Operational readiness of rural fire fighters - Understanding Air Toxics in the Urban Interface

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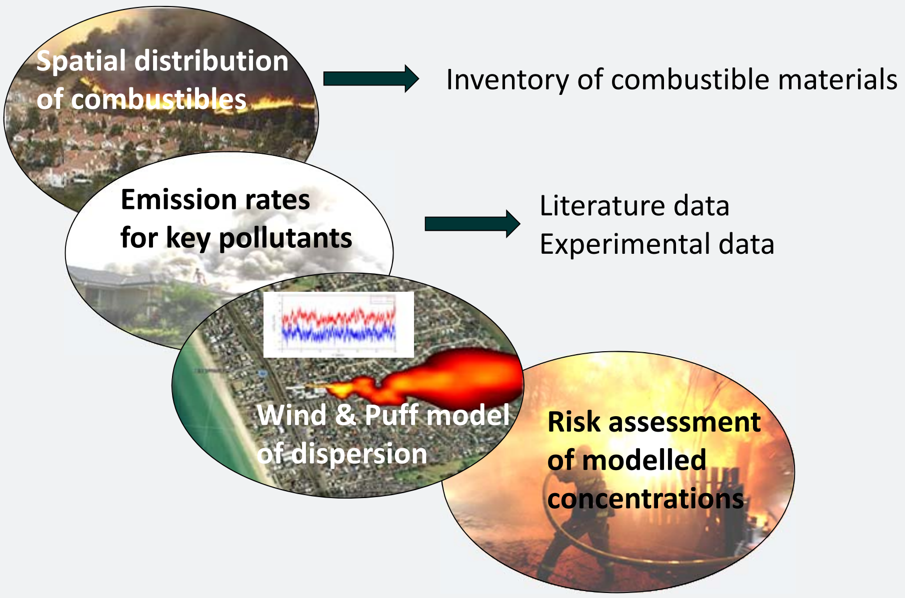
OBJECTIVE

RESEARCH APPROACH

ELEMENTS



I. FUEL

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→ Inventory of combustible materials

THE RURAL-URBAN INTERFACE: FUEL

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Complex mix of vegetation and other fuels

- House structure
- House contents
- Surrounding elements
- Vehicles
- Sheds

Complex spatial distribution of materials

THE RURAL-URBAN INTERFACE: FUEL

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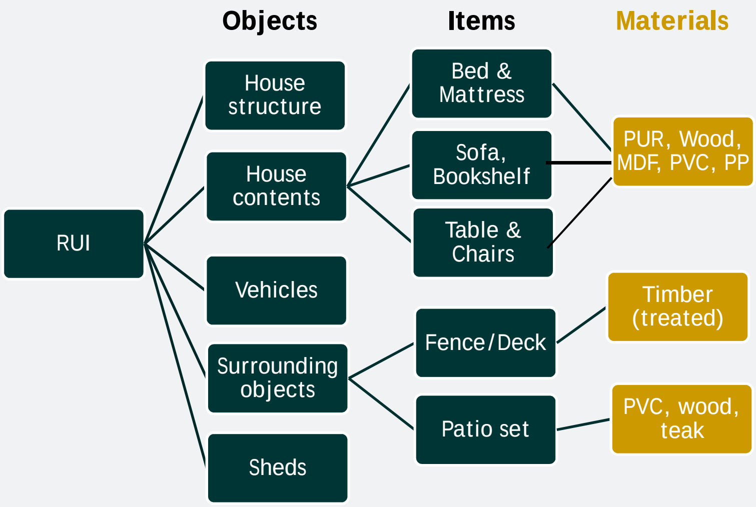

COMBUSTIBLE MATERIALS

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	Estimated amount of combustible materials (kg)					
Material	**House structure**	**House contents**	**Surroundings**	**Vehicle**	**TOTAL**	**Mass fraction (%)**
Wood	9450	1520	840		11810	60
MDF	2780	1240			4020	20
Paper		400			400	2
Textile	325	700	20		1045	5
PUR	150	190	20	40	360	2
PVC	300	250	140	20	710	4
PE/PP/PS	150	900	190	140	1380	7
Rubber				30	30	<1

SPATIAL DISTRIBUTION OF COMBUSTIBLES

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Finite number of point source emissions characterised by a scale, by material and hence emission type and estimate of emission rates

UNCERTAINTIES

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Significant variability in:

- type, amount and material composition of items present at the RUI
- spatial distribution of materials
- elemental composition of materials
- presence of fire retardants in materials

⇨ Develop a useable scenario-based database including an inventory of materials and items present at RUI

II. EMISSIONS

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Emission rates for key pollutants

→ Literature data
Experimental data

EMISSIONS

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Combustion products

- Nature/toxicity
- Emission rates

Factors

- Nature of fuel/material
- Ventilation
- Temperature
- Fire geometry

FACTORS DRIVING EMISSION COMPOSITION

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Type of material	Combustion Product
Wood, PE, PP, PS, polyester	CO, CO_2, aliphatic, aromatic and oxygenated hyrdrocarbons (HC), PAHs
Nitrogen-containing material e.g., nylon, PUR, melamine, urea-formaldehyde	HCN, NOx (NO, NO_2), NH_3, nitriles, amines, isocyanates, organic nitro-compounds
Halogen-containing material, e.g. PVC, FP	Halides (HCl, HF), Dioxins, chlorinated PAHs or hydrocarbons
Sulphur-containing material, e.g. wool	SO_2, H_2S, organic sulphur compounds

Yield ↗ with ventilation	Yield ↘ with ventilation	Yield independent of ventilation
CO_2, NO, NO_2, SO_2	CO, HCN, NH_3, H_2S, HC, VOCs, PAHs	HCl, HF, HBr

EMISSIONS – COMBUSTION PRODUCTS

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- Review of existing literature data
- Identify gaps for setting up experimental burns

Small bench-scale experimental burns under controlled conditions for pure materials

- Emission rates of gaseous and particle species for combustible materials that serve as input into dispersion model
- Validation and potential use of e-nose technology
- Collection and analysis of ash residue

EMISSION FACTORS (g/kg) – LITERATURE DATA

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Pollutant	Wood	MDF	Paper	Textile	PUR	PVC	PE/PP/PS
CO_2	750-1750	800-2250	750-1750	100-2500	600-2250	500-1500	400-3200
CO	10-140	10-160	10-140	10-350	40-250	20-200	10-300
HCN	0.01	1	0.01	1-70	1.5-17	0.01	0.01
NH_3				1-10	1-2		
NOx	1.4	0.3-1.5	1.4	0.01-40	2-90	036	0.1
HCl						130-500	
THC				1-300	1-5	5-45	1-100
VOCs	1-20	1-20	1-20	1-40	1-50	1-50	5-30
PAHs	0.01-1.0	0.1-1.0	0.01-1.0	0.1	1-10	0.5-12	0.01-40
PM	2.4	3.9	2.4		26	1-30	20-160

EXPERIMENTAL BURNS - DESIGN

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- Exhaust flow: 0.024 $m^3 s^{-1}$
- Irradiance level: 25kW m^{-2}
- 100 × 100 mm samples conditioned at 23 ± 2° C and 50 ± 5% RH

MATERIALS

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Materials	Thickness (mm)	Weight (g)	Comments
Pine	20	124	Reference material
Painted pine (100% acrylic self-priming exterior white paint)	20	128	Limited
Particle board	16	105	Speciated VOCs, PAHs, PM
Particle board w/ melamine	16	109	limited
Medium-density fibreboard	16	111	Speciated VOCs, PAHs, PM
Carpet (wool/nylon blend)	12	19	Speciated VOCs, PAHs, PM
Polyester insulation	37	6	Limited
PUR foam (23/130)	30	5	Speciated VOCs, PAHs, PM
PUR foam (36/130) CM	30	11	Speciated VOCs, PAHs, PM
Polystyrene (high density) with cladding	30	35	Speciated VOCs, PAHs, PM
Plasterboard	10	68	Limited
CCA-Treated pine	15	52	

EXPERIMENTAL SETUP

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EXPERIMENTAL SET-UP: PARTICLES

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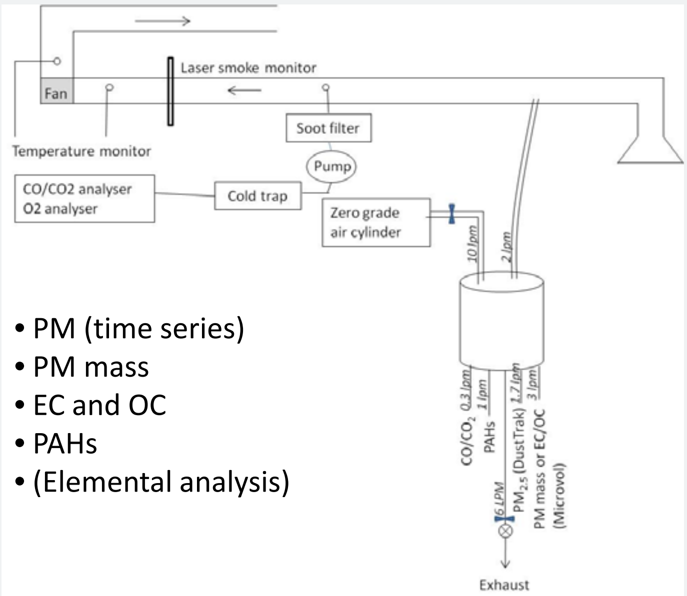

- PM (time series)
- PM mass
- EC and OC
- PAHs
- (Elemental analysis)

EXPERIMENTAL SET-UP: VOLATILES

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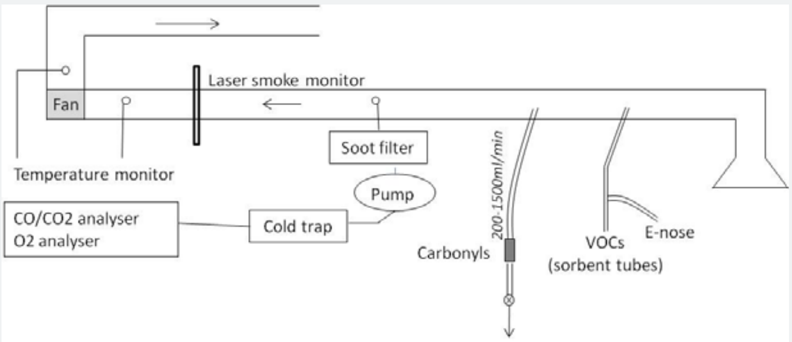

- Carbonyls (Aldehydes & Ketones)
  - ⇨ integrated measurements
- Volatile Organic Compounds (VOCs)
  - ⇨ 200 ml spot samples taken before and after ignition

RESULTS - COMBUSTIBILITY

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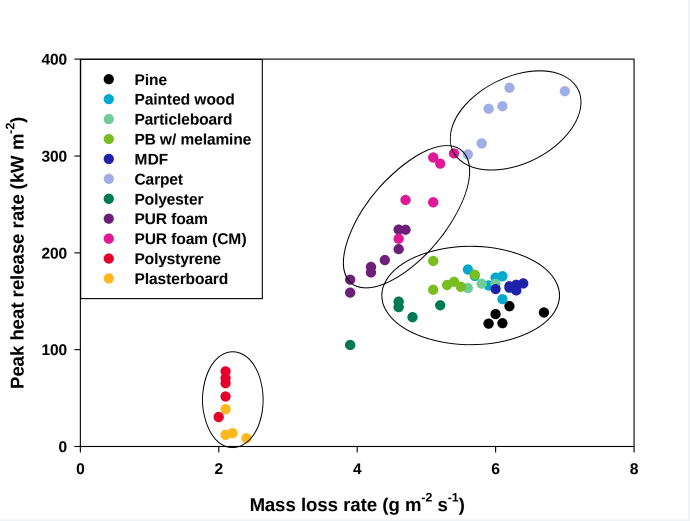

TIME SERIES ANALYSIS OF CO, CO_2 AND PM: WOOD-BASED PRODUCTS

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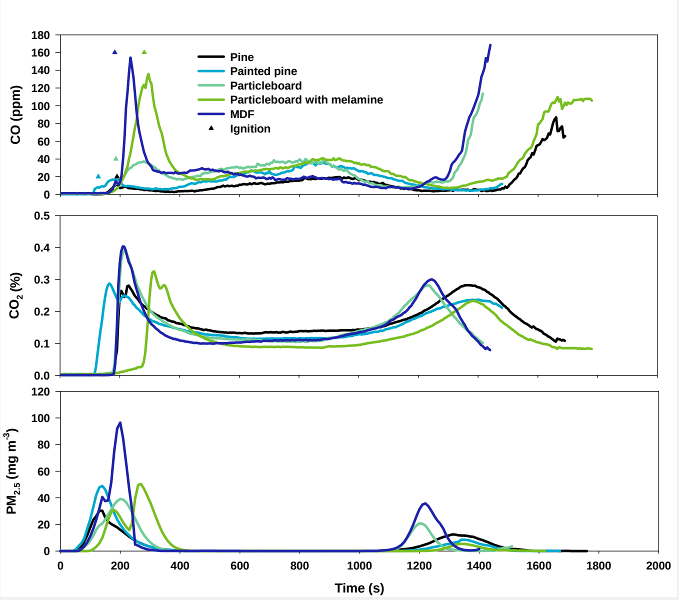

TIME SERIES ANALYSIS OF CO, CO_2 AND PM: POLYMERIC MATERIALS

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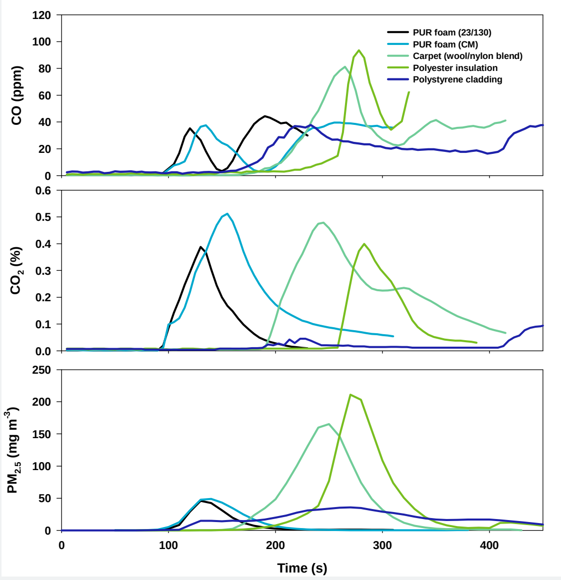

EMISSIONS OF CO, CO_2 AND PARTICLES

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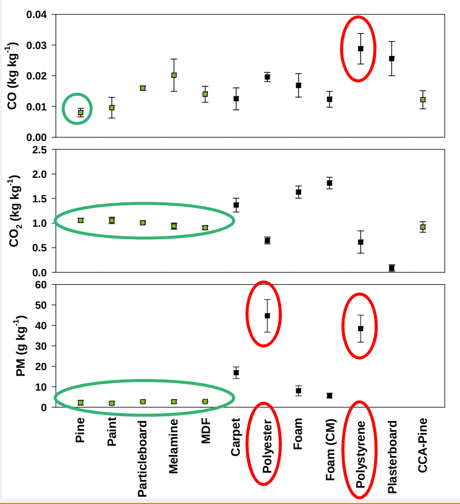
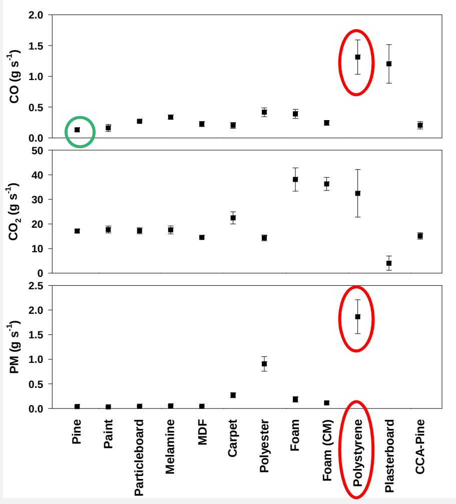
Emission factors (g/kg)



Emission rates (g/s)



ELEMENTAL AND ORGANIC CARBON

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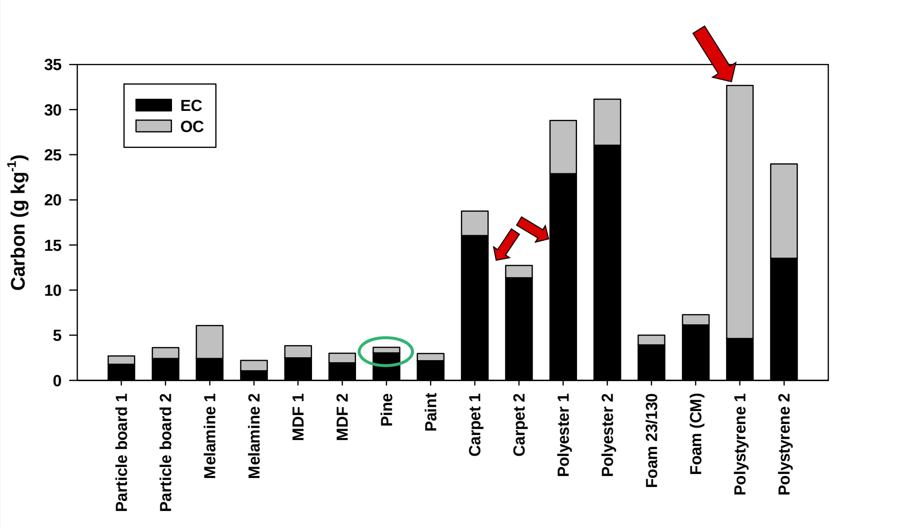

UNCERTAINTIES

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- Variability in fire conditions : **ventilation** and **temperature** have an effect on composition and amount of combustion products emitted
  - ⇨ **Variability in emission factors**
- Fire geometry – influence on emission yields
- Pure materials vs. mixture of materials

⇨ It is not feasible to determine one single EF for a material that would represent all types of fires
⇨ Emission rates – the most uncertain input into model

III. DISPERSION

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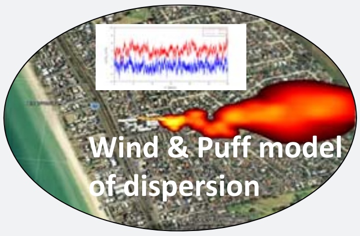

Combustion products

↓

Exposure/Ground concentration

PUFF-GENERATED PLUMES

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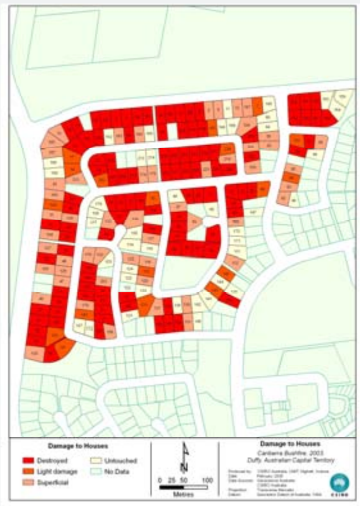
- Finite number of point source emissions characterised by
  - a scale
  - material
  - emission type
  - estimate of emission rates
- Puff-generated plumes from multiple point sources coupled with complex correlations of winds at source emissions
- High time resolution for near field peak concentration exposures



MODELLED EXPOSURE CONCENTRATIONS

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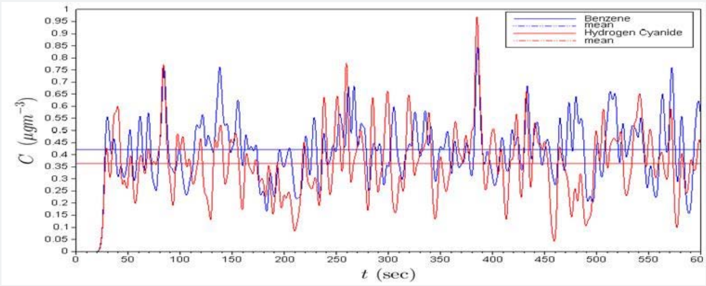

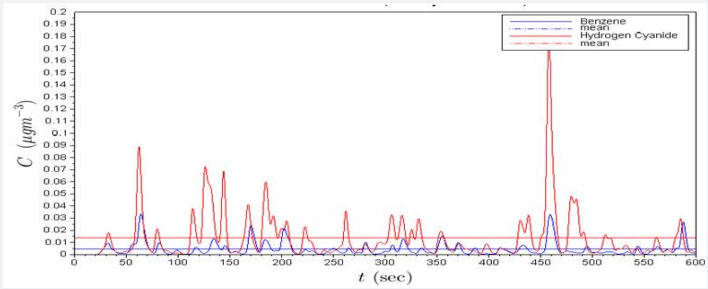

INTEGRATED SYSTEM TO ESTIMATE RISKS

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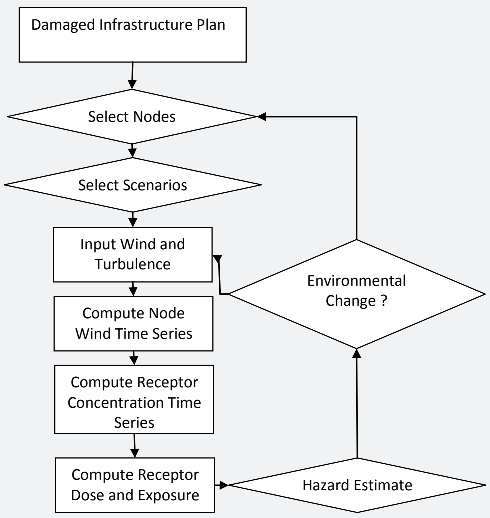

IV. EXPOSURE ASSESSMENT

Compare modelled ground concentrations of key pollutants to occupational exposure standards

MODELLED GROUND CONCENTRATIONS

New dispersion model technique:

- Provides ground concentrations for a range of pollutants at short-time resolution
- Allows for peak, short-term and average workshift exposure assessment
- Takes into consideration exposures to a mixture of air pollutants which may have additive or synergistic effects

AIR TOXICS – HEALTH EFFECTS

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Air toxic	TWA (mg/m³)	Health effect
CO_2	9000	Changes to respiratory patterns
CO	34	Asphyxiant
HCN	11 (peak)	Asphyxiant
NH_3	17	Respiratory irritant
NO	31	Hypoxia at high concentrations
NO_2	5.6	Respiratory irritant
HCl	7.5 (peak)	Severe irritant
SO_2	5.2	Irritant
Hydrocarbons	3.2 (benzene)	Irritant; asphyxiant; carcinogen
VOCs	1.2 (formaldehyde)	Irritant; probable carcinogens
PAHs	52 (naphthalene)	Irritant; probable carcinogens

TARGET ORGANS

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Respiratory tract

Benzene, toluene, styrene, formaldehyde, acrolein, phenol, isocyanates

Asphyxia

CO, HCN

Central nervous system

CO, benzene, toluene, phenol, 1,3-butadiene

Carcinogen

Benzene, formaldehyde, naphthalene, B(a)P, isocyanates

EXPOSURE ASSESSMENT - UNCERTAINTIES

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- Emission estimates for materials burnt and their spatial distribution within the RUI
- Firefighters' activities and position in relation to the smoke plume
- Changing meteorological conditions

⇨ Develop a useable set of scenarios

⇨ Compare modelled exposure concentrations to previously measured exposures at structural fire incidents

ACKNOWLEDGEMENTS

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THANK YOU

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