
Metal manufacturing, refining and finishing works

*electroplating and other metal finishing
works*

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

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

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

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

Acknowledgements

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

Arup Environmental (Ove Arup and Partners)
Mr J F Cannell (Phoenix County Metals Limited)
Mr P Chave (National Rivers Authority)
Dr M Harris (ECOTEC Research and Consulting Limited)
Mr B J Hughes (British Aerospace Defence Limited, Royal Ordnance Division)
Mr R R Read (Honorary Secretary General of the Institute of Metal Finishing)
Dr M R G Taylor (Consultants in Environmental Sciences Limited)
Arup Environmental (Ove Arup and Partners)

DOE Industry Profile

Metal manufacturing, refining and finishing works: electroplating and other metal finishing works

	Page
Preface	(iii)
1. Background	1
1.1 History	1
1.2 Location	2
2. Activities	3
2.1 Raw materials	3
2.2 Processes	3
2.3 Effluent treatment	6
2.4 Waste management	7
3. Contamination	8
3.1 Factors affecting contamination	8
3.2 Migration and persistence of contaminants	9
4. Sources of further information	10
Annex Potential contaminants	13
Table 1 Main groups of contaminants and their probable locations	17

This profile is based on work by Aspinwall & 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.

Metal manufacturing, refining and finishing works: electroplating and other metal finishing works

1. Background

Metal finishing operations encompass a wide range of processes, including machining, cleaning and degreasing, surface treatment processes, coating of metal surfaces, and the application of metallic coatings and polishing. Metal plating is the predominant process operating at metal finishing works and therefore is considered in most detail in this profile.

1.1 History

The earliest form of plating was the decorative gilding of ecclesiastical or domestic vessels during the Middle Ages. Metal plating as an industrial trade emerged in the 1740s after a technique was developed for plating silver on to copper by fusing silver plate on to copper ingots, which were then rolled and worked into finished articles. This process was adopted at works established in Sheffield and Birmingham. In the early 1800s the first commercial electroplating works was opened in Birmingham, specialising in the gold and silver plating of military equipment and ornaments. The original method of plating involved deposition of the metals from boiling alkaline carbonate solutions but was refined in the 1840s with the use of alkaline cyanide baths, which produced silver coatings of superior thickness and quality.

By 1871 the following metal plating processes were available:

Gilding and silvering	The application of a thin film of gold/silver to a surface, traditionally by mixing the metal with mercury to form an amalgam, coating the surface of the object with the amalgam and then driving off the mercury by heating.
Electroless deposition	The deposition of a thin metal layer on an object by chemical reduction of a solution containing the ions of the metal being deposited.
Hot-dip deposition	The deposition of a thin layer of metal on an object by immersion in a molten bath of the metal being deposited.
Plating by the application of pressure and heat	For example tinning lead pipes.
Casting and electroplating	The deposition of a thin layer of metal on an object by passing an electric current through a solution containing the ions of the metal being deposited.

Nickel plating was widely utilised to improve the wear of military components during the First World War. As automobile production grew during the 1920s, methods of plating zinc were introduced. Chromium electroplating from chromic acid solutions was developed during the late 1920s, and mechanised electroplating methods were adopted by the larger works.

New metal finishing technologies have been developed since the Second World War, although electroplating remains the principal process employed at metal finishing works. Automation was introduced into small and large works in the 1960s. Recent developments in electroplating have seen a shift away from the use of toxic chemicals and increasing emphasis on recycling metals. For example, plating from trivalent chromium solutions was introduced during the 1970s and, around the same time, there was a growth in the use of acid chloride rather than alkaline cyanide solutions for zinc electroplating.

It is estimated that there are some 2000 electroplating and other metal finishing works currently operating in the United Kingdom, excluding operations performed in-house in specialist departments of other manufacturing works. Most of these are small businesses, averaging 20 employees.

The metal finishing industry undertakes work for a wide range of customers, as most metal goods are required to undergo one or more metal finishing processes. The major associated industries are:

- vehicle manufacture
- general engineering
- aircraft manufacture
- armaments
- electrical engineering
- electrical and electronic products manufacture
- printing
- hardware/tools manufacture
- domestic appliance manufacture
- the production of fancy goods and leisure products.

1.2 Location

The United Kingdom metal finishing industry is fragmented, with the vast majority of works located in urban areas associated with the engineering industry. The highest concentrations of metal finishing works occur in the Midlands, London and the South East, Lancashire and Yorkshire.

2. Activities

A diverse range of technologies is available to apply metallic and metal compound coatings to surfaces, but the most common processes encountered at metal finishing works are electroplating, hot-dip deposition and anodising.

2.1 Raw materials

The principal raw materials, other than the components to be finished, are cleaning agents, metals (particularly for hot-dip deposition), hot-dip fluxes, plating and anodising bath chemicals, and effluent treatment reagents. A brief description of each type of raw material is given in the appropriate section, and lists of compounds used in each process are provided in the Annex.

Effluent treatment chemicals are commonly required to reduce hexavalent chromium to trivalent chromium, to oxidise cyanide and to precipitate heavy metals.

2.2 Processes

Continuous and batch production are carried out in metal finishing works, depending upon the scale of operation. Automated works routinely handle large quantities of similar components requiring similar finishes and comprise continuous lines of pre-treatment, plating and rinsing baths along which workpieces, mounted on jigs, are transported by overhead conveyor. Smaller works which process a greater variety of work usually contain clusters or short sequences of tanks in a plating room. Jig-stripping, electropolishing (a non-mechanical means of polishing a metal using a process which is the reverse of electroplating), chemical storage, effluent treatment and other ancillary processes are usually undertaken in designated areas. Many works also include a laboratory.

2.2.1 Pre-treatment processes

Undesirable metallic, metal oxide and other coatings may be removed from workpieces by dissolving them in an acidic or alkaline stripping bath or in a pickling bath.

Abrasive blast cleaning processes use small sharp particles propelled by an air stream or water jet to impinge on the surfaces of large items. This removes contaminants such as paint and heavy scale by the force of the impact. Abrasive blast cleaning agents include steel grit and shot, sand and glass (ground or as beads).

Cleaning processes are designed to remove soil, oil and grease and may involve swabbing, soaking, spraying, flushing or vapour degreasing. Solvents and acid cleaners generally dissolve the dirt, while emulsions, some hydrocarbon solvents and alkaline cleaners function by loosening dirt particles from surfaces and then holding them in suspension. Acid cleaners are normally only used in conjunction with alkaline cleaners which are generally based on sodium salts. Aqueous organic pre-cleaners based on mixtures of amines are also used. Emulsions usually incorporate a petroleum fraction, such as kerosene. Cleaning solvents may include aliphatic petroleum fractions, chlorinated hydrocarbons, alcohols and other solvents. Acidic cleaners and pickling solutions may be based on mineral acids, acid-solvent mixtures, and solutions of organic acids and salts.

Electrolytic cleaning is also employed. This involves imposing an electric current on the workpiece immersed in an aqueous alkaline bath, causing vigorous degassing of hydrogen or oxygen at the workpiece surface, which releases any adhering dirt.

2.2.2 Electroplating

Electroplating is the deposition of a thin layer of metal on a workpiece by passing an electric current through an aqueous solution of the relevant metal salt. Most common metals and alloys, such as brass and bronze, may be deposited by this process. The workpiece constitutes the cathode in the electrolytic cell, which is immersed in the plating solution (ie the electrolyte). The anode usually consists of the metal to be deposited and dissolves as the process proceeds. If the anode is insoluble, then soluble salts of the plating metal have to be added to the bath to avoid depleting the concentration of metal ions in solution. The thickness of the coating layer is controlled by the period of immersion in the plating bath and the intensity of the current applied. After each plating cycle, the components are rinsed to remove residues of the plating solution. Contaminated rinse waters are usually used to top up the plating baths, thus minimising the loss of chemicals and the volume of effluent generated. Plating solutions may be periodically cleaned using activated carbon adsorption to remove accumulated impurities. Most components go through a series of plating and rinsing cycles before being dried.

2.2.3 Hot-dip galvanising

This process involves the immersion of iron and steel workpieces into a bath of molten zinc to form an adherent protective coating of zinc and zinc compounds. It is used for large steel structures such as petrochemical plant, bridge structural members, railway electrification structures, highway guard-rails and marine pilings. The substrate is degreased and shot blasted or acid pickled, in hydrochloric acid, before galvanising. The 'dry' galvanising process is the most common technique, which involves immersing the workpiece in an aqueous zinc chloride/ammonium chloride flux solution, drying it, and then immersing it in the molten zinc bath.

2.2.4 Hot-dip tinning

The tinning process involves the application of a thin coating of molten tin to a metallic (usually iron or steel) object. This process is used to protect articles employed in the handling or packaging of food products, and to facilitate the soldering of electronic components. After degreasing, pickling and/or shot blasting, the workpiece is fluxed either by immersion in aqueous acidic solution prior to immersion in a molten tin bath, or by immersion through a layer of molten flux salts floating on top of the molten tin. The flux contains zinc, ammonium and sodium chlorides. For large workpieces where immersion is impractical, the flux solution/paste/powder is applied to the hot work surface prior to wipe tinning. In the 'two-pot' tinning process, the coated workpiece is plated a second time by immersion into a bath of molten tin covered by an oil layer.

2.2.5 Anodising

This is an electrolytic treatment process, primarily applied to aluminium and magnesium, which results in the oxidation of the metal surface to form an adherent protective film of metal oxide. The film may increase corrosion resistance, improve subsequent coating adhesion, give a decorative appearance, and/or provide electrical insulation. The surface of the metal must initially be clean. Oxides are removed by etching or pickling in an acidic or alkaline solution. Any residual deposits (alloying elements) on the etched surface are removed by 'desmutting' using nitric acid or chromic acid with sodium bisulphate. Anodising is

accomplished by immersion in sulphuric, oxalic or chromic acid solutions. A coloured finish may be achieved through impregnating the pores of the oxide coating with organic dyes or mineral pigments, by immersing the workpiece in a sealing bath.

2.2.6 Other finishing treatments

Other processes include the following:

Mechanical plating

The application of an adherent metal coating by compacting finely divided particles of the metal into a coherent layer.

Flame spraying

The deposition of an adherent metal coating by spraying molten particles on to a surface.

Chemical vapour

The deposition of a coating by the low temperature deposition decomposition of gaseous chemical compounds.

Vacuum evaporation

The deposition of a coating by condensation of a material evaporated at high temperature in a vacuum, on to a surface at a relatively low temperature.

Passivation

The process by which metals, for example iron, chromium and stainless steel, are treated with strong oxidising agents to produce a corrosion resistant oxide coating on the metal.

Phosphating

The process in which a protective metal phosphate film is formed on a steel substrate. The cleaned steel surfaces are coated with a complex zinc-iron phosphate/chromate film by spraying and dipping in phosphoric acid, zinc phosphate and chromic acid solutions.

2.2.7 Buffing and polishing

Limited buffing of chromium, nickel, copper and silver coatings is undertaken at metal finishing works after electroplating, but most coatings are 'bright' from the baths. Buffing is performed by cloth wheels using buffing compounds that contain abrasives, bonding and lubricating agents.

Polishing is a more aggressive abrading operation, which is largely restricted to the uncoated components since it involves metal removal and is typically undertaken at manufacturing works. Electropolishing however, is undertaken at metal finishing works. It involves the anodic dissolution of projections on a metal surface, producing a very smooth, bright finish on stainless steel, aluminium alloys, brass, zinc, beryllium/copper alloys and nickel/silver alloys. The workpieces are mounted in acidic or alkaline baths and form the anode in an electrolytic cell when an electric current is applied, encouraging the metal surface to dissolve. The same process is used to strip metal deposited on the jigs which hold workpieces in electroplating baths. The stripped metal is gradually deposited as a sludge on the bottom of the tank.

2.2.8 Organic coatings

The coating of metals using organic substances, for example painting using various solvent-based, water-based or powdered substances, constitutes a significant sector of the metal finishing industry. Major examples of where organic coatings are used include powder paint coating of domestic appliances and painting vehicles. These processes can be a major source of contamination via sludges and filter cakes.

2.3 Effluent treatment

Conventional wastewater treatment at an electroplating works involves a number of steps. Initially, acidic hexavalent chromium-bearing effluent is collected in a chrome sump or acid dump tank. This is reduced to less toxic trivalent chromium, usually by sodium bisulphite or metabisulphite in a chrome reduction tank, after the pH has been adjusted through the addition of sulphuric acid. Alternative reducing agents such as sulphur dioxide, ferrous sulphate, and finely divided iron, copper or brass have also been used. Alkaline cyanide-bearing effluents collected in the cyanide dump tank are oxidised to a less toxic cyanate under strongly alkaline conditions and may be oxidised further to nitrogen (or nitrate) and carbon dioxide by the addition of dilute acid. Sodium, potassium, cadmium, copper and zinc cyanides are rapidly oxidised, while nickel, silver and gold cyanides are less reactive and their cyanide salts could precipitate. Acid and alkaline waste streams, including pre-treated effluents, are then mixed and the pH adjusted to precipitate heavy metal hydroxides from the mixture. The neutralised effluent is then clarified, usually by gravity sedimentation, and the wastewater discharged from the works. The sludge is generally de-watered further in thickening tanks, or by centrifuge, rotary drum vacuum filter or pressure filter.

Most effluent treatment plants were, until about 1960, designed on the gravity flow principle, taking wastewater from metal finishing shops in open floor gullies to below ground level. The wastewater was channelled into reinforced concrete or brick tanks lined with chemical resistant tiles set in special cements, often over a polymer membrane. Plants of this type were difficult to maintain and repair and were prone to leaks. In addition, desludging was difficult to carry out efficiently. In situ effluent treatment plants with sub-surface tanks and sumps have now been largely superseded by surface plants which are modular in design and can be relocated.

Recovery systems have been used for effluent treatment since the late 1970s to abate pollution, reduce waste volumes and to conserve raw materials and water. The technologies employed include evaporation (atmospheric and vacuum), ion exchange, reverse osmosis, electrodialysis (the separation of ions in solution by attracting them through semi-permeable membranes by the application of an electric current, leaving pure water in a central chamber) and electrowinning (a technique of extracting a metal from a solution in an electrolytic cell).

2.4 Waste management

Liquid effluents, sludges and solid wastes are generated at metal finishing works. The principal waste types are summarised as follows.

Liquid wastes	Spent process solutions Spent degreasing agents Spent pickling, stripping and desmutting solutions Contaminated rinse waters Treated effluent from the effluent treatment plant Waste dyeing and sealing solutions for anodised components Liquid wastes comprising acid dissolved metals, depending on the type of plate used Suspended solids and oil
Sludges	Tank sludges from process tanks, stripping tanks, pickling tanks, cleaning tanks and storage tanks Chemically precipitated effluent treatment sludge (mainly precipitated metallic compounds, eg hydroxides, carbonates and sulphides)
Solid wastes	Filter cake (or otherwise de-watered effluent treatment sludge) Exhausted carbon filter media used to clean plating solutions Dust and solidified metal salts from air extraction filter systems Metal fragments, for example from shot blasting and grinding 'Lost' components and precipitates scraped from plating tanks Buffing residues Flux skimmings from hot-dip processes

Gaseous emissions which may occur are fumes from ventilating or drying installations.

Liquid wastes are generally discharged to the foul sewer or to a watercourse following treatment or may even be returned to the process. Spent solvents and oil-water emulsions are typically recycled off site. However, the on-site disposal of untreated liquid effluents to soakaways could have occurred in the past at old metal finishing works sites and so could the discharge of small quantities of untreated liquid effluents to the sewerage system.

Most sludges and solid wastes are usually disposed of off site to landfill, frequently after some form of fixation treatment to immobilise heavy metals. Techniques recently developed to recover metals from finishing sludges are not economically viable at present and have not been widely adopted. Some on-site disposal of sludges and solid wastes may have occurred on older metal finishing works sites, including the intentional burial of rejected components and wastes in building foundations and landfills.

Wastes may have been tipped into canals and rivers in the 1950s and 1960s.

3. Contamination

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

3.1 Factors affecting contamination

Contamination of electroplating and other metal finishing sites may have resulted from leaks, spillages or on-site disposal of raw materials, in-process materials or waste products.

Acidic materials which may be found include mineral acids and some organic acids. Alkaline sludges containing residual hydroxides, carbonates, silicates, borates and phosphates may also be found. These materials are located principally in on-site sludge disposal areas and, possibly around leaking floor drains, sumps and tanks containing acidic or alkaline solutions or effluents.

A range of metals might be found in pre-treatment effluents and sludges and in effluent treatment sludges (see Annex). Contamination by heavy metals may be found in storage areas for plating chemicals, around floor drains and sub-surface tanks in pre-treatment, process and effluent treatment areas, at on-site disposal locations, and in waste storage areas.

Contamination may arise from spillages of plating chemicals and solutions, leaking effluent drains, sumps or tanks, on-site disposal of sludges and effluents to soakaways. Contamination may also arise from spillages of sludges stored on site pending off-site disposal, the disposal of sludges on site, the demolition of redundant plant containing process or effluent residues and the on-site disposal of contaminated building rubble.

Contamination may be found around virgin oil, waste oil and solvent storage tanks, at on-site effluent disposal soakaways, along the lines of drains in pre-treatment areas and at on-site disposal locations for degreasing sludges. Oils used as electrical insulators may have leaked from transformers and other electrical equipment. The presence of such equipment on a site raises the possibility of soil contamination by polychlorinated biphenyls (PCBs) which were used in insulating oils until 1977.

Asbestos may have been used to lag pipework and as a cladding or roofing material. Asbestos may still be present in such installations and may also have been disposed of on site.

Demolition and clearance works may release materials into the environment and spread them around the site. Building materials impregnated with contaminants (for example from demolished tanks and floors), asbestos insulation materials (from old sites) and oils containing PCBs may also be released by demolition works.

3.2 Migration and persistence of contaminants

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

The leaching action of slightly acidic rainwater infiltrating through metal-contaminated soils poses a threat to underlying groundwater. Surface run-off from contaminated soils may carry metals in solution and suspension into neighbouring watercourses, or drains discharging into watercourses. Contaminants in acidic or alkaline leachate are highly mobile, until the pH is brought to near neutral by reaction with and dilution in the soil or rock through which it is moving. Acidic leachate may contain and mobilise metals, cyanide, fluorides, nitrates, phosphates, sulphates and chlorides. The corrosive nature of many pre-treatment and process effluents may have degraded floor drains, sub-surface sumps or tanks, causing them to leak. This is likely to be a major contaminant pathway on old sites. Leaching from acidic or alkaline sludges by rainwater infiltration or run-off may also occur.

Cyanides may occur at sites as both the free cyanide anion and as complex metal/cyanide anions. Simple alkali metal and ammonium cyanides and some complex cyanides are water-soluble. However, complex cyanides may precipitate out of solution in the presence of some heavy metal cations. The infiltration of rainwater through cyanide-contaminated soils may leach cyanide into groundwater, while surface run-off from contaminated land can transport cyanide into surface watercourses. The slow breakdown of complex cyanides in the soil may act as a long-term source of free cyanide contamination to groundwater.

The oils and solvents used are liquids and are able to flow under the influence of gravity or positive pressure. Common chlorinated solvents and light petroleum fractions are highly volatile and may also migrate as vapours. Alcohols, acetone and most ethylene glycol ethers are water-soluble. Hydrocarbons and chlorinated hydrocarbons have limited water solubility, but this is still well in excess of commonly used guidelines for drinking water quality. Groundwater is therefore at risk from the downward flow of solvent or oil through permeable soils, from the infiltration of rainwater through solvent or oil-contaminated soils, and from the dissolution of solvent vapours migrating in the unsaturated zone. Free solvent or oil may form in a floating layer above the groundwater table, or may sink through an aquifer, depending on its density. Chlorinated solvents are denser than water, while most hydrocarbons float. Solvent or oil is also retained in the soil matrix through which the free liquid has passed. The soil may therefore act as a long-term source of groundwater contamination. Surface waters may be contaminated by surface water run-off from contaminated land, or the discharge of contaminated groundwater into watercourses.

4. Sources of further information

4.1 Organisations

For information concerning the electroplating and metal finishing in the United Kingdom, the following organisations should be consulted:

The British Surface Treatment Suppliers Association
136 Hagley Road
Edgbaston
Birmingham
B16 9PN

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

The Metal Finishing Association
27 Frederick Street
Birmingham
B18 6LT

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

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

Case study including information relevant to this Industry 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

Metal manufacturing, refining and finishing works: iron and steelworks.
Metal manufacturing, refining and finishing works: non-ferrous metal works (including lead works)
Metal manufacturing, refining and finishing works: precious metal 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. Of particular relevance are:

Her Majesty's Inspectorate of Pollution. *Processes for the production of zinc and zinc alloys.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 2/4. London, HMSO, 1994.

Her Majesty's Inspectorate of Pollution. *Processes for the production of refractory metals.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 2/6. London, HMSO, 1994.

Her Majesty's Inspectorate of Pollution. *Processes for the production, melting and recovery of cadmium, mercury and their alloys.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 2/7. London, HMSO, 1994.

Her Majesty's Inspectorate of Pollution. *Processes for the production of aluminium.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 2/8. London, HMSO, 1994.

Her Majesty's Inspectorate of Pollution. *Processes for the production of copper and copper alloys.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 2/9. London, HMSO, 1994.

Her Majesty's Inspectorate of Pollution. *The extraction of nickel by the carbonyl process and the production of cobalt and nickel alloys.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 2/11. London, HMSO, 1994.

Her Majesty's Inspectorate of Pollution. *Tin and bismuth processes.* Chief Inspector's Guidance to Inspectors. Process Guidance Note IPR 2/12. London, HMSO, 1994.

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

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

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

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

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

4.5 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 is:

Department of the Environment. *Metal finishing wastes*. Waste Management Paper No. 11. A technical memorandum on arisings, treatment and disposal including a code of practice. London, HMSO, 1976.

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.

Cleaning, stripping and pickling agents

Inorganic compounds

Sodium salts	phosphates hydroxides silicates carbonates cyanide borates sulphide bisulphate
Ammonium persulphate	
Mineral acids	hydrochloric orthophosphoric sulphuric hydrofluoric

Organic compounds

Organic acids	acetic citric oxalic tartaric gluconic
Amines	
Chlorinated solvents	dichloromethane tetrachloroethane trichloroethylene 1,1,1-trichloroethane trichlorotrifluoroethane
Alcohols	ethanol isopropanol methanol
Non-chlorinated solvents	acetone benzene toluene ethylene glycol ether petroleum fractions eg kerosene, naphthas

Plating chemicals

Copper plating

copper cyanide
sodium pyrophosphate
copper metal
sodium carbonate
copper sulphate
copper fluoroborate
sulphuric acid

Chromium plating

chromic anhydride
sodium dichromate
sulphuric acid
potassium and ammonium trivalent
chromium chloride complexes

Nickel plating

nickel sulphate
nickel chloride
nickel sulphamide
boric acid
zinc chloride
zinc sulphate
sodium hypophosphite
organic acids
aminoboranes
sodium borohydride

Zinc plating

ammonium chloride
potassium chloride
sodium chloride
sodium cyanide
sodium hydroxide
sodium poly and tetrasulphides
zinc chloride
zinc cyanide
zinc oxide
zinc metal
boric acid

Cadmium plating

cadmium cyanide
cadmium oxide
sodium cyanide
sodium hydroxide
sodium carbonate
cadmium metal
cadmium fluoroborate
sulphuric acid

Tin plating	potassium stannate tin metal stannous fluoroborates boric acid stannous sulphate sulphuric acid phenol sulphonic or cresol sulphonic acid sodium acetate sodium stannate
Lead plating	lead fluoroborate litharge (lead oxide) fluosilicic acid fluoroboric acid lead sulphamate sulphamic acid lead metal lead nitrate
Silver plating	silver cyanide sodium cyanide potassium silver cyanide copper cyanide sodium carbonate
Gilding and silvering	mercury amalgams
Hot-dip galvanising	zinc zinc chloride/ammonium chloride flux
Hot-dip tinning	tin zinc ammonium chloride sodium chloride oil
Anodising	aluminium magnesium mineral acids eg nitric, sulphuric and chromic sodium bisulphate oxalic acid alkalis (see cleaning, stripping, pickling) manganese (from potassium permanganate) nickel and cobalt salts
Organic coating	organic solvents (see cleaning, stripping, pickling)

Other contaminants

Effluent treatment	mineral acids sodium metabisulphite ferrous sulphate sodium hypochlorite sodium hydroxide sodium carbonate calcium oxide (lime) aluminium sulphate (alum)
Flux	zinc ammonium chloride sodium chloride
Desmutting	nitric acid chromic acid sodium bisulphite
Anodising	sulphuric acid oxalic acid chromic acid
Finishing treatments	nickel acetate cobalt acetate boric acid sodium dichromate nickel acetate/sodium hydroxide sodium sulphate lacquers or varnishes nitric acid solutions (with or without sodium dichromate) zinc phosphate and chromic acid solutions
Polishing and buffing	aluminium copper zinc beryllium nickel silver
Others	polychlorinated biphenyls (PCBs) asbestos

Table 1 Main groups of contaminants and their probable locations

Metal manufacturing, refining and finishing works: electroplating and other metal finishing works

Main groups of contaminants		Location													
		Pre-treatment	Electro-plating	Gal-vanising	Hot-dip tinning	Anodis-ing	Passiv-ation	Phos-phating	Polishing and buffing	Effluent treatment	Roofing and pipe lagging	Process building	Waste storage	Drains sumps and tanks	Trans-formers and switchgear
Alkalies															
Mineral acids															
Organic acids															
Oil															
Organic solvents															
Electroplating metals ¹				2	2	3	4	5							
Other metals	Beryllium														
	Aluminium														
	Magnesium														
Inorganic compounds	Borates														
	Cyanides														
	Chlorides														
	Sulphates														
	Nitrates														
	Phosphates														
Asbestos															
Polychlorinated biphenyls (PCBs)															

¹Electroplating metals: copper, cadmium, chromium, lead, nickel, mercury, silver, tin, zinc

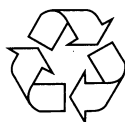
²Tin, zinc

³Chromium

⁴Chromium, nickel, zinc

⁵Chromium, zinc

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

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.