

JOURNAL
OF THE
ASSOCIATION OF PUBLIC ANALYSTS

Symposium on Toxic Waste and Environmental Pollution

Six papers were read at a symposium held by the Association of Public Analysts at the School of Pharmacy, University of London, on 18 March 1976. The contents of these papers are summarised in this and other issues of the *Journal*.

IS LAND DISPOSAL OF TOXIC WASTES A HAZARD FOR FUTURE GENERATIONS?

J. H. HAMENCE

Dr Bernard Dyer and Partners, 20 Eastcheap, London EC3

All living processes produce a waste which may become toxic if allowed to accumulate, and in the same way industry, on which we largely depend for our existence, also produces waste which must be disposed of.

The disposal of toxic waste is by no means a new problem and at one time the local river was frequently the dumping ground. This was not always the case, as I found quite early in my professional life when a farmer submitted a sample of yellow crystalline material which had been brought to the surface following extra deep ploughing of one of his fields. The material was found to consist of T.N.T., and subsequent enquiries showed that it had been buried there after World War I.

My second experience came just before the second World War when the cellars of certain houses became flooded, during a comparatively dry spell. Samples of the water from the cellars were all found to be acid in reaction and to contain both free sulphuric acid and free phosphoric acid. The presence of these acids suggested an industrial waste and after an exhaustive analysis traces of lanthanum and other rare earths were established in the water. The effluent was finally traced to a factory in which minerals containing rare earths were processed and whose waste had been disposed of for years on land that was considered suitable for the purpose. Both methods of disposal were clearly satisfactory initially, but subsequently gave rise to trouble.

In these days, many Public Analysts are called upon from time to time to advise on the subject of disposal of toxic waste, and the volume of this work has increased during recent years, following the Act of Parliament governing this matter. Although few regulations have as yet emanated from Whitehall and few official guidelines have been supplied, nevertheless, Public Analysts have a duty to give their authorities the best possible advice.

The general strategy adopted at the present time by local authorities is to dispose of the waste in such a way that it does not constitute an immediate

hazard to the public; while this is undoubtedly a satisfactory policy in the short term, nevertheless, it may pose very serious problems for the future. For example, disposal on land in relatively isolated parts of the country where there is a thick stratum of clay is apparently one of the usual methods of such disposal. The theory behind the technique is that if clay is of sufficient thickness to be impervious to water then hazards arising from seepage of the waste to adjoining watersheds and arable land is extremely remote.

In my submission we should be thinking further ahead and considering whether or not we are in fact creating the "toxic barrens" of the future. There is a misguided theory in some quarters at the present time that the soil will purify anything, and that given sufficient time these disposal sites will be converted into lush and fertile areas. This view is confirmed by the statement that we hear from time to time from some disposers of waste that they are not "dumping" but are in fact reclaiming waste land.

The point I would like to consider today is whether they are correct in assuming that the soil is such a wonderful purifying agent. Clearly this view comes about by the ready manner in which many putrescible organic substances become decomposed in the soil. Indeed, normal fertile soil was largely built up in this way; but the substances which decomposed in the soil were originally of natural organic origin. The toxic wastes we are now considering and which constitute a big problem are very different from natural organic substances. Indeed, the very description of the substances as "toxic" makes this abundantly clear. Some specific examples will now be considered.

Toxic Metals

Toxic metals applied to a soil either in the liquid or solid form can only accumulate in the soil. No natural purification process could possibly alter their toxicity; at best a very chalky or alkaline soil could render these metals less available to plant growth, but, nevertheless, a toxic hazard still must remain. We have had abundant examples of this in the build-up of toxic metals in sewage farms and in the areas where vast amounts of sewage sludge have been deposited. Such substances deposited on waste land, therefore, can only remain as a hazard for all time.

Acid and Alkalis

Every year vast quantities of liquid waste containing acids and alkalis are disposed of on land and in some disposal areas the wastes are kept separate. What is the fate of these substances in the soil? Most soils have the capacity to neutralise a substantial amount of mineral acid but saturation point is soon reached and a significant excess of acid remains in the soil. This acid in due course must form an acid clay and the point arises, will the resulting acid clay behave in the same way as ordinary clay from the point of view of water penetration? Also, what happens to the ever-increasing amount of free acid which must ultimately remain in these tips?

Similar remarks clearly apply with regard to free alkali wastes and we are faced with the situation of soils with either a low or a high pH which are quite useless from the point of view of any plant growth.

If an alternative procedure is utilised whereby the acids and alkalis are mixed, then the ultimate effect is to build up a heavy concentration of water-soluble salts in the soil. Plants in general are very intolerant of even low concentrations of water-soluble salts and here again we have all the makings of a "barren area" which is all too familiar in some parts of the world.

Toxic Organic Compounds

Organic compounds of an objectionable nature will be included in a number of toxic wastes and once again the problem arises, will they decompose in the soil? It is sometimes assumed that fertile soil is capable of breaking down any organic compound mainly by bacterial action; to a limited extent this is true but for the successful destruction of such compounds in this way two factors are necessary.

1. The compound should be distributed at a very low concentration in the top soil.
2. The soil must be given sufficient time to build up the necessary organisms which can destroy such compounds.

There is a wealth of experience to show that some compounds are extremely difficult to break down in this manner. For example, some of the weed killers remain in the soil for several years and we know from somewhat bitter experience that some organic pesticides such as dieldrin may remain in the soil for many years, and it must be remembered that this is under ideal conditions where a few parts per million of the toxic compound only are present. It is abundantly clear that if relatively large amounts of these substances are involved then decomposition will be excessively slow. Some years ago a limited series of tests were made with organo-phosphorus compounds in soil, added as waste materials, and these were surprisingly slow to decompose.

With the type of waste disposal that we are considering at the present time, in all probability the very nature of the wastes will render the soil nearly sterile, the beneficial bacteria having been killed off. Moreover some dumps must of necessity become waterlogged in the lower depths from the amounts of waste continually applied. Again, we all know how difficult it is to break down significant deposits of mineral oil or tar in sub-soil.

Effect of Anaerobic Conditions

We also have to consider the type of tip in which household waste forms an absorbent for large quantities of liquid waste, and to ask ourselves whether this is a sound proposition. Fuel ash in the household waste is usually alkaline and would assist in neutralising any acid wastes applied, but the problem of waterlogging in the bottom layers is another matter.

These layers must be completely anaerobic and we all know what happens when organic matter is deposited on the bed of a lake and the vast amounts of sulphides which are produced. It is conceivable that at least a part of any sulphuric acid waste applied in this manner will end up as sulphide. We have ourselves found dilute yellow ammonium sulphide running out of the

bottom of one tip. It is also probable that many organic materials such as tar would remain unchanged at the bottom of a waterlogged dump.

There is a possibility that waterlogging may give rise to other hazards. For example, there is the possibility that both arsenic and phosphorus compounds may give rise to their poisonous hydrides under such conditions.

In conclusion, I would say that the majority of local authorities have tackled this extremely difficult problem very well considering the limited knowledge which is available on the subject, but considerable research is needed into the whole problem and this clearly can be carried out only with help from central Government. Those concerned with these problems should consult the document entitled "Programme of Research on the Behaviour of Hazardous Wastes in Land Filled Sites. Interim Report on Progress, September 1975", obtainable from the Department of the Environment, 2 Marsham Street, London SW1.

THE CONTROL OF POLLUTION ACT—THE NEED FOR SCIENTIFIC ADVICE

A. J. HARRISON

*Avon County Scientific Services, Canynge Hall, Whatley Road,
Bristol BS8 2PR*

Concern for the state of the human environment was clearly reflected in the evidence presented by the United Kingdom to the United Nations Conference in Stockholm in 1972¹.

"Part of the threat to the environment is pollution. So large in volume and so complex in nature are man's wastes becoming that they threaten in many areas to dirty the air and foul the water to a point where these common assets are no longer fit to be used. Great lakes and parts of the seas are so poisoned by industrial waste that they can no longer sustain fish—or, if they do, it is not fit to eat. At the same time, man's greatest monument, that complex agglomeration of people, buildings and transport systems which we call the City is becoming progressively less manageable".

The United Kingdom view stemmed largely from the first Report of the Royal Commission on Environmental Pollution² under the chairmanship of Sir Eric Ashby, which had been established by Royal Command in February 1970. In this Report, the Commission summarised the national and international situation, recognising that, whilst such evidence as was available at that time gave no cause for immediate alarm, there were no grounds for complacency. The Commission outlined a series of priorities which it considered should be investigated if we were to "strike a balance between the benefits gained from economic and technical achievements and what is being lost in terms of deterioration of the environment". The choice of priorities was between pollution of air, the pollution of land by agriculture and waste disposal, the pollution of fresh and sea water, and noise.

On the question of qualifications and training for those who monitor the situation, the report drew attention to the wide variation in technical competence for the implementation of control systems (particularly among smaller local authorities), and to the apparent lack of communication between small units and more experienced sources of scientific and technical knowledge. These are vital factors when, in order to assess changes in the human environment, it becomes necessary to monitor with only limited resources. It is most important, therefore, that the available resources should be used effectively.

The Royal Commission published its second Report³ in March 1972, and raised three issues; (a) the confidentiality of information on industrial effluents and wastes, (b) the need for an early warning system about the possible impact of new chemicals on the environment and (c) legislation to control the tipping of potentially dangerous waste on land. Within one month, the *Deposit of Poisonous Waste Act 1972*⁴ was published and local authorities were, for the first time, specifically involved over the true nature of wastes which were being tipped in their areas. The DoE Circular 70/72⁵, however, drew attention to the point that "in particular, the quantity of the waste which was involved, as well as its nature and chemical composition, needed to be taken into account". The legislation relies very heavily upon a notification procedure, and hence upon the integrity of the depositor. Its implementation by local authorities has varied enormously and there have never been firm guidelines or adequate resources for effective enforcement. Nevertheless, the legislation has served a useful purpose in alerting industry to the needs of society and improving attitudes to the necessity for controlling the disposal of waste.

A Report concerning the pollution of estuaries and coastal waters was published by the Royal Commission in September 1972⁶ and it proposed that the very onerous responsibilities for monitoring this situation should rest with the Regional Water Authorities. One statement made in the Report is, however, worth mention. It was, "Monitoring in its simplest form requires repeated measurement of *how much* of a particular kind of pollutant is present in various parts of the natural environment, so that change can be detected".

In 1974, almost coincidentally with the reorganisation of local government, the *Control of Pollution Act 1974*⁷ was enacted, consolidating many of the proposals which had been made, and co-ordinating much of the hitherto unrelated legislation which had served to control pollution. Consequently, it too had a bearing upon the general human environment. The main provisions of the Act set out to control the disposal of solid waste on land, noise pollution, the pollution of water and the pollution of the atmosphere. Also in 1974, the Royal Commission published its observations concerning pollution control⁸, reviewing progress made since the publication of the first Report, and the needs for the future. In considering staffing requirements, their qualifications and organisation, the Commission could see no immediate problem in central Government departments, but nevertheless it considered a review to be necessary. At local authority level, the position was thought to be less satisfactory. Attention was drawn to a deficiency in the number of environmental health officers who were nationally available, and to the need to recognise the

increased demands which would be placed upon those involved by the introduction of the Act. In England, County Councils are generally responsible for the disposal of all types of solid waste.

The Commission drew attention to the fact that waste disposal authorities had a duty under the provisions of the Act to make a survey of all wastes arising in their areas and to draw up long-term disposal plans. It was considered essential that "disposal authorities should be able to call on staff with sufficient expertise to be able to decide whether any danger would result from the deposit of toxic materials at particular sites". It did not consider it desirable that the disposal authorities should rely exclusively upon the water authorities as sources of expert advice in these matters. For safe disposal, the Commission felt that it was necessary for licensing authorities to be able to call upon "a wide range of experience and scientific knowledge" and added: "We suspect that it may not be feasible for the smaller authorities to establish teams with the necessary range of skills, and we see here scope for collaboration between authorities and the pooling of knowledge and expertise".

Referring to professional institutions, the Commission recognised the need for approved qualifications for staff involved with pollution control, and it recommended that consideration be given to more specialisation by environmental health officers to enable more staff to concentrate on pollution control work. The possibility of establishing a professional diploma in pollution control was proposed. This was seen as an additional qualification for professionally qualified scientists and engineers and could in time become a statutory requirement for the administration of environmental protection legislation, as with the qualifications of a Public Analyst in relation to the Food and Drugs Act.

Concerning monitoring, the Royal Commission stated: "Monitoring of pollutants in the environment is essential to provide the factual basis for decisions on standards and controls". It also stressed the need for a uniform approach, ultimately on an international basis. In particular, the report highlighted the possible waste of costly monitoring resources which might result from random and uncoordinated data collection.

The Department of the Environment have now produced five Reports⁹ about monitoring the environment and the strategy for co-ordinating the many activities in this direction. The main theme throughout these Reports is centralised co-ordination of national effort (largely applied at local authority level), and they deal with all aspects of monitoring pollution of air, water and land. In the latter connection, reference is made to pollution of foodstuffs by heavy metals and pesticide residues, and to the concentration of such materials in animal tissues used for human food. The incidence of lead formed the basis of the second Report, and the non-agricultural uses of pesticides that of the third. The fourth Report, entitled "Controlling Pollution" summarised the progress which has been made since the first Royal Commission Report, and the objectives for the future.

Summarising, therefore, all these Reports stress the need for overall co-ordination by central government, but with day-to-day control at local authority level, and they look forward to an adequate level of expertise at both national

and local level in order that these functions may be carried out properly. There is particular emphasis upon the need for harmonised methods of analysis in order to achieve effective control and full value from accumulated data. This latter point is emphasised strongly in the first Department of the Environment Report concerning monitoring.

Both Counties and Districts in England therefore require day-to-day scientific advice on a wide range of pollution matters covered by the Control of Pollution Act 1974, and the division of responsibilities may be broadly identified as follows:

Waste disposal	—County Councils
Water pollution	—Regional Water Authorities
Noise	—District Councils
	—County Councils (highway noise control)
Air pollution	—District Councils
	—County Councils (motor fuel regulations)

The Royal Commission and the Department of the Environment in their reports have repeatedly drawn attention to the need for high levels of expertise in all those who become involved in the provision of comprehensive pollution control. It is significant that neither body has apparently considered the provision of day-to-day scientific advice to the local authorities, in spite of the clearly identified need. An authority may not be aware that it has a pollution problem until it has made investigation, identified a pollutant and, more important, has some knowledge of the pollutant's concentration. The latter requirements can only be met reliably by using the services of an analytical chemist, who is familiar with the precautions which must be observed when trace contaminants are under consideration.

Such knowledge of analytical chemistry is already available at County Council level since the authorities are statutorily bound to appoint both a Public Analyst and an Agricultural Analyst. The qualifications for such appointments are laid down in Regulations¹⁰ made under the Food and Drugs Act 1955. A Public Analyst thus must have the post-graduate qualification of Master of Chemical Analysis, which embodies all the requirements laid down in the Regulations. In 1968, the Royal Institute of Chemistry, which has the responsibility for conducting this examination, widened its syllabus to keep pace with the increasing demand for a more comprehensive range of scientific services from Public Analysts. A further revision occurred in October 1974, to embrace a total of thirteen enactments, including the Deposit of Poisonous Waste Act, the Water Act and the Public Health Acts. The revision highlights the fact that Public Analysts are in a position to deal with problems arising from pollution of the environment and that the candidate is required to have "a knowledge of uses and hazards of dangerous chemicals which may be found in industry, agriculture and commerce—including toxic waste—and an ability to give advice on a wide range of scientific problems with which a local authority is now likely to be concerned".

Being established at County level, a Public Analyst is able to provide scientific advisory services both for Counties and Districts within his area.

By consolidating all scientific demands on one laboratory in each County, effective use could be made of analytical expertise and might provide justification for the purchase of the expensive instrumentation necessary for effective pollution control. Central government's concern for the harmonising of analytical techniques and interpretation would be largely met since, through the Association of Public Analysts, a network of some 50 local authority laboratories would be harnessed, most of which have some 100 years of accumulated experience and are already used to working in close co-operation with each other. The problem of achieving standardised or comparable methods of analysis could thus be accommodated, and the necessary communications network is already established.

One attractive bonus at the present time is the economy in these proposals. These laboratories exist and are already local authority maintained. It is interesting to note that the fifth and most recent report of the Royal Commission¹¹, which calls for an integrated system for pollution control, proposes the establishment of a new central inspectorate (Her Majesty's Pollution Inspectorate) to replace and expand the duties of the present Alkali Inspectorate. Scientific services have been supplied to that Inspectorate in the past by the Laboratory of the Government Chemist. There is a traditional link between Public Analysts and the Government Chemist, in connection with the enforcement of Food, Drugs and Agricultural legislation, and further co-operation would be completely in tune with these proposals.

The provision of scientific services from a small number of local authority laboratories has the additional advantage that the Scientific Adviser in each case would be aware of the consequences of action taken elsewhere. An air pollution problem in District A will not stop at the boundary of District A but will go on to affect Districts B, C and D. Activities at both County and District levels may also have implications for the water authority.

Local authorities at the time of reorganisation failed to recognise the growing need for scientific advice despite a suggestion from the Royal Institute of Chemistry that Public Analysts should be additionally appointed as Scientific Advisers to their local authorities and given much wider terms of reference. However, many Public Analysts *were* additionally appointed Scientific Adviser and, in those instances, provide scientific services in connection with pollution matters. There is a need at the present time for initiation of a dialogue between the Department of the Environment and the Association of Public Analysts in order to harmonise national and international approaches to the analytical aspects of pollution control. There is a need for local scientific support in administering the Control of Pollution Act. The quality and reliability of the advice will be fundamental to the success of this comprehensive piece of legislation. The highly emotive issues surrounding pollution are essentially the concern of local authorities who, at the end of the day, will be left with local problems to solve, with all the political, emotional and financial limitations of the local community.

There exists now, a network of highly skilled local authority laboratories which are geared and qualified to deal with these matters. The same laboratories have provided virtually all local scientific services to date, and would be

well able to do so in the future, provided that modest resources (which would be less than those required for any other system) can be made available.

References

1. "The Human Environment—the British View", Department of the Environment, H.M.S.O., London, 1972.
2. "Royal Commission on Environmental Pollution, First Report", H.M.S.O., London, 1971.
3. "Royal Commission on Environmental Pollution, Second Report", H.M.S.O., London, 1972.
4. "Deposit of Poisonous Waste Act", H.M.S.O., London, 1972.
5. Department of the Environment Circular 70/72—Deposit of Poisonous Waste Act, 1972, H.M.S.O., London, 1972.
6. "Royal Commission on Environmental Pollution, Third Report", H.M.S.O., London, 1972.
7. "Control of Pollution Act, Chapter 40", H.M.S.O., London, 1974.
8. "Royal Commission on Environmental Pollution, Fourth Report", H.M.S.O., London, 1974.
9. Five Reports from the Department of the Environment, H.M.S.O., London:
(i) "The Monitoring of the Environment in the United Kingdom" (Pollution Paper No. 1), 1974; (ii) "Lead in the Environment and its Significance to Man" (Pollution Paper No. 2), 1974; (iii) "The Non-agricultural Use of Pesticides in Great Britain" (Pollution Paper No. 3), 1974; (iv) "Controlling Pollution" (Pollution Paper No. 4), 1975; (v) "Chlorofluorocarbons and their Effect on Stratospheric Ozone" (Pollution Paper No. 5), 1976.
10. "The Public Analysts Regulations", S.I. 1957 no. 273, H.M.S.O., London, 1957.
11. "Royal Commission on Environmental Pollution, Fifth Report", H.M.S.O., London, 1976.

SOME GUIDELINES ON THE RE-USE OF INDUSTRIALLY CONTAMINATED LAND

W. B. CHAPMAN, P. BAKER AND D. BURNS

*Scientific Branch, Greater London Council, County Hall,
London SE1 7PB*

In contrast to some of today's speakers, who are discussing the type of control which can be exercised in the disposal of potentially toxic materials, we consider the problems that face a local authority which needs to develop areas of land which may have become contaminated by controlled or uncontrolled industrial use, tipping, etc. This is likely to be an increasing problem in the future, particularly in large urban conurbations, because of the scarcity of what may be termed "virgin land". Local authorities are having to look more and more to areas of land which have been used previously by all types of industry, for the development areas they need. A number of industries, particularly some of the long-established ones, are able to release land which has been rendered superfluous to their future requirements by modern technology. Typical of such sites are old gas works and land used for sewage farming. These sites may present possible health and safety hazards unless some study of the condition of the site is made before using them for housing, schools, etc.

Our comments are based upon the experience we have acquired in the G.L.C. from the consideration of a number of sites of industrially-contaminated land. They are not meant to be exhaustive but cover a fairly wide range of problems which have arisen in the London area.

Possible Risks

Before commenting upon the mechanism by which such studies may be carried out, it may be useful to seek to classify the hazards which may arise.

A. *Who or What is at Risk*

1. Construction workers.
2. Eventual residents (of housing) or users (of schools, etc.) including particularly "sensitive" groups in the population and neighbouring residents, etc.
3. Animals, plant life, including aquatic life.
4. Building structures, etc., e.g. by corrosion.

B. *Type of Risk*

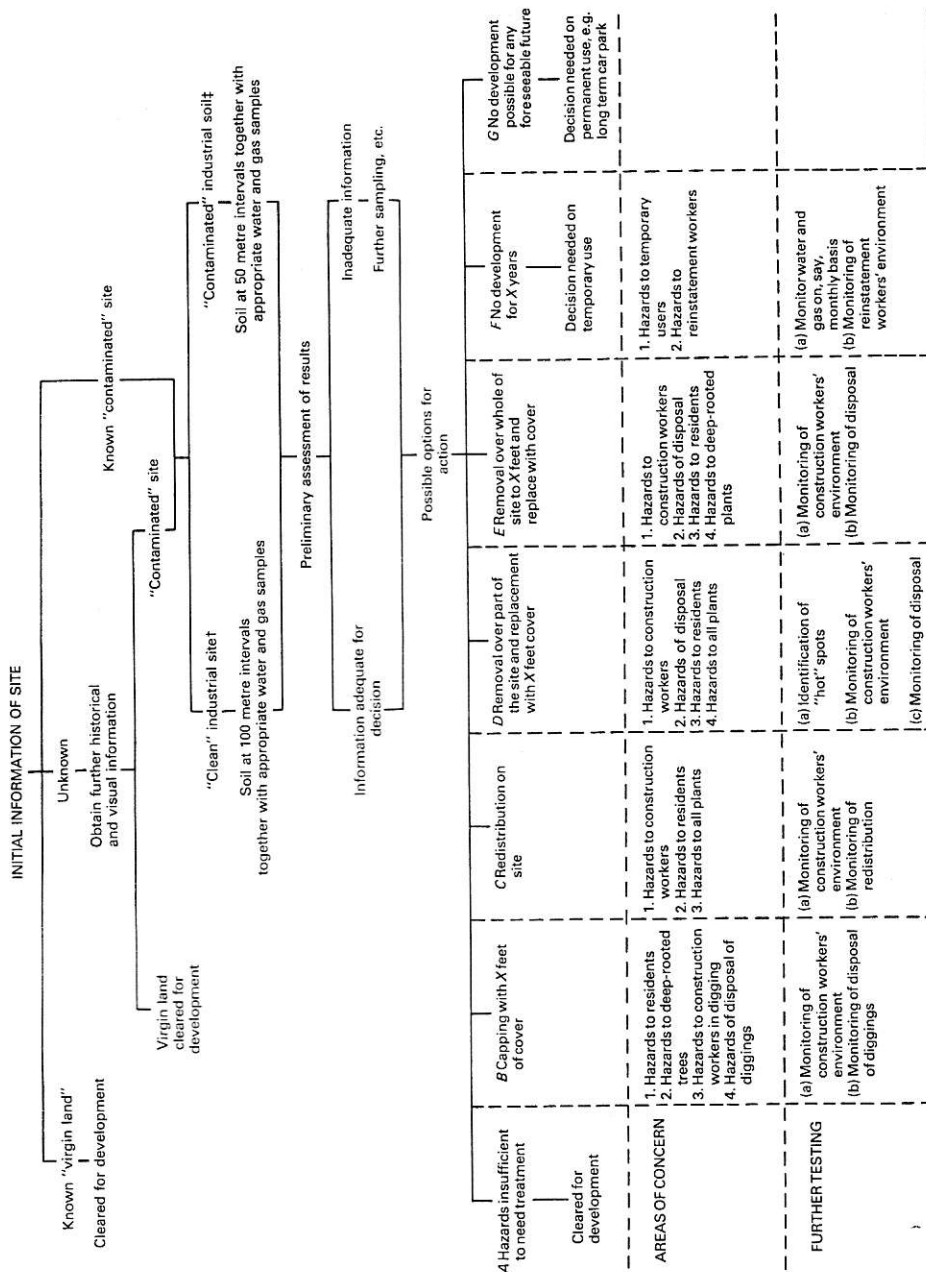
1. Physical:
 - (a) explosion;
 - (b) subsidence.
2. Inhalation:
 - (a) dust,
 - (b) toxic gases.
3. Direct ingestion:
 - (a) from fingers, etc. (particularly children);
 - (b) contamination of food.
4. Indirect ingestion:
 - (a) uptake of toxicants by edible plants;
 - (b) contamination of environmental waters.
5. Contact:
 - (a) skin irritation, etc.;
 - (b) retardation or death of plants, etc. by contact with contaminated soil;
 - (c) corrosion of structures (metal, concrete, etc.).

A more detailed classification could also be based upon the contaminants which may be present in the soil, which could be responsible for potential hazards. This classification is discussed later, in relation to the types of examination undertaken on samples.

Mechanism of the Study of a Site

In order to assess the potential health and safety hazards of a particular site, a considerable amount of information must be acquired. Methods of obtaining this information include the following:

- (a) History of site:
 - (i) from previous occupiers;
 - (ii) from library records, archives, etc.
- (b) Visual inspection:
 - (i) direct—e.g., obvious contamination;
 - (ii) indirect—appearance of plant life, water courses, etc.
- (c) Tests on readily accessible materials:
 - (i) ambient air, e.g., mercury vapour;
 - (ii) surface water, e.g., ditches, pools, etc.;
 - (iii) surface soil.
- (d) Tests of materials after borings, digging of pits, etc.:
 - (i) gas analysis;
 - (ii) water;
 - (iii) soil.



*Virgin land = land never developed, land used exclusively for housing or agriculture, land untreated with sewage sludge or other potentially hazardous chemicals.

†Clean industrial site = land known to have been used for industry (irrespective of previous use) but not visibly contaminated.

‡Contaminated industrial site = land visibly contaminated or known from previous history to be heavily contaminated.

Fig. 1.

Before relatively expensive testing under (c) or (d) is undertaken it is useful to obtain the maximum information possible from (a) and (b), since these can often help not only in the interpretation of any results from tests but also in deciding which particular tests or areas require urgent attention, in order to meet the construction programme.

In planning the assessment of a site, it is beneficial to ensure that decisions on particular aspects are taken as soon as adequate information is available. To aid this type of approach the simple "decision tree" shown in Figure 1 indicates a method of working which has been found useful.

Sampling Strategy

In the above mechanism, mention has been made of samples at specified intervals and it is worthwhile to look at the sampling strategy. In sampling agricultural land, the assumption is generally made that reasonably-sized areas of land, say a field, do not vary greatly in composition from one part of the field to another. The sampling strategy is designed therefore to obtain a number of samples (say 25) distributed fairly evenly over the whole area and to mix these to give one composite sample which may be used as a basis for any advice on type of crops or treatment, etc. The objectives when sampling industrially-contaminated land are different and differing sampling strategies are necessary. It is important to know, for example, what variation can occur in the concentration of contaminants from one part of the site to another and to know the depths at which the contamination is present. Average concentrations for the whole site are less important than the highest levels of contamination which may be present on the site. In addition, because the land may have been used for specific purposes, the variation from point to point cannot be assumed to be insignificant and small pockets of contaminants may well be distributed irregularly across the site. To meet all these points, whilst at the same time attempting to keep the amount of testing and its cost within reasonable limits and yet to obtain adequate information for the initial investigation of the site, we have found that for relatively clear sites (other than "virgin land"), boreholes or pits on about a 100 metre grid across the site are an acceptable compromise, provided that any areas visually identified as being of importance are investigated in more detail. With land which is initially known to be more heavily contaminated, or which the above 100 metre grid testing indicates a need for more extensive sampling, boreholes on the basis of a 50 metre grid are undertaken. The depth to which such borings are taken will depend upon a number of factors such as the initial levels of the land, the eventual levels of the finished development, expected presence of trees, possibility of growing edible crops, use for grassing only, expected hard core areas such as roads, concrete structures, etc. Generally, where relatively low-rise housing is concerned, which usually involves the possibility of vegetable growing, samples down to at least one metre below either the initial or the final level of the ground is essential. Deeper borings are often advisable especially on heavily contaminated land, and are particularly important if trees are likely to be needed, since the roots of some of these may reach 5 or even 10

metres. In relation to the actual sample, we favour spot samples at different levels rather than, for example, a composite sample representing 0-0.5 or 0-1 metre. No sampling strategy, short of an examination of the site so complete as to be inordinately expensive, can guarantee not to "miss" a local pocket of contamination. For this reason, visual observations during boring and digging operations are a most valuable additional safeguard. If it is not possible to arrange for scientific staff to be present at all times during such operations, it is most important to ensure that any unusual factors are noted by the contractor undertaking the sampling, and that the scientist is informed immediately so that the regular sampling suggested above can be supplemented by any other "spot" samples considered necessary in the light of the site condition discovered.

Although the above sampling strategy is developed principally for soil samples, similar considerations apply to water sampling. In addition, consideration needs to be given to ambient air testing for dust or specific materials such as mercury. For water sampling, it is usual to obtain samples of water from each borehole, as far as is practicable. This sometimes necessitates deep boring, depending upon the water table. These samples should be supplemented by samples from any surface water (ditches, pools, lakes, etc.) which is present on the site, or which develops during building operations. It should be noted that specialised equipment and techniques are necessary to obtain representative water samples and the involvement of scientific staff in the sampling is essential.

To summarise, it cannot be emphasised too strongly that a few random samples taken from a site can be grossly misleading. It may lead to either unwarranted confidence in the absence of significant contamination or to an unnecessarily gloomy picture of the degree of potential hazards present. Only by a planned sampling strategy coupled with careful observation of site conditions can adequate information be obtained with the minimum use of costly sampling and testing resources in order for an assessment of health and safety risks on the site to be made.

Type of Examination

Having decided upon a general sampling strategy we need to identify the tests to which the samples are to be submitted. It would be economically impracticable to cover all possible contaminants for even one small site and an acceptable compromise must be made. One of the types of site which is becoming available is land used in the past for gasworks, and therefore a search for potential dangerous substances derived from the gas industry is an obvious first approach. Soil samples have therefore been examined for coal tar, phenols, cyanides, complex cyanides such as ferrocyanides, thiocyanates and sulphides. Another class of potential contaminants from a wide range of industries comprises the toxic metals and included in our search for contaminants are the elements arsenic, cadmium, copper, lead, mercury, nickel and zinc. In the case of zinc, nickel and copper, a major consideration is their effect on plant growth and therefore the so-called "available" amount of metal is of particular interest (as well as the total present). In the case of the other

elements, their human toxicity is the major concern and total concentrations are more significant.

In a simple, rather crude attempt to cover a range of contaminants of unknown composition, we also carry out "germination" tests on soil samples. This consists of exposing a number of grass, mustard and cress seeds, supported on a portion of the soil sample kept continuously moist, to normal daylight and laboratory temperature conditions and recording the appropriate percentage of seeds showing germination and growth in comparison with suitable controls, during a three-week period. Other tests on soils include sulphate concentrations and pH, particularly aimed at the possibility of corrosion of concrete structures.

Water samples are, in general, tested for similar contaminants but, in addition, such parameters as dissolved oxygen, B.O.D., permanganate value and other indications of water pollution such as ammonia, nitrite and nitrate are also determined as well as mineral constituents, e.g. hardness, which may indicate contact with building materials, etc.

Ambient air samples have been tested for dust concentrations and for individual elements such as lead, mercury or cadmium, since the level of these may be completely independent of particulate matter.

This list is by no means comprehensive but covers a usefully wide range of possible contaminants. If particular information is available about a site which indicates that possibly dangerous contaminants may be present which would not be detected by such tests, additional work would be undertaken. In particular, a general qualitative and quantitative examination of any unusual-looking material exposed by borings and building operations is attempted with a minimum of delay so that further work can be initiated as soon as practicable. For this purpose, good liaison between site personnel and scientists is vital. No doubt, many of you may choose other parameters to assess contamination but we attempt to undertake all the above tests on the initial survey in order to obtain as good coverage as is possible within acceptable economic restraints. Subsequent work may, of course, be concentrated on individual aspects but the initial wide search is considered essential.

Interpretation of Data

Having indicated the sampling strategy and the types of examinations which are undertaken, I would now like to turn to some of the considerations which affect the interpretation of all this data. The reaction of different individuals to the same dose of a particular substance can vary considerably and in some cases enormously. It is not possible to state categorically that a particular concentration of a specific contaminant is hazardous. However, if the data on a site are to be interpreted at all, some guidelines must be evolved for assessing the hazards arising from the actual concentrations found. The drawing up of these guidelines, and their application to results from a particular site, must be guided by medical opinion. With some exceptions, chronic, as distinct from acute, toxicity is likely to be the limiting factor in setting such guidelines. In addition, they must have regard to the persons at risk. For example, the same guidelines are not applicable to construction workers who

are exposed during 40 hours a week for a comparatively short period, as are appropriate for a resident population, including children, who may be exposed continuously during their whole lives. In establishing such guidelines four types of considerations arise, as follows.

DIRECT INGESTION

In considering the hazards from direct ingestion of the soil, it may be instructive if we consider lead as an example. The relationship between an acceptable level and the actual daily intake of lead must be considered. A large part of the lead is excreted unchanged and does not become "available" to the body. Since the proportion of lead absorbed by the body by different routes (e.g. ingestion, inhalation) shows marked differences, it is suggested that the average adult should not *absorb* more than one microgram per kilogram body weight per day. To assess the hazard of soil therefore, it is necessary to estimate the daily intake of soil itself. Estimates in the literature indicate a range of 10–100 milligrams per day. This ignores the condition known as "pica" in which children may well consume very considerable amounts of materials other than food, e.g. plaster, paint and soil.

It can be calculated, on the basis of a maximum of 1 $\mu\text{g/kg/day}$, that a lead concentration in dust in excess of 300 p.p.m. may be detrimental to a 2-year-old child in an urban environment. Alternative calculations may be made, as follows, based on the *intake* recommendation of W.H.O. (rather than the *absorption* level). The relationship between dose and age (up to 12 years) has often been expressed as:

$$\text{dose for } X\text{-year-old child} = \frac{\text{adult dose} \times X}{12 + X}$$

On this basis, a dose of 420 micrograms per day of lead for an adult (the recommendation of W.H.O.) is equivalent to 60 micrograms per day for a 2-year-old child. Assuming half of this acceptable *intake* to be derived from soil, of which 100 milligrams might be consumed in a day, the level of lead in the soil should not exceed 300 p.p.m., similar to the above calculations. In addition, lead content of soils up to 200 p.p.m. have been recorded as "natural" (excluding areas near lead-bearing strata) with apparently no ill effect on the resident population. In view of this information, there would appear to be no potential risk to a 2-year-old child (or to the other residential population) if the lead concentration in the soil does not exceed 200 p.p.m. Above this guideline some hazard may arise, particularly if the amounts are several times this guideline level. It must be emphasised, however, that it cannot be assumed that there is a positive indication of hazard as soon as levels exceed this guideline (or any of the other guidelines which may be suggested in this paper). All the results from a particular site need to be assessed medically in relation to such a guideline and to other contaminants present before a recommendation can be made for action needed to render this site free from a significant health or safety hazard. Since the toxicology of lead has been the subject of a considerable body of literature, it is likely that the guideline for

other elements, for which less information is available, will be even less precise than that for lead.

INHALATION

A problem arises in connection with the inhalation of dust by construction workers. At various stages of construction, the site conditions may be particularly prone to produce dusty atmospheres, particularly in dry windy periods. After development and occupation, the dust hazard from the soil is probably reduced because some of the land is covered with houses, roads, grass, etc. To assess the level of lead in dust which may represent a hazard, the acceptable level of uncontaminated and inert dust must be considered. It has been suggested that concentrations above 10 milligrams per cubic metre of such dust may be considered a nuisance and presumably should not be exceeded under the Health and Safety at Work, etc., Act. However, a TLV for lead in air of 0.15 mg/m³ has also been proposed. It could therefore be argued that until the lead in dust reaches a concentration of 15,000 p.p.m. the nuisance of the uncontaminated dust itself is greater than the health hazard of the lead and therefore would enable us to reach a guideline for the dust hazard to industrial workers of particular elements.

INDIRECT INGESTION

The direct ingestion of soil, or inhalation in the form of dust, is not the only route by which contaminants from the soil may reach the body. As indicated earlier, both uptake of contaminants by plants and the contamination of the water-table can represent further potential hazards. An example may again be instructive and, in relation to uptake by plants, perhaps cadmium is a good element to choose. The first criterion to establish is the level of cadmium which would be acceptable in the edible parts of crops. Unlike lead, there are no legal requirements in relation to cadmium in food and, following a recent survey, the Food Additives and Contaminants Committee of the Ministry of Agriculture, Fisheries and Food did not consider that a legal standard was necessary. In our view, the level of cadmium in food which is acceptable should be less than 0.5 p.p.m. and it could well be argued that it should be no more than 0.1 p.p.m. The literature suggests that the cadmium content of edible parts of crops may reach, and in some cases exceed to a considerable extent, the cadmium level in the soil. However, the natural cadmium content of soils is said to be 0.1 to 1.0 p.p.m.—again apparently without ill effect. As a guideline therefore it would appear that the cadmium content of soil may well be suspect if it significantly exceeds 1 p.p.m. This example further illustrates the contrast in approach necessary with different elements. In the case of lead, translocation in the plant does not appear to occur readily and therefore in considering the limiting guideline the direct ingestion of soil is more important. In the case of cadmium, however, because of its relative ease of translocation, the guideline is set more by considering the possibility of uptake by plants than by the process of direct ingestion.

TOXICITY TO PLANTS

In the foregoing paragraph, the effect of uptake by plants was considered only in relation to the eventual edibility of any crops. However, some contaminants are likely to affect the growth of the plant itself, irrespective of whether the plants are then potentially toxic to man. The elements which are considered to be most toxic to plants are zinc, nickel and copper. The Agriculture Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food have published their views on these contaminants in relation to agriculture (ADAS 10, 1970). Summarising, a zinc equivalent (available zinc + $2 \times$ copper + $8 \times$ nickel) is regarded as the major criterion of plant toxicity and ADAS consider that this parameter should not exceed 250 p.p.m. in the soil of good agricultural land. This effect is greatly affected, however, by the pH of the soil and also by the expected use of the land. For instance, grass is considered to be more tolerant of such contamination than wheat. Since in many situations considered by local authorities, the growing of vegetables is perhaps the most "sensitive" type of crop, the above level of 250 p.p.m. zinc equivalent may be taken as the guideline for this type of contaminant.

Tentative Suggestion on Guidelines for Contaminants

The previous discussion indicates the considerations that contribute to identifying the necessary guidelines for assessment of data on particular sites. The information available on the toxicity, absorption by the body by different routes, translocation of materials in plants, etc. is often too limited to enable a reasonably firm estimate to be made of the level at which hazards may arise. Nevertheless, if the analytical work is to have any meaning at all, some levels must be decided above which the site conditions must be regarded as suspicious from a toxicity viewpoint. It is emphasised therefore that, in the tables given below, the guidelines may be very imprecise and should only be used as a rough indication that action may be necessary to make a particular site acceptable after assessment by medical authorities.

TABLE I
TENTATIVE GUIDELINES FOR SUSPICION OF TOXICITY

Contaminant	For resident population, <i>p.p.m. in soil</i>	Concentration at which toxicity may exceed dust nuisance*, <i>p.p.m. in soil</i>
Arsenic	40	50,000
Cadmium	1	5000
Copper	(EDTA-available) 000	(total) 100,000
Lead	200	15,000
Mercury	1	1000
Nickel	(N/2 acetic acid-available) 20	—
Zinc	(N/2 acetic acid-available) 200	(total) 500,000
Zinc equiv.	(Zn + $2 \times$ Cu + $8 \times$ Ni) 250	—
Coal tar	200	—
Phenols	200	—
Cyanides	10	—

* Principally related to construction workers.

Again may I emphasise that these are tentative suggestions, with which results for a particular site may be compared. If all samples on a representative grid were below the above levels, I would suggest that the medical opinion may be that there is no indication that any problems are likely to arise. The contrary is not necessarily true.

Examination of Water Samples

It is also essential to examine samples of both surface water and water derived from the boreholes used for soil sampling. The composition of a water can often be indicative of the soil and other material with which it has been in contact. For example, high hardness figures, significantly above those normal for the area, could indicate contact with builders' rubble, particularly if sulphate concentrations were high. Water in contact with natural organic matter contains high levels of ammonia and other constituents and some idea of the age of the tip can often be derived from a consideration of the full analysis of the water. Since the water samples from boreholes are often representative of the water table, they are probably largely indicative of the average conditions across the site rather than of localised pockets of contaminants, but in some cases the latter can be detected in water samples when the soil samples have failed to indicate their presence because of the positioning of the boreholes.

Another useful aspect of water sampling is in its use as an early indication of leaching of contaminants or migration through the soil. For example, if a surface lake is part of the site development, the examination of the lake water may give an early warning of extraction of toxic substances from surrounding contaminated land even if these materials are some feet below the surface. Again, migration of chemicals through the soil by the action of water may possibly occur and water examination in boreholes may give an indication of such migration. The need on some sites for disposal of large volumes of water due to pumping during building operation also calls for examination of the water to ascertain its possible polluting effect on any surrounding water courses into which it may be pumped. The examination of water samples must therefore include not only all those parameters tested for in soil samples but also additional tests which give information on the polluting and other effects mentioned above.

Monitoring of Sites During and After Development

As will be apparent, there are a number of situations in relation to development of industrially contaminated land which, even with all the tests suggested, will still not be sufficiently identified to give absolutely clear indications of future hazards. In such circumstances it is essential, if future difficulties for construction workers or residents are to be avoided, to undertake some kind of monitoring of the developing situation. Mention has already been made of the need for scientific staff to be present during sampling of the site and a close liaison between scientists and the contractors and/or site personnel

should be maintained throughout the construction period. Additionally, continual monitoring for a period of several years after occupation of the site may be necessary in order to ensure the safety of residents. This may also provide useful information for problems of a similar nature on other sites. The examinations to be made on any samples taken for monitoring purposes will depend largely on the original findings of the survey and it may well be that the full range of tests is unnecessary. While particular emphasis should be placed on the examination of water samples in relation to this monitoring exercise, continual visual check of vegetation, and of waterways, lakes, etc. may give valuable additional early warning of contamination, e.g. plant or fish kill.

Cost of Analysis and Remedial Work

The cost of such extensive testing, even if that of obtaining the sample is not included, is clearly considerable and the benefit of undertaking this work must be clearly identified before large commitments of resources are undertaken. The full analysis suggested for soils and water costs in the region of £50-£100 per sample so that any sizeable area, say 40 acres, even at 100 metre spacing and only 3 soil samples and 1 water sample per borehole may require £10,000 for such sample analysis. If a more closely spaced grid becomes essential the costs can become very large indeed. However, the cost of either complete or partial removal of "X" feet of contaminated land and replacement or cover by clean material is also very expensive and the two costs must be viewed together to reach a reasonable minimum cost consistent with maximum safety. The analytical work is clearly non-productive as it does nothing to improve the situation itself. However, it may enable a decision to be made which reduces the cost of remedial work by a considerably greater amount than the cost of the analyses. The survey costs and remedial work on each site must therefore be kept continually under review, during and after the survey period, if maximum benefit is to be derived from limited resources.

Future Developments

Comparing the information which is needed to deal with industrially-contaminated land with that which is actually available, there are clearly a considerable number of gaps in our knowledge. It would be of considerable assistance, for example, if more positive indications of the translocation of a wide range of materials in a number of different vegetables were available. Similarly, more experimentation is needed on the problems associated with leaching of contaminants into the water table and other bodies of water, as well as on the slow migration of contaminants in the soil. On the toxicological side, much more information is needed on the long-term effects of some contaminants and more particularly on the levels which are acceptable. Obtaining this information would require a significant research programme and as this is likely to be a national problem rather than a localised one, it would appear most appropriate if central government could find the resources to undertake this kind of work. Considerable help has, in fact, been available

from central government departments but largely in relation to specific sites. However, we would suggest, in view of the likely increase in this type of development, that the most appropriate future approach would be that central government should indicate a set of guidelines which local authorities could use to interpret any investigations of sites which they undertake.

Conclusion

We have attempted in this paper to indicate the approach that we have taken in the Scientific Branch of the G.L.C. to the problems raised by industrially-contaminated land. It is not possible in the space of one paper to deal with all aspects in any great detail. Only passing reference has been made, for example, to the problems associated with normal domestic tipping and land reclamation and the associated problem of methane production. Similarly, the virological, bacteriological and other microbiological hazards arising from use of sewage-treated land have been excluded. The major comments have been largely confined to soil and water tests and related matters. Even here, the treatment has been far from exhaustive, but we have indicated some guidelines which have been found useful in this difficult field of work.

VENTILATING CONDITIONS

G. V. JAMES

Hallen Lodge, Henbury, Bristol BS10 7RH

Physiologists speak of ventilating the lungs when fresh air from outside the body is taken in and exchanged in the lungs for air in which some of the oxygen has been replaced by carbon dioxide. The two other changes which have occurred are that the expired air has been warmed in the lungs and also its humidity has been increased. On average, humans require 7.5 litres of air per minute or 450 litres (about 16 cubic feet) of air per hour.

In a room or other enclosed space, the ventilation rate is the total volume of air passing in unit time and is sometimes quoted as the number of changes per hour. If the number of occupants of a space varies, the important fact is that the volume of air in that space is sufficient to provide a satisfactory fresh air supply, and these air changes give the ventilation rates.

For persons who are lightly occupied, or are sedentary, the carbon dioxide production is 0.6 cubic feet per hour. This is the figure most commonly assumed and used in calculations but it may, and does, vary since the production of carbon dioxide by each individual occupant of a room will vary. It must be stressed that this figure applies more particularly to those in sedentary occupations. As carbon dioxide is being produced oxygen is being used up, but, unless heavy muscular work is being performed, it takes a long time before symptoms of hurried breathing are apparent, at which point about a third of the oxygen in the air will be used up. Following this, symptoms of anoxaemia

will appear. These are headache, visual disturbance, mental dullness, loss of muscular power, weakened cardiac action and often loss of memory.

A normal man at rest gives out heat amounting to about 1000 kilocalories or 400 Btu per hour. Heat is lost by radiation and convection and by the evaporation of moisture (in the expired air or as sweat). As the temperature of the environment rises, a larger proportion of the heat lost by the body is produced by evaporation and also the humidity of the air rises. It is thus readily appreciated that in a room occupied by one person, temperature, humidity and carbon dioxide will all rise. The effect is enhanced when more people are present, the enhancement being directly proportional to the number of people present. In addition, we have not taken any account of bacteria or body odours. These latter are particularly noticeable by persons entering direct from fresh air outside but, as the sense of smell is quickly fatigued, these odours may be unnoticed by those people who have been exposed to them for some time.

It will now be appreciated that air change or ventilation of a room is as important as ventilation of the lungs. Resulting from this, it is possible to define how a pleasant atmospheric environment may be achieved and the six desirable points are as follows:

1. The room should be as cool as is compatible with comfort.
2. Adequate air movement is necessary but no local draughts.
3. The air movement should be variable rather than uniform and monotonous, as the body is stimulated by a continuous change of environment.
4. The relative humidity (r.h.) should not exceed 70 per cent. and preferably be below that figure.
5. The temperature of the walls and solid surroundings, for preference, should be higher than the air temperature. A combination of cold walls and warm air often leads to feelings of stuffiness.
6. The air at head level should not be warmer than near the floor and the heads of occupants should not be exposed to excessive radiant heat.

The temperature factor is mentioned in several of the above points and therefore it is necessary to consider "comfortable warmth" as the next point. It is obviously impossible to specify a temperature for "comfortable warmth" that will be acceptable to everyone but it is possible to find the condition that is most generally acceptable.

This is defined by Bedford¹ as that zone of temperature in which not less than 70 per cent. of the subjects were comfortable. Formerly, a figure was used based on 50 per cent. of subjects but Bedford narrowed this so that greater comfort was enjoyed by more people. Even in the House of Commons during ordinary sittings 67–68°F was recommended but the temperature could be reduced by 2–3°F when crowded or during a heated debate and the temperature should be raised during a late night sitting. Indoor temperatures in the U.K. are lower than in America as we tend to wear warmer indoor clothing and are also acclimatised to lower indoor temperatures.

The question of clothing is of course important and experiments performed in the U.S.A.² showed that women usually liked the temperatures to be higher than those liked by men. This difference is about 4°F and was entirely due to differences of clothing.

Apart from other forms of heating, attempts are made nowadays to cut down heat losses either by double glazing or by cavity filling, or both. I was asked to investigate a case where a family had suddenly developed sore throats. It was found that the cavity walls in the house had been recently filled in with an expanded plastic compound and it was feared that this substance was decomposing and liberating chemicals into the atmosphere. Experiments showed that this was a groundless theory but that the room temperature had been raised by 3°F and the humidity correspondingly reduced leading to dry throats, which were cured by the use of a humidifier and also by slightly reducing the thermostat setting of the central heating system.

There are various ways of expressing the humidity of the atmosphere. Briefly, 100 per cent. humidity means that the air is holding all of the moisture it can at a particular temperature. Humidity also affects the intangible property of "freshness"; thus a change of humidity that would be insufficient to affect one's impression of warmth could have a distinct effect on an impression of freshness. Mental alertness is associated with lower humidity and lethargy with higher humidity. Thus Markham³ has shown that 55 per cent. relative humidity was ideal for mental activity but 70 per cent. was desirable for rest and recuperation.

Musicians suddenly find their instruments out of tune in late autumn. Pottery and terracotta flake and powder away. This is caused by turning on the central heating; intensely dry air results so that valuable objects such as ivory, parchment, leather and wood, which are hygroscopic, twist, crack and peel. Another sometimes amusing event occurs with use of nylon wall-to-wall carpeting in a dry centrally heated house or flat. The humidity may be as low as 10 per cent. and when one person greets another who has entered the room, the sparks may literally fly as static electricity builds up a charge on the one person and this has to be discharged. This "state" may be overcome by frequently touching windows, walls, etc. and by raising the humidity to about 50 per cent.

An estimate of the amount of water required to keep a medium sized room (15 ft × 10 ft × 9 ft) at a comfortable humidity is 10 fl oz per hour. Humidifiers for homes are of three types, as follows.

Free Standing

These are electrically operated and work by

- (a) atomising water into small droplets which then evaporate,
- (b) heating water until it steams, or
- (c) using a fan to blow air over a damp cloth.

Duct Type

These fit into ducts taking warm air back to the heating unit and are either evaporating pads or the atomising type.

Radiator Hangings

These consist of troughs of water hung on the side of a radiator and containing a pad of material, saturated with water, which will allow water to evaporate over a large area.

Mention of sore throats earlier must have raised some thoughts about bacteria, moulds, etc. During sneezing and coughing, bacteria-laden droplets are discharged and may spread over a distance of at least 15 feet, and, as the droplets evaporate, they become steadily smaller until they can float on air—indeed they are airborne. It has been shown that organisms sprayed into the air of a basement room could be recovered on every floor of a three-storey building. Bacteria can be spread by a ventilating system and also, reduced ventilation can increase spread of some diseases. Experiments in New York⁴ showed that the highest number of bacteria was present in school air, while in air-conditioned theatres, counts were only a quarter of those in theatres which were not air-conditioned; indeed Central Park was on a par with a good air-conditioned theatre.

Bacteria may be removed from the atmosphere in several ways and three methods in particular must be mentioned.

- (a) The high bactericidal power of ultra-violet light is well known and is effective against bacteria in fine particles but less so against those on dust. Hence the air should first be filtered to remove dust and then passed over the lamps.
- (b) Use of bactericidal sprays may be valuable. Substances which are useful are sodium hypochlorite, chloramine-T, resorcinol, catechol, etc., especially when the organic compounds are dissolved in propylene glycol. Care must be exercised in the use of sodium hypochlorite as it must be finely atomised, since coarse drops may have a deleterious effect on fabrics or metal parts. Humidity is also important with hypochlorite as, below 50 per cent. r.h., inactivation of organisms is slight but is rapid with r.h.'s of 70–90 per cent.
- (c) Ozone is also a bactericide and rather exaggerated claims have been made commercially for its efficacy; but the concentrations necessary for germicidal purposes would produce undesirable effects on the occupants of a room.

So far, we have been discussing physical factors, i.e. temperature, moisture, etc., but at the outset it was pointed out that carbon dioxide was produced in metabolism. This is done at the expense of oxygen; the normal oxygen content of air is 20.9 per cent. and this may be reduced to 19 per cent., which is the minimum at which people should be allowed to work. At 17 per cent. oxygen a candle would be extinguished, but air is still breathable down to 15 per cent. oxygen, at which collapse can occur.

The changes in carbon dioxide concentration which are normally encountered exert no injurious physiological effects, but in gas-tight chambers, such as submerged submarines, the carbon dioxide content may go up even higher. In order to take care of this, the air is "regenerated". This is not a correct

expression as it really means removing the carbon dioxide by means of lithium hydroxide. In submersible vessels associated with oil drilling at sea, oxygen is bled into the cabin to maintain pressure and the carbon dioxide absorption system is used as required to maintain the carbon dioxide level below 0.5 per cent.

It must be remembered that air or oxygen with 5 per cent. of carbon dioxide increases the depth and frequency of respiration, which is the reason why oxygen with 5 per cent. of carbon dioxide is used as a respiratory stimulant.

A comfortable temperature in a room is attained by the use of one or more methods of heating. The ancient Greeks used braziers and developed hypocausts which were improved upon by the Romans and remains of this type are to be seen in Bath and many other Roman sites in this country. The open fireplace developed after centuries of experiment and only in very recent times has it been replaced. A closed stove gives better distribution of heat to the whole room than does a fireplace. Less labour is also involved in maintenance than with a fire. However, the danger with a stove is in its production of carbon monoxide. During combustion of fuels such as coal, coke, wood and oil, the major products of combustion are moisture and carbon dioxide. Now, carbon dioxide, in the presence of an excess of carbon such as anthracite, is reduced to carbon monoxide. Other effective reducing agents are iron and zinc. Iron pipes usually lead from stoves to chimneys and, apart from the metal, contain carbon. As time goes on pin-holes appear in the pipe, and as the pipe becomes red-hot, more carbon monoxide is formed and it may then leak into the room where it can be breathed in by the occupants. (In particular here I am thinking of the modern hermetically sealed room.) As with many factors associated with ventilation, thanks should be given to investigations carried out by the three Services and in particular the Army and Navy for much information about traffic conditions and carbon monoxide production. Nowadays, even the design of a multi-storey car park has an influence on carbon monoxide production.

Severe toxic symptoms arise from breathing air containing 400 p.p.m. carbon monoxide for an hour, whilst 50 p.p.m. in a chemical plant indicates unsatisfactory conditions. The threshold limiting value is 100 p.p.m.

Another interesting impurity I once found in the air of a room was phosphine. This discovery followed a request by the occupier to investigate the smell of "acetylene" which was noticed whenever he bled off gases which had collected in the radiators. A visit showed that, when bled off, the gas burnt with a bright luminous flame some 8 in or 9 in long. The gas had a faintly alliaceous smell and was identified as phosphine. Further investigation showed that this had come from the heating system, as the metal separating the oil burners from the circulating water was rich in phosphorus and under the conditions of local overheating which existed, a reaction occurred resulting in phosphine production which accumulated in the radiators throughout the premises and particularly on the upper floors. The T.L.V. of phosphine is 0.05 p.p.m.

Recently there has been an increase in the use of panel heating in which the floor or ceiling is warmed either by electrical heating elements or hot water

travelling through embedded pipes. This enables us to have solid surroundings at a temperature higher than air temperature. The use of ceiling heaters is bad practice, since heads should not be exposed to excessive heat.

Direct gas heating has not been mentioned for the reason that it is much less used than formerly, partly due to distrust caused by faulty installation of gas water-heaters leading to some deaths from carbon monoxide poisoning, and also to cost. Gas-fired central heating was at one time the most expensive form. It is understood that this is no longer correct. At one time, however, town gas used to contain sulphur compounds and, when burned on the incandescent bars, it produced sulphur trioxide. It was interesting to observe in one ladies' gown shop with overhead incandescent radiant heaters that the shoulder seams were so attacked by the trioxide that the cotton disintegrated and potential users found the dresses falling apart.

Most factors associated with ventilation have now been touched upon, save the important one of air movement, which is achieved by extraction of air, propulsion of air, a combination of the two and, of course, natural ventilation. Natural ventilation depends on diffusion, movement of air by inequality of temperature, air being replaced via doors, windows or ventilators, i.e. specially-made openings and, of course, wind movement.

The following comparisons are of interest⁵:

London flats,	1939,	940 ft ³	—0.44 changes per hour
London flats,	1888,	900–1435 ft ³	—0.71 changes per hour
London cottages,	1860,	620–1280 ft ³	—1.51 changes per hour

The only result giving over one change per hour was that obtained in the London cottages of 1860 where leakages around doors and windows resulted in up to 2 changes of air per hour.

Extraction methods are used extensively in theatres and factories and where much toxic material is produced. They have the disadvantage that the incoming air quality is not easily controlled and may be drawn from undesirable places such as toilets, etc.

In the propulsion system, also known as the plenum system, there is dependance on keeping doors and windows closed whilst inlets are above outlets. This system depends upon having a slightly positive pressure in the room. It was used in the Maginot Line, the positive pressure being an anti-gas defence. The advantages of this system are that the source of fresh air may be selected and the air conditioned, hence it is particularly useful in "tower blocks", hospitals, theatres, etc.

Finally, air-conditioning should not only be delivering pure fresh air at the correct rate to an enclosed space, but it should be cleaned, dried, moistened, cooled or warmed according to requirements. Unfortunately, there are few places where this is correctly applied.

References

1. Bedford, T., "Basic Principles of Ventilation and Heating". H. K. Lewis, London, 1964, p. 104.
2. Yaglon, C. P., and Mercer, A., *J. Am. Med. Assoc.*, 1941, **117**, 1261.
3. Markham, S. F., *J. Inst. Heat Vent. Engrs*, London, 1937, **4**, 570.
4. Bachbinder, L., Solowey, M., and Solotorovsky, M., *J. Heat. and Air Condition.*, 1945, **17**, 389.
5. Bedford, T., Warner, C. B., and Chrenko, F. A., *J. R. Inst. Br. Archit.*, 1943, **51**, 7.

