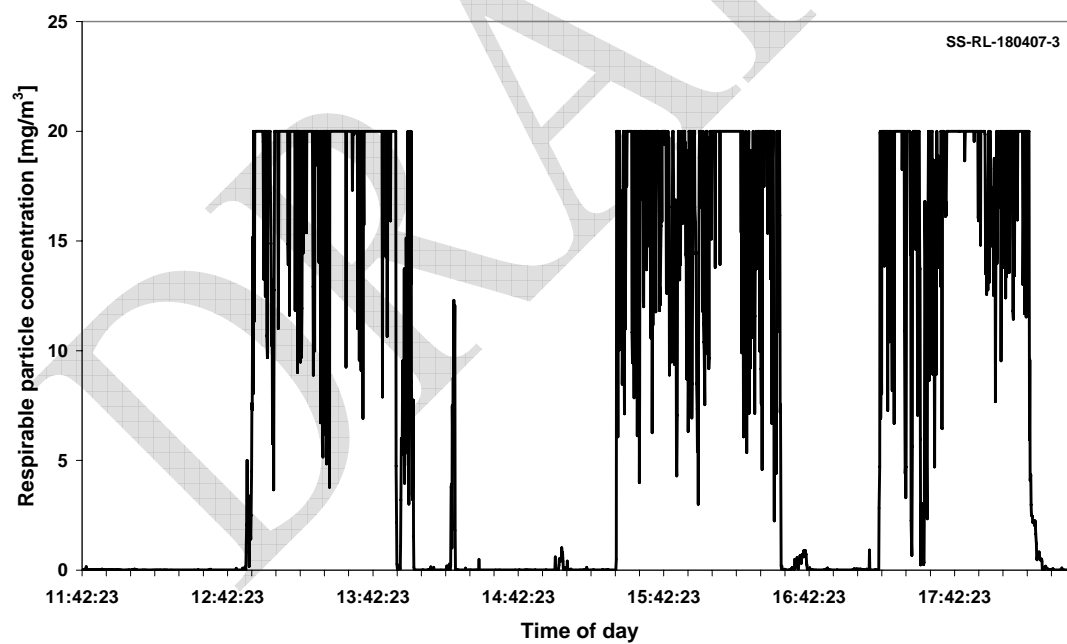


Figure 29 Data-logging record of respirable particle levels at a prescribed burn (Dandenong Ranges NP, VIC)

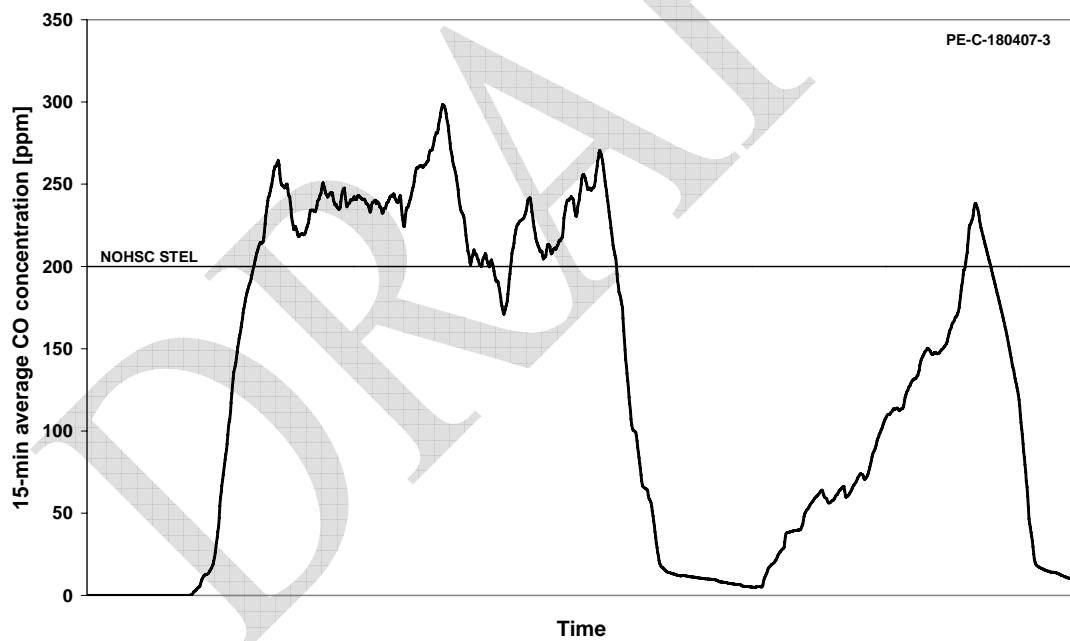
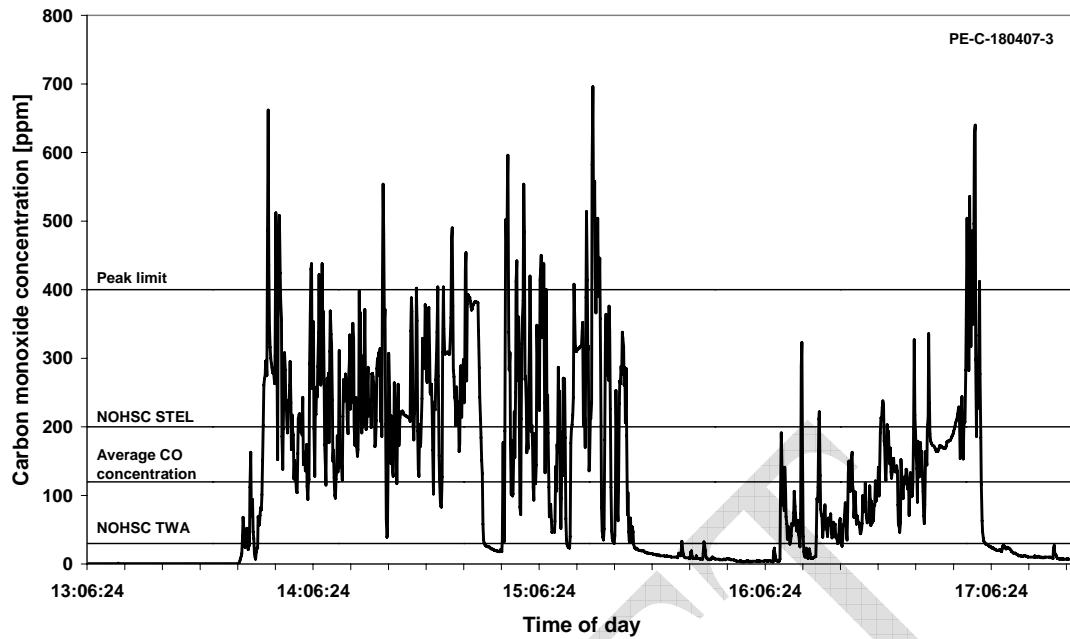


Figure 30 Data-logging record of a firefighter's exposure to CO: (a) 10-seconds running average CO concentrations and (b) 15-minute running average CO concentrations (Dandenong Ranges NP, VIC)

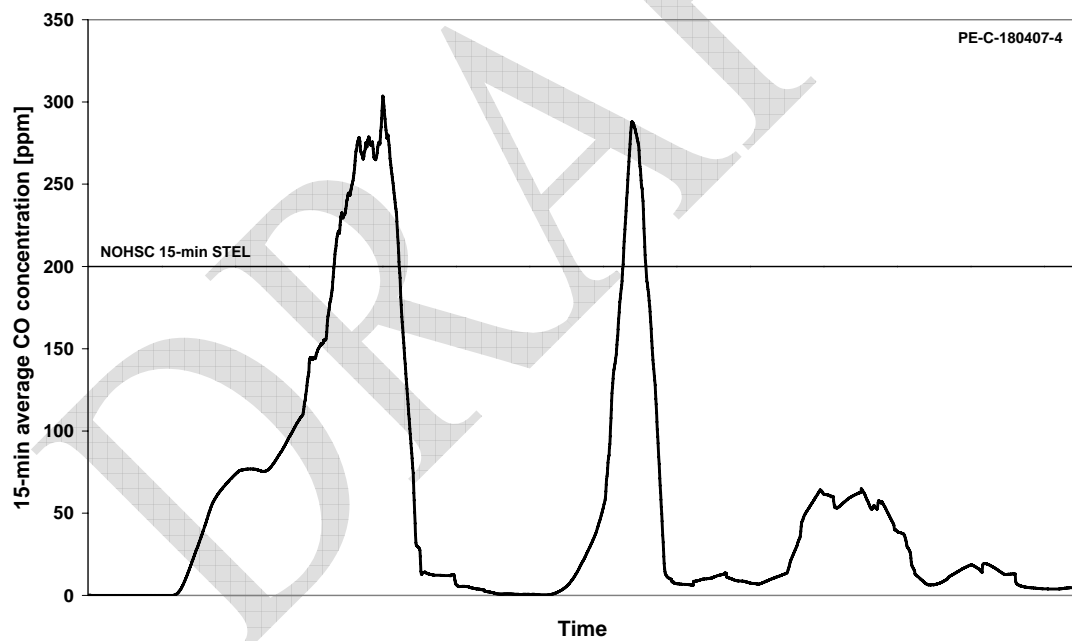
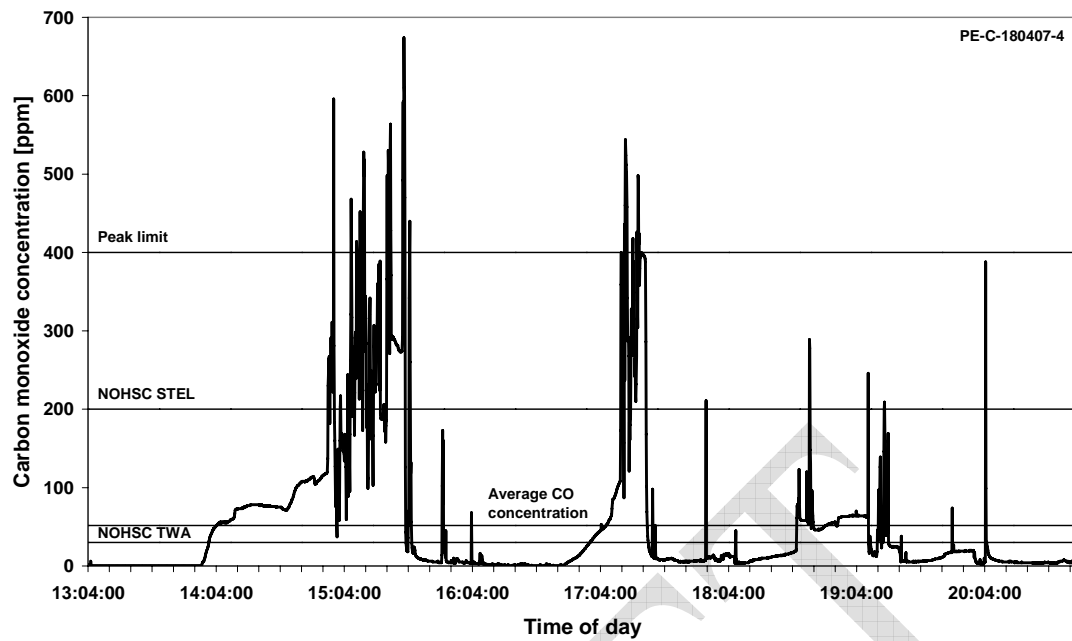


Figure 31 Data-logging record of a firefighter's exposure to CO: (a) 10-seconds running average CO concentrations and (b) 15-minute running average CO concentrations (Dandenong Ranges NP, VIC)

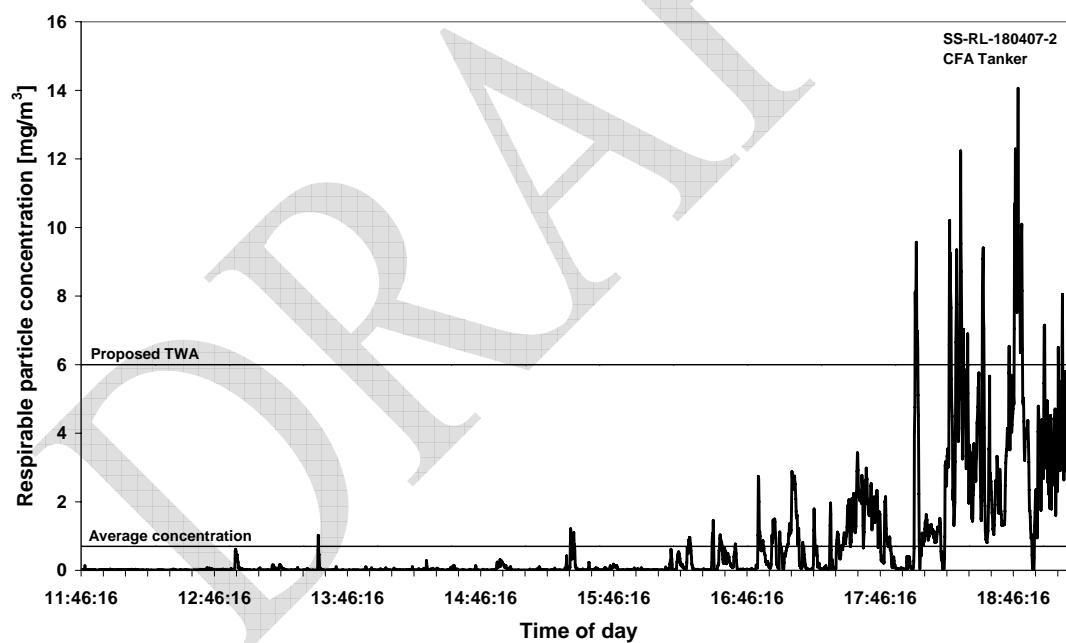
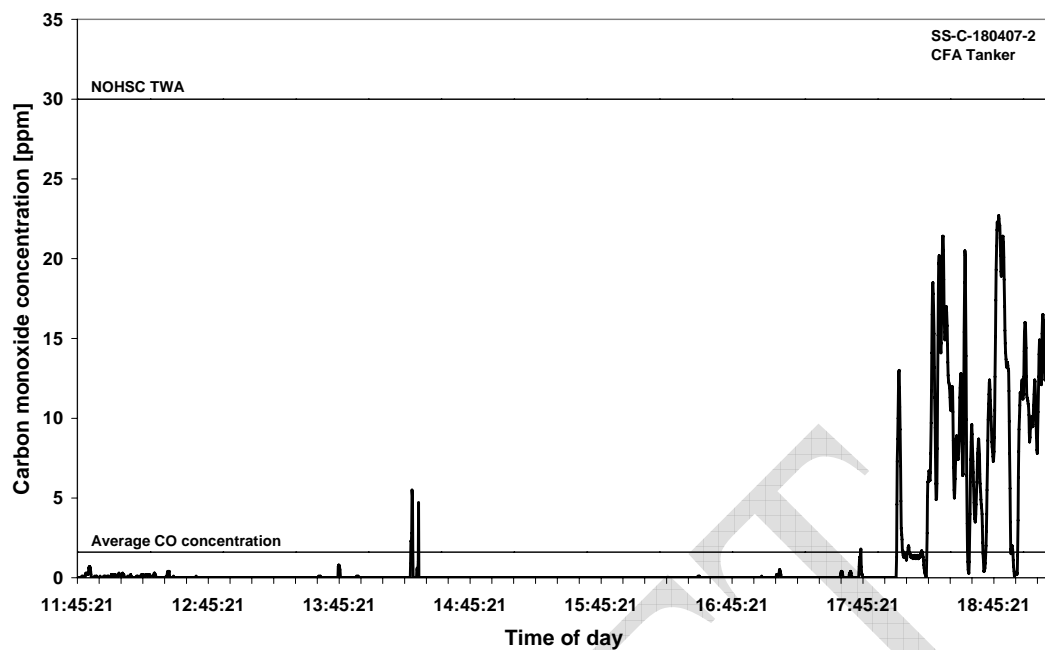


Figure 32 Data-logging record of CO and respirable particle levels at a prescribed burn (Dandenong Ranges NP, VIC)

7.3 Aquaduct East, Langwarrin Flora & Fauna Reserve, VIC – 25/04/07

7.3.1 Fire site record

SITE	Langwarrin; Burn name: R95 Aquaduct east
DATE	25/04/2007
TYPE OF BURN	Prescribed
FUEL DESCRIPTION	Shrubby heathland
BURN AREA (TOTAL)	13 ha
BURN AREA TODAY	13 ha
DESCRIPTION OF AREA	Flat
WEATHER DESCRIPTION	Low winds 5 km/h
FIRE AGENCIES IN ATTENDANCE	DSE (Slip-on units & tanker)
NUMBER IN FIRE CREW	~ 25
PERSONAL PROTECTIVE EQUIPMENT	
LENGTH OF DAY SHIFT	Briefing at 11:00 followed by lighting at about 11:30 on north-western corner.
NUMBER OF CREW SAMPLED	5 personal; 3 sample boxes (1 on DSE tanker; 2 on slip-on units)
TASKS OF SAMPLED CREW C.F. REST OF CREW	<p>Personal samples were all taken on DSE crew members patrolling in slip-on units</p> <p>Main tasks at burn:</p> <ul style="list-style-type: none"> - Lighting crew - Patrol crew in vehicles <p>PE-250407-1: Waiting at staging area on north west corner in case problems would occur</p> <p>PE-250407-2 & PE-250407-3: followed lighting crew along the Aquaduct Track</p> <p>PE-250407-4: Supervising fire line along Aquaduct track</p> <p>PE-250407-5 (just CO): patrol in SOU on eastern edge with lighting crew</p>
CREW SAMPLE EXPERIENCE	<ul style="list-style-type: none"> - HEADACHE ?, N, N, N - IRRITATION ?, N, N, N - OTHER (specify) ?, N, N, N
SAMPLE BOXES	<ul style="list-style-type: none"> ▪ DSE tanker called in at about 13:30 (Box A) ▪ 1 slip-on units patrolling on western edge (PE-250407-3) (Tube C) ▪ 1 slip-on unit on eastern edge (PE-250407-5)

7.3.2 Air sampling results

Table 11 Air sampling results of personal exposure and smoke signature measurements taken at the prescribed burn in Langwarrin Fauna & Flora Reserve, VIC on 25/04/07

Sample #	PE-250407-1	PE-250407-2	PE-250407-3	PE-250407-4	PE-250407-5
Description	Patrol	Lighting & Patrol	Patrol	Supervisor	Patrol
Smoker	Y	N	N	Y	N
Avg CO [ppm]	13.2	6.2	22.2	6.6	5.3
Max CO [ppm]	292 (337)	76 (83)	283 (305)	111 (122)	166 (176)
Avg RP [mg/m ³]	0.1	1.1	N/A	N/A	N/A
Max RP [mg/m ³]	2.4	30	N/A	N/A	N/A
Avg RP (grav) [mg/m ³]		N/A	N/A	1.4	N/A
Formaldehyde [ppb]	N/A	> 85	41	N/A	N/A
Acetaldehyde [ppb]	N/A	> 9	23	N/A	N/A
Acrolein [ppb]	N/A	ND	ND	N/A	N/A
2-Furaldehyde [μg/m ³]			N/A	N/A	N/A
Benzene [μg/m ³]			N/A	N/A	N/A
Toluene [μg/m ³]			N/A	N/A	N/A
Acetic acid [μg/m ³]			N/A	N/A	N/A
Phenol [μg/m ³]			N/A	N/A	N/A
Xylenes [μg/m ³]			N/A	N/A	N/A
TVOCs [μg/m ³]			N/A	N/A	N/A

Sample #	SS-250407-1	SS-250407-2	SS-250407-3
Description	DSE tanker	Slip-on unit	Slip-on unit (PE-250407-3)
Avg CO [ppm]	Did not log	6.1	N/A
Max CO [ppm]	Did not log	137	N/A
Avg CO ₂ [ppm]	Did not log	400	N/A
Max CO ₂ [ppm]	Did not log	673	N/A
Avg RP [mg/m ³]	Did not log	0.2	N/A
Max RP [mg/m ³]	Did not log	5.7	N/A
Avg RP (grav) [mg/m ³]	0.13	0.4	3.6
Formaldehyde [ppb]	21	22	N/A
Acetaldehyde [ppb]	6	10	NA
Acrolein [ppb]	ND	ND	N/A

7.3.3 Graphs of personal exposure and area measurements for CO and RP (data logging records)

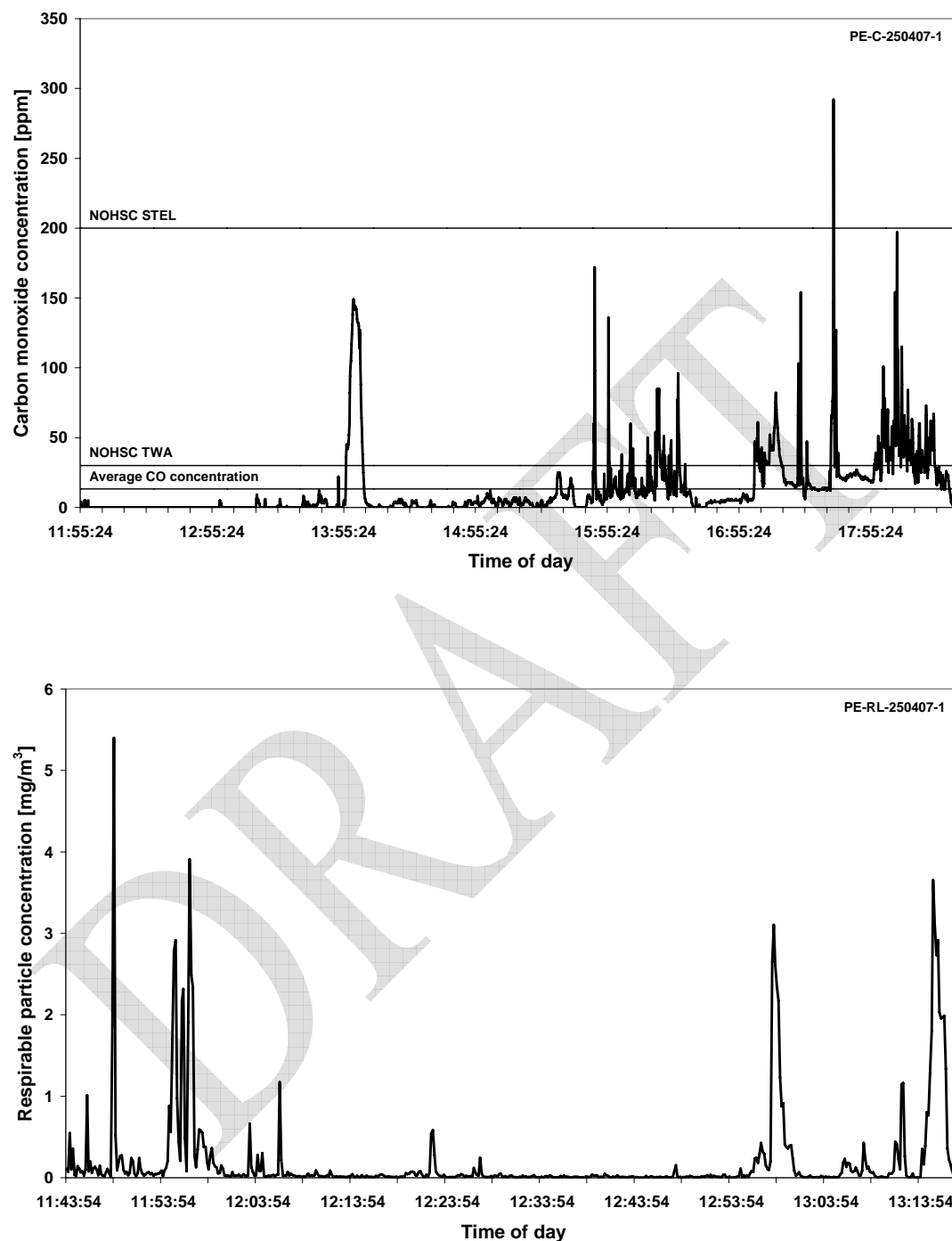


Figure 33 Data-logging record of a firefighter's exposure to CO and RP (Langwarrin, VIC)

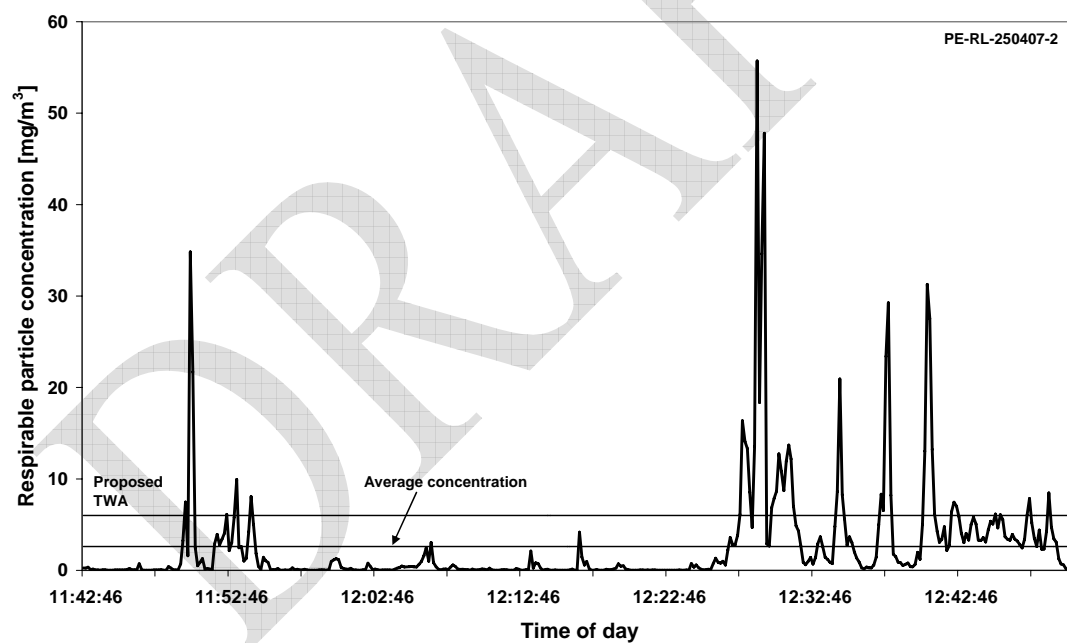
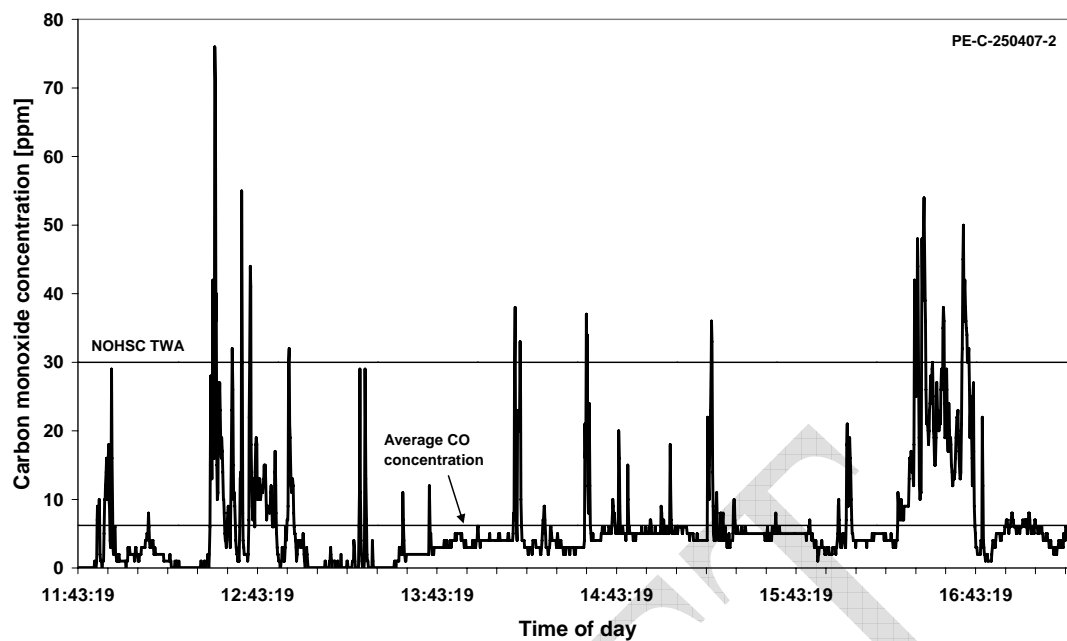


Figure 34 Data-logging record of a firefighter's exposure to CO and RP (Langwarrin, VIC)

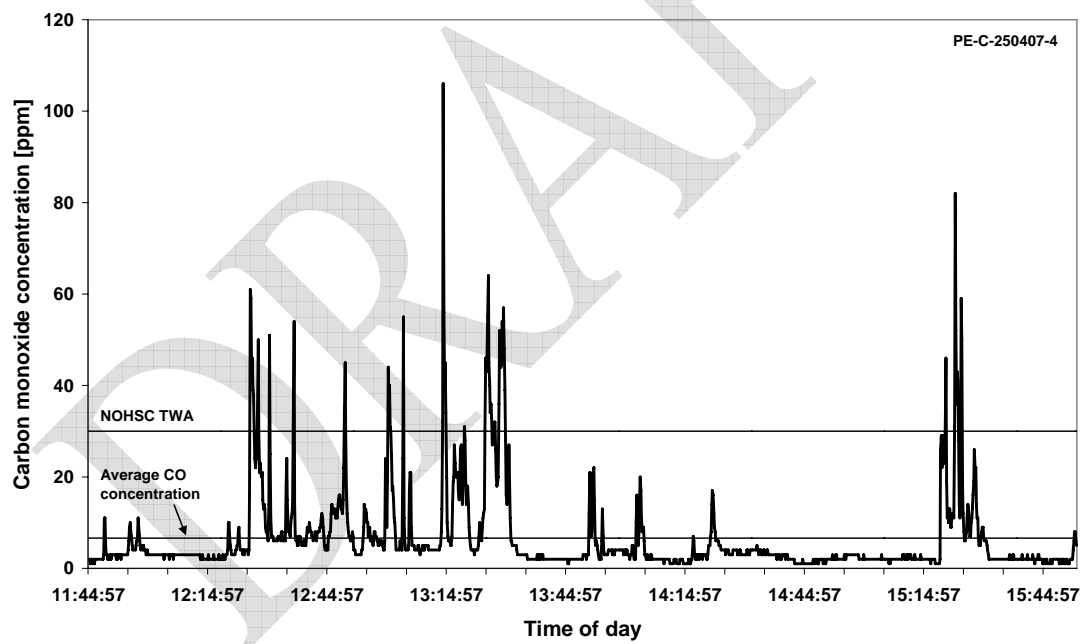
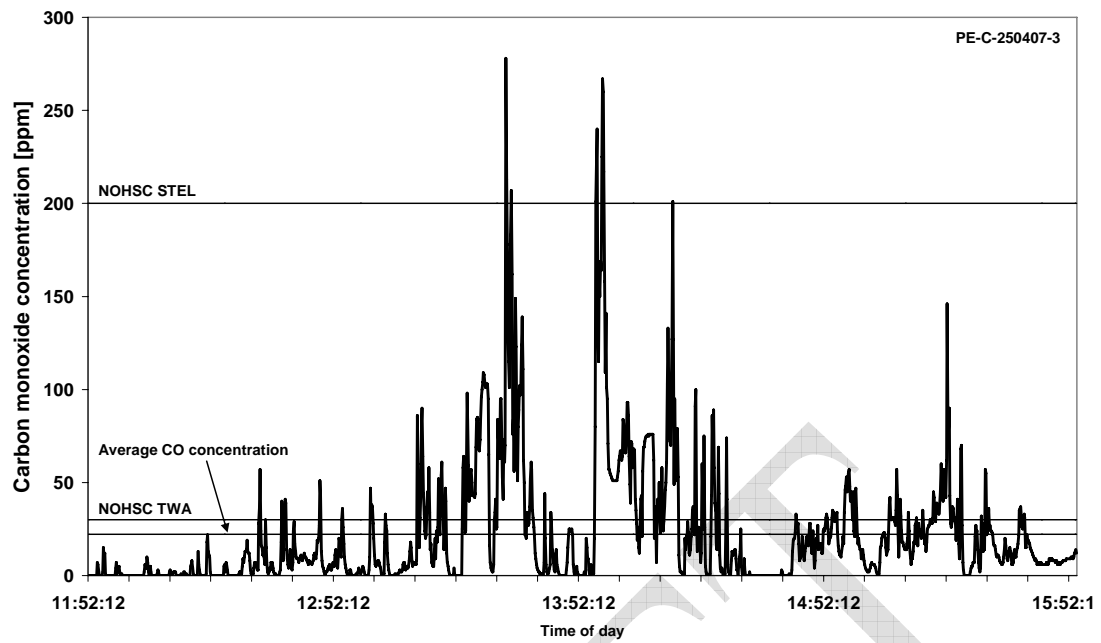


Figure 35 Data-logging record of firefighters' exposure to CO (Langwarrin, VIC)

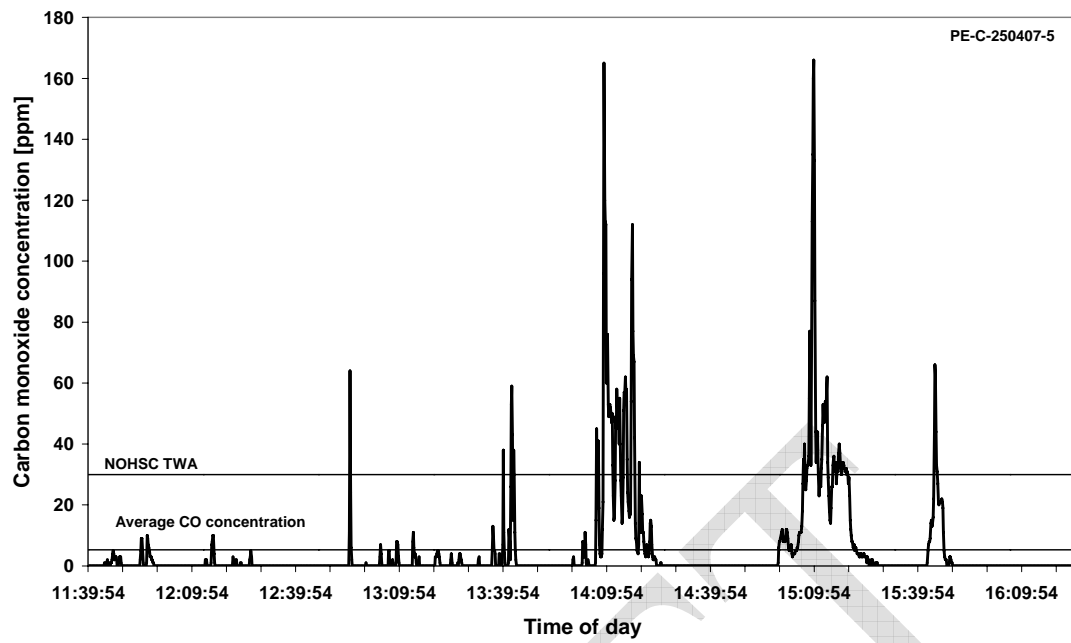


Figure 36 Data-logging record of a firefighter's exposure to CO (Langwarrin, VIC)

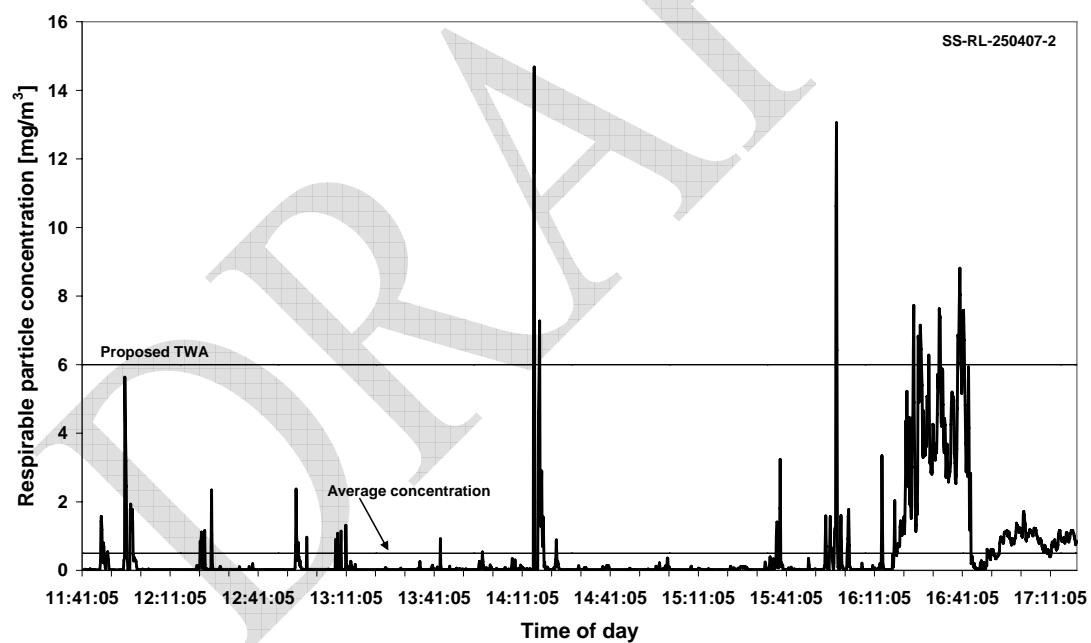
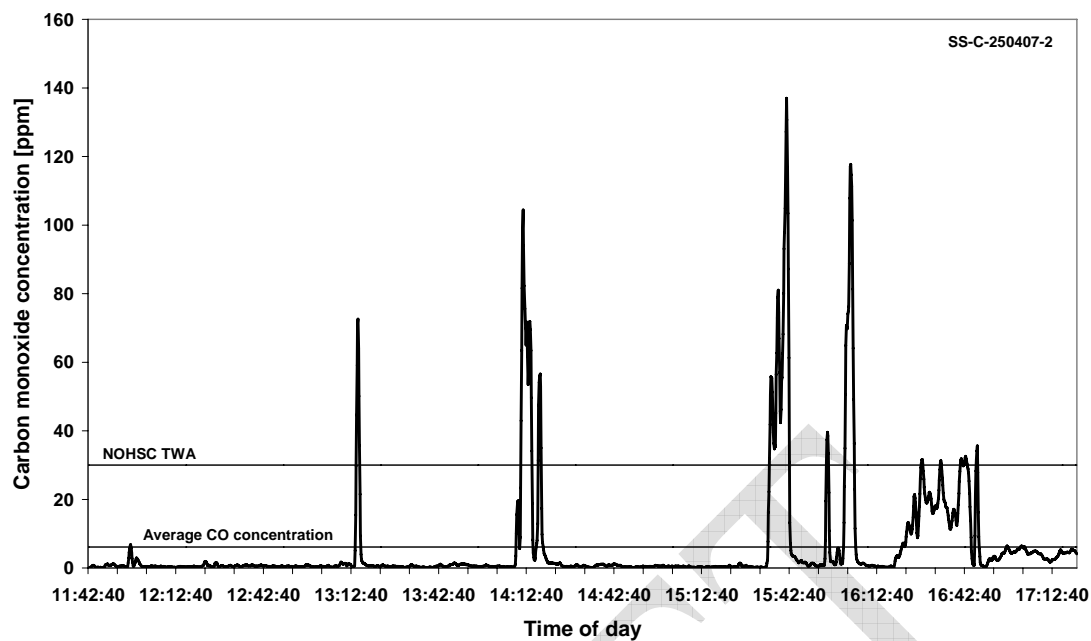


Figure 37 Data-logging record of CO and RP levels at a prescribed burn (Langwarrin, VIC)

7.4 Healesville Watts Outlet, Yarra Ranges NP, VIC – 26/04/07

7.4.1 Fire site record

SITE	Healesville, Yarra Ranges NP; MW13 Watts Outlet
DATE	26/04/2007
TYPE OF BURN	Prescribed
FUEL DESCRIPTION	Open eucalypt forest; high to extreme fuel hazard.
BURN AREA (TOTAL)	76 ha
BURN AREA TODAY	76 ha
DESCRIPTION OF AREA	Low to moderately steep. Area surrounded by reservoir, river and housing area.
WEATHER DESCRIPTION	Max temp (20C); 40% RH; overnight 11C Winds low 5 g 10 km/h (NE)
FIRE AGENCIES IN ATTENDANCE	DSE (Slip-on units & tanker) Melbourne water slip on units and tanker
NUMBER IN FIRE CREW	25-30
PERSONAL PROTECTIVE EQUIPMENT	
LENGTH OF DAY SHIFT	Briefing at 11:30 followed by lighting at about 12:00 on top of mountain. Ignition done until about 17:00. Shift ended at about 19:30
NUMBER OF CREW SAMPLED	4 personal; 3 sample boxes (2 on DSE tankers; 1 on slip-on unit)
TASKS OF SAMPLED CREW C.F. REST OF CREW	Personal samples were all taken on DSE crew members patrolling in slip-on units Main tasks at burn: <ul style="list-style-type: none"> - Lighting crew - Patrol crew in vehicles (not much exposure at the initial phase of the burn) PE-260407-1: Patrol (reservoir sector) PE-260407-2: Bulldozer driver, along the western edge, close to housing area PE-260407-3: Patrol (reservoir sector) PE-260407-4: Patrol (with bulldozer driver)
CREW SAMPLE EXPERIENCE	<ul style="list-style-type: none"> - HEADACHE N, N, N, - IRRITATION N, N, N - OTHER (specify) N, N, N
SAMPLE BOXES	<ul style="list-style-type: none"> ▪ DSE tankers in reservoir sector (Box A) and weir sector (Box B) ▪ Slip-on unit following bulldozer driver

7.4.2 Air sampling results

Table 12 Air sampling results of personal exposure and smoke signature measurements taken at the prescribed burn in Yarra Ranges NP (Healesville, VIC) on 26/04/07

Sample #	PE-260407-1	PE-260407-2	PE-260407-3	PE-260407-4
Description	7.5 h sample – patrol	Bulldozer driver	7.5 h sample – patrol	7 h sample – patrol
Avg CO [ppm]	0.4	4.8	1.7	2.9
Max CO [ppm]	128 (171)	110	53 (68)	868 (1000)
Avg RP [mg/m ³]	0.1	1.1	N/A	N/A
Max RP [mg/m ³]	8.4	58	N/A	N/A
Avg RP (grav) [mg/m ³]	-	N/A	N/A	0.5
Formaldehyde [ppb]	N/A	> 29	15	N/A
Acetaldehyde [ppb]	N/A	> 85	8	N/A
Acrolein [ppb]	N/A	ND	ND	N/A
2-Furaldehyde [µg/m ³]	N/A		N/A	N/A
Benzene [µg/m ³]	N/A		N/A	N/A
Toluene [µg/m ³]	N/A		N/A	N/A
Acetic acid [µg/m ³]	N/A		N/A	N/A
Phenol [µg/m ³]	N/A		N/A	N/A
Xylenes [µg/m ³]	N/A		N/A	N/A
TVOCs [µg/m ³]	N/A		N/A	N/A

Sample #	SS-260407-1	SS-260407-2	SS-260407-3
Description	DSE tanker – Res sector	DSE tanker – Weir sector	Slip-on with bulldozer
Avg CO [ppm]	2	0.7	N/A
Max CO [ppm]	59	41.4	N/A
Avg CO ₂ [ppm]	370	394	N/A
Max CO ₂ [ppm]	996	812	N/A
Avg RP [mg/m ³]	0.6	0.03	0.05
Max RP [mg/m ³]	21	0.8	0.33
Avg RP (grav) [mg/m ³]	0.4	0.08	0.09
Formaldehyde [ppb]	33	3	N/A
Acetaldehyde [ppb]	16	2	NA
Acrolein [ppb]	ND	ND	N/A

7.4.3 Graphs of personal exposure and area measurements for CO and RP (data logging records)

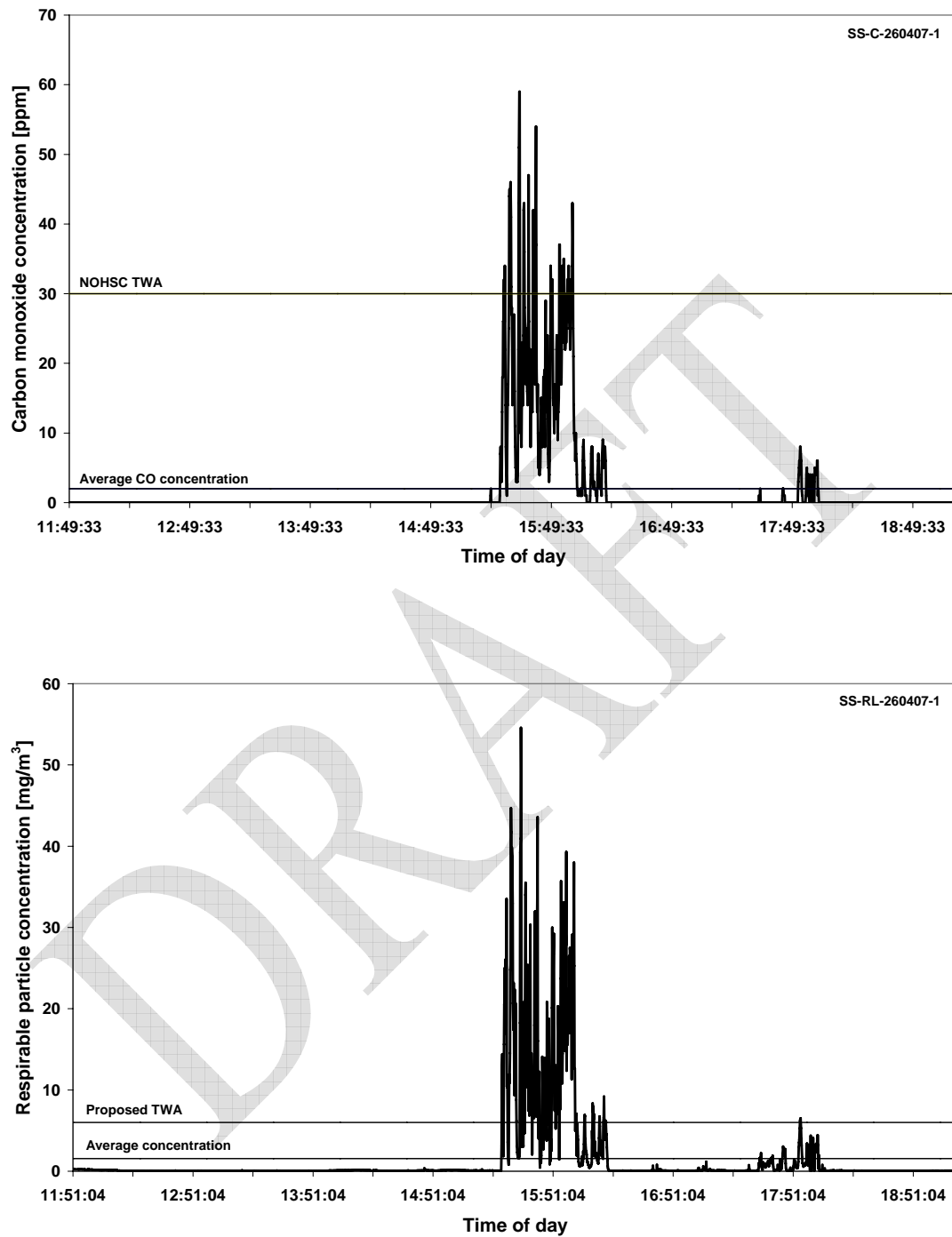


Figure 38 Data-logging record of CO and RP levels at a prescribed burn (Healesville, VIC)

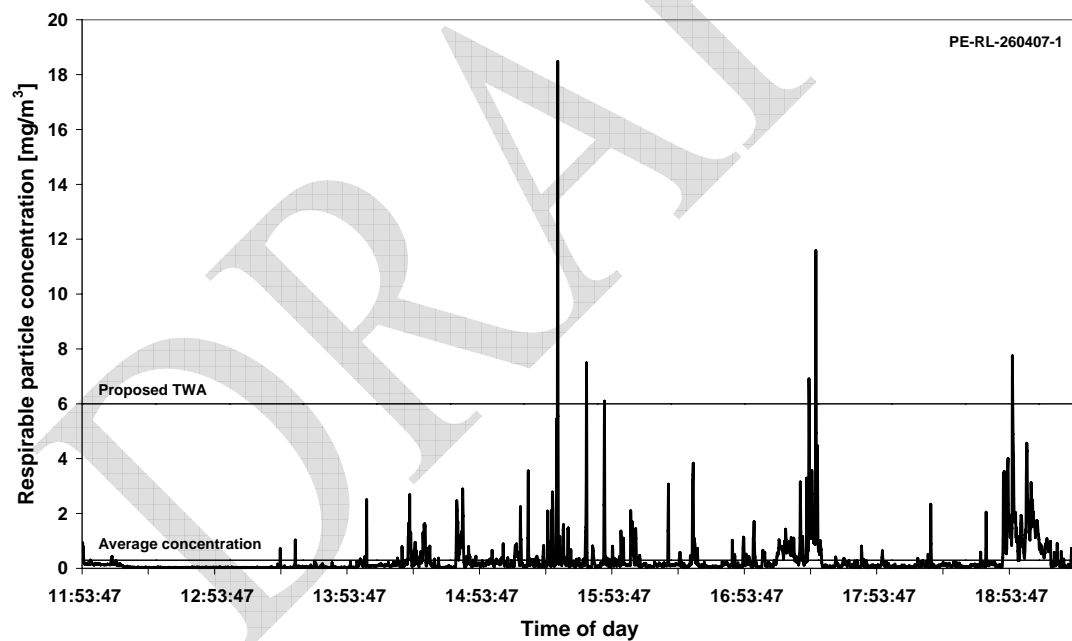
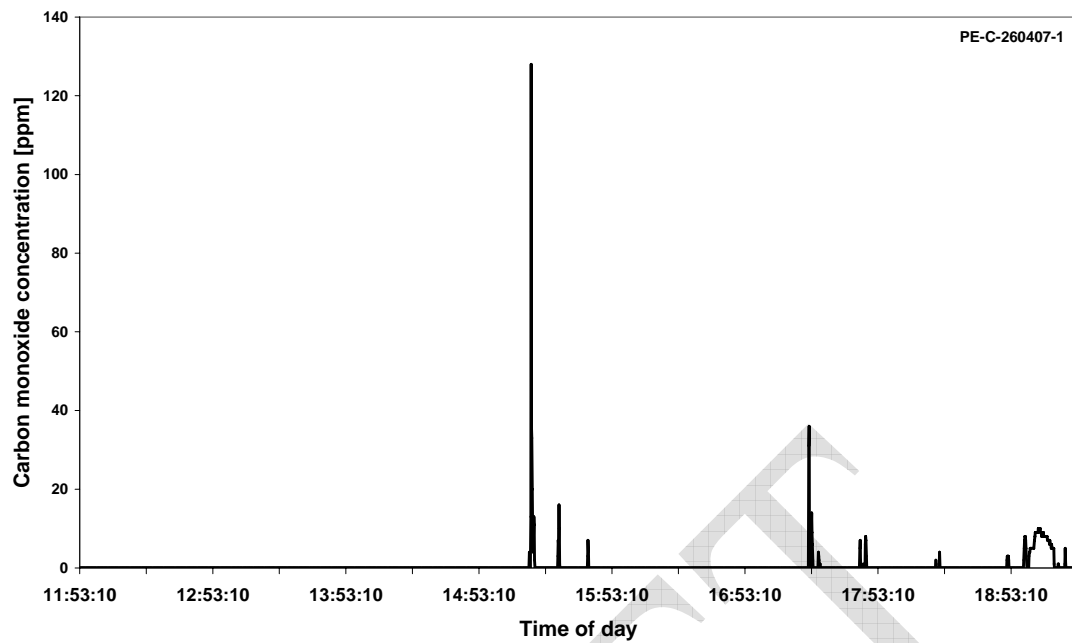


Figure 39 Data-logging record of a firefighter's exposure to CO and RP (Healesville, VIC)

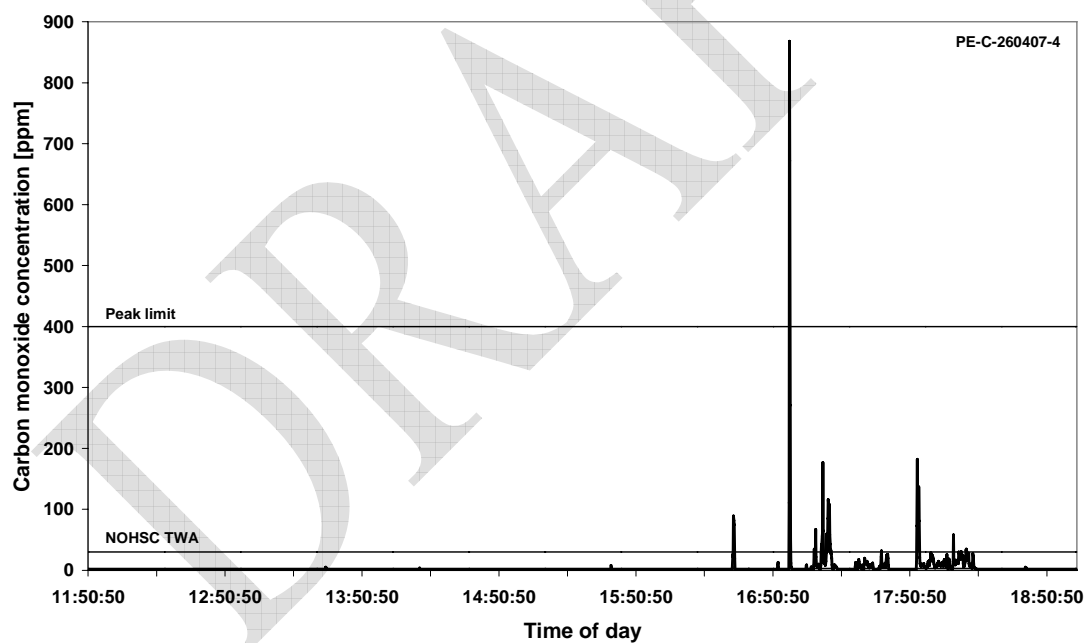
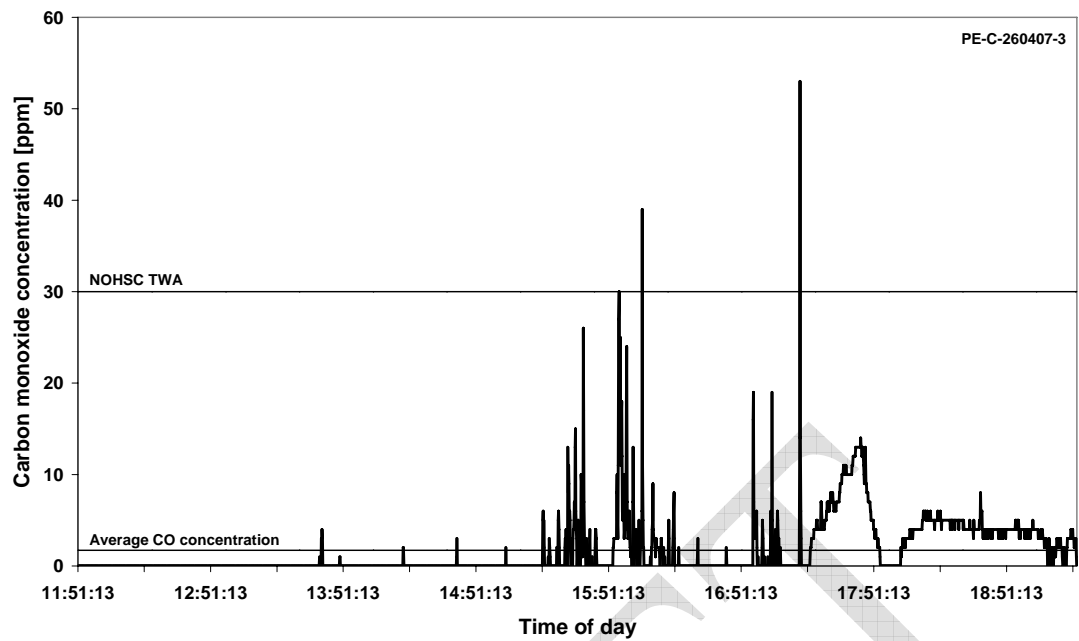


Figure 40 Data-logging records of firefighters' exposure to CO (Healesville, VIC)

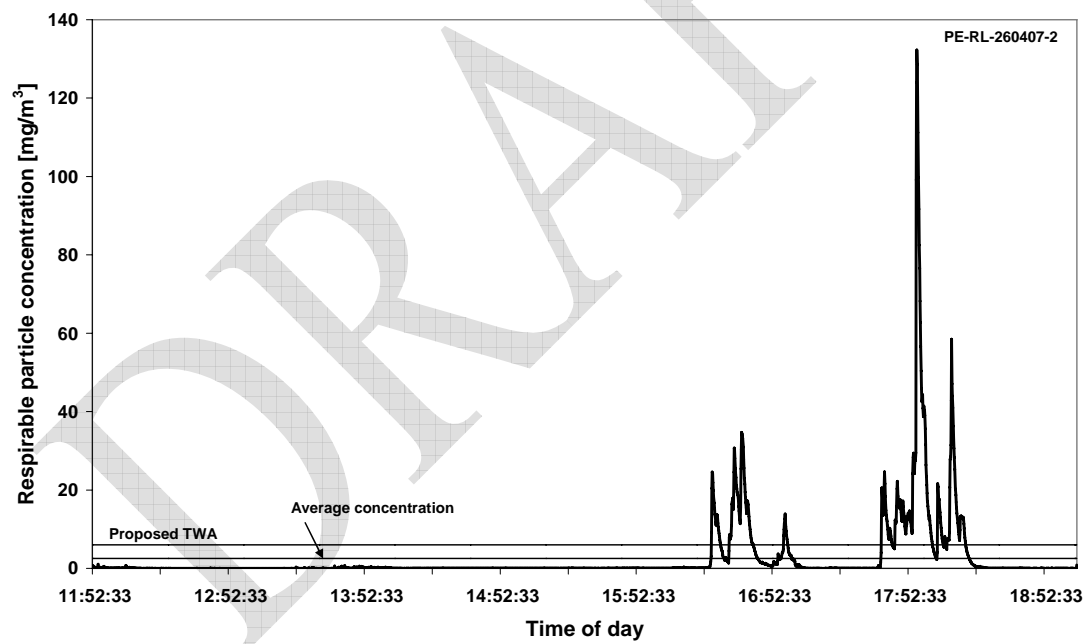
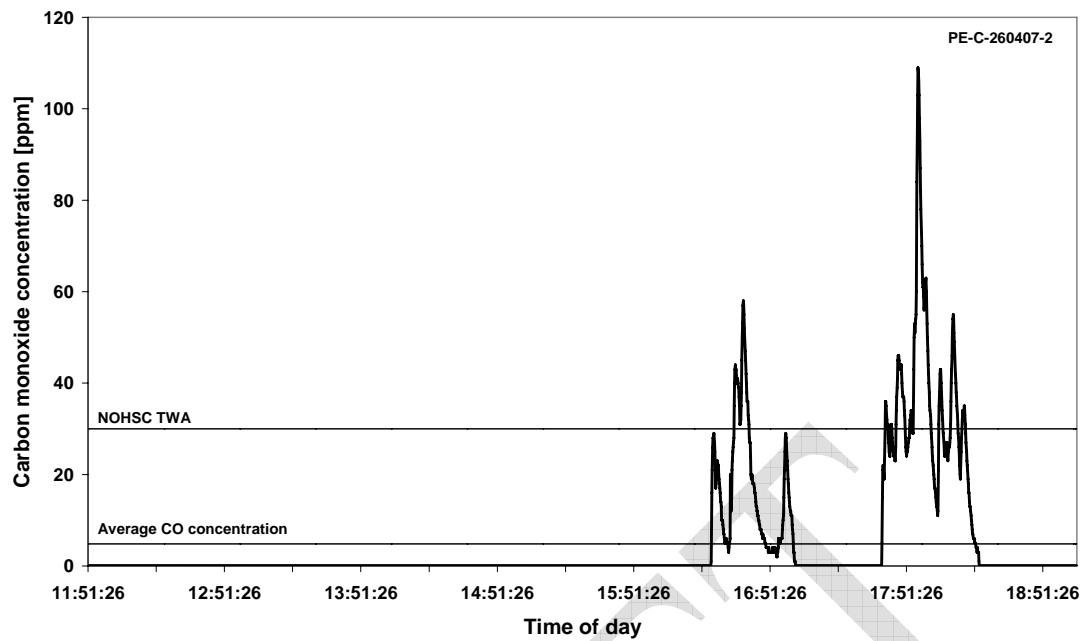


Figure 41 Data-logging record of a firefighter's exposure to CO and RP (Healesville, VIC)

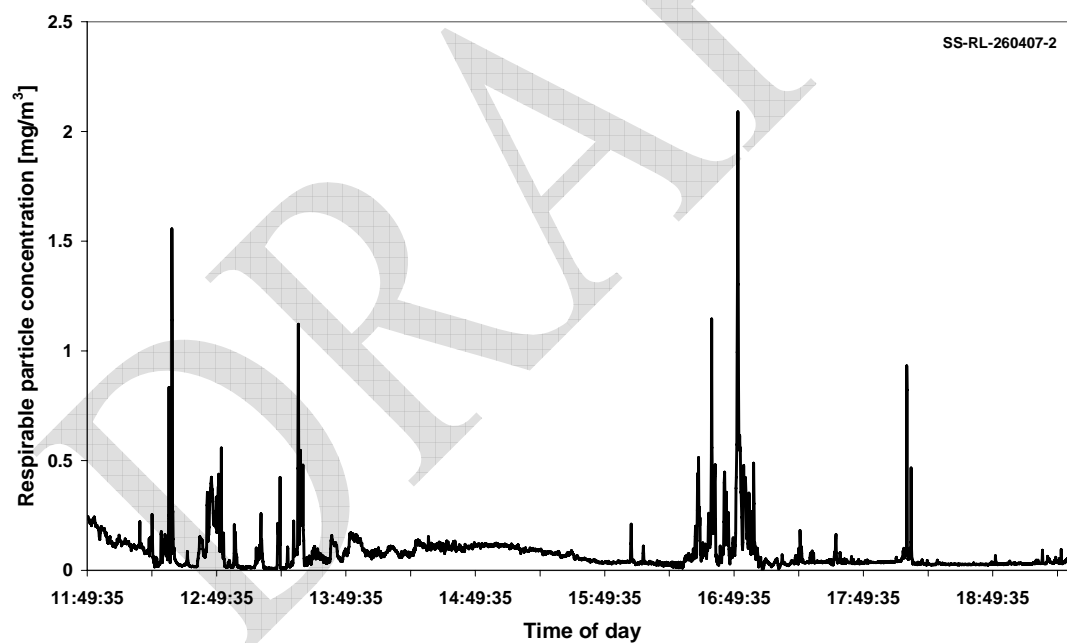
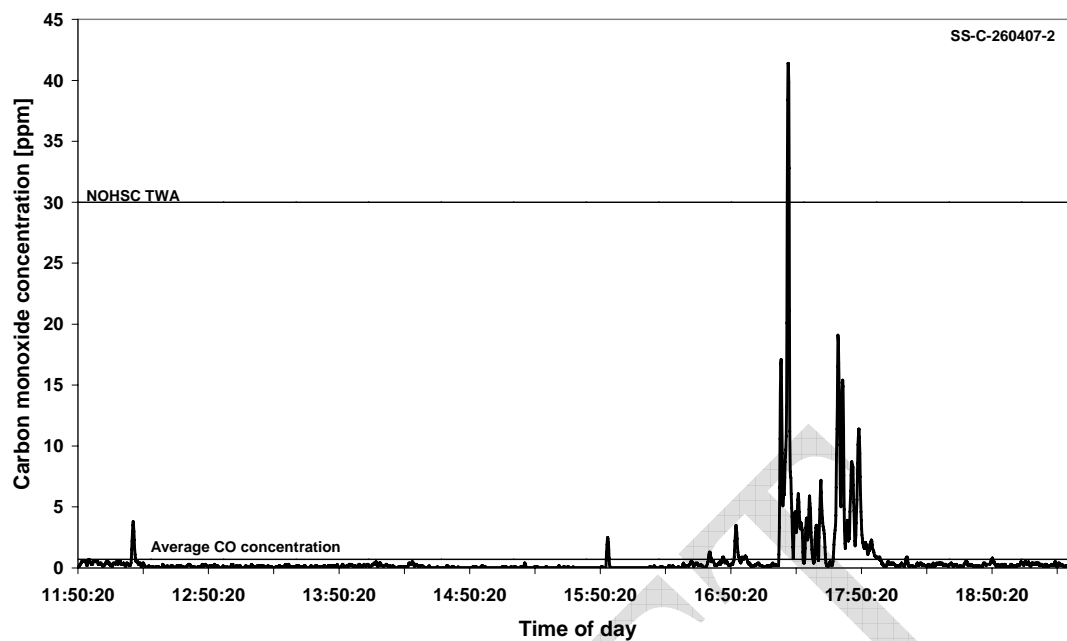


Figure 42 Data-logging record of CO and RP levels at a prescribed burn (Healesville, VIC)

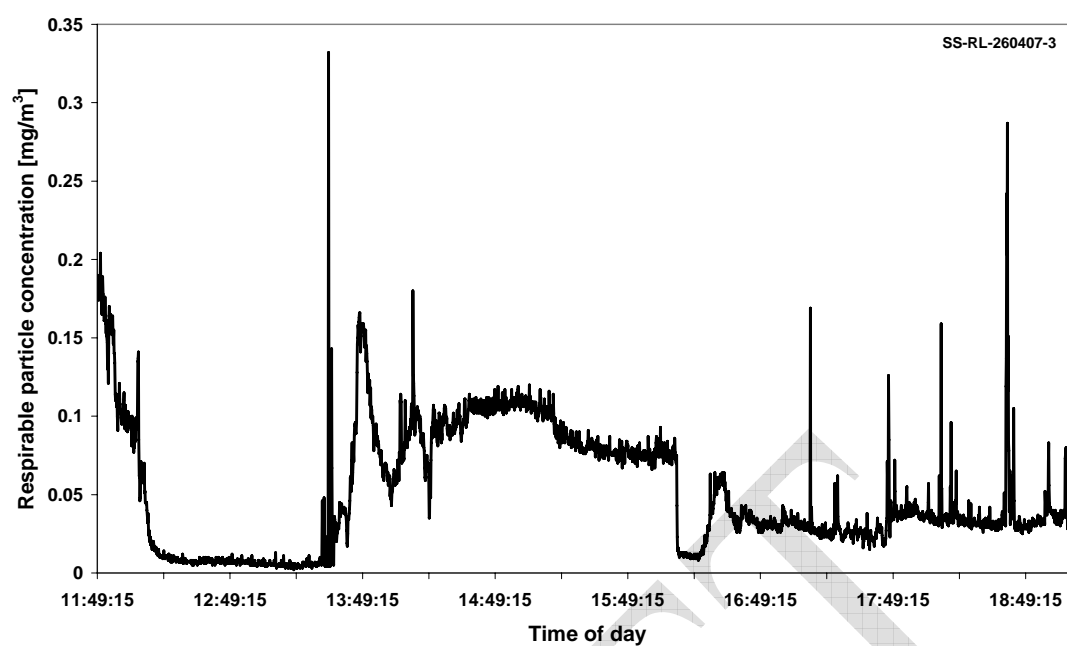


Figure 43 Data-logging record of RP levels at a prescribed burn (Healesville, VIC)

7.5 Pine Plantation burn-off, Rosewhite VIC – 03/05/07

7.5.1 Fire site record

SITE	Pine plantation burn - Rosewhite
DATE	03/05/2007
TYPE OF BURN	Prescribed
FUEL DESCRIPTION	Windrow burn of pine debris
BURN AREA (TOTAL)	20 + 40 ha
BURN AREA TODAY	20 + 40 ha
DESCRIPTION OF AREA	Moderately steep
WEATHER DESCRIPTION	
FIRE AGENCIES IN ATTENDANCE	Hancock Victorian Plantations
NUMBER IN FIRE CREW	7
PERSONAL PROTECTIVE EQUIPMENT	None
LENGTH OF DAY SHIFT	Meet at HVP depot at 8 am; drive to burn area. Ignition started by 9 am
NUMBER OF CREW SAMPLED	4 personal; 2 sample boxes (placed in smoke); Tube on top of Bushfire CRC vehicle
TASKS OF SAMPLED CREW C.F. REST OF CREW	Ignition of windrows with handheld drip torch
CREW SAMPLE EXPERIENCE	<ul style="list-style-type: none"> - HEADACHE N, N, N, N - IRRITATION N, N, N, N - OTHER (specify) N, N, N, N
SAMPLE BOXES	<ul style="list-style-type: none"> ▪ 2 sample boxes placed downwind of smoke ▪ Tube put on rooftop of Bushfire CRC vehicle (driving around burn area)

7.5.2 Air sampling results

Table 13 Air sampling results of personal exposure and smoke signature measurements taken at the pine plantation burn-off in Rosewhite, VIC on 03/05/07

Sample #	PE-030507-1	PE-030507-2	PE-030507-3	PE-030507-4
Description	Ignition with hand held drip torch			
Avg CO [ppm]	3.4	4.8	5.5	5.0
Max CO [ppm]	77 (92)	183 (205)	248 (258)	139 (167)
Avg RP [mg/m ³]	N/A	N/A	N/A	N/A
Max RP [mg/m ³]	N/A	N/A	N/A	N/A
Avg RP (grav) [mg/m ³]	0.7	0.4	N/A	N/A
Formaldehyde [ppb]	N/A	38	N/A	N/A
Acetaldehyde [ppb]	N/A	18	N/A	N/A
Acrolein [ppb]	N/A	ND	N/A	N/A

Sample #	SS-030507-1	SS-030507-2	SS-030507-3
Description	Downwind of smoke		Bushfire CRC vehicle
Avg CO [ppm]	45	77.2	12.3
Max CO [ppm]	225	265	212 (1030)
Avg CO ₂ [ppm]	850	943	N/A
Max CO ₂ [ppm]	2167	2501	N/A
Avg RP [mg/m ³]	2.2	7.8	0.7
Max RP [mg/m ³]	8.7	47	33.5
Avg RP (grav) [mg/m ³]	3.3	5.5	
Formaldehyde [ppb]	> 30	> 45	N/A
Acetaldehyde [ppb]	> 3	> 6	N/A
Acrolein [ppb]	ND	ND	N/A
2-Furaldehyde [μg/m ³]	N/A		N/A
Benzene [μg/m ³]	N/A		N/A
Toluene [μg/m ³]	N/A		N/A
Acetic acid [μg/m ³]	N/A		N/A
Phenol [μg/m ³]	N/A		N/A
Xylenes [μg/m ³]	N/A		N/A
TVOCs [μg/m ³]	N/A		N/A

7.5.3 Graphs of personal exposure and area measurements for CO and RP (data logging records)

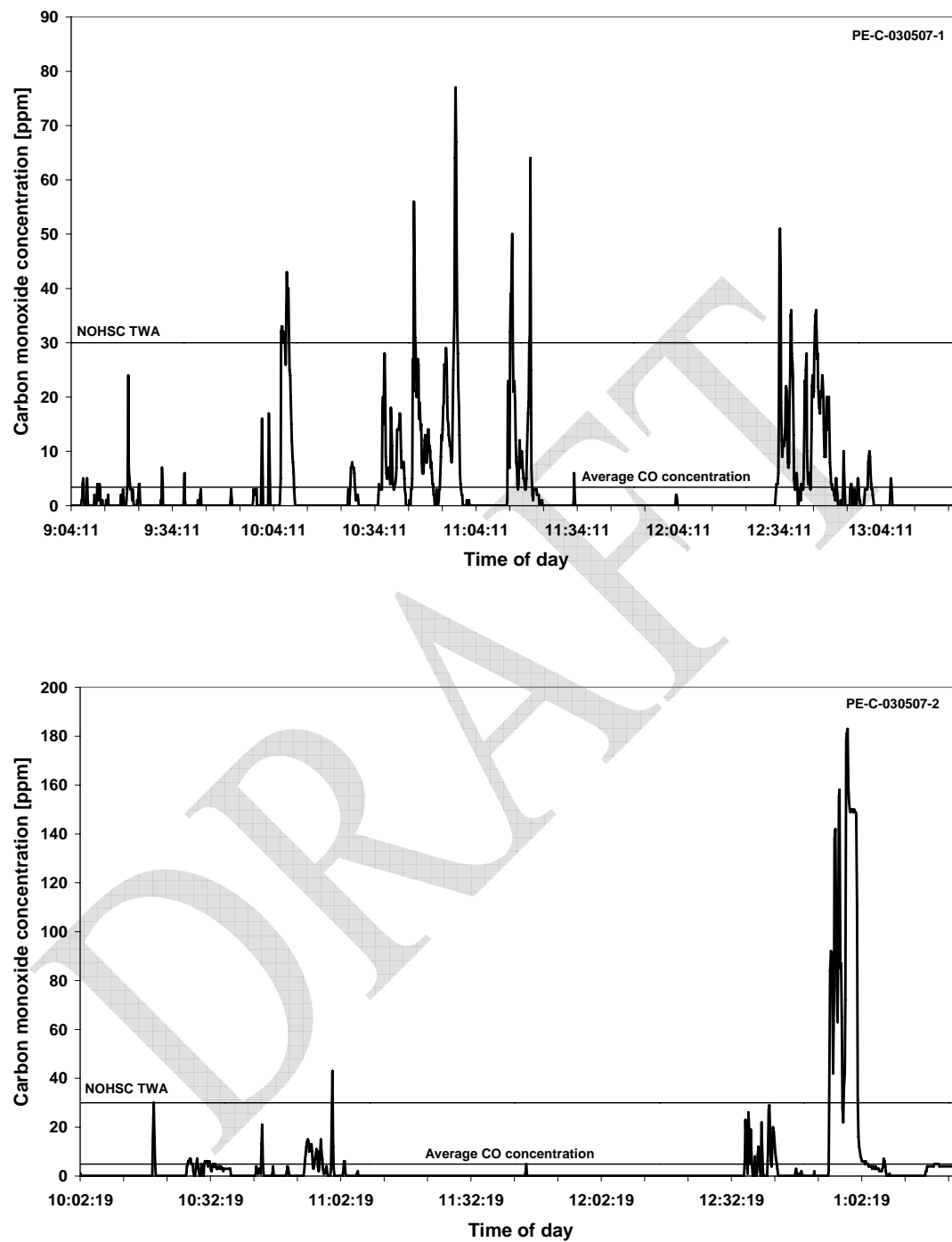


Figure 44 Data-logging records of firefighters' exposure to CO at windrow burns in pine plantations (Northeast VIC)

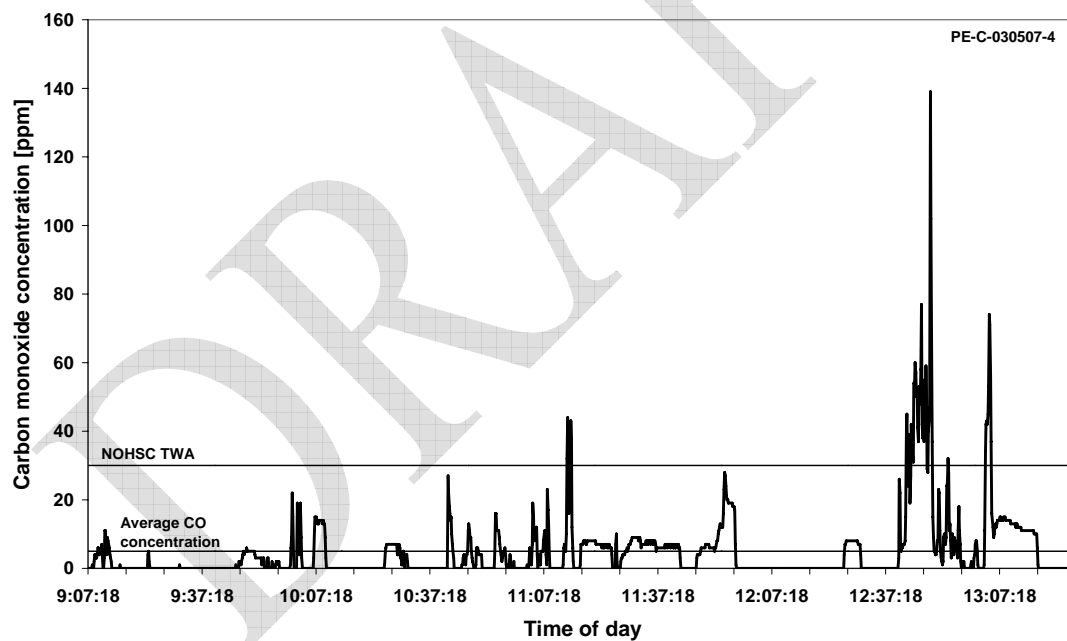
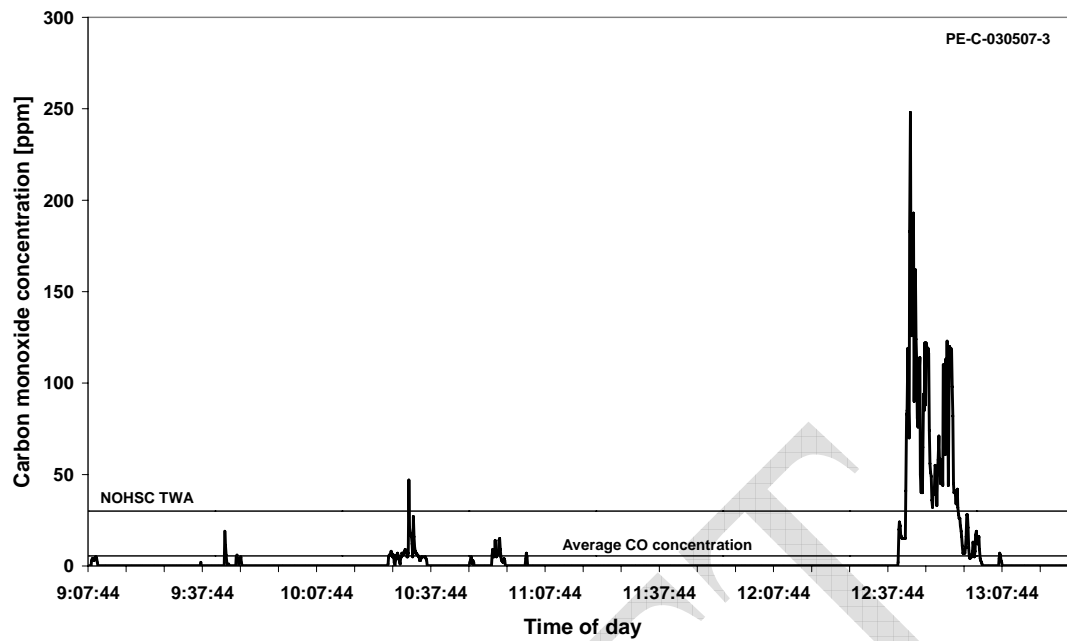


Figure 45 Data-logging records of firefighters' exposure to CO at windrow burns in pine plantations (Northeast VIC)

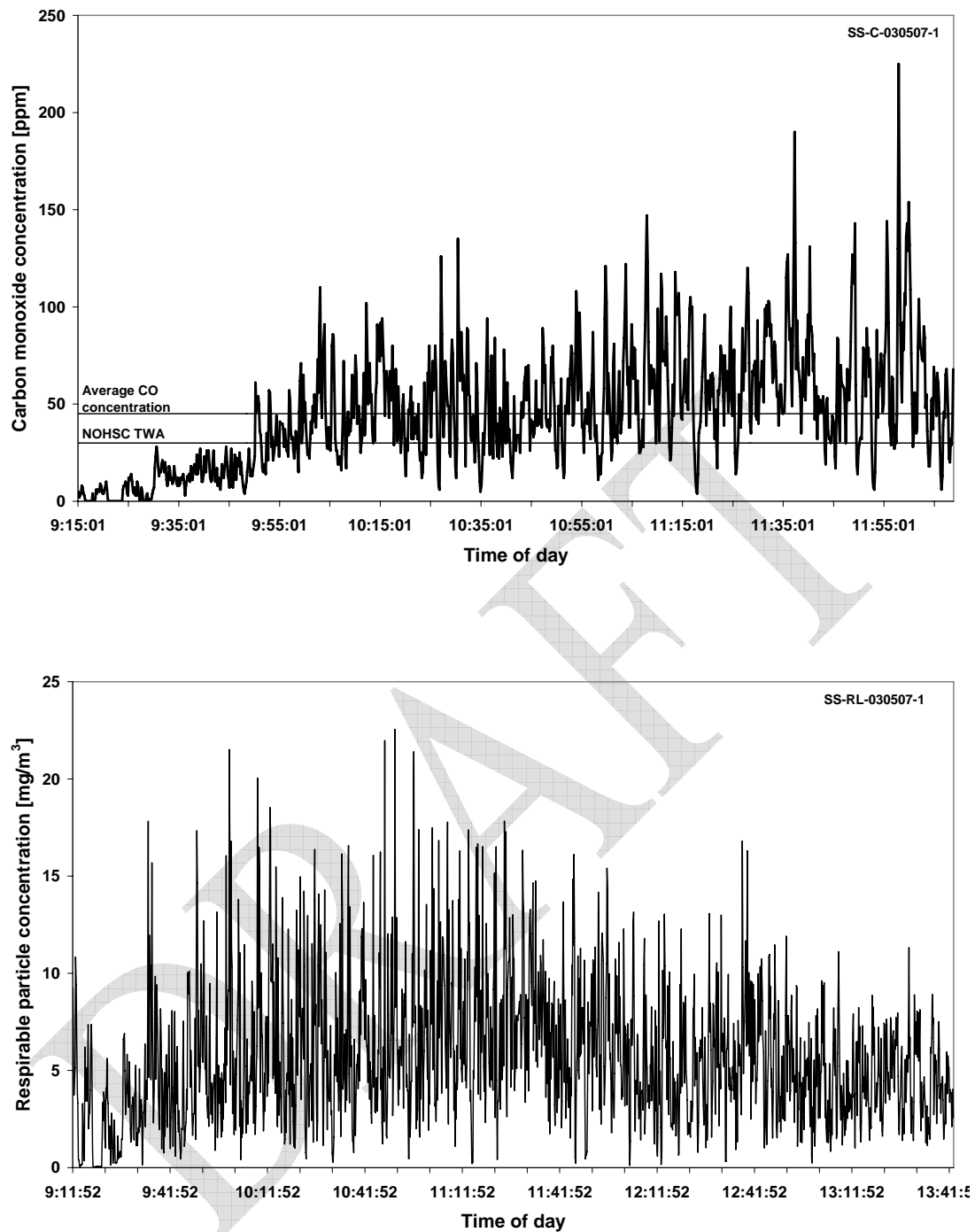


Figure 46 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

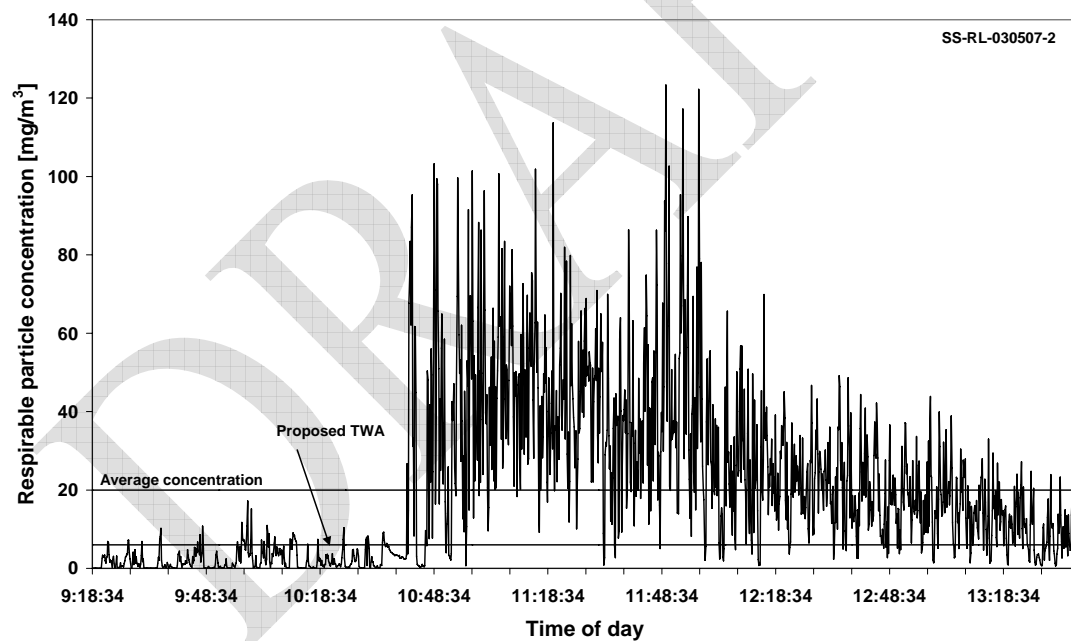
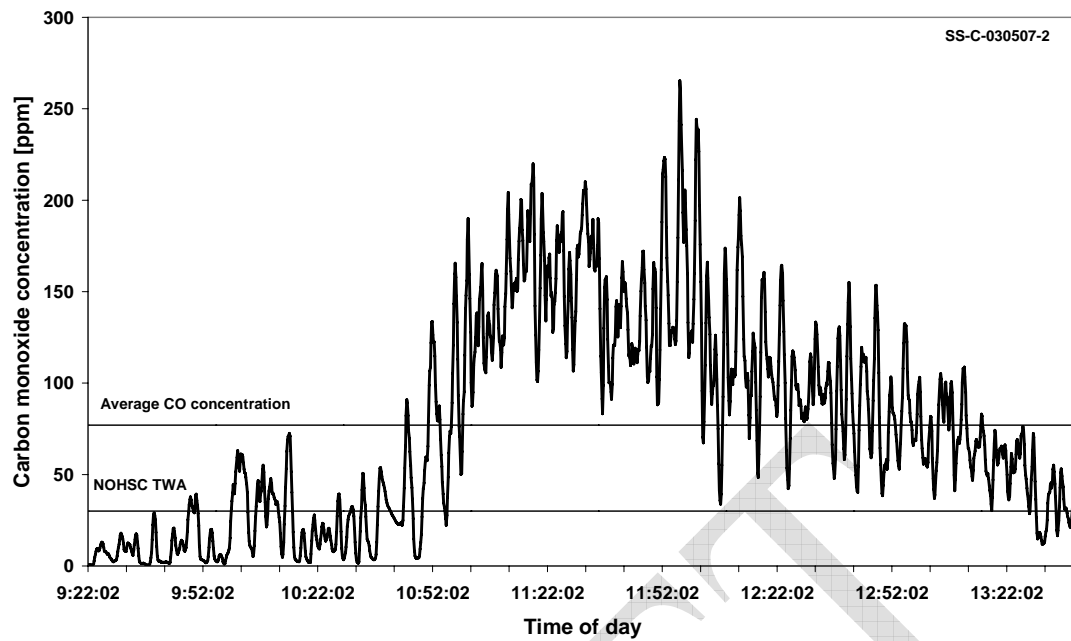


Figure 47 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

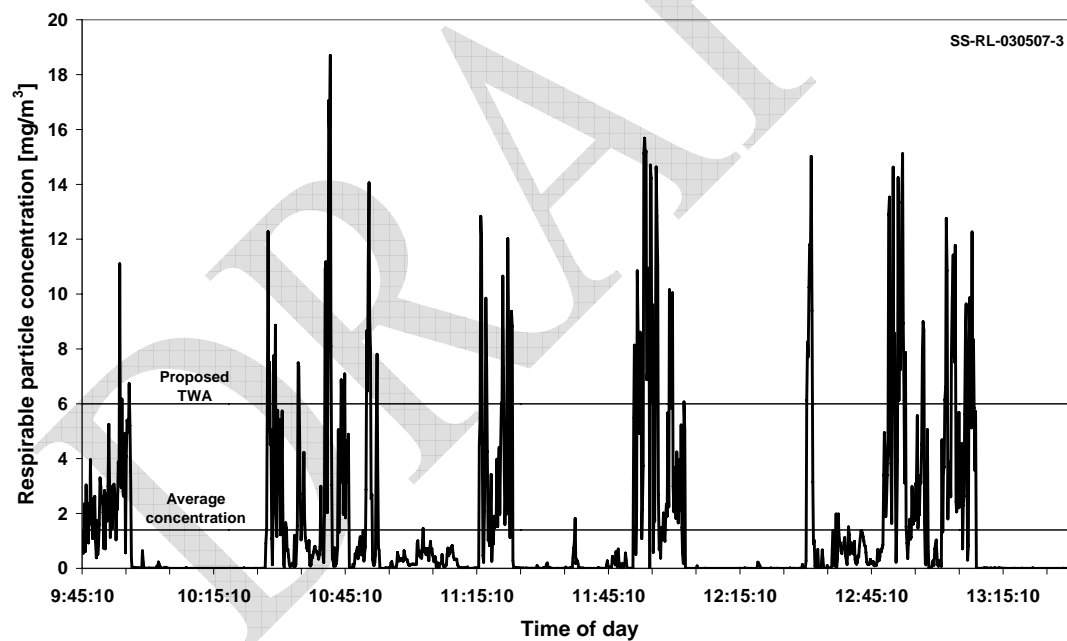
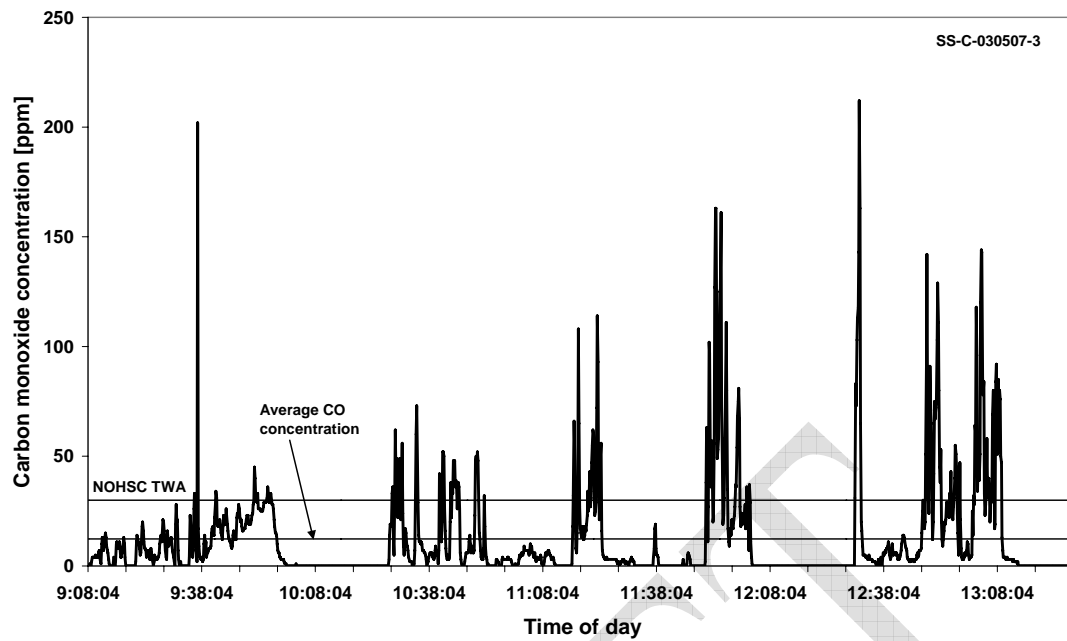


Figure 48 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

7.6 Pine Plantation burn-off, Buffalo River VIC – 04/05/07

7.6.1 Fire site record

SITE	Pine plantation burn – Buffalo River
DATE	04/05/2007
TYPE OF BURN	Prescribed
FUEL DESCRIPTION	Windrow burn of pine debris
BURN AREA (TOTAL)	
BURN AREA TODAY	
DESCRIPTION OF AREA	Steep
WEATHER DESCRIPTION	
FIRE AGENCIES IN ATTENDANCE	Hancock Victorian Plantations
NUMBER IN FIRE CREW	7
PERSONAL PROTECTIVE EQUIPMENT	None
LENGTH OF DAY SHIFT	Meet at HVP depot at 8 am; drive to burn area. Ignition started by 9:15 am
NUMBER OF CREW SAMPLED	4 personal; 2 sample boxes (placed in smoke); Tube on top of Bushfire CRC vehicle
TASKS OF SAMPLED CREW C.F. REST OF CREW	Ignition of windrows with handheld drip torch
CREW SAMPLE EXPERIENCE	<ul style="list-style-type: none"> - HEADACHE N, N, N, N - IRRITATION N, N, N, N - OTHER (specify) N, N, N, N
SAMPLE BOXES	<ul style="list-style-type: none"> ▪ 2 sample boxes placed downwind of smoke - Tube put on rooftop of Bushfire CRC vehicle (driving around burn area)

7.6.2 Air sampling results

Table 14 Air sampling results of personal exposure and smoke signature measurements taken at the pine plantation burn-off in Buffalo River, VIC on 04/05/07

Sample #	PE-040507-1	PE-040507-2	PE-040507-3	PE-040507-4
Description	Ignition with hand held drip torch			
Avg CO [ppm]	5.4	2.6	1.3	3.9
Max CO [ppm]	1085 (1515)	198 (209)	58 (76)	173 (189)
Avg RP [mg/m ³]	N/A	N/A	N/A	N/A
Max RP [mg/m ³]	N/A	N/A	N/A	N/A
Avg RP (grav) [mg/m ³]	1.1	1.4	N/A	N/A
Formaldehyde [ppb]	N/A	43	N/A	N/A
Acetaldehyde [ppb]	N/A	29	N/A	N/A
Acrolein [ppb]	N/A	ND	N/A	N/A

Sample #	SS-040507-1	SS-040507-2	SS-040507-3
Description	Downwind of smoke		Bushfire CRC vehicle
Avg CO [ppm]	98	46.3	7.9
Max CO [ppm]	606	119	224
Avg CO ₂ [ppm]	1215	996	N/A
Max CO ₂ [ppm]	5894	2147	N/A
Avg RP [mg/m ³]	14.2	4.0	1.0
Max RP [mg/m ³]	92	62	121
Avg RP (grav) [mg/m ³]	14.8	5.7	1.5
Formaldehyde [ppb]	> 132	> 57	N/A
Acetaldehyde [ppb]	> 19	> 11	N/A
Acrolein [ppb]	ND	ND	N/A
2-Furaldehyde [μg/m ³]	N/A		N/A
Benzene [μg/m ³]	N/A		N/A
Toluene [μg/m ³]	N/A		N/A
Acetic acid [μg/m ³]	N/A		N/A
Phenol [μg/m ³]	N/A		N/A
Xylenes [μg/m ³]	N/A		N/A
TVOCs [μg/m ³]	N/A		N/A

7.6.3 Graphs of personal exposure and area measurements for CO and RP (data logging records)

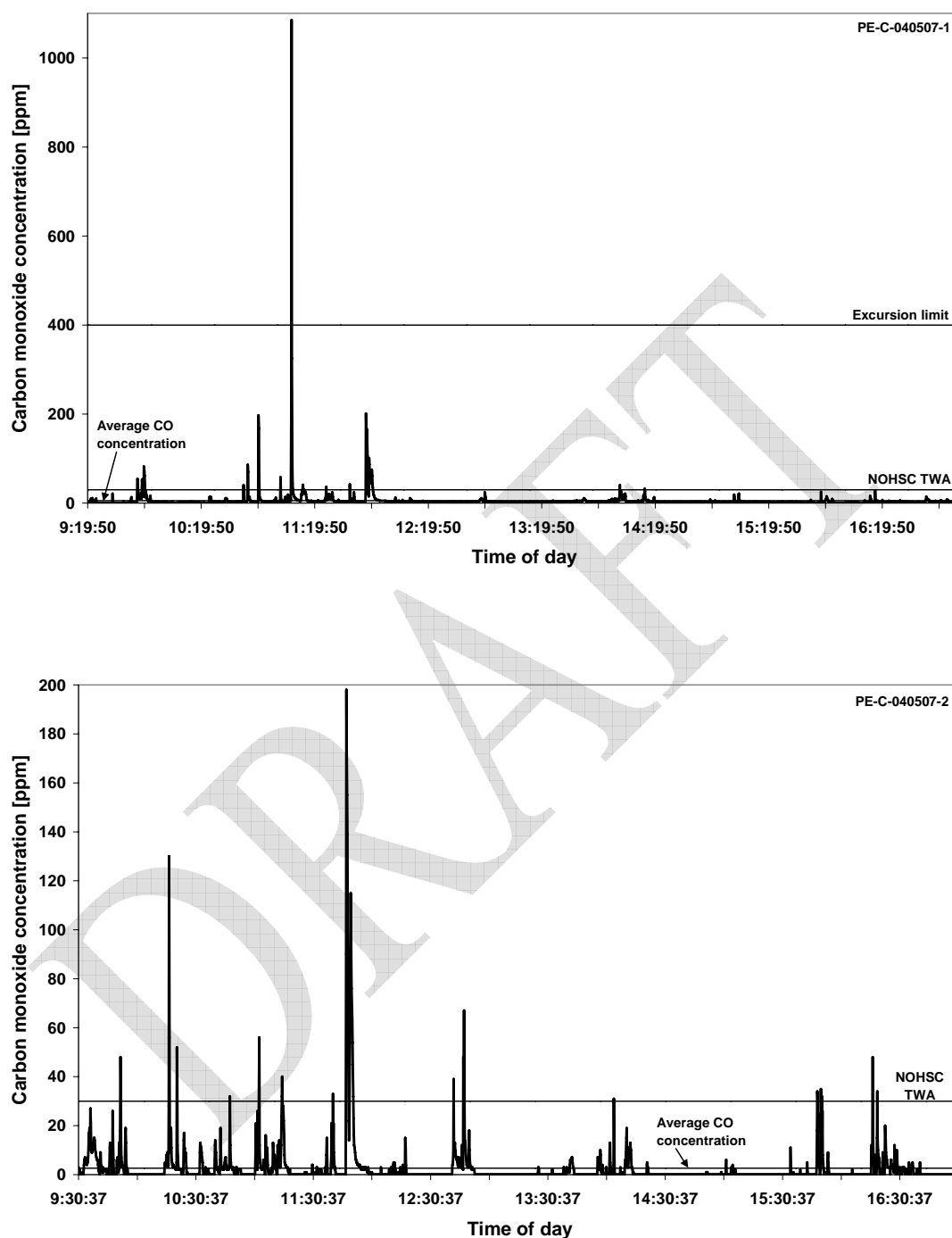


Figure 49 Data-logging records of firefighters' exposure to CO at windrow burns in pine plantations (Northeast VIC)

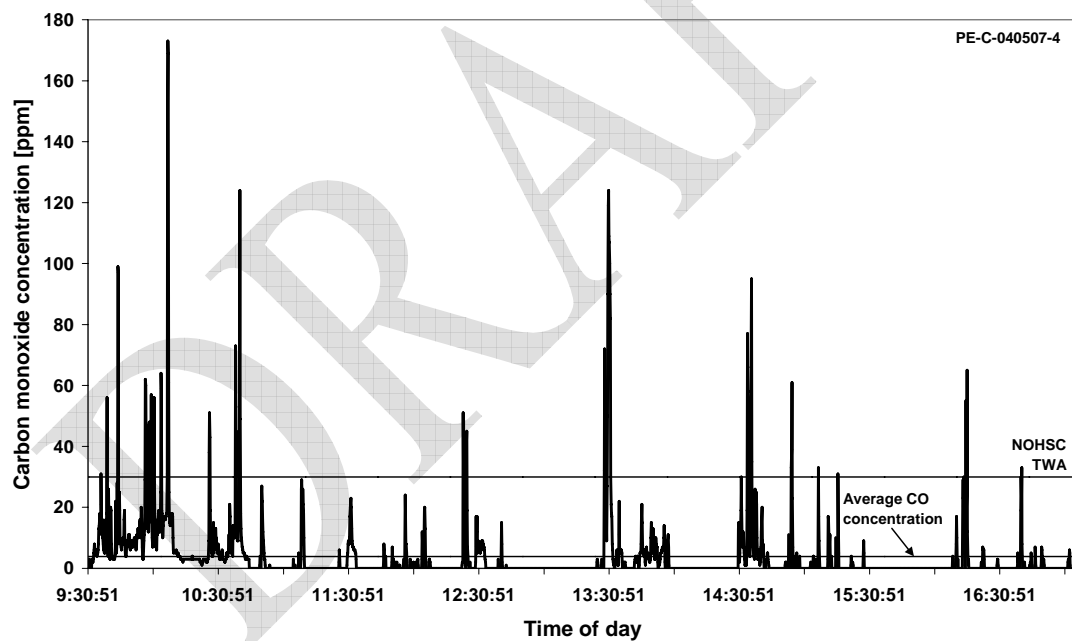
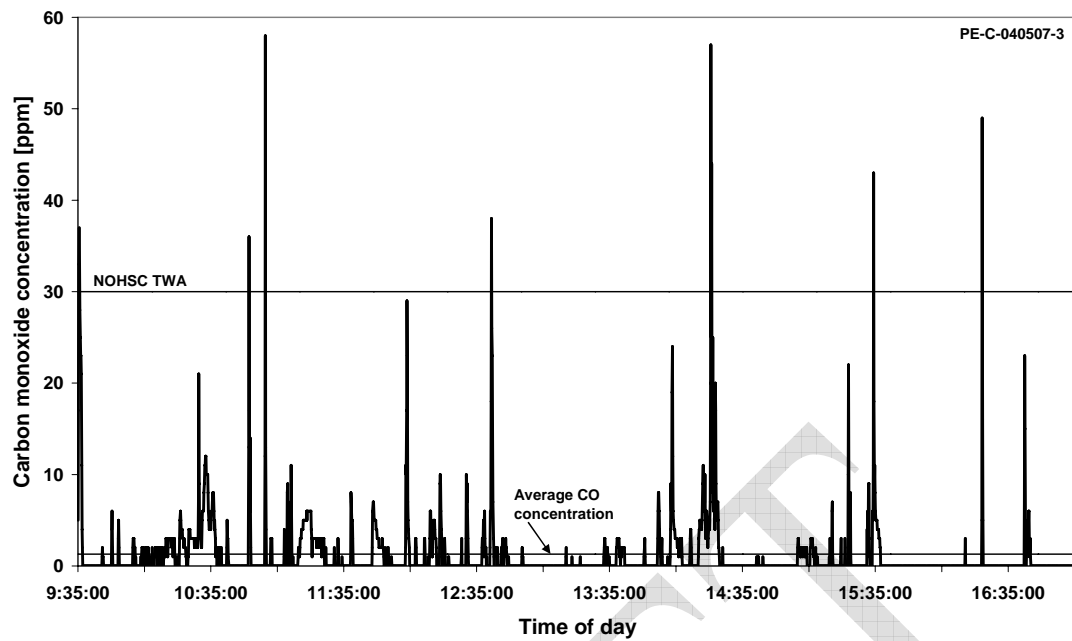


Figure 50 Data-logging records of firefighters' exposure to CO at windrow burns in pine plantations (Northeast VIC)

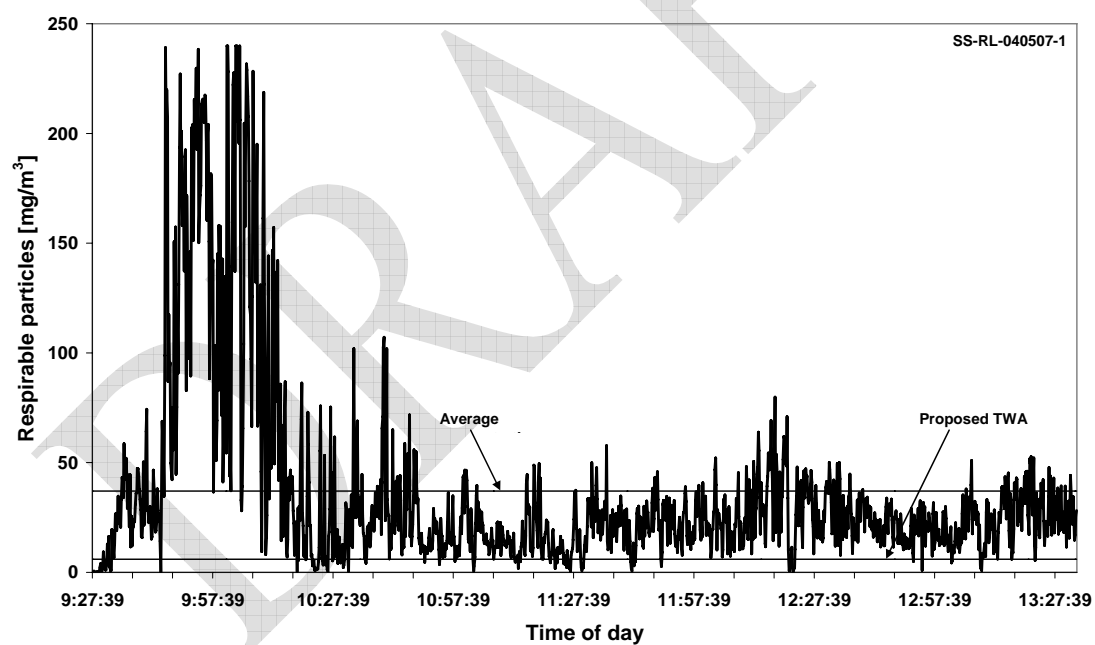
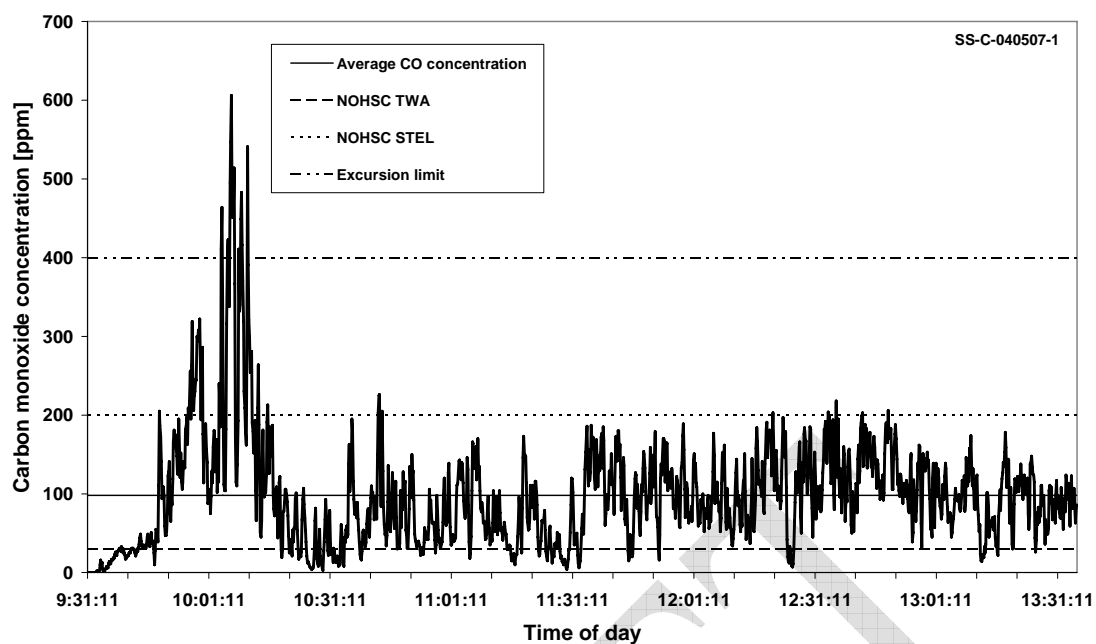


Figure 51 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

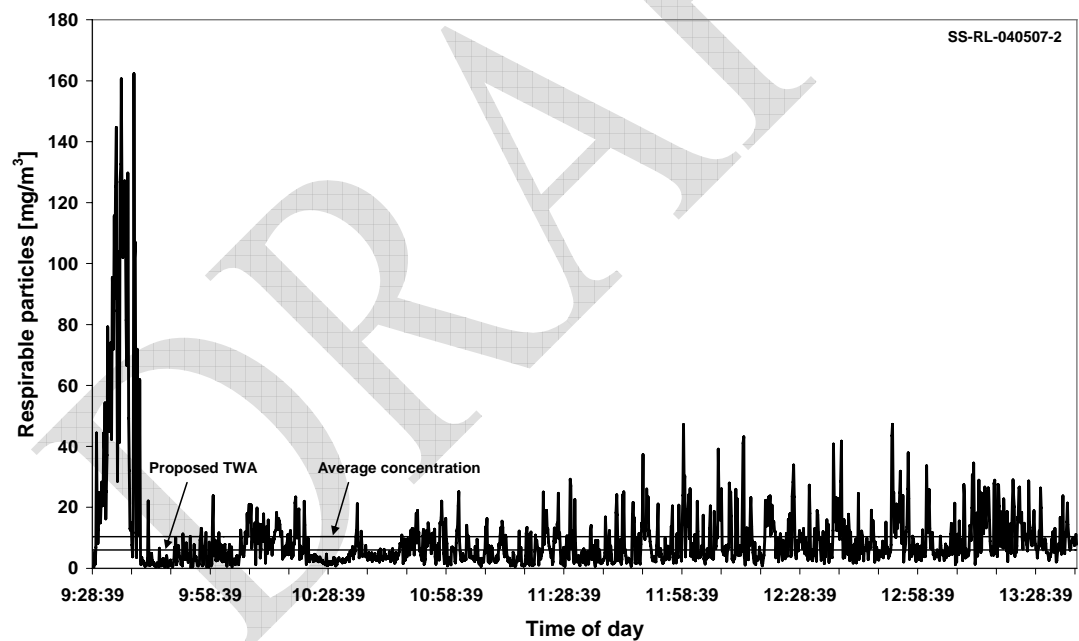
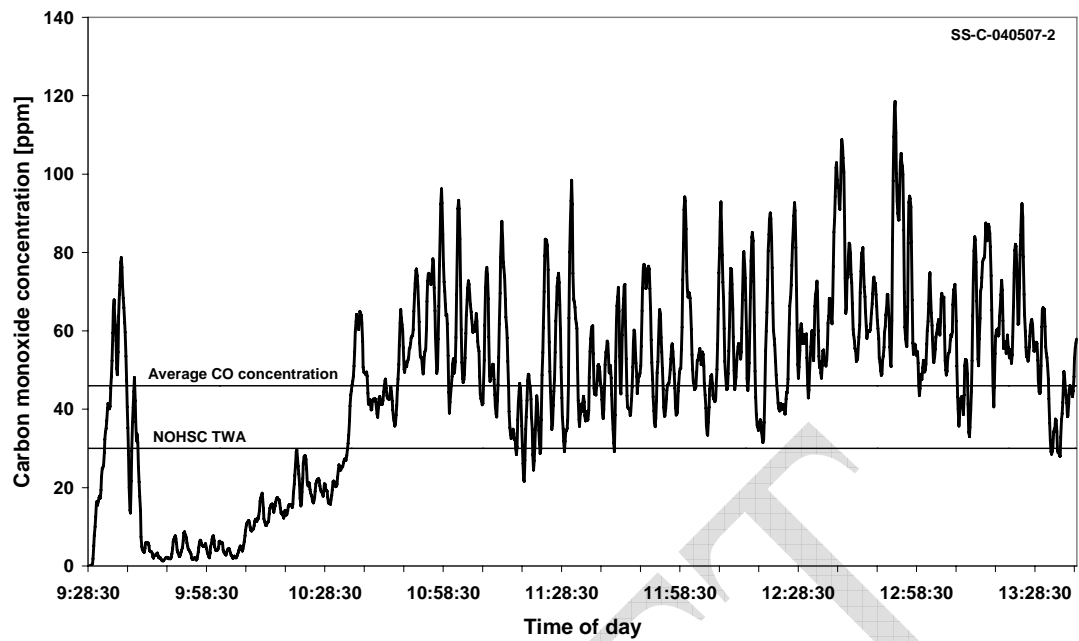


Figure 52 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

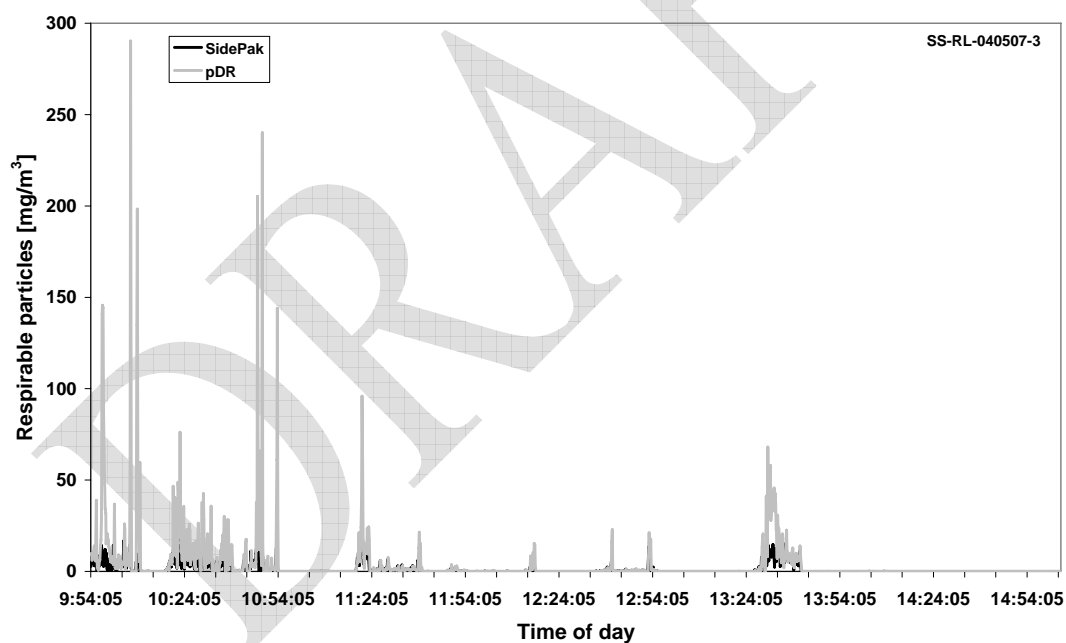
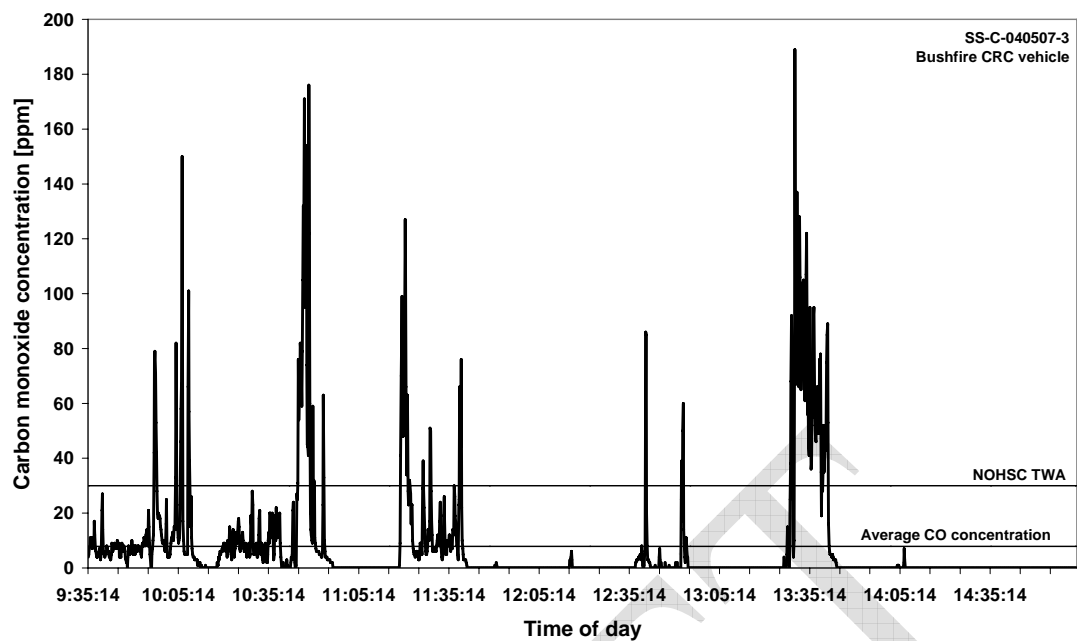


Figure 53 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

7.7 Pine Plantation burn-off, Meeriyang South VIC – 05/05/07

7.7.1 Fire site record

SITE	Pine plantation burn – Meeriyang South
DATE	05/05/2007
TYPE OF BURN	Prescribed
FUEL DESCRIPTION	Windrow burn of pine debris
BURN AREA (TOTAL)	
BURN AREA TODAY	
DESCRIPTION OF AREA	Moderately steep
WEATHER DESCRIPTION	
FIRE AGENCIES IN ATTENDANCE	Hancock Victorian Plantations
NUMBER IN FIRE CREW	6
PERSONAL PROTECTIVE EQUIPMENT	None
LENGTH OF DAY SHIFT	Meet at HVP depot at 8 am; drive to burn area. Ignition started by 8:30 am
NUMBER OF CREW SAMPLED	4 personal (only CO); 2 sample boxes and tube (placed in smoke)
TASKS OF SAMPLED CREW C.F. REST OF CREW	Ignition of windrows with handheld drip torch
CREW SAMPLE EXPERIENCE	<ul style="list-style-type: none">- HEADACHE N, N, N, N- IRRITATION N, N, N, N- OTHER (specify) N, N, N, N
SAMPLE BOXES	<ul style="list-style-type: none">▪ 2 sample boxes placed downwind of smoke▪ Tube placed downwind of smoke (light)

7.7.2 Air sampling results

Table 15 Air sampling results of personal exposure and smoke signature measurements taken at the pine plantation burn-off in Meeriyang South, VIC on 05/05/07

Sample #	PE-050507-1	PE-050507-2	PE-050507-3	PE-050507-4
Description	Ignition with hand held drip torch			
Avg CO [ppm]	1.2	1.1	0.9	1.4
Max CO [ppm]	55 (74)	121 (193)	18 (36)	128 (148)
Avg RP [mg/m ³]	N/A	N/A	N/A	N/A
Max RP [mg/m ³]	N/A	N/A	N/A	N/A
Avg RP (grav) [mg/m ³]	N/A	N/A	N/A	N/A
Formaldehyde [ppb]	N/A	N/A	N/A	N/A
Acetaldehyde [ppb]	N/A	N/A	N/A	N/A
Acrolein [ppb]	N/A	N/A	N/A	N/A

Sample #	SS-050507-1	SS-050507-2	SS-050507-3
Description	Downwind of smoke		
Avg CO [ppm]	N/A	13.2	6.3
Max CO [ppm]	N/A	50	37
Avg CO ₂ [ppm]	N/A	609	N/A
Max CO ₂ [ppm]	N/A	1080	N/A
Avg RP [mg/m ³]	0.5	1.2	0.7
Max RP [mg/m ³]	1.3	21	7.5
Avg RP (grav) [mg/m ³]	1.0	1.2	0.9
Formaldehyde [ppb]	> 195	99	N/A
Acetaldehyde [ppb]	> 69	60	N/A
Acrolein [ppb]	ND	11	N/A
2-Furaldehyde [μg/m ³]	N/A		N/A
Benzene [μg/m ³]	N/A		N/A
Toluene [μg/m ³]	N/A		N/A
Acetic acid [μg/m ³]	N/A		N/A
Phenol [μg/m ³]	N/A		N/A
Xylenes [μg/m ³]	N/A		N/A
TVOCs [μg/m ³]	N/A		N/A

7.7.3 Graphs of personal exposure and area measurements for CO and RP (data logging records)

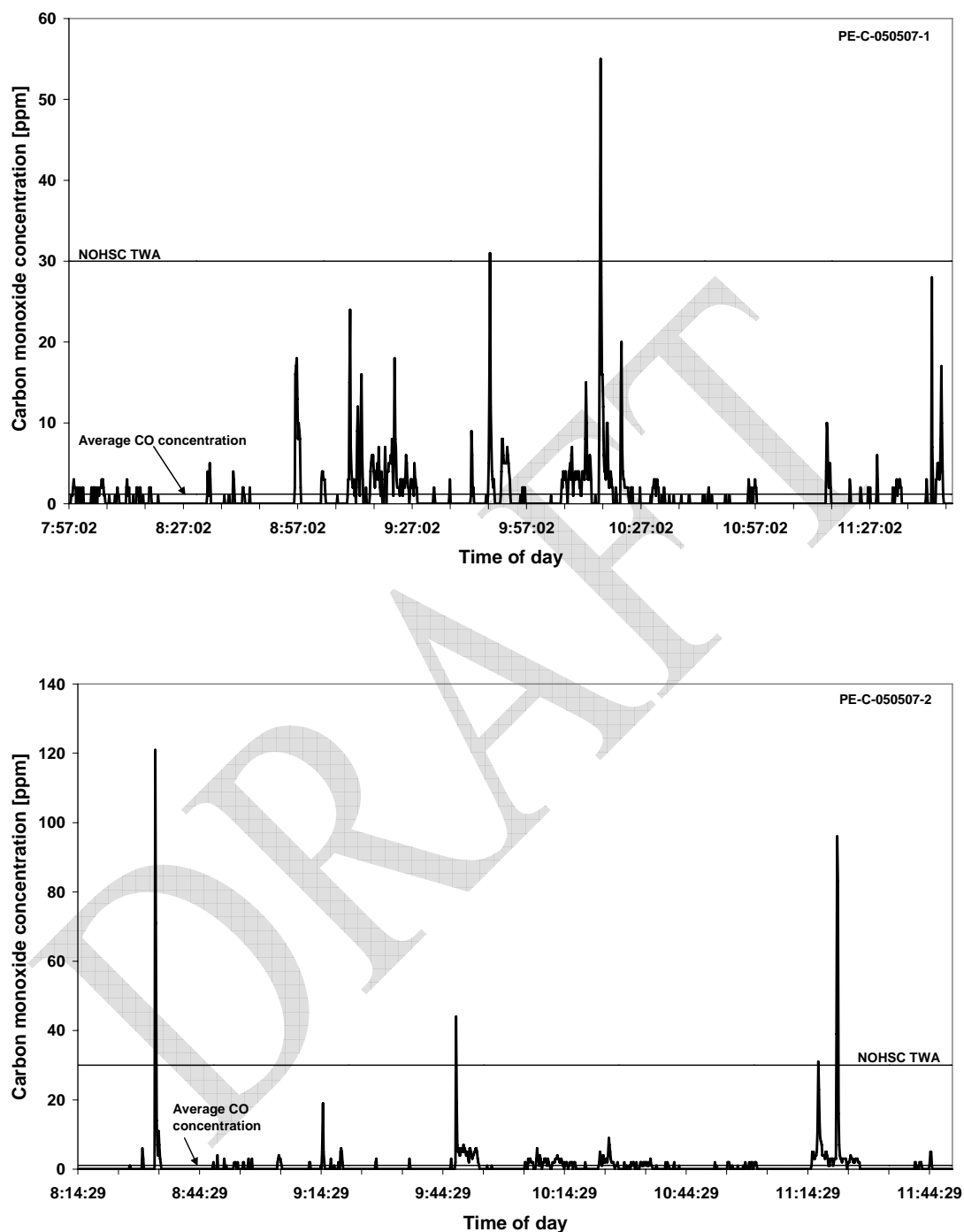


Figure 54 Data-logging records of firefighters' exposure to CO at windrow burns in pine plantations (Northeast VIC)

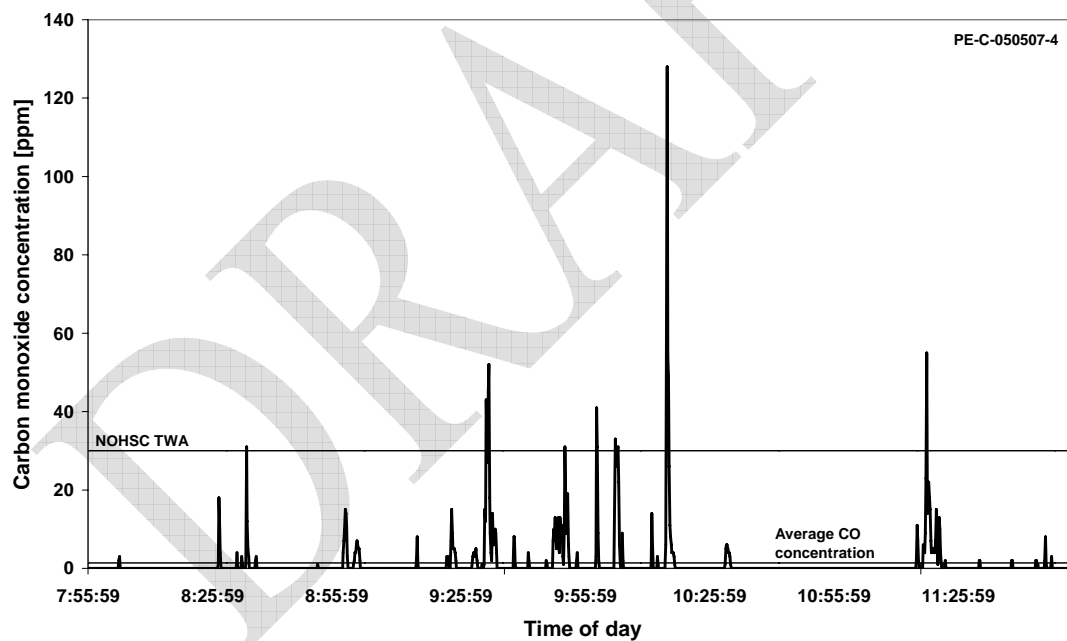
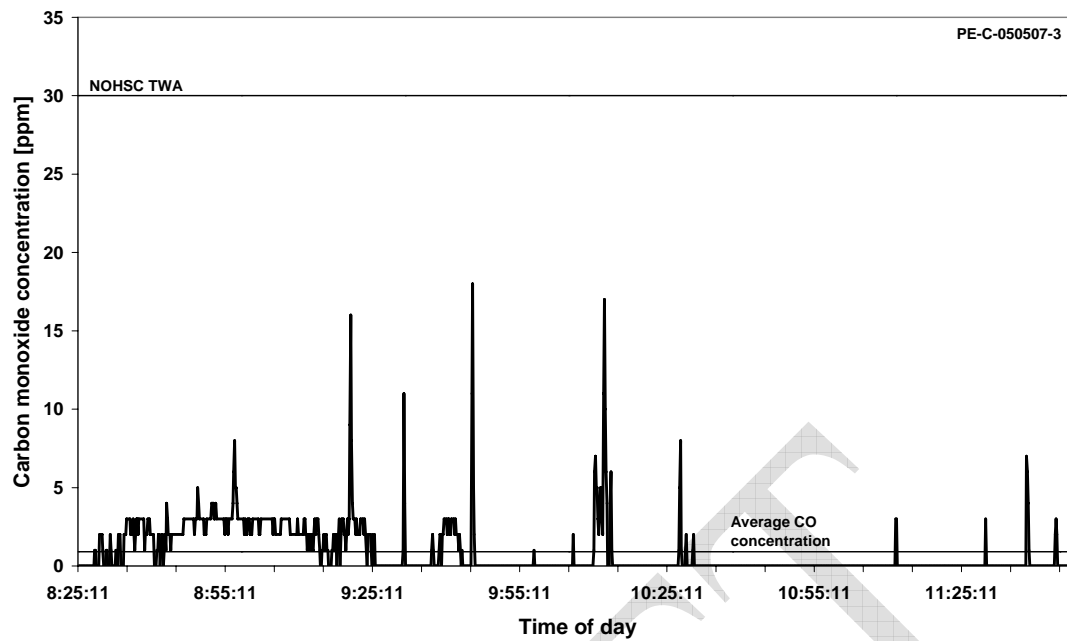


Figure 55 Data-logging records of firefighters' exposure to CO at windrow burns in pine plantations (Northeast VIC)

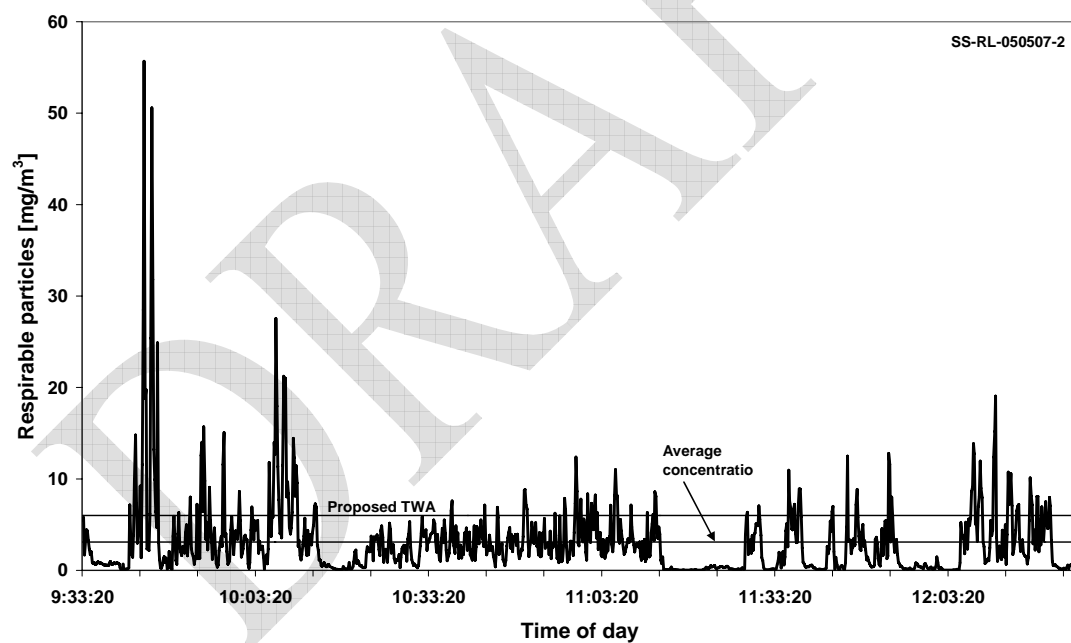
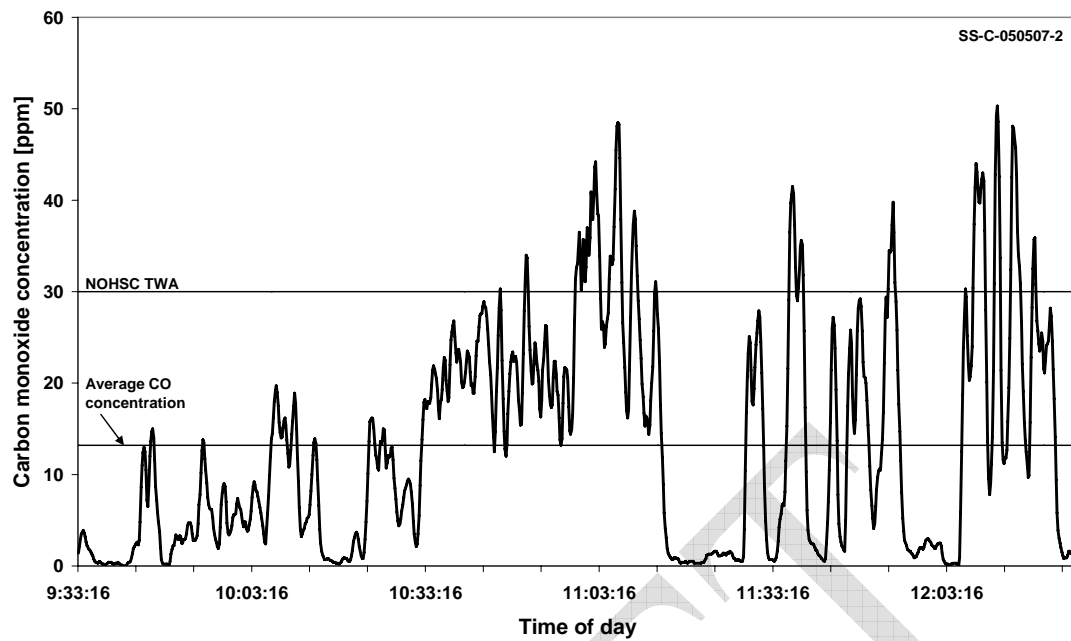


Figure 56 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

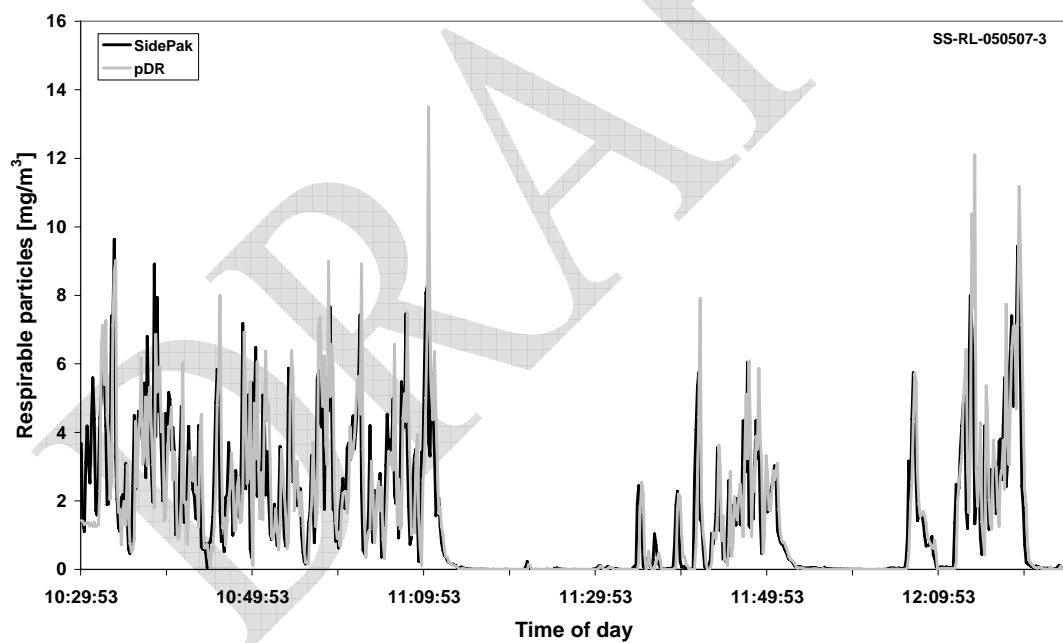
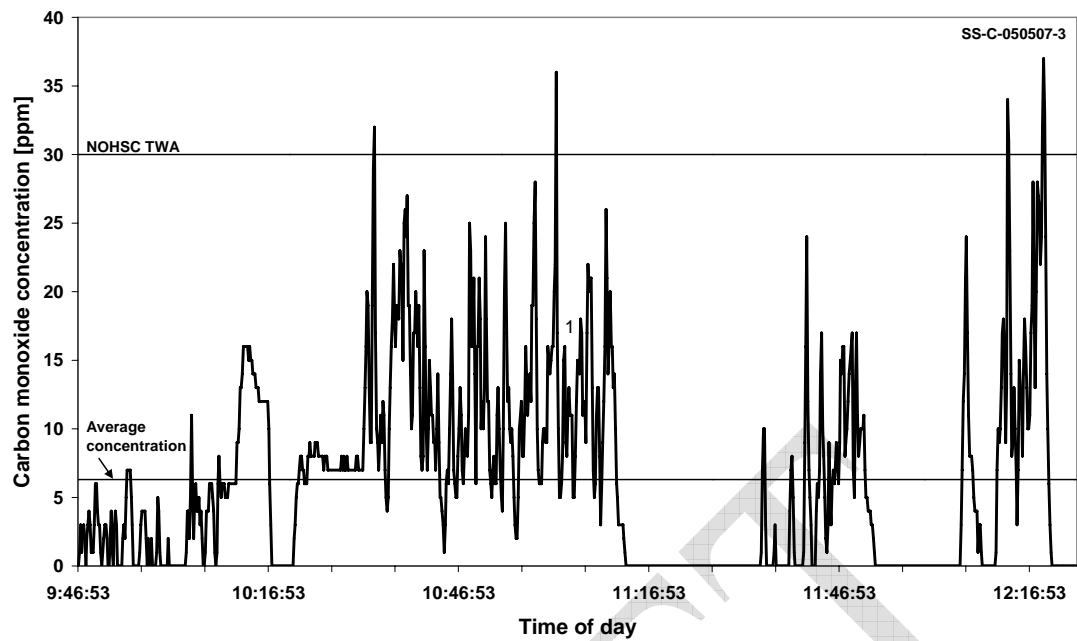


Figure 57 Data-logging record of CO and RP levels at windrow burns in pine plantations (Northeast VIC)

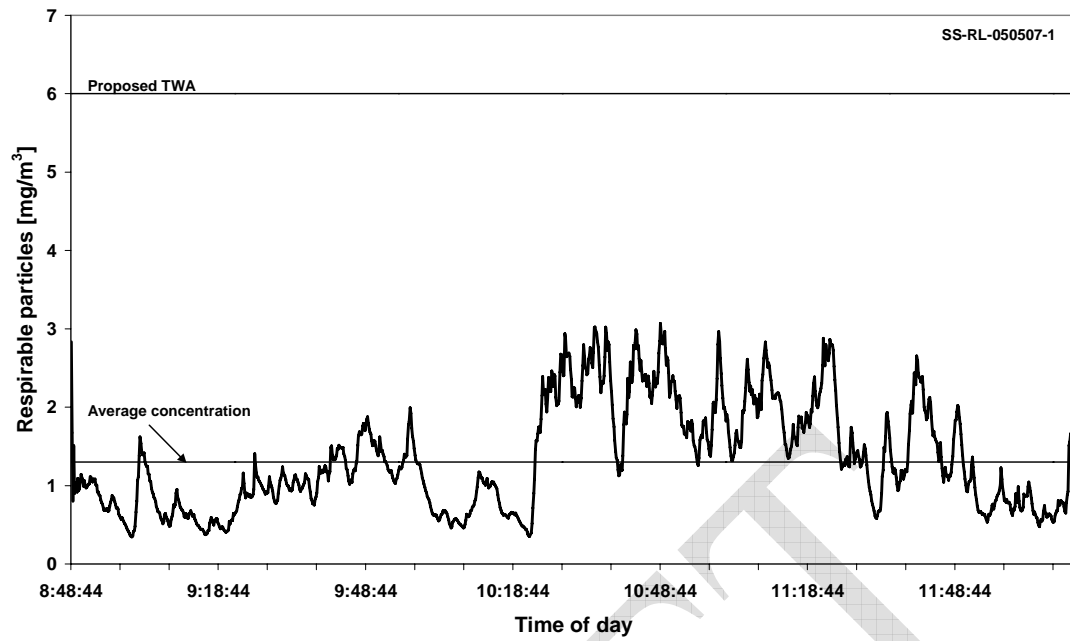


Figure 58 Data-logging record of RP levels at windrow burns in pine plantations (Northeast VIC)