GISERA
Gas Industry Social and Environmental Research Alliance

NOVEMBER 2019
WATER RESEARCH FACTSHEET

Microbial degradation of chemicals used in onshore gas production (South Australia)

This study improves understanding of the extent to which chemical compounds used in onshore gas production are degraded by microbes in soils and sub-surface aquifers specific to the south east region of South Australia.

KEY FACTS

- Chemical spills from conventional gas operations in the south east of South Australia are rare, due to comprehensive regulation, mandatory reporting and strict operational practices. According to the SA Department of Energy and Mining, there have been two reportable chemical spills in 17 years.
- This study investigated 28 hazardous chemical compounds found in fluids used in onshore gas activities in South Australia.
- Soils and sub-surface aquifer samples used in this research were taken from the Penola region in south east South Australia.
- The study assessed the extent of degradation of the chemicals once they were added to soils, as well as in anoxic (without oxygen) groundwater samples.
- Those chemicals tested using physicochemical methods appear to be completely degraded in soils after 34 days.
- Most chemicals are able to be used as sole-carbon sources (a source of energy) for microbial growth.
- Soil bacterial communities were largely unaltered by chemical additions.
- Soil fungal communities are altered more by chemical additions, which may affect ecosystem services provided by soil fungi.
- In the aquifer tests, some chemicals were degraded and some were not, probably due to limitations of important macronutrients.
- Prokaryotic aquifer communities (single celled organisms that lack a cellular membrane) were proportionally more affected by the addition of the various chemicals examined. Further work is required to understand the ecosystem services supported by these microbial communities.
- It can be inferred from study results that chemical spills or leaks if they were to occur present lower residual risk in soils as the compounds tested in the study either degraded, had identifiable degrading organisms or had minimal impacts on the soil prokaryotic community.
- In groundwater, results show the residual risk is unchanged, and while study data do show effects, what this means from an ecosystem function perspective is not clear.

Exploration drilling operation near Penola.

The south east South Australia (Limestone Coast region) imports gas from interstate to support a range of local manufacturing industries. The South Australian Government is encouraging exploration for local gas resources which could lead to new onshore conventional gas development in this region.

Onshore gas technologies use chemicals in operational activities to improve gas production. Community concerns have been raised about potential risks of chemical contamination from such activities to water and soil quality.

This study investigated both the microbial degradation and microbial community impacts of 28 identified hazardous chemical compounds found in fluids used in onshore gas activities.

Degradation refers to biological (mostly microbial), chemical, and physical (e.g., light, heat) processes that break down chemical substances into simpler components.

The results of this study builds on other GISERA research in South Australia study which examined potential groundwater contamination causes, pathways and vulnerability to better understand onshore gas water quality impacts.

The objective of the study was to better understand the impacts and residual risk of these chemical compounds to environmental contamination over time in natural environments.

CSIRO | Australia Pacific LNG | QGC | origin | Santos | NSW Government | Australian Government Department of Industry, Science, Energy and Resources | Supported by Government of South Australia | Queensland Government | Northern Territory Government | Pangaea Resources Pty Ltd

Chemical compounds

In onshore gas production activities, water, proppants (e.g sand), and chemicals are mixed onsite to produce drilling fluids and/or hydraulic fracturing (HF) fluids.

The chemicals used in onshore gas drilling and HF activities typically comprise only a small fraction of drilling and HF fluids. In the case of HF fluids, the remainder is typically water (90-91%) and sand/proppant (8%).

These chemicals perform various functions by acting as viscosity modifiers, friction reducers, surfactants, anti-scalants, and biocides.

A range of naturally occurring processes have the capacity to attenuate (alter or degrade) such chemicals in the environment.

It is important to identify these processes when assessing potential impacts in areas where onshore gas activities are about to be undertaken.

Table 1 Onshore gas production chemical compounds of interest examined in this review

Compound	Use in onshore gas activities
Bronopol	Biocide
Methylchloroisothiazolinone	Antimicrobial preservative
Polyacrylamide / polyacrylate copolymer	Friction reducer
Acrylamide	Friction reducer
Xanthan gum	Viscosity management
Polyoxypropylene diamine	Pipework/Epoxy resins
Hexahydro- 1,3,5-tris(2-hydroxyethyl)-sym-triazine	Biocide
Glyoxal	Drilling additive
2-Aminoethanol	Drilling additive
Limonene	Surfactant
2-Methylphenol (o-cresol)	Biocide
Naphthalene	Corrosion inhibitor
Acetic acid	Buffer, stabiliser, solvent
Alcohols, C6-12, ethoxylated	Surfactant
Alkanes, C12-26 branched and linear	Surfactant
Benzisothiazolinone	Biocide
2-Butoxyethanol	Surfactant
Diethylene glycol ethyl ether	Solvent
Ethanol	Surfactant
Ethylene glycol	Viscosity management
Glutaraldehyde	Biocide
Isopropanol	Surfactant
Methanol	Surfactant
Methylisothiazolinone	Biocide
Pigment Red 5	Viscosity management
Triethanolamine	Viscosity management
Propylene glycol	Viscosity management
2-Ethylhexanol	Surfactant

Methods

A literature and policy review was conducted at the commencement of the project to assess prior knowledge of the degradation of the compounds of interest and their breakdown mechanisms.

Soil samples and water samples from the Tertiary Limestone Aquifer were collected in the study area near the Katnook Gas Plant in Penola, South Australia.

Soil sample experiments were conducted under oxic (with oxygen) conditions and aquifer water sample experiments were conducted under anoxic conditions to reflect aquifer geochemistry.

Samples were dosed with chemicals and then incubated for 34 days, with a day/night cycle of 12 hours light and 12 hours of darkness, under humidity conditions expected in the Penola region.

A carbon-free soil mimicking medium was used to model the soil for tests designed to determine the existence of organisms capable of degrading a given chemical by using the chemical as a single source of carbon (energy).

A variety of analyses were employed to assess experiment results, including chemical analysis by Australian Laboratory Services and DNA sequencing performed by the Ramiciotti Centre for Genomic Analyses (UNSW).

Sampling locations in Penola, South Australia.

Results – soil

Overall, chemicals examined by physicochemical analyses in the present study appear to be completely degraded in Penola soil. Most of the chemicals tested as sole-carbon sources supported microbial growth by organisms in Penola soils.

All chemical compounds examined by commercially available accredited tests were undetectable in soil after 34 days.

While soil bacterial communities are largely unaltered by chemical additions, soil fungal communities are altered more by chemical additions.

Soil bacteria are responsible for a range of geochemical processes and their resilience to chemical additions indicates these ecosystem services undertaken by bacteria are largely unaffected.

In contrast, fungal communities support a range of soil functions such as carbon cycling and translocation, support of plant growth through fungal interactions in the root zone.

Alterations to soil fungi community structure, resulting from chemical additions, have unknown implications to ecosystem services provided by affected fungi.

Results – aquifer

In experiments based on water samples taken from the Penola Tertiary Limestone Aquifer, some chemicals were significantly degraded, while others were not degraded.

Unlike soils, the aquifer is limited in the important macro-nutrients carbon, nitrogen and phosphorus. An absence of degradation may be due to nitrogen or phosphorus limitation rather than the inability of microbes present in the aquifer to degrade these chemicals.

Prokaryotic (single celled organisms that lack a cellular membrane) aquifer communities were proportionally more affected by the addition of the various chemicals examined. Further work is required to understand the ecosystem services supported by these microbial communities.

Residual risk

It can be inferred from study results that microbial degradation of chemicals helps further reduce residual risk in soils, as the compounds tested in the study either degraded, had identifiable degrading organisms or had minimal impacts on the soil prokaryotic community.

Soil fungal communities appeared to be more affected and what this means from an ecosystem function perspective is not clear.

In groundwater the residual risk is unchanged, and while study data do show effects, what this means from an ecosystem function perspective is not clear.

Conceptual model

Data presented in the current study was on a by-chemical basis. CSIRO researchers have used insights gained during this project and from the literature review to build conceptual model (right) which highlights that many chemicals share common intermediates.

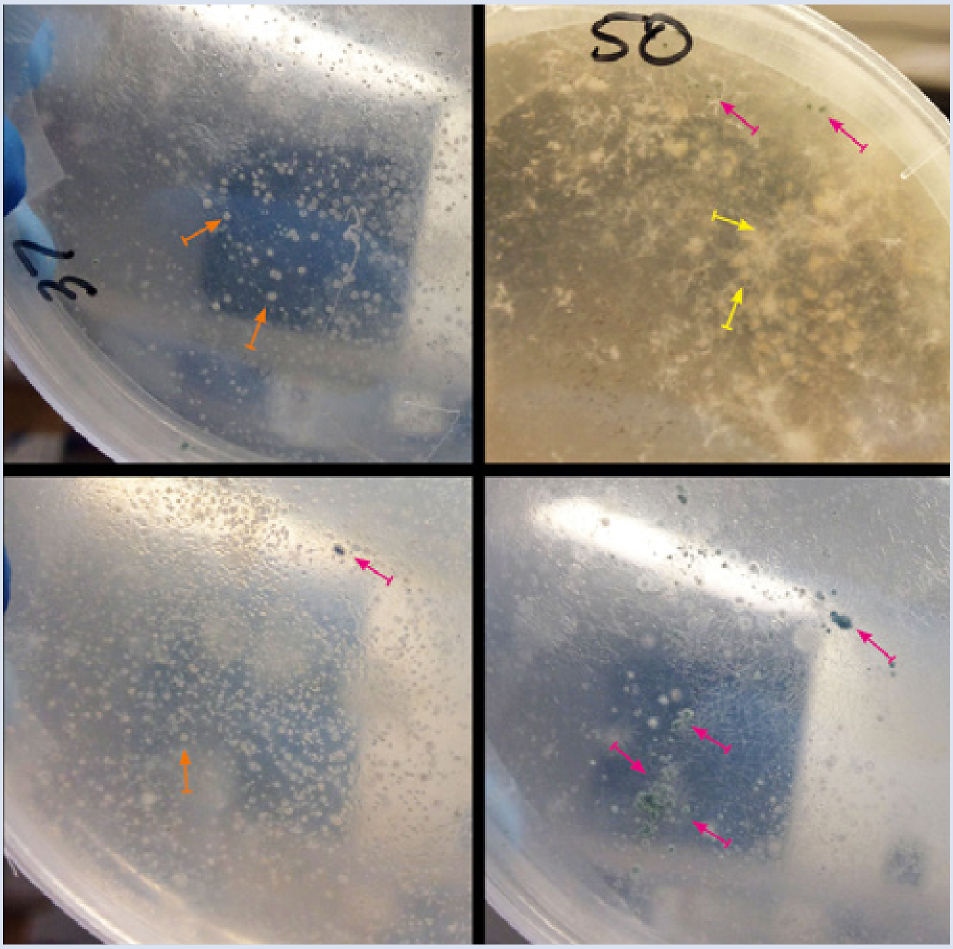
This model provides a useful framework for understanding the potential fates of chemicals in the soils and, to a lesser extent, aquifers of the Penola area of South Australia.

In the conceptual model most of the pathways are shown with blue arrows, indicating oxic (with oxygen) pathways.

The model does not describe central metabolism in detail, however it shows key intermediates that feed into central metabolism.

Conceptual model of chemical catabolism in soils and aquifers of south east South Australia.

Black arrows indicate anaerobic pathways of degradation. Blue arrows indicate aerobic pathways of degradation. Red arrows indicate microaerophilic pathways of degradation.



Photos of microbial growth on plates with target chemicals.

Top left: untreated, Top right: pristane, Bottom left: naphthalene, Bottom right: xanthan gum. Magenta arrows show green conidia on small fungal colonies, yellow arrows show thick white unevenly margined colonies on pristane, orange arrows show some example bacterial colonies.

Other research

The results of this study builds on other GISERA research in South Australia study which examined potential groundwater contamination causes, pathways and vulnerability to better understand onshore gas water quality impacts.

The aim is to better understand the impacts and residual risk of these chemical compounds to environmental contamination over time in natural environments.

This is one of six GISER research projects underway in SA, and one of GISERA's first assessments of chemical breakdown of hydraulic fracturing fluids.

More information

Read more about this project
gisera.csiro.au/project/microbial-degradation-of-onshore-gas-related-chemical-compounds/

Learn about other GISERA research in South Australia
gisera.csiro.au/project/states/sa/

Find out about GISERA gisera.csiro.au

ABOUT GISERA

The Gas Industry Social and Environmental Research Alliance (GISERA) is a collaboration between CSIRO, Commonwealth and state governments and industry established to undertake publicly reported independent research. The purpose of GISERA is to provide quality assured scientific research and information to communities living in gas development regions focusing on social and environmental topics including: groundwater and surface water, biodiversity, land management, the marine environment, and socio economic impacts. The governance structure for GISERA is designed to provide for and protect research independence and transparency of research. Visit gisera.csiro.au for more information about GISERA s governance structure, projects and research findings.

FURTHER INFORMATION: 1300 363 400 | gisera@gisera.org.au

B&M | 19 00552