Department of the Environment
Industry Profile

Engineering works

vehicle manufacturing works

Industry Profile sponsored by
Contaminated Land and
Liabilities Division

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).

ISBN 1 85112 301 6

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 (W S Atkins Environment)
Mr P Chave (National Rivers Authority)
Mr C D Ironside (Ironside Farrar, Environmental Consultants)
Mr B Moore (The Society of Motor Manufacturers and Traders Limited)

DOE Industry Profile

Engineering works: vehicle manufacturing works

This profile is based on work by Aspinwall and Company Limited and W S Atkins Environment 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.

Engineering works: vehicle manufacturing works

1. Background

This profile deals with the manufacture of vehicles powered by internal combustion engines, ie cars, lorries, buses and motor cycles.

The first purpose-built car factory in the United Kingdom was erected in Guildford, Surrey, in about 1903. A new works was begun in 1905 in the same town to manufacture fire engines, buses and other commercial vehicles. In 1913 there were 198 different models of cars being manually produced, in the United Kingdom, on an individual basis.

Between the two World Wars, the industry was characterised by the change over from wood and canvas bodies to all-metal bodies and by the emergence of a few large companies using American automated assembly techniques. Morris was producing all-metal cars by the late 1920s and, by the mid 1930s, Leyland was producing all-metal buses. By 1938 six companies (Morris, Austin, Ford, Vauxhall, Rootes and Standard) produced 90% of the cars manufactured in the United Kingdom.

Vehicle production shrank during the Second World War as plants were converted to undertake war-related work, particularly the production of aircraft. However, the War created extra production capacity at one-time vehicle manufacturing works, which allowed the industry to expand rapidly after 1945.

Production increased steadily until the mid-1960s when problems, such as low productivity and foreign competition, began to impede the industry. Large producers absorbed their suppliers while, at the same time, there were mergers between companies. By 1970, amalgamations left one or two major manufacturers in each market: Ford producing cars and light commercial vehicles; British Leyland Motor Company (BLMC) producing cars and lorries and Triumph producing motor cycles and buses.

The problems of the industry multiplied in the 1970s. There was industrial unrest, low investment and the oil crisis of 1973. In 1975, the United Kingdom's major manufacturing company, BLMC, was nationalised to prevent its liquidation and was renamed British Leyland (BL). The company was rationalised after 1977 and many works closed.

Recession precipitated further changes during the 1980s, including the fragmentation of BL. British Aerospace took control of the Rover Group and the lorry manufacturing business was amalgamated with the Dutch company DAF. The more recent recession of the 1990s severely affected traditional United Kingdom vehicle manufacturers and further plant closures are possible. In 1994, the Rover Group, which was the last major United Kingdom vehicle manufacturer, was sold to the German company BMW.

The manufacture of other vehicles has undergone a similar decline. In 1945 there were 27 lorry manufacturers in the United Kingdom but by 1982 this number had fallen to eleven.

In contrast to the decline of traditional United Kingdom car producers, in the last decade, Japanese manufacturers have set up a number of new works on sites in the United Kingdom: Nissan Motor at Sunderland, Tyne and Wear; Toyota Motor at Burnaston, Derbyshire and Honda Motor at Swindon, Wiltshire. Assembly operation has become highly sophisticated, involving high precision machining operations, computer-controlled systems and increased automation.

The greatest concentration of manufacturing works, both in the past and now, is to be found in the Birmingham and Coventry areas. Other past and present regions of production include Oxford, Greater London, Luton, Southampton, South Wales, Lancashire, Cheshire and Derbyshire.

Vehicle production has traditionally had a strong association with other engineering industries. Some specialist vehicle manufacturers maintained their association with their original engineering interests, for example Rolls Royce and aeroplane engines and, historically, BSA (Daimler) with machine tools, bicycles and weapons.

A high percentage of 'bought-out' components form the finished vehicle and a specialist component supply industry, dominated by a few large manufacturers, has developed around the vehicle production industry.

2. Production processes

Car producers frequently manufacture vans, light trucks and tractors. Medium to heavy commercial vehicles, such as buses, road tankers and articulated tractor units, are generally made by specialist firms. The production processes involved in the manufacture of all vehicles are essentially the same.

Most vehicle manufacturing activities are confined to the production of body parts, final assembly, the machining of the engine and other mechanical components, and the construction and painting of body shells. The other parts are typically 'bought-out' and include the following:

castings and forgings for cylinder blocks, cylinder heads, crankshafts etc, typically supplied by subsidiary companies

electrical and electronic equipment, for example starter motors, alternators, engine management control modules, lamps, horns, wiring harness, batteries and spark plugs

wheels, tyres, brakes and suspension system components

instruments, carburettors, steering gears, fuel pumps, door handles, locks, nuts, bolts, wire, cloth and plastic trim items.

A typical integrated United Kingdom vehicle manufacturing works comprises the press shop, the 'body in white' (BIW) plant, the paint shop, the engine and transmission plant and the final assembly plant. These production areas may be present on the same, or a separate, site.

Production assembly plants have become highly sophisticated. Automatic gauging is used to ensure assembly and machining operations are performed properly. Computer systems are used to monitor and adjust operation systems. The use of robot mechanisms is becoming increasingly common.

2.1 Production materials and their delivery to site

The materials required for vehicle manufacture are principally:

steel sheet panels for the body
welding and soldering alloys
paints, solvents, sealants and waxes for finishing
fuel oils, transmission and engine oils, cutting fluids and cleaning fluids
plastics for upholstery and some body parts
bought-out components.

Steel and body parts are normally delivered by road or rail and off-loaded by crane or fork-lift. Bulk liquids such as fuels and oils are delivered by tanker and piped to storage/production areas. Other fluids are delivered by drum or keg and transferred by fork-lift.

2.2 Press shop

2.2.1 Materials

After 1927, when Morris helped to establish the Pressed Steel Company, steel bodies became the norm for most motor cars. Sheet steel remains the principal material for motor car body construction, although plastics are finding increasing use, mainly for non-structural body panels (eg the bonnet and boot), bumpers and spoilers, and aluminium is used for some body panels.

2.2.2 Processes

The principal activity undertaken in the press shop is the forming of body panels from high strength sheet steel and sheet aluminium. Usually there is a preliminary operation comprising the cutting of the metal sheets from larger blanks by shearing the metal between two dies. Mechanical and hydraulic presses are used to form the body panels from the sheet metal.

2.3 Body in white (BIW) plant

2.3.1 Materials

Formed body panels are the principal material in the BIW plant.

Small quantities of welding alloys (principally comprising steel), solders and fluxes are also used. Solder filler metals include lead, soft solder (a lead-tin alloy), silver solder (a copper-silver-zinc alloy) and 'spelter' (a copper-zinc and sometimes tin alloy).

Silver soldering and brazing use fluxes containing boron to ensure good solder adhesion. A recent development has been the use of epoxy resin and nitrile-phenolic adhesive bonding, together with the use of polyvinyl chloride (PVC) plastisol sealants (PVC dispersed in a plasticiser), to replace traditional joining processes, for example welding or traditional riveting.

2.3.2 Processes

BIW manufacture essentially comprises:

Sub-assembly	The construction of basic building units from pressed panels.
Body framing	The joining of sub-assemblies to form the skeletal body shell.
Body finishing	Final pick-up welding, soldering and the bolting on of doors, bonnets, tail-gates etc.

Traditionally, these operations were carried out on a series of conveyors linking manned work stations. However, in recent years flexible manufacturing systems (FMS), which use welding robots and automatic transfer stations, have been widely introduced.

Metal joining is still primarily achieved by spot welding and, to a lesser extent, arc welding. Welding processes involve the application of heat so that melting and re-solidification of the metal occurs. Soldering and brazing involve the introduction of a molten filler metal to form a joint between materials with higher melting points; these are typically used to fill gaps and indentations.

2.4 Paint shop

2.4.1 Materials

Steel body shells, paints, solvents, pre-treatment reagents, abrasives, sealants, underseal, paraffin wax, polishing compounds and masking materials (typically adhesive tape and paper) constitute the main materials used during the painting process. Until the 1920s, vehicle paints were based on inorganic pigments (largely metal salts and oxides), turpentine, linseed oil and natural resins. Synthetic polymers replaced natural resins with the development of cellulose nitrate lacquers during the 1920s and alkyd enamels during the 1930s. These in turn were superseded by thermosetting acrylic enamels in the late 1950s and today a diverse range of polymers is used. Polymers in petroleum and coal tar-derived solvents, such as white spirit (a mixture of aliphatic, alicyclic and aromatic hydrocarbons) and benzol (mainly benzene), replaced the traditional drying oils. A wide range of other solvents has subsequently been employed.

Organic pigments have largely superseded inorganic pigments and aluminium flake has been introduced to give a metallic finish.

A recent development in vehicle paint shops has been the move towards water-based paints. Whilst these paints reduce atmospheric emissions of volatile organic compounds (VOCs), there may be an increase in release to water of acrylic monomers and associated fungicides.

2.4.2 Processes

Historically, air-drying paint was applied to wooden bodies, largely by manual brushing. Mass production in the 1930s became possible with the development of fast-drying synthetic paints which could be applied by spraying and immersion, and the introduction of chemical pre-treatment for all-steel bodies. Increasing automation led to technological advances in paint shop processes, particularly the development in the 1960s of electroprimer paint which can be electrophoretically deposited on the vehicle body during painting.

The principal processes undertaken in the modern paint shop are as follows:

pre-treatment
application of primer coat
seam sealing and underbody preparation
application of filler and final finishing coats
polishing, inspection and rectification
undersealing and wax injection.

Pre-treatment involves an alkali degreasing process to remove the protective oil film from the steel surfaces of the body shell. The cleaned steel surfaces are then coated with a corrosion inhibitor, usually a complex zinc-iron phosphate/chromate film, by spraying and dipping in phosphoric acid, zinc phosphate and chromic acid solutions. This is known as phosphating. The primer is then applied by dipping and is cured by baking the body in an oven, after which PVC/polyurethane plastisol sealant is sprayed onto the underside of the vehicle body. Gaps between upper body panels are filled with sealant to ensure water-tight joints. Filler coats of surfacer and sealer paints, and finishing colour and clear gloss paint coats are applied by spraying. Lead compounds are no longer used in top coat paints. The painted vehicle body is oven-baked, 'flatted' and cleaned between paint coats. Polishing is followed by inspection. Bituminous and PVC/polyurethane underseal is sprayed onto the underside, and paraffin wax is injected into the box sections of vehicle bodies which pass inspection.

The typical modern paint shop comprises a continuous conveyor system for pre-treatment and priming. The conveyor may split into parallel finishing lines.

A separate rectification line refinishes vehicle bodies which do not pass inspection.

Paint is supplied to spray booths and dipping tanks from a central mixing house. The airflow in spray booths is controlled to trap any overspray in recirculating water flowing beneath the booths. Paint and solvent storage and dipping tanks are typically above ground, though sumps for recirculating water and pre-treatment effluents may be below ground.

2.5 Plating

Metallic coatings are often applied to metals or other conductive surfaces by electroplating in order to modify surface characteristics such as corrosion resistance, lubricity and wear resistance. Electroplating involves immersing the components in a series of baths to deposit elemental metal. Several metals are used as surface coatings, including cadmium, copper, chromium, nickel and silver. Multiple rinsing is required between baths on a plating line, and post-deposition treatment may be used, such as passivation.

Cadmium plating
This uses a mixture of cadmium oxide and sodium cyanide, or cadmium cyanide with sodium hydroxide. Cadmium-plated materials were often passivated in a chromic acid solution to increase resistance to certain organic vapours.

Chromium plating
The items to be chromium plated are sometimes pre-etched with an anodic alkaline cleaner containing cyanide. Chromium plating uses tin-lead alloy plate anodes and a mixture of trivalent chromic acid and sulphuric acid solutions, which are often contained in antimonial lead-lined tanks.

Nickel plating
This is used as a precursor to cadmium or silver plating. The 'strike' solution contains nickel chloride. Nickel plating solutions consist of nickel, nickel sulphate and boric acid. Electroless nickel plating solutions contain nickel chloride, sodium citrate, ammonium chloride and sodium hypophosphite.

Copper plating
The items for copper plating are immersed in baths containing copper cyanide, or copper carbonate and potassium cyanide.

For more information on electroplating, consult the relevant Industry Profile (see Section 4).

2.6 Engine/transmission plant

2.6.1 Materials

Iron, steel and aluminium castings and forgings and a variety of cutting fluids are used in the manufacture of the engine and transmission sub-assemblies.

Mineral, animal, vegetable, fish and synthetic oils, sometimes as an oil-water emulsion, are commonly employed as cutting fluids. The principal mineral oils used are derived from heavy petroleum fractions. Animal, vegetable and fish oils essentially comprise a mixture of glycerides and fatty acids. Synthetic oils are made from petroleum or vegetable oil substrates. Additives in cutting fluids include a wide range of emulsifiers, thickeners, detergents, plasticisers, anti-oxidants, corrosion inhibitors and anti-microbial agents.

Small quantities of cleaning agents, such as solvents, oil emulsions and acidic or alkaline solutions, may also be used.

Quenching media used in heat-treatment processes include mineral oils, brine, sodium hydroxide and sulphuric acid solutions. Sodium cyanide and barium compounds may also have been used in certain carburising processes. Spent quenching oils and cutting fluids contain polycyclic aromatic hydrocarbons (PAHs).

2.6.2 Processes

Manufacture of the engine and transmission involves the machining of castings and forgings into component parts, such as cylinder blocks, crankshafts, cylinder heads, camshafts, gears etc, followed by their assembly into engine and transmission sub-assemblies. Machining comprises a number of different processes, such as planing, turning, drilling, milling, grinding etc, which result in the removal of metal 'chips' (swarf) from the workpiece by the action of a tool. Cutting fluids are required to lubricate and cool the tool and workpiece; these are recycled, generally via a settling tank to remove tool and workpiece particles.

The basic machining operations employed have not changed fundamentally over the history of the industry, although the level of automation involved in production has increased. Traditionally, machine tools have been stationed along transfer lines to perform different machining operations on batches of components passed down the line (see also the profile on mechanical engineering, Section 4). Flexible manufacturing systems (FMS) using industrial robots and computer-controlled machine tools have recently been introduced. Assembly operations are carried out on continuous conveyors.

Cleaning, by hot vapour or cold solvent degreasing, is sometimes necessary to remove oil, grease, metal chips and other contaminants from machined components prior to subsequent processing.

Certain machined components are heat treated to improve properties such as hardness and strength. Heat treatment involves controlled heating and cooling, the latter usually in a bath of quenching medium. Carburising is a specific heat treatment process in which the carbon content of a steel surface is increased by heating it in a carbonaceous medium, either a bath of molten sodium cyanide/sodium carbonate/sodium chloride, or a carbon/barium carbonate rich environment.

Engines are tested prior to dispatch to the assembly plant.

2.7 Assembly plant

2.7.1 Materials

A diverse range of bought-out components, together with engine and transmission sub-assemblies and painted vehicle bodies, form the main materials for the final assembly lines.

Upholstery materials, including leather, cloth, carpet, PVC-backed fabric, polyurethane foam and wooden board, are used in the trim shop.

Adhesives and sealants are widely employed, particularly solvent-based contact adhesives (based on polychloroprene) which are used for fixing water-deflecting sheets, headliners, floor carpet etc. Polyurethane adhesive and butyl rubber-based mastic are used to bond windscreens.

Paints, varnishes and solvents may be used for body repair work and the preparation of wooden fascias. Fuel, engine and transmission oils are required for the finished vehicle.

2.7.2 Processes

Final assembly is a continuous process in which the vehicle body passes along an assembly line and different components and sub-assemblies are fitted. This activity has not changed fundamentally since its introduction in the 1920s, although the sequence of assembly operations has altered. Before the Second World War, it was common practice to combine sub-assemblies, such as the engine, transmission and chassis frame, to form the chassis (ie all the working parts except the body, which was often produced by a separate company). This practice has continued for most commercial vehicles manufacture. Assembly operations for cars changed following the adoption of unitary (body and chassis) construction for car bodies during the 1950s, and now starts with the painted car body.

Seats, interior panels and furnishings which are not bought-out are typically manufactured in a separate trim shop and are fed to the main assembly line.

Assembly and trim operations involve both mechanical fixing and adhesive bonding. Assembled and tested vehicles are polished prior to dispatch. Damaged paintwork is repaired in a separate paint rectification shop.

2.8 Waste management

The principal waste from the press shop is sheet metal off-cuts which currently, as in the past, are typically recycled off site.

In the BIW plant, the abrasive 'discing' of welds and soldered joints to form smooth surfaces generates a metal-rich dust. Calcium carbide residues may also be present if acetylene gas for welding was produced on site.

Waste materials generated by paint shop processes include paint sludges, sludges from degreasing and phosphating processes, low-level radioactive luminous paint for luminous dials, waste solvents, waste paper and plastic and soiled disposable clothing. Wastes are typically disposed of or recycled off site.

Soluble oil cutting fluids are widely used on manufacturing sites, and these consist typically of an approximate 5% oil-in-water emulsion. The oil is split or 'cracked' from the emulsion by adjustment of pH at a treatment plant known as the 'oil splitter'. The separated water is discharged to foul sewer in accordance with discharge consents. The waste oil accumulates in an interceptor (typically holding 5 000 gallons) and is regularly tankered off site for recovery or disposal as appropriate.

Plating and painting shops have traditionally produced hazardous wastes. Between chemical stages they use large quantities of rinse waters which contain dilutions of the solutions previously dipped. Contaminants are primarily toxic metals such as chromium and cadmium. In the past, wastewater was typically discharged to sewers. Now it is sent to an effluent treatment plant where the metals are precipitated out, usually by neutralisation. The metallic sludge produced is disposed of off site. In the past sludges may have been deposited on site. See the profile on hazardous waste treatment plants, Section 4.

Wastes from machining operations comprise metal chips or swarf, usually contaminated by cutting fluids, spent cutting fluids and contaminated cleaning agents. Other sludges include those from settling pans, tanks or underground sumps. These are generally stored temporarily on site prior to specialist recycling or disposal off site. Heat treatment wastes include spent quenchers, sludges from quenching baths, and possibly spent solidified cyanide bath media. These materials are usually disposed of or recycled (in the case of oils) off site.

Many vehicle manufacturing plants have facilities for wastewater treatment which will generate sludge for off-site disposal.

A wide range of relatively inert waste material is generated, including packaging materials, empty containers (some containing residues) and trim shop off-cuts, which are typically disposed of off site.

While there may be a high level of care taken with current waste management practices, older sites may have been contaminated by less rigorous practices in the past, including the indiscriminant dumping of waste.

3. Contamination

The contaminants on a site will largely depend on the history of the site and on the range of activities undertaken 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 area with the greatest potential for contamination is the paint shop, followed by the engine and transmission plant. The most common contaminants are oils, solvents and hydrocarbon fuels.

Contamination by oils or solvents may result from spillages during the filling and emptying of storage tanks or, in production areas, leaks from storage tanks and drums, leaks from drums and skips containing oily sludges or machining swarf, or from the on-site disposal of waste cleaning solvents or paint sludges.

Areas likely to be affected by heavy metal contamination include those where floor sweepings from discing work stations in the BIW plant have been stored or disposed of, storage and disposal areas for paint and phosphating sludges, and the area occupied by the pre-treatment line in the paint shop. Contamination is likely to be localised, except where wind dispersion of metal dusts has occurred.

Contamination by fuels may be found in the area of fuel storage tanks, at the engine test bay (engine and transmission plant) and around fuel tanks at the assembly plant supplying finished vehicles undergoing testing.

Other potentially contaminating materials which may be encountered include acids and alkalis used in pre-treatment processes in the paint shop, wastes from carburising processes, and materials which may have been released as a result of former demolition works.

Asbestos may have been used for pipe and plant lagging, fireproofing or for roofing or cladding of buildings. Some asbestos dust may by produced by brake lining machining which in the past may have been disposed of on site.

Electrical equipment such as transformers and capacitors may have used polychlorinated biphenyls (PCBs) as dielectric fluids and these may have caused local contamination during refilling or dismantling.

3.2 Migration and persistence of contaminants

3.2.1 Oils and solvents

Oils and solvents are typically highly mobile, volatile liquids, and pose a considerable threat to water resources. Close to the soil surface, some may be lost directly to the atmosphere by evaporation. Groundwater may be contaminated by the downward seepage of liquids under gravity, the movement of vapours in unsaturated soils and their subsequent solution in groundwater, and the infiltration of groundwater through oil and solvent-contaminated soils. Oils and cutting fluids are mobile liquids and flow under the influence of gravity and the surface tension forces exerted by unsaturated soils. Surface water may be affected by run-off from, or rainwater infiltration through contaminated soil and by the discharge of oils and solvents into drains or sewers and ultimately into nearby water bodies.

The transport and fate of both inorganic and organic compounds within the soil will be dependent on a combination of physical, chemical and biological factors. The higher the natural organic matter and clay content of the soil, the greater the degree of adsorption of the organic compounds and the greater the reduction in contaminant migration. Thus, the greatest degree of mobility will occur in coarse-grained sands and gravels with little natural organic matter. The less soluble compounds which become adsorbed on to clay or organic matter may be sources of water pollution long after the source has been removed, by continuing to desorb into the soil-water. The risk to potential water supplies may therefore be considerable.

Additives and certain cutting fluids, such as those containing glycols, are water soluble. Although the solubility of some oils and solvents is relatively low, their dissolved concentrations may be several orders of magnitude greater than water quality standards permit. Relatively small quantities of solvents can have a severe impact on water resources, particularly potable water supplies. In most cases, these compounds are less dense than water and will, therefore, float on the surface of the water table. However, chlorinated solvents are denser than water and tend to migrate to the bottom of water bodies. They have a low taste threshold and may taint potable water supplies at very low concentrations. Their migration may not be consistent with the general groundwater flow.

Widespread contamination by solvents may improve the mobility and potential for groundwater contamination by other compounds (eg metals and other organics) which, although of low aqueous solubility, may dissolve in organic solvents.

Biodegradation processes in soils can be influenced by a number of factors including 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, 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. As a result of these factors, at high concentrations in soil, even relatively non-persistent compounds may not biodegrade readily.

3.2.2 Metals

Metals, metal salts in paint sludges, and phosphating sludges are not readily water-soluble. Because of their limited mobility, heavy metals are unlikely to present as significant a threat to the quality of water resources as oils and solvents. The movement of metals through the soil is significantly retarded by the presence of clay minerals and natural organic matter.

The solubility of some metals (eg copper, zinc and lead) increases 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. If phosphating solutions or other acidic effluents containing heavy metals have seeped into the ground, migration of these metals may be increased. Some compounds such as chromium trioxide, lead acetate, sodium cyanide and to a lesser extent antimony trioxide, are soluble in water.

Metals may pose a hazard to plant life through uptake and concentration. They are not biodegradable.

3.2.3 Inorganic compounds

Simple cyanides are slowly hydrolysed in water to form the carbonate and ammonia. Mineral acids are soluble but not biodegradable. Asbestos is insoluble and non-biodegradable. Wind dispersal of contaminated soil may be a further transport mechanism where there is gross surface contamination by some of the less mobile contaminants, particularly metals and asbestos.

3.2.4 Other organic compounds

The presence of organic anti-microbial agents will interfere with microbial populations and hence the biodegradation of compounds such as oils. The non-solvent materials contained in paints and resins are not water-soluble, are of high molecular weight and are only very slowly biodegradable. They are therefore expected to be fairly persistent.

Polycyclic aromatic hydrocarbons (PAHs) are persistent.

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

4. Sources of further information

4.1 Organisations

For information concerning vehicle manufacturing works in the United Kingdom, the following organisations should be consulted:

The Institute of the Motor Industry
Fanshaws
Brickendon
Hertfordshire
SG13 8PQ

The Motor Industry Research Association
Watling Street
Nuneaton
Warwickshire
CV10 0TU

The Society of Motor Manufacturers and Traders Limited
Forbes House
Halkin Street
London
SW1X 7DS

Transport Research Laboratory
Old Wokingham Road
Crowthorne
Berkshire
RG11 6AU

4.2 Sources of information concerning the activities described in this profile

Hilger-Hartley J. *Management of vehicle production.* Butterworths, 1981.

Maxcy G. *The motor industry.* George Allen and Unwin, 1959.

Nachtman E S and Kalpakjian S. *Lubricants and lubrication in metalworking operations.* Marcel Dekker, 1985.

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: coatings (paints and printing inks) manufacturing works
Engineering works: mechanical engineering and ordnance works
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works
Metal manufacturing, refining and finishing works: iron and steelworks
Waste recycling, treatment and disposal sites: hazardous waste treatment plants

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.

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.

Verschueren K. *Handbook of environmental data on organic chemicals.* 2nd 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.

Metals, metalloids and their compounds	aluminium antimony barium cadmium chromium copper iron lead nickel selenium silver tin zinc
Inorganic ions	borates chlorides phosphates (iron, zinc) sulphates (barium, lead) sulphides (zinc, cadmium) cyanides
Acids	sulphuric phosphoric chromic
Alkalis	sodium hydroxide
Fuel and other oils	petrol diesel mineral oils (including engine and transmission oils) cutting fluids polycyclic aromatic hydrocarbons (PAHs) (in oils and cutting fluids) alkylated aromatics (in oil)
Solvents (non-chlorinated)	mixed hydrocarbon solvents eg turpentine white spirit, solvent naphtha ethyl acetate benzene toluene xylenes alcohols eg ethanol propanol

	ketones
	eg acetone
	    methyl ethyl ketone (MEK)
	glycols
	eg propylene glycol
	    ethylene glycol (also in antifreeze)
	    ethylene glycol diacetate
	    hexyleneglycol (also in
	    brake fluids)
	glycol ethers
	eg ethylene glycol monoethyl and monobutyl ethers
	glycol esters
	eg ethylene glycol monoethyl ether acetate

Solvents (chlorinated)	1,1,1-trichloroethane trichloroethylene dichloromethane dichloroethane dichlorobenzene

Other organic materials	adhesives/sealants
	eg epoxy resins
	    nitrile-phenolic resins
	    polyvinyl chloride
	    bituminous materials
	    paraffin wax
	paints/lacquers
	eg natural resins
	    alkyd resins/enamels
	    maleic resins
	    amino resins
	    cellulose nitrate lacquers
	    acrylic enamels
	    organic pigments
	    low level radioactive luminous paints
	corrosion inhibitors
	eg aluminium paints
	    chromic acids
	    potassium ferricyanide
	    potassium fluorozirconate
	    sodium fluoroborate
	anti-microbial agents and fungicides
	eg tributyltin oxide

General contaminants	asbestos polychlorinated biphenyls (PCBs)

Table 1 Main groups of contaminants and their probable locations

Engineering works: vehicle manufacturing works

Main groups of contaminants	Location									
	Building fabric/ pipe insulation	Fuel storage/ pipework	Press shop	Body in white plant	Paint shop	Plating area	Engine transmission plant	Assembly plant	Waste storage/ disposal areas	Electrical transformers
Metals, metalloids and their compounds										
Inorganic compounds										
Acids										
Alkalis										
Asbestos										
Solvents										
Fuels and oils										
Polychlorinated biphenyls (PCBs)										

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

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

Copies may be purchased from:
Publications Sales Unit
Block 3, Spur 7,
Government Buildings,
Lime Grove,
Ruislip, HA4 8SF

Price £10
Cheques payable to DOE.