

Metal manufacturing, refining and finishing works

iron and steelworks

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:

Mr D L Barry and Mr J E Steeds (WS Atkins Environment)
Mr J Coggins (Ironsides Farrar Limited)
Mr G D Funnell (The British Iron and Steel Producers Association)
Dr E Hutton (British Steel plc)
Dr M R G Taylor (Consultants in Environmental Science Limited)
Mr J M Thayer (British Steel plc)

DOE Industry Profile

Metal manufacturing, refining and finishing works: iron and steelworks

	Page
Preface	(iii)
1. Background	1
1.1 Location and development	1
1.2 Historical scale of the industry	2
2. Manufacturing processes	3
2.1 Ore preparation	3
2.2 Coke making	3
2.3 Iron making	3
2.4 Steel making	4
2.5 Casting processes	5
2.6 Rolling and finishing operations	6
3. Waste management	7
3.1 Ore preparation wastes	7
3.2 Coke making wastes	7
3.3 Iron making wastes	8
3.4 Steel making wastes	8
3.5 Casting wastes	9
3.6 Wastes from rolling and finishing operations	9
3.7 Wastes not related to specific steelworks processes	10
4. Contamination	10
4.1 Factors affecting contamination	10
4.2 Migration and persistence of contaminants	11
5. Sources of further information	11
Annex Potential contaminants	15
Table 1 Main groups of contaminants and their probable locations	16

This profile is based on work by Environmental Assessment Group 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: iron and steelworks

1. Background

Iron ore consists of iron oxide and usually other substances, known as gangue minerals, such as oxides of calcium and aluminium, silicates, phosphates and sulphates. It is smelted in a blast furnace with coke and limestone to produce iron.

Steel is an alloy of iron produced by refining iron to remove excess carbon and other elements, particularly silicon and phosphorus. The carefully controlled amounts of carbon and other elements which are left, and some aluminium, nickel and chromium which may be deliberately added, determine the steel's properties and therefore its applications.

1.1 Location and development

In the United Kingdom, steel manufacture developed as a large-scale industry after 1850. Over the following hundred years, large works were built near extensive ironstone deposits. Although these deposits were low in iron content (between about 25% and 45%), they were excavated from not far below ground surface and were located fairly close to coalfields. Consequently they were economically workable. Notable examples were those in North Lincolnshire and Northamptonshire.

Other works, based on imported iron ore, were located near ports such as Liverpool and Glasgow and ports in South Wales and North East England. Steel making also became an established industry alongside the engineering centres of the Midlands and Sheffield, with the latter becoming recognised throughout the world for its expertise in steel.

When the British Steel Corporation (BSC) was established under the Iron and Steel Act 1967 by the nationalisation of the 14 largest iron and steel companies, it inherited some 39 plants in the United Kingdom, stretching from South Wales northwards to the Glasgow area.

In the 25 years following the Second World War, United Kingdom steel output almost doubled, with about 16 million tonnes being produced in 1950 and almost 28 million tonnes in 1970. Three important process changes led to this increase:

- increased use of high-quality imported ore and a gradual decline in the use of low-quality local ores (the tonnage imported more than doubled whilst the use of domestic ore decreased by about a quarter)

- improved preparation processes, such as sintering and briquetting, given to the iron ores prior to their smelting in enlarged blast furnaces

- application of pure oxygen, in bulk, to the furnaces used for refining iron into steel.

As well as increased output, these developments significantly reduced the overall energy requirements of the steel making process. There was also a marked reduction in the amount of slag produced at the blast furnaces as the unwanted substances in the ores decreased.

A further development in the industry was the introduction of the Electric Arc Furnace (EAF) process, which now accounts for a quarter of all steel production in the United Kingdom. The input to the process is 100% scrap steel and it produces high quality carbon and low alloy steels.

By the end of the 1970s it became clear that the United Kingdom's future share of the world crude steel market was unlikely to exceed 15 million tonnes per annum. Consequently, BSC concentrated production in six main areas – Newport (Llanwern) and Port Talbot in South Wales, Scunthorpe, Sheffield, Middlesbrough (Redcar) and Motherwell (Ravenscraig).

Towards the end of 1988, BSC was privatised as British Steel plc. Since then, steel production has been concentrated further and the plant at Motherwell has been closed.

A significant number of other steel companies also exist in the United Kingdom as well as British Steel plc. The British Iron and Steel Producers Association (BISPA) listed 42 companies in their membership at July 1995, including British Steel plc.

Over the years increasing awareness of the potentially polluting effects of the iron and steel industry has led to the industry introducing measures to reduce these, many of which are mentioned in the profile. The industry is also aware of the advantages of reusing materials. For example, two million cars, five million white goods (cookers, fridges, washing machines etc) and 1.5 billion cans, which would otherwise have been landfilled, have been converted by the United Kingdom steel industry into new products.

1.2 Historical scale of the industry

The size of the iron and steel industry has changed radically in the 20th Century. The total number of works (with blast and/or steel furnaces) was 82 in 1929, peaking at just under 200 in 1945 and dropping to 66 in 1992, the largest drop occurring with the concentration of production by the BSC in the 1970s. The number of works with steel furnaces only, increased from zero in 1929 to a maximum of 142 in 1945. From 1945 these steelworks continued to number over 100 until a large reduction occurred in the 1980s.

An estimate of the scale of the whole iron and steel industry, encompassing both works with furnaces and those involved in secondary processes such as rolling and finishing operations, can be obtained from Census of Production data between 1924 and 1991. The number of works in 1930 was 1759, the maximum number of works recorded occurred in 1968 with a total of 1910, and thereafter the number decreased to 610 in 1991. Census data from 1935 and 1968 indicate that most of these works were small scale operations, with about 70% employing less than 100 people and only 5% employing more than 750 workers.

2. Manufacturing processes

The manufacture of steel can be considered to comprise six processes:

- iron ore preparation
- coke making
- iron making
- steel making
- casting (ingot or continuous)
- rolling and finishing.

Integrated works operate all six processes and may occupy areas of over a thousand hectares, whereas EAF works using 100% scrap operate only the last three of the six processes, or possibly just steel making and casting.

Many small steel companies in the rolling and finishing field use ingots and semi-finished products such as slabs, blooms, billets, strips, bars and rods from integrated works or EAF routes as their raw material. Their whole operation may be carried out on not more than a couple of hectares.

2.1 Ore preparation

Most of the ores in common use today contain about 60% or more of iron or they are pre-refined to this standard. Some are prepared as pellets, generally near the ore mines, by bonding together very finely ground ore.

Most of the ore now used in the United Kingdom is turned into sinter before being charged into the blast furnace. Sinter is basically an agglomeration of ore, coke and limestone heated together in a sinter plant to form sinter. Dry dust from blast furnace gas cleaning plants and oxide scales from the rolling mills (mill scale) generally become part of the raw feed to the sinter plant.

2.2 Coke making

Coke is used in the blast furnace as a fuel and as the reducing agent. Therefore, coke manufacturing is performed as part of integrated steelworks activities. In the United Kingdom, by-product (chemical recovery) coke plants are used. Essentially they consist of silica brick ovens in which bituminous coal is heated in the absence of air to drive off the volatile components. The rectangular ovens are arranged side by side in groups called batteries. The heat is applied by burning gas in flues located between the walls of adjacent ovens. The residue remaining in the ovens is coke. The volatile components are recovered and processed in the by-product plant to produce tar, light oils and other materials of potential value, including coke oven gas. For many years ammoniacal liquor, a waste product formed during the manufacture of cokes, posed one of the main liquid pollution and sludge disposal problems at integrated steel plants. Biological treatment systems are now used widely to clean these effluents.

2.3 Iron making

Most of the ore used contains iron oxides along with gangue minerals such as oxides of calcium, silicon, phosphorus and sulphur. The primary purpose of smelting in a blast furnace is to reduce the iron oxide to iron which, in the process,

becomes saturated with carbon from the coke. The materials for iron making – iron ore, coke, sinter/pellets and limestone – are charged through the top of the blast furnace while heated air is blown through tuyères (nozzles) at the bottom. The gangue minerals are absorbed into the limestone-based flux, forming a slag. The iron tapped from the furnace may be cast into solid pieces known as 'pig iron', or may be left in the molten state, when it is known in the industry simply as 'hot metal'. In the past the iron was sent to pig casting plants, but today it is sent straight to the steel furnaces as hot metal. Gas is drawn off at the top of the blast furnace and, after cleaning, used as a fuel throughout the works.

The oxygen in the air reacts with the hot carbon (coke) to form carbon monoxide which reduces the iron oxide to release the iron. The iron is free to melt and collect in the hearth of the furnace and the limestone reacts with the other impurities to form a slag. This also collects in the hearth but, being less dense than the iron, floats on its surface. The iron and slag are tapped off through tap holes at the base of the furnace. The slag is cooled and processed as a saleable product, although in the past it would have been almost exclusively sent to waste tips.

2.4 Steel making

Steel is an alloy of iron, carbon (less than 2%) and manganese (less than 1%), although other alloy metals are used to produce specific properties. Mechanical properties can be varied by changes in composition (for example mild steel contains less than 0.15% carbon, hard steel more than 0.3% carbon) or by heat treatment. Stainless steel also contains 8-25% of chromium.

Either the hot metal from the blast furnace or iron/steel scrap, or a mixture of both, is the main raw material for any steel furnace. The respective amounts used vary according to the process and the type of steel required. During the first half of this century, basic Open Hearth Furnaces (OHFs) accounted for about 80% of steel production. Since then the electric arc and basic oxygen processes have replaced OHFs, and Basic Oxygen Furnaces (BOFs) now account for 75% of United Kingdom steel production, with EAFs responsible for the remainder.

2.4.1 Basic Oxygen Furnace (BOF)

Hot metal is the principal material used in a BOF. The furnace is charged first with scrap and then with molten iron; typically 70-85% of the charge is hot metal and the remainder is scrap. A water-cooled lance is lowered into the furnace and high purity oxygen is blown into the metal. The oxygen combines with carbon and other unwanted elements, thus eliminating them from the molten metal as the slag. During the 'blow', lime is added as a flux which removes the oxidised impurities and forms a floating layer of slag. When the desired quality is achieved, the steel is poured into a ladle for casting. The slag is poured into a separate ladle for removal to a slag pit where metal reclamation takes place. Modern BOFs can make up to 400 tonnes of steel in about 40 minutes.

2.4.2 Electric Arc Furnace (EAF)

EAFs were originally used solely for making steel of special high qualities because of the close control they gave over the composition of the metal. Nowadays they are also widely used for making large quantities of the more common steels.

An EAF consists of a refractory-lined circular bath with a swivelling roof through which carbon electrodes can be lowered to a position above the scrap in the furnace.

Arc furnaces are charged with clean scrap, limestone and possibly anthracite or broken electrodes as a source of carbon, and melted as quickly as possible. Nickel and molybdenum, when required, are added with the scrap as these elements are not removed by oxidation during refining. If alloy steels are being made, the scrap is selected to ensure that the furnace charge contains some of the elements required, for example nickel, molybdenum, chromium, etc. The larger EAFs can produce up to 150 tonnes of steel in 1-2 hours, depending on the steel type.

2.4.3 *Secondary steel making*

In a purely EAF process, using 100% scrap metal, carbon is removed to low levels by lancing the bath with pure oxygen. At equilibrium conditions, chromium oxidises out, contrary to requirements, as the carbon content lowers. Secondary steel making processes were developed to overcome this problem. Two of them, the AOD (Argon Oxygen Decarburisation) and CLU (Creusot-Loire-Uddeholm) processes, change the equilibrium states, so that chromium is retained (at 8-25%) whilst carbon is removed to low levels (ie less than 2%).

'Ladle treatments', to bring about the final adjustments in steel content, can also be classified as secondary steel making processes. These are among the fastest growth areas in steel making and have a much wider application in non-stainless areas. Examples of ladle treatments are:

Ladle stirring, in which a stream of argon or nitrogen bubbles rise through the steel, which is gently stirred. Unwanted oxides in the steel rise to the top of the vessel, and are removed as slag.

Degassing processes which depend on bubbles of argon entraining other gases (including hydrogen), thus reducing the amount of gases in the steel.

To remove effectively both nitrogen and hydrogen, both degassing and stirring are required. Nowadays, developments in ladle processing are reducing the function of both BOFs and EAFs to the provision of clean molten steel, thereby allowing these primary steel-making units to operate more efficiently.

2.5 **Casting processes**

After the molten steel has been tapped from the steel furnace, it is cast into ingots or special castings, or directly into slabs, blooms or billets by the continuous casting process.

Prior to the mid-1960s, most molten metal was released through the base of the ladle into moulds in which the metal was allowed to solidify. Continuous casting processes were subsequently developed and are now used for most steel making. Molten steel is channelled down through a water-cooled mould.

2.6 Rolling and finishing operations

Semi-finished cast steel from the steel making plant is formed in rolling mills into products for the market place. A wide range of mills exists, varying in size, profile, complexity and output. Some form part of large integrated steelworks and may be almost 2 kilometres long. Others, more numerous, produce a limited range and size of products and occupy a site of a few hundred square metres. However, they can be considered in two categories ie hot rolling and cold rolling plants.

2.6.1 Hot rolling

Products from hot rolling include flat strip, plate, structural sections, bars, rods, etc. During the rolling, the pre-heated steel is exposed to the atmosphere and this results in the formation of oxide scale (mill scale). To maintain surface quality this scale must be removed quickly with high pressure water. Recovery and effluent treatment plants for dealing with these contaminated aqueous waste streams are commonplace, purifying the water for recycling within the process.

2.6.2 Cold rolling

Cold rolling is a secondary operation which further reduces the thickness of hot rolled strip, at the same time giving superior surface quality and closer thickness control. In the cold rolling process, stable oil/water emulsions are applied at the rolling surfaces to reduce friction and dissipate the heat caused by the high friction forces that are involved. Although the emulsions are recirculated, they become contaminated with dirt/iron particles and a portion must be discarded in order to limit the degree of contamination.

2.6.3 Finishing

Steel is subjected to a variety of 'finishing' processes to meet market demands, including acid pickling, painting, galvanising, tinning and plastic coating. The processes are complex and the detailed procedures vary from plant to plant. Removal of oxide scale by pickling with acid is a common feature of almost all finishing processes applied to commercial steels. Acid pickling generally precedes cold rolling. The various pickling agents are well documented and generally involve the use of sulphuric acid, hydrochloric acid or a mixture of hydrofluoric and nitric acids (for special steels). Mechanical de-scaling methods such as shot blasting are also used as an alternative to pickling.

Galvanising and tinning, the two most widely used finishing processes applied to steel products, involve cleaning/degreasing with alkali solutions and various additives prior to application of the zinc or tin coating by electrolytic methods or by hot dipping. For further information see the Industry Profile on electroplating and other metal finishing works (Section 5).

3. Waste management

This section describes the solid and liquid wastes associated with each of the processes discussed in Sections 2.1 to 2.6. Aqueous wastes and potential water pollutants arising from the processes have become subject to increasingly stringent discharge consent levels. These consents necessitate the use of efficient treatment, recycling and recovery systems for effluents prior to any discharge.

3.1 Ore preparation wastes

Significant waste products do not arise during sintering of iron ore but the gases generated do contain sulphur dioxide and significant amounts of dust consisting of ore and coke particles. Dusts are collected by electrostatic precipitators and fed back onto the sinter strand after appropriate blending with the other raw materials.

3.2 Coke making wastes

The dusts arising at coke ovens during coal and coke handling are collected in filters. Quenching towers are also equipped with means of reducing the grit given off during the quenching process. The dusts and fines from the quenching-water settling ponds are largely carbon in content and are recycled, usually to the sinter plant.

The three main solid or semi-solid wastes from coke ovens are:

- earth/sand contaminated by leaks and accidental spillage of tars, liquors, etc

- tar/coke grit mixtures which solidify in the decantation and storage tanks and have to be removed periodically

- settled solids from the distillation of ammoniacal liquor.

In the past, the solids and tars may have been sent to the works tips and the semi-solid sludges to on-site storage/evaporation lagoons. Nowadays, the majority of carbonaceous wastes arising are recycled into the coal blend and returned to the coke ovens as feed material. As well as having high alkalinity due to the lime used, the solids from the ammoniacal liquor include significant amounts of phenol, sulphide, tar oils, etc from the coking process.

In the past, off-gases were used for domestic purposes and desulphurisation was carried out in purifiers containing iron oxide. When saturated, the 'spent' oxide (essentially iron sulphide) was allowed to weather and revive on open ground. Once revived, it was recycled into the blast furnace. Relatively small quantities of spent oxide may still be found on certain sites. Spent oxide was also commonly used as a feedstock for the manufacture of sulphuric acid in the lead chamber process. For the relevant Industry Profiles see Section 5. The iron oxide resulting from this and other sulphide-roasting processes could then be re-used or utilised as feed material for iron making.

3.3 Iron making wastes

Materials produced in the iron making process are:

- blast furnace slag
- dry dust from gas cleaning
- wet solids from gas cleaning
- refractory waste from the ladles and runners.

Modern blast furnace practice typically gives rise to about 300 kg of slag per tonne of iron produced, compared with three times that amount during the first half of this century. The slag has traditionally been used as a building material, the raw material for blast furnace cement and aggregate for roads and land reclamation. During recent years, old slag tips have been quarried to extract saleable slag. Blast furnace slag differs from steel making slag in that it contains no iron oxide or phosphorus, but does have very small amounts of iron physically entrapped in its structure.

Dust is entrained as the blast furnace gas passes through the upper part of the furnace. Coarse dust, consisting largely of iron oxides and coke residues, is removed in a dust catcher or cyclone and generally is re-used in the sinter plant. Wet scrubbers of varying types are incorporated in the gas cleaning process. The residue is a slurry which is difficult to re-use because of the presence of lead, zinc and alkalis. The general practice has been to allow it to dry out in large lagoons and either to store the solids until recycling methods are in hand or to dispose of them as site backfill, often in worked-out open cast ore mines.

The effluent water associated with the slurries is treated before recycling or release in order to conform with discharge consent levels.

3.4 Steel making wastes

Solid materials produced in the steel making process comprise:

- slag
- arising scrap
- dust and slurries
- refractory materials.

The quantity of slag produced depends largely on the quality of the steel being made and on the scrap to hot metal ratio in the charged materials. The higher the proportion of high-grade scrap, the smaller the quantity of slag since the process is really only one of remelting and refining. Specific slag quantities can therefore vary over the range 70 to 170 kg/tonne of liquid steel. Steel making slags are normally poured into contained areas and allowed to solidify. Steel contained in the slag is recycled to the blast furnace via the sinter or BOF plant after breaking, removal of iron by magnetic separation and size grading.

Steel making slags have also been used as a construction material, for example in road making, and may also have been used in the past as site backfill, often in worked-out open cast ore mines. Owing to the high phosphorus content of the ores used, slags produced from the now obsolete converter process of steel making, contained more than 15% of phosphorus pentoxide. These slags were ground and

sold as fertiliser. As large steel producers used more ores low in phosphorus, the slags became less attractive as a fertiliser.

Fume cleaning is an integral part of steel making; specific quantities of around 10 to 15 kg per tonne of steel arise as dust or slurry. Although its iron content may be around 50%, the presence of lead, zinc and other metals (originating chiefly from the steel scrap) causes severe problems in blast furnaces if this material is recycled. Since the late 1970s, most of the slurries have been lagooned on site or landfilled. The water component of the slurry also contains significant amounts of lead, zinc and fluoride dissolved from the dust and needs effective treatment in order to meet stringent discharge consent levels. Dry dust containment methods, for example electrostatic precipitators and bag filters, are also widely used.

The composition of the slag and fume arising from the EAF process is different from that produced by the BOF process, for example the sulphur content of all wastes is lower and the zinc levels may be higher.

3.5 Casting wastes

The residues from pouring steel into the casting pit or continuous casting plant are readily recycled and do not present waste disposal problems. Refractory waste arises from relining steel making vessels, ladles and the tundishes into which the hot metal is poured at the continuous casting plant. Metallic elements and reusable bricks are usually recovered and the remainder sent to the on-site tip or landfill. Such materials generally present low contamination risks.

3.6 Wastes from rolling and finishing operations

The scrap waste is recycled to the steel furnaces. Mill scales are usually high in iron content and, at an integrated works, the bulk of them are fed back to the sinter plant. Some of the finer scales become coated with oil from roll bearings, etc and then cause problems with the electrostatic precipitators if recycled to the sinter plant. A number of methods of handling oily scale have been tried, such as solvent extraction (using halogenated solvents), weathering and burning-off in a fluidised bed, but have met with limited success. Mill scales containing large amounts of oil are usually discharged into lagoons and eventually sent to on-site tips or landfills. Some mill scales are sold for use in cement manufacture.

Refractory wastes arise from soaking pits, reheating furnaces and similar equipment in the rolling mill. Unusable residues are usually disposed of to on-site landfills or tips. Used oil is generally refined by specialist contractors or incinerated.

Cold rolling produces little waste. Oil emulsions are recycled and, when periodic replacement is necessary, they are reclaimed by specialist contractors.

Spent sulphuric acid, hydrochloric acid and sodium hydroxide from pickling can be treated to regenerate the acids or alkalis. Such treatments are widely applied in large plants, but uses for the acid are often found elsewhere on smaller sites (for example in the neutralisation of water treatment sludges) or the acid sludge itself may be neutralised before being sent to landfill.

The waste products from galvanising, tinning and other finishing processes are produced in relatively small quantities compared with the volume of wastes arising from the industry as a whole. Various methods have been devised for recovering any of the coatings which appear in the wastes, for example zinc dross is recovered for re-use.

3.7 Wastes not related to specific steelworks processes

Other wastes arise which are not specific to the making of iron and steel. At integrated works, such wastes are generally included in the overall waste disposal procedures whereas, at smaller sites, they are most likely handled by waste contractors. Building and demolition rubble, slurries from water treatment plants, insulation materials such as asbestos (including material used for roofing and cladding pipes) and empty chemical containers are examples of items likely to be found on a works' tip in addition to the process wastes. Since the mid-1970s, the actual location of some of these materials (especially asbestos) has normally been accurately logged within the industry, but information recorded before then should be viewed with caution.

4. Contamination

The contaminants on a site will largely depend on the history of the site and on the range of materials produced there. The main groups of contaminants and the processes with which they are associated 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.

4.1 Factors affecting contamination

Metals and metal compounds and the products of coke making and metal finishing are potentially the most significant contaminants at iron and steelworks. The potential for contamination is likely to be related to the type of process and material storage taking place on the site. Contamination may also be present in or near waste storage areas, wastewater drainage systems and wastewater treatment plants. In particular, contamination may be present in and around bulk storage areas. Leakages may have occurred from tanks and pipework carrying process products or wastes. On old-established sites, contaminants may be present in on-site landfills, lagoons or soakaways. Transformers and other electrical equipment may contain polychlorinated biphenyls (PCBs).

In the past, the storage of oily scrap could have led to ground contamination, but this is less likely with modern practices (see Section 5 for related profiles).

Prior to the 1980s, closure and demolition of complete integrated works was virtually unknown in the United Kingdom, although the demolition of parts of works did occur, for example blast furnaces or rolling mills closed and were replaced by larger and more modern plant. After demolition, the land remained part of the works and was generally re-developed as offices, workshops or storage space. Any areas where potentially polluting materials had been stored or dumped were readily identified by many of the original personnel still on the payroll. In many instances,

waste from an earlier plant became part of the raw material for the modernised process, for example the dry dust accumulated in dumps over many years from the cleaning of blast furnace gas was recycled to the furnaces via the sinter as sintering techniques developed. On the other hand, indiscriminate or poorly controlled decommissioning may have led to significant ground contamination, for example disturbance of asbestos fibres from lagging, spillages from tanks/pipes during removal and the spreading of wastes generally.

4.2 Migration and persistence of contaminants

Metal contamination is likely to be closely related to the locations of specific deposits and processes except where leaching has occurred. 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 zinc and lead) may increase under acidic conditions. In other cases the relationship is more complex. For example, trivalent chromium is more soluble under acidic conditions, whereas the solubility of hexavalent chromium is increased under both acidic and alkaline conditions and arsenic may become more soluble at higher pH. Metals in surface soils may also be transported across a site by wind action.

Mineral acids migrate within soil-water in the dissociated form, ie as the hydrogen ion and the corresponding anion (eg nitrate or sulphate). The buffering capacity of most soils tends to neutralise slight acidity. Dissolved nitrate and sulphate migrate fairly freely through the soil.

Metal contaminants, asbestos, mineral acids (eg sulphuric acid) and sodium hydroxide are not biodegradable. PCBs, present in certain types of electrical equipment, have a low solubility in water and do not degrade. They are fat-soluble and tend to accumulate in food chains.

Sites adjacent to mines, or with deep underground structures, may have been dewatered by groundwater pumping. If pumping is stopped, the water table may rise to lie within lagoons and landfills, causing groundwater contamination and increasing the potential for migration of contaminants.

5. Sources of further information

5.1 Organisations

For information concerning the iron and steel industries in the United Kingdom, the following organisations should be consulted:

British Steel plc
9 Albert Embankment
London
SE1 7SN

The British Iron and Steel Producers Association
5 Cromwell Road
London
SW7 2HX

The Iron and Steel Statistical Bureau
2 Sydenham Road
Croydon
CR9 2LZ

5.2 Sources of information concerning the activities described in this profile

British Iron and Steel Producers Association. *Annual Report.*

British Steel Corporation. *Iron ore.* Publication No 732/11.72/10M.

British Steel Corporation. *Making iron.* Publication No 732/12.72/10M.

British Steel Corporation. *Scrap is our business.* Publication No 918/10.71/50M.

Carbone W E. *Control of coke oven emissions.* ECE Symposium on Coal and Coke. Rome, 1973.

Doubleday G P (Editor). *Reclamation of former iron and steelworks sites.* Proceedings of a conference at Windermere, 5-7 October 1983.

Gronbech R W. *Water systems for cooling and cleaning in rolling mills.* In: Management of Water in the Iron and Steel Industry. Publication No. 128. The Iron and Steel Institute. 1970.

Galloway R E and Colville J F. *Treatment of spent pickling plant liquors.* In: Management of Water in the Iron and Steel Industry. Publication No. 128. The Iron and Steel Institute. 1970.

International Iron and Steel Institute. *Management of by-products and wastes.* Section 5 in 'Environmental Control in the Iron and Steel Industry'. 1978.

International Iron and Steel Institute. *Treatment of coke oven waste water.* Technical Information Exchange Session. Brussels, 1978.

International Iron and Steel Institute. *Air and water pollution in the iron and steel industry.* Special Report No 61. 1958.

Kilsby P E and Riley R V. *Liquid waste treatment and disposal at a British integrated steel and tube works.* CEC Conference on the Quality of the Environment in the Iron and Steel Industry. Luxembourg, 1974.

McGavin R F. *Suppression of liquid effluents from plants using hot sulphuric acid solutions to descale plain carbon and low-alloy steel bars and wire coils.* In Management of Water in the Iron and Steel Industry. Publication No 128. The Iron and Steel Institute. 1970.

Moore C and Marshall R I. *Steelmaking.* Book No 460. London, The Institute of Metals, 1991.

O'Connor A, Elliott W J and Williams H. *The treatment and recovery of chemicals in the effluent from tinplating and associated processes.* International Iron and Steel Institute Second Symposium on Environmental Control in the Steel Industry. Chicago, 1979.

US Steel Corporation. *The making, shaping and treating of steel.* 1971.

Vaizey J. *The history of British Steel.* London, Weidenfeld Nicholson, 1974.

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.

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

Census of Production Reports. Board of Trade, HMSO (from 1924 to 1969).

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

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

Department of the Environment. *Documentary Research on Industrial Sites.* DOE, 1994.

5.3 Related DOE Industry Profiles

Chemical works: inorganic chemicals manufacturing works
Gas works, coke works and other coal carbonisation plants
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works
Waste recycling, treatment and disposal sites: metal recycling sites

5.4 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. *Carbonisation and associated processes – coke manufacture.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 1/9. London, HMSO, 1992.

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

Her Majesty's Inspectorate of Pollution. *Iron and steel making processes: Integrated iron and steelworks.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 2/1. London, HMSO, 1994.

Her Majesty's Inspectorate of Pollution. *Processes for electric arc steelmaking, secondary steelmaking and special alloys production.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 2/3. 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.

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

5.5 Waste disposal and remediation options

Useful information may be obtained from the Department of the Environment series of Waste Management Papers, which contain details of the nature of industrial waste arisings, their treatment and disposal. A current list of titles in this series is available from HMSO Publications Centre, PO Box 276, London, SW8 5DT.

Publications containing information on the treatment options available for the remediation of contaminated land sites, prepared with the support of the Department of the Environment's Research Programme, can be obtained from National Environmental Technology Centre Library, F6, Culham, Abingdon, Oxfordshire, OX14 3DB.

A full list of current titles of Government publications on all aspects of contaminated land can be obtained from CLL Division, Room A323, Department of the Environment, Romney House, 43 Marsham Street, London, SW1P 3PY.

Advice on the assessment and remediation of contaminated land is contained in guidance published by the Construction Industry Research and Information Association (CIRIA), 6 Storey's Gate, Westminster, London, SW1P 3AU.

Annex Potential contaminants

The chemical compounds and other materials listed below generally reflect those associated with the industry and which have the potential to contaminate the ground. The list is not exhaustive; neither does it imply that all these chemicals might be present nor that they have caused contamination.

Metals and metalloids	iron manganese aluminium arsenic nickel chromium vanadium molybdenum lead zinc tin
Inorganic compounds	phosphates sulphates sulphides (iron sulphide) sulphur cyanides thiocyanate fluoride
Acids	sulphuric hydrochloric hydrofluoric nitric
Alkalis	sodium hydroxide calcium oxide
Contaminants particularly related to coke-making	coal tars (including polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, xylene) ammoniacal liquor sulphides sulphates sulphur phenols cyanides thiocyanates
Fuels and oils	fuel oils lubricating oil coal and coke
Organic solvents	
Asbestos	
Polychlorinated biphenyls (PCBs)	

Table 1 Main groups of contaminants and their probable locations

Metal manufacturing, refining and finishing works: iron and steelworks

Contaminants		Location				
Main groups	Individual compounds	Coke making ²	Iron making	Steel making	Casting	Rolling and finishing ³
Metal and metalloids ¹	Iron					
	Aluminium					
	Arsenic					
	Chromium					
	Lead					
	Manganese					
	Molybdenum					
	Nickel					
	Tin					
	Vanadium					
	Zinc					
Inorganic compounds	Fluoride					
	Ammoniacal liquor					
	Cyanide					
	Thiocyanate					
	Sulphates					
	Phosphates					
Acids/alkalis						
Asbestos (roofing and lagging)						
Organic compounds	Fuels and oils					
	Tar					
	PAHs					
	Phenols					
	PCBs					

¹The most likely forms are compounds or alloys

²See also DOE Industry Profile: 'Gas works, coke works and other coal carbonisation plants'

³See also DOE Industry Profile: 'Metal manufacturing, refining and finishing works: electroplating and other metal finishing works'

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.