

# Chemical works

*linoleum, vinyl and bitumen-based floor  
covering 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).

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# **DOE Industry Profile**

## **Chemical works: linoleum, vinyl and bitumen-based floor covering 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.

# **Chemical works: linoleum, vinyl and bitumen-based floor covering manufacturing works**

## **1. Background**

The main products covered in this profile are linoleum and polyvinyl chloride (PVC)-based floor coverings, commonly known as 'vinyls'; bitumen-based floor coverings are also discussed. The profile does not consider the manufacture of plastics from raw materials, or the production of plastic mats, carpet protectors and similar rubber-based products, which are covered in other profiles (see Section 4).

Linoleum was first made in the 1860s and grew in popularity as both a domestic and a commercial flooring. Linoleum was initially produced by a number of manufacturers in the United Kingdom, both for the home market and for export. The attractions of linoleum were its low cost, good wearing properties and chemical and heat resistance.

'Vinyls' were first produced on a large scale after the Second World War when significant amounts of PVC became available. The first vinyls were produced using similar equipment and materials to linoleum but, as the industry developed, new mixes and ingredients were used. Vinyl grew in popularity because of its low cost, the bright colours and patterns that could be produced, and its durability.

From the 1950s onwards, the sales and production of linoleum began to fall as a result of increasing competition from vinyls and carpets. Manufacturers of linoleum either switched to vinyl manufacture, merged or ceased business. In recent years, there has been a renewed interest in linoleum because it is produced mainly from natural, renewable resources and because product quality and design have been improved. However, only one producer of linoleum was thought to be operating in the United Kingdom in 1995.

Bitumen-based flooring products first appeared on the market in 1910 and were produced in the United Kingdom until recently. They were developed as hard wearing, cheaper alternatives to linoleum.

The number of manufacturing works, based on Census of Production data, increased from about 30 in 1924 (mainly linoleum works) to 65 in 1990 (almost exclusively vinyl floor covering works). The number of establishments fluctuated considerably throughout this period. Works have varied, and continue to vary, a great deal in size.

The linoleum manufacturing industry developed in areas with good port access, enabling the import of raw materials and the export of finished products. Kirkcaldy in Scotland was well positioned due to its coastal location but also because flax and jute, the important raw materials, were processed locally. Other important locations were Teesside, Lancaster and Staines.

The production of vinyls does not rely heavily on imported materials, so firms either remained on their existing sites, if previously involved in linoleum manufacture, developed in new areas close to raw materials (ie areas where the chemical

industry was located) or close to their domestic markets. Today, the major areas for vinyl production are Kirkcaldy, Teesside, Manchester, the South East and Midlands.

## **2. Processes**

### **2.1 Raw materials**

#### *2.1.1 Linoleum*

The following raw materials are used in the manufacture of linoleum:

##### *Linseed oil*

A triglyceride oil obtained from the seeds of the flax plant which may be delivered in a refined or unrefined state.

##### *Tall oil*

This is derived from pine trees and is added to the linseed oil.

##### *Driers*

Added in small quantities to the linseed oil to aid oxidation. Typical driers are based on lead, magnesium and cobalt.

##### *Ground cork dust filler*

Produced from the bark of the cork oak tree. The cork is ground and sieved. Waste cork is often used.

##### *Woodflour filler*

Softwood sawdust mainly from sawmills. The sawdust is milled and screened to give a standardised product.

##### *Mineral fillers*

Used to add bulk and strength to the product. The most commonly used are limestone or calcium carbonate in the amorphous form known as whiting. Coarser limestones are sometimes used. There are a number of other special-purpose fillers which can be used to impart different properties, for example barytes (higher density), asbestos and antimony oxide (fire resistance).

##### *Pigments*

Historically, these were inorganic, for example lead, iron, cadmium-based, with some organics such as phthalocyanines and benzidines. The industry is at present changing to organic pigments.

##### *Resin*

Several resins are normally added to the oxidised linseed oil gel to modify properties such as hardness, tack and chemical resistance. The most common are wood rosin or gum rosin and other natural resins. Synthetic or modified resins may also be used or have been used in the past, for example melanised resins, glycerol or penta erythritol esterified rosins, modified phenolics or 100% phenolic terpol resins.

##### *Backing cloth*

This is usually a cotton/jute fabric for roll products or glass fibre/polyester mix for tile products.



### *Polishes and finishes*

A number of naturally-based and artificial finishes are available which may contain solvents such as toluene and methyl ethyl ketone (MEK).

## *2.1.2 Vinyl floor coverings*

The following raw materials are used in the manufacture of vinyl floor coverings:

### *Vinyl resin*

The vinyl resin, a PVC homopolymer, is manufactured by the plastics industry and supplied as a powder.

### *Vinyl co-polymer*

A mixed polymer, typically vinyl chloride-vinyl acetate co-polymer. These modify the properties of the vinyl resin to those required in the finished product. They may also be added to printing inks.

### *Plasticisers*

The main plasticisers used are phthalates. Other plasticisers are used or may have been used to impart different characteristics to the final product, for example phosphates (flame retarder); adipates and azelates sebacates (low temperature applications); chlorinated paraffin (secondary plasticiser or extender to reduce costs by dilution and a flame retarder); polyester and polymeric plasticiser (resists plasticiser migration); epoxidised soybean oil (extender).

### *Fillers*

These are used to give bulk, strength and good wear properties. The most common filler is limestone. Other fillers that may be used to give special properties, normally used with limestone, are quartz, aluminium oxide and graphite. The use of asbestos as a filler ceased in the late 1970s.

### *Pigments/inks*

Both organic and inorganic pigments are used. Pigments are used both for bulk colouring and surface printing (when mixed with inks). The pigments used are typical of those used in the paint and pigments industry. Inks are normally solvent-based containing, for example toluene, isopropyl acetate, and MEK. However, there is a general move towards the use of water-based inks.

### *Stabilisers*

Used to help prevent heat degradation of the polymer during processing. Normal stabilisers are lead salts, organo-tin compounds or mixed metal compounds (barium-cadmium/barium-zinc/calcium-zinc).

### *Processing aids*

External processing aids are used to ease the flow of the individual mixture units, and internal aids are used to loosen the mix. Examples are lead stearate, stearic acid, sodium sulphonates. Solvents such as toluene may also be added to loosen the mix.

### *Impact modifiers*

Rubber compounds may be added to improve impact resistance.

#### *Blowing agents*

Used to produce the domestic cushion floor type vinyls. They are normally heat activated, ie the agent is added to the mix and on heating produces a gas. Usual blowing agents are azo compounds, such as azo dicarbonamide, or sodium bicarbonate. A catalyst such as zinc oxide may also be used. A foam inhibitor, for example malates, is often used to inhibit foaming in certain areas to produce a relief pattern.

#### *Flame retardants and smoke suppressants*

Used to reduce flammability and smoke production. A phosphate ester plasticiser is usually employed together with additives such as antimony oxide, alumina trihydrate, zinc borate or chlorinated alkanes.

#### *Biocides*

These are typically arsenic-based, and may be added to protect against bacterial attack.

#### *Backing cloth*

Backing/support cloth is normally a glass fibre-based mat (the binder may contain formaldehyde).

#### *Finishes*

These commonly include surface polishes and non-slip finishes. Protective coatings (complex plastic compounds) are used to protect against stains and damage.

### *2.1.3 Bitumen-based floorings*

The following raw materials were used in the manufacture of bitumen-based floor coverings:

#### *Bitumen*

Various grades of bitumen were used. Production of bitumen is covered in the profile on ceramics, cement and asphalt manufacturing works (see Section 4).

#### *Backing cloth*

This would normally have been a felt made from rags and waste paper.

#### *Sealing paint*

A number of sealing layers were normally applied to prevent interaction of oil-based paints with the bitumen, for example acrylic emulsions, linseed oil-based coatings, and sodium silicate-based coatings.

#### *Printing inks*

The pigments and inks used were generally linseed oil-based. The pigments used were similar to those used in vinyl and linoleum manufacture.

#### *Protective coating*

A protective coating of, for example plasticised PVC, was normally applied to protect the printed surface.

## 2.2 Transport and handling

The raw materials are usually delivered by road in tankers, drums or in bags.

Solids that arrive in bags or drums are stored in their containers or transferred to bulk silos. Drums and bags are transported on pallets. Transfer of bulk solids around the site is by pneumatic or mechanical conveyors.

Liquids are transferred in drums, pumped or gravity fed in pipelines from bulk storage tanks.

In general, bulk storage vessels are sited on impervious floors with bund walls, but this may not always have been the case in the past. Storage areas may be found within the manufacturing unit and also in adjacent designated storage areas.

## 2.3 Production processes

### 2.3.1 *Linoleum*

The first stage of linoleum manufacture is the processing of the linseed oil. If unrefined oil is used, the oil must be matured by leaving it to stand in large vessels for several weeks. During the maturing process water and 'foots' (mucilaginous phosphatides) settle out and are drained from the vessel.

The refined linseed oil then goes through a one- or two-stage oxidation process.

In the one stage process, refined linseed oil is mixed with wood resin in approximately a 3:1 ratio, followed by the addition of driers. Air is blown through the mixture in an oxidation vessel called a smacker and an exothermic oxidation reaction occurs. Temperature is maintained by water-cooling coils in the vessel. The product, a viscous polymerised gel or cement, is then discharged for further processing.

The first stage of the two stage process begins with mixing the refined linseed oil with small quantities of driers and charging the mixture to a primary oxidation vessel. The oil is vigorously stirred in the vessel while air is blown through it to produce an exothermic reaction. The temperature of the vessel is maintained at about 60-80°C by water-cooling. The product, a soft gel, is discharged to a smacker for the second stage of the process. Wood resin is added, with small quantities of other resins, to impart particular properties to the final product. The mixture is heated in a smacker to about 80°C, causing vigorous depolymerisation, followed by repolymerisation and an increase in viscosity.

After the oxidation process, the gel is mixed with other ingredients in a mixer, usually of the Banbury or German type, to produce a finely granulated homogenous mix. The ingredients added to the mixture depend on the properties that are required of the finished product. For example, mineral fillers add bulk and strength to the product.

The granulated mix is formed into a flat sheet. The most common method is by calendering, as this is a more efficient and cost effective method; heated flat presses are also used. The calender is made up of two large cylinders which can be heated or cooled as required.

Two calendering methods are available, depending on the product required.

#### *The direct method*

The canvas backing sheet is fed directly to the calender and pressed onto the linoleum sheet.

#### *The indirect method*

This is used to produce the patterned types of linoleum. A number of granulated mixes of different colours (normally 3 to 5) are blended together. After blending, the colours are passed to the calender where an unsupported linoleum sheet is formed. The Jaspe (grained) pattern is produced by the shear action of the rollers dragging out individual granules. The Moire (feathered) pattern is produced by blocking off areas of the rollers, causing lateral shearing. The marble effect is produced using two calenders. Ground trimmings and linoleum wastes with small amounts of cement and plasticiser are calendered on to a backing sheet. The backing sheet is then fed, with the unsupported sheet, to a large heated rotary press which laminates the two together. Various thicknesses (1.5 mm to 4.5 mm) are produced depending on the roller separation.

The next process is the drying or maturing of the relatively soft linoleum. It is hardened by hanging it in an oven at elevated temperatures (about 70-80 °C). Drying time can be up to about 30 days, depending on the thickness and hardness required. Malodorous, but non-toxic, fumes are emitted. Further polymerisation is thought to occur during drying. The dried and hardened linoleum is then treated with a coating of a wax emulsion or nitrocellulose type polish, which acts as both a decorative finish and a dirt inhibitor.

The linoleum is either rolled or cut into tiles. It is then packaged in plastic or paper wrappings. The products are stored in a warehouse or plant storage area before dispatch.

### *2.3.2 Vinyl floor coverings*

The production processes for manufacturing vinyl floor covering are similar to those used in the manufacture of linoleum.

The raw materials, powders and liquids are transferred from storage, weighed and charged to a mixer. The charge, together with any pigments, is introduced into a Banbury/Winkworth type mixer where the ingredients are blended into a homogenous mix. This is then introduced into a high speed, steam heated, intermixer. Mixing may be either high shear with cooling, or low shear with heat applied at intervals during or after mixing. The resultant softened mass is fed onto a two roll mill (an extruder). The material is then fed to a calender, the configuration of which is dependent on the type of film being produced. Generally, a 2 bole calender will produce a finished product to its final thickness, whereas an inverted 4 bole calender manufactures a thin film for lamination. The resultant sheet is embossed to provide surface texture and is then passed through annealing ovens before the long process of cooling. Vapours consisting of plasticiser, solvents used in the mix, and hydrogen chloride fumes are emitted during heating.

If the sheet product is being manufactured, the material is trimmed and reeled into specific lengths. If tiles are required, the sheet is first guillotined and then fed into a punch press where a die stamps out the respective tile sizes.

Cushion vinyl flooring is manufactured by applying a number of layers of PVC paste on to a glass fibre substrate and gelling each layer in turn. The sheet is printed by passing it through a sequence of printing heads and drying ovens to build up the desired pattern. The material is then passed through an oven at very high temperature, where the blowing agents within the material activate and cause the sheet to expand to produce cells of uniform construction. Any condensate from the ovens is collected and sold for separation and re-use.

The final products are packaged in paper, cardboard or plastic packaging and stored in warehouses prior to dispatch.

#### *2.3.3 Bitumen-based floorings*

A fibrous mat of polyester, glass fibre or asbestos was passed through tanks of molten bitumen at about 240 °C. The saturated felt was then applied to a backing cloth and cooled. Finally, the felt was coated with a number of sealing layers, printed, and given a final protective coating.

### **2.4 Ancillary activities**

The manufacturing processes require significant amounts of heat for the ovens and calenders, so that on-site generation of steam is common. Various fuels may be used such as fuel oil, coal, natural gas and petroleum gases. Waste gases from the ovens and the incineration of waste materials are other possible sources of heat. Boiler houses, incinerators and their associated storage areas may be present. Some sites may have had their own electricity sub-station.

### **2.5 Waste management**

Waste management practices have advanced significantly over the last 20 years. Waste minimisation, recycling and safe disposal to licensed tips or incinerators are now the normal procedures. Previously, wastes were disposed of to landfill sites (either municipal or owned by the facility) or were burnt for fuel.

The amounts of aqueous wastes are relatively small, so wastewater is normally discharged to sewer. Solvent-contaminated water is currently disposed of by a specialist contractor as required by current best practice. However, in the past it may have been disposed of to on-site soakaways.

## **3. Contamination**

The contaminants on a site will largely depend on the history of the site and on the range of materials produced 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 be carried out to determine the exact nature of the contamination associated with individual sites.

### **3.1 Factors affecting contamination**

Contamination may result from leaks, spillages or on-site disposal of waste materials. In the past, there is likely to have been less emphasis on secure handling and storage of potential contaminants. Unbundled tanks, unsecured storage areas

and underground tanks may have been common in the industry. Each production unit will have its own storage facilities both for raw materials, products, and wastes. Potential contaminants will normally be stored close to or in the production area.

Potentially contaminative solvents and associated compounds include toluene, MEK, white spirit, isopropyl acetate, phthalate plasticisers and degreasing solvents. Various quantities of these are stored in drums and on small tank farms.

Although natural gas is generally used for manufacturing purposes, fuel oil may be stored for use as a back-up. Fuel storage facilities may be present for vehicles and plant on site. Leakages or spillages from such facilities may have resulted in significant soil contamination.

Metals and metal salts (used as driers), stabilisers and pigments may also be significant as potential contaminants. These will have been used mostly as powders, but also in solvents. Other organic and inorganic compounds, which may be used in the production process and are potential contaminants, include fillers, resins, polymers, plasticisers, processing aids, blowing agents, flame retardants and biocides.

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

Some sites may have had their own electricity sub-stations and transformers which may have contained polychlorinated biphenyls (PCBs), used in dielectric fluids. There may be contamination due to spillage or leakage of these fluids.

### **3.2 Migration and persistence of contaminants**

The organic solvents which are likely to be encountered are mostly volatile and have moderate to high vapour pressures. They will occur in the vapour phase, resulting in high concentrations in the soil pore space above the saturated zone. Close to the soil surface some will be lost directly to the atmosphere by evaporation. Free phase product, consisting of the less soluble organic solvents, or any hydrocarbons may migrate to the water table.

In most cases such compounds are less dense than water and will therefore float on the water table surface. The more water-soluble organic solvents, such as MEK and isopropyl acetate, will readily migrate through the soil system and eventually to the groundwater. Although the solubility of some of the other organic compounds is relatively low, their dissolved concentrations may be several orders of magnitude greater than current water quality standards permit.

Significant spillages of organic solvents into the soil may accelerate the migration of some of the organic compounds which have a low solubility in water, but are readily soluble in organic solvents. Such solvents could, therefore, increase the potential for groundwater contamination by organic compounds of low aqueous solubility, for example some of the organic pigments, bitumen components, blowing agents and possibly even some of the resin-associated materials. Groundwater discharge of dissolved or free phase products may also impact on surface water bodies. Phenolic compounds are particularly mobile and can migrate considerable distances from source.

The transport and fate of both organic and inorganic compounds within the subsurface environment will be dependent upon physical, chemical and biological factors. Organic matter and clay in the soil cause adsorption of contaminants which reduces the potential for migration. The greatest degree of migration will occur in coarse grained sands and gravels with little organic matter. The less soluble organic compounds which become adsorbed on to clay or organic matter will continue to desorb into the soil-water, providing ongoing sources of water pollution long after the source has been removed.

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. Consequently, at high concentrations in soil, even relatively non-persistent compounds may not biodegrade readily.

Contaminants may arise as breakdown products or be produced as a result of the reaction of other contaminants. Phenolic residues (possibly from some of the resins used in linoleum manufacture) and formaldehyde (from the binder used for the backing/support cloth) may be released. Both these substances have significant solubilities in water and have strong odours; both are potentially biodegradable.

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 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 pH.

Asbestos is insoluble and does not biodegrade. Wind dispersion of contaminated soil may be a further transport mechanism, if there is gross surface contamination by some of the less mobile contaminants, particularly metals and asbestos.

PCBs have a low solubility in water, do not biodegrade and are highly persistent. They are fat-soluble and tend to accumulate in food chains

## **4. Sources of further information**

### **4.1 Sources of information concerning the activities described in this profile**

**Austin G T.** *Shreve's chemical process industries*. 5th Edition. McGraw-Hill, London. 1984.

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

Estimates of the size and geographical distribution of the linoleum and plastic floor coverings industries can be obtained from the following Central Government statistics, held principally by the Guildhall Library, Aldermanbury, London and the City Business Library, 1 Brewers Hall Garden, London:

*Census of Production Reports*. Board of Trade, HMSO (from 1924 to 1990).

*Business Monitor Series: Annual Census of Production Reports*. Central Statistical Office, HMSO.

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

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

## 4.2 Related DOE Industry Profiles

Ceramics, cement and asphalt manufacturing works  
Chemical works: coatings (paints and printing inks) manufacturing works  
Chemical works: organic chemicals manufacturing works  
Chemical works: rubber processing works (including works manufacturing tyres or other rubber products)  
Textile works and dye works

## 4.3 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.

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 environmental 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.

**Verschuieren K.** *Handbook of environmental data on organic chemicals*. 2nd Edition. New York, Van Nostrand Reinhold Company, 1983.



#### 4.4 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. Of particular interest is:

**Department of the Environment.** *Special Wastes: a technical memorandum providing guidance on their definition.* Waste Management Paper No. 23. London, HMSO, 1981. New edition in preparation.

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.

### Linoleum

Metals, metalloids and their compounds	antimony barium cadmium cobalt iron lead zinc
Inorganic ions	sulphates
Organic solvents	toluene methyl ethyl ketone (MEK) white spirit (petroleum hydrocarbons)
Other organic compounds	benzidines phenolic compounds phthalocyanine pigments

### Vinyl floor coverings

Metals, metalloids and their compounds	aluminium antimony arsenic barium cadmium lead zinc
Inorganic ions	phosphates borates
Organic solvents	chlorinated solvents toluene methyl ethyl ketone (MEK) isopropyl acetate white spirit (petroleum hydrocarbons)

Other organic compounds

sulphonates  
phthalate esters  
benzidines  
adipic, azelaic, sebacic and stearic acids  
and their esters  
mineral oil  
organotin compounds

### **Bitumen-based flooring**

Organic compounds

long chain aliphatics  
aldehydes  
ketones  
phenols  
polycyclic aromatic hydrocarbons (PAHs)  
amines  
solvents eg petroleum extracts  
isopropyl alcohol

### **General contaminants**

Polychlorinated biphenyls (PCBs)

Asbestos

Glass fibre

Fuels

fuel oil  
coal/coke

**Table 1 Main groups of contaminants and their probable locations**

Chemical works: linoleum, vinyl and bitumen-based floor covering manufacturing works

Main groups of contaminants	Location								
	Raw materials delivery storage/transfer	Transport and handling	Manufacturing process			Waste storage/on-site disposal	Heating and steam generation systems	Building fabric	Electricity substations and transformer areas
			Linoleum	Vinyl floor coverings	Bitumen-based floor coverings				
Metals and metalloids									
Inorganic compounds									
Organic compounds									
Solvents									
Fuels									
Asbestos									
Polychlorinated biphenyls (PCBs)									

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

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Glass manufacturing works

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