Department of the Environment
Industry Profile

Chemical works

organic chemicals manufacturing works

Industry Profile sponsored by
Contaminated Land and
Liabilities Division

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

Chemical works: organic chemicals manufacturing works

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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.

Chemical works: organic chemicals manufacturing works

1. Background

This profile is concerned with primary aliphatic (eg ethylene, propylene, butadiene) and aromatic (eg benzene) organic chemicals and the intermediate and final product chemicals derived from them.

Synthetic organic chemicals are manufactured from natural organic materials, such as petroleum, natural gas and coal which have undergone at least one chemical reaction, eg oxidation, hydrogenation or chlorination.

1.1 History

Until the Second World War, organic chemical manufacture in the United Kingdom was based mainly on coal, the by-products of the manufacture of coal-based town gas (coal tar and benzole) and on the fermentation of carbohydrates to produce ethanol.

A major feature of the post war period has been the growth of the oil refining industry as the main source of both aliphatic and aromatic primary organic chemicals. This has been in response to the decline in town gas production as oil and natural gas have replaced it as fuel. In addition, more crude oil was converted to petroleum spirit to keep pace with the increase in the numbers of cars. An economic outlet was needed for the by-product hydrocarbons from the conversion processes, such as ethylene, propylene and butadiene. Natural gas has provided a source of methane since the 1960s.

The use of petroleum stocks as a raw material for the organic chemicals industry increased from only 6% of all material in 1949, to 51% in 1959 and to over 90% in 1990.

1.2 Location

Heavy organic chemical works in the United Kingdom have generally been linked to the source of the principle organic raw materials, traditionally coke works and town gas works, and later, oil refining and petrochemical complexes.

Oil refineries and petrochemical complexes have been located at coastal or estuarine sites which provide both good handling facilities for seaborne raw materials (eg sheltered deep water harbours for tankers) and plentiful supplies of cooling water. The present locations of the petrochemical industry in the United Kingdom include Fawley near Southampton, Milford Haven in West Wales, Baglan Bay near Swansea, Grangemouth, Stanlow on Merseyside, Killingholme on Humberside, as well as Teesside and Severnside.

In contrast to the industry generally, the part concerned with the manufacture of chlorinated hydrocarbons grew up around the historical sites of the chlor-alkali industry, which provided the chlorine required for their manufacture. The chlor-alkali industry in turn grew up in the 19th century near the mineral sources required for certain processes within the industry.

Manufacture of the products derived from heavy organic compounds tended to develop adjacent to the sites of heavy organic manufacture. For example, one of the two principal manufacturers of chlorofluorocarbons (CFCs) has developed its operations alongside the traditional chlorinated hydrocarbon processes which are the source materials for CFC manufacture. The chlorination hydrocarbon processes developed alongside a chlorine plant. Synthetic fibres and plastics plants have developed alongside producers of feedstocks such as ethylene and polyethylene, polyvinyl chloride (PVC) and chlorine, nylon and aromatics.

Other examples of locations of organic chemicals manufacturing plants are Wilton in Cheshire, Spondon in Derbyshire and Carrington in Greater Manchester.

2. Products

2.1 Primary organic chemicals

In the past carbonisation, or distillation, of coal yielded coal tar and a gaseous fraction including methane and ethylene. The coal tar could be further distilled to produce aromatic hydrocarbons, such as benzene and naphthalene, and phenols.

Other source materials were ethanol (which was dehydrated to produce ethylene) and acetylene (which was used to produce ethylene by hydrogenation and to produce propylene by the addition of methane).

Crude oil, now the principal carbon source for the manufacture of bulk organic chemicals, comprises a complex mixture of saturated hydrocarbons, cycloalkanes and small amounts of alkenes and aromatic hydrocarbons. Oil refining processes use distillation to separate the crude oil into fractions eg naphtha, kerosenes etc. These fractions are further separated into their components by physical and chemical processing (ie further distillations or cracking, reforming etc) to yield the simpler compounds of ethylene, propylene and butadiene, which are the basis for processing a huge variety of intermediate and final product organic chemicals.

Almost 3000 organic chemicals are currently derived from petrochemical sources, involving a vast range of unit process operations which cannot all be described here.

The following sections deal with the six major sources of organic chemicals.

acetylene
methane
ethylene
propylene
butanes, butylenes and higher aliphatic hydrocarbons
aromatics.

Figures showing their most important past and present derivatives appear at the end of the profile.

2.2 Chemicals produced from acetylene

Acetylene was derived from the hydrolysis of calcium carbide (produced by heating lime with coke) but its production ceased in the United Kingdom with the advent of cheaper petroleum-based products. These now provide the precursors, such as vinyl chloride monomer and acrylonitrile, for the chemicals shown in Figure 1 which were previously derived from acetylene.

2.3 Chemicals produced from methane

Methane was produced by various reactions, such as the catalytic reduction of carbon monoxide or carbon dioxide. It is also the major component of natural gas which is the main source of methane today. Methane is relatively inert chemically and its conversion into commercial chemicals generally requires high temperatures and pressures, or reactive chemicals such as chlorine.

See Figure 2 for the important derivatives of methane.

2.4 Chemicals produced from ethylene

Before the Second World War ethylene, for use as a source of other chemicals, was derived from ethanol vapour. Ethanol was produced by the fermentation of carbohydrates, eg sugar cane, sugar beet, molasses. Today, industrial fermentation processes have been almost entirely superseded by petrochemical processes (ie hydrocarbon cracking).

More chemicals are synthesised from ethylene than any other organic petrochemical and the volume of ethylene production is greater than all other organic petrochemicals. The largest consumers of ethylene are the producers of various polyethylene types; other consumers include producers of ethylene oxide and ethylene dichloride (one of the major synthetic organic chemicals). Over 90% of ethylene dichloride is used to make vinyl chloride monomers.

See Figure 3 for the important derivatives of ethylene.

2.5 Chemicals produced from propylene

Propylene is a product of petroleum refinery operations and is a co-product of ethylene cracking. Polypropylene manufacture is one of the large chemical uses for propylene.

See Figure 4 for the important derivatives of propylene.

2.6 Chemicals produced from butanes, butylenes, Liquid Petroleum Gas (LPG) and higher aliphatic hydrocarbons

Butanes occur naturally in crude oil and natural gas, and are produced from other hydrocarbons during the various petroleum refining processes. Butylenes do not occur in nature but are derived from butanes or other hydrocarbons. About 10% of butanes and butylenes are used as chemical raw materials; the rest are consumed as fuel. One of the major chemical products is methyl t-butyl ether (MTBE), an octane booster for petrol.

Butadiene is derived from butanes or butylenes and is mainly used in the production of synthetic rubbers, for example polybutadiene, nitrile rubbers (with acrylonitrile), styrene butadiene rubber (with styrene) and many other co-polymers.

See Figure 5 for the important derivatives of butanes, butylenes, Liquid Petroleum Gas (LPG) and higher aliphatic hydrocarbons.

2.7 Chemicals produced from benzene, toluene and xylenes

Since the Second World War, most commercial benzene, toluene and xylene manufacture has been based on petroleum rather than on coal. About half the benzene and less than 10% of the toluenes and xylenes are used as raw materials for the chemical industry; the rest go into fuels. Benzene is by far the most important aromatic petrochemical raw material.

Toluene is used as a solvent for coatings, paints and lacquers. Derivatives of toluene are benzene, toluene diisocyanate, benzoic acid and benzyl chloride.

Xylenes are obtained from petroleum as mixed isomers ie p-, m- and o-. The chemicals obtained from the xylenes are:

Terephthalic acid and dimethyl terephthalate	Precursors for the manufacture of polyester fibres and film, bottles and polyester thermoplastic resins.
Phthalic anhydride	Used for plasticisers and resins.
Isophthalic acid	For resins.
Naphthalene	For the manufacture of phthalic anhydride, carbaryl (an insecticide), surfactants, dispersants and moth-repelling agents.

See Figure 6 for the important derivatives of benzene, toluene and xylenes.

2.8 Wastes

A wide range of wastes are generated during the manufacture and processing of organic chemicals. Process wastes arising at various stages of manufacture may include the following:

Unreacted source materials	These are normally recycled back into the process but, where this is uneconomic, they may be discharged as waste.
By-products and side products	If there is no further possible economic utilisation of these products they will be discharged as waste.
Tars, filter cakes, precipitated compounds and solvent-containing residues	These derive from operations involving separation and purification of feedstock and end-products.

Spent scrubber solutions	These are produced from washing process streams and are frequently acidic or caustic.
Distillation residues	
Spent catalysts and contaminated containers.	

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. 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

Modern organic chemical manufacturing works tend to be located within large integrated oil refinery and petrochemical complexes, where a large number of recently established, frequently interdependent, processes are likely to be in operation. On sites with a long history of chemical processing, there may be contamination from past production processes. It is very important to establish the early history of a site in order to assess the possible nature of any contamination.

Organic materials are likely to be the principal source of any contamination. There may be coal tar residues on older sites. Organic materials may be present on all sites owing to the spillage, leakage and disposal of raw materials and products. Material may also have been lost during processing operations (eg from leaks in valves, pipes etc).

Organosulphur compounds and sulphates may be found in acid tar lagoons and surrounding soils, from the use of sulphuric acid in coal tar distillation and crude oil processing.

There may be contamination by lime residues and carbon residues on sites where acetylene was manufactured in the past.

Contamination may arise on older sites through the storage and disposal of wastes. In the past little care was taken with the management of these materials. Waste management practices have improved as a result of self-regulation by the chemical industry through the 'Responsible care' programme, and as a result of legislative pressures.

Wastes consist mainly of organic chemical compounds, but they may also contain inorganic chemicals, eg spent catalysts, active carbon and filter aids. Wastes may have been dumped on site in landfills or left as surface deposits. They may also be found in association with remaining infrastructure, eg tanks, lagoons and pipework.

Asbestos insulation products and other asbestos-containing materials, eg roofing materials, may have been used on sites. Asbestos wastes may be found on disused sites, in landfills, as surface deposits or in association with remaining infrastructure.

If the site had its own electricity substation, this may have contained transformers or capacitors filled with polychlorinated biphenyls (PCBs). Localised soil contamination may have occurred as a result of filling or dismantling transformers.

3.2 Migration and persistence of contaminants

The transport and fate of the contaminants in the soil will depend on physical, chemical and biological factors. The higher the organic matter and clay content within the soil, the greater the degree of adsorption of some contaminants, and the slower their migration. Thus the greatest degree of migration will occur in coarse-grained sands and gravels with little organic matter. Contaminants (particularly those which are less soluble in water) that become adsorbed on to clay or organic matter, will provide on-going sources of water pollution long after the original source of contamination has been removed, by continuing to desorb into the surrounding water.

It is difficult to determine which of the many contaminants listed in the Annex may disappear rapidly through evaporation, chemical reaction or biodegradation. Many are persistent and although none are gases at normal temperatures and pressure, some, for example propylene oxide, are quite volatile and reactive.

3.2.1 Coal tar products

Groundwater contamination may occur as a result of leaks in pipework and tanks. Damage to buried pipework during site investigation work may release tars or sludges into the soil and residues of coal tar may remain in pipework. The more soluble components may contaminate surface water through run-off in rainwater, or percolate in solution through soil to the groundwater.

Phenols are extremely soluble in water and may migrate through plastic pipework, polluting water supplies. In water treated by chlorination, they can form chlorinated phenols. Both phenols and chlorinated phenols have an objectionable taste even at low concentrations.

Tars are generally persistent because of their insolubility and chemical complexity and because conditions are generally unfavourable for their degradation.

3.2.2 Chlorinated hydrocarbons

Chlorinated hydrocarbons are generally mobile and may be transported widely in surface run-off, surface water and groundwater. Their water solubilities vary but they can affect drinking water supplies even at very low concentrations. Chlorinated hydrocarbons may attack and dissolve plastic and cause damage to infrastructure or infiltrate water supplies carried by plastic pipes. They are more dense than water and will tend to migrate to the bottom of aquifers, sometimes moving in the opposite direction to general groundwater flow. Halogenated organic compounds may require highly specific conditions for biodegradation to take place, and may degrade very slowly. The biodegradability of chlorinated hydrocarbons decreases with increasing complexity in structure and increasing chlorine substitution. The degradation products of chlorinated organic compounds may be more toxic than their precursors.

3.2.3 Non-halogenated solvents and other organic contaminants including petroleum constituents

Non-halogenated solvents such as the alcohols (eg methanol), acetone and ethyl acetate are very water soluble, are therefore mobile and will migrate to the groundwater.

Other less soluble solvents eg toluene, petroleum and oil hydrocarbons will also tend to migrate to the groundwater. These are usually less dense than water and will float on the water-table surface. Despite their limited solubility, the amount dissolved in water may be several orders of magnitude greater than water quality standards permit.

Solvents, both non-halogenated and halogenated, may increase the solubility and hence mobility of organic compounds that are not water-soluble.

Some organic contaminants will biodegrade naturally but some (eg benzene, toluene, pyridine, petroleum hydrocarbons) may persist owing to unfavourable environmental conditions for degradation. These conditions may be the lack of microbial populations which can degrade specific compounds, too high a concentration of a toxic compound, low pH, low temperatures, or an oxygen content which is inappropriate for the particular micro-organisms.

3.2.4 Organonitrogen and organosulphur compounds

Organonitrogen compounds possess a wide range of water solubilities (generally they are low but significant) and some water contamination may occur.

Organosulphur compounds are mostly insoluble in water; their presence may be suspected by their strong and unpleasant odour.

Both organonitrogen and organosulphur compounds are likely to be persistent, with biodegradability decreasing with greater nitrogen/sulphur substitution.

3.2.5 Metals

Metals are not mobile, although their salts and organo-metallic compounds may be. The solubility of some metal compounds (eg copper, zinc and lead) may increase under acidic conditions. In other cases the relationship is more complex. For example, trivalent chromium is more soluble under acidic conditions, whereas the solubility of hexavalent chromium is increased under both acidic and alkaline conditions and arsenic may become more soluble at higher pHs. If organic solvents are widespread, they may provide the opportunity for groundwater contamination by metal compounds which have low solubilities in water but are readily soluble in these solvents. Inorganic metal salts such as cyanides are water soluble and may reach the groundwater.

The movement of metal compounds through the soil is significantly retarded by the presence of clay minerals and organic matter.

3.2.6 Other compounds

Acids (eg sulphuric acid) and alkalis are water-soluble and therefore very mobile, but not biodegradable. Acid spillages near buildings may affect the integrity of concretes/cements used in foundations and drain connections. Corrosion of drains may also occur.

Wind dispersal of contaminated soil may be a further transport mechanism where there is gross surface contamination by some of the less mobile contaminants, particularly metals and asbestos. Asbestos is neither soluble or biodegradable and persists in the soil.

PCBs have a low solubility in water, do not biodegrade and are highly persistent. They are fat-soluble and tend to accumulate in food chains.

4. Sources of further information

4.1 Organisations

For further information concerning the organic chemicals processing industry in the United Kingdom, the following organisations should be consulted:

Chemical Industries Association Ltd
Kings Buildings
Smith Square
London
SW1P 3JJ

Society of Chemical Industry
14/15 Belgrave Square
London
SW1X 8PS

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

Hardie D W F and Davidson Pratt J. *A history of the modern British chemical industry.* Pergamon Press, 1969.

Heaton C A. *The chemical industry.* Blackie, 1986.

Kent J A (Editor). *Reigel's handbook of industrial chemistry.* 9th Edition. New York, Van Nostrand Reinhold Company, 1992.

Wiseman P. *An introduction to industrial organic chemistry.* 2nd Edition. Applied Science Publishers Limited, 1979.

Case study including information relevant to this profile:

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

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

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

4.3 Related DOE Industry Profiles

Gas works, coke works and other coal carbonisation plants
Oil refineries and bulk storage of crude oil and petroleum products

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. Series 4 of the Process Guidance Notes covers many aspects of the Chemical Industry Sector. Of particular relevance are:

Her Majesty's Inspectorate of Pollution. *Petrochemical processes.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/1. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Processes for the production and use of amines, nitriles, isocyanates and pyridines.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/2. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Processes for the production or use of acetylene, aldehydes etc.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/3. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Production or use of organic sulphur compounds, carbon disulphide.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/4. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Batch manufacture of organic chemicals in multipurpose plant.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/5. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Production and polymerisation of organic monomers.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/6. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Processes for the manufacture of organo-metallic compounds.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/7. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Processes for the sulphonation and nitration of organic chemicals.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/12. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Processes for the manufacture of, or which use or release halogens, mixed halogen compounds or oxohalocompounds.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/13. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Processes for the halogenation of organic chemicals.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 4/15. London, HMSO, 1992.

Her Majesty's Inspectorate of Pollution. *Tar and bitumen processes.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 6/2. London, HMSO, 1995.

Her Majesty's Inspectorate of Pollution. *Di-isocyanate manufacture.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 6/4. London, HMSO, 1995.

Her Majesty's Inspectorate of Pollution. *Toluene and di-isocyanate use and flame bonding of polyurethanes.* Chief Inspector's Guidance to Inspectors, Process Guidance Note IPR 6/5. 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 are:

Department of the Environment. *Halogenated hydrocarbon solvent wastes from cleaning processes: a technical memorandum on reclamation and disposal.* Waste Management Paper No 9. London, HMSO, 1976.

Department of the Environment. *Tarry and distillation wastes and other chemical based wastes: a technical memorandum on arisings, treatment and disposal.* Waste Management Paper No 13. HMSO, London, HMSO, 1977.

Department of the Environment. *Solvent wastes (excluding halogenated hydrocarbons): a technical memorandum on reclamation and disposal.* Waste Management Paper No 14. London, HMSO, 1977.

Department of the Environment. *Halogenated organic wastes: a technical memorandum on arisings, treatment and disposal.* Waste Management Paper No 15. London, HMSO, 1978.

Department of the Environment. *Special wastes: a technical memorandum providing guidance on their definition.* Waste Management Paper No 23. 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.

Note that the soil may be contaminated by reaction or degradation products of the chemicals set out in Figures 1 - 6, as well as any of those listed below.

Coal tar constituents/ products	polycyclic aromatic hydrocarbons (PAHs) eg naphthalene, anthracene, phenanthrene, benzo(a)pyrene, 1,2:5,6-dibenzoanthracene phenols cresols xylenols pyridine quinoline pyrrole benzene toluene xylenes tars tar acids ammoniacal liquors pitch creosote
Petroleum constituents	crude oil aliphatic hydrocarbons alicyclic hydrocarbons aromatic hydrocarbons eg benzene, toluene, xylenes
Organosulphur compounds	mercaptans butyl mercaptans (n-, sec- and tert-) thiophenes alkyl/dialkyl sulphides
Organonitrogen compounds	alicyclic amines aromatic amines ethanolamines organic diisocyanates eg toluene diisocyanate acrylonitrile (vinyl cyanide) acetonitrile (methyl cyanide) 2,4- dinitrotoluene 2,6- dinitrotoluene nitrobenzene aniline carbaryl

Halogenated hydrocarbons and halogenated solvents	chlorinated aliphatics chlorinated alicyclics chlorinated aromatics dichloroaniline chloronitrobenzenes (o-,m- and p-) chlorhydrin and derivatives chlorinated phenols tetrabromobisphenol-A alkyl aluminium halides trichlorofluoromethane
Solvents	alcohols aldehydes ketones cyclohexane ethylbenzene ethylene glycol diethylene glycol triethylene glycol 1,3-butylene glycol triethyl phosphate morpholine tetrahydrofuran carbon disulphide
Other organic compounds	butylene oxide propylene oxide heptene 1-octene butane-2-hydroperoxide trioxymethylene triacetin phthalic anhydride diisononyl phthalate dioctyl phthalate isophthalic acid bisphenol bisphenol-A butyl cresols phenols and their derivatives methyl tert. phenyl carbinol maleic anhydride formaldehyde solution tert-butyl formamide methyl tert. butyl ether (MTBE) hexamethylene glycol glycidol alkyl benzenes b-naphthol methyl methacrylate terbufos

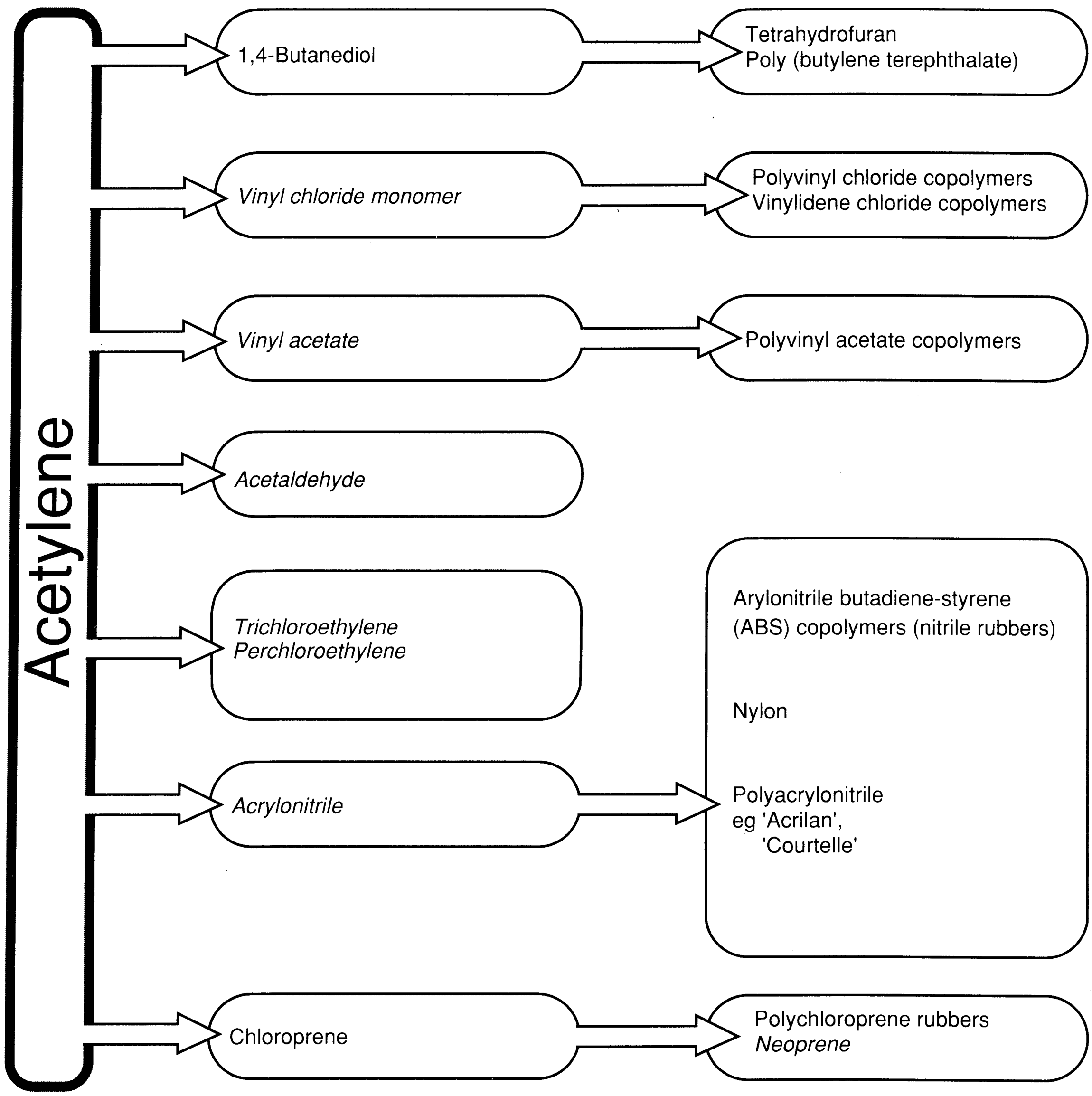
	triphenyl phosphine sodium dodecylbenzenesulphonate tetramethyl lead triethyl aluminium aluminium alkyls isobutyl aluminium compounds various polymers, plastics, elastomers and resins
Acids	acetic acrylic methacrylic formic peracetic maleic sulphuric nitric hydrochloric hypochlorous phosphoric
Alkalis	calcium oxide (lime) sodium hydroxide
Inorganic chemicals	boron calcium chloride phosphorus sulphur
Anions	phosphides phosphates sulphides sulphate bromides chlorides fluorides iodides cyanides arsenides
Metals, metalloids and their compounds	bismuth chromium cobalt copper iron lead manganese molybdenum nickel platinum silver

tin
vanadium
zinc
aluminium oxide
aluminium chloride
copper chloride
cobalt iodide
cobalt carbonyls
ferric chloride
iron oxide
rhodium-iodide (catalyst)
stannic chloride
organo-vanadium halides

Polychlorinated biphenyls (PCBs)

Asbestos

Figure 1 Important derivatives of acetylene



Figures in italic are substances that were no longer produced in the United Kingdom by 1990 but may have contributed to site contamination when they were produced

Figure 2 Important derivatives of methane

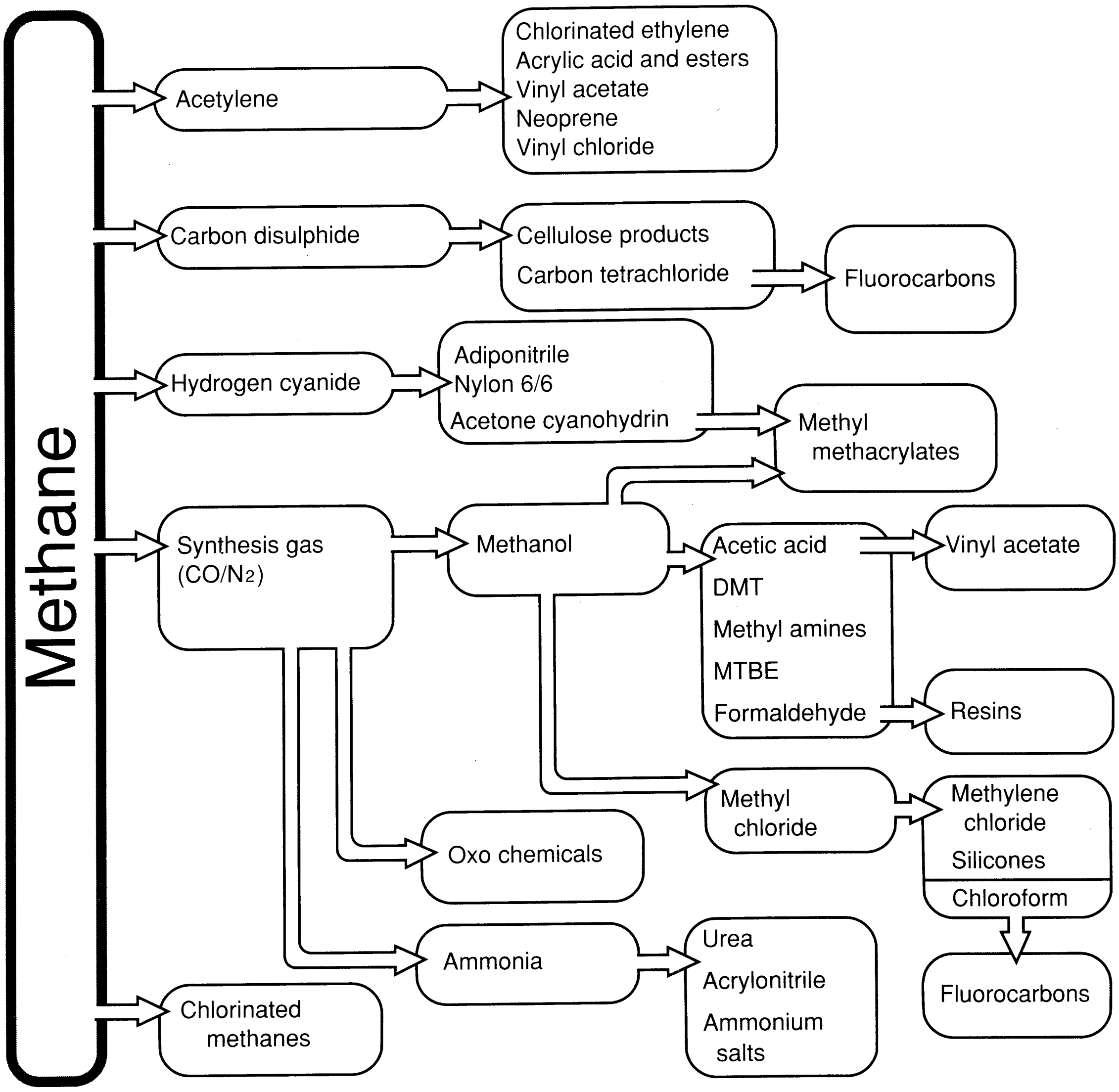


Figure 3a Important derivatives of ethylene

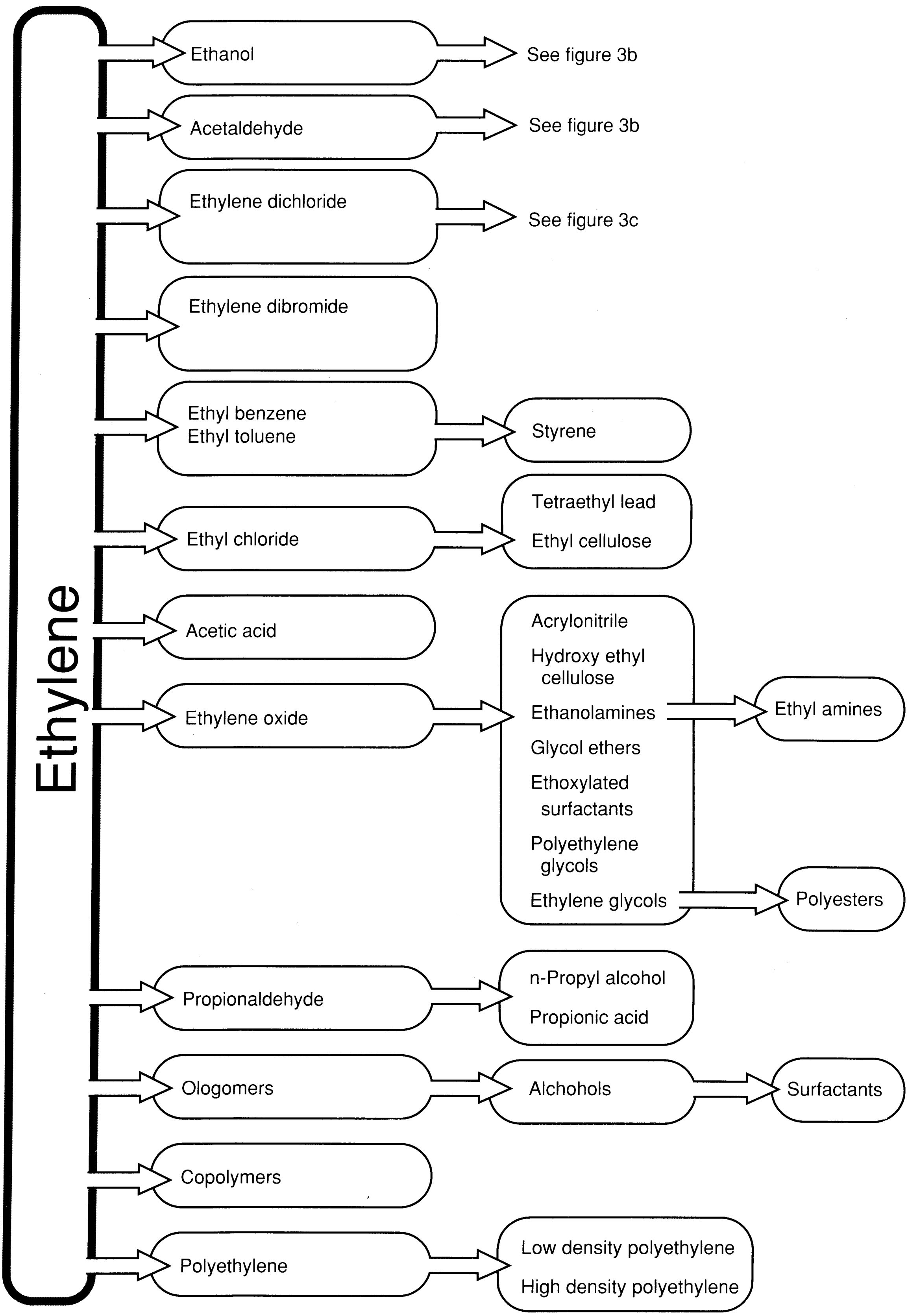


Figure 3b Important derivatives of ethylene (continued)

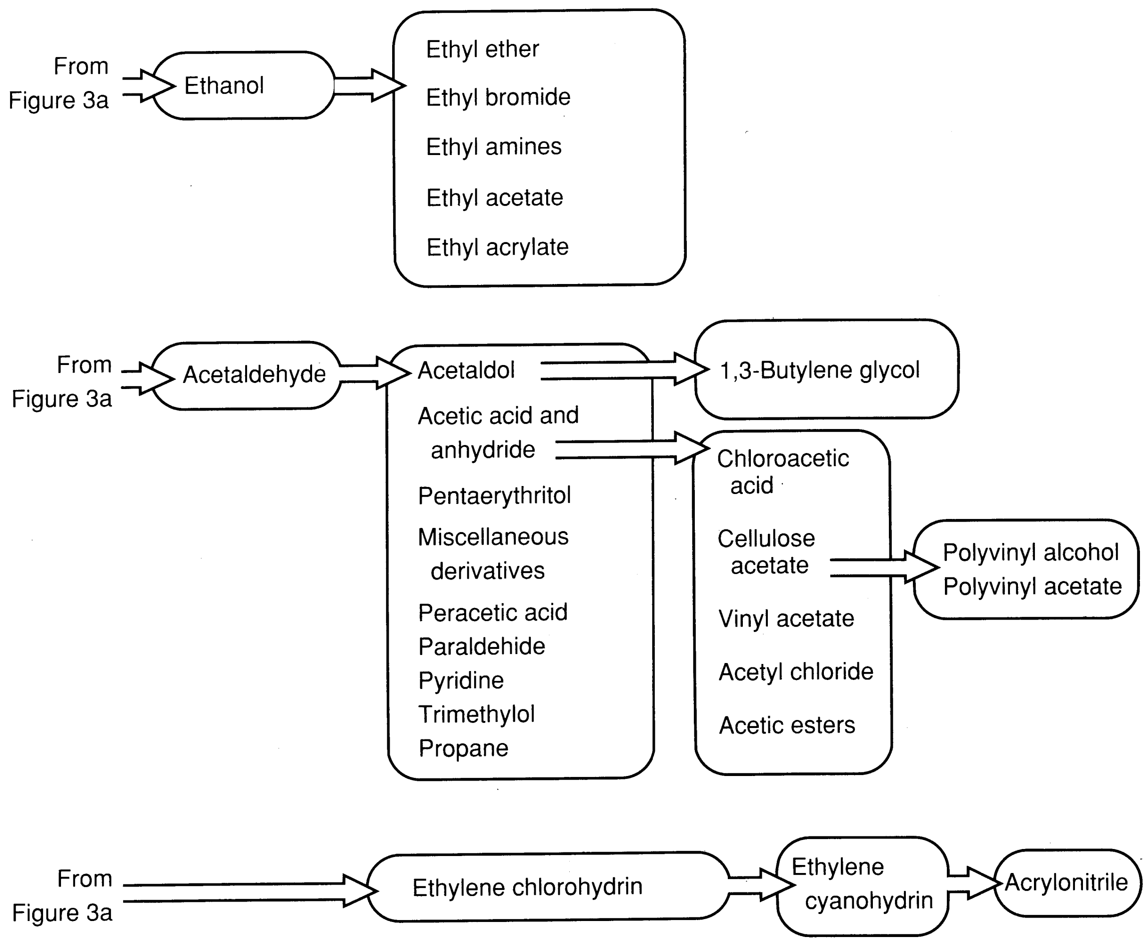


Figure 3c Important derivatives of ethylene (continued)

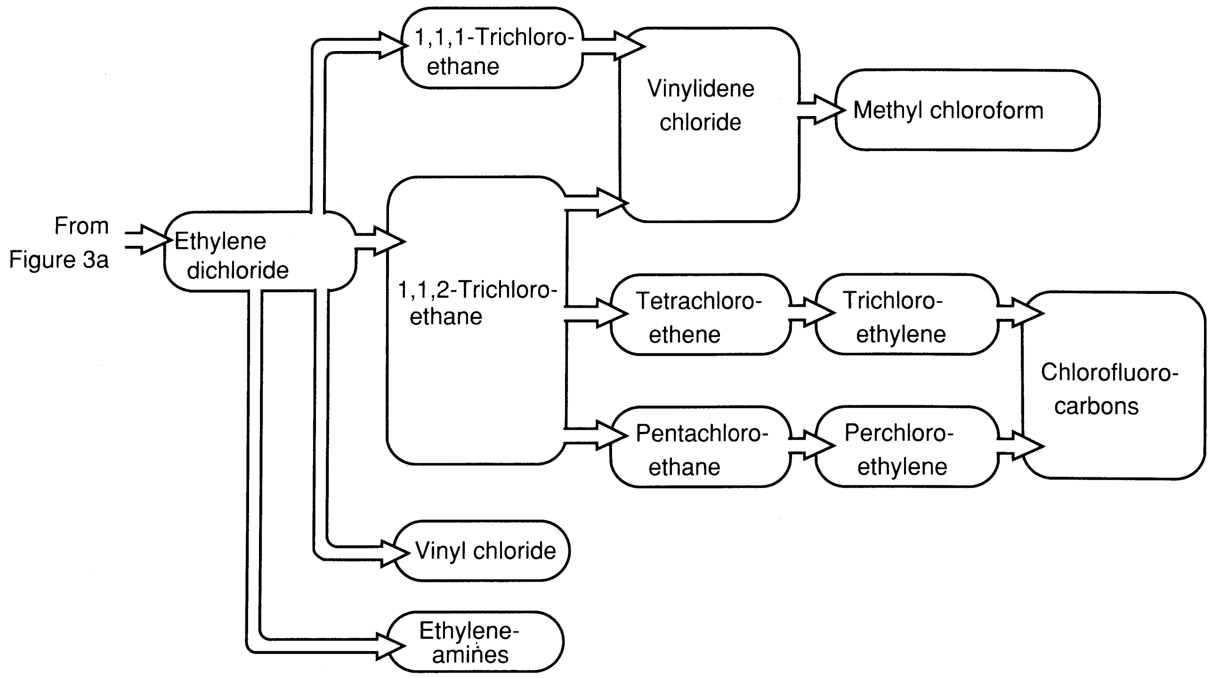


Figure 4 Important derivatives of propylene

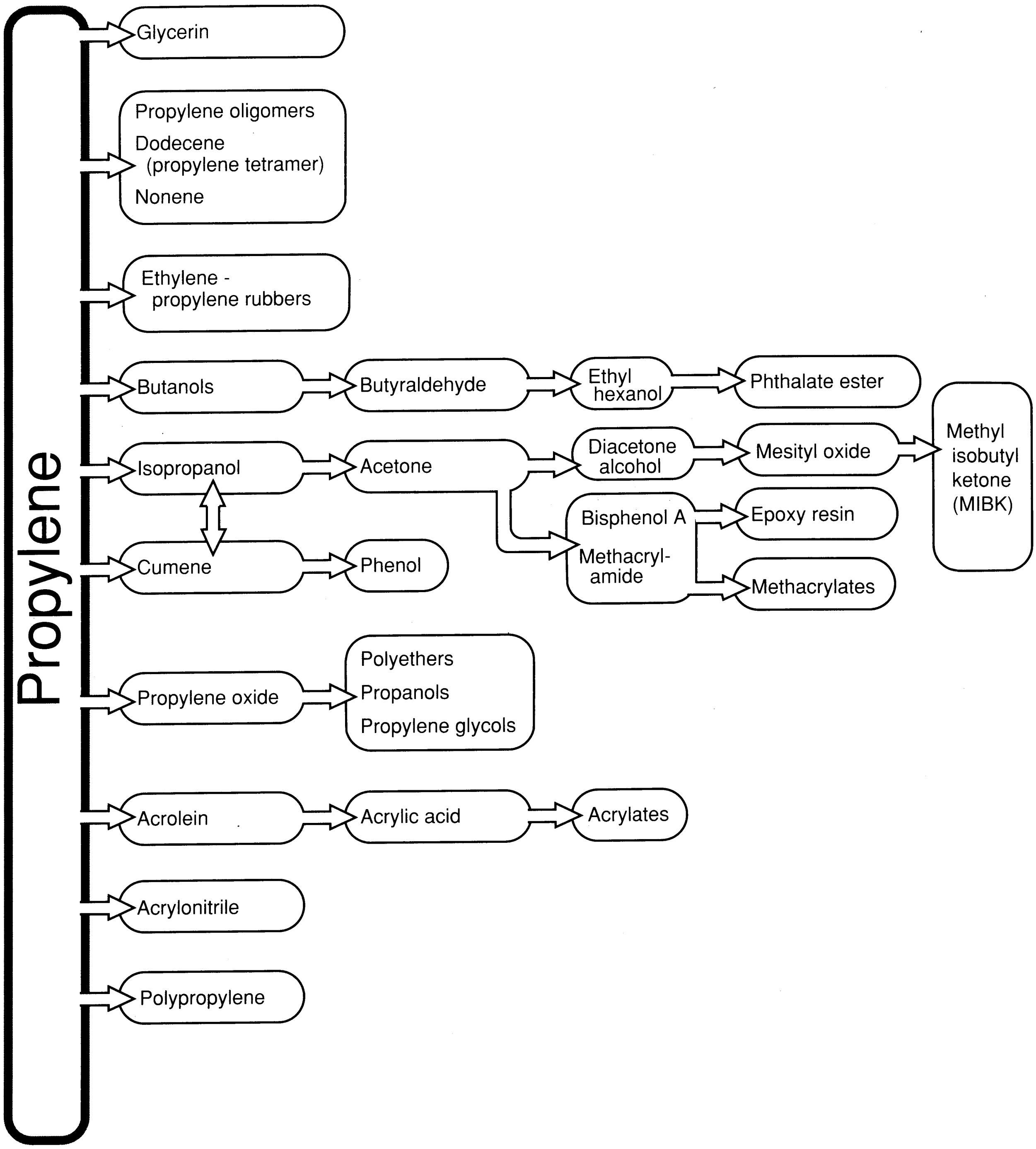


Figure 5a Important derivatives of butanes, butylenes, Liquid Petroleum Gas (LPG) and higher aliphatic hydrocarbons

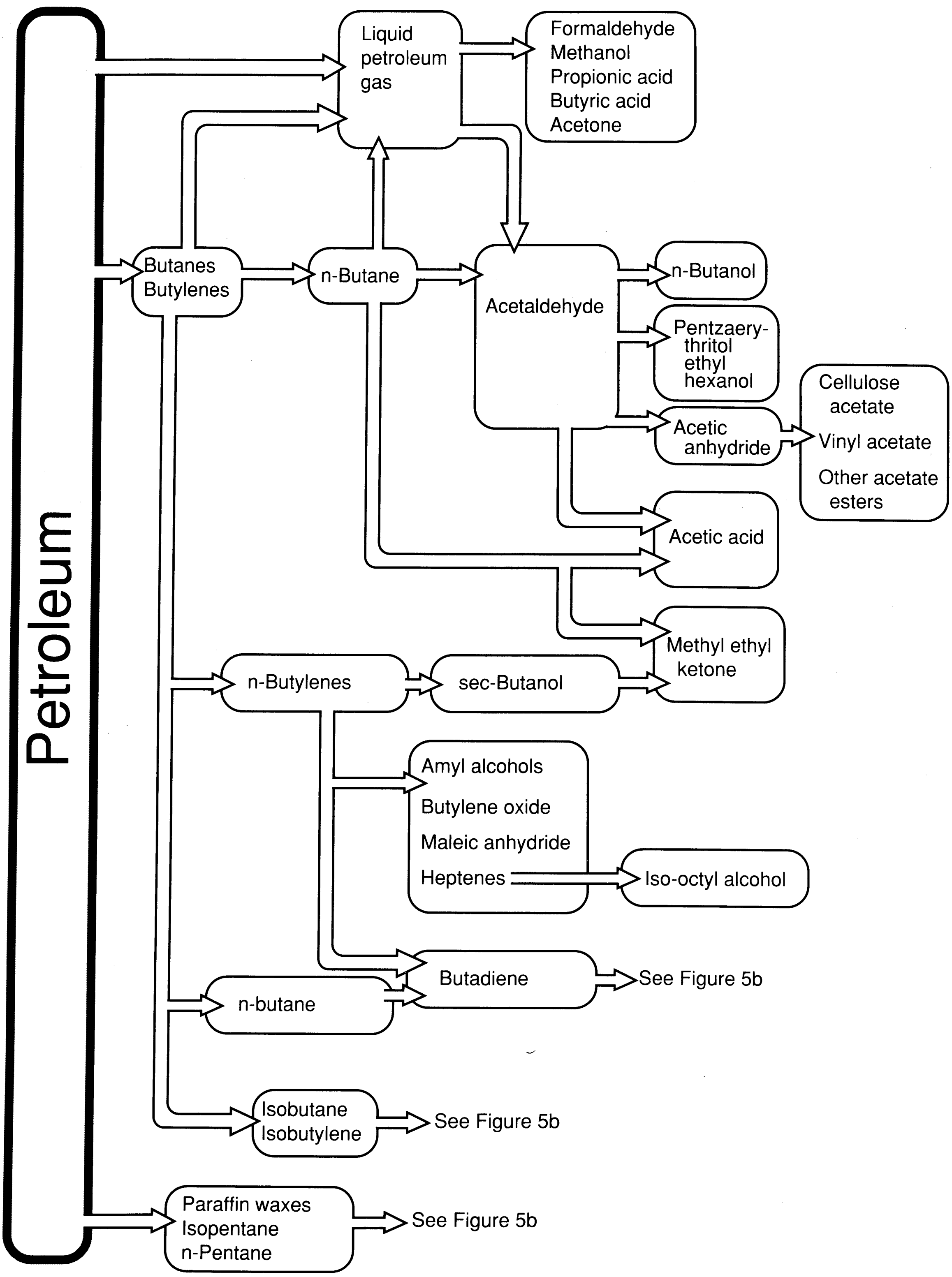


Figure 5b Important derivatives of butanes, butylenes, Liquid Petroleum Gas (LPG) and higher aliphatic hydrocarbons (continued)

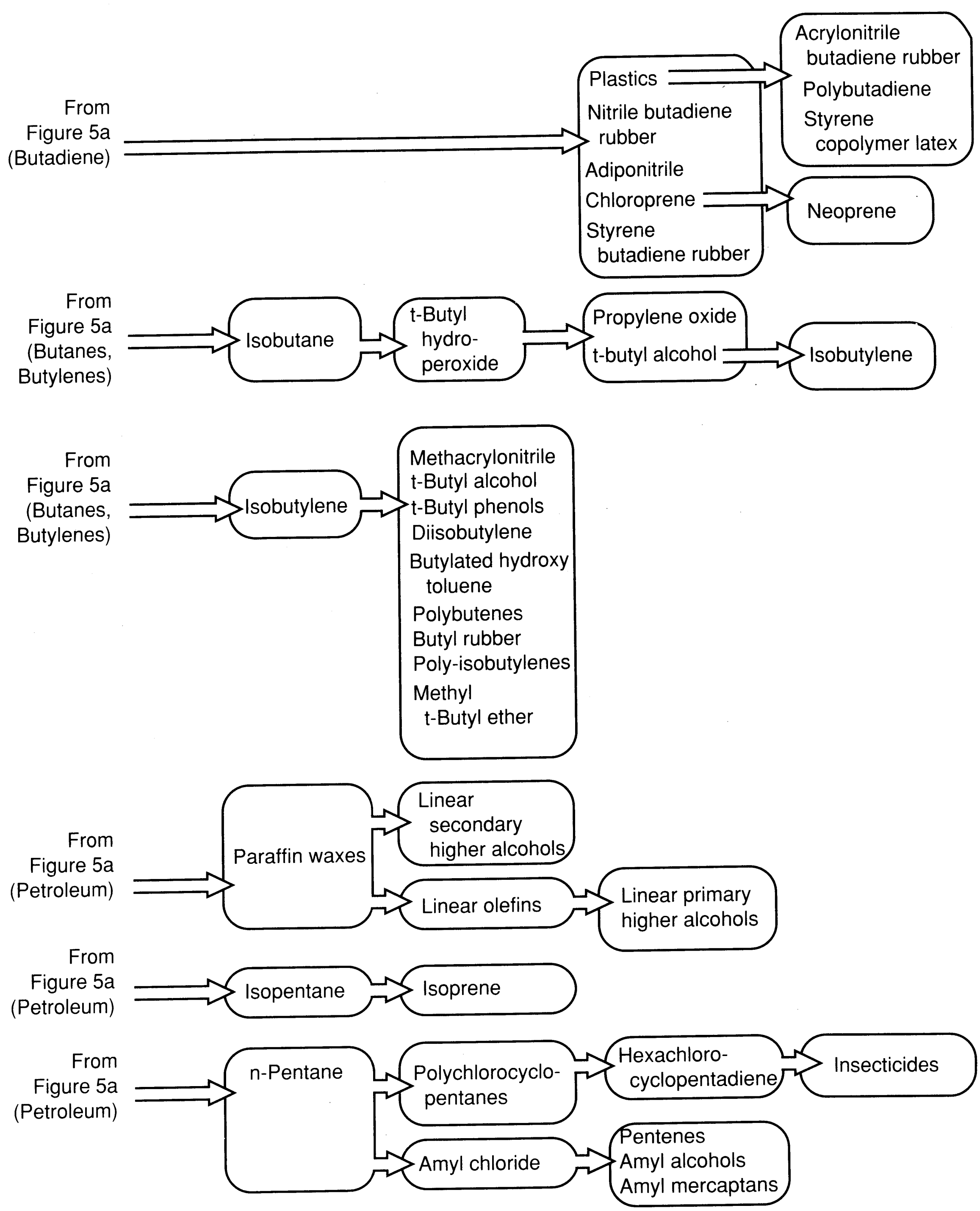
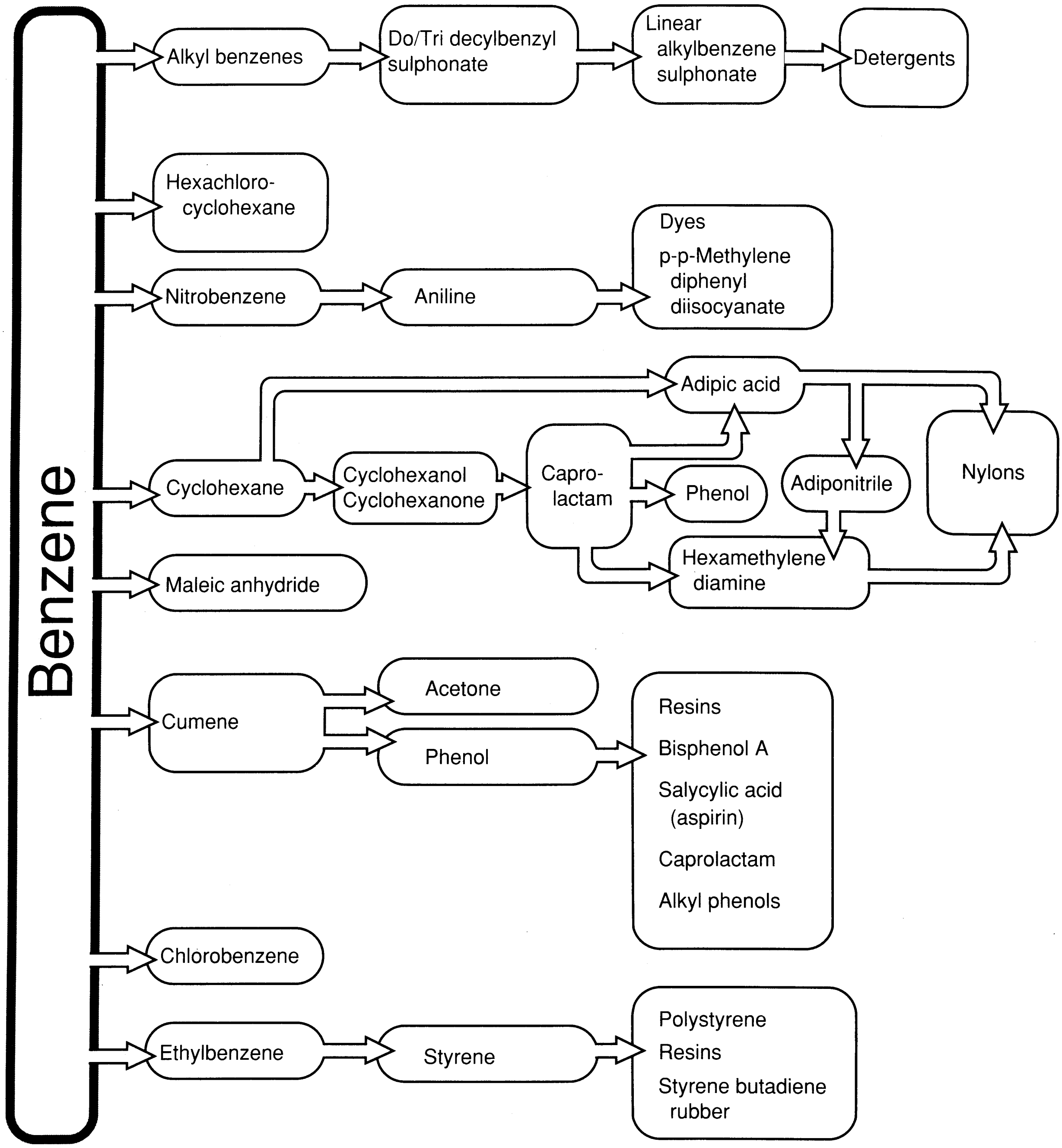


Figure 6 Important derivatives of benzene



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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