Health Protection Agency
Chemical Hazards and Poisons Division (London)
London
WC1V 7PP
24 Hr Tel: 0870 606 4444

PRODUCTS OF COMBUSTION

DRAFT SUMMARY INFORMATION

Incident Summary

Key Points

- Health risks associated with exposure to smoke and toxic substances released in fires is evident, but precise details are uncertain as smoke frequently contains a cocktail of substances, which changes with the temperature of the fire and through interaction with other pollutants[1]
- Products of combustion are likely to act as respiratory irritants and may cause coughing, choking, hypoxia and pulmonary oedema
- Contact with products of combustion may cause skin and eye irritation
- ***Protective clothing and breathing apparatus should be worn. In the event of a large fire, stay up wind and out of low areas. Stay indoors until plume has passed, ventilate closed spaces***
- This handout is produced in conjunction with specific CIRS chemical information sheets, for instance carbon monoxide (CO) and hydrogen cyanide (HCN)

First Aid

- Terminate exposure and support vital functions
- The casualties should be moved to an uncontaminated area
- Rescuers should, ideally, be trained personnel and must be careful *not to put themselves at risk* and *so wear appropriate protective clothing and, if available, respiratory protection*
- If the casualty is unconscious a clear airway should be established and maintained; give 100% oxygen if available

- **Inhalation exposure:** If the patient stops breathing then expired air resuscitation should be started immediately using a pocket mask with a one-way valve, if available. It is important in cases where the face is contaminated or where the exposure was by inhalation that expired air resuscitation is NOT attempted unless an airway with rescuer protection is used
- Intubate immediately if burns to face or neck or airway obstruction
- Give bronchodilators if bronchospasm occurs
- **Dermal exposure:** If skin irritation has occurred, seek medical attention and flush the area with water. In order to prevent further tissue damage removing clothing
- **Eye exposure:** If eye irritation occurs seek medical advice as soon as possible and irrigate thoroughly with water or saline for 15 minutes

Detailed information[1,4]

- Smoke consists of a mixture of gases, liquid droplets and solid particles representing the decomposition and combustion products from fires. See Appendix 1 for types of fires
- Toxic products from fires can be considered in three categories (see Table 1 at the end of the document):

    - ***Asphyxiants***: A major hazard inside buildings: simple asphyxiant gases (eg methane, nitrogen) displace oxygen causing hypoxia, chemical asphyxiants interfere with oxygen delivery and include hydrogen cyanide (HCN) and carbon monoxide (CO) which may be rapidly fatal

    - ***Irritants***: ***inorganic acid gases and organic irritants***.
        - Smoke irritants are important as potential causes of adverse health effects not only inside buildings but also in smoke dispersed into wide open areas
        - Inorganic acid gases include hydrogen chloride (HCl), hydrogen bromide (HBr), hydrogen fluoride (HF), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and phosphorous pentoxide (P_2O_5)
        - Organic irritants include formaldehyde, acrolein and crotonaldehyde
        - Irritants cause immediate sensory irritation of the respiratory tract
        - The severity of effect depends on the concentration exposed to and the solubility of the irritant in the smoke. Those with high water solubility tend to cause predominantly upper airway irritation (e.g. hydrochloric acid), whereas those with lower water solubility may reach further down the respiratory tract and can lead to pulmonary oedema which may be delayed (e.g. phosgene)
        - Other symptoms range from mild eye and throat irritation, to severe pain and death from respiratory arrest or laryngeal spasm at very high concentrations.

    - ***Unusual organic products***: Any chemical present in bulk or which is toxic at low concentrations could be released in the fire plume and may have important short and long term health implications (e.g particulates)

- As toxic products may differ at varying distances from a fire, it is simpler to consider the hazards in relation to difference zones of proximity to the fire:

- **Zone 1** – *Close proximity to the fire (i.e. within building).* The major risks are from heat, toxic smoke and asphyxiant gases which may be rapidly lethal.
- **Zones 2** – *immediately outside the fire zone (area depending on size of fire and chemical nature of hazard).* The major hazards are toxic smoke, irritant gases and particulates and any release from bulk chemicals if present.
- **Zone 3** – *the surrounding locality*. Hazards as for Zone 2 but less pronounced.

Summary of Human Toxicity

- For specific toxicological information on individual chemicals refer to relevant CIRS fact sheet
- For Risk Assessment of Exposure see Appendix 2
- The mortality rate following smoke inhalation is between 45-78%[2] with most deaths occurring before the patient reaches hospital usually as a result of carbon monoxide and/or cyanide poisoning
- Smoke and heat inhalation can damage both the airways and the lung parenchyma[3]
- Smoke constituents can cause atelectasis by destruction of lung surfactant, and a consequent risk of pneumonia
- Smoke can also damage the pulmonary capillary endothelium directly causing pulmonary oedema and impaired gas exchange often leading to pulmonary insufficiency[3]

Acute Clinical Effects

- Irritation of the eyes, nose and throat may be followed by coughing and wheezing, dyspnoea, sputum production and chest pain
- Bronchospasm, atelectasis, pneumonitis and pulmonary oedema may occur in severe cases
- Laryngeal oedema, muscosal oedema and sloughing may occur

Management

Inhalation Management

- Maintain a clear airway, give humidified oxygen and ventilate if necessary
- If respiratory irritation occurs assess respiratory function, monitor oxygen saturation and/or blood gases and if necessary perform chest X-ray
- Bronchodilators should be given if bronchospasm occurs
- For carbon monoxide and cyanide poisoning, see specific Carbon Monoxide and Cyanide information sheets
- Where methaemoglobinaemia occurs, give methylene blue if level is between 15-20% (avoid in G6PD deficiency); discuss further management with a Poisons Information Service or a Chemical Incident Provider Unit
- Symptomatic and supportive care

Investigations[4]

- Carbon Monoxide level (see separate Carbon Monoxide information sheet)
- Arterial blood gases for PO_2, A-a gradient and pH

- Chest X-ray (relatively insensitive for presence of smoke inhalation and pulmonary complications)
- Cyanide level (see separate Cyanide information sheet). There is no rapid assay available but suspect cyanide poisoning clinically if the patient is slow to respond to treatment or has a persistent acidosis
- Also consider:
    - methaemoglobin levels
    - ECG if >40yrs
    - Spirometry or Peak Flow (requires full cooperation but useful as baseline if symptoms develop later)
    - Laryngo/bronchoscopy to evaluate the upper airway for soot deposition

Admission Criteria for Inhalation Exposure

- *Discharge home:*
    - Asymptomatic patients, but they should be advised to return if symptoms develop within 12-36 hours
    - Patients with mild effects (what is mild) may be discharged, but if symptoms recur or develop over the following 24-36 hours they should be advised to return
- *Admission for 24 hours and then reassessed:*
    - All patients showing immediate, moderate or severe effects
    - Asymptomatic individuals with high risk of exposure to toxic smoke (enclosed space, plastics fire or steam explosion)
    - Asymptomatic with pre-existing lung disease, asthma or heart disease or elderly
    - Evidence of burns, neurological signs, abnormal blood gases, high CO levels, CXR or spirometry

Further Inhalation Management

- The airway should be assessed regularly and blood gases/chest X-rays taken if indicated by the clinical condition of the patient.
- Give humidified oxygen with regular suction
- If delayed pulmonary oedema develops, ventilate with high frequency ventilation and PEEP[4]
- All patients who have developed moderate or severe clinical effects, even if pulmonary oedema did not occur, should be reviewed after discharge for lung function tests

Dermal Management

- Remove any remaining contaminated clothing, place in double, sealed, clear bags, label and store in a secure area away from patients and staff
- Irrigate with copious amounts of water
- Treat burns symptomatically, including the use of silver sulphadiazine cream (Flamazine®), if indicated

Eye Management

- Irrigate thoroughly with running water or saline for 15 minutes
- Stain with fluorescein and refer to an ophthalmologist if there is any uptake of the stain

Written by: Henrietta Harrison and Desiree Elkabir
Last updated: May 2002

References

1. Dubber ML (ed). *Draft Smoke Toxins, Science & Toxicology.* National Focus for Chemical Incidents and Department of Health, 2002
2. Heimbach DM, Waeckerle JF. Inhalation injuries. Ann Emerg Med 1988; 17(12):1316-20
3. Hathaway GJ, Proctor NH & Hughes JP. Proctor and Hughes' Chemical Hazards of the Workplace, 4th ed. Van Nostrand Reinhold, New York, 1996
4. Lee-Chiong, TL. Smoke Inhalation Injury. When to suspect and how to treat. Postgraduate Medicine 1999; 105(2): 55-62

APPENDIX 1

Types of fires[1]

- *Smouldering/non-flaming fires*: Slow thermal decomposition results in oxidation in non-flaming conditions; the products are rich in organic compounds, and usually highly irritant to the respiratory tract. Other products include inorganic acids (further irritants) and CO. These fires are rarely a public health risk beyond the building, although they may have a strong smell and represent an environmental nuisance to surrounding areas
- *Well ventilated fires*: Occur when there is plenty of air, therefore combustion is most efficient (e.g. the early stages of most fires). Initially the smoke and toxic products are low but as the fire develops carbon monoxide and carbon dioxide production can be significant, and many inorganic materials may be released as acid gases.
- *Ventilation limited? controlled flaming fires*: Occur when the air supply is restricted compared to the fuel available for combustion. This type of fire is of most interest in the context of large fires threatening the wider environment beyond the building of origin, as well as the occupants within large buildings. High concentrations of carbon monoxide, carbon dioxide, hydrogen cyanide, organic products, smoke and inorganic acid gases occur

APPENDIX 2

Risk assessment

This is difficult in the light of the current information, however, the following may be useful in assessing potential hazard and therefore possible risk in conjunction with data on casualty and exposure location:

- *exposed within the plume (zone 1):* This is the zone of greatest risk for toxic exposure. An unknown number of fire officers are attending the fire: all should be wearing appropriate breathing apparatus and protective clothing as required

- *exposed from plume fall out (zone2):* the wind and weather dilution factors for the plume will reduce the potential toxicity. Therefore a small risk of adverse health effects exists for those who may be exposed from plume fall out. Those with pre-existing respiratory diseases such as asthma may be more at risk

- *concerned about potential toxicity (zone3):* those who are potentially at risk but who have not in fact been exposed may become anxious and develop exacerbation of concurrent disease. Where there is no evidence of direct exposure, they should be observed and treated for the concurrent disease and reassured

Table 1: Relationship between fire type and hazard development[1]

Fire type	Risk Assessment Zone	CO	HCN	HCl	P_2O_5	Isocyanate -NCO	Irritants eg Acrolein	HF & HBr	PAHs eg Benzene	NO_2	SO_2	NH_3	Particles	Exotics eg dioxins	O_3
Rubber,	Emissions	+++	+	+	–	–	+++/ ++	–	++	+	++++	–	+++	+++/ ++	+
Tyres,	Zone 2 Risk	±	±	+	–	–	++/+	–	±	±	+++/ ++	–	++	++	+
Belting	Zone 3 Risk	–	–	–	–	–	+	–	–	–	++	–	+		–
Petrol storage eg Petrol station	Emissions	++	–	–	–	–	++	–	+	–	–	–	+++	+	+
	Zone 2 Risk	–	–	–	–	–	+	–	±	–	–	–	++	–	
	Zone 3 Risk	–	–	–	–	–	–	–	–	–	–	–	+	+	
Plastics Factory/ Warehouse	Emissions	+++	+++	+++	+	++	++	+	++	++	+	+	+++	+++	+
	Zone 2 Risk	±	±	++	–	++	++	±	±	+	+	±	++	++	
	Zone 3 Risk	–	–	+	–	+	+	–	±	–	–	–	+	++	
Resins and Adhesives	Emissions	+++	++	+	–	++	++	+	++	++	–	+	+++	++	+
	Zone 2 Risk	±	±	+	–	++	++	±	±	+	–	±	++	+	
	Zone 3 Risk	–	–	–	–	+	+	–	–	–	–	–	+	+	
Paints and Solvents	Emissions	+++	–	++	+	++	++	–	++	–	–	–	++	++	+
	Zone 2 Risk	±	–	+	–	++	+	–	±	–	–	–	+	+	
	Zone 3 Risk	–	–	–	–	+	–	–	–	–	–	–	–	+	
Upholstery-Polyurethane	Emissions	+++	+++	+++	–	++	++	+	++	++	+	+	+++	+++	+
	Zone 2 Risk	±	±	++	–	++	++	±	±	+	+	±	++	++	
	Zone 3 Risk	–	–	+	–	+	+	–	–	–	–	–	+	++	
Vegetation -	Emissions	+	–	–	–	–	+	–	+	+	–	–	+++	+	++

HARZARD LEGEND: +++ HIGH ++ MEDIUM + LOW ± POSSIBLE – UNLIKELY

Fire type	Risk Assessment Zone	CO	HCN	HCl	P_2O_5	Isocyanate -NCO	Irritants eg Acrolein	HF & HBr	PAHs eg Benzene	NO_2	SO_2	NH_3	Particles	Exotics eg dioxins	O_3
Forests	Zone 2 Risk	–	–	–	–	–	+	–	±	±	–	–	±	+	
	Zone 3 Risk	–	–	–	–	–	–	–	–	–	–	–	–	+	
Oil Refineries Storage Tanks	Emissions	+	–	–	–	–	++	–	+++	–	+	–	+++	++	++
	Zone 2 Risk	–	–	–	–	–	++	–	±	–	+	–	++	+	
	Zone 3 Risk	–	–	–	–	–	+	–	–	–	–	–	+	+	
Waste Tips	Emissions	–	+	+	–	+	++	+	+	+	+	+	++	+++	+
	Zone 2 Risk	–	±	+	–	+	+	±	±	+	+	±	+	++	
	Zone 3 Risk	–	–	–	–	–	–	–	–	–	–	–	–	++	
Pesticide and especially OP stores	Emissions	+++	–	++	++	++	++	–	+	–	–	–	++	++	+
	Zone 2 Risk	±	–	++	++	++	+	–	±	–	–	–	+	++	
	Zone 3 Risk	–	–	+	+	+	–	–	–	–	–	–	–	++	
Phosphorus fires	Emissions	+++	–	+	+++	++	++	–	+	–	–	–	++	++	+
	Zone 2 Risk	±	–	+	++	++	+	–	±	–	–	–	+	++	
	Zone 3 Risk	–	–	–	+	+	–	–	–	–	–	–	–	++	

Note: Chlorine Not applicable as chlorine is the main risk

HAZARD LEGEND: +++ HIGH ++ MEDIUM + LOW ± POSSIBLE – UNLIKELY