PhD (Public Health)

Smoke Deconstructed

Not just particles

John Laurence Edwards
Edith Cowan University
Faculty of Computing, Health and Science
School of Exercise and Health Sciences
Department of Environmental Health

Introduction

Pyrolysis

Energy + Fuel + Oxygen = New product + Energy

Pyrolysation is the chemical decomposition of a substance by heat

- Starts at low temperatures prior to ignition
- Increases in proportion to heat exposure
- Can occur without oxygen present
- Can occur without ignition
- Can continue after fire is extinguished.

Josh McDaniel 2006

Fire Phases

Ignition – Small pieces are in full combustion while larger pieces are still being heated to their combustion point (water and VOC (ether & Benzene) are outgassed

Flaming - Large pieces ignite (350-600oC) burning cellulose, lignins, VOC, minerals. The majority of components are CO and CO2 – complete combustion.

Smouldering - Particles increase as the temperature is reduced.

2011 California – 700K Ha

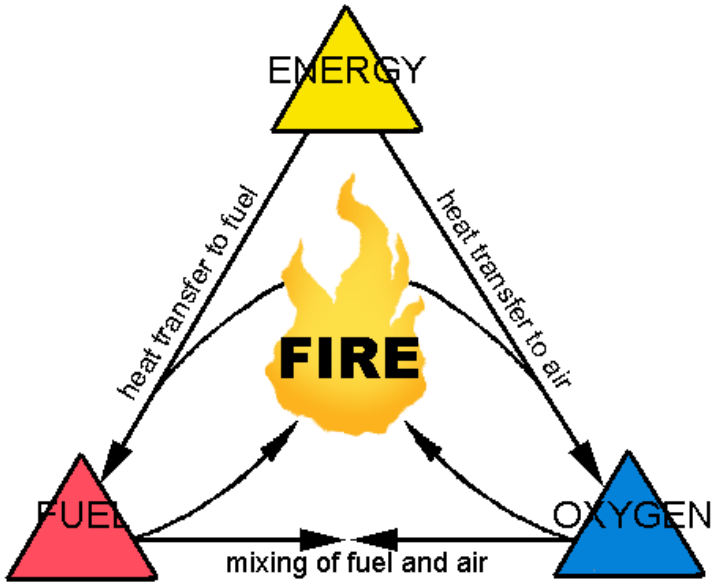
2009 - Victoria – 450K Ha

Smoke and Particulate matter

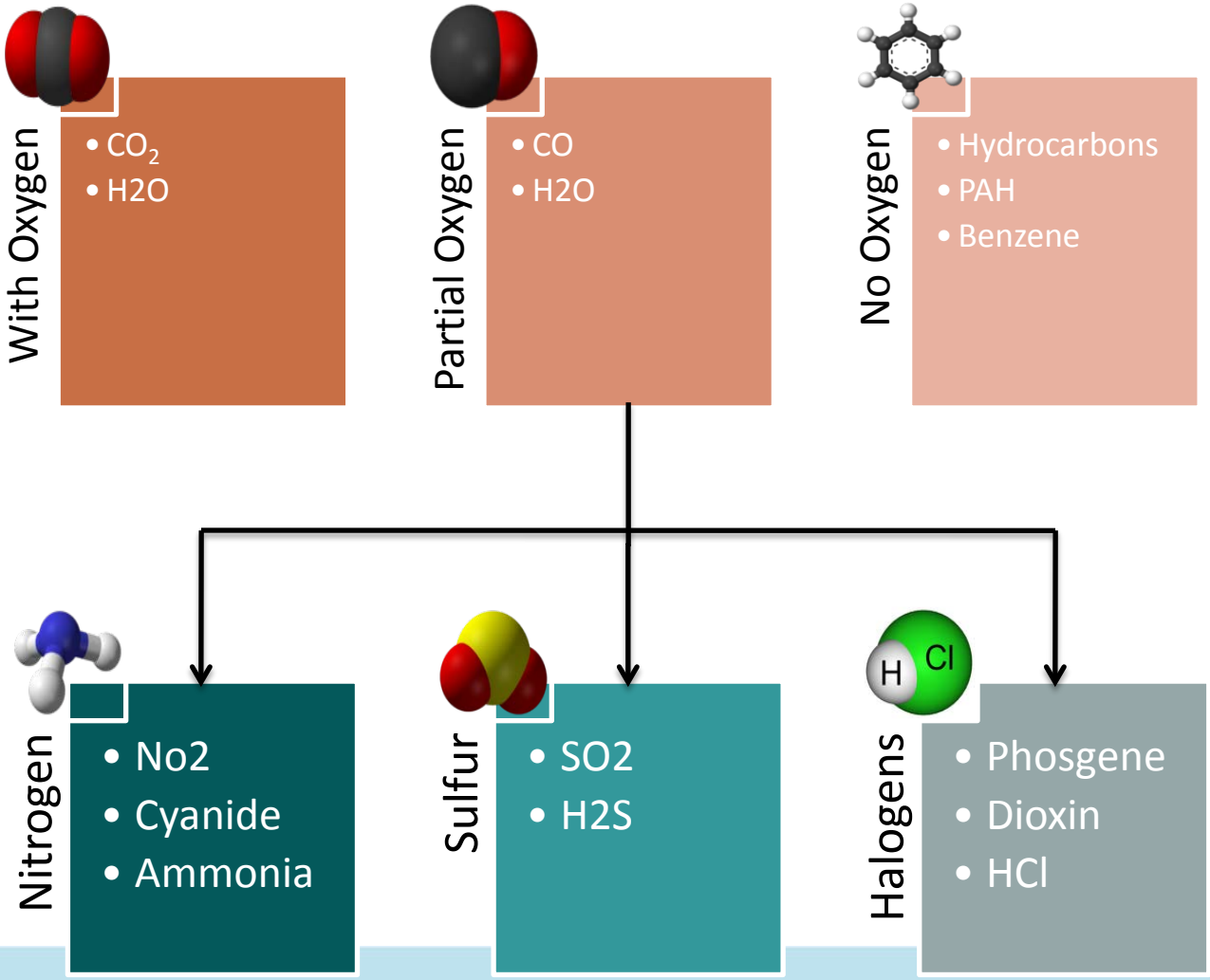
- Smoke results from incomplete combustion and high temperature pyrolysis reactions at low oxygen concentrations leading to the formation of unsaturated molecular species.

- The chemical composition and structure the biomass fuel will determine the composition, size and structure of the smoke “soot” particle.

(Drysdale, 2009)



Smoke composition sources



Health Effects & Occupational exposure

Health effects of smoke

- The majority of the population quickly recover from exposure to bushfire smoke
- Infants, the elderly or individuals with pre-existing diseases of asthma or bronchiolitis, or cardiovascular disease are among the most vulnerable to adverse impacts of air pollution.
- Particulate matter in bushfire smoke influence health effects such as respiratory and carcinogenic morbidity and mortality in an exposed population.

(Hamid, et al., 2010; Noonan et al., 2010; Jalaludin, et al. 2004; Naeher, et al., 2007)

Chimney Sweep Disease

- *Chimney sweeps cancer* (soot wart) *scrotal squamous cell carcinoma* didn't occur until the sweep was in his late teens or twenties.

- The disease was reported in 1775 by Sir Percival Pott in climbing boys or chimney sweepers.

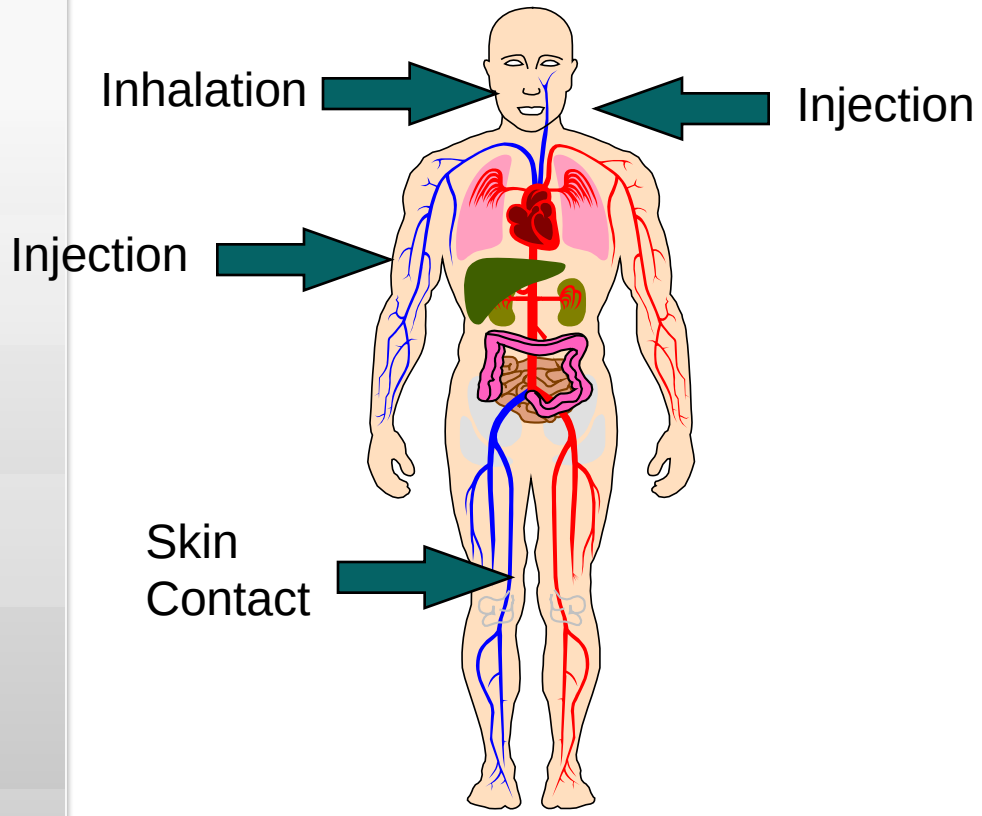
- It is the first industrially related cancer to be found

Fire Fighter Cancer

- Research shows firefighters are more than **three** times more likely to develop cancer -leukaemia, bladder, brain and kidney cancer than the general population.
- Professional firefighters are exposed frequently and continuously during their careers to a toxic combination of chemicals that arise from fire, and that exposure is a part of the unavoidable occupational risk.
- WA laws to be introduced would recognise that career firefighting is a carcinogenic occupation.
- Compulsory to wash turn out uniforms – change in culture

Skin absorption varies by region
Relative regional permeability of human skin

Plantar Foot arch	1
Lateral Ankle	3
Palm	6
Ventral Forearm	7
Back	12
Scalp	25
Forehead	43
Jaw Angle	93
Scrotum	300



Particulate Matter

- Particulate matter in air pollution generally comprises a mixture of organic and inorganic compounds such as carbonaceous material, organic chemicals, metals and polyaromatic hydrocarbons.

- The physical attributes of particulate matter, such as varying size fractions, play an important role in determining their effect on human health.

- Smaller respirable particles ($PM_{2.5}$) have the capacity to become lodged in the lungs resulting in increased difficulty for the body's defences to extricate the material.

(Hamid et al., 2010; Karthikeyan et al. 2006)

Chernobyl Forrest

- An extreme example of particulate contamination risk comes from the Chernobyl exclusion zone.
- This area contains 260,000 hectares of forest and is highly contaminated with Plutonium 238, 239, 240, Caesium 137 and Strontium 90 in the vegetative soil and litter.
- The lack of forest management over the past 25 years has meant that there is approximately 1.4 million cubic meters of dead radioactive wood located within the zone.
- This poses serious health risks for local and regional communities from the smoke itself and the radioactive material entering the food chain

(Zibtsev et al., 2011).

http://newsimg.bbc.co.uk

The PhD Study

Air Pollutants

- Air pollutants can be defined as substances, which exist in such concentrations as to cause unwanted effects, and are composed of solid particles, liquid droplets and gases.
- The main indicator pollutants include nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and particulate matter.
- Other air pollutants include substances in low concentrations but with characteristics of toxicity or persistence that make them hazardous to human health, including volatile and semi-volatile organic compounds (VOC's), polyaromatic hydrocarbons and heavy metals

(Kunii et al. 2002; Hamid et al. 2010)

Air Pollutants and Forests

- Forests surrounding cities are susceptible to high heavy metal loading by industry, motor vehicles and individuals. Thus the heavy metal composition of plant material is correlated with air pollution levels
- Some species of plants can accumulate higher levels of heavy metals and are known as hyper-accumulators.
- Eucalyptus & Acacia species are two hyper accumulators used in mine site bioremediation.

(Beer, 2001; Jonsson, et al. 1997)

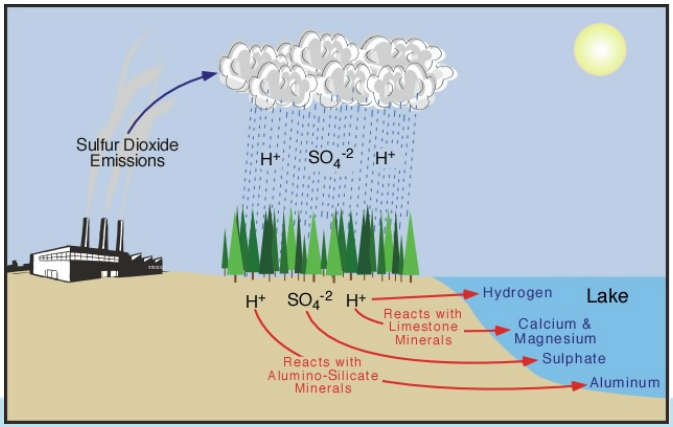
Heavy Metals & Trees

- Heavy metals are ubiquitous in the environment and are found within soil, air, water and plant matter.
- Plants require essential trace elements (Iron, copper and zinc etc), for growth
- bioaccumulation and biorestriction to ensure that the level of heavy metal uptake is optimal for plant growth and survival.
- Plants uptake minerals through root systems and when burnt these become airborne pollutants.
- Airborne particles are then deposited elsewhere on leaf material, soil and water

(Brunner et al., 2007; Unterbrunner, et al., 2006; Lyon & O'Connor, 2008; Radojevic, 2003)

Heavy Metals Imbalance

- Anthropological inputs into an ecosystem alter the natural balance, thus effects through the release of high concentrations of heavy metals into the environment.
- Tomasevic et al (2003) in his study of heavy metal accumulation in leaves from urban areas found a positive relationship between the atmospheric deposition of heavy metals and heavy metal concentrations in plant material.
- Kahle (1992) also found increasing problems from the airborne burden of forest soils in industrialised and rural regions of the world.



Prescribed Burns

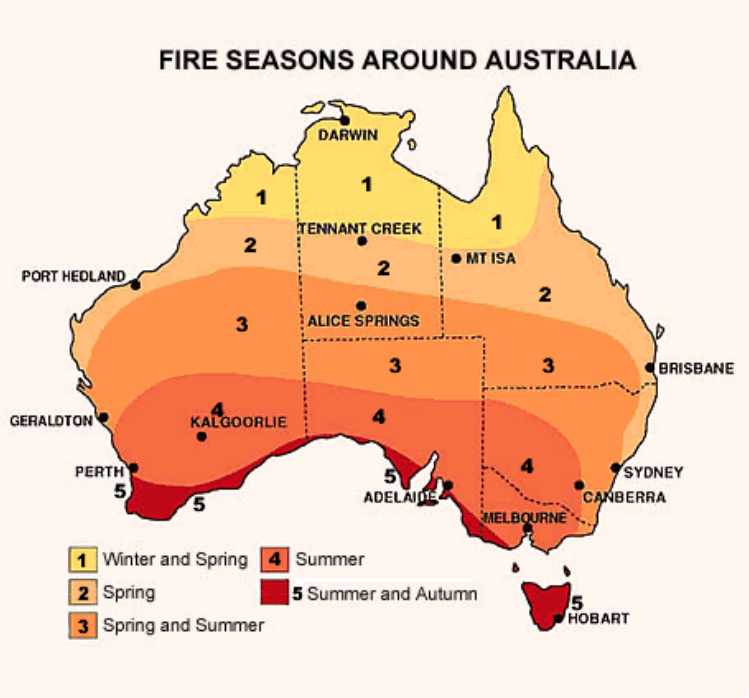
- The Western Australian Government's position is that prescribed burning is the most effective method to manage fuel loads and mitigate the potential impact of uncontrolled bushfires.
- Prescribed burning is defined as the manipulation of the fuel load across the landscape for the purpose of minimising the size and intensity of bushfires.
- The reduced fuel load leads to a reduction in fire intensity and rate of spread of subsequent bushfires which allows firefighters to effectively combat the fire and to limit its impact (Gould et al., 2007; McCaw et al., 2008).

Responsible Agency

- The Department of Environment and Conservation (DEC) is responsible for the management of fuel loads on more than 26 million hectares across Western Australia.
- The land that DEC manages includes national & regional parks, State forests and timber plantations.
- DEC utilizes a landscape-scale management approach to its prescribed burning program that is designed to ensure that a “mosaic” of fuel-reduced areas is maintained.

(Kealty, 2011)

Location



- The Darling Scarp is an escarpment adjacent to the Perth metropolitan area extending towards Toodyay and Boddington.
- The Swan Coastal Plain is a low lying area, 30 kilometers wide from the Indian Ocean to the Darling Scarp
- Rainfall ranges between 600 and 1000 mm annually and the climate is Mediterranean (Mitchell, et al. 2002).

Hamid, *et al.*, 2010; Noonan *et al.*, 2010; Jalaludin, *et al.* 2004; Naeher, *et al.*, 2007, Kunii *et al*, 2002

Previous Studies in this area

- a study of bushfire ash on roofs and settling on rainwater tanks. Too many other confounding variables made it impossible to identify ash as the contamination source.
- Another study of metals of smoke haze in Singapore detected metals (Aluminium, Cobalt, Copper, Iron, Manganese, Lead, Zinc, Cadmium, Nickel, Thallium, Vanadium and arsenic) but the origin could not be determined as there were other sources of metal contamination, such as industry and motor vehicle usage.
- Overall the trace element concentration constituted approximately 3-5% of the total $PM_{2.5}$ mass concentration.

(Spinks et. al. & Karthikeyan et al. 2006,)

Study Gap

- Despite the fact that there have been numerous studies of smoke composition, few have focused on the chemical composition associated with particulate matter derived from biomass smoke.
- Many researchers have identified the need to conduct further research in this area.
- The prominence of other contaminants within the plume, immediate health effects of these other contaminants and the belief that heavy metals may represent only a small component of the smoke composition.
- The sampling and analysis of heavy metals is costly.
- Gaining access to the fire grounds for most researchers is difficult due to safety reasons.

(Jalaludin *et.al*. 2004; Naeher, et. al. 2007; Reisen & Brown, 2006)

Study Logic

- The collection of samples close to the smoke plume will reduce the influence of other contaminant sources.

- Prescribed burns were chosen for this study for a number of reasons:
  - It is possible to prepare the equipment in advance, as it is known when and where the burns will commence and be undertaken.
  - The unpredictable nature of bushfires means it is too dangerous to be located at the head of the fire.
  - Prescribed burns are manageable events and the study results may provide additional information that can contribute to the management and effectiveness of the burn.

(Jalaludin *et.al*. 2004; Naeher, et. al. 2007; Reisen & Brown, 2006)

Equipment

Data will be collected simultaneously over a one-hour period, as close to the fire front as possible utilising the following instruments;

1. Davis Vantage Pro 2 mobile weather Station – Temperature, wind speed & direction and relative humidity
2. Microvol 1100 – Particulate matter (PM) using a 0.8µm and 1.2µm filter
3. Turnkey Dustmate – TSP, PM_{10}, PM_4 and $PM_{2.5}$ measurements.
4. VRaes Multi meter – Oxygen, Volatile Organic Compound and Carbon Monoxide.

Collection for analysis

- The filters will be weighted before and after the sampling.
- Leaf litter and soil samples obtained prior to the prescribed burn will also be shipped to the NATA accredited laboratory to determine metal content and pH.
- After gravimetric assessment of the filters they will be shipped to an external NATA accredited laboratory for further analysis for metal content.
- 13 Metals (NEPM Suite) (As, Ba, Be, Cd, Cr, Co, Cu, Mn, Ni, Pb, V, Zn, Hg)

Questions?