ICRCL Guidance Note 61/84
Second Edition
July 1986

INTERDEPARTMENTAL COMMITTEE ON THE REDEVELOPMENT OF CONTAMINATED LAND

Notes on the fire hazards of contaminated land

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£1.35p

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NOTES ON THE FIRE HAZARDS OF CONTAMINATED LAND

SUMMARY

The use of land for industrial purposes or for waste disposal may result in chemical contamination which can restrict or prevent subsequent development. Such contamination can occur in several forms, each of which may give rise to hazards: for example the presence of toxic or corrosive substances, the generation of toxic, asphyxiant or flammable gases, and the instability of poorly compacted fill. These hazards, together with other general problems of investigating and assessing contaminated land, are discussed in other papers in this series (see list on back cover). The present paper is concerned solely with the fire hazards due to the combustible nature of materials in the ground. The problems posed for redevelopment are outlined and the possible remedial measures are discussed briefly.

I. FIRE HAZARDS

1. Wherever combustible material is present below ground there is a possibility that fires may start and propagate beneath the surface. Occasionally they may break through to the surface and flames may appear, but most frequently, because the supply of oxygen at depth is limited, such fires proceed slowly by smouldering or charring and not by flaming. Their presence may not be obvious: slow combustion may proceed for long periods with little visible evidence at the surface. There may be occasional emissions of steam or smoke, or the vegetation may die or become blackened; however, these signs are not always observed. At some sites the vegetation may be particularly lush above the fire due to the increased soil temperatures.

2. Under conditions of which favour heat conservation, smouldering combustion may continue even with a limited supply of oxygen. This property has two important implications for the detection and control of underground fires: first, the zones of active combustion tend to be well below the surface and it is then difficult to locate their position and extent; second, it may not be possible to extinguish them either by ground compaction or by using porous covering materials to smother the fire. The best result that may be possible in such circumstances is to reduce the rate of propagation.

3. Underground fires are often extremely difficult to extinguish. In the early stages when the area affected is limited, digging out, accompanied by the application of water, may extinguish the fire. Once the fire is well established, this process may increase the air supply and cause the fire to advance faster than the digging. The construction of barriers to control the spread is expensive and frequently difficult, especially if the fire is large or the combustible material deep. In some cases grouting techniques can be used to limit the spread of combustion.

4. The main hazards of underground fires are:

   i. production and release of toxic, asphyxiant or noxious gases which can travel considerable distances through the ground;

   ii. subsidence of the burnt ground, causing physical damage to any buildings or other structures on or near the site of the fire, and creating hidden cavities which may make tackling the fire or reclaiming the land more hazardous; and

iii. heat damage to buried structures and site services, such as power supply cables.

All these hazards are dangerous on derelict sites and much more so on sites which are being or have already been developed. After development has been completed, it may be much more difficult and expensive to repair the damage.

II. SOURCES OF IGNITION

5. Smouldering fires are generally started by sustained application of heat, from a variety of sources which need not themselves be at very high temperatures, for example underground electrical cables or heat from boiler houses and furnaces. Direct ignition may result if, for example, a bonfire or building fire were to occur on the surface of a site containing combustible material, and the burning may continue below ground even after the fire on the surface has been extinguished. At a waste disposal site, direct ignition may be caused by the tipping of hot or burning material.

6. In a few materials, notably colliery waste and spent oxide from gas purification, self-heating caused by slow chemical oxidation can occur. If the rate at which such heat is generated exceeds that at which it is released to the surroundings, the temperature may rise sufficiently for combustion to start and propagate: this phenomenon is known as spontaneous combustion. Self-heating may be controlled if the supply of air can be sufficiently restricted; maintaining a high moisture content may assist in this.

7. Self-heating can, however occur in putrescible waste matter (eg domestic refuse, food wastes), with a high moisture content. In such wastes the respiration of bacteria generates heat and the temperature below the ground may reach 75°C. Heating from biological causes appears to be unlikely to result in ignition in landfill sites: the organisms responsible for the self-heating do not survive at the higher temperatures necessary to start and sustain a smouldering fire. Self-heating may make a site appear to be on fire by the emission of steam and by raising the temperature of the soil.

8. In waste disposal sites, chemicals may leak into the ground as their containers gradually disintegrate: in some combinations, they may react exothermically and produce high temperatures which might be sufficient to ignite combustible materials.

III. RELEVANT PROPERTIES

9. Several properties have been suggested as criteria to assess whether a sample, and consequently a site, can ignite and smoulder. Many of the methods used to measure these properties are based on those described in BS 1016 for the analysis of coal and coke (1). The most widely used criterion is the Calorific Value (CV), also known as the heat of combustion, which is the quantity of heat which can be released from a sample after complete combustion in excess oxygen under 30 atmospheres pressure. The result is expressed in megajoules per kilogram (MJ/kg), calories per gram (cal/g) or British Thermal Units per pound (BTU/lb) (for conversion factors see APPENDIX). The test seems to have become adopted largely because it is available and not because it is the best suited. There is unlikely to be any simple relationship between the quantity of heat measured under such conditions and that released by the same material underground with a limited air supply. Nonetheless the measurement of CV is quick and may be useful for the initial screening of potentially combustible materials. Dry coal has a calorific value of about 20 MJ/kg, wood 19 MJ/kg, rubber 40 MJ/kg, polythene 47 MJ/kg, polyurethane 24 MJ/kg and PVC 18 MJ/kg. A typical loamy soil has a CV of about 1.7 MJ/kg. For comparison, the CV of dynamite is about 5 MJ/kg: ie towards the lower end of the range. This illustrates the limitations of CV measurements for assessing potential combustibility. In general, however, it seems likely that materials whose CVs exceed 10 MJ/kg are almost certainly combustible, while those with values below 2 MJ/kg are unlikely to burn. Within this range of values, there is likely to be a large number of potentially combustible materials.

10. Other quantities frequently measured and quoted are the moisture content, the percentage ash, which is the percentage of material in a sample remaining after heating in air at 815°C, the percentage volatile matter, which is the percent loss on heating in an inert atmosphere at 900°C, and the carbon content.

IV. ASSESSING THE HAZARD

11. Clearly each of the properties outlined above has some bearing on whether or not the sample and the site is combustible. Samples with higher CVs, lower ash contents and higher carbon contents are perhaps more likely to be combustible than other samples, but it is still not clear how the results of such measurements should be interpreted. As yet there are no accepted methods to assess whether a sample is combustible and under what circumstances it might smoulder.

12. Some authors have suggested that there is an unacceptable risk of smouldering when the CV of the soil or fill material exceeds 7 MJ/kg. Work at the Fire Research Station has, however, shown that smouldering can propagate in test samples with a CV much lower than 7 MJ/kg. Moreover, some of these samples had CVs as low as those of soils which did not smoulder in these tests. It is therefore inadvisable to use CV as the sole measure of the combustibility of a site.

13. The rate at which heat is released under the influence of elevated soil temperatures is probably much more important in determining whether a material will ignite, and propagate flame. That rate depends not only on the composition of the material but also on its physical properties such as the porosity (voids), moisture content and temperature. These factors, together with the heat loss, determine whether ignition will occur. Even were it established that under relatively favourable conditions, a material may be ignited, it does not necessarily follow that an underground fire can propagate. Nonetheless, a test based on the ignitability of the material may provide a possible method of assessing samples from landfills. Methods based on the measurement of the rates of heat release and ignitability are currently under development.

V. REMEDIAL MEASURES

14. The only certain way to remove the fire risk from a potentially combustible site is to excavate the suspect material and dispose of it elsewhere. In practice, this solution is frequently unacceptable because of its cost: moreover, unless the material is incinerated, the problem is not solved, merely moved. Where such removal is impracticable or undesirable, methods which contain or isolate the combustible material from potential sources of ignition are necessary.

15. The remedial measures required to reduce the risk of fire on a particular site will depend on circumstances and intended use. The average depth of the water table is important: if there is normally a very high water table, no remedial action may be necessary. For certain end uses, for example where it is proposed to develop a site as public open space with no buildings and no services laid underground, and it has been established that the site material is not liable to spontaneous ignition, the chances of an underground fire starting are small. For other uses, however, some form of protective action may have to be taken.

16. The usual method is to cap the potentially combustible fill with about one metre of a non-combustible material that will isolate it thermally from the effects

of any intense sustained fire on the surface. A lesser thickness of cover may suffice, provided that the site will not be disturbed: for housing and gardens a greater depth than 1 metre may be necessary since it is important that combustible material should not become exposed through any normal activities on the site during or after development.

17. The capping layer and the site as a whole should be designed so that the likelihood of the protection being damaged or destroyed during the life-time of the development is acceptably small. The material used for covering the site should be non-combustible and chemically compatible with the chosen form of development; otherwise its nature is not important. Structures, for example foundations, can form part of the cover.

18. In addition to covering the combustible material with an inert layer, all services to the site should be laid in inert material. This is especially important when electrical cables (which may become warm) are present, but it is also important for other services, which may have to be excavated for future repair or maintenance. The appropriate public utilities (eg. gas, water) should be consulted.

19. The application of an inert cover only protects the combustible material from sources of ignition at the surface. If the material is liable to self-heating and spontaneous combustion, capping the site provides no protection against an underground fire. Additional measures, for example to compact the material adequately, to prevent it drying out and to reduce the ingress of oxygen, are then required. At sites where such action is taken, it is particularly important to ensure that the treatment remains effective for the life-time of the proposed development and that surface fires are avoided. Normally such sites should not be developed, but where it is essential that they are developed then the choice of use should be limited to those which do not present hazards to life or property.

VI. SITE DEVELOPMENT AND MAINTENANCE

20. The stability of any site which is or has been on fire must be assessed before vehicles or machinery are brought on site, because an underground fire may form cavities in the ground which could collapse immediately or at a later date.

21. Whenever work is carried out on sites which may be combustible, great care must be taken to ensure that an underground fire is not started. Those working on such a site must be made aware of the dangers of lighting bonfires on exposed material. This applies not only to work carried out during the development of the site, but to

all works which may be carried out in future. Those responsible must be aware that problems may continue for the whole life of the new use of the site.

VII. REFERENCE

1. British Standards Institution: Methods for analysis and testing of coal and coke. BS 1016: 1979.

Professional advice on the specific problems of individual sites can be obtained from specialist consultants with appropriate experience. Specialist advice on combustibility problems can be obtained from the Fire Research Station (Department of the Environment), Borehamwood, Hertfordshire, WD6 2BL (telephone 01 953 6177).

APPENDIX

Conversion factors for calorific value measurements:

1 cal/g = 4.187 kJ/kg (= 1.8 BTU/lb)
1 k cal/g = 4.187 MJ/kg
1 BTU/lb = 2.326 kJ/kg