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INTERDEPARTMENTAL COMMITTEE ON THE REDEVELOPMENT OF CONTAMINATED LAND

Notes on the redevelopment of gasworks sites



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NOTES ON THE REDEVELOPMENT OF GAS WORKS SITES

SUMMARY

Sites where town gas was made from coal are numerous and widely distributed. They are likely to have become chemically contaminated with a wide range of substances derived from the production and purification of gas. Similar substances can occur on other sites where coal carbonisation processes were operated, for example, coke ovens, tar distillation plants and by-products works.

The hazards that these substances may pose can affect the health of users or occupiers of the site, or damage the buildings and their essential services. These undesirable effects may limit the choice of future uses for such sites. However, provided that these hazards are recognised and the sites investigated properly to establish what remedial treatment is needed, it is usually possible to restore the land to beneficial use for a suitable purpose. In general, the more sensitive the proposed use to the presence of contaminants, the more extensive will the site investigation and the necessary remedial measures need to be.

These notes have been prepared so that those concerned with the assessment and redevelopment of gas works sites can ensure that the effects of contamination are properly evaluated and allowed for in their schemes.

I INTRODUCTION

1. Sites where town gas was made, or where other coal carbonisation processes were operated, are likely to have been chemically contaminated by substances derived from the products, by-products and waste materials present. These substances may pose hazards which may restrict the choice of future use. The main hazards are to:

- i. the health and safety of those engaged in demolition, clearance and construction work on the site;
- ii. the future users and occupiers of the site;
- iii. any buildings to be constructed, including their essential services; and
- iv. the growth of plants.

2. The possible future uses of these sites differ in the extent to which they are risk from these hazards. Forms of development in which most of the site will have a permanent hard-surfaced cover, for example industrial or commercial buildings, may be preferable since such uses are generally more tolerant of any contamination: some protective treatment may, however, still be needed. Development for housing, gardens, allotments or agriculture may not be practicable unless extensive remedial action is carried out.

3. Before deciding on any particular use for a given site, prospective purchasers or developers of the land should consider the importance of these hazards and ensure that the site is properly investigated to provide information on the nature and extent of any contamination. After an adequate investigation has been carried out to establish the condition of the site, its suitability can be assessed and an appropriate use chosen. The need for remedial action can then be decided before application is made to the local planning authority for permission to proceed with the chosen form of development.

4. When considering such applications, local planning authorities may need to impose appropriate conditions in order to ensure that the proposed development will not expose the future users or occupiers, or any buildings or services, to the hazards associated with the contaminants present. The remedial action needed, if any is required, should be designed and carried out in such a way as to provide adequate protection for the lifetime of the development.

5. These notes have been prepared from readily available information and are of an interim nature: they may be revised from time to time. Any comments or suggestions for their improvement should be sent to the Secretary of the Interdepartmental Committee at the address given on the back cover.

II ORIGIN AND NATURE OF CONTAMINATION

6. Commercial production of coal gas ("town gas") began in the first half of the 19th century, and continued until the 1970s, when it was replaced by natural gas. Coxe is still produced in connection with the manufacture of iron and steel, and some coal-tar and by-products works are still in operation.

7. Coal is "carbonised" by heating it in closed retorts in the absence of air, yielding gas, coke, tar and ammoniacal liquor as the main products. The process conditions can be adjusted to increase the yield of any of the first 3 - hence sites specialised in the production of gas, coke or tar. During carbonisation,

about one-third of the original mass of the coal is converted to gas. The impure gas leaving the retorts contained tar, ammonia, cyanides and hydrogen sulphide, which had to be removed before the gas could be used or distributed to consumers.

8. Contamination occurred in various ways during the operation of gas-making and purification processes. There were, inevitably, accidental spills and leakages of process liquids, by-products and wastes, and sometimes the discharge of liquors to land. Solid by-products such as clinker and 'spent oxide' were often deposited on adjacent land, or used as fill and hard-core during extension or rebuilding of the plant.

9. The contaminants may have been spread around the site during demolition and site clearance, thus contaminating parts of the site where they would not normally have been found. The normal practice was to empty underground storage tanks and the bases of gas holders before back-filling them with solid rubble. However, semi-solid sludges were not always removed. At some sites these sludges were converted to a less mobile form by mixing in fly ash or 'spent oxide'. Usually the tank or gas holder base, once filled, was then capped with clay or concrete to prevent water entering. However, this was not always effective: at some sites water has accumulated inside the tank until eventually it has spilled over, thus spreading the contamination.

10. The solid waste most often present in any appreciable quantity is 'spent oxide': the residue from iron oxide used in the purification of coal gas to remove sulphur, cyanide and other harmful constituents. This material often consists of a deep blue friable solid ('blue billy'), the blue coloration resulting from the presence of ferric ferrocyanide ('Prussian Blue'). When the sulphur content of the iron oxide reached 50-60% the material was termed "spent"; it was then either discarded as waste or used in the production of other chemicals such as sulphuric acid. Other solid wastes which may be present include coal and coke particles, ash, clinker and pitch.

11. Many organic substances are present but the most important form in which they occur on gas works sites is as coal tar. 'Coal tar' is an extremely complex mixture of substances such as benzene, toluene, xylenes, ethyl benzene, styrene, phenol, cresols, xylenols, tar acids (polyhydric phenols), naphtha, naphthalenes, anthracene, and phenanthrene. On most works, the crude tar was stored in tanks from which it was periodically removed for processing at another site. Some large works had their own tar distillation plants, and many such plants were operated by associated companies.

12. Ammoniacal liquor, another valuable by-product, was also stored in tanks for further use. Its most important constituent is ammonia, usually in the form of ammonium salts, chiefly the cyanide, sulphide and carbonate ('free ammonia') but also as the chloride, thiocyanate, thiosulphate, sulphate and ferrocyanide ('fixed ammonia').

III POTENTIAL HAZARDS

13. Remedial action may have to be taken to reduce the hazards from:

i. toxic substances;

ii. combustibility;

iii. chemical attack of contaminating substances on building materials and site services;

iv. emissions of toxic or flammable gases;

v. general problems of site drainage and stability.

14. For most contaminants it is not possible to specify the concentrations that would automatically require action to be taken on a particular site. Each site needs to be judged on the basis of all the data available, taking into account the use to which the site is to be put and the exposure routes for those likely to be at risk. If the proposed use of the site does not expose anyone or anything to the hazards, then the presence of contaminants may not require any remedial action to be taken.

Presence of toxic substances

15. Toxic substances in soil can pose hazards either indirectly, through the uptake of metals such as cadmium and lead by vegetables and other food crops; or directly, by ingestion of contaminated soil or dust. Children with a tendency to 'pica' (habitual ingestion of soil and other materials) are a special group for which protection may be needed, but the number at risk is small. Generally these hazards will be unimportant when planning the redevelopment of a gas work sites except when housing or agricultural use is proposed. Repeated contact with contaminated soil may increase the risk of irritation of the skin due to some organic compounds.

16. Some contaminants are phytotoxic (toxic to plants) and this is important when the proposed use of the site includes areas to be planted with grass or other species. The most important phytotoxic elements are boron, zinc, copper and nickel. Some constituents of coal tars may also be toxic to plants.

17. Some tentative "Threshold Trigger Concentrations"* for various contaminants and land uses are given in another note in this series (ICRCL 59/83), and a detailed assessment of the hazards posed by contaminants typical of gas works sites has also been published (1). Table 2 of these notes is based upon that assessment, which should be consulted for further information.

Potential combustibility

18. Several of the materials likely to occur on gas works sites are potentially combustible. Spent oxide contains a considerable proportion (up to 60%) of sulphur, and can start to smoulder through self-heating. On at least one site large quantities of sulphur dioxide were evolved during a fire in an oxide heap. Some tarry materials may also produce unpleasant and possibly dangerous fumes, if ignited. Accumulations of coal or coke residues in former storage areas could also support combustion.

19. The criterion used most frequently to indicate potential combustibility is calorific value (CV), which is the amount of heat that can be released from a sample by burning it in an excess of oxygen. It is usually claimed that materials with high CVs, low ash contents and high carbon contents are more likely to be combustible than others but it is not yet certain how such measurements should be

*Threshold Trigger Concentrations are values below which a site can be regarded as uncontaminated. They should not be interpreted as the maximum permissible concentrations, nor to define sites where remedial action is essential. See ICRCL 59/83.

interpreted. The Fire Research Station has found (2) that materials with CVs greater than 10 MJ/Kg are almost certain to sustain smouldering. In some circumstances, however, smouldering can propagate in materials with CVs similar to those of soils: a typical loamy soil has a CV of about 1.7 MJ/Kg, but does not smoulder. For specialist advice on problems of combustibility the Fire Research Station (tel 01-953 6177) should be contacted.

Chemical attack on building materials and site services

20. Some contaminants attack building materials. Sulphate and acid attack on concrete are the most common but there may also be enhanced corrosion of metals and attack on plastics, eg pipes, protective coatings to metals, jointing and sealing compounds, etc. Certain polymeric materials used for the construction of water distribution pipes are permeable to some organic chemicals without suffering structural damage. Contaminants can, in this way, enter water supplies. Corrosion can also affect buried metal pipes and other underground services. The insertion of piles into the ground may create pathways for liquid contaminants to move through the ground and attack the surface of the pile, causing a loss of structural strength and loss of adherence to the surrounding ground. The liquids may accumulate at the base of the pile, or continue to percolate downwards and eventually pollute groundwater.

Emissions of toxic or flammable gases

21. Some contaminants eg oily liquids and tarry substances may produce emissions of toxic or flammable gases. Other constituents may also need to be considered:

i. Methane is not toxic but, in sufficient concentration, is an asphyxiant. Its density is approximately half that of air. It is flammable at concentrations between 5% and 15% in air. In buildings and other confined spaces accumulations of methane can lead to explosions.

ii. Hydrogen sulphide is a highly toxic, flammable gas and can exhibit similar explosive characteristics to methane. The explosive limits are 4.3 to 45.5% in air.

iii. Carbon dioxide is an asphyxiant. It is denser than air and its accumulation in deep excavations, tanks or pits, is potentially hazardous.

Site drainage and stability

22. Demolition, clearance and construction operations can spread contamination inside and outside the site. Release of liquids from tanks and sumps, and the surface run-off from hard-covered areas of the site, can pollute water-courses or underground aquifers. Liquid contaminants tend to move readily through the relatively permeable fill materials frequently found on gas-works sites.

23. The precautions needed to ensure site stability for structural purposes will depend on the local conditions, such as site geology and hydrogeology, previous history etc. The British Standard Code of Practice for Foundations (CP 2004) states that "All made ground should be treated as suspect because of the likelihood of extreme variability". A geotechnical investigation of the site may therefore be needed to assess the load-bearing properties of such materials. If such an investigation shows that these properties are unsuitable for constructing buildings and cannot be improved, then there is no point in investigating the site for contaminants which attack building materials or site services since their presence is not the factor which precludes such forms of development.

IV. SITE INVESTIGATION

24. After identifying the principal hazards likely to affect the intended use, the next stage is to investigate the site to assess its suitability. A site investigation should only be omitted when sufficient knowledge of the site history and ground conditions already exist or for certain low-grade end-uses (eg hard cover for vehicle parking) which do not depend on extensive remedial measures to make the site suitable for redevelopment.

25. The specific objectives of site investigation are:

- i. to identify the various buildings or other structures present;
- ii. to identify the materials present and to ascertain their distribution;
- iii. to assess the concentrations of contaminants both on and below the surface.

Preliminary investigation

26. The first stage consists of the collection and examination of maps, plans, aerial photographs and other available information about the site. In some cases the local authority or Factory Inspectorate will have useful information and the British Gas Corporation may be able to identify former uses of sites and the processes operated on them.

27. Having obtained such information, a site inspection should be made in order to correlate the documentary evidence with the present condition of the site. Particular attention should be paid to the nature of the ground surface and the site layout: these features can provide useful indications of the types of contaminants likely to be present.

28. During the site visit, the various types of materials and structures present should be identified and recorded on a plan. Attention should be given to possible infilled areas and structures which may not be readily apparent at the time of investigation. Old site maps, plans and aerial photographs often indicate the locations of possible infilled structures.

29. The historical information and evidence obtained from site inspection should be used to decide whether further investigation is needed. The scope of the investigation should be related to the type of development envisaged and the stage it has reached: for example, a pre-purchase survey may not need to be so comprehensive as one needed to provide data on which detailed plans for remedial treatment and subsequent development can be based.

Sampling and analysis

30. The next stage of site investigation is to collect samples for analysis, in order to determine the nature, concentration and distribution of contamination both laterally and vertically over the whole site.

31. For most purposes the positions of sampling points should be based on a grid pattern, the grid spacing being chosen so as to give an adequate number of points for the particular site. The spacing should, in principle, be no larger than the largest area of contamination that could be handled without difficulty if it were not found during the investigation but only discovered during development. On large sites, typical grid intervals of 50 m or 100 m may be adequate, while closer spacings (eg 10 m or 25 m) may be needed for smaller sites or for selected areas of larger sites intended for sensitive end uses.

32. When the locations of sampling points have been decided, samples should be collected from trial pits or boreholes of the immediate surface layers and of the sub-surface materials at varying depths, for example 0-0.10 or 0.15m; 0.5 m; 1 m etc. The use of trial pits excavated by a mechanical digger permits samples to be taken at depths of up to about 3 m, and allows the sub-surface ground conditions to be observed readily, including the nature of the materials present and the levels at which water is encountered. For sampling at depths greater than about 4-6 m it is necessary to use boreholes rather than trial pits.

33. Comprehensive analysis of every sample can be costly and time-consuming, and for some end uses is not necessary. To save time and expense, the analysis to be carried out should be related to the particular immediate needs for the information: the samples can always be retained for further examination, or fresh samples collected, should a more detailed study be needed.

34. The chemical analyses required depend on which hazards are important for the proposed use of the site: for most purposes those indicated in Table 1 will suffice. Determinations of metallic contaminants are not normally required unless sensitive uses or phytotoxic effects are likely to be important. Whilst Table 1 lists most of the determinations likely to be needed for assessment of a typical gas works site, local knowledge and conditions should be taken into account and appropriate modifications made.

V. ASSESSMENT OF ANALYTICAL RESULTS

35. A site investigation carried out in accordance with section IV should provide adequate information from which to assess the significance of the contamination using the threshold and action trigger concentrations (3) developed for this purpose.

36. The analytical results for each contaminant and each sample should be compared with the values given in Table 2. Provided that the concentrations found are below these trigger concentrations, there is no significant risk that the hazard(s) associated with that contaminant will occur. The site can therefore be considered to be uncontaminated, and developed in the normal way.

37. As the concentration of a contaminant increases, a value is reached at which its presence 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 equally at risk from the hazards, it follows that the threshold trigger concentration varies with the site use or proposed use.

38. At higher concentrations the risks of the hazards occurring become so great that the presence of the contaminant has to be considered undesirable or even unacceptable. The value at which this occurs is termed the action trigger concentration. The site then has to be regarded as contaminated, and action of some kind ranging from minor or major remedial treatment to changing the proposed use of the site entirely, is then automatically required.

39. When the concentration of the contaminant is between the two trigger values, the assessment of risks and the need for remedial action must depend on professional judgement. Even though the threshold trigger concentration is exceeded, this ought not to be taken automatically to mean that remedial action is essential: merely that there is a need to consider carefully whether the presence of the contaminant justifies taking such action.

TABLE 1: CONTAMINANTS AND HAZARDS

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 <u>free cyanide</u> <u>coal tars</u> <u>phenols</u> <u>sulphate</u>
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	<u>Sulphate</u> copper nickel zinc methane
Attack on building materials and services (3)	Housing developments, commercial and industrial buildings	<u>sulphate</u> <u>sulphide</u> <u>chloride</u> <u>coal tars</u> <u>phenols</u> mineral oils
Fire and explosion	Any uses involving the construction of buildings and services	methane <u>sulphur</u> <u>potentially combustible materials</u> , (eg coal dust, oil, tar, pitch, rubber)
Contact with contaminants	Hazard mainly short-term (to site workers and investigation teams during demolition, clearance and construction work)	<u>coal tars</u> <u>phenols</u> <u>oily and tarry substances</u> asbestos radioactive materials
Contamination of water (3)	Any operation which may lead to run-off or leaching	<u>phenols</u> <u>cyanide</u> <u>sulphate</u> soluble metals

Notes

1. These hazards are not mutually exclusive. Combinations of several hazards may need consideration.
2. Underlining indicates contaminants most likely to be present on a former gas works site. 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.

VI REMEDIAL MEASURES

40. Having compared the analytical data with the trigger concentrations the need for remedial measures to make the site suitable for the proposed use can be decided. Where the eventual end use of the site is not yet known, it is more difficult to specify any necessary remedial measures.

41. When the site is found to be so seriously contaminated that it cannot be made suitable for the intended use at an acceptable cost, either an alternative use (for which less costly remedial measures would suffice) has to be adopted or the site has to remain undeveloped. Whichever applies, any steps needed to reduce the immediate hazards to the public or the environment should be taken.

42. On larger sites where comprehensive development is envisaged it may be possible to overcome less serious contamination by adjusting the layout to minimise the hazards and so reduce the need for extensive treatment. This can sometimes be done by locating areas which will be permanently covered by roads and parking areas over the more severely contaminated parts of a site and using the cleaner areas for construction of buildings or for gardens.

43. Before specifying remedial work, developers should consider whether the need for action can be reduced or avoided by changing the intended use to one more tolerant of the conditions. The main options for dealing with contamination once it has been decided that action is necessary are:

- i. removal;
- ii. treatment; and
- iii. covering up.

The choice between them depends on the nature and extent of contamination, the purpose of the development and the cost of the work required.

Removal

44. Where the contamination is limited to a thin layer at or immediately beneath the ground surface, excavation for disposal off site may be a suitable and cost-effective solution. Some clearance of waste materials and residues may in any case be needed before construction can proceed. When the contaminants have penetrated to greater depths, for example on sandy sub-soils or through permeable fill materials, the volume of contaminated soil may be so large as to preclude its removal by excavation. The cost of disposing of large quantities of contaminated soil, and of providing replacement material to restore ground levels, usually makes such action uneconomic.

45. Excavation and disposal of contaminated material on any significant scale is undesirable as a general solution to contamination problems and should only be adopted as a last resort. If any contaminated material has to be removed from the site for disposal, the waste disposal authority must be consulted. Seriously contaminated materials may need to be disposed of as special waste under the provisions of Section 17 of the Control of Pollution Act 1974.

Treatment

46. Some contaminants can be reduced or removed from soils by treatment. Several commercial processes are available, for example chemical stabilisation, liquid extraction, thermal degradation and microbiological treatment. For most processes

**TABLE 2: TENTATIVE "TRIGGER CONCENTRATIONS" FOR CONTAMINANTS ASSOCIATED WITH FORMER COAL CARBONISATION SITES
(Taken from ICRCL 59/83 Second Edition: July 1987)**

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 analyses 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 redevelopment of Gas Works and Similar Sites". (Reference 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	Tigger Concentrations (mg/kg air-dried soil)	
		Threshold	Action
Polycyclic aromatic hydrocarbons (1,2)	Domestic gardens, allotments, play areas.	50	500
	Landscaped areas, buildings, hardcover.	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. (Reference 1).

(2): See "Problems Arising from the Redevelopment of Gasworks and Similar Sites" for details of analytical methods. (Reference 1).

(3): See also BRE Digest 250: Concrete in sulphate-bearing soils and groundwater. (Reference 4).

it is necessary to excavate the contaminated soil for treatment at a fixed plant; after decontamination the cleaned material may not always be suitable for re-use on the original site. In some cases, a specially designed mobile plant can be used on the contaminated site itself. In either case, the costs of transport and treatment will need careful consideration.

47. In one microbiological process the contaminated soil is treated in-situ with minimum excavation and disturbance. Natural micro-organisms present in the contaminated soil are developed in the laboratory so that when re-introduced to the site they break down specific organic compounds more rapidly. This process is currently being studied at one gas-works site in the UK, but no reports of its effectiveness are yet available.

Covering up

48. It is often possible and preferable to place contaminated material beneath permanent hard-covered areas of the new development, for example under pavements, roads and vehicle parking areas. This reduces the need to remove or treat the contaminated material. The provision of a suitable depth of clean cover material to isolate remaining areas of the new development from the underlying contaminants, eg where buildings or gardens are to be located, may also be effective. Some precautions may still be needed to protect essential services, such as drains, sewers and water supply pipes, but it is usually simpler to provide these where required than to try to treat the whole site to remove the contamination completely.

49. The thickness of cover needed depends on the nature and mobility of the contaminants and the intended use of the site: depths of 0.5 to 2 m are typical. Cover materials need not consist entirely of top-soil suitable for growing plants. Some top-soil may be needed in areas to be used as gardens or landscaped surrounds, but not elsewhere. To provide cover beneath future buildings, sub-soil materials can be used eg clean rubble, crushed stone, mine spoil etc. It is sometimes advantageous to place different grades of sub-soil in separate layers so as to prevent contaminated liquids moving upwards from the underlying material into the clean cover.

50. Where this solution is to be adopted, statutory undertakings eg gas, water and electricity should be consulted about the choice and depth of cover material. Some water undertakings have special provisions in their bye-laws governing the provision of supplies to contaminated sites: they may, for example, specify the materials to be used for constructing the mains or for the ground through which the pipes are to be laid.

51. Whatever remedial measures are adopted the aim should be to ensure that they are carried out responsibly and that they remain effective for as long as is required. Some provision for periodic monitoring and maintenance of the remedial work is desirable so that, if necessary, further action can be taken to maintain protection. Records of the contamination found and action taken should be kept and cross-referenced to documents concerned with land ownership and use, including planning aspects.

VII REFERENCES

1. Problems arising from the redevelopment of gas works and similar sites, by D C Wilson and C Stevens: AERE Harwell Report R-10366. (To be available from HMSO).

2. Assessment of fire hazards in contaminated land, by P F Beever. In "Contaminated Soil", ed J W Assink and W J van den Brink, publ M Nijhoff, Dordrecht, The Netherlands, 1986, pp 515-522.

3. Assessing contaminated land: UK policy and practice, by M J Beckett and D L Simms, Ibid, pp 285-293.

4. Concrete in sulphate - bearing soils and groundwater. BRE Digest 250: 1981, Building Research Establishment (Department of the Environment), Watford WD2 7JR.

Professional advice on the specific problems of individual sites can be obtained from specialist consultants with appropriate experience.

