

Ceramics, cement and asphalt manufacturing works

Industry Profiles, together with the Contaminated Land Research Report series, are financed under the Department of the Environment's contaminated land research programme.

The purpose of these publications is to provide regulators, developers and other interested parties with authoritative and researched advice on how best to identify, assess and tackle the problems associated with land contamination. The publications cannot address the specific circumstances of each site, since every site is unique. Anyone using the information in a publication must, therefore, make appropriate and specific assessments of any particular site or group of sites. Neither the Department or the contractor it employs can accept liabilities resulting from the use or interpretation of the contents of the publications.

The Department's Contaminated Land Research Report series deals with information needed to assess risks; procedures for categorising and assessing risks; and evaluation and selection of remedial measures.

General guidance on assessing contaminated land and developing remedial solutions which is complementary to the Department's publications is provided by the Construction Industry Research and Information Association (CIRIA).

Acknowledgements

The Department of the Environment is grateful to the members of the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL), and the following individuals and organisations for assistance in the compilation of this profile:

Arup Environmental (Ove Arup and Partners)
Mr D L Barry (WS Atkins Environment)
Mr P A Chave (National Rivers Authority)
Mr C P Hall (British Ceramic Federation)
Dr M R G Taylor (Consultants in Environmental Sciences Limited)

DOE Industry Profile

Ceramics, cement and asphalt manufacturing works

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This profile is based on work by Dames and Moore International and was prepared for publication by the Building Research Establishment.

Preface

DOE Industry Profiles provide developers, local authorities and anyone else interested in contaminated land, with information on the processes, materials and wastes associated with individual industries. They are not definitive studies but they introduce some of the technical considerations that need to be borne in mind at the start of an investigation for possible contamination.

Every site is unique. Investigation of a site should begin with documentary research to establish past uses. Information on the site's history helps to focus a more detailed investigation. This knowledge needs to be supplemented by information on the type of contamination that may be present and where on site it may be found. Profiles give information on the contamination which might be associated with specific industries, factors that affect the likely presence of contamination, the effect of mobility of contaminants and guidance on potential contaminants.

The date when industrial practices first commenced on a site and its location are important clues in establishing the types of operations that may have taken place, so each profile provides a summary of the history of the industry and its likely geographical spread within the United Kingdom.

Profiles should be read with the following reservations in mind:

- individual sites will not necessarily have all of the characteristics described in the profile of that industry;

- practices can vary between sites and change over time;

- as practices change, problems of possible contamination may also change;

- the profile may refer to practices which are no longer followed, and may omit current practices which avoid contamination.

The risks presented by contaminated sites depend on the nature of the contaminants, the targets to which they are a potential threat (such as humans or groundwater) and the routes or pathways by which they reach these targets. The current or proposed use of a site and its environmental setting are crucial in deciding whether treatment is necessary and if so, the methods to be used. Some sites may not need treatment.

The information in profiles may help in carrying out Control of Substances Hazardous to Health (COSHH) assessments for work on contaminated land - see Health and Safety Guidance Note HS(G) 66 *Protection of workers and the general public during the development of contaminated land*, Health and Safety Executive, 1991, and *A guide to safe working practices for contaminated sites*, Construction Industry Research and Information Association, 1995.

Note: the chemical names given to substances in this profile are often not the modern chemical nomenclature, but the names used historically for those substances.

Ceramics, cement and asphalt manufacturing works

1. Background

1.1 Ceramics

The production of the ceramics industry can be divided into three categories:

Structural clay products	These are bricks, pipes and roofing tiles. They are often, but not always, manufactured near to a site where clays are extracted.
Whiteware ceramics	These include tableware, sanitary ware, wall and floor tiles and electrical porcelain. They are almost always produced at locations remote from the raw material.
Refractories and technical/ industrial ceramics	This profile does not deal with these products.

Bricks have been widely used for construction purposes since the Middle Ages. Production processes have changed from small wood-fired kilns to modern, large scale automated electric or gas-fired kilns.

The United Kingdom brickmaking industry is divided into two categories: Fletton and non-Fletton. The location of the Fletton brick industry, dominated by the London Brick Company, has traditionally been influenced by the availability of the Lower Oxford Clay, which is found in a band running across the South Midlands, and is currently worked near Bedford and Peterborough. The manufacture of non-Fletton bricks is much more widespread, as a range of clays are used.

Josiah Wedgwood started his first pottery factory at Burslem, Staffordshire, in 1759. The Staffordshire Potteries soon became the centre of manufacture in the United Kingdom, eclipsing existing places of manufacture like Chelsea and Derby. The firm of Wedgwood introduced mass production techniques in the early 19th Century and these were later adopted throughout the industry. Most production of whiteware ceramics continues to take place in the Stoke-on-Trent area of Staffordshire.

In the 19th Century the use of ceramics increased. Sanitary ware became very important after the first practicable water closet was patented in 1778. As electric lighting became common, the demand for porcelain insulators grew. The chemical industry became dependant on ceramic containers and containers lined with ceramic materials.

During and after the Second World War, the application of ceramics in the field of electronics grew, mainly for the production of transducers, resistors and semi-conductors; high alumina ceramics have been used in many mechanical and electrical components. The nuclear industry uses ceramics in the production of moderators and controls in nuclear reactors.

1.2 Cementitious materials

Cement is produced by the reaction of crushed and ground calcareous rocks (limestone or chalk) and argillaceous rocks (clay or shale) at high temperatures. The resulting clinker is ground with various additives to impart different properties to the products.

The Greeks and Romans first made cements from lime (calcium oxide), volcanic ash and water approximately 2000 years ago; over time the use of cements in construction work spread throughout Europe. In 1824 Portland cement was patented by the British engineer Joseph Aspdin. This was a new type of cement which was relatively stronger and more water resistant than its predecessors. Today, cements can be manufactured with a variety of physical and chemical properties, for example increased sulphate or water resistance, by changing the mix of raw materials and including additives.

The cement industry of the 19th Century developed around the rivers Thames and Medway. Later, the industry spread to the limestone areas of Derbyshire, Staffordshire, East Lothian and County Durham. Currently, concrete is the most widely used construction material and the manufacture of cementitious materials has become widespread.

1.3 Bitumen and asphalt

Bitumen is a thick, dark material, currently obtained from oil distillation (see the profile on oil refineries, Section 4). The term asphalt was originally applied to the natural equivalent of bitumen, formed where crude oil had seeped to the surface, evaporated and oxidised, leaving a thick, tar-like deposit. Now that natural deposits of asphalt are largely exhausted, the term is generally applied to the material manufactured from bitumen and ground mineral fillers. In 1847, James Young was granted British patents for his process of oil distillation from bituminous shale and common coal.

The main application of asphalt is in road surfacing, where it is commonly mixed with granular aggregates for use as a surfacing. Macadam developed an asphalt-based material for hard surfacing roads, known as tarmacadam, which was adopted from the mid-19th Century.

Asphalt is also used for roofing, coatings, floor tiling, soundproofing and waterproofing. Bitumen-based floor coverings made from asphalts mixed with synthetic resins, asbestos fibres, pigments or mineral fillers are non-porous, non-flammable, resistant to fungal attack, mild acids, oil and grease and are relatively low in cost (for relevant profile, see Section 4).

Other industrial uses include the manufacture of batteries and paints, as a containment medium for radioactive waste disposal, pipeline and underground cable coatings, hot-dip coatings and corrosion protection coatings.

Works manufacturing asphalt and other bitumen-based products are located in the main industrial areas of the country such as Hull, the Midlands and Teesside.

2. Production processes

2.1 Raw materials delivery, storage and handling

The extractive industries (quarrying and mining) provide many of the raw materials, including sandstone, limestone, clay and shale. They are delivered to the processing works by either quarry conveyor belt systems (where the works is adjacent to the extraction site for the main raw material), road or rail. In the past, inland and coastal waterways were used for delivery.

Bitumen is normally delivered as a viscous liquid, usually by heated road tankers or railway tankers. Transfer of bitumen to storage tanks is by pipe transfer. Trace heating is usually required to ensure that the bitumen remains sufficiently mobile to be pumped.

Other raw materials, for example metal oxides and additives, may be delivered in 25 kg bags or discharged as bulk powder to storage silos.

Raw materials, additives and fuels are stored as follows:

- raw quarry products in hoppers or covered piles
- slurries in tanks
- gypsum in hoppers and silos
- metal oxides in 25 kg bags
- additives and plasticisers in 200 litre drums or tanks
- bitumen in trace-heated bulk storage tanks
- coal in hoppers and silos
- other kiln fuels, for example tyres, stored on the ground, and industrial waste solvents in tanks.

After drying, crushing and milling of the raw materials, the resultant powders are usually stored in silos. Transfer of these powders to and from silos is often by air fluidisation, but may be by open or screw conveyors. Other raw materials, including additives in drums and bags, are transported by fork-lift trucks.

2.2 Ceramics manufacture

2.2.1 Structural clay products, including bricks

These are manufactured from clays or shales which mainly consist of finely crystalline hydrated aluminosilicates. Another important component is quartz (silica). The most common clay minerals are kaolinite, illite and smectite.

The clay is crushed, ground and blended with colouring agents and other material to produce a claybody ready for shaping and then firing.

Bricks are shaped by one of four processes: extrusion, semi-dry pressing, stiff plastic shaping or moulding. The shaped bricks undergo a drying process to dewater the clay and prevent the brick from disintegrating during the next stage, firing in a kiln.

The properties of bricks are dependent on the type of raw material used, the addition of other materials during preparation of the clay and the final firing temperature and time.

2.2.2 *Whiteware*

China clay used in the manufacture of whiteware ceramics is washed and purified (refined). The kaolinite is separated from coarser impurities by gravity. Ball clay (reworked kaolinite) is not usually refined except in the production of certain sanitary wares.

Small quantities of other minerals, metals and oxides are added to the ground mix to create products of different colours and properties. Colloidal properties are controlled by the addition of inorganic compounds such as sodium sulphate and alum.

The preparation of the ceramic whiteware body, which contains china clay, ball clay, quartz and a feldspathic flux, is as follows. A clay slip or suspension is produced by mechanically mixing the ground material with water; particles of unwanted size are removed from the mix by screening and excess water is removed by filtration.

The mix is then put into a drying unit which may be a vacuum dryer, a tunnel dryer or a filter press. Alternatively, drying may be achieved by airing the material outdoors.

The required shape is achieved by plastic forming (now superseded), slip casting or pressing. Slip casting is carried out under controlled pH conditions.

The formed ware may be given a glaze or enamel coating. In the past, these may have been formulated on site but today are generally provided by specialist manufacturers.

The formed ware is kiln-dried. The temperature and length of firing is dependent on the amounts of refractory materials and fluxing oxides in the mix.

Historically, ceramics were fired in wood, charcoal or coal-fired intermittent kilns. Modern kilns are continuous tunnel kilns fired by gas, oil or electricity. Other sources of heat, for example induction or arc heating, may be used. After firing, the products are cooled prior to packaging and storage or dispatch.

2.3 **Cementitious materials manufacture**

The various cementitious materials include Portland cement, pozzolan cement, sulphate-resistant cement, slag cements, high alumina cement, gypsum, lime and plaster.

The uses of cement are as a grout, cement mortar, render and concrete. Cement mortar, used to bed bricks or as render, is produced by mixing cement with builder's sand and lime and sometimes an air entraining agent (for example a plasticiser), which improves frost resistance and workability. The strength of the mortar depends on the proportions of cement to sand and lime, and the grade of sand used in the mix.

Concrete is formed by mixing cement with aggregate, gravel or crushed stone. The strength of concrete is dependent on the type of cement, mix proportions, the water/cement ratio and the properties of the aggregate.

2.3.1 Cement

Cement manufacturing processes can be wet (ground wet and fed to the kiln in a slurry), semi-dry (ground dry and moistened before feeding to the kiln) or dry (ground dry and added as a dry powder). The dry processes are more recent developments which consume less energy. Cement is highly alkaline, having a pH of 12-13. Cement powder is stored and distributed in either bulk or bag form.

Cement is derived from mixing limestone/chalk and clay or shale, together with other minor materials which impart different properties to the resulting product. There are four stages in the manufacture of cement.

Crushing and grinding the raw materials.

Blending the materials in the correct proportions.

Burning the prepared mix in a kiln to produce cement clinker. In the past, bottle or chamber, later continuous, shaft kilns were used; modern works use rotary kilns, fired by coal, oil or gas.

Grinding the cement clinker together with about 5% gypsum/anhydrite in a ball mill to produce a fine powder; the gypsum is used to control the setting time of the cement.

The constituents of different cements are as follows:

Portland cements

Portland cement comprises approximately 60-67% lime, 19-25% silica, and 3-8% alumina, with varying small amounts of iron oxide, sulphur trioxide, magnesia, titanium oxide and manganese oxide.

Modified Portland cements include:

Sulphate resistant	These contain less than 3% tricalcium aluminate.
Ultra-high early strength	Extra gypsum is added to the mix.
White	Obtained by careful selection of the raw materials.
Coloured	5-10% pigment is added to the mix.
Air entrained	A plasticiser is added to improve frost resistance and workability.
Waterproofing	Small amounts of calcium and aluminium compounds are added to the mix in the final grinding stage.

High alumina cement

A mixture of bauxite and lime containing the following:

35-40% lime
40-50% alumina
up to 25% iron oxide
no more than 5% silica.

Slag cements

Comprise a mixture of Portland cement and slag. There are three main types:

Portland blast furnace slag cement	A mixture of Portland cement and 50-90% blast furnace slag.
Supersulphated blast furnace slag	A mixture of blast furnace slag, calcium sulphate and a small amount of Portland cement.
Portland pulverised fuel ash cement	A mixture of Portland cement and pulverised fuel ash (PFA).

Pozzolan cements

Portland cement mixed with natural pozzolanic material, for example ground pumice.

2.3.2 Plaster and plaster products

Gypsum (hydrated calcium sulphate) is the major starting material in the production of plaster products. Plaster is produced by first grinding the gypsum and placing it in large calciners or kilns. The temperature is raised to 120-150°C to make 'first kettle plaster' (plaster of Paris). This may be mixed with various materials, for example sand, wood pulp, hair/fibre and vermiculite/perlite, to modify its properties for specific uses.

Plasterboard is produced by mixing plaster with water to produce a slurry which is then encased in paper liners. A continuous plasterboard sandwich is produced which is cut to the right length and passed to a kiln for removal of excess water.

Keene's cement is produced by the complete dehydration of gypsum at 750°C and the addition of alum after grinding.

2.3.3 Lime

Lime is produced by burning crushed, high purity limestone/chalk (96-98% calcium carbonate) in kilns, at temperatures of between 800°C and 1500°C. At these temperatures, carbon dioxide gas is liberated and calcium oxide is produced. The lime is cooled, stored and used as the burnt lime (quick lime), or mixed with water and used as the hydrated lime (slaked lime).

2.4 Asphalt manufacture

Bitumen contains a mixture of organic compounds including long-chain aliphatics, aromatics, aldehydes, ketones, phenols, polycyclic aromatic hydrocarbons (PAHs) and amines. To manufacture asphalt, bitumen is heated to around 150°C and is mixed with a flux oil (kerosene). Water and other chemical additives may be added, including:

- hydrochloric acid
- emulsifiers, including blends of amines, creosote oil and solvents, for example petroleum extracts
- calcium carbonate
- quaternary ammonium compounds.

Granular material is often added to asphalt for road construction. After mixing the various materials, the emulsions are pumped to storage tanks and then loaded into drums for distribution.

2.5 Ancillary activities

Works usually have workshops and maintenance areas where plant machinery etc are serviced.

Sites may have on-site petrol, diesel, gas and oil storage for associated quarry plant, delivery vehicles and on-site heating.

Normally, mineral processing plants are heavy users of electricity, especially for the crushers, ball mills, conveyor systems and electrostatic precipitators.

3. Contamination

The contaminants on a site will largely depend on the history of the site and on the range of materials used there. Potential contaminants are listed in the Annex and the probable locations on site of the main groups of contaminants are shown in Table 1. It is most unlikely that any one site will contain all of the contaminants listed. It is recommended that an appropriate site investigation is carried out to determine the exact nature of the contamination associated with individual sites.

Many of the raw materials used in these industries are major constituents of rock and may not be considered to be potential contaminants. The final products of the respective industries are essentially of low contaminative potential. For example, ceramic and bitumen/asphalt products are effectively inert in terms of leachability, while cements will readily hydrate when exposed to water to produce an inert solid.

3.1 Factors affecting contamination

3.1.1 *Ceramic and cement industries*

The most relevant potential contamination in these industries will probably relate to kiln and other fuels, workshops and waste disposal facilities.

Contamination could arise through leaks and spillages of oils and lubricants around storage areas where bunding might not have been provided. Underground tanks and pipelines could be a source of ground contamination since leaks may have occurred without being noticed during normal inspection procedures. Loading and transfer operations may have resulted in leakages or spillages. Works which use high calorific wastes from other industries as a kiln fuel source (eg solvents) may be contaminated by leakage or spillage during transfer and storage of these materials.

Brick, kiln ash and workshop wastes may have been disposed of to on-site landfill and dumps.

Leakage or spillage of metal oxides, plasticisers and other additives, glazing and enamelling materials may have caused contamination in storage, transfer or production areas, but the quantities of these are likely to be low.

Works may have used asbestos materials as pipe insulation, cladding or roofing . These may have been replaced and disposed of on site.

Some works may have had electrical transformers or capacitors in which polychlorinated biphenyls (PCBs) were used as components of dielectric oils. Any spillages could have resulted in ground contamination.

3.1.2 Asphalt works

The most significant source of potential soil contamination is associated with asphalt coating operations. Bitumens, tars and asphalts comprise complex mixtures of semi-volatile aromatic compounds, including polycyclic aromatic hydrocarbons (PAHs). Phenols also tend to be associated with tarry materials. These compounds have the potential to give rise to persistent soil contamination.

Other additives, such as hydrochloric acid, amines and creosote oil, may also cause contamination, as can solvents used in the blend of bitumen emulsions. The areas which may be contaminated include tanker off-loading stands (for oil and bitumen), underground storage and associated pipework and the mixing and batching plant.

Drainage systems, particularly soakaways, could be a further location of contamination, especially in areas where surface spillages may have occurred.

It is possible that plant buildings and infrastructure were insulated with asbestos lagging, or asbestos cement sheeting was used in roofing or cladding. Waste asbestos material may be found in discrete dumps on the site where plant has been dismantled or asbestos may still be associated with existing buildings and plant.

There may be contamination by PCBs during decommissioning or refilling of transformers or capacitors which used these materials.

3.2 Migration and persistence of contaminants

Except where buried in an on-site waste disposal facility, contamination by compounds which are not organic is likely to be near the surface. Since most process wastes are in dust form, the effects of wind may be significant in terms of migration of potential contamination about the site.

Organic compounds associated with the bitumen/asphalt industries may be a source of ground contamination which could migrate. Although the aqueous solubility of PAHs and some of the other organic compounds is relatively low, their dissolved concentrations may still exceed water quality standards. In addition, these organic compounds are soluble in many organic solvents, some of which may also be present if used as emulsifiers in the manufacturing process. This could result in the migration of relatively insoluble compounds. Isopropyl alcohol, a component of some of the emulsifiers used in bitumen production, has significant water solubility and will readily migrate through the soil to the groundwater. Phenolic compounds are very mobile, particularly phenol, and can migrate considerable distances. Phenol can permeate water supply pipes of polymeric materials such as polyvinyl chloride (PVC).

Free phase products, such as various petroleum hydrocarbon fractions, also tend to migrate to the water table. Generally, these compounds are less dense than water and float on the surface of the water table.

Many of the higher boiling point hydrocarbon fractions, such as asphaltenes, waxes and resins, are very immobile and are likely to be confined to the surface layers of the soil.

The transport and fate of the organic compounds within the sub-surface environment is dependent upon physical, chemical and biological factors. The higher the organic matter and clay content within the soil, the greater the degree of adsorption of the organics which will reduce the degree of contaminant migration. Therefore, the greatest degree of migration will occur in coarse-grained sands and gravels with little organic matter.

Aromatic compounds which become adsorbed on to clay or organic matter will provide on-going sources of water pollution long after the source has been removed, by continuing to desorb into the soil-water.

The movement of metals through the soil is significantly retarded by the presence of clay minerals and organic matter. The solubility of some metals (for example copper, zinc and lead) may increase under acidic conditions. In other cases the relationship is more complex. For example, trivalent chromium is more soluble under acidic conditions, whereas the solubility of hexavalent chromium is increased under both acidic and alkaline conditions and arsenic may become more soluble at higher pHs.

Biodegradation processes in soils can be influenced by a number of factors, namely moisture content, oxygen concentration and pH, acting separately or in combination. For example, low moisture content reduces microbiological activity, while high moisture content can reduce oxygen penetration and possibly lead to anaerobic soil conditions. Such conditions enhance the biodegradation of some materials, for example chlorinated compounds, while aerobic conditions are needed to biodegrade many oils. Also, low pHs tend to reduce the bacterial population and encourage fungal activity; at pHs lower than 5, microbiological activity is much reduced. The presence of heavy metals also inhibits micro-organisms. As a result of these factors, at high concentrations in soil, even potentially biodegradable compounds, such as petroleum hydrocarbons, may not biodegrade readily.

PCBs and some of the halogenated organic compounds are non-biodegradable. They are insoluble in water but are fat-soluble and have a propensity to accumulate in food chains.

Asbestos is neither soluble nor biodegradable. Wind dispersal may be method of distribution around the site where there is surface contamination by asbestos.

4. Sources of further information

4.1 Organisations

For information concerning ceramics, cement and asphalt manufacturing works in the United Kingdom the following organisations should be consulted:

British Aggregate Construction Materials Industries (BACMI)
156 Buckingham Palace Road
London
SW1W 9TR

British Ball Clay Producers Federation
Park House
Courtenay Park
Newton Abbot
Devon
TQ12 4PS

British Cement Association
Wexham Springs
Slough
Berkshire
SL3 6PL

British Ceramic Confederation, The British Ceramic Manufacturers Federation
and The National Federation of Clay Industries, all at
Federation House
Stoke-on-Trent
ST4 2SA

British Ceramic Research Limited
Queens Road
Penkhull
Stoke-on-Trent
ST4 7LQ

Brick Development Association
Woodside House
Winkfield
Windsor
Berkshire
SL4 2DX

China Clay Association
John Keays House
St. Austell
Cornwall
PL25 4DJ

Minerals Industry Research Organisation
Expert House
Sandford Street
Lichfield
Staffordshire
WS13 6QA

Refined Bitumen Association Limited
6 Birchdale Close
West Byfleet
Weybridge
Surrey
KT14 6QA

4.2 Sources of information concerning the activities described in this profile

Austin G T. *Shreve's chemical process industries*. Fifth Edition. McGraw-Hill, London, 1984.

Dragun J. *The soil chemistry of hazardous materials*. Hazardous Materials Control Research Institute, Silver Spring MD, USA, 1988.

Perry R H and Chilton C H. *Chemical engineers handbook*. Fifth Edition. McGraw-Hill, London, 1973.

Information on researching the history of sites may be found in:

Department of the Environment. *Documentary research on industrial sites*. DOE, 1994.

4.3 Related DOE Industry Profiles

Chemical works: linoleum, vinyl and bitumen-based floor covering manufacturing works
Gas works, coke works and other coal carbonisation plants
Oil refineries and bulk storage of crude oil and petroleum products

4.4 Health, safety and environmental risks

The Notes issued by the Chief Inspector of Her Majesty's Inspectorate of Pollution (HMIP) provide guidance for the processes prescribed for integrated pollution control in Regulations made under the Environmental Protection Act 1990. Of particular relevance are:

Her Majesty's Inspectorate of Pollution. *Cement manufacture and associated processes*. Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 3/1. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Lime manufacture and associated processes*. Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 3/2. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Ceramic processes.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 3/6. London, HMSO, 1992.

The Control of Substances Hazardous to Health (COSHH) Regulations 1994 and the Management of Health and Safety at Work Regulations 1992 are available from HMSO. Information on relevant health and safety legislation and approved codes of practice published by HSE publications are available from Health and Safety Executive Books, PO Box 1999, Sudbury, Suffolk, CO10 6FS (telephone 01787 881165), as well as HMSO and other retailers.

Information on the health, safety and environmental hazards associated with individual contaminants mentioned in this profile may be obtained from the following sources:

Howard P H. *Handbook of environment fate and exposure data for organic chemicals.* Vols I and II. USA, Lewis Publishers, 1990.

Sax N and Lewis R. *Hazardous chemicals desk reference.* New York, Van Nostrand Reinhold Company, 1987.

Verschueren K. *Handbook of environmental data on organic chemicals.* Second Edition. New York, Van Nostrand Reinhold Company, 1983.

4.5 Waste disposal and remediation options

Useful information may be obtained from the Department of the Environment series of Waste Management Papers, which contain details of the nature of industrial waste arisings, their treatment and disposal. A current list of titles in this series is available from HMSO Publications Centre, PO Box 276, London, SW8 5DT.

Publications containing information on the treatment options available for the remediation of contaminated land sites, prepared with the support of the Department of the Environment's Research Programme, can be obtained from National Environmental Technology Centre Library, F6, Culham, Abingdon, Oxfordshire, OX14 3DB.

A full list of current titles of Government publications on all aspects of contaminated land can be obtained from CLL Division, Room A323, Department of the Environment, Romney House, 43 Marsham Street, London, SW1P 3PY.

Advice on the assessment and remediation of contaminated land is contained in guidance published by the Construction Industry Research and Information Association (CIRIA), 6 Storey's Gate, Westminster, London, SW1P 3AU.

Annex Potential contaminants

The chemical compounds and other materials listed below generally reflect those associated with the industry and which have the potential to contaminate the ground. The list is not exhaustive; neither does it imply that all these chemicals might be present nor that they have caused contamination.

Ceramics

Transition metal compounds	cadmium chromium copper lead mercury nickel zinc
Rare earth metal oxides (specialist ceramics only)	cerium europium
Refractory bricks	may contain hexavalent chromium
Other inorganic compounds	alum (hydrated aluminium potassium sulphate) aluminium sulphate Group V compounds eg arsenic compounds calcium carbonate potassium salts sodium carbonate sodium silicate sodium sulphate

Cement

Inorganic compounds	calcium oxide calcium hydroxide calcium carbonate calcium chloride hydrated calcium sulphate (gypsum) manganese dioxide titanium dioxide
Blast furnace slag	
Pulverised fuel ash (PFA)	constituents of PFA include: calcium chloride calcium hydroxide calcium oxide silica sulphates eg magnesium sulphate
Air entraining agents	sulphonated hydrocarbons
Plasticisers	lignosulphonic or hydrated carboxylic acid

Cement dusts

Flue gas dusts

Asphalt

Bitumen	long-chain aliphatics aldehydes ketones phenols polycyclic aromatic hydrocarbons (PAHs) amines
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Asphalt	bitumen kerosene
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Other organic compounds	amine blends eg propylene diamine derivatives ethylene diamine ethanolamine creosote oil kerosene solvents eg petroleum extracts isopropyl alcohol tar eg phenol
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Acids	hydrochloric
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Quaternary ammonium compounds

General

Fuels	fuel oils coal industrial waste solvents
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Other oils	lubricating oils
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Ash

Polychlorinated biphenyls (PCBs)

Asbestos

Table 1 Main groups of contaminants and their probable locations

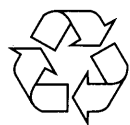
Ceramics, cement and asphalt manufacturing works

Main groups of contaminants	Location								
	Raw materials delivery/ storage/ transfer	Process plant			Product storage	Drainage system including soakaways	Fuel storage/ power generation	Waste disposal/ storage areas	Electricity substations/ transformer areas
		Ceramics	Cement works	Bitumen/ asphalt works					
Metals, metalloids and their compounds									
Inorganic compounds									
Acids/bases									
Asbestos		1	1	1					
Solvents ²									
Phenols/polycyclic aromatic hydrocarbons (PAHs)									
Polychlorinated biphenyls (PCBs)									
Hydrocarbon (fuels)									

¹ Pipe insulation or building cladding

² Waste industrial solvents may be used as fuels in some kilns

Shaded boxes indicate areas where contamination is most likely to occur.



Recycled paper

DOE Industry Profiles

Airports
Animal and animal products processing works
Asbestos manufacturing works
Ceramics, cement and asphalt manufacturing works
Chemical works: coatings (paints and printing inks) manufacturing works
Chemical works: cosmetics and toiletries manufacturing works
Chemical works: disinfectants manufacturing works
Chemical works: explosives, propellants and pyrotechnics manufacturing works
Chemical works: fertiliser manufacturing works
Chemical works: fine chemicals manufacturing works
Chemical works: inorganic chemicals manufacturing works
Chemical works: linoleum, vinyl and bitumen-based floor covering manufacturing works
Chemical works: mastics, sealants, adhesives and roofing felt manufacturing works
Chemical works: organic chemicals manufacturing works
Chemical works: pesticides manufacturing works
Chemical works: pharmaceuticals manufacturing works
Chemical works: rubber processing works (including works manufacturing tyres or other rubber products)
Chemical works: soap and detergent manufacturing works
Dockyards and dockland
Engineering works: aircraft manufacturing works
Engineering works: electrical and electronic equipment manufacturing works (including works manufacturing equipment containing PCBs)
Engineering works: mechanical engineering and ordnance works
Engineering works: railway engineering works
Engineering works: shipbuilding, repair and shipbreaking (including naval shipyards)
Engineering works: vehicle manufacturing works
Gas works, coke works and other coal carbonisation plants
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works
Metal manufacturing, refining and finishing works: iron and steelworks
Metal manufacturing, refining and finishing works: lead works
Metal manufacturing, refining and finishing works: non-ferrous metal works (excluding lead works)
Metal manufacturing, refining and finishing works: precious metal recovery works
Oil refineries and bulk storage of crude oil and petroleum products
Power stations (excluding nuclear power stations)
Pulp and paper manufacturing works
Railway land
Road vehicle fuelling, service and repair: garages and filling stations
Road vehicle fuelling, service and repair: transport and haulage centres
Sewage works and sewage farms
Textile works and dye works
Timber products manufacturing works
Timber treatment works
Waste recycling, treatment and disposal sites: drum and tank cleaning and recycling plants
Waste recycling, treatment and disposal sites: hazardous waste treatment plants
Waste recycling, treatment and disposal sites: landfills and other waste treatment or waste disposal sites
Waste recycling, treatment and disposal sites: metal recycling sites
Waste recycling, treatment and disposal sites: solvent recovery works
Profile of miscellaneous industries incorporating:
Charcoal works
Dry-cleaners
Fibreglass and fibreglass resins manufacturing works
Glass manufacturing works
Photographic processing industry
Printing and bookbinding works

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