

# Chemical works

*rubber processing works (including works manufacturing tyres or other rubber products)*



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: rubber processing works (including works manufacturing tyres or other rubber products)

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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: rubber processing works (including works manufacturing tyres or other rubber products)**

## **1. Background**

This profile covers the manufacture of products from natural and synthetic rubbers, including tyres, footwear, belts, hoses and numerous miscellaneous products and components. More than half of the total United Kingdom rubber consumption is associated with tyre manufacture. Rubber products also include latex products such as latex foam, carpet backing, condoms and gloves (latex is a stable dispersion or emulsion of minute particles of rubber dispersed in an aqueous medium). The manufacture of products from latex represents about 3% of the overall United Kingdom production of rubber goods.

The rubber industry dates back 100 to 130 years. Historically, rubber products including tyres were manufactured from natural rubber, although the use of synthetic rubbers began in the 1930s. Data from the United Kingdom Census of Production show that in 1930 there were 520 natural rubber manufacturing works. In 1968 there were 548 establishments manufacturing natural rubber and 310 manufacturing 'synthetic resins, plastic materials and synthetic rubber'. In 1993 the corresponding figures were 660 and 599 respectively.

The use of carbon black as a filler was adopted around the turn of the century. Development in process technology and equipment has taken place over the years, prompted by factors such as product improvements, the need for reductions in dust emissions, and a drive to reduce energy requirements and improve the efficiency of the manufacturing processes. Changes in raw material usage have reflected changes in technology and product requirements.

In the past, manufacturing sites were associated with port facilities for the import of natural rubber. In 1948 the most important areas of production were London and the South-East, and the Midlands. At present there is little evidence of the siting of the industry on the basis of raw materials. Rubber product manufacturing facilities are located throughout the United Kingdom although they are concentrated in the Midlands and around Manchester and Newcastle. Facilities range from very small companies with only four or five employees to large businesses with over one thousand employees.

There are six companies in the United Kingdom which manufacture road vehicle tyres. About 85% of the tyre industry is concerned with road vehicle tyres, while the remaining 15% is concerned with the manufacture of aircraft and industrial tyres. 60% of tyre manufacture is based in or around the West Midlands, close to what was the heart of the automotive manufacturing industry.

## 2 Production processes

### 2.1 Raw materials

Natural and synthetic rubbers, inorganic and organic compounding ingredients or additives are the main raw materials delivered to rubber processing works. The different uses of these substances are summarised below.

#### *Main ingredients*

Rubbers	Natural and synthetic rubbers are usually hydrocarbon-based polymers.
Rubber preservatives	Added at early stages of rubber manufacture to prevent unwanted chemical and physical changes in the mixture during the process.
Vulcanising or curing agents	Usually elemental sulphur (see explanation of vulcanisation in Section 2.3.2).
Fillers	Reinforcing fillers improve tensile strength, abrasion resistance and tear resistance in the final product. Carbon black is the principal reinforcing filler, but clays and silicas are also used. Cheap non-reinforcing fillers such as chalk are sometimes used in non-critical products.
Processing aids, plasticisers and extenders	These compounds are added to rubbers to make them more amenable to processing, to soften the rubber and to facilitate mixing processes.
Anti-degradants	These include anti-oxidants, anti-ozonants and thermal and UV stabilisers. These compounds protect the rubber from oxidation and other degradation processes which would lead to product failure.
Accelerators	These compounds increase the vulcanisation rate at higher temperatures. The rubber industry has used many compounds such as delayed action accelerators which become more active on heating. In the past, MBS (see Annex) and other secondary amine-based accelerators were used. These began to be phased out in the 1960s (though they are still being used) owing to concern over their ability to react with nitrosating agents, when present in the mix, to produce carcinogenic nitrosamines. Nowadays, compounds such as TBBS (see Annex) are used.
Activators	These compounds assist the action of organic accelerators in the sulphur vulcanisation process.

Stain protectors	These are complex organic compounds added early on in manufacture to prevent discolouration of the final product.
Retarders	These are used to avoid premature vulcanisation.
Solvents	Some solvents are used in factories carrying out specific rubber processes, eg fabric-proofing operations, production of inflatable products etc. Benzene was used in the past. Petroleum naphtha was a constituent of rubber solutions formerly used in tyre manufacture. Chlorinated solvents are commonly used as degreasing agents and are often solvents for bonding agents.

### ***Miscellaneous additives***

Waxes	Paraffin waxes are not very soluble in rubber. They tend to come slowly to the surface of the finished product, so protecting the rubber beneath from ozone attack.
Tackifying resins	Tackifying resins are polymerised products, which possess adhesive properties and make rubber sticky during processing.
Hardeners	These are added to harden the rubber.
Desiccants	Examples given in Annex.
Peptisers	Peptisers are complex organic solids which are used as promoters for the mastication of some natural raw rubber, to make it easier to mix, and to promote dispersion of additives.
Colouring pigments	Examples given in Annex.
Flame retardants	Examples given in Annex.

## **2.2 Delivery, handling and transfer of materials on site**

Raw materials are usually delivered to sites by road. Raw dry rubber is delivered in the form of bales and stored on site in warehouses. Some manufacturers buy uncured rubber compound from a custom compounder (ie a manufacturer who makes a rubber compound to a customer's specification). Latex is usually delivered to the site in tankers and stored in bulk tanks.

Other bulk liquids are delivered by bulk tanker direct to storage. Historically, underground storage tanks were common for storing liquids but most new facilities use above-ground storage. Pumps are usually employed to transfer bulk liquids within the facility.

Depending on the size of the facility and rate of use, powders will typically be brought to the site by tanker and transferred to hoppers, or brought in bags and

stored in warehouse areas. There has been an increased tendency to use these materials in pellet form in an attempt to reduce dust contamination. Once on site, some granular materials may be distributed by pneumatic systems.

Small bags and kegs of materials may be handled manually, whereas larger drums are often transported within the facility by fork-lift truck and then emptied by manual and/or semi-automatic methods.

Carbon black, which constitutes almost a third of most rubber products, can be delivered in 25 kg bags but is nowadays more typically delivered in 1000 kg 'big bags' made from woven polypropylene. The bags are automatically emptied into hoppers and are returned to the supplier for refilling. The 'big bag' approach is now also being applied to many other powdered raw materials within the industry, although the bag capacity is of the order of 200 kg for materials such as anti-oxidants, sulphur and resins.

Batch production processes are now widely employed in the rubber industry. With batch processes, stockpiling of raw materials between operations is minimised, primarily for economic reasons but also to reduce changes in the properties of the mix which occur with time. Stockpiling was more prevalent in the past. The size of the batch dictates the method of transportation between stages; systems used include conveyor belts, bins, hooks and trolleys.

## **2.3 Manufacturing processes**

A wide range of production technologies and rubber formulations exists; the type used depends on the nature of the required end-product.

The two main types of processing (dry and wet) are described separately; as is tyre production which has some specific operations.

### *2.3.1 Preparation*

Prior to mixing of the feedstocks for rubber manufacture, initial preparation of the rubber may be required. Raw rubber bales may require cutting to weight or occasionally into smaller pieces by means of a bale cutter. Some manufacturers cut up each or a proportion of bales in each batch to inspect for contamination from, for example, glass or iron. Natural rubber is sometimes pre-treated prior to mixing by a mastication process, in which the rubber viscosity is reduced by heat and working. Some companies may buy in uncured rubber compound (see Section 2.2).

### *2.3.2 Dry processing*

Dry processing is most commonly used and involves the following basic operations.

#### *Mixing*

Mixing is the process by which raw rubber and compounding ingredients, such as plasticisers, activators and fillers, are combined. Mixing can be carried out either in internal mixers (eg Banbury mixers) or occasionally on two roll mills. The compounding ingredients may be added in one or more stages of mixing. Curing chemicals (vulcanising agents) are usually added at the last stage of mixing to prevent pre-curing of the compound.

### *Shaping and fabrication*

Shaping can be carried out in one or more stage operations. Extruded products such as tubing and cable insulation are formed in one stage. Moulded products generally require two stages; the uncured mix is initially formed into crude shapes suitable for placing in the moulds, followed by final shaping in the moulds with concurrent vulcanisation. There are three main types of moulding process; compression, transfer and injection moulding.

Some products are made by forming several separate rubber components which are then combined in a building operation. Many products are formed by combining the rubber mix with fibres or fabrics (eg cotton, nylon, steel etc), sometimes by means of a calendering process, where the product is compressed between rotating rolls to produce the final product of a desired thickness. Moulded rubber components may be bonded to metal parts.

### *Vulcanisation*

Vulcanisation is normally accomplished by heating the compound together with sulphur, to temperatures in excess of 140°C, with or without pressure. The heat causes a reaction in which the sulphur chemically links (cross-links) the rubber chains. This process of cross-linking gives a product which is strong, elastic, flexible, tack-free (non-sticky), abrasion-resistant and no longer readily soluble in common solvents. With moulded products, moulding and vulcanisation are carried out in a single operation.

### *Finishing*

Trimming (known as deflashing) operations may be required on some moulded products. Testing and inspection of the products is always undertaken.

#### *2.3.3 Wet processing*

Wet processing methods apply only to the manufacture of latex products. Production operations involve latex compounding (mixing), forming, solidification and vulcanisation.

Dipping is usually used to produce items such as condoms and gloves. A 'former' in the shape of the article to be produced is dipped into the compounded latex. The deposited film is usually coagulated with dilute acid before being dried, vulcanised, and then stripped from the 'former'.

There is also a large application for SBR (styrene butadiene rubber) latex films on the underside of tufted carpets and rugs. Latex is applied by rollers; curing and drying are carried out in an oven.

#### *2.3.4 Tyre manufacture*

Rubber compounding takes place as for other rubber products. The mixing typically takes place in batches of around 500 kg. Fabric and steel wire are coated with rubber compound by calendering. The various parts of the tyre are then assembled into a cylindrical mould on a collapsible rotating drum. The tread, which is made by extrusion, is also laid onto the tyre cylinder. The drum is then collapsed; the uncured tyre is placed in a press where a rubber bag is inflated inside the tyre. High pressure hot water or steam is applied as the press is closed, and the metal mould is heated with steam. The cured tyre is checked for quality, stacked and stored.

Mould manufacturing is sometimes carried out on tyre manufacturing sites and involves the use of aluminium.

In retreading (a specialist operation) the remaining tread is removed from worn tyres mechanically and new tread rubber is moulded onto the casing.

## **2.4 Ancillary activities**

A number of supporting activities are necessary for the running of the plant and production process. These include steam generation systems (ie boilers etc) and cooling water systems for hot process machinery. There may be centralised facilities supplying a number of machines with lubricant and compressed air.

Boiler/steam generation systems require the storage of fuel oil or coal. Petrol, diesel, fuel oil and wastewaters may have been stored underground. Sites may also have their own electrical sub-stations which may have utilised polychlorinated biphenyl oils (PCBs).

## **2.5 Waste management**

Waste management practices largely depend on the size of the facility and the recycled/resale value of the material. Disposal of wastes is typically in landfills, mostly off-site.

Off-specification uncured rubber compound may be recycled on-site at low levels back into fresh compound within the production process and thus is of economic value. Recycling of rubber wastes is also possible after vulcanisation, when the rubber is sometimes ground to a fine crumb for recycling. Rubber flash (excess material) is removed from moulds using compressed air.

Moulds are also often cleaned by water blasting, chemical treatment and occasionally shot blasting.

Wastewaters are generated principally from heat exchange systems, although effluents are also generated in latex processing operations. Some treatment chemicals, both for wastewater treatment and boiler feed water and cooling water treatment, may be stored on site.

The storage and disposal of empty containers and bags varies depending on the waste management policy on site. Some facilities may store wastes in the open.

## **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

The varieties and quantities of the chemicals used, and the contaminants that may result, are largely dependent upon the size of the production facility and the range of rubber products manufactured. Those of greatest importance are probably additives in the production process and their breakdown products (such as phenols and amines), solvents and fuel oils.

Raw material storage and transfer areas are potential sources of ground contamination through accidental spillage. Spillages of latex may occur.

Contamination by carbon black during transfer and mixing operations is a possibility. Carbon black and other dust contaminants may be present around the off-loading and storage areas and the process (mixing) areas. Polycyclic aromatic hydrocarbons may be associated with carbon black.

Hydrocarbon solvent contamination is most likely to occur around bulk storage, drum storage and transfer areas as well as underneath machines that may be cleaned using such solvents, although the use of cleaning solvents on process equipment is not widespread. In addition, waste storage areas for these drums are a potential source of ground contamination.

Surface water soakaways on any site with a long history of industrial use will also be prime areas for contamination.

Contamination from fuel oil and underground storage tanks for raw materials is dependent on their construction and location, and that of any associated pipework. Old tanks and distribution pipework systems may leak, causing contamination of the surrounding soil and, potentially, of the underlying groundwater. Leakage of hydraulic and lubricating oils from the processing units is also a possibility. There may be leaks from a centralised lubrication facility. The water vapour condensate resulting from the rapid expansion and cooling of compressed air may contain oils.

Most materials used in rubber manufacture and processing are potentially flammable and combustible. Large quantities of potentially combustible material, including rubber crumb and sulphur (elemental or sulphur compounds), may be present on some sites. Fires and fire-fighting activities are also likely to lead to widespread contamination by raw materials and their combustion products.

Until the early 1970s, rubber was bonded onto steel components (eg engine mountings) by first plating the steel with bronze. This was done on site, and therefore plating chemical contamination could be found on old sites. Bonding agents are now used instead of bronze plating.

If the site has transformers containing PCBs, then localised soil contamination is a possibility. There may be localised asbestos contamination where it has been used as pipe insulation. Buildings may also have utilised asbestos cement materials for roofing and partitioning.

## 3.2 Migration and persistence of contaminants

### 3.2.1 Rubbers and additives

Rubbers themselves, including latex, are immobile, very slowly biodegradable and highly persistent. The additives for rubber manufacture (ie preservatives, antidegradants, vulcanisation agents, activators, retarders, peptisers, stain protectors, pigments and synthetic resins) are not soluble in water, are generally not mobile, and despite varying degrees of biodegradability, they are moderately persistent. Flame retardants and phenols are water-soluble, mobile and not persistent; phenols can permeate pipes made of polymeric material.

### 3.2.2 Carbon black

Deposits of carbon black are likely to be relatively immobile, not biodegradable and remain in the upper layers of soil. Polycyclic aromatic hydrocarbons (PAHs) may be associated with carbon black, are adsorbed onto the surfaces of carbon particles and are persistent. However, PAHs may be leached from carbon black by solvents (see also oils and solvents).

### 3.2.3 Organic materials

Where surface water bodies are present there is a particular risk of contamination by oils and solvents. The organic solvents liable to be encountered are volatile, and can move through the soil as vapour. Close to the soil surface most is lost directly to the atmosphere by evaporation.

Many petroleum hydrocarbons and solvents tend to migrate to the water table, at a rate influenced by the presence of impermeable surface cover such as concrete. In most cases, the oils and solvents are less dense than water and therefore float on the water surface. However, chlorinated solvents are heavier than water and tend to migrate to the bottom of aquifers. They are persistent chemicals and can render groundwater unsuitable for public supply at low concentrations. Chlorinated solvents are one of the most common groups of pollutants of groundwater found beneath old industrial sites.

Although the aqueous solubility of solvents, such as toluene and xylene, and organic additives is relatively low, their dissolved concentrations may be several orders of magnitude greater than water quality standards permit; they also have the potential to migrate readily through the soil system to groundwater. In addition, some of the organic contaminants which are insoluble in water may be soluble in some organic solvents. The presence of contamination by such solvents at rubber-manufacturing sites may therefore accelerate the mobility of less soluble organic contaminants (eg PAHs which may be associated with carbon black) and enhance their eventual passage into groundwater.

The transport and fate of the organic compounds within the sub-surface environment will be 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 and the greater the reduction in the degree of contaminant migration. Thus the greatest degree of migration will occur in coarse-grained sands and gravels with little organic matter. The less soluble compounds which become desorbed on to exchange sites in clay or organic matter will provide on-going sources of water pollution long after the source has been removed, by continuing to desorb and dissolve into the soil-water.

Biodegradation processes in soils can be influenced by a number of factors, namely moisture content, oxygen concentration and pH values, 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, eg 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. Notwithstanding these factors, at high concentrations in soil, even relatively non-persistent compounds may not biodegrade readily. It should be noted that biodegradation may not result in general decontamination.

PCBs, present in certain types of electrical equipment, have a low solubility in water and do not degrade. They are fat-soluble and tend to accumulate in food chains.

### 3.2.4 *Inorganic materials*

Zinc, like many other metals, is readily adsorbed onto clay or organic matter present, so it is likely that, where it occurs, zinc contamination is also generally confined to the upper soil horizons. However, mobility of zinc may be accelerated under acidic condition. Other metal contaminants, eg pigments, would be expected to behave similarly. Some inorganic contaminants, eg the borates occasionally used as flame retardants, are soluble and may be leached through the soil profile, eventually to groundwater.

Deposits of sulphur are likely to be oxidised microbially to sulphate, resulting in an increase in the soil acidity where this has taken place. (Sulphides may be formed microbially in the absence of oxygen). If extensive sulphate contamination has arisen or if spillages of acid have occurred (as a result of storage for wastewater treatment), these could affect the integrity of concrete and cements used in building foundations. However, sulphur is not normally dumped or lost from the rubber production process in large amounts.

Wind dispersion of contaminated soil may be a further transport mechanism, but it is only likely to be a major factor at sites where there is gross surface contamination by, for example, carbon black, and where the soil is exposed to the wind. Widespread contamination of the site may occur through the wind-blown dispersion of surface deposits containing loose asbestos fibres. Asbestos is not biodegradable and will persist in soil.

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 is still associated with existing buildings and plant.

## 4. Sources of further information

### 4.1 Organisations

For further information concerning the rubber processing industry in the United Kingdom, the following organisations and trade associations should be consulted:

The British Rubber Manufacturers' Association  
90 Tottenham Court Road  
London  
W1P 0BR

The Plastics and Rubber Institute  
11 Hobart Place  
London  
SW1W 0HL

RAPRA Technology Limited  
Shawbury  
Shrewsbury  
Shropshire  
SY4 4NR

The Retread Manufacturers Association  
10 Queen Street  
Newcastle-under-Lyme  
Staffordshire  
ST5 1ED

### 4.2 Sources of information concerning the activities described in this profile

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

**British Rubber Manufacturers' Association.** *Toxicity and safe handling of rubber chemicals*. Code of Practice. 3rd Edition. HS11.

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

**Morton M.** *Rubber technology*. 3rd Edition. London, Van Nostrand Reinhold Company, 1987.

Estimates of the size and geographical distribution of the pesticides industry 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 1969).

Business Monitor Series: *Annual Census of Production Reports*, Central Statistical Office, HMSO (from 1970 to date).

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

Engineering works: mechanical engineering and ordnance works  
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works

#### 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. Series 4 of the Process Guidance Notes covers many aspects of the Chemical Industry Sector. Of particular relevance is:

**Her Majesty's Inspectorate of Pollution.** *Combustion processes. Combustion of fuel manufactured from or comprised of tyres, tyre rubber or similar rubber waste in appliances with a net rated thermal input of 3 MW or more.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 1/6. 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:

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

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

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

#### 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.

### Rubber product ingredients

Precursors for synthetic rubbers	isoprene (2-methyl-1,3-butadiene) chloroprene (2-chloro-1,3-butadiene)
Rubbers	natural rubber — a polymer of isoprene synthetic rubbers SBR (styrene butadiene rubber, a copolymer of butadiene and styrene) nitrile rubber (a copolymer of butadiene and acrylonitrile) polychloroprene, known as neoprene (a polymer of chloroprene) polysulphide rubbers (compounds of bischloroethylformal and alkali polysulphides)
Rubber preservatives	halogenated cyanoalkanes
Vulcanising agents	elemental sulphur 4,4'-dithiodimorpholine
Fillers	carbon black
Processing aids, plasticisers, extenders	oils (carbon chain length approximately C <sub>20</sub> ) activated ester alcohols
Anti-oxidants	based on amines eg dimethylamine, para-phenylenediamine based on substituted phenols and dibenzyl disulphide
Accelerators	MBS (2-morpholino-thio-benzothiazole- sulphenamide) N-oxydiethylene-benzothiazole-sulphenamide ziram 1,3-diphenylguanidine N,N'-diphenylthiourea disulfiram 2,2'-dithiobis (benzothiazole) TBBS (N-tertiary-butyl-benzothiazole- sulphenamide)
Activators	zinc oxide stearic acid magnesium oxide (used in neoprene)
Stain protectors	2,5 di-tert-pentylhydroquinone 4,4'-dithiodimorpholine

Retarders	organic acids (eg salicylic acid) used in the past N-cyclohexyl-thiophthalimide (CTP)
Waxes	paraffin waxes (carbon chain length C <sub>18-50</sub> )
Tackifying resins	polymerised products, carbon chain length >C <sub>500</sub>
Hardeners	phenol derivatives
Desiccants	calcium oxide
Peptisers	2,2'-dibenzamidediphenyl disulphide zinc dibenzamidediphenyl disulphide dicyclohexyl carbodiimide
Colouring pigments	iron oxide antimony pentasulphide
Flame retardants	zinc metaborate dihydrate sodium borate sodium metaborate

### **General contaminants**

Solvents	toluene xylene benzene petroleum naphtha chlorinated solvents (eg 1,1,1-trichloroethane)
Polycyclic aromatic hydrocarbons	anthracene phenanthrene benzo(a)pyrene
Phenols	
Amines	
Oils	fuel oil
Acids and alkalis	sodium hydroxide
Metals and metal compounds	zinc and iron compounds aluminium bronze
Combustible materials	rubber crumb elemental sulphur or sulphur compounds
Plating chemicals	see the profile on electroplating and other metal finishing works, Section 4
Polychlorinated biphenyls	
Asbestos	

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

Chemical works: rubber processing works (including works manufacturing tyres or other rubber products)

Contaminant		Location					
Main group	Sub-group	Raw material delivery and storage	Process areas	Tanks, pipework and pumps	Product storage and blending	Waste storage/on-site disposal	Wastewater treatment facilities
Metal and metalloid contaminants	activators						
	desiccants						
	colouring pigments						
Inorganic compounds	flame retardants						
Organic compounds	rubber precursors						
	rubber						
	rubber preservatives						
	vulcanising agents						
	processing aids, plasticisers and extenders						
	accelerators						
	activators						
	stain protectors						
	retarders						
	waxes						
Other	tackifying resins						
	hardeners						
	peptisers						
	vulcanising agents						
	fillers						
	anti-degradants						

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  
Gasworks, 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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