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INTERDEPARTMENTAL COMMITTEE ON THE REDEVELOPMENT OF CONTAMINATED LAND

Guidance on the assessment and redevelopment of contaminated land

IMPORTANT NOTE Please read the paper before quoting the tables. The values given in Tables 3 and 4 are tentative. They should only be taken as guidance and used subject to the conditions set out in the Tables.
This paper replaces ICRCL 3/78, 16/78, 38/80 and 47/81. These papers are now withdrawn and should not be quoted or used.

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SUMMARY

The demand for land suitable for development often exceeds the supply, especially in inner cities and urban areas. Reclamation and redevelopment of previously used sites can help to make good the shortfall, but such land may have been contaminated by its former uses. This does not automatically mean that it is unsafe or unuseable, but the contamination may need to be taken into account by those buying, selling or developing such land and in particular by planning authorities responsible for controlling its development. This paper sets out a systematic approach for the assessment of contaminated sites: first, by the collection of historical information about the site and then, where necessary, by detailed sampling and analysis of soil samples.

The concept of "trigger concentrations", which depend upon the intended use of the site, has been introduced to assist in determining the significance of contamination. Examples of these concentrations are given for the principal contaminants. If, after a thorough investigation, the samples from the site show values below the lower trigger concentrations, it is reasonable to regard the site as uncontaminated and to proceed with the development accordingly. If, however, the results exceed the upper trigger concentrations, it follows that some remedial action is required if the chosen form of development is to proceed. Alternatively, a different use should be considered. Trigger concentrations do not apply to sites already in use, and they may have to be modified where development has already begun before contamination was discovered.

Finally the paper outlines some of the methods available for dealing with contamination when remedial action is required. Following these principles should enable sites to be restored to beneficial use at the lowest risk and at reasonable cost.

I. INTRODUCTION

1. The use of land for industrial purposes or for waste disposal may result in contamination of the soil. There are many possible sources of contamination: leakages or spillages from pipes and tanks; deposition of airborne particles; storage and disposal of raw materials, unwanted wastes and residues, and the application of sewage sludge to land. Naturally occurring materials, such as mineralised rocks and soils, are also a source of contamination in certain localities. The emphasis in this paper is, however, on man-made contamination. The presence of some contaminants may pose immediate or long-term hazards to human health, to plants, to amenity, to construction operations, or to any buildings and services. These hazards may be serious enough to limit or preclude development of the land.

2. In 1986 almost half of all new development took place on re-used land, particularly in inner cities and urban areas. This gives rise to a need for advice on the problems that may occur and on the measures needed to overcome them. The aim of this paper is to provide those who may have responsibilities for development of land with advice on the planning implications of contamination and with guidance on the recognition, investigation and assessment of sites that may be contaminated. The problems posed by asbestos, biological contamination, and (very rarely) by radioactive materials generally lie outside the scope of this paper and are not considered.

3. The hazards differ from site to site both in nature and importance; they also depend on the intended use of the land. The basic objective is to enable contaminated land to be used safely and economically: to achieve this, a balance has to be struck between the risks from contamination and the need to restore the land to beneficial use. The simplest and most cost-effective way of redeveloping a contaminated site is to choose the end use that is most tolerant of the contamination present. However, this is only possible where there is a real choice of end use; sometimes the land has to be used for a specific purpose and the problem is then how to achieve this most effectively in terms of safety and cost. At some sites the risks may be so important as to render the proposed use unsafe or uneconomic unless some remedial action is taken to reduce them. When this is the case, contamination will need to be taken into account at an early stage of preparing proposals for development of the land. This will normally be at the planning stage.

4. Each site must be considered on its merits. Whenever the previous history of a site suggests that contamination may have occurred, prospective developers should investigate the site to check whether it is suitable for their intended uses, before deciding the form and layout of their developments. The investigation should normally precede the submission of a planning application. If the investigation is omitted, or left too late, and the site is subsequently found to be contaminated, any or all of the following undesirable consequences may occur:

i. emergency action may have to be taken during development to remedy the contamination: such action may be very expensive;

ii. the value of the land may be affected: both buyers and sellers of land may form unrealistic views of the costs of redevelopment;

iii. there may be delays to redevelopment schemes while contamination problems are being remedied; and

iv. there may be adverse publicity about the safety of a proposed or an actual development.

5. The specific precautions needed will depend on the circumstances: where buildings are to be constructed, the provisions of the Building Regulations and/or the NHBC's Technical Requirements (for private housing) will apply. For other end uses the remedial measures needed, if any, should be those identified by the findings of the site investigation.

II. PLANNING ASPECTS

6. Contamination, or the potential for it, is a material planning consideration which needs to be taken into account at various stages of the planning process, including the preparation of development plans and the determination of planning applications. Contamination is unlikely to present problems in the preparation of structure plans: existing land uses will, for the most part, continue unchanged. DOE Circular 21/87 (Welsh Office 22/87) "Development of Contaminated Land" (HMSO 1987) deals specifically with the planning aspects of developing contaminated sites.

Development Plans and Policies

7. Development plans provide an opportunity to set out policies for the reclamation and use of contaminated land. Local plans and Part II of Unitary Development Plans could include detailed criteria which will be applied in determining planning applications. They may also set out any site-specific proposals for land use in these areas, so that they may be readily identifiable to landowners and prospective purchasers or developers. General guidance on the preparation and modification of development plans is published in DOE Circular 22/84 (WO Circular 43/84), "Memorandum on Structure and Local Plans".

Determining Planning Applications

8. Even before an application is made, informal discussions between a potential developer and the local planning authority can be very helpful. If the local planning authority has reason to believe that there is a possibility that the land might be contaminated, this may be brought to the attention of the developer at this stage, and the implications explained. The applicant can then design his scheme so as to take full account of the likely requirements of the planning authority. Applications need not, however, be delayed pending an investigation by the developer to establish the nature and extent of contamination unless there is good reason to suppose that the land in question is actually contaminated. If an application is received without prior discussion and the planning authority suspects that the site may be contaminated, it should advise the applicant accordingly and outline the factors which will be taken into account in determining the application. The applicant may then wish to consider whether or not to proceed.

9. When it is known or strongly suspected that the site is contaminated to such an extent that the proposed development would be adversely affected, the developer will normally need to carry out a specialist investigation to identify any remedial measures required to deal with the hazards before the application can be determined. Should the degree of contamination be such that remedial action is required to protect any buildings, building services, future users or occupiers of the site from the hazards, then planning permission may be granted subject to conditions specifying the measures to be carried out.

10. Where there is only a suspicion that the site might be contaminated, or where the evidence suggests that there is potentially only slight contamination, planning permission may be granted but conditions should be attached to make it clear that development will not be permitted to start until a site investigation and assessment has been carried out and that the development itself will need to incorporate all the measures shown in the assessment to be necessary.

11. The local planning authority may grant planning permission without conditions relating to contamination if it is satisfied on reasonable grounds that in the circumstances none are required.

12. Where planning permission is granted for a site where the presence of contamination is known or suspected, a separate notice should be issued to the applicant informing him that the responsibility for safe development and secure occupancy of the site rests with the developer It should also warn the applicant that the local planning authority has determined the application on the basis of the information available to it, but this does not mean that the land is free from contamination.

Building Control

13. The Building Regulations 1976 were made by the Secretary of State for the Environment and revised in 1985. They superseded the former Building Byelaws made by individual local authorities and include provision for the giving of notices, the deposit of plans and information, and the inspection of works. Their purpose is to ensure the health, safety, welfare and convenience of persons in or about the buildings and of others who may be affected by buildings or matters concerned with buildings. District Councils are required by statute to administer and enforce the Building Regulations, and in ensuring compliance they owe a duty of care to the above persons. If the Council fails to take reasonable care and as a result the building is damaged or persons are injured then the Council can be held liable for damages for breach of statutory duty or negligence.

14. Where it is proposed to build on a contaminated site, particular attention should be paid to the requirements of (1985) Building Regulations C1 and C2. These require that (C1) the ground to be covered by the building should be reasonably free of vegetable matter and (C2) that precautions should be taken to avoid danger to health caused by substances on or in the ground to be covered by the building. It would be unreasonable to refuse Building Regulation approval for development on the grounds that a site is contaminated unless the contamination affects the development and cannot be remedied by appropriate action.

15. If during the course of development new information comes to light which indicates that there is a substantially higher risk from contamination than was previously assessed, powers under the Public Health Act 1936, the Housing Act 1957 and the Building Act 1984 may be invoked.

16. Whether or not development should be allowed to proceed on a contaminated site will depend on the assessment made as part of the Development Control procedures. There will, however, be instances where planning approval is not required but where the Building Regulations still apply. There are also some types of development which do not require approval under the Building Regulations and for which planning is the only means of control.

III. SITES, CONTAMINANTS AND HAZARDS

Sites

17. Examples of sites on which contaminants may be found include:

landfills and other waste disposal sites;
gasworks, other coal carbonisation plants and ancillary by-products works(1);
sewage works and farms;
scrap yards;
railway land, especially large sidings and depots;
oil refineries, petroleum storage and distribution sites;
metal mines, smelters, foundries, steel works and metal finishing installations;

chemical works;
munitions production and testing sites;
asbestos works;
tanneries;
paper and printing works;
industries making or using wood preservatives.

The above list is not exhaustive. Advice and guidance on the redevelopment of some of these sites is given in the relevant ICRCL Guidance Notes (see list on back cover). Other types of sites may need to be considered where local conditions and experience suggests that they may have been contaminated.

Types of Contaminants and Hazards

18. A wide range of potentially harmful substances may occur on the sites of the above industries. Table 1 lists some commonly encountered contaminants, the sites where they are likely to occur, and the principal hazards they produce.

TABLE 1

Type of contaminant	Likely to occur on	Principal hazards
"Toxic" metals eg cadmium, lead, arsenic, mercury. Other metals eg copper, nickel, zinc.	Metal mines, iron and steel works, foundries, smelters. Electroplating, anodising and galvanising works. Engineering works, eg shipbuilding. Scrap yards and shipbreaking sites.	Harmful to health of humans or animals if ingested directly or indirectly. May restrict or prevent the growth of plants.
Combustible substances, eg coal and coke dust.	Gasworks, power stations, railway land.	Underground fires.
Flammable gases eg methane.	Landfill sites, filled dock basins.	Explosions within or beneath buildings.
"Aggressive" substances eg sulphates, chlorides, acids.	"Made ground" including slags from blast furnaces.	Chemical attack on building materials eg concrete foundations.
Oily and tarry substances, phenols.	Chemical works, refineries, by-products plants, tar distilleries.	Contamination of water supplies by deterioration of service mains.
Asbestos	Industrial buildings. Waste disposal sites.	Dangerous if inhaled.

Hazards

19. The following may need to be considered:

i. Uptake of contaminants by food plants grown in contaminated soil: The accumulation of metals such as cadmium and lead in the edible portions of some food plants may make the crops unsafe to eat if they are likely to be consumed over a long period of time. Uptake depends on the concentrations of

these metals in the soil, and particularly on the chemical forms in which they are present. Factors such as the soil pH value, the plant species, and the proportion of home-grown food in the diet also influence the importance of this hazard.

ii. Ingestion and inhalation: Metals may be ingested:

a. by eating plants whose leaves, stems or roots are contaminated by particles of soil or dust which have not been removed by washing; and

b. by young children playing on contaminated soil - children suffering from pica are at greatest risk.

Metals, and some organic materials, may also be inhaled from dusts and soils.

iii. Skin contact: Contaminants such as tars, oils and corrosive substances may cause irritation to the skin through direct contact with contaminated soil.

iv. Phytotoxicity: Phytotoxicity - the prevention or inhibition of plant growth - may be due to contamination, although there are a number of other possible causes - notably the absence of topsoil or lack of essential fertilisers (2). The principal phytotoxic elements are boron, copper, nickel and zinc: however, at low concentrations these are essential for successful plant growth. The concentrations of zinc at which phytotoxic effects occur are well below those which are hazardous to human health. Methane and other gases may also give rise to phytotoxic effects by depleting the oxygen content of the soil in the root zone.

v. Contamination of water resources: Disturbance of the site during construction work may release contaminants into watercourses and aquifers.

vi. Fire and explosion: Materials such as coal and coke particles, oil, tar, pitch, rubber, plastic and domestic waste are all combustible (see ICRCL 61/84). If they are heated, for example by contact with buried power cables or by careless disposal of hot ashes or waste materials, or the lighting of fires on the site surface, they may ignite and continue to burn beneath the ground. Underground fires are particularly difficult to control and extinguish. They may result in ground subsidence which may pose a risk to the structural integrity of buildings. Toxic gases may be liberated during combustion. Flammable gases, eg methane, may be produced on sites formerly used for the disposal of domestic waste or other putrescible materials. These gases may migrate laterally or vertically for considerable distances. If they accumulate in a confined space beneath, or within, buildings, there may be a significant risk of explosion (3).

vii. Chemical attack on building materials and building services: Sulphate may attack concrete (4). Acids, oily and tarry substances, and other organic compounds may accelerate the corrosion of metals in soils and attack plastics, rubber and other polymeric materials used in pipework and service conduits or as jointing seals and protective coatings to concrete and metals. They may migrate through plastic pipework without causing structural failure and thus contaminate water supplies (5).

Identification and assessment of principal hazards

20. The importance of any hazard on any site depends primarily on the site use, since the use determines who and what may be at risk and the routes by which they may become exposed. These include: allotments, domestic gardens on residential developments, amenity and recreational areas, public open spaces and industrial and commercial buildings. The principal hazards for these uses, and the contaminants which give rise to them, are shown in Table 2. Its purpose is to assist with the selection of relevant contaminants to be included in site investigations. If, after investigating the site for the contaminants which give rise to the principal hazards likely to affect the chosen form of development, the land is found to be unsuitable, there is no point in determining the concentrations of contaminants which give rise to less important hazards: in these circumstances, another use will have to be considered.

21. The hazards of individual sites must therefore be assessed against the proposed use:

i. Explosive or flammable gases, combustible materials, and contaminants which attack building materials are likely to be important for any building operations and construction work. These contaminants, together with toxic or asphyxiant gases or harmful liquids are those most likely to affect site investigation teams and construction workers, especially in excavations, borings and tunnels. They may also affect the suitability of the ground for gardening or landscaping purposes.

ii. Uptake of contaminants by food crops is only likely to be significant for individuals who depend upon home-grown food over a long period of time. Most gardens in modern housing developments are too small for the residents to raise sufficient food crops for them to be at risk from this hazard, but some allotment holders may be at risk.

iii. Ingestion and uptake from plants is not likely to occur on amenity and recreational areas, public open spaces, flats with landscaped surrounds, or commercial and industrial developments. Inhalation of contaminants is not important on these types of development. The cover provided by vegetation, by the buildings themselves, or by roads, pavements and vehicle parking areas reduces the likelihood that contaminants will be inhaled from soils and dusts.

iv. Phytotoxicity is not an important hazard in developments with permanent hard-surfaced cover. It may be a problem in allotments and domestic gardens, as well as in amenity, recreational and public open space areas. However, grass is more resistant to phytotoxic effects than most other plants. The absence of plant cover may increase the risk of contaminants being ingested by young children, and increase the amount of contaminated dust in homes and gardens.

v. Where remedial measures are carried out to protect building materials against chemical attack, or to permit successful plant growth, these normally provide sufficient protection against long-term risks from contaminants which are hazardous through contact with the skin. Site investigators and those working on the site during clearance or construction operations may need to be given short-term protection where such contaminants are present.

TABLE 2 PRINCIPAL HAZARDS AND CONTAMINANTS

HAZARD (1)	TYPICAL END USES WHERE HAZARD MAY EXIST	CONTAMINANTS (2)
Direct ingestion of contaminated soil by children	Domestic gardens, recreational and amenity areas	arsenic cadmium lead free cyanide polycyclic aromatic hydrocarbons phenols sulphate
Uptake of contaminants by crop plants (3)	Domestic gardens allotments and agricultural land	cadmium lead
Phytotoxicity (3)	Any uses where plants are to be grown	sulphate copper nickel zinc methane
Attack on building materials and services (3)	Housing developments, commercial and industrial buildings	sulphate sulphide chloride tarry substances phenols mineral oils
Fire and explosion	Any uses involving the construction of buildings and services	methane sulphur potentially combustible materials, (eg coal dust, oil, tar, pitch, rubber)
Contact with contaminants during demolition clearance and construction	Hazard mainly short-term (to site workers and investigation teams)	polycyclic aromatic hydrocarbons phenols oily and tarry substances asbestos radioactive materials
Contamination of water (3)	Any operation which may lead to run-off or leaching	phenols cyanide sulphate metals

NOTES

1. These hazards are not mutually exclusive. Combinations of several hazards may need consideration.

2. Other contaminants may need to be considered where local factors require this.

3. The pH of the soil will affect the importance of these hazards.

IV. A SYSTEMATIC APPROACH TO ASSESSMENT OF CONTAMINATED SITES

22. This approach is based upon the general principle that the significance of contamination can best be determined in two steps: first, by identifying the hazards likely to affect the proposed uses of the land and then, after investigating the site for the contaminants which can give rise to those hazards, by assessing their importance against the use actually proposed or allocated.

23. The following sequence of questions and their answers defines the individual stages of the systematic approach: identification; investigation; assessment; remedial action and monitoring. Their answers should provide the information needed to assess a site properly before deciding its future use:

i. What is the history of the site? This indicates the likelihood of finding contamination that might affect future land uses.

ii. What is the intended use of the site? This provides an initial check on the possible significance of that contamination.

iii. Which hazards are likely to affect that use? These decide whether the use is practicable or needs modifying.

iv. Which contaminants give rise to those hazards? These are set out in summary form in Table 2.

v. Are those contaminants present, and if so in what concentrations and with what distributions? This is the purpose of any site investigation.

vi. Are there any hazards, and if so how might they be removed or reduced? This is the result of the assessment of the findings of site investigations.

vii. Could the hazards be more effectively removed or reduced by choosing a different land use? This is to determine whether a change of proposed use would markedly reduce the significance of the contamination.

viii. What remedial treatment is practicable, and what monitoring is needed to enable the site to be used for the chosen purpose?

Identification

24. The first step is to recognise the possibility that the site may be contaminated: certain types of site are particularly likely to have been contaminated by their previous uses (see paragraph 17). This possibility can be checked by obtaining information on the site history, including both written and oral records of the previous uses. If this information indicates that uses likely to have contaminated the site were operated there at any time, further inspection and investigation will be needed. Provided that the information on the history of the site is adequate and indicates that contamination is unlikely, the site may be regarded as "clean " and be developed in the normal way. It is still prudent to inspect the site to check the historical information against the present condition of the land. A site inspection will in any case normally be required to identify the safety precautions necessary for the site investigation team.

25. During any inspection of the site, particular attention should be paid to the surface topography and site layout: both can provide useful indications of the types of contaminants likely to be present. This helps to specify the design of the sampling and analytical programmes. The following are useful indicators:

i. vegetation: the absence or poor growth of vegetation may indicate the presence of phytotoxic substances;

ii. surface materials: unusual colours may be due to chemical wastes and residues;

iii. fumes and odours: these are often readily detectable at very low concentrations;

iv. drums and similar containers: these may contain hazardous substances; and

v. infilled areas: old plans, aerial photographs etc will often shown their locations.

The following features if present, will also require inspection:

i. existing buildings and other structures, including tanks and pipework;

ii. hard covered areas: eg roadways, storage areas, vehicle parks;

iii. waste disposal tips and their contents;

iv. abandoned pits and sumps, with or without standing water; and

v. land still subject to contamination from external sources, eg emissions from smelters.

Site investigation

26. Investigation of sites for ground engineering and geotechnical purposes is common practice (6). When in addition the site history and inspection show that substances likely to cause contamination are present or were made or used there, then a detailed chemical investigation is also needed. This may require soil samples to be collected and analysed for the contaminants likely to give rise to the principal hazard(s) (see Table 2) for the proposed use of the site. The main objectives of such investigations are:

i. to identify the various buildings or other structures present on the site;

ii. to identify the contaminants present; and

iii. to ascertain their distribution over the site area and their concentrations both on and below the surface.

27. At most sites, the number of sampling points needs to be sufficient both to identify the presence of contaminants and to determine their distribution with sufficient certainty for the intended use. If too few sampling points are used, the chances of finding small local "pockets" of contamination are lessened and this may cause difficulty later when the site is being developed. The number and location of sampling points ought therefore to depend on the size of the site and its history. In principle, the distance between the sampling points should be no greater than the largest area of contamination that could be dealt with economically if it were missed during the investigation and only discovered at a later stage, eg during construction work on the site. Within this criterion, the number of samples taken is usually a compromise between that which is desirable and that which is possible given the limits imposed by time and cost. The positions of sampling points should be based on knowledge of the site history.

28. The two principal sampling patterns are:

i. random sampling (non-systematic); and

ii. regular sampling grids (systematic).

29. The use of a regular sampling grid enables the points to be accurately located over the whole site. This helps to establish the distribution of contaminants more fully.

30. The two principal methods for obtaining samples are:

i. from boreholes; and

ii. from trial pits or trenches.

31. Trial pits permit easy visual inspection of conditions at depth, but most mechanical excavators cannot operate at depths greater than 3 to 4m. This limitation may be important should the development of the site require the use of deep foundations (eg piles) or drainage collection systems. Boreholes can be deeper, but with some drilling techniques the samples may be contaminated by the drilling fluids. If possible, these should be avoided. Whichever method is employed, the location of the sampling point and the conditions encountered in the borehole or trial pit must be recorded adequately. The samples should not be bulked or composited, as this reduces the value of the information obtained. Each sample should therefore be collected and analysed separately.

32. Comprehensive analysis of all samples collected during a site investigation can be costly and time-consuming. For some end uses it is unnecessary. To reduce delays and costs, the initial analysis should be related to the immediate need for information; that is, to the type of development proposed and the stage it has reached. A pre-purchase survey may not need to be so comprehensive as one intended to provide data on which detailed plans for remedial treatment and subsequent development will be based Samples can always be retained, or fresh samples collected, should a more detailed study be needed.

Assessment

33. Careful assessment of the significance of contamination and of the importance of the risks disclosed by the site investigation is crucial. Because the risks posed by contamination are difficult to quantify, an indirect method based on "threshold" and "action" trigger concentrations has been devised to assess the findings of site investigations. Their purpose is to assist in selecting the most appropriate use for the site and in deciding whether remedial action is required.

34. The trigger values define three possible concentration zones (see Fig. 1) for each contaminant. The concentrations actually present on the site will fall within these zones:

i. In the first zone, a contaminant is found only in relatively low concentrations. These can usually be disregarded, because there is no significant risk that the hazard(s) will occur. As the concentration increases, a value is reached at which the risk begins to become significant. The concentration at which this occurs is defined as the threshold trigger concentration for that contaminant. Since not all site uses are at equal risk from the hazards, it follows that the threshold trigger value varies with the actual or proposed use of the site. Below the threshold trigger value the site can be regarded as uncontaminated for that end use, and therefore no remedial action is needed even though the concentrations present may be above the normal background values typical for the area.

ii. In the second, intermediate, zone the concentration of the contaminant is between the threshold value and the upper trigger concentration. Even though the threshold trigger value is exceeded, this does not automatically mean that the risk of the hazard is significant: merely that there is a need to consider whether the presence of the contaminant justifies taking remedial action for the proposed use of the site. If such considerations suggest that some action is justified, then it should be taken: the decision to do so is therefore based on informed judgement.

iii. In the third zone, where the concentration is equal to or greater than the action trigger value, the risks of the hazard(s) occurring are sufficiently high that the presence of the contaminant has to be regarded as undesirable or even unacceptable, ie the site has to be regarded as contaminated. Action of some kind, ranging from minor remedial treatment to changing the proposed use of the site entirely, is then unavoidable.

35. For the purposes of setting trigger concentrations, contaminants can be divided into three categories:

i. Those which may present a hazard even in very low concentrations: examples are methane, and asbestos. For these, any measurable concentration requires action to be considered or taken. Their threshold concentration is, therefore, effectively zero.

ii. Those for which a given concentration in the soil produces a measurable effect on a "target": examples are sulphate (attack on building materials); phenol and organic compounds (contamination of water supplies) (Table 4); phytotoxic metals (eg zinc, copper and nickel - see Table 3, Group B); and cyanide (toxic through ingestion).

and iii. Those for which no "dose-effect" relationship between the concentrations in the soil and the effects has been determined experimentally. Most of the contaminants of importance to man's health, whether through uptake by plants or by direct ingestion, fall within this category. There is at present insufficient evidence to specify precise trigger values for these contaminants, although for certain metals Group A Table 3 indicates concentrations above which the need for remedial action should be considered.

36. In both Tables 3 and 4, the tentative trigger values are based on professional judgement after taking into account the available information. <u>They are only applicable when used in accordance with the conditions and notes specified in the Tables, most especially only after an adequate investigation of the site. They do not apply to sites which have already been developed.</u>

37. These assessments are seldom simple. As may be seen from Tables 3 and 4, trigger concentrations are available only for a limited range of contaminants, though these are generally the most important. For most contaminants, it is very difficult at present to set upper values at which the concentration would automatically be considered undesirable or unacceptable. Given the paucity of information about some contaminants and the difficulty of obtaining it for others, it is unlikely that some of these values could ever be derived experimentally. The assessment of risks and of the need for remedial action must therefore depend instead on subjective or qualitative criteria.

38. Trigger concentrations only apply before a decision to develop has been taken, i.e. to sites being considered for development. They do not apply to sites already in use, nor to those in the course of development, and must certainly not be regarded or used as standards which all sites must meet. This restriction is very important. Trigger concentrations have been set on the basis of an implied

economic condition. The cost of taking remedial action, which normally increases development costs and extends the time required, has to be weighed against the likely risks. Where the risks are judged to be high, then remedial action will be necessary unless the original proposals are to be abandoned. The cost of abandoning a completed building which is already in use is likely to be judged high, and the practical constraints on designing and implementing remedial measures will certainly be much greater than before development started. The risks might, in these circumstances, have to be regarded as acceptable: in the case of a site still to be developed, this judgement might well be different.

39. The following working rule is suggested with the aim of reducing the risks as low as is reasonably practicable:

i. where the source of the contamination has ceased and the site investigation has shown that the contamination is no worse than that of surrounding areas in similar use or equivalent areas elsewhere, then at worst the risks and the associated hazards and consequences at this site can be no greater than at other sites in use; but

ii. nonetheless, when an opportunity arises to take action to clean the site, or in some way reduce the risks, this should be done.

Remedial Action

40. Remedial action, which usually requires some form of treatment to be carried out to reduce the risks, can also include a change in the proposed use or layout of the development. Such changes are often the most cost-effective solution. Where assessment has indicated that remedial measures on the site are required, but changes in the form or layout of development are not possible, the options are limited. Only four methods are used to any significant extent:

i. excavation of the contaminated soil for disposal elsewhere, followed where necessary by replacement with clean material;

ii. isolation of the contaminated soil by covering it with a suitable thickness of clean inert fill or hard cover;

iii. chemical, biological or physical treatment to destroy or immobilise the contamination; and

iv. mixing the contaminated material with clean soil or sub-soil in order to reduce the maximum concentrations of contaminants to below the threshold trigger values.

41. The first method is applicable to most contaminants on most sites, but the costs may be high if the volumes are large. The main disadvantage, however, is that the problem is not solved but merely transferred to another site, which itself may eventually be required for re-use. Off-site disposal is, therefore, the option of last resort. The third method, although technically effective for some types of contaminants, may also be expensive; its main disadvantage, however, is that only a limited range of contaminants can at present be treated. The fourth method is most likely to be successful when the site area is sufficiently large and the range of uses wide enough to permit flexibility in allocating them within the site. In practice, the preferred method is usually the second: the layout of the proposed development is adjusted so that the most badly contaminated areas are located beneath permanent hard cover (roads, pavements, parking areas) leaving the less contaminated parts of the site for the main buildings or for gardens and amenity areas.

42. Other special precautions that may be necessary are:

i. Essential site services such as water, gas and electricity supplies, drains, and sewers can be protected by excavating all the contaminated soil from a trench large enough to contain the services and then back-filling it with clean inert material before installing the services. The size and location of the trench needs to be such that access for future maintenance does not require any other parts of the site to be disturbed. The clean material must not not be allowed to be contaminated by mixing with, or the movement of,contaminants.

ii. The composition of concrete to be used in aggressive ground conditions must be adjusted to provide adequate resistance against sulphate and other substances. When mobile liquid contaminants are present, especially oily substances, there may also be a need to protect concrete piles by coating them with resins or other resistant materials.

iii. Where good quality top-soil is in short supply, the most suitable plant species for revegetating the site are those with shallow roots. Grass is more resistant to most forms of contamination than other plants, and does not have deep roots. If trees or saplings have to be planted, the ground may need to be prepared first by excavating the contaminated soil to a sufficient depth around the root zone and backfilling with clean top-soil.

Most flowering plants and vegetables are able to grow without such precautions provided that the concentrations of phytotoxic metals or other substances are not excessive and that proper care is taken with plant nutrients and fertilisers. When plants fail to grow on restored sites the cause is more often poor quality top-soil or inadequate husbandry than contamination.

43. Some hazards are always important and the sites where they occur should preferably not be built upon or utilised, but if they have to be, then special precautions may be necessary. Two particular examples are:

i. Sites known or suspected to emit flammable gases. Redevelopment while gas is still being emitted should take place only when either (a) the proposed use would not be at risk from the emissions, which is unlikely, or (b) a system for collecting and extracting the gases safely can be provided.

ii. Sites containing combustible materials may ignite and smoulder underground and so put buildings or other structures at risk. If an underground fire starts, it may, if detected in time, be controlled or extinguished by digging out the combustible material ahead of the burning zone and applying water to the whole area. These measures may, however, increase the rate of combustion, if the burning area has become large. Where the fire is already large the construction of deep curtain walls to contain or enclose the burning zone may limit the spread. This will not, however, put out the fire while the burning zone still contains combustible material and it will either have to be left to burn out or be dug out before redevelopment begins.

Monitoring

44. Monitoring may be desirable to ensure that the decision either to proceed with unchanged development plans or to take remedial action remains justifiable. The scale and duration of the monitoring required depends on the certainty of the evidence on which the original decision was based. In some sites, such as those

reclaimed for amenity purposes, it may suffice simply to check that the remedial action has been carried out satisfactorily. In others, such as those where there is a need to check the safety of the building or protect human health, more thorough monitoring may be necessary and the cost accepted as part of the costs of developing and maintaining the site.

V. REFERENCES

1. D C WILSON AND C STEVENS: Problems arising from the redevelopment of gas works and similar sites. Second Edition 1988 (To be published by HMSO).

2. R A DUTTON AND A D BRADSHAW: Land Reclamation in Cities. HMSO, London, 1982.

3. BUILDING RESEARCH ESTABLISHMENT (DOE): Fire and explosion hazards associated with the redevelopment of contaminated land. BRE Information Paper 2/87, by D. Crowhurst and P. F Beever, April 1987. Available from BRE, price 75p.

4. BUILDING RESEARCH ESTABLISHMENT (DOE): Concrete in sulphate-bearing soils and groundwaters. BRE Digest 250. 1986.

5. WATER RESEARCH CENTRE (WRC): The effect of soil contaminants on materials used for distribution of water. WRC Report PRC 1452-H/1, 1987. Available from the WRC Medmenham Laboratory, price £7.50.

6. BRITISH STANDARDS INSTITUTION: Code of Practice for Ground Engineering Investigations, BS 5930: 1981.

ICRCL 59/83 (Second Edition): TABLE 3 TENTATIVE "TRIGGER CONCENTRATIONS" FOR SELECTED INORGANIC CONTAMINANTS

CONDITIONS

1. This table is invalid if reproduced without the conditions and footnotes.

2. All values are for concentrations determined on "spot" samples based on an adequate site investigation carried out prior to development. They do not apply to analysis of averaged, bulked or composited samples, nor to sites which have already been developed. All proposed values are tentative.

3. The lower values in Group A are similar to the limits for metal content of sewage sludge applied to agricultural land. The values in Group B are those above which phytoxicity is possible.

4. If all sample values are below the threshold concentrations then the site may be regarded as uncontaminated as far as the hazards from these contaminants are concerned and development may proceed. Above these concentrations, remedial action may be needed, especially if the contamination is still continuing. Above the action concentration, remedial action will be required or the form of development changed.

Contaminants		Planned Uses		Trigger Concentrations (mg/kg air dried soil)	
				Threshold	Action
Group A: Contaminants which may pose hazards to health					
Arsenic		Domestic gardens, allotments		10	*
		Parks, playing fields, open space		40	*
Cadmium		Domestic gardens, allotments		3	*
		Parks, playing fields, open space		15	*
Chromium (hexavalent) (1)		Domestic Gardens, allotments		25	*
		Parks, playing fields, open space			
Chromium (total)		Domestic gardens, allotments		600	*
		Parks, playing fields, open space		1,000	*
Lead		Domestic gardens, allotments		500	*
		Parks, playing fields, open space		2,000	*
Mercury		Domestic gardens, allotments		1	*
		Parks, playing fields, open space		20	*
Selenium		Domestic gardens, allotments		3	*
		Parks, playing fields, open space		6	*
Group B: Contaminants which are phytotoxic but not normally hazards to health					
Boron (water-soluble)	(3)	Any uses where plants are to be grown	(2, 6)	3	*
Copper	(4, 5)	Any uses where plants are to be grown	(2, 6)	130	*
Nickel	(4, 5)	Any uses where plants are to be grown	(2, 6)	70	*
Zinc	(4, 5)	Any uses where plants are to be grown	(2, 6)	300	*

NOTES:

* Action concentrations will be specified in the next edition of ICRCL 59/83.

1. Soluble hexavalent chromium extracted by 0.1M HCl at 37°C; solution adjusted to pH 1.0 if alkaline substances present.

2. The soil pH value is assumed to be about 6.5 and should be maintained at this value. If the pH falls, the toxic effects and the uptake of these elements will be increased.

3. Determined by standard ADAS method (soluble in hot water).

4. Total concentration (extractable by $HNO_3/HClO_4$).

5. The phytotoxic effects of copper, nickel and zinc may be additive. The trigger values given here are those applicable to the 'worst-case': phytotoxic effects may occur at these concentrations in acid, sandy soils. In neutral or alkaline soils phytotoxic effects are unlikely at these concentrations.

6. Grass is more resistant to phytotoxic effects than are most other plants and its growth may not be adversely affected at these concentrations.

ICRCL 59/83 (Second Edition) TABLE 4: TENTATIVE "TRIGGER CONCENTRATIONS" FOR CONTAMINANTS ASSOCIATED WITH FORMER COAL CARBONISATION SITES

CONDITIONS

1. This table is invalid if reproduced without the conditions and footnotes.

2. All values are for concentrations determined on "spot" samples based on an adequate site investigation carried out prior to development. They do not apply to analysis of averaged, bulked or composited samples, nor to sites which have already been developed.

3. Many of these values are preliminary and will require regular updating. They should not be applied without reference to the current edition of the report "Problems Arising from the Development of Gas Works and Similar Sites"(1)

4. If all sample values are below the threshold concentrations then the site may be regarded as uncontaminated as far as the hazards from these contaminants are concerned, and development may proceed. Above these concentrations, remedial action may be needed, especially if the contamination is still continuing. Above the action concentrations, remedial action will be required or the form of development changed.

Contaminants	Proposed Uses	Trigger Concentrations (mg/kg air-dried soil)	
		Threshold	Action
Polyaromatic hydrocarbons(1,2)	Domestic gardens, allotments, play areas.	50	500
	Landscaped areas, buildings, hard cover.	1000	10000
Phenols	Domestic gardens, allotments.	5	200
	Landscaped areas, buildings, hard cover.	5	1000
Free cyanide	Domestic gardens, allotments landscaped areas.	25	500
	Buildings, hard cover.	100	500
Complex cyanides	Domestic gardens, allotments.	250	1000
	Landscaped areas.	250	5000
	Buildings, hard cover.	250	NL
Thiocyanate(2)	All proposed uses.	50	NL
Sulphate	Domestic gardens, allotments, landscaped areas.	2000	10000
	Buildings(3).	2000(3)	50000(3)
	Hard cover.	2000	NL
Sulphide	All proposed uses.	250	1000
Sulphur	All proposed uses.	5000	20000
Acidity (pH less than)	Domestic gardens, allotments, landscaped areas.	pH5	pH3
	Buildings, hard cover.	NL	NL

NOTES

NL: No limit set as the contaminant does not pose a particular hazard for this use.
(1): Used here as a marker for coal tar, for analytical reasons. See "Problems Arising from the Redevelopment of Gasworks and Similar Sites" Annex A1. (1)
(2): See "Problems Arising from the Redevelopment of Gasworks and Similar Sites" for details of analytical methods. (1)
(3): See also BRE Digest 250: Concrete in sulphate-bearing soils and groundwater. (4)

FIG 1 INTERPRETATION OF "TRIGGER CONCENTRATIONS"