Preventing Groundwater Contamination

05 Environment Series

This information sheet describes the types of contaminants that are generated from coal gasification. It also looks at ways Underground Coal Gasification (UCG) can release contaminants and the methods for prevention through effective planning, operational control and decommissioning.

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Background

In the 1970s, an American UCG trial at Hoe Creek in Wyoming resulted in the contamination of aquifers used for drinking water. The incident, whilst elevating concerns regarding the impact of UCG operations on groundwater, also provided very valuable information about where the safe operational bounds of UCG lie.

In particular, analysis of the operation highlighted the importance of site selection in UCG planning and in determining criteria for operating parameters. The design of today's UCG operations incorporates the elements of the most successful trials, including controls to prevent recurrence of incidents where UCG has resulted in groundwater contamination.

By studying past trials and groundwater contamination associated with industries that produce similar contaminants to UCG (such as gas works), information is available that assists in developing tools to predict, control and manage contamination mechanisms, including:

- The types of contaminants that may be generated by UCG and how they can be prevented from entering the groundwater system
- Their fate in the subsurface and factors that dictate decomposition of the contaminants
- How contaminant behaviour can be modelled.

Mechanisms

Trial and commercial scale UCG operations have identified that groundwater can be contaminated during and after gasification by two mechanisms:

- Gas loss during gasification
- Leaching of residual products from the spent gasification cavity.

Gas loss

High temperature synthesis gas (syngas) contains products of pyrolysis that condense when the gas cools. The typical contaminants in the condensed liquids are:

- Benzene, ethylbenzene, toluene and xylenes (BTEX)
- Phenolic compounds
- Polycyclic aromatic hydrocarbons (PAHs) and heterocyclic compounds.

Other gas phase contaminants like ammonia can dissolve in water. The ultimate composition and volume of potential contaminants in syngas is a function of coal composition, the oxidant used and the gasification conditions.

If syngas escapes the cavity, cooling occurs in the surrounding strata and gaseous hydrocarbons condense.The volume and extent that gas travels in the formation outside of the UCG cavity ultimately dictates the risk and extent of contamination.

Cavity leaching

Ash residues remain in a UCG cavity after decommissioning and contaminants can dissolve from this ash.

The soluble ash components can increase the total dissolved solids content of the groundwater and introduce an array of ionic species, such as calcium, sodium, sulphate and bicarbonate. There are other inorganic species that can be leached into groundwater, albeit in lesser quantities. These typically include metals, and their composition is a function of coal composition, gasification conditions and initial groundwater quality. Any organic contaminants in the cavity are effectively stripped with steam during decommissioning so they do not present an additional source of contamination.

Prevention

Groundwater contamination[a] is prevented in UCG operations by appropriate site selection, operating below hydrostatic pressure, and effectively decommissioning the process.

Operating pressure

The balance between the hydrostatic pressure (the force of water inwards) and the operating pressure (the force of gas outwards) dictates the rate of water ingress and the ability to contain gas within the cavity. Operating pressure is maintained below the hydrostatic pressure so produced gases are drawn from the cavity via production wells, rather than escaping into the surrounding formation. At the same time, groundwater flow will be preferentially towards the cavity, preventing migration of water borne contaminants away from the cavity.

Site selection

Groundwater contamination can be avoided by careful site selection. Suitable UCG sites should be isolated from groundwater resources used for other purposes or have significant environmental values. Contamination can also be avoided by meeting other criteria that has been well developed over time[b].

The nature of the overlying geology and the coal resource, in particular its permeability and strength, also are key considerations when selecting a suitable site from a groundwater contamination and management perspective. Sites should be selected where the overlying geology provides a seal to minimise vertical gas loss from the cavity.

Decommissioning

Shutting down the gasification process and ensuring the spent gasification chamber does not contribute to groundwater contamination is a critical part in the lifecycle of a UCG operation. Successful decommissioning has been proven at many UCG operating sites in the past, and is based on basic, yet effective principles of generating steam to strip the cavity of contaminants[b].

Contaminant fate

Mobility and attenuation

The behaviour of contaminants associated with UCG operations has been evaluated using data obtained from a number of UCG trials and similar industries. For the majority of trials, historic data has indicated that pollutants tend to decrease, both with time and distance from the cavity, so that no active remediation has been required[c].

The consistently observed improvements in water quality with time are due to the natural attenuation and cleansing processes of the aquifer, particularly in coal.

Mobility

Mobility of contaminants is a function of adsorption, ion exchange and groundwater flow velocity. Mobility is often related to solubility. If the solubility of a component is very low, it frequently has a high adsorption affinity for surrounding solid strata which prevents rapid migration.

On the other hand, materials having little affinity for solid surfaces, such as many of the inorganic components, will not be retained by the strata and will travel at the rate of groundwater flow with little reduction from peak concentrations, and will generally attenuate only by dilution.

Mobility at UCG sites may be increased because there are natural and artificial permeability conduits. Coal seams typically contain many natural fractures, cleats and joints. The fracturing of the coal enhances these conduits which can increase groundwater flow velocity. Conversely, coal seams have a higher affinity for adsorption of organics.

Natural attenuation

There are natural attenuation processes by which the groundwater concentrations of contaminants can be reduced. These include:

- Adsorption and ion exchange in the surrounding strata
- Precipitation reactions
- Dilution and dispersion by natural groundwater flow
- Biotic or abiotic conversion reactions.

Only the last process destroys or converts contaminants to non-harmful products. These mechanisms determine how long a given contaminant will persist and how far it will migrate in the groundwater.

The persistence of contaminants depends on how quickly the contaminant source dissolves and how quickly they are converted into other forms (in biotic or abiotic processes).

Microbial mediated transformations

(biotic) are generally many times faster than abiotic reactions (chemical reactions not involving a biological intermediary)[d]. Degradation of hydrocarbons occurs as a redox reaction in which hydrocarbons are oxidised if:

- A bacterial population capable of utilising the hydrocarbons is present (at least in low concentrations)
- Electron acceptors to participate in the redox reaction, such as oxygen, nitrates, sulphate or carbon dioxide are present
- Basic nutrient requirements for the bacteria such as nitrogen, phosphorous, ammonia or trace metals are present[e].

Environments containing all three requirements for natural attenuation typically exist in coal seams.

Modelling

Modelling of contaminant fate and transport usually involves two stages of simulation which may influence each other:

1. The groundwater flow field, including modifications to permeability, density and temperature resulting from UCG operations.
2. Processes affecting transport of contaminants dissolved in the groundwater including dispersion, diffusion, ion exchange, adsorption, precipitation, and biochemical reactions.

Numerical methods are then used to find solutions for partial differential equations representing these processes.

Models require input data that is site specific such as pre-development geology, groundwater levels, groundwater flow direction and velocity. The model can then be calibrated by using observations from the site being investigated.

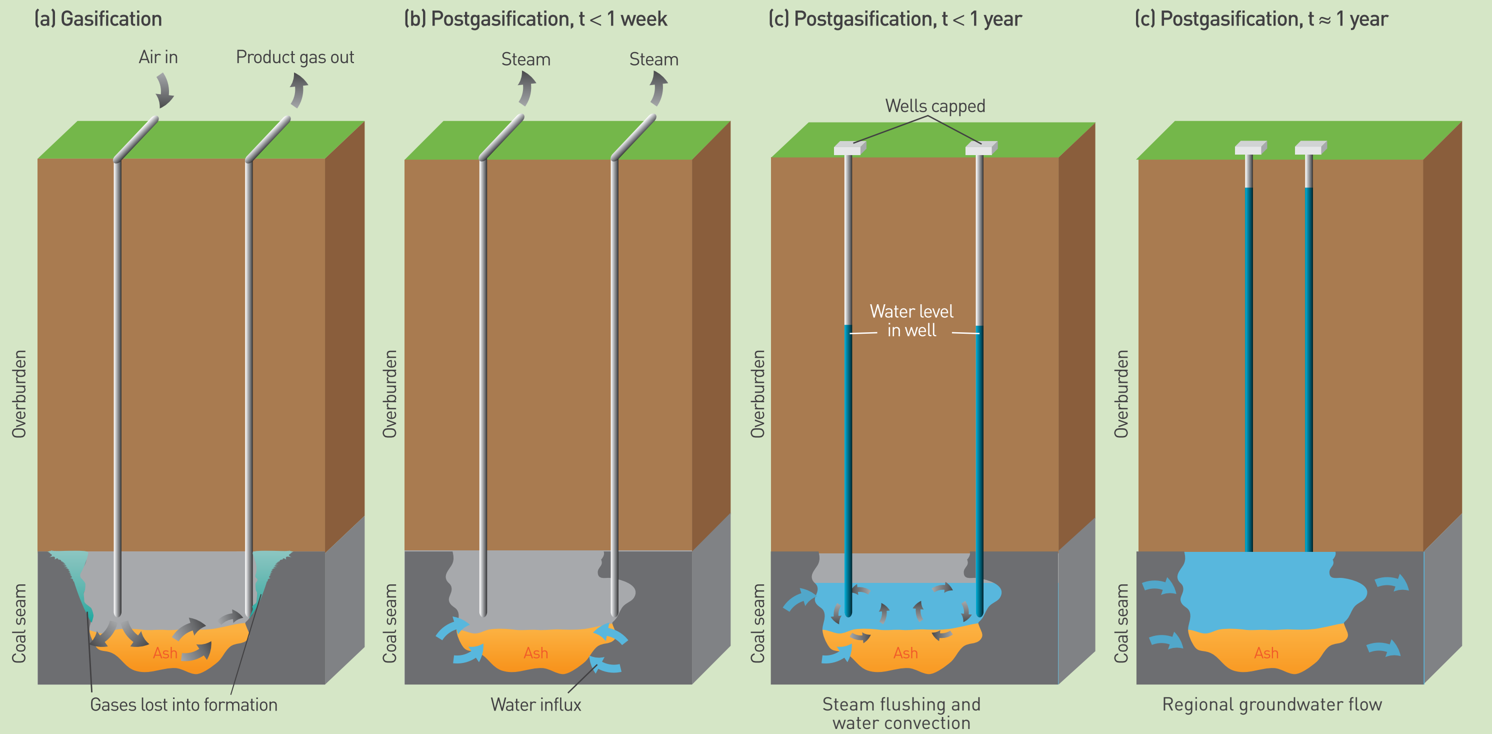
Once constructed, the model can be used to:

1. Identify the likelihood of groundwater contamination at a particular site.
2. Optimise generator design including panel layout, operating conditions and burn sequence.
3. Form the basis for an environmental risk assessment.

Remediation

With modern prediction, control and monitoring techniques, it is unlikely that groundwater contamination would occur to the extent that it needs remediation. Should this occur, proven remediation techniques can be implemented to restore groundwater quality.

Modern UCG operations also include effective sampling and monitoring of groundwater to ensure early identification of contamination, before any widespread contamination occurs.



Potential mechanisms for groundwater contamination associated with Underground Coal Gasification

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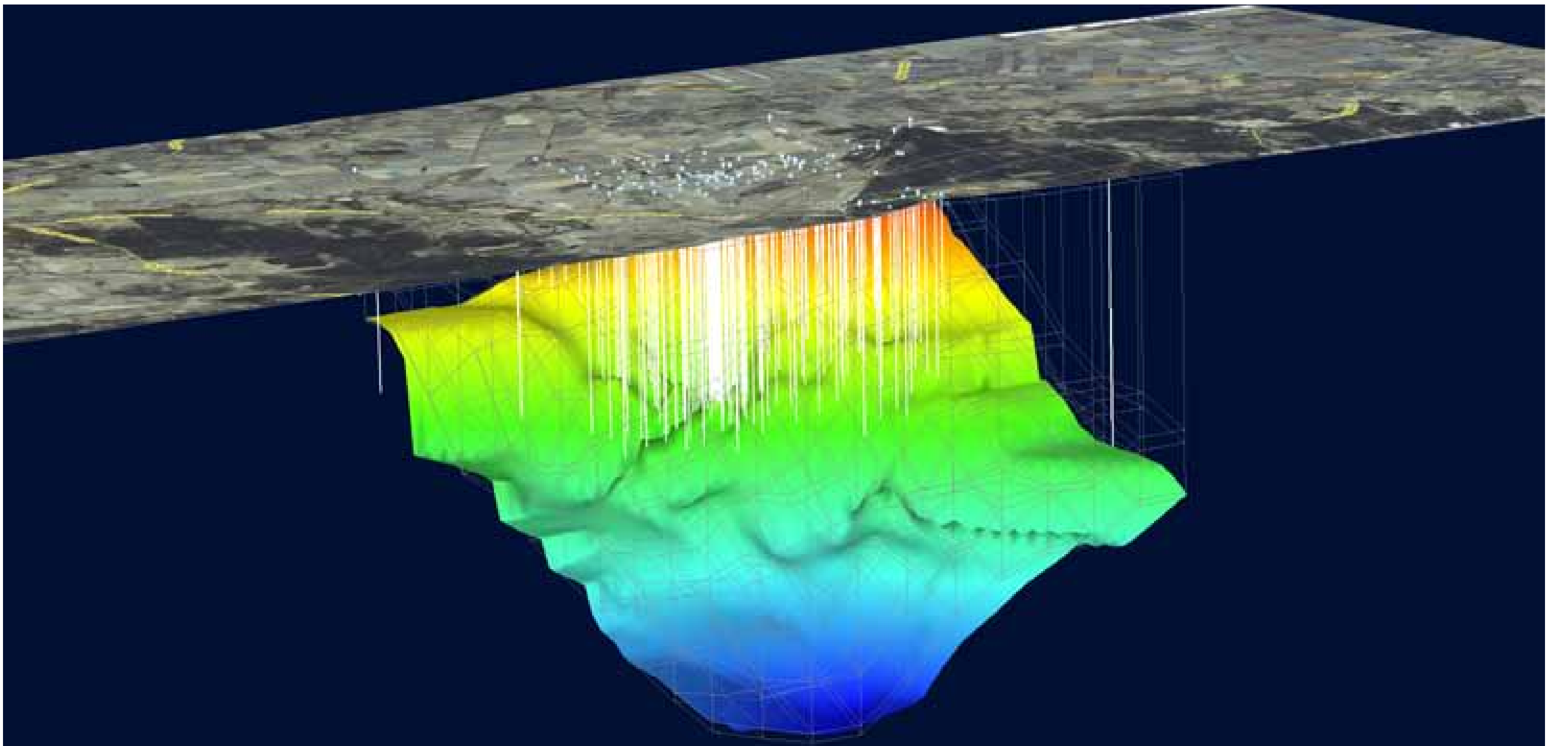

Linc Energy regional groundwater model (Chinchilla)

[a] "Contamination" means the condition of land or water where any chemical substance or waste has been added at above background level and represents, or potentially represents, an adverse health or environmental impact. National Environment Protection (Assessment of Site Contamination) Measure 1999.

[b] See Linc Energy Information Sheet UCG No 2, *UCG Explained.*

[c] Humenick, M. J., Edgar, T. F., and Charbeneau, R. J., (1983), *"Environmental Effects of In-Situ Coal Gasification,"* AIChE Symposium Series, Vol. 79, pp 139-153 (1983).

[d] Schwarzenbach RP, Gschwend PM, Imboden DM, (1993), *Environmental Organic Chemistry*, John Wiley & Sons, Inc., New York, p 681.

[e] Prommer H, Davis GB, Barry DA, Miller CT, (2003), In A Langley, M Gilbey & B Kennedy (Eds), *Proceedings of the Fifth National Workshop on the Assessment of Site Contamination*, pp 21-45.

About Linc Energy

Linc Energy is an Australian energy company which listed on the Australian Securities Exchange (ASX) in May 2006 and the OTCQX in December 2007. Through the unique combination of Underground Coal Gasification (UCG) and Gas to Liquids (GTL) technologies, Linc Energy is at the forefront of providing the world with a newer, cleaner, greener energy solution.

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