Combustion hazards from building materials

Abstract. Fire smoke has a highly variable composition which is dependent on several factors, including oxygen supply, heating rate, temperature and the chemical structure of the materials that are burning. One area that is particularly important is the determination of volatiles that can have a negative effect on the environment as well as posing a serious hazard to human health. Prediction of toxic fire hazard depends on two parameters: time-concentration profiles for major products. These depend on the fire growth curve and the yields of toxic products; toxicity of the products, based on estimates of doses likely to impair escape efficiency, cause incapacitation, or death. Toxic product yields depend on the material composition, and the fire conditions. The most significant differences in fire conditions arise between flaming and non-flaming combustion. The burning of an organic material, such as a polymer, is a complex process, in which volatile breakdown products react, to a greater or lesser extent, with oxygen, producing a cocktail of products. These range from the relatively harmless carbon dioxide (CO₂) and water, to products of incomplete combustion, including carbon monoxide (CO), hydrogen cyanide (HCN), organo-irritants etc. In addition, depending on the other elements present, halogen acids, oxides of nitrogen, and sulphur, may be formed. The fire toxicity of building materials were investigated under a range of fire conditions, oxidative pyrolysis (smouldering) and well-ventilated flaming to under-ventilated flaming. The yields of the major toxic products, carbon monoxide, hydrogen cyanide and irritant gases nitrogen dioxide, hydrogen chloride and hydrogen bromide together with polycyclic aromatic hydrocarbons are presented as a function of fire condition. The toxicities of the effluents, showing the contribution of individual toxic components, are compared using the fractional effective dose (FED) model and LC₅₀ (the mass required per unit volume to generate a lethal atmosphere under specified conditions).

Keywords: fire smoke, toxicity, fire hazard.

Fig. 1. Fire Hazard Assessment [2]
Exposure effects from fire effluents

**Behavioural Effects.** There are both behavioural and physiological effects associated with exposure to fire effluents that can impact significantly upon occupants’ taking effective action to accomplish their own escape. Behavioural effects impacting escape are human factors commonly contributing to estimation of the time required for escape, examined in detail in ISO/TR 16738 [7]. However, for escape from fire, it is also necessary to consider the ways in which human behaviour would be modified by exposure to fire and its combustion products. The behavioural consequences of such exposure could lead to escape being aborted or even prevented by reduced visibility, hyperthermia, impaired breathing due to upper-respiratory tract sensory irritation, etc. [1, 8].

**Physiological Effects.** There are a number of primary physiological effects of exposure to fire and its combustion products. These can include visual obscuration due to smoke optical density, reflex blinking of the eyes, pain in the eyes, nose, throat and chest, coughing, laryngeal spasms, and various types of hypoxia due to lack of oxygen supplied to body organs. Hypoxia results in central nervous system depression, the effects of which are manifest by varying degrees of impaired judgement, disorientation, loss of motor co-ordination, unconsciousness and, ultimately, death [2].

In order to ensure safe evacuation, ISO 13571 [9] subdivides the hazards to people escaping from a fire into:

- **Asphyxia** from the inhalation of toxic gases, resulting in confusion and loss of consciousness;
- respiratory tract pain and breathing difficulties or even respiratory tract injury resulting from the inhalation of irritant smoke;
- impaired vision resulting from the optical opacity of smoke and from the painful effects of irritant smoke products and heat on the eyes;
- pain to exposed skin and the upper respiratory tract followed by burns, or hyperthermia, due to the effects of heat preventing escape, which can lead to collapse.

It treats each of the four components separately, defining untenability when any of the four reach a level which would prevent a potential victim effecting their own escape. The effect of asphyxiants and deep lung irritants depend on the accumulated doses, the sum of each of the concentrations multiplied by the exposure time, for each product; upper respiratory tract irritants are believed to depend on the concentration alone [2]. As this process is dynamic time-based, it depends upon the time-concentration curves (the exposure concentration (kg m⁻³), or exposure dose (kg m⁻³·min), requiring inputs on smoke and toxic product yields under different fire conditions. List of main asphyxiant and irritant gases is given in Table 2.

**Table 2. List of main asphyxiant and irritant gases**

<table>
<thead>
<tr>
<th>Asphyxiant gases</th>
<th>Irritant gases</th>
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</thead>
<tbody>
<tr>
<td>Carbon monoxide (CO)</td>
<td>Hydrogen chloride (HCl)</td>
</tr>
<tr>
<td>Hydrogen cyanide (HCN)</td>
<td>Hydrogen bromide (HBr)</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>Nitrogen dioxide (NO₂)</td>
</tr>
<tr>
<td>Sulphur dioxide (SO₂)</td>
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Fire effluents present two hazards to human life, as toxicants causing collapse and death directly, or as incapacitating irritants, impairing the function of the lungs and eyes, preventing escape [10, 11]. Carbon monoxide (CO), and hydrogen cyanide (HCN), (interacting synergistically with the hyperventilatory effect of carbon dioxide) are recognized as some of the most immediately life-threatening products.

**Asphyxiants.** Carbon monoxide binds to the haemoglobin in red blood...