# Information for the assessment of former gasworks sites


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# Preface

This document[1] provides readers with a broad understanding of the contamination issues that can be associated with former gasworks sites in NSW.

It includes background information about gasworks sites, a summary of existing guidance material that is available for assessing the sites and useful references for further reading.

[1] This document provides general information for the assessment of former gasworks sites and is not prepared as a guideline for the purposes of s.105 of the *Contaminated Land Management Act 1997*.

# Introduction

Over 60 former gasworks sites have been identified in NSW. The gasworks produced 'town gas' for heating, lighting and cooking. Most ceased operating in the early- to mid-1900s and the last of the known gasworks was decommissioned in 1985.

Typically, gasworks were located near waterways or train lines for easy delivery of coal (the principal material used to make gas in NSW). They were often also close to the centre of the city, to minimise the size of the network of pipes used for gas distribution.

The soil and groundwater at these former gasworks sites are invariably contaminated by materials produced during the gas-making process even though operations ceased many years ago. These sites need some level of assessment to ensure that the contamination is not posing a threat to human health or the environment.

# Gasworks activities

### The production process

The production of 'town gas' was a complex, multi-stage process that varied from site to site. Understanding the manufactured gas plant processes will assist in the investigation and remediation required at these sites. In general, three major processes were used to produce town gas:

- coal carbonisation
- the carburetted water gas process
- the oil gas process.

Coal carbonisation was the most commonly used process in NSW and is therefore the focus of this document. This process involved heating crushed bituminous coal in a sealed, oxygen-deficient chamber (the retort) to generate gas, coke, tar and ammonia as shown in the figures below (more information on all three processes can be found in the references listed under the Further reading section):

Figure 1: Schematic diagram of plant in the coal carbonisation process

Figure 2: The main steps in the coal carbonisation process

Figure 3: Process flow diagram outlining coal carbonisation process

### Wastes and potential contaminants of concern

Major wastes associated with former gasworks sites include tars, oils, hydrocarbon sludges, spent oxide wastes, ash and ammoniacal recovery wastes. Some of the wastes, such as tars, commonly exist in soils and in groundwater in the form of non-aqueous phase liquids (NAPLs), which are a range of contaminants that can either float on a water body or sink to the base of an aquifer. While many of these wastes and by-products were recycled or reused, it was common for some to be buried on or near the gasworks site, for instance in underground tar wells, liquor wells, pipes and purifier beds and were not removed when the gasworks were decommissioned. It is essential that the locations of these plant items are identified in the investigation stage.

Many of the principal wastes can be identified visually or by the odour they emit. For example, tar oils are easily identifiable as a black, odorous ooze and iron cyanide

complexes (formed during the removal of hydrogen cyanide) are recognisable by their intense Prussian blue colour. Table 1 provides a summary of the principal waste types at gasworks sites and Table 2 provides the principal chemicals of interest at these sites.

Provided conditions are suitable, over time, natural degradation processes can reduce concentrations of some of the 'lighter' chemicals, for example, phenolic compounds, volatile monocyclic aromatic hydrocarbons and some polycyclic aromatic hydrocarbons. Degradation rates for some 'heavier' organic compounds can be slow in many soil and groundwater environments and as a consequence these compounds may persist for many years. Heavy metals and complex cyanides do not break down and will remain in the soil unless they are leached out.

# The regulatory framework for contaminated sites

In NSW, the management of contaminated land is shared by the Department of Environment and Conservation (DEC)[2] and planning consent authorities (usually local councils).

Under the *Contaminated Land Management Act 1997* (CLM Act), DEC:

- regulates contamination that poses an unacceptable risk to human health or the environment given the current or approved site use
- administers the NSW accredited site auditor scheme
- makes or approves guidelines for use in the assessment and remediation of contaminated sites
- administers the public record of regulated sites under the CLM Act.

Contaminated sites that are not regulated by DEC are managed by local councils through the land-use planning scheme, including State Environmental Planning Policy 55 – Remediation of Land (SEPP 55) and the *Managing Land Contamination – Planning Guidelines (1998)*. This type of site, although contaminated, is not unsuitable for its current or approved use. If the land is to be made suitable for a different use and where approval is required to do so, the planning and development control process will determine what remediation is needed.

# Assessment of gasworks sites

### Community consultation

Before commencing assessment or remediation work at former gasworks sites, it is important to consider the need for community consultation about that work. Measures to keep the community informed of the associated issues should be developed and implemented as a matter of priority. Such measures may include letterbox drops, individual consultation and public meetings. The scale of the consultation will depend on the particular site and is likely to be influenced by matters such as the size of the site, the nature and extent of the contamination on and off the site, the proximity of residential and other sensitive land uses and the manner in which the site work is to proceed (i.e. any interruptions or inconvenience to the local neighbourhood).

The community consultation process should continue throughout the site assessment. If remediation is required, the community should be given an opportunity to review and comment on the proposed remediation program.

[2] The Environment Protection Authority (EPA) is now part of DEC. While the EPA is the regulatory entity under the *Contaminated Land Management Act 1997*, for ease of reference, this publication refers to DEC.

Further information on community consultation can be found in the National Environment Protection (Assessment of Site Contamination) Measure 1999, Schedule B(8) *Guideline on Community Consultation and Risk Communication*.

**Assessment stages**

Gasworks are usually very complex sites to assess because they operated for a long time and often a wide range of contaminants were buried on and near the site. The site-specific geological and hydrogeological conditions, difficulties in identifiying the exact location of tar or purifier wastes burried on site and the heterogeneous nature of the contamination make it impractical to prescribe a single protocol for sampling soil components that is all encompassing but not overly conservative. An appropriately qualified and experienced contaminated land consultant should be engaged (refer to *Engaging a consultant* for more information) to develop and implement a site-specific approach for the assessment and remediation work.

Assessments should always be consistent with the recommendations in the National Environment Protection (Assessment of Site Contamination) Measure, 1999, Schedule B(2) *Guideline on Data Collection, Sample Design and Reporting*. All reporting should be in accordance with the *Guidelines for Consultants Reporting on Contaminated Sites* (1997) available from DEC's Environment Line. This guideline should be consulted in the preparation of detailed reports on the assessment, remediation and validation of former gasworks sites.

*Preliminary assessment*

A preliminary assessment (sometimes called a 'desktop study') should be done prior to any field work. It should, among other things, confirm whether or not the site was used for gas production, describe the condition of the site, collate information on the location of former gasworks infrastructure as well as on gasworks waste disposal practices both on and off the site. State libraries and local council records can provide useful historical information on the location of infrastructure. Former gasworks employees may also give valuable insights into atypical chemicals used at a particular site and waste disposal practices and locations. In general, if more information is gathered in the desktop study it is more likely that costs of a more intensive sampling program can be reduced.

*Designing a soil sampling program for a former gasworks site*

Once it is confirmed that the site was used for a gasworks, and based on the information from the desktop study, it is necessary to design and undertake a sampling and analysis program.

The sampling program should aim to identify the areas of concern, for example, tar and liquor wells, on-site wastes disposal, gas holders, retort house, and purifiers. The *Contaminated Sites: Sampling Design Guidelines* (1995) available from DEC's Environment Line, provides useful information for determining the minimum number of sampling locations required at various depths to locate areas of contamination, based on the estimated size of 'hot spots'[3]. In the case of gasworks, the hot spot size can be quite small (e.g. less than 1 m in diameter) and the assessor should be careful to ensure an appropriate number of sample locations are selected

[3] A 'hot spot' is a discrete localised area where the level of contamination within that area is noticeably greater than in the surrounding areas.

A number of techniques are available for sampling gasworks, including using boreholes, hand augers and test pits. Geophysical testing is another technique useful in locating buried structures. The use of test pits or trenches is generally recommended for field investigations as being efficient and cost effective. However, it involves considerable soil disturbances and may generate odour. It is highly recommended that an environmental management plan is developed and implemented to ensure that there will be no off-site impact.

*Assessing groundwater at a former gasworks site*

The potential for groundwater beneath the site being contaminated and for it moving off-site must be assessed at all former gasworks sites. The groundwater sampling strategy should consider the complexity of local and regional hydrogeology and the potential pathways and mechanisms by which contamination may be transported from the site.

It is important to recognise that some gasworks structures can extend to a considerable depth – particularly gas holders and tar pits – and have the potential to intercept local aquifers and change local groundwater movement. It is also important that any groundwater investigation at a former gasworks site assesses the potential for both light non-aqueous phase liquids (LNAPLs) and dense non-aqueous phase liquids (DNAPLs) to be in the groundwater beneath the site. Guidance for assessing groundwater is provided in National Environment Protection (Assessment of Site Contamination) Measure, 1999, Schedule B(6) *Guideline on risk assessment of groundwater contamination*.

Separate phase contaminants are a potential ongoing source of groundwater contamination and should be removed.

**Investigation levels**

Investigation levels are contaminant specific concentrations (developed for soils, sediment, surface water and groundwater) that, if exceeded, provide a trigger for further action which might include additional investigations and/or remediation. There are soil and groundwater investigation levels.

Investigation levels are available from guidelines made or endorsed by DEC under s.105 of the CLM Act. The principal sources are Schedule B(1) of the National Environment Protection (Assessment of Site Contamination) Measure, 1999 and the *Guidelines for the NSW Site Auditor Scheme* (1998 or updates) available from DEC's Environment Line.

*Soil investigation levels*

There are two types of soil investigation levels – health-based investigation levels and phytotoxicity (toxicity to plants) investigation levels. Concentrations above these investigation levels will require further assessment to determine, in the context of urban redevelopment, what action is needed to protect human health and the ecology. These levels should be used in conjunction with the 'Decision process for assessing urban redevelopment sites' (in *Guidelines for the NSW Site Auditor Scheme* (1998 or updates) available from DEC's Environment Line).

Where there are no investigation levels for a particular contaminant of concern, a site-specific health risk assessment can be conducted in accordance with the framework provided in Schedule B(4) of the National Environment Protection Measure (NEPM) – *Guideline on Health Risk Assessment Methodology* and enHealth Council's *Environmental health risk assessment – Guidelines for assessing human health risks from environmental hazards*. Where an investigation level is from a source that is not

endorsed by DEC under s.105 of the CLM Act, its use can be justified if no other endorsed sources are available. However, an appraisal by the proponent of the methodology used for deriving the criteria detailing the level of conservatism and range of uncertainties inherent in the approach must be stated in the relevant report.

*Groundwater investigation levels*

An assessment of groundwater quality should consider what the groundwater is or may be used for (e.g. drinking water, stock watering, gardens, etc) and the current and potential receptors of contamination. The regional hydrogeologist from the Department of Infrastructure, Planning and Natural Resources (DIPNR) can provide assistance with this assessment. If groundwater has the potential to be used for drinking water, the levels in the *Australian Drinking Water Guidelines* (NHMRC & ARMCANZ, 2004) should be used.

Where the protection of an ecosystem is necessary, the risk-based decision process and the trigger levels in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000) should be used.

The NEPM guideline suggests that the above levels should be used as:

- investigation levels at the point of extraction
- clean-up or response levels at the point of use.

## Reporting to DEC

If the owner of a site becomes aware that the site has a contaminant that poses a significant risk of harm to human health or any other aspect of the environment, the owner has a duty under s.60 of the CLM Act to report this contamination to DEC. A person who becomes aware that their activities have caused a contamination of this sort has the same duty.

Further information on what 'significant risk of harm' means and the duty to notify contamination can be found in *Guidelines on Significant Risk of Harm from Contaminated Land and the Duty to Report*.

## Remediating former gasworks sites

Remediation of former gasworks sites is complicated by the presence of mixed organic and inorganic contaminants commonly found in the soil and groundwater around the sites. The organic contaminants (e.g. polycyclic aromatic hydrocarbons – PAHs) are usually the driver for the remediation, rather than heavy metals, although both organic and inorganic contaminants need to be considered.

Remediation operations must not result in adverse impacts on the environment or human health. Aspects to be considered include air quality, odours, water quality, noise levels and waste management. All work on-site must take into account the various provisions of planning, environmental and occupational health and safety legislation.

The *Guidelines for Consultants Reporting on Contaminated Sites* (1997) and *Guidelines for the NSW Site Auditor Scheme* (1998 or updates) provide guidance on issues relevant to the remediation of contaminated sites, including the development of a remedial action plan and a validation strategy. These publications are available from DEC's Environment Line.

The preferred hierarchy of options for site clean up and management as published in the *Guidelines for the NSW Site Auditor Scheme* (1998 or updates) is:

- on-site treatment of the contamination so that it is destroyed or the associated risk is reduced to an acceptable level
- off-site treatment of excavated soil so that the contamination is either destroyed or the associated risk is reduced to an acceptable level, after which it is returned to the site.

If neither of these options is practical, consider the following:

- removal of contaminated material to an approved site or facility – refer to *Environmental Guidelines: Assessment, Classification and Management of Liquid & Non-Liquid Wastes (1999*) – and replacement, where necessary, with validated clean fill, or
- consolidation and isolation of the soil on-site by containment with a properly designed barrier (this will require the development and implementation of a site management plan with appropriate approvals from, and possibly regulation by, DEC and/or a relevant planning authority, and may also require ongoing monitoring to ensure the integrity of the barrier/containment cell).

Where the assessment indicates that remediation would have no net environmental benefit – or a net adverse environmental effect – an appropriate management strategy must be implemented to address the contamination.

**Validating the success of remediation at former gasworks sites**

Following remediation, validation sampling must be undertaken to confirm whether the clean up objectives have been achieved and to ensure that the site is suitable for the current or approved use. Validation involves samples being collected at an area that has been cleaned up. The rationale and justification for the validation strategy and results of the remediation should be set out in a Validation Report prepared in accordance with the *Guidelines for Consultants Reporting on Contaminated Sites* available from DEC's Environment Line.

A systematic sampling pattern is recommended for the validation sampling plan. The data obtained should be statistically analysed. For a former gasworks site to be considered appropriately validated, the calculated value, known as the '95% upper confidence limit' (95% UCL), of the average concentration for each analyte should be below the relevant threshold concentration (refer to *Contaminated Sites: Sampling Design Guidelines* (1995), available from DEC's Environment Line, for more information on this statistical analysis). Where the 95% UCL is less than the relevant threshold value but one or more individual sample measurements are more than 250% above the criteria, any sampling point which exceeds this level should be re-investigated to determine whether or not it constitutes a 'hot spot'.

Note that restrictions on the future use of the site may depend on the nature and extent of remediation at the site.

**Use of a site auditor**

The assessment and remediation of gasworks sites are technically difficult because of the complex behaviour of chemicals in the environment and their myriad effects on ecosystems and human health. Expert independent review of a consultant's work by a

site auditor accredited under the CLM Act helps to determine the reliance that can be placed on the consultant's assessment and/or remediation, in particular with regard to the suitability of the site for its intended use. If a site auditor is to be engaged, it is best to do this early in the assessment/remediation process.

## Further reading

The following selected references and links will provide the reader with additional information on gasworks sites and the environmental site assessment process in general. The references listed are those not previously referred to in this booklet.

**Gasworks processes and assessment**


- Australian Academy of Technological Sciences and Engineering (1998) 'Technology in Australia 1788-1988'. Chapter 11, Energy – Manufactured Gas, pp 816-819. Melbourne
- Department of Environment (1987) *Problems Arising from the Redevelopment of Gas Works and Similar Sites (Second Edition)*, prepared by Environmental Resources Limited, Her Majesty's Stationery Office, London
- Haesler F, Blanchet D, Druelle V, Werner P, & Van de Casteele J P (1999), 'Analytical Characterisation of Contaminated Soils from Former Manufactured Gas Plants', pp 825–830 in *Environmental Science & Technology* 33(6), American Chemical Society, Washington
- Gas Research Institute (1996) 'Management of Manufactured Gas Plant Sites: The Gas Research Institute's Two Volume Practical Reference Guide' Volumes 1 and 2 GRI-96/0470.1 & GRI-96/0470.2, Gas research Institute, Chicago
- Meade A (1934) *New Modern Gasworks Practice*, Vol 1, Eyre and Spottiswoode, London, (in UK Atomic Energy Authority, Harwell, 1981)
- Middleton A (1995) 'Historical Overview of Manufactured Gas Plant Processes Used in the United States' pp 5–17 to 5–19, in *Land Contamination & Reclamation*, 3(4), EPP Publications, Richmond, Surrey, 1995
- Mon G J, 'History of the Manufactured Gas Business in the United States', pp 1–1 to 1–3, in *Land Contamination & Reclamation*, 3(4), EPP Publications, Richmond, Surrey, 1995
- New Zealand Ministry for the Environment (1997) 'Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand'
- USEPA (1999) 'A Resource for MGP Site Characterisation and Remediation: Expedited Site Characterisation and Source Remediation at Former Manufactured Gas Plant Sites', Office of Solid Waste and Emergency Response, technology Innovation Office, US Environment Protection Agency, Washington DC
- Turczynowicz L (1993), 'The Assessment and Management of Gasworks Sites' in The Health Risk Assessment and Management of Contaminated Sites: Contaminated Sites Monograph Series No. *2*, South Australian Health Commission, Adelaide


**Site assessment – general**

Readers are directed, in the first instance, to the list of guidelines made or approved by DEC under s.105 of the CLM Act.

## Contacting DEC

Any queries or comments relating to this information booklet or contaminated site issues in general can be directed towards DEC's Contaminated Sites Section.

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Mention of documents (that are not published or approved by DEC under the CLM Act) or presentations included in this publication does not constitute a DEC endorsement of their contents, only an acknowledgment that they exist and may be relevant for the assessment of gasworks sites.

**Figure 1: Schematic diagram of plant in the coal carbonisation process (from Meade 1934)**

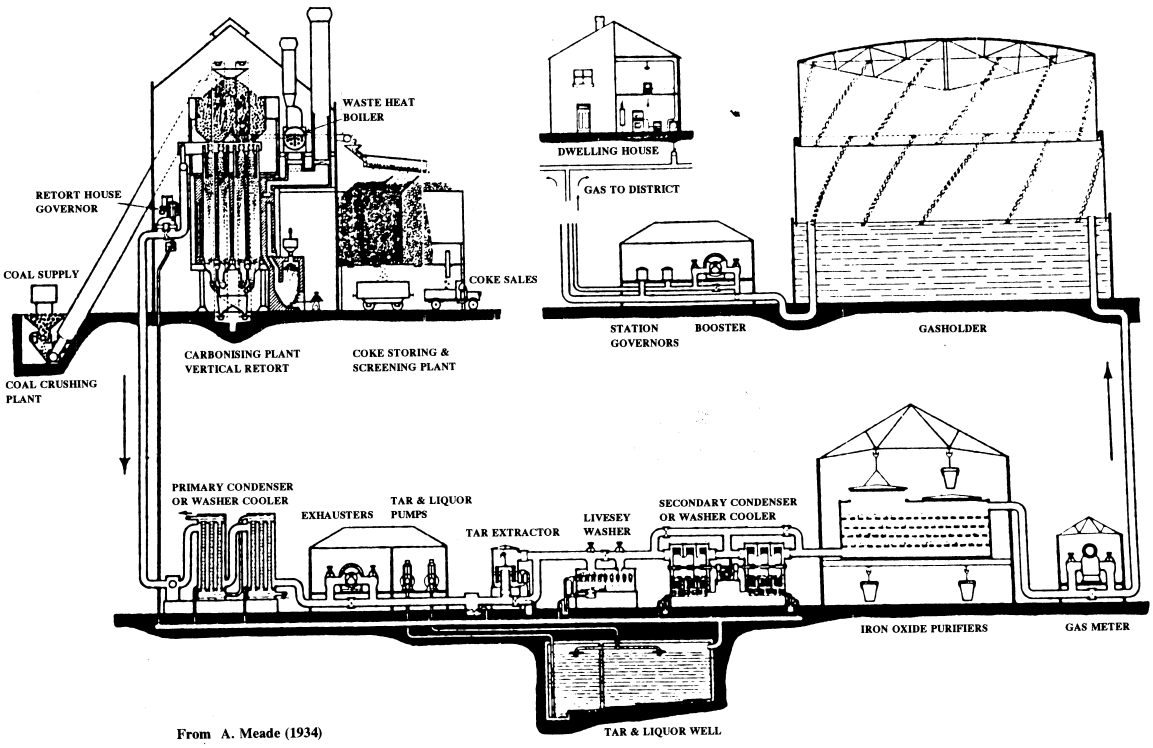


**Figure 2: The main steps in the coal carbonisation process**

- Bituminous coal was crushed and fed to the retort, where high temperatures carbonised the coal to produce gas and coke.
- The coke was sold or used to manufacture 'producer gas' that provided heat for the coal carbonisation process.
- To remove impurities, the raw gas (containing tars and other by-products) was:
  - scrubbed with weak ammonia liquor in the hydraulic and foul mains
  - cooled in the primary condenser
  - blown through the exhauster
  - treated by the tar extractor to remove tars from the gas
  - scrubbed to remove ammonia from the gas
  - diverted through iron oxide purifiers to remove hydrogen sulfide and other impurities, including cyanide.
- The purified gas was metered, stored and distributed to consumers.
- Tars and condensates collected during gas production were combined and fed to a tar-liquid separator.
- Weak ammonia liquor was separated from the tar.
- The tar was either processed further, recycled as an alternative fuel, or sold as raw coal tar.

**Figure 3: Process flow-diagram for a coal carbonisation gas plant (based on a flowchart in Mon, 1995)**

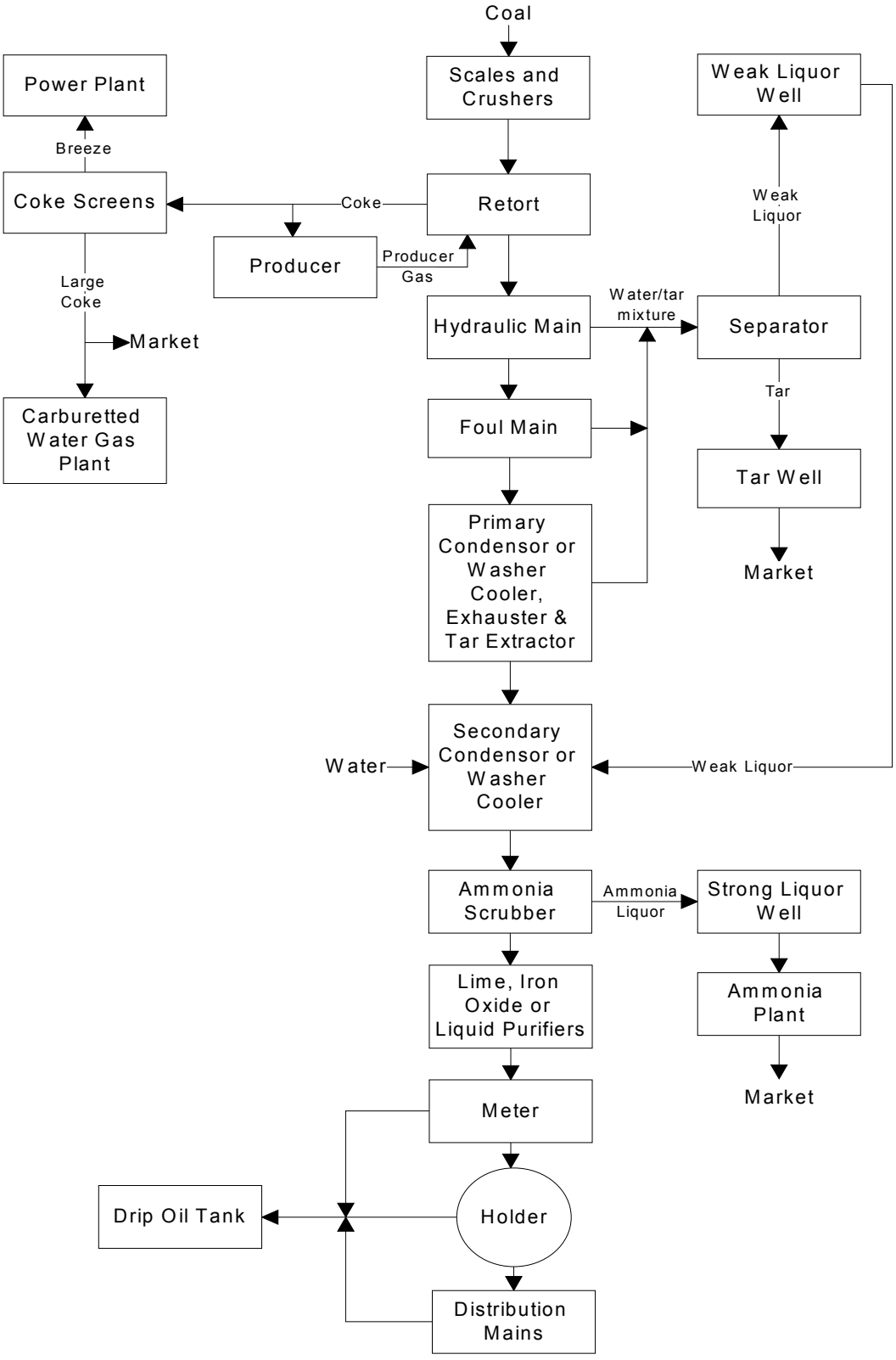

**Table 1: Summary of the principal waste types at gasworks sites**

| Principal waste type | Source | Distinguishing characteristics | Likely chemical groups |
|---|---|---|---|
| Coal tar<br>Tar oils | Separated from gas and liquors at various stages of the purification processes. | Dark brown to black colour<br>Strong phenolic odour<br>May be present as non-aqueous phase liquids, either dense (DNAPLs) or light (LNAPLs)<br>Lower melting point than petroleum tars<br>Different phases have low to high density and viscosity | PAHs<br>Petroleum hydrocarbons, including BTEX<br>Phenols |
| Spent oxides (including complex cyanides) | Used to remove sulfur during gas purification. | Strong sulfurous odour<br>Distinctive Prussian blue colour when weathered/oxidised<br>Grey/black/green, very dusty when not weathered/oxidised<br>Granular appearance<br>Iron staining common | Complex cyanides<br>Free cyanides<br>Metals |
| Coke, cokebreeze (powder), Ash, Clinker residues (glassy material) | By-products and furnace residues. | Granular or powdery texture<br>Light grey to black | PAHs<br>Metals |
| Light oils<br>Drip oils | Light oils used around all machinery and as scrubbing agent in recovery process.<br>Drip oils condensed from gas. | Oily smell and appearance | Petroleum hydrocarbons, including BTEX |
| Ammoniacal recovery wastes | Nitrogen removal during gas purification processes. | Ammoniacal odours<br>Fine powders or sludges | Phenols, Nitrates, sulfates, sulfides, PAHs |
| Asbestos | Used as lagging around many of the 'hot' processes and pipes. | Fibrous to powdery texture, Grey-white/blue/greenish colour (crystalline) | Asbestos |
| Lead, Mercury, Zinc | Lead from batteries, pipelines, paint, etc.<br>Mercury sometimes used in metering switches. | | Metals |

**Table 2: Principal chemicals of interest at gasworks sites**

| Inorganic compounds | Metals and metalloids | Monocyclic aromatic hydrocarbons (MAHs) | Phenolics | Polycyclic aromatic hydrocarbons (PAHs)[4] |
|---|---|---|---|---|
| Ammonia | Aluminium | Benzene | Phenol | Acenaphthene |
| Cyanide | Antimony | Ethyl benzene | 2-Methylphenol | Acenaphthylene |
| Nitrate | Arsenic | Toluene | 4-Methylphenol | Anthracene |
| Sulfate | Barium | Total Xylenes | 2,4-Dimethylphenol | Benzo(a)anthracene |
| Sulfide | Cadmium | | | Benzo(a)pyrene |
| Thiocyanate | Chromium | | | Benzo(b)fluoranthene |
| | Copper | | | Benzo(g,h,I)perylene |
| | Iron | | | Benzo(k)fluoranthene |
| | Lead | | | Chrysene |
| | Manganese | | | Dibenzo(a,h)anthracene |
| | Mercury | | | Fluoranthene |
| | Nickel | | | Fluorene |
| | Selenium | | | Naphthalene |
| | Silver | | | Phenanthrene |
| | Vanadium | | | Pyrene |
| | Zinc | | | Indeno (1,2,3-cd) pyrene |

[4] There are 23 USEPA priority PAHs. In Australia, PAHs are commonly analysed for the above 16 compounds.