



PD 6503: 1982

UDC 614.841.13 : 615.9

Report and recommendations on the development of tests for measuring the toxicity of combustion products

Rapport et recommandations sur la mise au point d'essais en vue de mesurer la toxicité des produits de la combustion

Bericht und Empfehlungen über die Entwicklung von Prüfungen für das Messen der Giftigkeit von Verbrennungsprodukten

Contents

	Page		Page
Foreword	1	10. Bio-assay	5
Cooperating organizations	Back cover	11. Additional comments	7
0. Introduction	2	Appendices	
1. Scope	3	A. Bibliography	8
2. References	3	Figure	
3. Definitions	3	1. Proposed stages in the testing of combustion products	6
4. General toxicity considerations	3		
5. Objectives of a test	3		
6. General requirements of the tests	4		
7. Fire model	4		
8. Overall test procedure	5		
9. Analysis of combustion products	5		

Foreword

This Published Document has been prepared under the direction of the Fire Standards Committee.

The toxicity of combustion products produced by fires in buildings has become a subject of increasing study in recent years with the growing recognition of the importance of these products in causing injury and death in fires.

This Published Document surveys the current situation for the testing of combustion products and outlines the philosophy necessary for the development of such tests. It further indicates how the tests results, when obtained, could be used to determine the overall toxic hazard, drawing attention to the need to take account of information obtained from other fire tests, such as those given in BS 476. In preparing this document, the committee responsible has consulted with others in widely different but related fields of activity and it represents a common technical approach. The wider issue of possible use for regulatory purposes has not been considered.

Work on the development of test methods is being undertaken in the International Organization for Standardization (ISO), and BSI is participating in this. In due course BSI will be required to evaluate the draft international test methods for possible acceptance as British Standards. This ISO work supports a view that, with existing knowledge, the evaluation of toxicity of combustion products cannot be carried out solely with analytical and/or chemical methods and that bio-assay tests will be required. This document describes what should be involved in such procedures and what would need to be considered in assessing any test

procedures. For example, methods of test under consideration in other countries that are based on simple decomposition and/or combustion models do not currently follow these guidelines in all cases, particularly in that there is no proven relevance to real fires.

It must be emphasized that in the UK there is currently no nationally agreed view that standard methods of test for combustion toxicity are necessary or would be effective in the selection or control of materials to reduce toxic hazard in fires. It is however agreed that in any test sequence to be used, it is necessary for analytical and/or chemical screening of products to be carried out prior to any biological testing, since this screening may remove the need to carry out biological testing. Since several countries are moving towards testing for combustion toxicity, it is essential that discussion takes place now about the possible methods of test and their application to ensure that progress can be made should it be deemed necessary in the future that a standard test(s) is required.

This document is published in order to encourage as wide as possible feedback of information and comment to BSI at this early stage of work from interested organizations. Readers with information which will be helpful to the BSI Technical Committee on this subject are invited to send it to the Secretary of the Committee FSB/16 for study.

NOTE. The numbers in square brackets used throughout the text of this document relate to the bibliographic references given in appendix A.

Report and recommendations on the development of tests for measuring the toxicity of combustion products

0. Introduction

0.1 In the United Kingdom the number of people killed each year by fires is estimated [1] to be about 1000 and in addition about 6000 are injured in one way or another. The proportion of these casualties occurring in buildings was about 85 % and in domestic buildings (dwellings) was about 70 %. Therefore, the data derived from these statistics relate particularly to casualties in buildings, with private dwellings predominating.

0.2 The conclusions from this study of statistics [1] were:

- (a) there had been a large increase in both the absolute and relative numbers per annum of fatal and non-fatal casualties in fire who are classed as 'overcome by gas or smoke', and the proportion of casualties so classed has increased by a factor of about three;
- (b) while no causal relationships could be established, the factors most likely to make a major contribution to this increase are considered to be an increase in the amounts and, perhaps, the irritancy of gas and smoke generated in fires;
- (c) the proportion of non-fatal casualties among those overcome by gas or smoke was about 60 % for the period studied, with no significant trend, and therefore, there was no evidence of a significant change in the nature of the toxic agent;
- (d) an increase in multiple-death fires associated with multiple occupancy dwellings may be associated to a minor extent with the increase in casualties overcome by gas or smoke, but whether as cause or effect cannot be decided.

0.3 Whilst statistics show that over 80 % of fatalities were found in the room where the fire originated, it is to be expected that fire gases will penetrate other parts of the building and overcome people away from the room of origin. This expectation is strengthened by the study [1] discussed in 0.2 where an analysis of multiple-death fires showed that the proportion of fatal casualties caused by gas or smoke is higher for these incidents than the average for all fires, especially among casualties remote from the seat of the fire.

0.4 Recent pathological studies of fire fatalities in the Strathclyde region of Scotland have shown that carbon monoxide was present in fatal levels in one half of the cases examined [2]. Hydrogen cyanide, which can be produced during the burning of both natural and

synthetic nitrogen-containing polymers, has, in the past, been difficult to analyse in blood because of interference from cyanide generated during biological degradation. With special analytical precautions the Glasgow study has indicated that about 6 % of all the fatalities may have potentially dangerous levels of cyanide in the blood, although a high cyanide level was usually accompanied by a high a carbon monoxide level.

0.5 The materials involved in a fire will come from the total contents of a building and therefore the fire gases evolved from building products, furniture and furnishing (including books and leather) will be relevant to this study. Two recent papers by the Building Research Establishment [3 and 4] illustrate this aspect vividly and conclude that the rate of spread of a fire in homes furnished with modern upholstered seating could be so rapid that the people might be overcome before they are aware of the danger, or before they could escape. The importance of the time of exposure, in that a short exposure to a highly toxic environment may allow survival while a long exposure to a moderately toxic one may lead to narcosis or incapacitation, is also stressed.

0.6 In these terms short exposure will be of the order of a few minutes while long exposure can be hours. The oft-repeated tragedy of warming sleeping quarters with an unventilated fire (brazier) illustrates the latter situation. In most fires the expectation is that all persons will be evacuated from the building in less than half an hour, but this relates to the stability of the structure. Frequently the occupants of domestic dwellings have less than five minutes grace to make their escape [4].

0.7 The toxicity of fire gases may be of two types; that which is manifest quickly, in a matter of minutes, and which reduces the chances of or prevents escape and/or survival, and that which may not be apparent for hours, days or weeks. In the emergency situation of a fire, the gases which produce an acute effect pose the greater hazard.

0.8 The average citizen never expects to be exposed to fire gases, except when smoking, gardening or on social occasions, such as Guy Fawkes night or when entertaining with barbecued meats. However, firemen may encounter repeated and long-term exposure to a wide variety of fire gases and this has led to increased usage of self-contained breathing apparatus for professional fire fighters. Another class of citizen exposed to a variety of fire gases is the researcher who develops or conducts

fire tests in general, or smoke and toxic gas tests in particular. Both these groups may expect to benefit from the study of the effects of fire gases, but the prime purpose of this is the safety of occupants in buildings.

1. Scope

This Published Document reports on the toxic hazard in fire and makes recommendations concerning problems related to the development of tests for the measurement of toxicity of combustion products from products used in building and structures, contents of buildings and transport.

2. References

The titles of the standards publications referred to in this Published Document are given on the inside back cover.

Bibliographical references are listed in appendix A.

3. Definitions

For the purposes of this Published Document the following definitions apply:

3.1 combustion. Reaction of a substance with oxygen, resulting in a release of heat generally accompanied by flaming and/or glowing and/or emission of smoke and fumes.

3.2 fire model. A means for the decomposition and/or combustion of the specimens under defined conditions that represent known stages of fire, in order to generate airborne products (gases and aerosols) for toxicity measurement.

3.3 bio-assay. A method for the estimation of a parameter based on the use of a living organism as a test system.

3.4 specimen. A material, composite or assembly about which information is required.

3.5 toxicity. The capacity of a substance to cause injury to a living organism.

3.6 toxicity index. A comparative measure of the toxicity of decomposition products evolved by specimens when subjected to specified test conditions.

3.7 toxic hazard. The danger caused to people in fire situations by the formation of toxic products, with respect to their nature, quantity and rate of production.

4. General toxicity considerations

4.1 Long and short term effects

4.1.1 General. The toxicity of combustion products may be separated into either of two main types, long and short term effects.

4.1.2 Long term effects. The long term effects may not materialize for weeks or years. An example is the low grade, but debilitating, bronchitis that is often seen in heavy smokers. At the extreme are the effects of exposure to some organic carcinogens which may result in death a long time after exposure. These long term effects are of great importance, but in the context of this report, because they do not affect the immediate survival of a fire victim they are not considered at present.

4.1.3 Short term effects. The short term effects can militate against escape and/or survival. These take several forms, which cannot always be rigidly separated, because an inhaled dose of a material producing one type of effect may cause another if the dose, i.e. the concentration or time of exposure, is increased. However, two main types of effect exist, incapacitation and death.

(a) *Incapacitation.* It is in the field of incapacitation that most difficulty is experienced in both defining and measuring the effects, always accepting that the ultimate model, man, is not available for experimentation.

Ignoring the effect of smoke concentration on visibility, which is already the subject of separate study, incapacitation may be divided into the following.

(1) *Irritant effects.* The effects of irritant materials, such as acrolein which at low concentrations can cause such a degree of coughing, eye watering and sneezing, as to render the victim incapable of coordinated behaviour. Although the victim may make a rapid apparent recovery when removed from the source of irritation, such an exposure may be followed 12 h to 24 h later by an acute irritant lung reaction, resulting in severe respiratory distress which may last for several days.

(2) *Narcotic effects.* The effect of narcotic materials that produce various stages of unconsciousness, e.g. carbon monoxide, which at non-lethal concentrations can produce profound narcosis. If the victim is already asleep or drunk, this effect can be very insidious, e.g. the classic accidents associated with faulty stoves.

(3) *Paralytic action.* Certain materials, such as some phosphorus compounds, exert effects on the nervous system which display themselves by violent muscular tremors, producing, in the extreme, total muscular incoordination, thus making it impossible to escape.

Not all of these effects occur with all chemicals; most produce only one, but there is a high probability that in conditions of smoke and gases produced by a fire, several different effects at different levels will occur simultaneously.

(b) *Death.* Death is the final effect of exposure to high enough concentrations of combustion effluent for sufficient time. In this context, the concentrations of carbon monoxide would be of the order of 1 % with the time until death in the order of minutes.

4.2 Intoxication route. The most likely route of intoxication is by inhalation, although irritancy may be exerted directly upon the eyes. The effects of materials absorbed through the skin are similar to that by inhalation; however, the time scale is very much longer. As a general rule materials penetrate the skin at such a low rate that the percutaneous hazard is non-existent in the 'escape' context.

5. Objectives of a test

5.1 The objective of a test or tests would be to measure the short term (acute) toxicity and/or incapacitation effects of fire gases and smoke (excluding obscuration) on animals and further to relate these results to the likely reaction of humans to inhalation of the gases and smoke.