

Power stations (excluding nuclear power stations)

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

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

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

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

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DOE Industry Profile

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This Profile is based on work by Environment 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.

Power stations (excluding nuclear power stations)

1. Background

This Industry Profile deals with possible contamination at power stations that generated electricity from coal, oil or gas. It does not deal with nuclear power stations or with hydro-electric power stations.

Before the First World War the electrical generation industry was small and fragmented. The different supply systems varied in voltage and frequency and were not easily interlinked. Many local authorities had made use of the Electric Lighting Act 1882 to build small power stations for supplying electricity to domestic users. But few statutory areas were large enough to justify the building of larger power stations for industrial customers. All the early power stations were coal fired and steam driven. Reciprocating steam engines were used at first but, since 1904, all steam power stations have used turbines.

The First World War, when power supplies were crucial to the production of munitions, exposed the shortcomings of the electrical generation industry. The government created the Electricity Commission in 1919 to put the industry on a coherent basis. The Central Electricity Board (CEB) was established in 1926 to control the construction of power stations and to set up the National Grid by linking the most efficient and largest power stations. The Grid was operational by 1938 and it led to the closure of low efficiency power stations. The number of power stations was reduced from 438 in 1926 to about 300 in 1948.

After the Second World War, the demand for electricity increased and a 'Supergrid' was introduced to improve its distribution. Under the Electricity Act 1947 the electricity companies in England, Wales and southern Scotland were nationalised and the CEB became the British Electricity Authority (later becoming the Central Electricity Generating Board (CEGB) in 1958). After nationalisation, further plants were made redundant.

Until the 1960s, except for nuclear and hydro-electric power plants, all power stations burned coal. Large coal-fired stations feeding the Grid were often located near coal-mining areas.

In the 1960s and 1970s oil-fired power stations were constructed, often in coastal areas close to oil refineries, and a few coal-fired stations were partially converted to burn oil. In 1984 approximately 20% of the total generating capacity of the United Kingdom was provided by oil-fired power stations, but the use of oil has declined in recent years.

Open Cycle Gas Turbines (OCGTs) were introduced in the 1960s. These normally used diesel as fuel. OCGTs are now only used at times of high electricity demand owing to the present high cost of diesel.

North Sea gas was used as a fuel for one coal/gas power station in the 1960s. Gas is currently being used on a larger scale for Combined Cycle Gas Turbines (CCGTs).

Between 1972 and 1984, 107 power stations were closed. In 1995 there were 86 power stations in England and Wales contributing to the National Grid. Of these, 26 were coal-fired, 25 were OCGTs, 13 nuclear powered, 8 CCGTs, 6 oil-fired and 8 hydro-electric and pumped storage plants. The current trend is towards power generation from CCGTs, with approximately 15 plants in total planned for the year 2000.

In 1990, the electricity industry, excluding the nuclear sector, was privatised, so that generation and supply are now under the control of separate companies.

2. Processes

2.1 Materials handling and storage

2.1.1 Coal

Coal handling and storage on the scale traditional for power stations requires extensive areas of stockpiles. These stockpiles are generally situated directly on the ground.

2.1.2 Oil

Fuel oil is stored in bulk storage tanks of about 100 000 tonnes capacity. It is pumped via surface pipes into oil heater houses and then passed under pressure into the boiler combustion chambers. Today all oil tanks are contained in bunds with most of the tankage and pipework above ground. The most common oils used in oil-burning power stations were heavy fuel oils and these solidify at ambient temperatures.

2.1.3 Cleaning and water treatment materials

Boiler cleaning solutions are not stored on site but are delivered when necessary, because the cleaning operation is infrequent. Bulk storage tanks are maintained on site in order to store materials for boiler water treatment and cooling water conditioning. Today, the acids, sodium hydroxide and sodium hypochlorite are stored in bunded tanks while hydrazine is stored in small drums.

2.2 Power generation

In coal-fired power stations, the coal is pulverised for maximum combustion efficiency and is fed into the combustion chamber of a boiler. The pulverised coal is blown into the furnace and burnt as a suspension in air and combustion gases, the pressure being maintained by the incoming air. Water circulating in tubes in the walls of the boiler evaporates into steam which is piped under high pressure into the turbines. As the steam expands, it turns the rotors within the turbines. The rotors turn electromagnetic generators which feed electricity to transformers, where the voltage of the produced electricity is transformed to that of the Grid system prior to distribution. Heavy fuel oil has been in use in coal-fired power stations since the mid-1950s. Its function is to stabilise the flame of the pulverised-coal burners. Diesel is used for the auxiliary boilers which are brought into operation during the start-up of the power station.

Electricity is generated from oil using similar methods to generation from coal. Oil is pumped under pressure into the boiler combustion chambers, producing steam to drive the turbines. The oil-burning power stations use heavy fuel oil.

Open Cycle Gas Turbines (OCGT) use light oil fractions, normally diesel, as a fuel. OCGTs are commonly described as gas turbines since they use the gases from fuel combustion (rather than steam) to drive the turbines.

Combined Cycle Gas Turbines (CCGT) use natural gas as a fuel. There are two stages involved. Firstly, the fuel burns to produce propellant gas to drive the turbines. The propellant gas leaving the turbines is still hot enough to take part in a second stage where it is used to heat water, producing steam to give power to a steam turbine. These two stages ensure a high efficiency (output/input energy) of 50-60%, compared to 35% for a modern coal-fired power station. For some CCGTs the gas supply cannot be guaranteed and this is described as an interruptible supply. In some instances, diesel can be used as a standby fuel and therefore some CCGT installations will store diesel for this purpose.

2.3 Chemicals and the power generation process

2.3.1 Boiler cleaning

During normal operation, boilers accumulate scale on their internal surfaces. This is predominantly iron oxide but copper oxide may also be present. The scale inhibits heat transfer and, if it becomes too thick, it can act as a site for corrosion of the boiler tube water-side surface. To avoid this happening, the boiler's internal surfaces are periodically cleaned using chemicals.

Various chemicals can be used in the cleaning process including citric acid, hydrochloric acid, ammonium bifluoride and sodium bromate. In addition, organic-based chemical inhibitors are used to ensure that the oxide rather than the metal of the boiler tubes is dissolved. Following cleaning the metal surfaces are 'passivated' using hydrazine and ammonia.

2.3.2 Water/steam circuit conditioning

The water/steam circuit of the boiler/turbine unit is effectively a closed one. The water/steam is circulated at high pressure and temperature. To avoid corrosion in the boiler and turbine, the water/steam has to be of high purity and is conditioned. Ammonia is added to maintain alkalinity and hydrazine is added to remove oxygen in the water feed to the boiler water. Other chemicals such as sodium hydroxide and sodium phosphate may also be added to the boiler water.

Both conditioning chemicals and impurities can be concentrated in the boiler water. Their concentrations are controlled by water blowdown, a process whereby water is bled from the boiler. The extent and frequency of the blowdown required is determined by the design of the boiler, the chemical treatment regime and the rate of ingress of impurities into the system. In past practice, where lower temperatures and pressure were used than in modern plant, conditioning comprised of water softening, with higher levels of impurities being tolerated.

2.3.3 Water purification.

Water losses from the system occur due to boiler blowdown and leakage. This water has to be replaced by high purity water to minimise the risk of corrosion in the water/steam circuit. Purified local water sources are used as make up water. The

most common purification process used is ion exchange. This involves the use of regenerated acids (sulphuric and possibly hydrochloric) and regenerant alkali (normally sodium hydroxide). Typically effluents from the regeneration process are neutralised by mixing in a holding sump and discharged, under authorisation, to surface water, usually via the cooling water outfall.

2.3.4 Conditioning of cooling water

At power stations where cooling water is employed (all except OCGTs), chemicals are often used to condition the cooling water. Typically the chemicals used include sulphuric acid to maintain the pH balance and sodium hypochlorite to reduce fouling. In the past, cooling water systems have been conditioned using chlorine, which would have been produced on site in an electrochemical plant.

2.4 Wastes and residues

2.4.1 Ash

Coal-fired power stations

Ash is the principal operational residue from the power generation process, particularly in coal-fired power stations (oil power stations produce very little ash). Two types of ash are formed during the combustion of the pulverised coal. Larger agglomerated particles of coal ash fall to the base of the boiler. These particles are known as Furnace Bottom Ash (FBA) or clinker.

The small and light combusted coal particles are carried out with exhaust gases such as sulphur dioxide, carbon dioxide and oxides of nitrogen, and collected by electrostatic precipitators. In the past, cyclones and other devices were used, which had a lower collection efficiency (80-90%) than electrostatic precipitators (99.5%). This fine ash is known as Pulverised Fuel Ash (PFA). Some 80% of FBA and PFA are alumina-silicates which form a glassy matrix enclosing the other compounds. Typically, 80% of ash produced is PFA and 20% FBA.

The semi-volatiles, which include a wide range of metals, emerge from the boiler in gaseous form. As the exhaust gas temperature drops, these semi-volatile materials condense on to the surface of the PFA particles.

Volatile elements, such as bromine and mercury, do not condense until the gas temperature is lower than that at the precipitators.

The levels of trace elements in the ash are dependent on both the composition of the coal and the way in which these elements become preferentially partitioned between the different types of ash. As the average ash content of coal is around 16-17%, this results in a mass concentration of about 6 between the proportion of non-volatile elements in the coal and in the ash.

FBA and PFA contain the following:

- aluminium, iron and silicon (81% together)
- carbon (2-16%)
- calcium, potassium, sodium and magnesium (6-15% together)
- sulphates
- trace elements including: arsenic, boron, cadmium, chromium, copper, manganese, molybdenum, nickel, lead, sulphur, selenium, titanium, vanadium, and zinc.

Currently, 40-50% of PFA is sold to make roads, embankments, cement, bricks and building blocks. All FBA is used for road-making and as aggregate for concrete.

Ash which is in excess of market demand is disposed of to dedicated coal ash disposal sites. The ash is wet sluiced to lagoons, or disposed of to landfills. PFA is compacted and shaped when disposed of to landfill, to allow adequate drainage of surface water. At PFA disposal sites, the top soil is stripped and a foundation of coarse FBA is laid to ensure structural stability. A PFA disposal site is usually surrounded by a drainage ditch to collect surface run-off and leachate, which are discharged to a local watercourse. A completed lagoon or landfill is covered with top soil and plants.

Oil-fired power stations

In comparison with coal-fired power stations, oil-fired power stations produce very little ash as the fuel contains less non-combustible material. Ash production is around 1% of the mass of fuel burned.

As with coal-fired power stations, much of the ash becomes entrained in combustion gas exiting the boilers. At oil-fired stations, because the concentration of ash in the flue gas is very low, the ash is not usually removed from flue gas by precipitators. Some stations are fitted with cyclones which capture a proportion of the ash before the flue gas is emitted to air. Ash is also accumulated in the base of the boiler as a slag which is periodically cleaned out.

Ash from oil-fired power stations tends to have lower concentrations of most metals apart from vanadium, which is enriched. Normal concentrations range from 2% to 12% vanadium pentoxide, although higher values have been reported.

Ash from oil-fired power stations is disposed of as a Special Waste by contractors to independently operated landfill sites licensed to accept this waste.

2.4.2 Flue gas desulphurisation

Flue gas scrubbing with seawater, to reduce emissions of sulphur dioxide, was first used in the United Kingdom during the late 1930s at the now decommissioned Thameside power stations. Current Flue Gas Desulphurisation (FGD) equipment is based on limestone scrubbing to form calcium sulphate (gypsum), which is expected to be sold, chiefly for plasterboard manufacture.

2.4.3 Timber treatment chemicals

Copper, chromium and arsenic-based chemicals and, to a lesser extent, coal tar creosote, were often used to treat timber used in the cooling towers. Cooling towers were usually demolished on decommissioning. In the past, the timber was sometimes disposed of in the ash disposal areas. More recently, it has been disposed of at licensed tips off site. If the wood was burnt on site, concentrated residues of copper and chromium remained in the ash, whilst much of the arsenic was volatilised. However, the quantities of disposed wood are likely to be small in relation to those of coal ash.

2.4.4 Other process and maintenance chemicals

Ancillary operations on power station sites, such as boiler water treatment, involve the use of a range of chemicals. These chemicals require storage, both as a raw

material and possibly as waste. Water treatment wastes include sulphates and chlorides.

Boiler blowdown water is cooled, neutralised, diluted and typically discharged to surface water.

Options for the disposal of boiler cleaning wastes include:

- disposal to the ash lagoon
- neutralisation and discharge with cooling water
- incineration in a furnace (citric acid/bromate cleaning solutions only)
- off site removal in tankers.

In the past, spent exchange resins may have been disposed of on coal storage stockpiles and subsequently burnt in the power station. More recently, spent exchange resins have been disposed of to licensed waste or ash disposal sites. Ion exchange resins are renewed only once every three, five or ten years and quantities of spent resins will be of orders of magnitude less than those of ash.

2.4.5 Asbestos

Since 1976 all power stations have disposed of asbestos under licence. Records detailing the methods of disposal of asbestos after 1976 are held by the local authorities and the power generating companies.

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. A chemical analysis of any ash and coal dust found on the site should be carried out to determine the nature of the associated compounds.

3.1 Factors affecting contamination

3.1.1 Coal and ash

The most likely areas of contamination are storage sites for coal and disposal sites for ash. Today, most ash is sold for use in roads or construction materials but in the past more would have been disposed of on site.

Soil contamination in coal storage areas may have resulted from loss of coal into the ground as a result of the weight of the stockpile. At derelict power station sites, coal stocks will have been used up during the decommissioning period. However, there may remain a combustible layer of soil mixed with coal remains where stockpiles and conveyors were situated. The dangers of combustion and organic reactions involving pyrites on the majority of power station sites are greatly reduced, as the coal stocks will have been compacted to preclude the ingress of air. Any coal that has entered the soil will have been compressed by the weight of the stockpile and is likely to have been both degraded and covered. This will further reduce the likelihood of combustion.

Coal storage tips and ash tips may contain other wastes, though in relatively very small quantities, for example spent ion exchange resins. It is possible that chemical wastes were disposed of on site, in ash lagoons or landfills.

3.1.2 Fuel oil

Oil contamination is possible through leakage or spillage in delivery, storage or transfer areas and from pipework.

3.1.3 Asbestos

Asbestos was extensively used as insulation in the infrastructure of most power stations built before the 1970s. Asbestos may be a contamination problem at power stations decommissioned prior to 1976. When a plant was decommissioned and the cooling towers demolished, the process buildings may have been left standing.

Contamination from asbestos can be due to:

- asbestos insulation, cladding or roofing materials from residual plant and buildings
- contamination of surface soils as a result of wear and tear, maintenance or demolition of plant and buildings utilising asbestos
- buried asbestos from disposal on site of asbestos waste arising from maintenance and replacement.

3.1.4 Polychlorinated biphenyls (PCBs)

Electrical transformers and capacitors on power generation sites built since the 1940s contained PCBs as a dielectric fluid. PCBs were only associated with new oils (1940-1950) and so are unlikely to be found at power stations decommissioned before 1940. The main use of PCBs, at 100% concentration, was in capacitors in litre quantities. Concentrations in transformer oils were of the order of hundreds of ppm at most. After it was recognised that PCBs may cause environmental problems, their use was phased out and the oils have been gradually replaced. At present, few transformers in existence contain oils with PCBs above 20 ppm. Contamination of soils may have occurred during spills, retrofilling, or break-up of a plant containing PCBs.

3.1.5 Radioactivity

Ash dumps may contain some residual radioactivity and low levels of radon, as coal is naturally radioactive. The radioactivity of coal depends on its type and source, and is likely to be of the same order as that of soils. Ash will be slightly more radioactive. The level of radioactivity associated with ash is unlikely to be a cause of concern, but its presence should be noted.

3.1.6 Other oils and solvents

The maintenance of plant and equipment on site involves the use of engineering departments. The on-site machining of metals, degreasing and paint spraying may have caused contamination. Localised contamination may have been caused through leaks or spillage from drums or bulk tanks during storage transfer or when the chemicals were in use. Further details may be found in the profile covering engineering and ordnance works (see Section 4.3).

Associated potential contaminants include:

- degreasing solvents (such as trichloroethylene)
- metal-based paints (cadmium, lead and chromium)
- cellulose thinners
- lubricating oils, cutting oils and greases, for example mineral oils and petroleum-based resins; lubricating oils are required in fairly large quantities.

3.1.7 Other factors

Contamination of the site may occur through the dispersion of airborne contaminants such as coal dust, ash and asbestos dust.

3.2 Migration and persistence of contaminants

3.2.1 Coal and ash

Coal stockpiles are potentially combustible and a source of particulate pollution of watercourses if washed out into streams or rivers. The water quality of leachate from coal piles is governed by the coal composition. In particular, the aerobic or biological oxidation of pyrites (iron sulphide) in coal can cause acidification of watercourses. Acidic conditions lead to increased mobility of some trace metals, which may contribute to the polluting effect of the leachate.

FBA, which is a glassy matrix formed at very high temperatures, requires very concentrated acids to solubilise its components and it is therefore inert. PFA is also a glassy matrix though it has water-soluble components such as metal sulphates. The major soluble components of PFA are base and earth metal salts, particularly sulphates, eg magnesium sulphate. PFA has cement-like properties owing to the presence of calcium oxides and hydroxides. The leachates produced from PFA in the United Kingdom are alkaline.

The proportion of PFA which can dissolve in water is 2-3% by mass. Saturation of the ash, when it is initially disposed of, may cause the release of soluble material into solution. This may result in the contamination of soil and groundwater, although the potential for contamination is limited. PFA may be considered to be potentially an extensive, but mild, contaminant.

3.2.2 Metals

Metal salt concentration is highest in PFA. The metal compounds are found mainly on the surface of the ash particles and many of them are soluble. Therefore, the potential mobility of metals is quite high even though the ash itself has considerable retentive properties. The movement of metals through the soil may be significantly retarded by clay minerals and organic matter. Some metals form anions, for example chromate, which are more mobile than cations.

Soil acidity, resulting from the presence of sulphates, increases the mobility of many metals, such as trivalent chromium and cadmium. At decommissioned power stations, measurements have been made of acid soils of pH 2-5 and alkaline soils of pH 8-12. There are a number of case studies of the impact of ash disposal on surface and groundwater, and there is certainly potential for leaching under particular conditions. The presence of calcium sulphate, boron, selenium and arsenic in water are important indicators of contamination by PFA.

3.2.3 Organics

Hydrocarbons such as fuel oil, lubricating oil and degreasing solvents are highly mobile and can migrate to contaminate a wide area. Free product released at the surface or leaking from tanks or pipes may flow through the ground and may contaminate groundwater. On encountering groundwater, the liquid may spread out on the surface of the water and migrate laterally, in the direction of the groundwater flow.

Chlorinated solvents and certain lubricating oils which are denser than water, will sink to the bottom of groundwater reservoirs. Solvents and components of fuel oils may have limited, but significant water solubilities. They pose a considerable threat to water supplies in relatively small amounts.

Residual or heavy fuels are solid at normal temperatures and have a very limited mobility. They are therefore able to contaminate surface soil but not groundwater.

The migration of contaminants within the sub-surface environment may be retarded by adsorption. The higher the organic matter and clay content within the soil, the greater the degree of adsorption of organic compounds and the slower the contaminant migration. The greatest degree of migration will therefore occur in coarse-grained sands and gravels containing little organic matter.

Biodegradation processes in soils can be influenced by a number of factors, namely moisture content, oxygen concentration and pH, acting separately or in combination. For example, low moisture content reduces microbiological activity, while high moisture content can reduce oxygen penetration and possibly lead to anaerobic soil conditions. Such conditions enhance the biodegradation of some materials, eg chlorinated compounds, while aerobic conditions are needed to biodegrade many oils. Also, low pHs tend to reduce the bacterial population and encourage fungal activity; at pHs lower than 5, microbiological activity is much reduced. The presence of heavy metals also inhibits micro-organisms. Because of these factors, at high concentrations in soil, even relatively non-persistent compounds may not biodegrade readily. It should be noted that biodegradation may not necessarily result in decontamination, for example, 1,1,1-trichloroethane may degrade to 1,1-dichloroethylene or 1,1-dichloroethane. It is possible for partial microbial transformation to produce a substance more toxic or mobile than its parent compound. PCBs have a low solubility in water and are highly persistent.

3.2.4 Other inorganics

Soluble inorganic contaminants may percolate through the soil to contaminate groundwater or contaminate surface waters through run-off in rainwater. Dissolved sulphate will migrate freely through the soil.

4. Sources of further information

4.1 Organisations

For further information concerning the operation of power stations in the United Kingdom the following organisations should be consulted:

Department of Trade and Industry
1 Palace Street
Victoria
London
SW1E 5HE

Electricity Association
30 Millbank
London
SW1P 4RD

Institution of Electrical Engineers
Savoy Place
London
WC2R 0BL

National Power plc
Windmill Hill Business Park
Whitehall Way
Swindon
SN5 6PB

Powergen plc
Westwood Way
Westwood Business Park
Coventry
CV4 8LG

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

Bowers B. *A history of electric light and power.* Peregrinus in association with the Science Museum, 1982.

Brown J, Ray N J and Ball M. *The disposal of pulverised fuel ash in water supply catchment areas.* Water Research Vol.10, pp 1115-1121, 1976.

Central Electricity Authority. *7-Year record, electricity supply in Great Britain 1948-1955.* 1955.

Central Electricity Generating Board. *Advances in power station construction.* Evidence to the Royal Commission on Environmental Pollution (October 1984). (Pollution by Wastes). Oxford, Pergamon Press, 1986.

Electrical Times Annual Report. Reed. Sutton, Surrey.

Electricity Council (CEGB). *Electricity and the environment.* 1970.

Environmental Resources Ltd. *Environmental impact of future coal production and use in the EEC.* Graham and Trotman, for the Commission of the European Communities, 1983.

Halstead W D. *Chemical aspects of trace element behaviour in coal-fired boiler plant.* In Proc. 20th Hanford Life Sciences Symposium: Coal Conversion and the Environment, Biomedical and Ecological Considerations. Washington DC, 1980.

Parsons R H. *Early days of the power station industry.* Cambridge, University Press, 1940.

Smith R D. *The trace element chemistry of coal during combustion and the emissions from coal-fired plants.* Progress in Energy Combustion Science, Vol. 6, pp 53-119, 1980.

Wadge A and Hutton M. *The leachability and chemical specification of selected trace elements in fly ashes from coal combustion and refuse incineration.* Environmental Pollution Vol 48, No 2 pp 85-89, 1987.

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

Engineering works: mechanical engineering and ordnance works
Gas works, coke works and other coal carbonisation plants
Oil refineries and bulk storage of crude oil and petroleum products

4.4 Health, safety, hazards, wastes and site clean-up

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. *Combustion processes: large boilers and furnaces 50 MW(th) and over.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 1/1 London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Combustion processes: gas turbines.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 1/2 London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Combustion processes: compression ignition engines 50 MW(th) and over.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 1/3 London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Bulk storage installations.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/17 London, HMSO, 1992.

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

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

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

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

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

4.5 Waste disposal and remediation options

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

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

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

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

Annex Potential contaminants

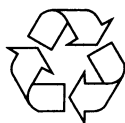
The chemical compounds and other materials listed below generally reflect those associated with the industry and which have the potential to contaminate the ground. The list is not exhaustive; neither does it imply that all these chemicals might be present nor that they have caused contamination.

Metals, metalloids and their compounds	aluminium antimony arsenic barium cadmium calcium chromium cobalt copper iron lead manganese mercury molybdenum nickel selenium tin titanium uranium vanadium (particularly at oil-fired stations) zinc
Coal constituents/products	polycyclic aromatic hydrocarbons (PAHs), eg naphthalene, anthracene, phenanthrene, benzo(a)pyrene, 1,2:5,6-dibenzanthracene
Other organic compounds	fuel oil (heavy oils, diesel) oils (eg lubricating oil) degreasing solvents (eg trichloroethylene, 1,1,1-trichloroethane) polychlorinated biphenyls (PCBs) wood preservatives
Inorganic compounds	ammonium salts boron hydrazine sulphide (iron sulphide - pyrites) sulphate phosphate chloride
Acids	sulphuric hydrochloric
Alkalis	sodium hydroxide
Asbestos	

Table 1 Main groups of contaminants and their probable locations**Power stations (excluding nuclear power stations)**

Main group of contaminants	Location					
	Raw materials delivery storage/ transfer	Fuel storage/ pipework	Process buildings	Drainage system	Electricity transformer areas	Waste disposal areas (ash lagoon)
Metals, metalloids and their compounds						
Coal						
Fuel oils						
Lubricating oils						
Water treatment chemicals						
Asbestos						
Timber treatment chemicals						
Solvents						
PCBs and other transformer oils						

Shaded boxes indicate areas where contamination is most likely to occur



Recycled paper

DOE Industry Profiles

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

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