Fire deaths and toxic gases

from Barbara Chernov Levin

AMONG the industrialized countries which record statistics on fires, the United States has the most fires per capita. The rate of fire death in the United States is almost twice the international average and is surpassed only by Canada¹. In 1979, approximately 7,800 people died and another 31,000 were reported injured². Direct dollar loss was greater than \$5 billion, but when indirect costs (meeting fire codes, installing fire protection systems, supporting fire departments and insuring property) are included in this calculation, the annual cost of fires in the United States is estimated at more than \$20 billion.

Large fires receive the most public attention and media coverage; for example, three hotel fires between November 1980 and May 1981 were the cause of 119 fire deaths and more than 1,000 injuries. Residential fires, however, continue to be the cause of most fire deaths and injuries. Approximately 80 per cent of these fire deaths are not due to burns, but are attributed to inhalation of toxic smoke and hot gases³. This information has prompted the fire community, materials manufacturers and building code officials to pose the following questions: do some building materials and furnishings produce combustion products that are much more toxic than others, and how can the occupants of buildings be protected from unnecessary risk in case of a fire? The answers to these questions are not simple and involve the evaluation of the total toxic hazard generated by a fire.

The potential for generating toxic gas from burning materials has long been recognized; for example, in the 1929 Cleveland Clinic fire, 123 people were killed by the decomposition products of nitrocellulose X-ray film⁴. Only recently, however, has the fire research community become acutely aware and concerned about the problem of the toxicity of combustion products and the possibility that toxic gases other than carbon monoxide (still a primary toxicant in fires) may have an important role. Autopsy data show a sample of fire victims with less than lethal amounts of carbon monoxide in their blood^{5,6}. Other factors may have been involved, however, as some of the victims had pre-existing heart disease and/or alcoholic intoxication.

Laboratory research studies also suggest a role for toxicants other than carbon monoxide. A highly toxic bicyclic phosphate compound produced during the thermal decomposition of a laboratory-formulated rigid flame-retarded polyurethane foam was identified by the University

of Utah⁷ and suggests the need for an animal testing system — conventional chemical techniques would have failed to detect such an unusual toxic product. Moreover, scientists at the National Bureau of Standards have found that carbon monoxide concentrations measured at the LC₅₀ of twelve thermally decomposed materials were 60–4,400 p.p.m., whereas the LC₅₀ of pure carbon monoxide was 5,000 p.p.m. The LC₅₀ here measures the amount of material necessary to kill 50 per cent of the rats exposed for 30 min. The death of the rats at less than the LC₅₀ of pure carbon monoxide indicated that additional toxic gases or other factors (for example, heat, lowered oxygen concentrations) were contributing to the cause of death. Many of the exposed rats also died during a 14 day post-exposure observation period, an occurrence which cannot be directly attributed to carbon monoxide poisoning.

Some of these thermally decomposed materials also produced the potent toxicants hydrogen cyanide and/or hydrogen chloride as well as carbon monoxide. Chemical analysis has detected many combustion products in addition to the frequently examined toxicants — carbon monoxide, carbon dioxide, hydrogen chloride, other halogens, oxides of nitrogen and sulphur, and ammonia. Scientists at the Fire Research Station in England have identified 20 chemical species from the thermal decomposition of polyacrylonitrile and 30 combustion products from polypropylene⁸. Michal *et al.* have identified 71 compounds from the combustion of polyethylene and 55 compounds from polypropylene⁹. Wood generates at least as many products¹⁰. The relative contribution of one or various combinations of these combustion products to animal toxicity is so far unknown and would require a major research effort to decipher.

The current awareness of the importance of combustion product toxicity is apparent from two recent symposia (Annual Society of Toxicology meeting, February 1982; American Chemical Society national meeting, March 1982), and by the newly convened combustion product toxicity committees of the US National Fire Protection Association and of the US National Institute of Building Sciences. Recently, three different animal-based test methods designed to assess the acute inhalation toxicity of combustion products were proposed to the Committee on Fire Standards of the American Society for Testing and Materials for their consideration. World-wide concern about the toxicity of combustion products is indicated by increased activity in a Subcommittee on Toxic Hazards of the Fire Test Committee of the

International Organization for Standardization and the development of separate tests in Germany, France, Japan and Belgium.

All these tests provide information on the acute toxicity resulting from the inhalation of combustion products, but each test is performed in different laboratory decomposition conditions. The tests do not address the problem of the total toxic hazard which a fire produces or the contribution of a material (or product in its actual end use) to that hazard under a 'real fire' situation. Nonetheless, some building code officials and state regulators are anxious to evaluate the combustion product toxicity of materials and are examining these test methods with that end in mind. It is important, however, that the acute toxicity (the harmful effects measured by the response of laboratory test animals to a single short exposure to combustion products generated by the thermal degradation of materials in specified conditions) be distinguished from the toxic hazard (the materials' properties and the environmental conditions which increase the probability that a toxic atmosphere will occur and an injury will result). Since any one fire is a dynamic, changing condition and no two fires are alike, no one test can duplicate all 'real fires'. Typical fire degradation modes (smouldering, radiant heat, non-flaming and flaming) can be reproduced in the laboratory, however, and materials can be tested in these conditions. The resultant laboratory toxicity data and other needed information, such as the projected end use of the product, the quantity of material present, its ignition and combustion properties, ventilation conditions, and the density and sensory-irritant properties of the smoke, may then be related to the total toxic hazard. Many of the investigators involved in this area of research are now turning their talents towards the more challenging field of toxic hazard analysis. □

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6. *Clark County Fire Department Report on the MGM Grand Hotel in Las Vegas, Nevada, on November 21, 1980*.
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8. Levin, B.C. *et al.* *Further Development of a Test Method for the Assessment of the Acute Inhalation Toxicity of Combustion Products* (NBSIR 82-2532, 1982).
9. Michal, J., Mitera, J. & Tardon, S. *Fire and Materials* 1, 160 (1976).
10. Alger, R. in *The Mechanisms of Pyrolysis, Oxidation and Burning of Organic Materials* (ed. Wall, L.A.) (NBS spec. Pub. 357, Washington DC, 1972).

Erratum

In the *News and Views* article 'Promiscuous DNA — chloroplast genes inside plant mitochondria' by John Ellis (*Nature* 299, 678; 1982), the word 'within' in the sentence 'Most polypeptides found in the bioenergetic organelles are encoded and synthesized within the organelles themselves' should be replaced by the word 'outside'.

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