

# **Pulp and paper manufacturing 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 D L Barry (W S Atkins Environment)  
Consultants in Environmental Sciences Limited  
Mr D Gillett (Paper Federation of Great Britain)  
Mrs J Salmon (Arjo Wiggins Limited)

# **DOE Industry Profile**

## **Pulp and paper manufacturing works**

	Page
<b>Preface</b>	(iii)
<b>1. Background</b>	1
1.1 Introduction	1
1.2 History and location	1
<b>2. Processes</b>	2
2.1 Raw materials, transport and handling	2
2.2 Pulp production	3
2.3 Paper production	5
2.4 Ancillary activities	6
2.5 Waste management	6
<b>3. Contamination</b>	8
3.1 Factors affecting contamination	8
3.2 Migration and persistence of contaminants	8
<b>4. Sources of further information</b>	10
<b>Annex Potential contaminants</b>	13
<b>Table 1 Size and distribution of the industry in 1996</b>	2
<b>Table 2 Main groups of contaminants and their probable locations</b>	15

*This profile is based on work by Dames and Moore International 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.

# **Pulp and paper manufacturing works**

## **1. Background**

### **1.1 Introduction**

The paper manufacturing industry converts raw materials, primarily waste paper and wood, into various paper and board products. Lignin (one of the main constituents of wood, which gives wood its strength) is removed by mechanical or chemical processes known as pulping, and the pulp fibres are bound together again to form the end product.

The wood can be either from coniferous trees (softwood) or from broad-leaved trees (hardwood). Softwoods are preferred for papermaking as they have longer fibres which give a stronger pulp. Hardwoods are favoured for corrugated board and newsprint. Other sources of pulp include recycled fibres (newspaper, cardboard, computer paper etc) and agricultural residues (for example plant fibre such as straw).

In the United Kingdom, over half the fibrous raw material currently consumed by the paper and board manufacturing industry is provided by waste paper; the remainder is from virgin wood pulp, 80% of which is imported.

About a hundred mills are currently in operation in the United Kingdom. Of these, only four are integrated, ie producing both pulp and paper.

### **1.2 History and location**

Nearly all paper in the United Kingdom is made from wood fibre but until the middle of the 19th Century much paper was handmade from rags and cloth. From the second half of the 19th Century until about 1950, esparto, a grass from Spain and North Africa, was also used as a raw material for paper pulp. The change in fibre sources was a result of the mechanisation of the industry.

Paper was first produced in England in the late 15th Century, when John Tate set up a mill in Hertford. In 1588, Sir John Spilman, a goldsmith to Elizabeth I, erected a paper mill at Dartford. The papermaking industry expanded from the 17th Century to the early part of the 19th Century. In 1821, there were 564 mills in England and Wales and 40 in Scotland. By this time, papermaking had spread out from its earliest centre in South-East England to Lancashire, Yorkshire and Durham.

During the 20th Century the number of mills has declined; Census of Production data indicate that there were 289 mills in 1902, 255 mills in 1939, 123 mills in 1980 and, the industry estimates, 105 mills in 1993.

The current size and distribution of the industry is shown in Table 1.

**Table 1 Size and distribution of the industry in 1996**

Type of mill	Number	Location
Integrated pulp and paper	4	Irvine, Gwent, Deeside, Cumbria
Manufacturers of newsprint	3	Ellesmere Port, Deeside, Kent
Manufacturers of graphics paper	about 40	Five main areas: Aberdeen, Fife, Greater Manchester, Lancashire, Kent
Manufacturers of tissue paper	3	Greater Manchester/Sheffield, Kent, Barrow-in-Furness
Manufacturers of packaging papers and cardboards and miscellaneous paper products	over 40	Four main areas: Devon/Somerset, Kent, West Yorkshire, Greater Manchester/Lancashire

Source: The Paper Federation of Great Britain.

## **2. Processes**

### **2.1 Raw materials, transport and handling**

The paper industry obtains less than 10% of its pulp requirements from timber grown in the United Kingdom. Most pulp is imported or comes from recycled waste paper.

Waste paper or wood is delivered to a storage area within the plant by water, rail or road transport. Wood can be brought to the mill in varying degrees of preparation. The ideal state for delivery is in the form of chips which have had their bark already removed. In some cases however, the wood is delivered as logs. Logs are stacked but chips are usually stored in covered heaps.

A range of chemicals is required for pulping, depending on the processes being used. In papermaking, fillers and additives are used to create a product with the required physical characteristics. Biocides, bleaches, sizes, barriers, coatings and dyes are also used to produce the desired brightness, finish and colour. Further details of the raw materials used are given in the following sections and in the Annex.

In the past, chemicals required for the process operations would have been delivered in drums. Today, chemicals are delivered in bulk where possible, in paste, slurry or liquid form. Bulk liquids are usually piped to storage tanks.

Historically, it was common for dyes, additives and adhesives used in the finishing processes to be stored separately and mixed in the appropriate proportions when



required for use. Transfer from storage to this mixing area would have been largely manual, creating a significant risk of spillage. In modern plants, dyes are added at an earlier stage and mixed close to the point of application. The addition, metering and mixing of additives is generally automated, reducing the likelihood of accidental spills.

Starch is stored in silos, although in the past it would have been stored in sacks or drum containers in a white granular form. There is little danger to water supplies from leakage or spills from stored starch, as starch is only slightly soluble in cold water.

Fuel oil for boilers and machine oil for plant is delivered either directly by tanker to storage tanks, or in drums. In recent years gas has been used as fuel in some works.

## **2.2 Pulp production**

### *2.2.1 Mechanical pulping*

Historically, pulp has been produced by mechanical processes. Three of the four integrated pulp and paper mills currently in operation in the United Kingdom use mechanical processes.

Logs are debarked mechanically in a revolving drum or (rarely) hydraulically using high pressure water jets. After debarking, the logs are mechanically reduced to their constituent fibres, either by forcing the log against a grindstone, or by chipping it into pieces about 30 mm square and 5 mm thick and mechanically reducing these chips. The chips are washed to remove mineral or metallic particles and passed to a refiner which reduces them to their constituent fibres. Either mechanical pulping (RMP) or thermo-mechanical pulping (TMP) processes are used in the United Kingdom.

Fibres which have not been separated are screened out after the refining process and returned to a rejects refiner for further working. These fibres tend to be the toughest and are blended with other fibres to give added strength.

The pulp is cleaned by adding water, and then thickened to remove dirty water. The thickened pulp is then sent to the pulp storage tank as unbleached pulp, prior to bleaching and/or stock preparation. Potentially the pulp can then be dried for transport and use off-site.

All three mechanical pulping mills in the United Kingdom are integrated with papermaking and the majority of the water required for pulping comes from the papermaking machine. Some of the water is re-circulated within the pulping process and some passes forward with the pulp to the papermaking machine.

Mechanical pulp is used in the United Kingdom in newsprint, board and lightweight coated papers (ie short life papers). Mechanical pulp has a lower strength than chemical pulp because the fibres have been mechanically shortened and because it has a high residual lignin content.

### *2.2.2 Chemical pulping*

Chemical pulp production has been limited in the United Kingdom. Chemical pulping results in a lower yield than mechanical pulping but the quality of the pulp is better since the fibres are not damaged.

### *The Kraft process*

This process is no longer undertaken in the United Kingdom. The Kraft pulping operation is an alkaline batch or continuous process which involves cooking the chips in a solution comprising sodium hydroxide and sodium sulphide, called the 'white liquor', at elevated temperature and pressure for 1-2 hours. The chips are then washed to remove the residual liquor, 'black liquor', screened and cleaned of any remaining impurities.

The recycling of the black liquor back to white liquor is an integral part of the process and the overall mill operation.

Chemical pulping processes that are known to be used now are:

### *Semi-chemical processes*

The chips are partially softened with chemicals and then refined in a mechanical pulper. Yields are higher than with chemical pulping and the chemical usage is lower. The main process is the neutral sulphite semi-chemical process which produces a pulp from hardwoods and is used primarily for high quality, strong fluting for packing cases.

Recovery and reuse of chemicals is more difficult than with full chemical pulping because the liquor is more dilute.

One of the four integrated pulp and paper mills in the United Kingdom uses this process.

### *Sulphite processes*

Alkaline sulphites are used under a range of pH conditions to dissolve the lignin.

Sulphite pulping can be carried out with a range of pulping liquors. Three small operations in United Kingdom use sodium sulphite and sodium hydroxide. As with the Kraft process, the wood chips or other fibres are cooked in the liquor at elevated temperature and pressure in batches; the cooking times can be up to 9 hours.

Recovery and recycling of the chemicals used in this process is possible.

### *Other processes*

Chemical pulping with hydrogen peroxide, sodium hydroxide and a stabiliser is used for non-wood fibres. The liquor is very weak compared with full chemical pulping and chemical recovery is not possible. One mill in the United Kingdom uses this process.

## **2.2.3 Recycled fibre (RCF) production**

Collection schemes for waste newspapers, board and office waste are expanding but the main source of recovered paper is from within the industry itself, for example trimmings, poor quality output and returned, unread newspapers. The choice of material depends on the required product.

RCF begins with coarse screening the waste paper or packaging to remove large impurities. The waste paper or packaging is then re-pulped. Treatment in the pulper is designed to maintain as much difference as possible between the physical characteristics of impurities and the fibres, whilst dispersing the fibres.

After re-pulping, centrifugal cleaning and fine screening are carried out to remove smaller impurities such as metals, plastics and adhesives (the latter, 'stickies', are the most difficult to remove). Fillers such as clays and chalks do not need to be removed except in the manufacture of tissues.

De-inking is carried out when high quality white paper or newsprint is produced. Ink can be removed from the fibre slurry by washing or flotation. Flotation involves the addition of collector chemicals, such as the alkali salts of fatty acids and soaps, and bubbling air through the slurry; ink particles adhere to the bubbles which concentrate as froth on the surface which is then easily removed. If a high standard of de-inking is required both washing and flotation are used.

#### *2.2.4 Bleaching and drying*

All pulp requires bleaching to remove residual lignin before papermaking commences.

For mechanical pulp, imported pulp or RCF pulp, hydrogen peroxide, sodium hydrosulphite or formamidine sulphuric acid are typically used for bleaching. Chlorine was widely used in the past but few mills use it today. Sodium hydroxide (peroxide bleaching only), sodium silicate and chelating agents such as DTPA (diethylenetriamine pentaacetic acid) are used for complexing heavy metals such as manganese which would inhibit the action of the hydrogen peroxide or sodium hydrosulphite.

In chemical pulping, the majority of the lignin has been removed in the pulping stage and bleaching is basically a continuation of the process. Sodium hypochlorite or hydrogen peroxide may be used for brightening chemically pulped fibres.

After bleaching, the pulp is washed and thickened. Where chlorine has been used for bleaching, chemicals are added to remove the residual chlorine.

Where pulp is to be transported it will be dried by thickening and/or pressing to increase the solids content (up to 90%).

## **2.3 Paper production**

### *2.3.1 Refining and chemical addition*

The manufacture of paper from pulp begins with 'slushing' which turns the pulp into an aqueous slurry that allows fibres to be dispersed. The paper is then treated by mechanical refining. During this process, clusters of fibres are brushed out and cut to a more uniform length, thereby further increasing their surface area and improving their adhesion.

Sizing is the process of coating the fibres and filling the pores of the paper to give it some degree of water or ink repellence. This can be done at the refining stage, by the addition of rosin, aluminium sulphate, starch or water-glass.

Fillers, dyes and other additives are also added at this stage to improve the strength and quality of the paper. Fillers increase opacity and give a better printing surface.

### *2.3.2 Paper formation and pressing*

Papermaking machines are based on the Fourdrinier machine of the early 19th Century. The pulp is distributed under pressure on to a moving fine mesh screen called the wire. The wire is continuous, and the fibres form a sheet whilst water is removed by gravity and suction. The surface of the paper may be sprayed with glue-like substances such as rosin and wax emulsions, to size the paper. The sheet is then passed through a number of presses to remove excess water and to force the fibres closer together.

### *2.3.3 Drying, smoothing, rolling and storage*

Residual moisture is removed and further fibre bonding occurs in the drying section of the machine. Here the paper is passed through a series of steam-heated cylinders. It may then be coated, further dried and possibly calendered, a process in which the sheet is pressed between metal rollers to reduce the thickness and smooth the surface. Finally the sheet is removed from the machine on to a reel.

Final products such as paper, paper board, cartons, boxes and bags are most likely to be stored, on reels or in boxes in bulk, in a warehouse and then transferred to a dispatch area for transport via truck or train.

## **2.4 Ancillary activities**

### *2.4.1 Input water treatment*

The paper industry uses large volumes of water as a fibre carrier and as a solvent. At the stage where the paper is formed on the wire, the ratio of water to fibre is 100:1. An increasing volume of water is being recycled, but additional water is required to make up losses. A bleached pulp and paper mill may use 100 m<sup>3</sup> of fresh water per tonne of product.

Some mills have readily available pure water sources that do not require treatment. However, in many cases incoming water must be treated to remove or reduce impurities to a level which will be consistent and will not impede the manufacturing process. Chlorine, chlorine dioxide, sodium hypochlorite and bromine compounds (for example hypo-bromous acid) are widely used. A range of organic biocides (for example dichlorophen, brominated compounds, organo-sulphur compounds and organo-nitrogen compounds) are used for micro-organism control. The main factor affecting water quality for paper manufacture is the level of suspended solids. Therefore treatment processes may include settling and sedimentation, filtering and coagulation, often using chemicals to aid flocculation. These treatments are also applied to re-circulated water.

### *2.4.2 Heat and power provision*

Mills will have their own heat generation systems. Oil is the most commonly-used fuel.

The electrical power used at the mill is likely to be a combination of purchased power and site-generated power (from steam). Transformers and capacitors on site may have contained polychlorinated biphenyls (PCBs).

## **2.5 Waste management**

### *2.5.1 Effluent treatment*

The major sources of effluent with a contamination potential include the following:

water used in wood handling and debarking  
water from screening and cleaning  
bleach plant washer filtrates  
waste sludge from the pulping process  
paper machine 'white' water containing chemicals not retained in the paper.

In the past, wastes produced as a result of pulping operations are likely to have been discharged directly to sewers or local watercourses. Such wastes, in addition to containing organic material from the wood, may also have contained chemicals used in the process, such as bleaching agents or biocides.

Effluent is nowadays treated before its disposal to sewers or rivers.

#### *Primary treatment*

Since the 1970s, primary effluent treatment has been carried out. This involves removal of fibres and clay by settling or by clarification using filtration/centrifugation.

#### *Secondary treatment*

Recovery processes reduce waste and increase the amount of chemicals recycled within the process, but there is now a trend towards secondary treatment systems to enable water to be recirculated within the system and to remove more chemicals from effluent before its discharge.

The waste from pulping has a very high biological oxygen demand (BOD). It is most commonly removed in a secondary treatment using an activated sludge process. Micro-organisms are added to the effluent and the mixture is aerated. Compounds such as wood sugars provide food for the growing micro-organisms which are then removed from the effluent by a settling stage.

Sludges are produced at both primary and secondary treatment.

#### *2.5.2 Cleaning of air emissions*

Emissions to air of compounds such as sulphur dioxide, mercaptans, hydrogen sulphide and of particulate matter may be reduced by scrubbing using precipitation and oxidation. The resulting filter cake, sludge or liquid waste may be treated and/or landfilled.

#### *2.5.3 Solid wastes*

Solid waste materials can include empty chemical containers, sacks and drums, and mixtures of fibres, sludge and chemicals.

Waste bark or sawdust are either burned on site for fuel or disposed of off site, for example for use as soft surfacing or in horticulture.

Sludge disposal is a major problem for the paper industry. There is difficulty in removing water from the secondary sludge; the primary and secondary sludges are often mixed to aid water removal, which is necessary if the sludge is to be incinerated. Generally, the sludges are landfilled; if they are not toxic, they can be used on agricultural land. In the past solid waste may have been disposed of to on-site landfills which may not have been lined.

Paper mill solid wastes may be toxic due to the use of chlorine bleaches, creating chlorinated compounds. This problem can be minimised by treatment of the waste with lime and biological organisms.

Debris specific to waste paper recycling, such as metal staples and wire, elastic bands, plastic, and large 'stickies', is usually landfilled.

### **3. Contamination**

The contaminants on a site will largely depend on the history of the site and on the processes carried out there. Potential contaminants are listed in the Annex and the probable locations on site of the main groups of contaminants are shown in Table 2. It is most unlikely that any one site will contain all of the contaminants listed. It is recommended that an appropriate site investigation be carried out to determine the exact nature of the contamination associated with individual sites.

#### **3.1 Factors affecting contamination**

The potential contaminants to be found at a pulp or paper mill can be categorised as either liquid effluent, or spills and leaks of solid or liquid process chemicals.

Liquids can contaminate the site through leaks in the transfer systems (pipes, drums etc), or simply through mishandling and accidents. Any of the chemicals used and stored on site may be spilled, most probably near to where they are used, stored or loaded/unloaded. Historically, the areas where process chemicals were mixed and diluted may have been contaminated by leakage or spillage. If handled and stored properly, there is not a great potential for leaks from drums. Spills of fuel or machine oil during its transfer from storage drums and tanks are possible.

Landfilling of chemical and organic wastes may have been practised on some sites.

It is possible that plant buildings and infrastructure were insulated with asbestos lagging, or asbestos cement sheeting was used in roofing or cladding. This asbestos material may be found in discrete dumps on the site where plant has been dismantled or it may still be associated with existing buildings and plant.

There may be contamination by polychlorinated biphenyls (PCBs) where transformers/capacitors containing these substances have been de-commissioned, or where transformer oils have been replaced on site.

The use of chlorine for the bleaching of pulp produces chlorinated organic compounds, including dioxins and furans, from the reaction with residual lignin. This may have led to contamination by these compounds.

#### **3.2 Migration and persistence of contaminants**

The magnitude of the risk to groundwater depends on the depth of the water table and the properties of the soil. Generally, the higher the natural organic matter and clay content within the soil, the greater the adsorption of contaminants and the lower their mobility. Conversely, the greatest migration of contaminants will occur in coarse-grained sands and gravels with little natural organic content. The less soluble and therefore less mobile compounds which become adsorbed on to clay or organic matter may cause water pollution long after the original source has been removed, as a result of the chemical continuing to desorb into soil-water.

The fate of a number of the compounds released may also be affected by microbiological activity. If a large volume of organic matter, for example from wood fibre, is deposited in on-site landfills, such material will have a high biological oxygen demand (BOD) and could result in anaerobic conditions. Under these conditions there may be generation of methane (which is potentially explosive), carbon dioxide, hydrogen sulphide and leachate containing various organic breakdown products, for example organic acids of high BOD.

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, for example chlorinated compounds, while aerobic conditions are needed to biodegrade many oils. Also, low pHs tend to reduce the bacterial population and encourage fungal activity; at pHs lower than 5, microbiological activity is much reduced. The presence of heavy metals also inhibits micro-organisms. As a result of these factors, at high concentrations in soil, even relatively non-persistent compounds may not biodegrade readily.

#### *3.2.1 Oils*

If there is a major spillage or prolonged leakage of oil, this will migrate towards the groundwater where it will tend to float on the water table. Although aqueous solubility is low, concentrations in water may be several orders of magnitude higher than water quality standards permit.

#### *3.2.2 Solvents*

Most of the organic solvents, which are non-chlorinated (see Annex), may be encountered in liquid or vapour form; close to the soil surface some of the organic solvents will be lost directly to the atmosphere by evaporation. These solvents are water soluble and are therefore very mobile.

#### *3.2.3 Other organic compounds*

Some of the chlorinated organic compounds, for example chlorinated phenols, which may be produced as a result of the bleaching process, may have significant aqueous solubilities and migration potential.

Urea formaldehyde resins are persistent. PCBs are very persistent, fat-soluble and tend to accumulate in food chains.

#### *3.2.4 Metals*

The movement of metals through the soil is significantly retarded by the presence of clay minerals and natural organic matter. The solubility of some metals (for example cadmium) may increase under acidic conditions. In other cases the relationship is more complex.

Metals are not biodegradable, but there is potential for some metals to be transformed biologically into more toxic forms.

#### *3.2.5 Other inorganic compounds*

Many of the compounds used in pulping liquor and bleaching solutions are soluble in water, and so they all represent a potential source of groundwater and surface water contamination; they are not biodegradable.

Spillage of acids and alkalis could have a significant effect upon the integrity of concrete foundations, and corrosive vapours may also affect structures in enclosed areas. These may be significant in view of the large quantities of acid being handled. High sulphate concentrations in soil may also be detrimental to concrete.

Asbestos is neither soluble or biodegradable.

Wind dispersal of surface contaminants such as asbestos or some metals may be a further transport mechanism.

## **4. Sources of further information**

### **4.1 Organisations**

For information concerning pulp and paper manufacturing industry in the United Kingdom, the following organisations should be consulted:

Paper Federation of Great Britain  
Papermakers House  
Rivenhall Road  
Westlea  
Swindon  
SN5 7BE

PIRA International  
Randalls Road  
Leatherhead  
Surrey  
KT22 7RU

### **4.2 Sources of information concerning the activities described in this profile**

**Austin G T.** *Shreve's chemical process industries*. 5th Edition. McGraw-Hill, London. 1984.

**British Paper and Board Industry Federation.** *United Kingdom pulp, paper and board mills (Map)*. 1992.

**Dragun J.** *The soil chemistry of hazardous materials*. Hazardous Materials Control Research Institute, Silver Spring, MD, USA. 1988.

**Hills R L.** *Papermaking in Britain 1488 - 1988. A Short History*. 1988.

**Kent J A.** *Riegel's handbook of industrial chemistry (Ch 7)*. 9th edition. Van Nostrand Reinhold, New York, 1992.

**Shorter A H.** *Papermaking in the British Isles, an historical and geographical study*. 1971.

**Smook G A (Editor).** *Handbook for pulp and paper technologists*. Joint Textbook Committee of the Paper Industry, 1982.



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 pulp and paper manufacturing industry 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:

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

*Census of Production Reports.* Board of Trade, HMSO (from 1924 to 1993).

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

**Department of the Environment.** *Documentary research on industrial sites.* DOE, 1994.

#### 4.3 Related DOE Industry Profiles

Chemical works: coatings (paints and printing inks) manufacturing works  
Chemical works: inorganic chemicals manufacturing works  
Textile works and dye 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.** *The making of paper pulp by chemical methods.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 6/8, London, HMSO, 1995.

**Her Majesty's Inspectorate of Pollution.** *Paper making and related processes including mechanical pulping, recycled fibre and de-inking.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 6/9, London, HMSO, 1995.

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. Of particular relevance is:

**Department of the Environment** *Special Waste: a technical memorandum providing guidance on their definition*. Waste Management Paper No 23, Special Waste. London, HMSO, 1981. New edition in preparation.

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 metallic compounds	aluminium sulphate (size) phenylmercuric compounds ethylmercuric compounds (biocides) chromium salts iron salts cadmium salts (dyes)
Inorganic elements and compounds	hypochlorites chlorates boron compounds thiosulphates sulphates sulphites sulphides bisulphites hydrosulphites sulphur phosphates ochre, sienna (dyes)
Acids	sulphuric
Alkalis	sodium hydroxide
Solvents (for pulp production)	acetic acid formic acid sulphonic acid sulpholane glycols acetone phenol cresol monoethanolamine triethanolamine ethanol methanol
Organic compounds: size	eg rosin alkyl ketene dimer (AKD) alkyl succinic anhydride (ASA)
wet strength additives	eg urea formaldehyde resins aminopolyamide-epichlorohydrin resins

dry strength additives	eg acrylamide polymers wax emulsions
coatings	eg polyvinyl alcohol carboxy-methyl cellulose styrene butadiene latex
softening agents (for tissues)	eg quaternary ammonium salts
optical brightening agents	eg bis(triazinyl-amine)-stilbene disulphonate
barriers and coatings	eg nitriles acrylics
dyes	eg indigo alizarin
chlorinated organic compounds (from the use of chlorine)	eg chlorinated phenols dioxins furans fatty alcohol polyalkylene glycols alkylphenol ethoxylate
biocides	eg dichlorphen bromonitrostyrene bromonitropropandiol bisthiocyanate organobromine compounds organosulphur compounds aldehydes
pesticides	eg lindane (in imported pulp)
Oils	fuel oils lubricating oils mineral oils (from ink-related processes)
Polychlorinated biphenyls (PCBs)	
Asbestos	

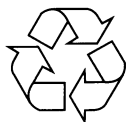
**Table 2 Main groups of contaminants and their probable locations**

**Pulp and paper manufacturing works**

Main groups of contaminants	Location							
	Raw materials and delivery	Transport and handling	Building fabric	Manufacturing process			Waste management	Water treatment
				A	B	C	Heating systems	Electricity transformer areas
Metals and metallic compounds								
Inorganic compounds								
Acids and alkalis								
Solvents								
Other organic compounds								
Oils								
Asbestos								
Polychlorinated biphenyls (PCBs)								

- A Pulp production from new wood
- B Pulp production from waste paper
- C Paper production

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.