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INTERDEPARTMENTAL COMMITTEE ON THE REDEVELOPMENT OF CONTAMINATED LAND

Notes on the redevelopment of sewage works and farms

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INTER-DEPARTMENTAL COMMITTEE ON THE REDEVELOPMENT OF CONTAMINATED LAND

NOTES ON SEWAGE WORKS AND FARMS

SUMMARY

Sites formerly used for the treatment of sewage or operated as sewage farms can be contaminated to an extent which could affect their suitability for various forms of redevelopment. Possible hazards to human health and to plants may need to be taken into account when redevelopment schemes for such sites are planned.

The nature and degree of the contamination depends on the types of treatment process formerly operated. The areas of land affected can in some cases be as much as several hundred hectares. A site survey to investigate the distribution and degree of contamination will usually be needed before a redevelopment scheme for any given site can be finalised.

These Notes have been prepared to assist those concerned with the redevelopment of sewage works and farms in ensuring that contamination problems are properly evaluated and allowed for in the design of their schemes.

I. INTRODUCTION

1. With the provision of sewage treatment facilities in large centralised works of greater capacity, many older sites,especially those serving smaller communities in rural areas, are becoming available for redevelopment. These sites can present problems for redevelopment owing to the possibility of contamination from the processes formerly operated.

2. Brief descriptions of the types of treatment processes and wastes likely to be present at sewage works sites are given in Section II. The principal problems which may occur in the redevelopment of sewage works sites are discussed in Section III. Other material may also be present, for example many works sites have since been used as disposal facilities for various wastes including domestic and commercial refuse, demolition rubble etc. In addition to the wastes present, sewage works sites may also present physical difficulties for construction work because of the presence of large concrete structures such as settlement tanks, drying beds etc.

3. In order to enable the structures and wastes present on a sewage works site to be recognised and identified, brief descriptions of the main sewage treatment processes have been included. These descriptions are not intended to give a detailed explanation of the physical, chemical and biological basis of sewage treatment, which if required can be obtained from standard works of reference.

4. The sites range from small works in rural areas, perhaps serving only a few hundred homes, to large city treatment works, which with their associated effluent disposal areas and farmland may cover many hectares. Thus the scale of the works installations and the extent of any contamination are likely to vary considerably from site to site. A survey to establish the extent of contamination should be an essential pre-requisite for redevelopment schemes, and a suggested outline for a site assessment survey is given in Section IV. Examples of typical remedial measures which may be appropriate to sewage works sites are discussed in Section V.

5. Possible hazards to human health and toxicity to plants may also be encountered on agricultural or horticultural land which has been treated by the repeated application of sewage sludge or effluent often for many years. Such land may be immediately adjacent to the sewage works and form an integral part of its operations, or may simply be on farms which have received the sludge for its value as a fertilizer.

6. These Notes attempt to describe the main problems which may be encountered, but they may not all occur on a particular site. Thus it is stressed that each site should be assessed individually. Before deciding on the form of redevelopment for a given site, there should be consultation at an early stage between, for example, planners, architects, valuers, building control officers, environmental health officers, engineers and developers.

7. The Notes have been prepared from information readily available and from limited experience, thus they are of an interim nature and 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 at the end of the notes.

II. SEWAGE TREATMENT PROCESSES

Background

8. Installation of comprehensive sewerage systems and treatment plants to serve towns and cities began in the UK in the mid-19th century, and has subsequently been extended to serve smaller communities and rural areas. With the continuining growth of population the early works were considerably enlarged and modernised, but in increasing numbers are now becoming redundant due to replacement by newer works. Such developments have been particularly rapid since multi-functional regional water authorities were established in England and Wales to take over responsibility for water supply, sweage disposal and river pollution prevention from a wide range of former authorities. Land previously used for treatment of sewage, but no longer required for the purpose, is therefore now frequently available for redevelopment. The extent to which such land is contaminated depends on the type of treatment process used, and should be assessed by a site survey prior to purchase of the land or the preparation of detailed redevelopment proposals.

Treatment Processes

9. Treatment of sewage comprises a number of stages, some of which are common to most plants while others depend on local conditions and requirements. The layout of a sewage works is related to the particular unit processes employed in each stage of treatment. In turn the type of process determines the waste materials likely to be present and the way in which they are distributed over the site. The following brief descriptions of the principal processes should enable the methods used at a given works site to be identified.

10. Preliminary treatment

This stage of treatment is given on virtually all works. It consists of the removal of most the suspended matter present in the crude sewage; the wastes generated are therefore likely to be found on the majority of sites. Large floating objects, detrital matter and coarse suspended particles are removed at the works intake by means of grit removers, screens and comminutors, and the solid matter thus removed is usually bulked and deposited in a part of the site pending ultimate disposal. After screening, the liquid sewage then flows through large sedimentation tanks whose capacity is sufficient to allow adequate time for lighter suspended particles to settle out under gravity. The solid matter thus separated is removed from the base of the sedimentation tanks by mechanical scrapers, and is known as raw sludge. It consists very largely of putrescible organic matter, and is usually subjected to further treatment processes (see paragraph 15) independent of those applied to the liquid sewage. After sedimentation has occurred, the liquid sewage then passes on to the next stage of treatment.

11. Secondary treatment

Two main processes are available: (i) biological filtration and (ii) the activated sludge process. Both depend on biological degradation to effect purification of the settled sewage from preliminary treatment, but they differ markedly in detail and plant layout. The biological filtration process is the older method and is therefore more likely to have been used on sewage works sites now available for redevelopment.

12. Biological filtration uses beds of coarse granular material (eg coke, clinker, foamed blast-furnace slag), through which the liquid sewage percolates under gravity and is collected at the base of the filter. The beds are usually either circular or rectangular in form, and the liquid is applied from a rotating sprinkler or travelling distributor. The filter medium supports a bacterial and microbial population which feeds on the biologically degradable constituents of the sewage and thus purifies the liquid. The effluent from the filters contains coagulated solids (humus) which is separated from the effluent in secondary settlement tanks known as humus tanks. A large area of filters is required to achieve a high standard of purification.

13. The activated sludge process also utilises biological degradation of waste components by micro-organisms, which in this case consist of flocculent cultures of "activated sludge" freely suspended in the liquid sewage and maintained by aeration in specially constructed tanks. After aeration the organic solid matter is removed from the purified liquid by sedimentation, together with some surplus activated sludge. Most of this matter is returned to the inlet of the aeration tanks, thus retaining it in the process to sustain the microbial population. The activated sludge process is preferred for most modern installations.

14. Tertiary treatment

This stage of treatment is not given on all works, but is used where a higher quality of final settlement is required. Several processes are available, and the following may have been used:

14.1 Lagooning: the effluent from secondary treatment is retained in lagoons for a further period, during which removal of suspended matter occurs through sedimentation and degradation of dissolved organic matter continues through biological oxidation. The area of land used for lagoons can be very extensive for larger works, eg individual lagoons can have an area of up to 0.4 hectares.

14.2 Sand filtration: the effluent flows through beds of sand (depth varies from about a foot up to 2-3 feet) supported on a base layer of coarser material, which itself rests on a system of underdrains for collection of the filtered liquid.

14.3 High-rate Irrigation: the effluent is allowed to flow over grassed areas of land by means of a system of distributing channels and after treatment is collected by a second series of channels. The grassed plots are constructed on a gently sloping land surface to permit the ready flow of liquid under gravity. Where this process is used, large areas of land are needed to allow individual grass plots to be rested periodically for recovery.

14.4 Low-rate Irrigation: in a number of cases, sewage works were associated with working farms (hence the term "sewage farm", though both the term and the process are now largely obsolete). Sewage sludge was repeatedly applied to certain areas (sometimes used for crop production) whilst other areas of the farm were used for effluent disposal through a system of permanent channels as described above, supplemented as required by various mechanical distribution systems. The flow of effluent over the field surfaces would depend on the natural topography of the land rather than on artificially graded slopes, thus the irrigation occurred at low rates.

In addition, effluent and sludge were sometimes transported for disposal on adjacent farms. Consequently contamination resulting from this process would be liable to affect very large areas of land: in one particular case it proved necessary to survey 800 hectares of land (1). An account of the development of such a sewage farm and some of the subsequent problems encountered has been published (2). A feature of land used for both high and low rate irrigation may be the existence of a comprehensive system of land drains at a depth of about 0.7-1.0m. Other tertiary treatment processes are available but as they are considered less likely to have been used on the smaller and older works sites proposed for redevelopment they are not described here. Details can be found in standard reference books on sewage treatment if required.

15. Sludge treatment

Raw sludge produced by preliminary treatment of sewage consists of a highly organic material with a low solids content, usually about 4% - 7% w/w. Most commonly, the raw sludge produced on older works is subjected to air drying on shallow beds, yielding a dried material (still containing between 50% and 75% w/w of moisture) which is then stockpiled on site pending final disposal. On more modern works, the raw sludge undergoes anaerobic digestion treatment. This process, for which enclosed heated digesters or open tanks are needed, converts the sludge to a more readily dewatered form and reduces the volume of solid matter that has eventually to be disposed of. Among its other advantages is the fact that the final dried product is much less obnoxious than raw sludge itself. The smaller quantities of sludge arising from other stages of treatment, such as surplus activated sludge and the solids removed from biological filters or final effluent clarifying tanks, are usually mixed with the raw sludge for combined treatment. In some processes, chemical additives were used to aid the degradation of the sewage or to promote coagulation and settlement of the solid materials. Examples of such additives are lime, ferrous sulphate (copperas), ferric chloride and aluminium sulphate. The presence of such chemicals in the final sludge or in ground treated with sludge or effluent may possibly be significant in respect of the effects on building materials (eg sulphate attack on concrete).

Although the major routes for disposal of sludge have been to landfill sites, to agricultural land, or at sea, some works operate sludge incinerators. Incineration serves to concentrate any toxic elements present in the sludge, thus the ash from sludge incinerators may present particular problems.

III. WASTES FROM SEWAGE TREATMENT

Physical forms

16. A variety of solid, semi-solid and liquid wastes may be present at sewage works sites. Most of these materials will have been derived from the processes formerly operated, but a significant number of sites have since sewage treatment ceased been used for other purposes such as waste disposal. Hence the sites may be contaminated with a wide range of potential pollutants.

17. The wastes present may include:

   i. Solid detrital material removed by screening in the preliminary treatment stage.

   ii. Sludges produced in various stages of treatment, and in a range of physical forms from dried solid matter to unconsolidated semi-solid and liquid sludges of high moisture content.

   iii. Liquids and settled solids present in lagoons, tanks, drying beds etc.

18. Deposits of materials on the land surface, such as detritus tips or sludge storage heaps, should be readily identifiable. The presence of wastes in lagoons, drying beds, humus tanks etc may be less obvious because with time their surface layers must have dried out and become vegetated so as to present the appearance of solid ground. Such areas may thus represent a physical hazard in addition to any potential contamination.

Potential hazards of sewage treatment wastes

19. The wastes of greatest significance are the various types of sludge. Liquid effluents will not normally be present in large volumes since they would usually have been discharged continuously from the works.

20. Preliminary treatment of sewage by sedimentation usually removes up to 60%-70% of the suspended matter present. The raw sludge thus produced would, on older works, frequently receive only air drying before final disposal on a tip or application to land as a fertiliser. These methods of sludge disposal can present problems for both human health and phytotoxicity in both the short and longer term.

21. Application of dried sewage sludge to land has been practised for many years. Besides representing a significant disposal route for large quantities of sludge, the material can also be beneficial to land by contributing valuable nutrients and trace elements to soil. More recently the practice of direct application of liquid sludge to agricultural land has been developed. Although this too can be beneficial, the possibilities for undesirable effects such as smell and edour nuisance, water pollution etc are greater than with dried sludge.

Presence of Toxic elements

22. Sewage sludge can contain a wide range of metals and other elements in varying - and sometimes very high - concentrations. Although the metals present in the sludge will usually be the main concern at sewage works sites, where irrigation of effluents on land was practised the metals present in the liquids may also have accumulated in the soil to an extent which may present difficulties.

23. Some of the trace elements found in sewage sludges are essential to the health of crops and animals, eg zinc, copper, iron, molybdenum and manganese. Others such as lead, cadmium, mercury, nickel and arsenic, may be harmful at relatively low concentrations. For most elements the difference in concentration between levels at which beneficial effects or toxic effects occur is relatively small. The concentrations of metals in sludge or soil may be such as to present hazards to site workers or subsequent users or occupants of a site, and to animals or plant life. A survey for toxic elements will usually be required when sites are developed or undergo a change of use particularly when the intended use is "sensitive" to the presence of such elements.

24. The availabilities of trace elements in soils and their uptake by crops depends on complex interactions between several factors, including soil structure and pH, crop species and cultivars, chemical behaviour etc. Uptake of metals by crops could in some cases increase the concentrations of certain toxic metals (eg cadmium, lead and mercury) in the human food chain. Cadmium is relatively easily taken up by plants but only very slowly released from human body tissues, and is of particular concern. Lead and mercury are less readily taken up and translocated from the roots of most crop plants.

25. In addition to the uptake of metals by crops grown for human consumption, there is the possibility of direct ingestion of contained soil. Grazing animals can ingest up to 20-30% w/w of soil together with the vegetation they consume, and a minority of young children suffer from the condition known as pica (the habitual ingestion of non-food materials which can include soil).

26. The main potential benefit from application of sewage sludge to agricultural land derives from the addition of basic nutrients such as nitrogen and phosphorus, rather than from its organic content. The addition of trace elements, eg metals, can also be beneficial but their rates of application need to be carefully controlled in order to avoid the problems mentioned above. Guidance on the quantities and rates of application of sewage sludge to agricultural land was given in the report of the Working Party on Disposal of Sewage Sludge to Land (3). These limits refer to soils having normal background levels of the relevant elements, and except for boron are expressed in terms of the total dressings which may be applied over a period of at least 30 years.

27. The normal ranges of concentration for various elements in soil are given in the following table. Concentrations in excess of these ranges may indicate contamination due to sewage or other causes.

Element	Normal Concentration Range in soil (mg/kg dry soil)
Zinc	10 - 300
Copper	2 - 100
Nickel	5 - 500
Chromium	5 - 500
Cadmium	0.1 - 1.0
Lead	2 - 200
Mercury	0.1 - 0.3
Molybdenum	2
Arsenic	0.1 - 40
Selenium	0.2 - 0.5
Boron	2 - 100
Manganese	5 - 500

Appropriate analytical techniques are described in MAFF Technical Bulletin 27: The analysis of Agricultural Materials (4).

28. Additionally, the soil pH value affects the degree to which the metals are available for uptake by crops. Most metals are rendered more readily available by acidic soil conditions, though molybdenum and selenium are exceptions. In most cases the soil pH will need to be maintained at or about neutral (pH6.5-7)) for arable land to which sewage sludge is applied. Where metal concentrations in soils are already high, the addition of lime or the application of lime-treated sludge can reduce the possible harmful effects.

29. It is not possible to define concentrations of contaminants that would be deemed unacceptable on a specific site. Each site needs to be judged on the basis of all the data available. The assessments needs to take into account the end use to which the site is to be put and the exposure routes for the population likely to be at risk. However, an example is provided by cadmium for which concentrations in soil above about 3 mg/kg (parts per million) may be undesirable if the land is intended to be used for allotments or the production of crops for human consumption.

30. Some tentative "trigger concentrations" for metals and other possible contaminants are given in another paper in this series (ICRCL 59/83). "Trigger concentrations" are values below which a site can be regarded as uncontaminated: they should not be interpreted as the maximum permissible concentrations, nor do they define sites where remedial action is essential. The trigger values differ for different land uses: this is because the relative importance of the various hazards also differs.

31. Presence of pathogens

Disease-producing organisms are present in sewage but their numbers are greatly reduced by treatment processes. The organisms may include bacteria, viruses and the eggs or cysts of parasites.

32. Pathogenic bacteria eg salmonellae can be present in sewage sludges. Members of this group or organisms are potentially pathogenic to both animals and man. Whilst anaerobic digestion does not entirely eliminate contamination with salmonellae, the numbers remaining after such treatment, and hence the risk of infection, may be significantly reduced. Lime conditioning of sludges raises their pH value from about 6.5 to about 12 and this can also eliminate salmonellae. Sewage treatment processes have the effect of rendering inactive a proportion of the viruses which may be present in fresh sewage. Liming is considered to be particularly effective in inactivating viruses.

33. Parasite eggs may be present in sewage sludge. The parasites of most importance are the beef tapeworm (Taenia saginata) and potato cyst eelworm (Heterodera rostockiensis). The former ingests man, and if sludge contaminated by the eggs is spread on grazing land cattle can become infected. The latter parasite can be introduced into sludge through the washing of crops infected with eelworm. The effects of anaerobic digestion or liming on the viability of eggs of Taenia saginata or other human parasites is not known.

34. Although the hazards due to the presence of pathogens on old sites are likely to be small, caution should be exercised and workers encouraged to follow good hygenic practices.

35. Smells and odours

Some sewage sludges, especially if untreated, produce unpleasant odours which may give rise to complaints. Similar problems can be caused by the contents of cess-pits or septic tanks which are sometimes discharged at sewage treatment works. Both liquids and semi-solid sludges can cause problems, which tend to increase in warm weather and when sludge is lifted from drying beds or applied to land.

36. The tendency to cause odour problems is greatly reduced by the anaerobic digestion process. Matured air-dried sludge is rarely offensive. Stabilisation of sludge with lime also reduces smell. Odour suppressants may find limited application in minimising nuisance during any work involving the disturbance or movement of sludge.

37. Possibility of Combustion

Dried sludges and sludge-treated soils may support combustion if ignited by an external source such as a surface fire, or by spontaneous ignition. Combustion may be able to proceed in thick deposits for some time without detection and affect large areas of land. Combustibility may also be a problem with other wastes (eg domestic refuse) which may have been deposited. The problem of the combustibility of fill materials is discussed in more detail in another paper in this series (ICRCL 17/78). Advice on problems of combustibility is obtainable from the Fire Research Station, Borehamwood, Herts (01 953 6177).

38. Methane and other gases

Sewage sludge contains a significant proportion of organic matter which may subsequently decay, with the production of methane (CH_4) and other gases. Other materials deposited on site, such as domestic waste, may also liberate methane. There may consequently be hazards due to the flammable and explosive nature of methane (explosive mixtures are formed with air in the concentration range 5-15% CH_4) or due to lack of oxygen in deep excavations. Hydrogen sulphide (H_2S) which is also highly toxic and flammable may also be present. The possibility of release of trapped methane should be particularly considered when areas formerly used for sludge drying and deposition are being excavated.

39. The problems represented by the presence of methane and other gases are discussed in detail in the notes on landfill sites in this series (ICRCL 17/78). Other sources of information and advice on gas-related hazards include the Health and Safety Executive, the Fire Research Station (01 953 6177) and the Environmental Safety Group at Harwell (0235 24141). The local Environmental Health Department may also often be able to provide guidance and may have available suitable monitoring equipment.

40. Possibility of water pollution

This is more likely to affect surface watercourses than underground aquifers, and can arise through direct application of liquid sewage sludge to land or from surface run-off and leaching from sludge stocking or drying beds. With appropriate precautions these possibilities can be minimised and they should not represent a major constraint on redevelopment of sewage works sites, at least from the viewpoint of site clearance and reconstruction. Some care may be needed at sites used for sludge disposal to avoid pollution of water for example by the leaching of nitrates and metals in concentrations which could contaminate underground water resources. Where this is of special importance, sludge should not be deposited close to water supply boreholes after its removal from the treatment works sites.

41. There is also a possibility of contamination of water supplies where these services pass through contaminated ground, and some statutory water undertakings have special provisions in their byelaws concerning such land. It is considered that in some circumstances (eg a burst water main) back-siphonage could result in pollutants being introduced into the supply. To prevent this, special protective measures may be required and the local water supply authority should be consulted.

IV. SITE ASSESSMENT

42. The main objectives of site assessment are:

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

ii. To identify the various types of materials present and to ascertain their distribution over the site area.

iii. To obtain information on the extent and degree of contamination both on and below the land surface. The information thus obtained can be used to evaluate the suitability of the site for various possible modes of redevelopment. A detailed site assessment should only be omitted in cases where sufficient knowledge of the site history and ground conditions already exists, or for certain low-grade end uses (such as hard cover for vehicle parking) which do not depend on extensive remedial measures to make the site suitable for redevelopment. A British Standards Institution technical Committee (EPC/47: Land Quality) has drafted a code of practice for the investigation of contaminated sites and this should be consulted for detailed guidance.

Preliminary stages

43. The first stage in the assessment of a former sewage treatment works should consist of the collection and examination of available maps, plans, aerial photographs and other records relevant to the site. In many cases the regional water authority will have useful information, though for older works it may be less complete and more difficult to obtain. Responsibility for the provision and operation of sewage treatment works was formerly shared between a number of authorities, including municipal councils, regional drainage boards etc. Where they do not themselves keep the records, the regional water authorities may be able to identify former owners or operators.

44. Some subsequent uses of sites, eg for waste disposal, may be documented in records kept by local government authorities. In recent years, waste disposal sites have required licences issued under the provisions of Part I of the Control of Pollution Act 1974. The issue of such licences is administered by waste disposal authorities (County Councils in England, District Councils in Wales) and these bodies should be able to provide information on the types and quantities of waste materials deposited at such licensed sites.

45. Having obtained such information as is available, a site visit should be made in order to correlate the documentary evidence with the conditions actually existing at the site. Particular attention should be paid to the surface topography and works layout, as these features can provide useful indications of the types of waste materials likely to be present. Sewage treatment works are predominantly open air installations: such buildings as are present will usually be relatively small and few in number, especially on older works, for example pump houses, valve chambers, switch-gear rooms etc. Identifiable structures on the remainder of the site may comprise old filter beds, settling tanks, effluent clarifying tanks, sludge drying beds, storage areas, lagoons etc. Where the site formerly operated the grass irrigation process for effluent treatment, there may be extensive areas of open grassed land.

46. As noted above, sludge deposits in lagoons, humus tanks etc may be dried out on the surface, and their apparently solid (and possibly vegetated) surfaces may conceal a considerable depth of still liquid sludge. Care should be taken during the investigation of such areas.

47. Vegetation on sludge deposits or sludge-treated soil may be prolific, because of the high nutrient value of such materials. The range of plant species may however be restricted to those able to utilise the nutrients whilst withstanding the toxic effects due to the presence of high concentrations of metals. Good plant cover is therefore not conclusive evidence that the site is free from problems of human or plant toxicity. Evidence of phytotoxicity may sometimes be seen in the form of limited plant growth on some parts of the site.

Site Surveys

48. After ascertaining the site layout and history in general terms, the next stage of site assessment is to identify the wastes present and to specify locations where more detailed investigation is required.

49. Materials present on the surface of the site may include:

i. Detritus and solids removed by the screens and/or comminutors at the works intake. These materials consist of heterogenous solids and bulk floating objects which become entrained in the flow of crude sewage. After removal they are frequently deposited elsewhere on the site, either temporarily pending ultimate disposal, or permanently in an area of the site reserved for the purpose. This may comprise as above-surface tip or mound, or an infill of a low-lying part of the site.

ii. Spent materials removed from filter beds and possibly replacement filter media. Such materials can include coke, clinker, foamed blast-furnace slag etc from percolating filters and finer materials (sand, gravel, etc) from slow sand filters. These materials may not be present on all works sites, but will usually be readily recognisable by their appearance.

iii. Sludges of various types (see Section II). These wastes are likely to represent the largest volumes of process-derived materials present on sewage works sites. In appearance and composition they can vary considerably depending on such factors as the process used, degree of dewatering, age of material etc. Mature well-dried sludge can take on the appearance of soil as natural weathering acts upon it. More recent material may be lighter in colour and may still show traces of the individual particulate matter it contains. Sludge lifted from drying beds may show the presence of straw or other base layers, and may contain white surface deposits of lime or other chemical conditioner. Dried or partially-dried sludges were often stockpiled, prior to final disposal, in large heaps around the site (frequently on hard surfaced areas). Liquid and semi-solid sludges may have been left in earth-banked lagoons or ponds in which some matural drying may have subsequently taken place.

iv. At works which have since closure been used as general waste disposal sites a wide range of materials may be present. The identification and investigation of such materials is described in ICRCL 17/78 "Notes on the redevelopment of landfill sites". It should be remembered that the original sewage treatment installations and wastes may still be present beneath materials deposited more recently.

50. When the various types of materials present on or above the site surface have been identified and recorded on a site plan, attention should then be given to possible infilled areas and structures. The locations of such areas will depend on the works layout, but may not be readily apparent at the time of investigation especially for works that have been closed for a considerable time. Structures such as sedimentation chambers, effluent tanks etc were frequently enlarged or replaced as works were expanded to handle greater volumes of sewage. Information from old works plans, aerial photographs etc will often be the best indication of the locations of possible infilled structures.

51. The next stage in the site survey is the collection of samples for analysis, in order to determine the extent and distribution of contamination both laterally and vertically over the whole area of the site.

52. For materials present as discrete deposits on the surface or in infilled structures, the number of samples taken should be sufficient to characteristise the materials in broad terms (eg "detritus", "dried sludge", "filter media" etc). Since it is probable that such deposits will (a) be inhomogeneous, and (b) may need to be removed from the site as part of the redevelopment plan, a complete chemical assay will often not be necessary. Enough information should however be obtained for such materials to indicate their general composition and any special hazards, and to satisfy the local waste disposal authority.

53. At sites where sludge was applied to land or where effluent was treated by the irrigation method, a detailed soil survey will be required. The sample locations should be based on a grid pattern, the grid interval spacing being chosen so as to give adequate numbers of samples for the particular site under investigation. On large sites, typical grid intervals of 50m or 100m may be adequate, while closer spacings (eg 10m or 25m) may be needed for smaller sites or for selected areas of larger sites intended for sensitive end uses such as allotments, gardens etc.

54. When the sampling intervals and locations have been decided, samples should be collected (by means of either trial pits or boreholes) of the immediate surface layers and of the sub-surface materials at varying depths, for example 0-100 or 150mm; 0.5m; 1.0m. etc. The use of trial pits excavated by means of a mechanical digger permits samples to be taken at depths of up to about 3m, and allows visual observations of the sub-surface ground conditions to be made readily, including the nature of the materials present and the levels at which water is encountered. For sampling at greater depths, the use of boreholes is necessary.

55. Comprehensive analysis of all samples collected for examination of a site can be costly and time-consuming, and for some end uses may not be necessary. To avoid unnecessary time and expense, the analyses to be carried out on samples 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. The scope of the sampling programme should also be related to the type of development envisaged and the stage it has reached, for example a pre-purchase survey is likely to be less comprehensive than that needed to provide data on which detailed plans for remedial treatment and subsequent development can be based.

56. In the majority of schemes for redevelopment of sewage works sites, the most sensitive end use will be housing here gardens or allotments are provided, and crops intended for human consumption may be grown. Hazards to construction workers may also need to be considered. The Factory Inspectorate of the Health and Safety Executive should be consulted at an early stage of any proposed construction activity. Thus the principal considerations are likely to be:

i. Human health effects, including the safety of workers on the site during clearance and redevelopment, and the health of future residents.

ii. Phytotoxic effects.

iii. Effects on construction materials.

57. The chemical analyses likely to be required depend on the proposed use of the site, and may include the following: arsenic, boron, cadmium, chromium (trivalent and hexavalent), copper, lead, mercury, nickel, selenium, zinc, pH, chloride, fluoride, sulphide and sulphate. Of these the "total" concentrations of arsenic, cadmium and lead, and the "plant-available"* concentrations of boron, copper, nickel and zinc are of particular importance. It should be noted that although copper, nickel and zinc are the elements usually considered when assessing phtotoxicity many other elements (eg arsenic, cadmium and lead) are also toxic to plants and may need to be considered. The determinations of pH, chloride, sulphide and sulphate should be carried out on both the solid samples and on water extracts from them where appropriate (see for example BRE Digest 250 and Current Paper -/79). Samples of ground water or other liquids encountered should also be collected for analysis. Some assessment of possible hazards due to the presence of pathogens may be necessary, though at present it is not possible to give guidance on scope or methods. The local Environmental Health Officer should be consulted.

58. Whilst the foregoing includes most determinands likely to be required for site assessment in the majority of cases, local knowledge and conditions should be considered as appropriate and the above list modified accordingly, taking into account the proposed use of the site.

Assessment of findings

59. If the site investigation has been carried out according to the above sequence adequate information should have been obtained to assess the degree and general distribution of contamination. If necessary, particular areas of the site can then be investigated in greater detail to define 'clean' areas or regions of excessively high contamination. Consideration can then be given to the remedial measures needed to make the site suitable for the proposed end use.

60. Where the eventual end use of the land is not yet decided it will be more difficult to specify the essential remedial measures. One possibility that may occur is that the site cannot be made suitable for the preferred use at an acceptable cost; consequently it may be necessary to consider alternative uses. It is therefore advisable to retain flexibility in the design of redevelopment schemes until the degree and pattern of contamination at any given site has been established. This should be allowed for in terms of time, site layout and remedial measures.

61. On larger sites where comprehensive development is planned it may be possible to adjust the layout so that the more "sensitive" uses (gardens, allotments, agriculture etc) are located on the least contaminated areas, leaving other uses (such as parking areas,roads,pavements,industrial and commercial buildings) which are more tolerant to the contaminants present,to be accommodated on remaining areas. In this way the hazards can be minimised and the need for extensive remedial treatment reduced.

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* The method of determination should be specified for plant-available concentrations.

V. REMEDIAL MEASURES

62. The available options for dealing with soil contamination can be broadly classified as (i) removal; (ii) treatment, (iii) covering up. The approach to be adopted in any particular case depends on the nature, degree and extent of contamination, and can vary within a given site.

63. The depth of contamination will depend on the characteristics of the sub-soil. On clay soils there may have been little penetration beneath the top surface but on sandy soils contamination may have affected greater depths. When contamination is restricted to a relatively thin layer, complete removal may be economic: some clearance of organic material from the site may in any case by needed before redevelopment can proceed. When contamination is present to considerable depths there may be little advantage in removing materials unless the newly exposed surface is significantly less contaminated than the existing one: in such cases the provision of an adequate depth of cover may be the best solution.

64. If sludge deposits are not significantly contaminated with heavy metals it may be possible to put them to beneficial use, for example as a soil amendment material on the site itself or in land reclamation elsewhere. It may sometimes be possible to use limited quantities in the agricultural or horticultural industries, but advice should be obtained from the Agricultural Development Advisory Service before this method is adopted. The regional water authority may also be able to offer advice or assistance. Sludge is often unlikely to be in a physical form which would permit its use as "soil" without admixture or incorporation into existing soil. It is also unlikely that "dry" sludge will be suitable for stockpiling to any significant extent, since unless water is excluded it may revert to a slurry.

65. If sludge or other deposited wastes are contaminated to a significant degree. it will probably be necessary to arrange for their removal. The local waste disposal authority (see para 44) should be consulted about removal and disposal of such material. If the quantities are small and the development plan permits, it may in some cases be possible to dispose of the material on site, eg by burial. In a few instances special disposal facilities have been created to deal with wastes on sites being redeveloped, but this requires the consent of the appropriate waste disposal authority.
The hazards associated with methane generation and potential combustibility should be borne in mind before any large new deposit is created.

66. The removal of waste materials stored on the site should alleviate long-term problems of smell and odour, and will reduce any hazards caused by pathogenic organisms although there may be some problems whilst work is in progress. Water pollution problems can largely be prevented by taking appropriate precautions during site clearance and reconstruction.

67. Where significant contamination of soil is present, it is often preferable to provide a sufficient depth of cover to enable all services to be installed within the clean material. If however it is necessary to excavate service trenches through contaminated ground, the trenches should be cut oversize and filled with clean material before installation of the services. When this procedure is used, appropriate precautions should be taken to minimise risks of re-contamination caused by any subsequent excavation of the service trenches. The statutory undertakings, particularly the water supply authority, should be consulted about their special requirements, if any.

68. It should be noted that liquid and semi-solid wastes can break out through some covering materials due to the effects of excessive loading through compaction or as the result of disturbance. Rather than allowing such materials to remain on site and covering them over, it may be preferable to remove them during site clearance operations. Appropriate precautions should be taken to reduce odour nuisance and minimise risks of water pollution, also to ensure that any materials removed from the site are disposed of safely.

69. It may sometimes be useful to take action to control the pH of contaminated topsoil or subsoil, by incorporation of lime or by placing a layer of limestone between clean cover materials and underlying contaminated ground.

70. Whatever remedial measures are adopted the aim should be to ensure that they are durable, ie continue to be effective for the required time period, and robust, ie practical and not unduly sensitive to bad workmanship.

VI. REFERENCES

1. K D Heeps and E R Pike: "Reclamation of a disused sewage farm". Proc.Conf. on Reclamation of Contaminated Land, Eastbourne, 1979 (Published by Society of Chemical Industry, London, 1980)

2. A A Wood and A H Ross: "Reclamation of agricultural land used for disposal of sewage and sewage sludge" (Source: as for reference 1).

3. Report of the Working Party on the Disposal of Sewage Sludge to Land. DOE/ NWC Standing Technical Committee Report No 5.

4. The analysis of agricultural materials. Technical Bulletin No 27, Agricultural Development Advisory Service (Ministry of Agriculture, Fisheries and Food), HMSO 1973.

5. Other Notes in this series:

    1. Guidance on the assessment and redevelopment of contaminated land. ICRCL 59/83.

    2. Notes on the redevelopment of landfill sites. ICRCL 17/78.

    3. Notes on the redevelopment of gasworks sites. ICRCL 18/79.

    4. Notes on the redevelopment of scrap yards and similar sites. ICRCL 42/80.

    5. Notes on the fire hazards of contaminated land. ICRCL 61/84.

    6. Asbestos on contaminated sites. ICRCL 64/85.

Copies of the above notes may be obtained from:

Central Directorate on Environmental Protection
Room A3.24
Department of the Environment
Romney House
43 Marsham Street
LONDON
SW1P 3PY
(Tel 01 212 5464)

General Enquiries should be directed to the Secretary of the Interdepartmental Committee Room A342 at the above address (telephone 01-212-6462).

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