Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC.

FIRE NOTE

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IDENTIFYING SMOKE IMPACTS FROM BUSHFIRES EXTENDING INTO THE RURAL-URBAN INTERFACE

SUMMARY

The expanding rural-urban fringe means there is likely to be increased firefighting activity in rural-urban settings. The rural-urban interface is an environment characterised by a more complex mixture of fuels, resulting in an increased risk of toxic combustion products, more complex fire behaviour and smoke plume dispersion. Different firefighting tactics are needed to ensure protection of people and property. These aspects add complexity to predicting firefighters' exposures to toxic chemicals and make it difficult to extrapolate from existing research findings on occupational exposures at bushfires.

While at structural fires, firefighters in general wear breathing apparatus protecting them against harmful chemicals in the air. However, firefighting at the rural-urban interface is often conducted with minimal respiratory protection, despite the high likelihood of exposure to toxic fumes and particles, both during and after fires.

ABOUT THIS PROJRCT

Research Program: Occupational Health & Safety – Surge Capacity.

Research project: Rural Urban Interface Air Toxics.

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CONTEXT

The objectives of the research project are to identify and characterise potential hazards due to exposure to air toxics while fighting bushfires that extend into the rural-urban interface; and to assess the risks of exposure to fire and emergency service workers and residents.

BACKGROUND

Extensive research on occupational exposures has been conducted at bushfires within Australia (see, for example, projects in www.bushfirecrc.com/research/program-d). However existing research findings cannot be easily extrapolated to the rural-urban context.

The rural-urban interface is characterised by multiple fuel types, including vegetation, combustible materials from house structures, house contents, vehicles, sheds, garages and other objects around a house. These burning materials are likely to emit toxic combustion products which may cause an increased health risk to firefighters, emergency service workers and the community.

Although research has been conducted on emissions from a range of materials, the composition of emissions and their concentrations in smoke plumes is not well studied. Results from research on the toxicity of fire effluents from house fires are not easily extrapolated to the rural-urban interface. For bushfires extending into the interface, exposures will not be due to burning of individual structures but to a combination of a number of burning houses and their surroundings.

Currently, fire and land management agencies do not have scientific evidence to quantify the exposure to air toxics faced by workers at the interface. There is a need to better understand the environment of the interface to assess exposure risks to firefighters, emergency service workers and residents during and after fires.

BUSHFIRE CRC RESEARCH

The aim of the project is to gain a better understanding of potentially toxic emissions and their exposure concentrations at the rural-urban interface. In the first instance this involves identifying the types and amount of major combustible materials in structure and contents of houses as well as in other objects commonly present around a house and determining emission products released from burning materials. This *Fire Note* reviews the current state of knowledge on the types and yields of combustion products from major classes of materials.

Combustible materials
The rural-urban interface is comprised of a large variety of combustible materials ranging from natural to synthetic products.

Wood and engineered or manufactured wood-based products such as particleboard, medium density fibreboards and plywood are widely used in building structures, flooring, shelving and cabinetry and make up a large proportion of combustible materials.

Another important class of combustible materials is the polymeric materials or plastics which have a wide range of properties and play a significant and ubiquitous role in everyday life. They are commonly used as furnishings, construction materials, textiles and in vehicles. The most common polymers and examples of their applications are shown in Table 1. Other products present at the interface include paper, paints, solvents, insecticides, pesticides, petrol, oil, rubber and other chemicals.

TABLE 1 MAJOR POLYMERS USED AS MATERIALS IN HOUSE STRUCTURE AND HOUSE CONTENTS

Polymer	Application/Use
Polyethylene	Plastic bags, cable insulation, garbage bins, water tanks
Polypropylene	Food containers, appliances, carpets, rugs, mats, roofing membranes
Polystyrene	Packaging foam, food containers, CD/cassette boxes, TV, fridge liners, insulation
Polyvinyl chloride (PVC)	Pipes and guttering, cable insulation, window frames, roofing membranes, flooring, curtains/blinds, cabinets, outdoor furniture, fences
Fluoropolymer	Cable-base material
Polycarbonate	Electronic components, CD, DVD
Polyurethane	Foams (sofa, mattress), thermal insulation, surface coatings
Polyisocyanurate	Thermal insulation
Polyester	Fibres/textile, insulation
Polyamide (nylon)	Fibres/textile
Melamine resin	Main constituent of high pressure laminates used in kitchen and bathroom cabinets, kitchen utensils and plates

Combustion products
Burning materials, either natural or synthetic, release a complex mixture of combustion products into the atmosphere. Many are linked to adverse acute or chronic health effects, including asphyxia, eye, nose, throat, lung or skin irritation, shortness of breath, exacerbation of existing respiratory or cardiovascular conditions, effects on the central nervous system and cancer.

Major factors that play a role in the composition and yield of potentially toxic combustion products released into the atmosphere are: the nature of the combustible material; the physical conditions of the fire; and distance from the fire.

Nature of combustible materials

- Combustion of natural or synthetic products that are based on carbon and hydrogen (such as cotton, polyethylene, polypropylene, polystyrene) emit primarily carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons. Significantly, benzene is one of the principal components of organic combustion products.
- Combustion of nitrogen-containing materials such as polyurethane

and nylon additionally produces hydrogen cyanide (HCN), ammonia (NH_3), nitrogen oxides, nitriles and nitrogenated hydrocarbons.

- Halogen-containing materials such as polyvinyl chloride (PVC) or fluoropolymer produce halides, hydrogen chloride (HCl) and hydrogen fluoride (HF), dioxins and chlorinated hydrocarbons.
- Sulphur-containing compounds such as wool, rubber and gypsum release sulphur dioxide (SO_2), hydrogen sulphide (H_2S) and other sulphur containing organic compounds.
- The presence of fire retardants can result in the release of additional toxic compounds and are also likely to result in a less efficient combustion and therefore likely higher emissions of organic compounds.

Fire conditions

Oxygen availability and fire temperature are important factors in both the composition and yield of combustion products formed. Well-ventilated or flaming fires will result in the production of mostly carbon dioxide, water, nitrogen oxides and sulphur dioxide, whereas less-ventilated conditions release a more complex mixture of combustion products including carbon monoxide, aliphatic, aromatic and oxygenated hydrocarbons, hydrogen cyanide and ammonia. As a result, non-flaming smouldering combustion releases more toxic products than flaming combustion.

RESEARCH OUTCOMES & CONTINUING WORK

A number of studies have investigated combustion products from a variety of materials generally under well-controlled bench-scale fire tests (reviewed in Reisen, 2011). The most extensively studied class of combustion products is inorganic gases (such as carbon monoxide, carbon dioxide, ammonia, hydrogen chloride, hydrogen sulphide and sulphur dioxide). A small number of studies also investigated other pollutants, including volatile organic compounds, polycyclic aromatic hydrocarbons, dioxins and particle characterisation. The organic compounds were considered to be a potential hazard, but in most studies individual compounds have not been identified or quantified.

The review of existing literature data on combustion products from materials present in house structure and contents has enabled us to design a set of experimental burns aimed at filling gaps in the current knowledge. The experimental burns, to be conducted in July and August 2011 at the fire facilities at CSIRO in Highett, Victoria, will be bench-scale fire tests using a cone calorimeter. The cone calorimeter is a small-scale fire test apparatus designed to measure rate of heat release, mass loss rate, ignitability, smoke density and gas species production rate. The cone calorimeter at CSIRO Highett has been modified to provide a controlled-atmosphere environment. This allows testing at varying oxygen conditions and performing tests at both well-ventilated and less-ventilated conditions. The cone calorimeter has two sample ports installed in the exhaust duct for sampling of combustion products. The aim of the tests is to identify and quantify major combustion products that have the potential to harm a firefighter's health or safety. The tests will look at materials that are commonly present at the rural-urban interface but for which limited information on their combustion products is currently available. A list of materials planned to be tested is shown in Table 2. As information on speciated volatile organic compounds, aldehydes, polycyclic aromatic hydrocarbons and particle composition is scarce, testing will focus on those combustion products. A number of these compounds are strong irritants and probable carcinogens and may add to the toxic effects of other toxic gases present in the smoke such as HCN and ammonia. Ash residue will also be analysed for its potentially toxic content.

TABLE 2 PROPOSED LIST OF TEST MATERIALS

Material	Use	Combustion product information
Wood (pine)	Reference material	Extended
Painted wood		Very limited
Medium density fibreboards or particle board	Important component of furniture	Limited on speciated volatile organic compounds, polycyclic aromatic hydrocarbons and particle composition
Laminated medium density fibreboards (melamine)	Kitchen and bathroom cabinets	Limited
Polyurethane foam	Important component of soft furnishings	Limited on speciated volatile organic compounds, aldehydes, polycyclic aromatic hydrocarbons and particle composition
Polystyrene	Cladding material	Limited on speciated volatile organic compounds, aldehydes and particle composition
Polyester	Insulation batts; textile	Limited
PVC		Limited on speciated volatile organic compounds, aldehydes and particle composition

REFERENCES /FURTHER READING

Reisen, F. (2011) Inventory of major materials present in and around houses and their combustion emission products. Report to Bushfire CRC.

◄ The cone calorimeter is a small-scale fire test apparatus designed to measure rate of heat release, mass loss rate, ignitability, smoke density and gas species production rate.

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