Department of the Environment
Industry Profile

Engineering works

mechanical engineering and ordnance works

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Contaminated Land and
Liabilities Division

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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

Engineering works: mechanical engineering and ordnance works

This profile is based on work by Environment Assessment Group Limited and Aspinwall and Company Limited 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: mechanical engineering and ordnance works

1. Background

In engineering works, metal raw materials are processed into commercial products which range from machine tools and engine components to nuts, bolts and wire.

This profile covers mechanical engineering in general. Light mechanical engineering is regarded as the manufacture of small products, primarily components for larger machines and also tools, implements, locks, metal and plastic furniture, etc. Heavy mechanical engineering involves similar operations producing large scale equipment such as bridge members, structural steel and industrial machinery. This diverse range of products is generally produced by the same fundamental processes such as casting, machining, surface treatment and finishing, and assembly.

The type of high precision engineering carried out on a large scale at ordnance works is also covered by this profile. The manufacture of ordnance equipment can be divided into: ammunition/rocket/bomb shells and casings; guns and weapons; and tanks and other armoured vehicles. These activities tend to be specialised, with production taking place on separate sites. Engineering and explosives are combined at 'filling sites' where empty (engineered) components are filled with explosives.

Explosives and propellants manufacture, which involves highly specialised chemical engineering processes, is dealt with in a separate profile (see Section 4.3). Some of the larger ordnance works may have had their own sources of gas and power and the related profiles (see Section 4.3) should also be consulted.

1.1 History

The origins and subsequent development of mechanical engineering are closely associated with the development of machine tools.

Steam power stimulated the development of the early machine tools during the 18th Century. The Soho Works in Birmingham, where steam engines were manufactured during the last quarter of the 18th Century, was arguably the first mechanical engineering works. Prototypes of turning, drilling, boring, slotting, shaping, forging and riveting machines were produced during the first half of the 19th Century at specialist workshops in London, Birmingham, Edinburgh and Manchester. Production of these machines expanded enormously after 1850 and led to the mechanisation of many small metal-goods industries which had hitherto been handicrafts. Many factories were set up during the second half of the 19th Century and early 20th Century to manufacture sewing machines, bicycles, small arms and motor cars. Milling and grinding technologies were imported from the USA and mineral oils replaced traditional animal and vegetable-derived lubricants. The accurate machining of interchangeable components by machine tools reduced the reliance of industry on skilled craftsmen and enabled mass production to develop.

Engineering works in general expanded rapidly during the First World War to manufacture munitions and armaments. However, after the war, there was excess capacity which, together with the onset of industrial depression, led to the decline of many engineering works during the 1920s and 1930s. At the same time, the emphasis in engineering switched from traditional products, such as marine engines and textile machinery, to machinery for food manufacture, machine tools and miscellaneous machines. Further developments in manufacturing technology took place with the introduction of electric power and the development of the National Grid.

Engineering expanded rapidly again during the Second World War as factories concentrated on producing war equipment. When the war ended, there was a brief contraction, but mechanical engineering enjoyed sustained growth during the 1950s and 1960s, with new industries such as oil refining and synthetic textile manufacture providing fresh opportunities for the manufacture of machinery.

Increasing automation has been a feature of the post-war period, as mechanisation of production has been extended and new types of power driven equipment have been devised, particularly in transport, agriculture and manufacturing. New materials have also been introduced, such as light metal alloys, plastics, synthetic adhesives, synthetic lubricants and polymer-based paints; computer-controlled machine tools have also found widespread applications.

A combination of factors including foreign competition and adverse economics, has caused the industry to decline since the 1970s. Until then there was a large number of small engineering firms but many of these have been replaced as a few dominant groups emerged. Heavy engineering has been largely superseded by light industry, electronics and communications. It can therefore be expected that many former engineering works sites will become available for alternative development in the future.

Before the 19th Century, arms were manufactured by many small independent producers; the components they produced were not interchangeable and supply in times of war was haphazard. From the 19th Century the Government took over some ordnance works and during the First World War sought to standardise weapons manufacture and supply by building three large engineering sites. During the early to mid 1900s, large research establishments were built which carried out engineering manufacture, explosives production and testing. The demand for diverse and more accurate weapons meant that during and between the wars, a number of new ordnance sites were built to restock weapons, update old forms of equipment and research new armaments.

1.2 Location

Historical tool-making centres include areas such as Manchester, the West Riding of Yorkshire, the Glasgow area, the West Midlands and parts of London. With the advent of mass production, machinery-making works subsequently developed in the neighbourhood of the mechanised industries which they served. Thus light engineering works concentrated in Birmingham (small arms), Coventry (bicycles and then motor cars), Clydebank (sewing machines) and Lincoln (agricultural machinery). These have remained important engineering centres, but the industry as a whole is scattered and no area of industrial development or population centre is without some form of engineering works.

The heavy engineering industry is located primarily in the industrialised North-East and North-West, the Midlands, South Wales and at major ports. In many cases, it is close to primary and secondary metal smelting operations.

Light engineering works are typically small and few exceed ten hectares in size. However, contamination resulting from on-site activities may extend beyond the confines of the site boundary where mobile substances such as solvents, oils and liquid hydrocarbon fuels are involved.

Ordnance engineering is not located in any specific separate locations from other types of engineering work, although those involved in the filling and testing of shells would be remote from centres of population.

2. Activities

2.1 Raw materials

An extensive range of feedstocks may be employed in mechanical engineering works.

Metals and alloys	Steels are the most widely used metal alloy. Since the Second World War, non-ferrous metals such as copper and zinc have been increasingly used, largely in alloys. Metals such as lead and tin are components of solders.
Plastics	Plastics are relatively recent arrivals. 'Bakelite' and celluloid were in use prior to 1939, but it was the shortage of metals during the Second World War which prompted the replacement of many metal components with plastic parts. The thousands of different plastics used in manufacture today fall into two major categories: thermoplastics and thermosets. Thermoplastic polymers are melted or softened in order to be formed under pressure into the required shape which is established on cooling the product. The process is reversible and the plastic material can be reshaped and therefore recycled. Examples of thermoplastic polymers are: polyethylene, polypropylene, polytetrafluoroethylene (PTFE), polystyrene, polyvinyl chloride (PVC), polymethylmethacrylate (eg Perspex), Nylon 66. Thermosetting plastics are converted into finished products with the application of heat and pressure. Chemical cross linking takes place and the process is not reversible; the materials cannot be recycled. Examples of thermosetting plastics are: polyester, phenol-formaldehyde (eg Bakelite), epoxy resins, amino resins and polyurethanes.

Lubricants	Lubricants are used in mechanical engineering works, both in processing (eg cutting fluids) and in final assemblies (eg greases). Animal and vegetable-derived lubricants were largely superseded by petroleum and coal tar-derived mineral oils during the late 19th Century. Synthetic oils have been introduced since the Second World War. Some applications require solid lubricants such as graphite. Petroleum-derived mineral oil, the most common lubricant, is used in cutting fluids, in combination with water to make an emulsion. These oils may be paraffinic or naphthenic in nature and frequently contain low concentrations of polycyclic aromatic hydrocarbons (PAHs); additives such as detergents, corrosion inhibitors, extreme pressure additives and viscosity improvers are typically included.
Surface treatment reagents	The heat treatment of metals requires quenching media. Common examples of such media are water, brine, mineral oils (the most prevalent) and acidic solutions based on sulphuric acid or alkaline solutions based on sodium hydroxide. Other surface treatments of metals are carburising, preparation of surfaces prior to painting, anodising, electropolishing and etching.
Cleaning compounds	Cleaning compounds include: alkaline cleaners, detergents, oil-water emulsions and solvents. Trichloroethylene was widely used from about 1930, but was largely replaced by 1,1,1-trichloroethane during the mid 1970s.
Coating materials	Coating materials include: temporary protective coatings, primers or base coats, top coats and plating chemicals. Primers are used as preparation coats for paint or adhesives and often contain a corrosion inhibitor when applied to steels. They have traditionally been based on red lead (lead oxide) and linseed oil. Zinc chromate, which was introduced during the Second World War and is still in use, is usually formulated with an alkyd resin or linseed oil. Zinc metal, zinc oxide, zinc molybdate and zinc phosphates have more recently been used as primer pigments in industrial maintenance coatings. Paint shops traditionally used solvent-based paints and coatings, and solvent thinners as additives prior to use. In recent years, the trend has been away from solvents towards water-based paints and less toxic bases.

Bonding materials	A wide range of adhesives and sealants have found applications in mechanical engineering, particularly since the Second World War. Some of the more common formulations are polyvinyl chloride (PVC) plastisols (dispersions of PVC in a plasticiser, usually a phthalate ester), nitrile-phenolic and epoxy adhesives.
Miscellaneous	These include fuels, hydraulic oils and water treatment reagents.

2.2 Production processes

A large number of different processes has been employed in engineering works. The most common and/or environmentally sensitive are as follows:

2.2.1 Metal-working processes

Molten metal processes (large-scale)

These are covered in the DOE Industry Profiles (see Section 4.3) on iron and steelworks, on lead works and on non-ferrous metals works.

Die-casting

This is the principal casting process undertaken in light mechanical engineering works. It involves pouring or pressure injecting molten metal (usually alloys) into a reusable steel mould, to give small, high definition components.

Manipulative processes

These involve shaping the hot or cold metal by plastic deformation; eg by rolling, forging (shaping bulk metal using hammers or presses) extruding and drawing (producing long lengths of wire, tubing etc by pulling material through a die, which is a shaped orifice), shearing (cutting sheets between two straight blades), bending and pressing operations.

Powder techniques

These essentially involve pressing a fine metal powder into the desired shape followed by sintering (ie heating so that the powder fuses together).

Machining processes

Large areas of sites are taken up by machine shops where metallic parts are physically cut, shaped, and bored into precision components. Machine shops can house a large number of individual machine units. Each unit contains water-based cutting oils to lubricate and cool the metal. These oils are usually contained and recycled but eventually require replacement. Each unit also has its own lubricating oils which also require replacement and disposal.

2.2.2 Plastic-forming processes

Injection moulding

The most common process entails the injection of a molten thermoplastic into a water-cooled mould to form pipe fittings, tool handles, control knobs etc.

Extrusion

This is probably the second most widely employed process. It involves forcing a molten thermoplastic through a die to make pipes, curtain rails, sealing strips, plastic bottles (by extrusion blow moulding) etc.

Shaping
Plastic sheets are heated and shaped by being pressed around moulds (mechanically, by vacuum, or by pressure) to make machine housings, drinking cups, margarine tubs, car bodies etc.

Machining
Conventional machining operations similar to those employed for metals are also used for plastics.

2.2.3 Heat treatment of metals
Certain metal components may be heat treated in order to change the microstructure and properties of the material to suit subsequent manufacturing processes or to improve the performance of the component in service. Heat treatment is usually applied to steel components and involves controlled heating and cooling to change properties such as hardness, strength, ductility and toughness. Heating is carried out in a furnace and cooling or quenching is usually done in a liquid bath or air blast. The different types of heat treatment processes commonly employed include:

Annealing
Steel is heated to a temperature above the upper critical temperature, then slowly cooled to make it more ductile.

Tempering
Hardened steel is reheated at any temperature below the critical range, in order to change (usually decrease) its hardness.

Flame-hardening
Surface layers of steel are heated and then the metal is quenched with oil or water to give a harder surface.

Carburising
Steel is heated in a carbon-rich environment to increase the carbon content of, and hence to harden, the surface layers. Sodium cyanide, with sodium carbonate and sodium chloride, form the heating medium for the liquid carburising process. The sodium cyanide is rarely replaced although eventually it becomes spent and requires disposal. Barium carbonate together with carbonaceous material (ie material containing carbon) may be used during dry carburising.

Nitriding
Steel is heated in a mixed ammonia/hydrogen atmosphere so that nitrides are formed on the surface to make a hard finish.

2.2.4 Metal cleaning and pre-treating
Mechanical cleaning
Surface finishing of machined parts is undertaken using physical abrasion and fine polishing. Mechanical cleaning may involve:

power brushing with a rotating fibre or wire brush to remove loose deposits;

grinding with abrasive wheels to remove burs;

abrasive blast cleaning (blasting the surface with high velocity sand or shot);

vibration of the product with abrasive materials (eg sand or special pellets).

Chemical surface treatment
Aluminium and its alloys are commonly surface hardened by dipping in chromic acid (alchromating), or by heating and quenching in water. Pre-treatment of steel surfaces by dipping or spraying with phosphoric acid (phosphating), hydrochloric acid or zinc phosphate can also be undertaken prior to painting. Surfaces may be painted with primers.

Chemical cleaning
This is achieved by the action of oil-water emulsions, liquid or vaporised solvents, alkaline or acidic solutions, or steam.

Smooth finishes
Filling irregularities with solder or putties may be necessary to give smooth finishes.

2.2.5 Plating and anodising
Many metals are given a decorative or protective coating to complete the manufacturing process. Surface plating and treatment of metals are often carried out in designated 'plating shops'. Some processes require the metal components to be moved through a succession of tanks.

Electroplating
A surface coating is applied to the base metal by immersing it in a bath (acid, alkaline or neutral) and passing an electric current through the bath.

Electroless plating
This is similar to electroplating but instead of an electric current, a reducing agent (eg formaldehyde) is used. A uniform and dense plating thickness is produced.

Hot-dip galvanising and tinning
Hot-dip galvanising involves immersion of the metal to be plated, usually iron or steel, into a bath of molten zinc to form a protective coating of zinc and zinc compounds. This process is used for all kinds of components including large structures such as bridge members and structural steel. Hot-dip tinning – a similar process using a molten tin bath – is frequently applied to food packaging equipment.

Anodising
Anodising is an electrolytic oxidation process in which the surface of the metal is converted into an insoluble oxide. It provides increased corrosion resistance, a base coat for subsequent coats, or a special surface for electrical applications. Aluminium is the main metal treated by anodisation.

2.2.6 Painting and coating
As with plating, painting can be carried out in designated 'paint shops'. Originally, painting would have been by hand or with spray guns in the open workshop.

Paint spraying and dipping
In recent years, 'spray booths' have been used to reduce emissions. Spray booths are enclosed areas where reduced air pressure draws the paint mist arising from spraying into a concentrated form through the use of water or by means of electrostatic deposition. 'Wet-backed' booths tend to be more common, where paint is entrained in water and collected in a trough as a sludge which then requires disposal. The quality of the sludge depends on the type of paint used. Many paints are based on metals, eg chromium, lead. Isocyanate-based paints are also used (forming ureas in water).

Grease coatings
Temporary mineral oil or grease-based protective coatings may be applied to protect machined components from corrosion during storage.

Varnishing and stoving
Where a harder surface coating is required, varnishes and stoving enamels are used. These are generally solvent-based organic resins which are heated or air-dried.

Powder coating
This is a modern non-solvent technique which is being increasingly used for metals.

Washdown
The cleaning of painting, stoving and varnishing equipment regularly involves the use of non-chlorinated solvents, eg acetone and methyl ethyl ketone, and chlorinated solvents, such as 1,1,1-trichloroethane, for washing.

2.2.7 Assembly
Assembly operations, in which component parts are combined into finished products, may be largely manual, highly mechanised or fully automated. Lubricants may be applied during these operations. Assembly areas are largely relatively 'clean', but they may involve the use of degreasing solvents to clean metal components.

The main joining processes are:

Adhesive bonding
Adhesives have found increasing applications, particularly for joining dissimilar materials (eg metals and plastics). Hardened resins, eg two-part epoxy or isocyanate mixes, are used to fix components in position.

Soldering and brazing
This process is used to form a joint between metal surfaces using a lower melting point metal or alloy.

Welding
The metal surfaces are joined by melting and fusing them together.

Spot welding
This is the type of welding where the joint formed is required to resist only light or temporary stresses, eg in steel meshes.

Mechanical fastening
A wide variety of mechanical fastenings, such as bolts and nuts, screws, rivets, pins, spring-retaining clips etc, is used to link both metal and plastic components. Press and snap-on fittings are also used to join plastics.

2.2.8 Explosives and propellant filling
On munitions manufacturing sites, shells are filled with explosives delivered from manufacturing works. Explosives and propellants which have very complex chemical compositions, are dealt with in a separate profile (see Section 4.3). Filling has always been a very labour intensive process with larger stores (shells) being filled by hand. Even though mechanisation has increased, some larger stores are still hand-filled or packed.

2.3 Ancillary processes

Most engineering sites will have boiler houses and effluent treatment plants. Plants are present on some sites for the storage, separation, recovery and disposal of waste oils.

2.4 Wastes

2.4.1 Metallic
Wastes from machining processes include metal swarf (fine shreds of metal arising from metal cutting), usually mixed with cutting oils and metal off-cuts. These invariably are disposed of off site by a scrap metal merchant. Metal off-cuts (larger pieces of waste metal) may be recycled on site, for example in a die-casting shop, if a furnace is available. Metallic materials include steel, nickel, aluminium, chromium and copper. In the past, these wastes may have been stored directly on the ground. More recently, scrap metal skips have been employed, allowing the metals to be more easily segregated.

Some of the metal-working processes, such as the extrusion of metal into lengths using dies, sometimes require high temperatures. The re-heating of the metal may cause emission of metal vapour and dust into the local environment. In the past these emissions were uncontrolled but, in more recent years, they have been extracted by exhausts and collected in precipitators.

Other metallic waste products are:

Dross	The floating scum of oxidised metals and other impurities skimmed from the surface of molten metals in furnaces in die-casting shops; some may be recycled.
Metal rich dusts and sludges	These are produced by mechanical cleaning processes and the welding and soldering of joints and are typically disposed of off site. In the past, the metal dust collected from extraction filters and floor-sweepings may have been disposed of by on-site burial. In current practices, this may be recycled.

Quench bath sludges	These are soluble metal salts which accumulate in heat-treatment quenchants and which come out of solution when the quenchant cools. The salts are deposited on the bottom of baths and tanks and are usually disposed of off site.

2.4.2 Plastics

The plastic wastes include swarf and off-cuts from machining and forming processes. Wastes contaminated by lubricants are typically disposed of off site. Thermoplastic wastes may be ground and recycled on or off site.

2.4.3 Oils

In the past, cutting, lubricating, hydraulic and quenching oils may have been disposed of by pouring directly onto the ground on site or via soakaways. More recent practice is to store them in drums ready for disposal off site. Spillages of oils on machine shop floors are commonly soaked up by sawdust, which used to be subsequently dumped. Cutting-oils draining from metal swarf could reach the ground if there is damage to the bases of the skips in which the swarf is stored ready for disposal.

Oily metal-rich sludges accumulate in sumps from recirculated cutting fluids, in floor drainage sumps in metal working areas, and in bottom sludges from tanks holding oil-based cleaning agents. The breakdown and recombination of hydrocarbon molecules in oils which are repeatedly heated and cooled leads to an increase in the concentration of PAHs. Some oils may be recycled.

2.4.4 Chemical surface treatment

The process of carburising yields cyanide wastes in the form of solidified salts from liquid carburising baths and residues of the cyanide-containing froth skimmed from such baths. Cyanide effluents are usually treated on site by chemical oxidation (using chlorine gas or sodium hypochlorite) to cyanate, prior to discharge to the sewer. Solids are usually disposed of off site. Care must be taken that wastes with cyanide and acid components do not mix to form the gas hydrogen cyanide.

2.4.5 Plating and painting wastes

Plating and painting shops have traditionally produced highly 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. Wastewater was passed directly to sewers or, more recently, to an effluent treatment plant where the metals are precipitated out, usually by neutralisation. The metallic sludge produced is disposed of off site as a sludge or filter cake. However, in the past sludges may have been deposited on site.

2.4.6 Cleaning fluids

Spent cleaning fluids, including both water-based detergents and organic solvents, used to be neutralised if necessary and then discharged to sewer or river. Recent practice is either to treat them in an effluent treatment plant or to drum them up for off-site disposal.

2.4.7 Other wastes

Scale which has accumulated in cooling water systems, is removed during periodic clean-outs and usually disposed of off site or flushed down the sewer.

Ash from coal-fired boilers and furnaces may be disposed of on or off site.

General wastes such as damaged pallets, empty containers and packaging materials are usually disposed of off site.

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 Tables 1a and 1b. 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 is particularly likely to be associated with materials handling and storage, accidental release of materials through spills and leaks in the engineering and ancillary processes, and from the disposal of waste on site.

Storage and movements of raw materials around sites may have caused localised contamination. Storage areas, particularly in the past, were rarely contained. Materials leaking form drums and tanks were able to percolate directly into the soil, where they could remain or disperse. If materials were of sufficient volume or mobility, they could reach groundwater. Materials of particular concern are solvents such as trichloroethylene, toxic metals (for example in plating chemicals) and oils, which would have been stored in large volumes and thus presented the potential for extensive contamination. The presence of underground storage tanks, soakaways, sumps, drains and pipework all indicate a potential for leakage of liquids into the soil.

Spillage of liquids during operations may have been quite common at older manufacturing sites. Contamination in this instance would be from the use of degreasing and washdown solvents and detergents. The degree of contamination depends on factors such as surfacing, condition of equipment etc. Liquids may have percolated from tanks and pipework to cause discrete contamination. Also, operational areas would be generally contaminated from surface spillages of materials. Residual equipment on sites may have retained contamination. For example, the brickwork of old plating shops often contains high concentrations of cyanides.

Some types of wastes may have been deposited on site, depending on the availability of land, or used to fill voids or make up ground levels. The disposal of wastes on site may have left concentrated residual contaminants in soils. Such materials could include asbestos sheets and lagging, oils, paints and general building materials from site redevelopment. Explosives wastes were traditionally disposed of on site.

The most likely contamination on ordnance sites would be from testing shells. Designated areas of sites where destructive testing was carried out are often heavily contaminated with metallic shot and metal fragments. Sites involved in non-destructive testing would have used X-rays which (prior to 1950) would have involved the use of an X-ray source. Specialist chemicals used in non-destructive testing, include mercurous nitrate. Some surplus or off-specification explosives and propellants may have been burned on site. The principal risks associated with the concentrations of the chemicals likely to be found on former ordnance works are toxic rather than explosive. Nitroglycerine, nitroguanidine and TNT are the most significant in terms of toxicity (see the profile on the explosives industry, Section 4.3).

3.2 Migration and persistence of contaminants

3.2.1 Oils and solvents

Of particular concern are oils, solvents and hydrocarbon fuels which, because of their mobile nature, can contaminate large areas. Chlorinated solvents and solvents containing aromatic hydrocarbons (eg benzene, toluene and xylenes) pose a considerable threat to water resources in relatively small amounts. In the past it was not uncommon practice for engineering works which used only small quantities of oils and solvents to discharge waste fluids into soakaways (eg trenches, conduits) or drains leading to the sewer (which may have leaked). Therefore the scale of use of these materials is not necessarily a guide to the likelihood of contamination. Misuse of solvents - to clean floors for example - could also have allowed solvent to seep into the ground.

Surface water may be contaminated by run-off from contaminated soil or the seepage of contaminated groundwater into drains which discharge into surface watercourses.

Once in the ground, oils and solvents flow downwards under gravity, but leave behind a residue held within the unsaturated soil. This residue may contaminate rainwater infiltrating through the ground and therefore may present a long-term source of groundwater pollution. If they reach the water table, light substances (eg hydrocarbon fuels and solvents, and most oils) float on top of the groundwater, spreading out as a covering film. This floating layer slowly leaches water-soluble components into the groundwater and may move in the direction of groundwater flow. Liquids more dense than water (eg halogenated solvents and certain lubricating oils) sink through the groundwater column, dissolving into it as they do so, until they encounter a low permeability barrier on which they may pool or flow down-gradient. Floating layers and sunken pools of oils and solvents present a long-term threat to groundwater quality. A further problem frequently encountered with volatile components is that vapours moving through unsaturated soils may subsequently dissolve into groundwater, giving rise to contaminant concentrations which exceed drinking water standards.

Soluble synthetic oils and oil-water emulsions pose a particular threat to water quality. The base constituents of mineral oils generally have very limited water solubility, although certain synthetic oils (eg polyglycols) will dissolve in water. Oil-water emulsions are usually less viscous than the neat oils and therefore flow more readily. The additives included in the oils may be water-soluble. Hydrocarbon solvents, chlorinated solvents and components of fuel oils have limited but still significant water solubilities. Many alcohols, ketones and glycols are completely

miscible with water. Soluble hydrocarbons will dissolve in groundwater and migrate in groundwater flow.

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. Because of these factors, at high concentrations in soil, even relatively non-persistent compounds may not biodegrade readily.

3.2.2 Metals

The metals and their salts contained in paint sludges and pre-treatment effluent sludges are not readily water-soluble. However, they may be slowly leached into solution by acidic rainwater.

With their limited mobility, metals do not present the same threat to the quality of water resources as do solvents or oils, except where releases of pre-treatment solutions have occurred (eg through leaking drains) or where acidic effluents (eg from metal cleaning) have been co-disposed with metal-rich wastes. Slow leaching by acidic rainwater infiltration or surface water run-off may present a threat to water quality where severe heavy metal contamination of soils occurs. Where the surface soil is contaminated, dispersion by wind may become significant. Metals are not biodegradable. Widespread contamination of the site may also occur through the dispersion of airborne contamination, eg metal vapour.

3.2.3 Polychlorinated biphenyls (PCBs)

PCBs, present in certain types of electrical equipment, have a low solubility in water and are highly persistent. They are fat-soluble and tend to accumulate in food chains.

3.2.4 Asbestos

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 it may still be associated with existing buildings and plant.

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.

4. Sources of further information

4.1 Organisations

For information concerning engineering works in the United Kingdom, the following organisations and trade associations should be consulted:

Engineering Industries Association
16 Dartmouth Street
Westminster
London
SW1H 9BL

METCOM (Mechanical and Metal Trades Confederation)
Carlyle House
235-237 Vauxhall Bridge Road
London
SW1V 1EJ

Engineering Construction Industry Association
17 Dartmouth Street
London
SW1H 9BL

Environmental Services Group
Royal Ordnance plc
Westcott
Aylesbury
Buckinghamshire
HP18 0NZ

Machine Tools Technologies Association
62 Bayswater Road
London
W2 3PS

Pera International
Melton Mowbray
Leicestershire
LE13 0PB

Institute of Metal Finishing
Exeter House
48 Holloway Head
Birmingham
B1 1NQ

British Foundry Association
8th Floor, Bridge House
121 Smallbrook, Queensway
Birmingham
B5 4JP

Institution of Mechanical Engineers
1 Birdcage Walk
London
SW1H 9JJ

4.2 Sources of information concerning the activities described in this profile

Information concerning specific engineering works sites may be available from the local studies sections of public libraries.

History and development of mechanical engineering

Gregory M S. *History and development of engineering.* Longman, 1971.

Allen G C. *British industries and their organisation.* 5th Edition. Longman, 1970.

Guest G M. *A brief history of engineering.* Harrop, 1974.

Ordnance

Health and Safety Executive. *Disposal of explosive waste and decontamination of explosive plant.* Health and Safety Guidance Note HS(G)36. London, HMSO, 1987.

Processes

American Society for Metals. *Metals handbook.* 9th Edition. 1981.

Her Majesty's Inspectorate of Pollution. *Combustion processes. Reheat and heat treatment furnaces.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 1/17. London, HMSO, 1993.

Contaminating materials

World Health Organisation, International Agency For Research On Cancer (IARC). *IARC Monographs on the evaluation of carcinogenic risks to humans.* Volume 47. Some organic solvents, resin monomers and related compounds, pigments and occupational exposures in paint manufacture and painting. 1989.

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

The Royal Society of Chemistry. *Chemical safety data sheets.* Volume 1: Solvents. RSC, 1988.

Case study including information relevant to this profile:

Paul V. *Bibliography of case studies on contaminated land: investigation, remediation and redevelopment.* Garston, Building Research Establishment, 1995.

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: explosives, propellants and pyrotechnics manufacturing works
Engineering works: aircraft manufacturing works
Engineering works: electrical and electronic equipment manufacturing works (including works manufacturing equipment containing PCBs)
Engineering works: railway engineering works
Engineering works: shipbuilding, repair and shipbreaking (including naval shipyards)
Engineering works: vehicle manufacturing works
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 metals works (excluding lead works)
Metal manufacturing, refining and finishing works: precious metals recovery 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.

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.

Verschueren 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. Of particular relevance are:

Department of the Environment. *Heat-treatment cyanide wastes.* Waste Management Paper No. 8. 2nd Edition. London, HMSO, 1985.

Department of the Environment. *Special waste.* Waste Management Paper No. 23. London, HMSO, 1982.

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.

General engineering works

Metals as raw materials		aluminium, copper, zinc, tin, beryllium, titanium, magnesium, chromium, tungsten, nickel, cobalt, lead, manganese, molybdenum, vanadium
Metals for solders		lead, cadmium, tin, copper, zinc, silver
Metal salts:		
	plating chemicals	salts of cadmium, chromium (trivalent and hexavalent), copper, nickel, tin, zinc and silver are commonly used in solution for the plating of metals. The salts used include cyanides, hydroxides, carbonates, chlorides, oxides and sulphates
	paints	salts of chromium, lead, cadmium, antimony and arsenic
	primers	red lead (lead oxide), zinc chromate, zinc oxide, zinc molybdate, zinc phosphate and manganese phosphate
Inorganic compounds:		
	carburising media	sodium carbonate, sodium chloride, barium carbonate, sodium cyanide
	effluent treatment chemicals	sodium hypochlorite, sodium bisulphite, sodium metabisulphite. Sodium hypochlorite and chlorine for cyanide treatment. Sodium bisulphite for chromium treatment. Ferric sulphate and polyelectrolytes for flocculation of solids in suspension
	carburising media	carbonaceous material
Organic compounds:		
	mineral oils	for lubricating, quenching and cleaning
	electroless plating chemicals	formaldehyde
	bonding materials	isocyanate mixes, nitrile-phenolic adhesives, epoxy adhesives
	coatings	primers, paints or enamels for machinery and other equipment, typically include alkyd, epoxy or polyurethane resins

	temporary protective coatings on steels	generally petroleum based (eg waxes, bitumen, lubricating-type oils)
Solvents:		
	chlorinated solvents	common halogenated solvents include 1,1,1-trichloroethane, dichloromethane (methylene chloride), tetrachloroethylene (perchloroethylene), trichlorofluoroethane and tetrachloroethane. Others are trichloroethylene and perchloroethane
	non-chlorinated solvents	alcohols, acetone, solvent naphtha, benzene, toluene and xylenes (in white spirit), glycols, glycol ethers and esters, ketones, methyl ethyl ketone, aldehydes. Aldehydes, ketones, alcohols and other organic compounds are added to plating baths as brighteners
Lubricants:		
	animal and vegetable	natural oils such as rape seed oil and castor oil
	synthetic oils	fatty acid esters, silicones, polyalkenes, polyglycols and phosphate esters
	solid lubricants	graphite, molybdenum disulphide and soaps
	petroleum derived mineral oil	may be paraffinic or naphthenic in nature and frequently contains low concentrations of polycyclic aromatic hydrocarbons (PAHs)
Fuel oils		light gas oil, medium fuel oil, diesel
Acids:		
	for water treatment	hydrochloric
	for quenching	sulphuric
	for anodising	sulphuric, oxalic and chromic
	for pretreatment before painting	hydrochloric, phosphoric, chromic
	for electropolishing	usually phosphoric, hydrofluoric, nitric, sulphuric and chromic (for chromating)
	for etching	hydrochloric or hydrofluoric with nitric for etching stainless steel

Alkalis:		
	for cleaning	alkali metal (eg sodium) orthophosphates hydroxides carbonates bicarbonates silicates borates sodium hydroxide for boiler maintenance
	for quenching	sodium hydroxide
	for etching	aqueous mixtures of sodium hydroxide, potassium hydroxide, trisodium phosphate or sodium carbonate are most commonly used for etching aluminium and its alloys
	for effluent treatment	sodium hydroxide sodium carbonate (eg for treatment of cyanide-containing effluent) calcium oxide (for neutralisation of acidic effluents)
Detergents		
Scale		
Ash		
Asbestos		
Polychlorinated biphenyls		

Ordnance works including the manufacture of military explosives and propellants

See also the profile on the explosives industry, Section 4.3.

Explosives and associated chemicals	silver and lead azides nitrite, nitrate, ammonium, chlorate, perchlorate and sulphate ions ammonium nitrate potassium sulphate ammonium perchlorate lead styphnate tetrazene TNT - 2,4,6-trinitrotoluene RDX - cyclotrimethylene trinitramine (cyclonite, hexogen) HMX - cyclotetramethylene tetranitramine (octogen) Tetryl - trinitrophenylmethylnitramine PETN - pentaerythritol tetranitrate nitroguanidine NG - nitroglycerine NC - nitrocellulose 2,4,6-trinitrophenol (picric acid) mono- and dinitrotoluene glycerine ammonia phenol anilines ethyl carbonate (solvent for NC) dibutylphthalate diphenylamine graphite polyisobutylene hydroxy-terminated polybutadiene isopropylnitrate hydrazine dimethylhydrazine
Radioactive sources	radioactive sources are associated with non-destructive testing equipment
Metals	these include lead (from shot etc), silver, magnesium, cadmium and arsenic. Mercury may also be present as mercury fulminate through its past use in detonators, and as mercurous nitrate for non-destructive testing
Acids	nitric, sulphuric, acetic
Alkalis	

Solvents	acetone ether ethanol cyclohexanone toluene
Asbestos	
Polychlorinated biphenyls	
Cyanides	
Oils	including oil-soaked sawdust
Fuels	diesel gas oil liquid rocket fuel

Table 1a Main groups of contaminants and their probable locations

Engineering works: mechanical engineering and ordnance works – general engineering works

Contaminant		Location								
Main group	**Sub-group**	**Building fabric**	**Raw material delivery and storage**	**Process areas**	**Tanks, pipework and pumps**	**Product storage and blending**	**Waste storage/ on-site disposal**	**Wastewater treatment facilities**	**Fuel storage**	**Electricity substations and transformers**
Metal and metalloid contaminants	metals and raw material		■	■						
	metals for solders		■	■	■					
Inorganic compounds	plating chemicals		■	■	■	■	■	■		
	paints		■	■		■	■	■		
	primers		■	■	■	■	■	■		
	carburising media		■	■	■	■	■	■		
	effluent treatment chemicals		■				■	■		
Acids and alkalis			■	■	■	■	■	■		
Asbestos		■								

Shaded boxes indicate areas where contamination is most likely to occur

Table 1a Main groups of contaminants and their probable locations

Engineering works: mechanical engineering and ordnance works – general engineering works cont.

Contaminant		Location								
Main group	Sub-group	Building fabric	Raw material delivery and storage	Process areas	Tanks, pipework and pumps	Product storage and blending	Waste storage/ on-site disposal	Wastewater treatment facilities	Fuel storage	Electricity substations and transformers
Organic compounds	mineral oils		■		■	■			■	
	carburising media		■	■						
	electroless plating chemicals		■	■			■			
	bonding materials		■	■		■	■			
	coatings		■		■					
	temporary protective coatings		■	■		■	■			
	solvents (chlorinated)		■	■	■	■	■	■		
	solvents (non-chlorinated)		■	■	■	■	■	■		
	lubricants[1]		■	■	■	■	■	■	■	
	polychlorinated biphenyls									■
Other	detergents		■	■	■	■		■		
	scale (from cooling systems)						■	■		
	ash			■			■			

[1]Solid lubricants unlikely to be found in tanks, pipework and pumps, wastewater treatment facilities or fuel storage areas.
Shaded boxes indicate areas where contamination is most likely to occur.

Table 1b Main groups of contaminants and their probable locations

Engineering works: mechanical engineering and ordnance works – manufacture of military explosives and propellants

Contaminant		Location								
Main group	**Sub-group**	**Building fabric**	**Raw material delivery and storage**	**Process areas**	**Tanks, pipework and pumps**	**Product storage and blending**	**Waste storage/ on-site disposal**	**Wastewater treatment facilities**	**Fuel storage**	**Electricity substations and transformers**
Metal and metalloid contaminants			■	■		■				
Inorganic compounds	explosives and associated products		■	■	■	■				
	cyanides		■	■	■	■	■	■		
Acids			■	■	■	■				
Asbestos		■								
Organic compounds			■	■	■	■				
Solvents			■	■	■	■				
Fuel oils					■				■	
Polychlorinated biphenyls										■
Other	explosives and associated products		■	■	■	■				
	radioactive sources			■		■				

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

Recycled paper

DOE Industry Profiles

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

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Block 3, Spur 7,
Government Buildings,
Lime Grove,
Ruislip, HA4 8SF

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