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Microbial degradation of chemical compounds used in onshore gas production in the SE of South Australia

Nai Tran-Dinh, Tania J. Vergara, Richard Schinteie, Carla Mariani, Paul Greenfield and David J. Midgley

Dr. David J. Midgley | Senior Research Scientist

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Background & Objectives

- Spills and leaks are very rare. Multiple hurdles (comprehensive regulation, mandatory reporting and strict operating procedures) exist to prevent their occurrence.

- Microbial biodegradation offers an addition defence against environmental harm

- Understanding organisms that respond to chemicals provides additional indicators of leaks/spills.

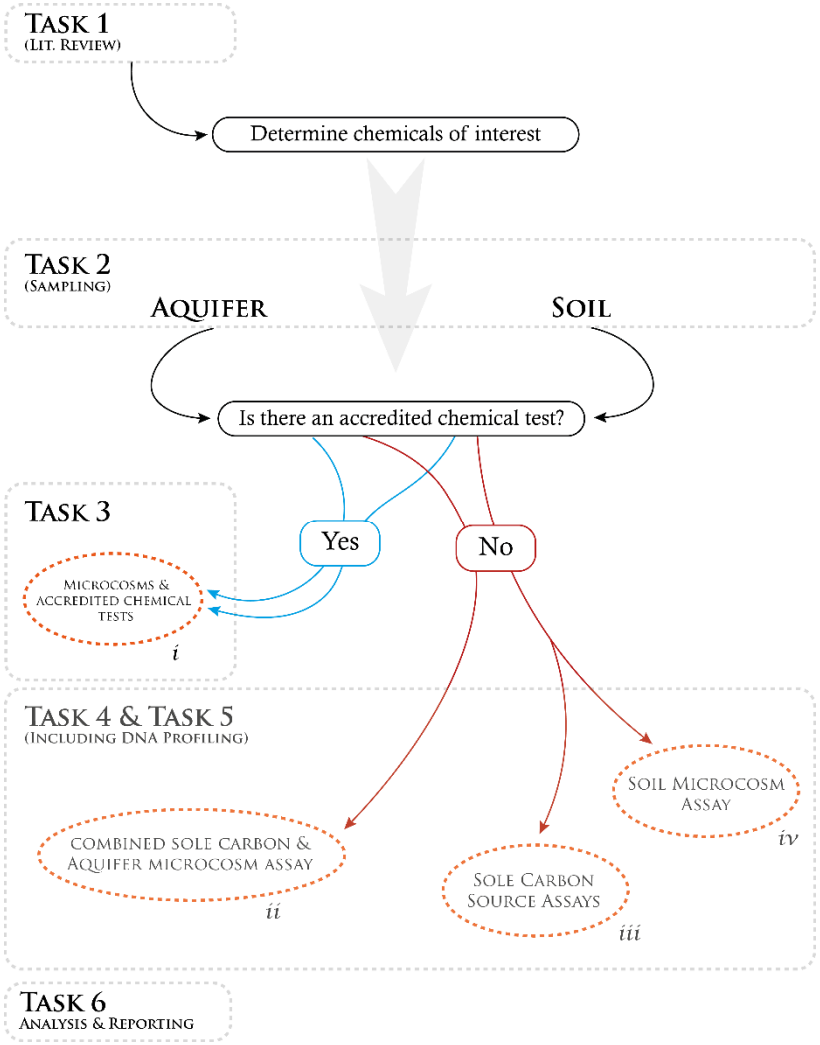
Objectives

- This study aimed to study soils and aquifers of SE South Australia, to understand chemical
  - (1) biodegradation
  - (2) biodegrading organisms and,
  - (3) effects on microbial communities.

Table 1-1: Onshore gas production chemical compounds and their uses.

Chemicals	Additive role in onshore gas activities
2-aminoethanol	Viscosity management/ drilling additive
2-butoxyethanol	Surfactant
2-ethylhexanol	Surfactant
acetic acid	Buffer, stabiliser, solvent
benzisothiazolinone	Biocide
bronopol	Biocide
c12 alcohol ethoxylate	Surfactant
diethylene glycol ethyl ether	Solvent
d-limonene	Surfactant
eicosane	Surfactant
ethanol	Surfactant
ethylene glycol	Viscosity management
glutaraldehyde	Biocide
glyoxal	Viscosity management/ crosslinker
hexahydro-1,3,5-tris(2-hydroxyethyl)-sym-triazine	Biocide
isopropanol	Surfactant
methanol	Surfactant
methylchloroisothiazolinone	Biocide
methylisothiazolinone	Biocide
naphthalene	Corrosion inhibitor
o-cresol	Biocide
polyacrylamide	Friction reducer
polyoxypropylene diamine	Pipework/Epoxy resins/Hardener
pristane	Surfactant
propylene glycol	Viscosity management
triethanolamine	Viscosity management
xanthan gum	Viscosity management

Methods


TASK 1
(LIT. REVIEW)
Determine chemicals of interest
TASK 2
(SAMPLING)
AQUIFER
SOIL
Is there an accredited chemical test?
TASK 3
Yes
No
MICROCOSMS & ACCREDITED CHEMICAL TESTS
i
TASK 4 & TASK 5
(INCLUDING DNA PROFILING)
SOIL MICROCOSM ASSAY
iv
COMBINED SOLE CARBON & AQUIFER MICROCOSM ASSAY
ii
SOLE CARBON SOURCE ASSAYS
iii
TASK 6
ANALYSIS & REPORTING

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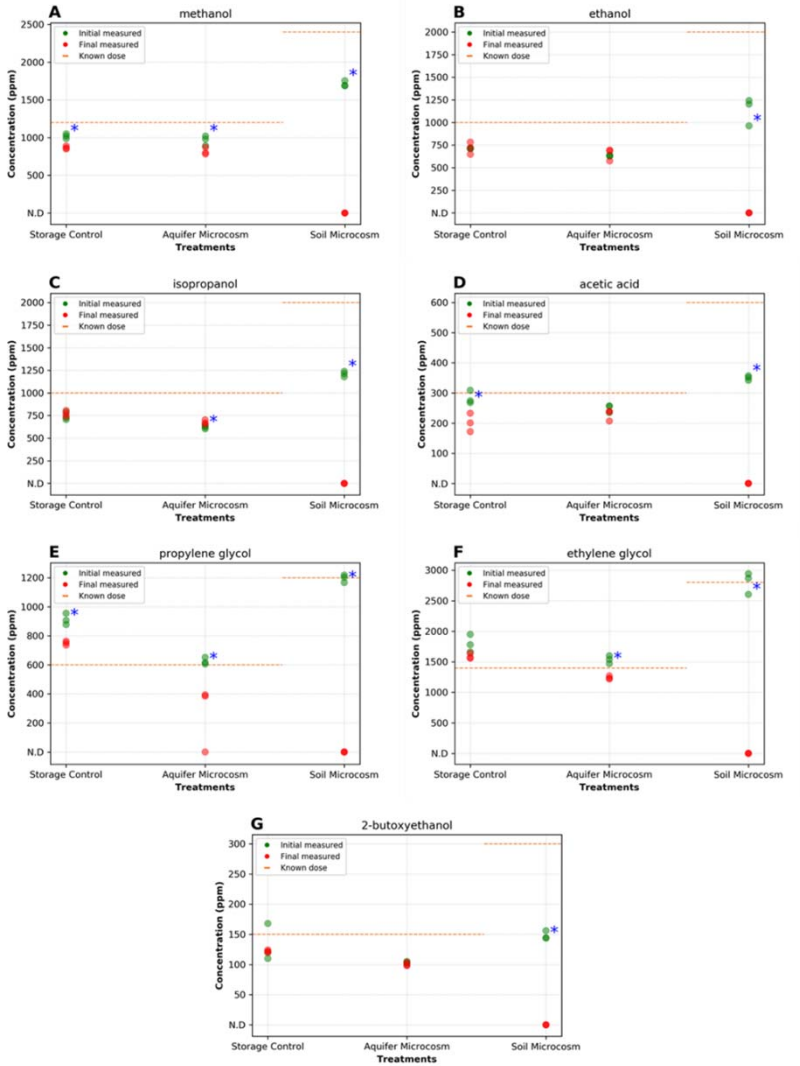
Key findings – chemical degradation

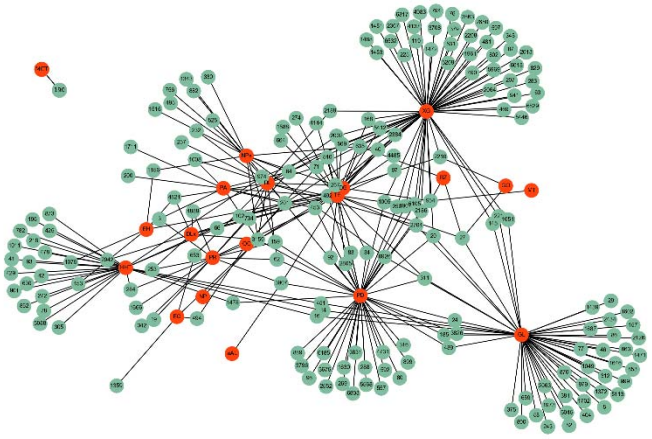
Chemicals tested in soils were undetectable in soil after incubation.

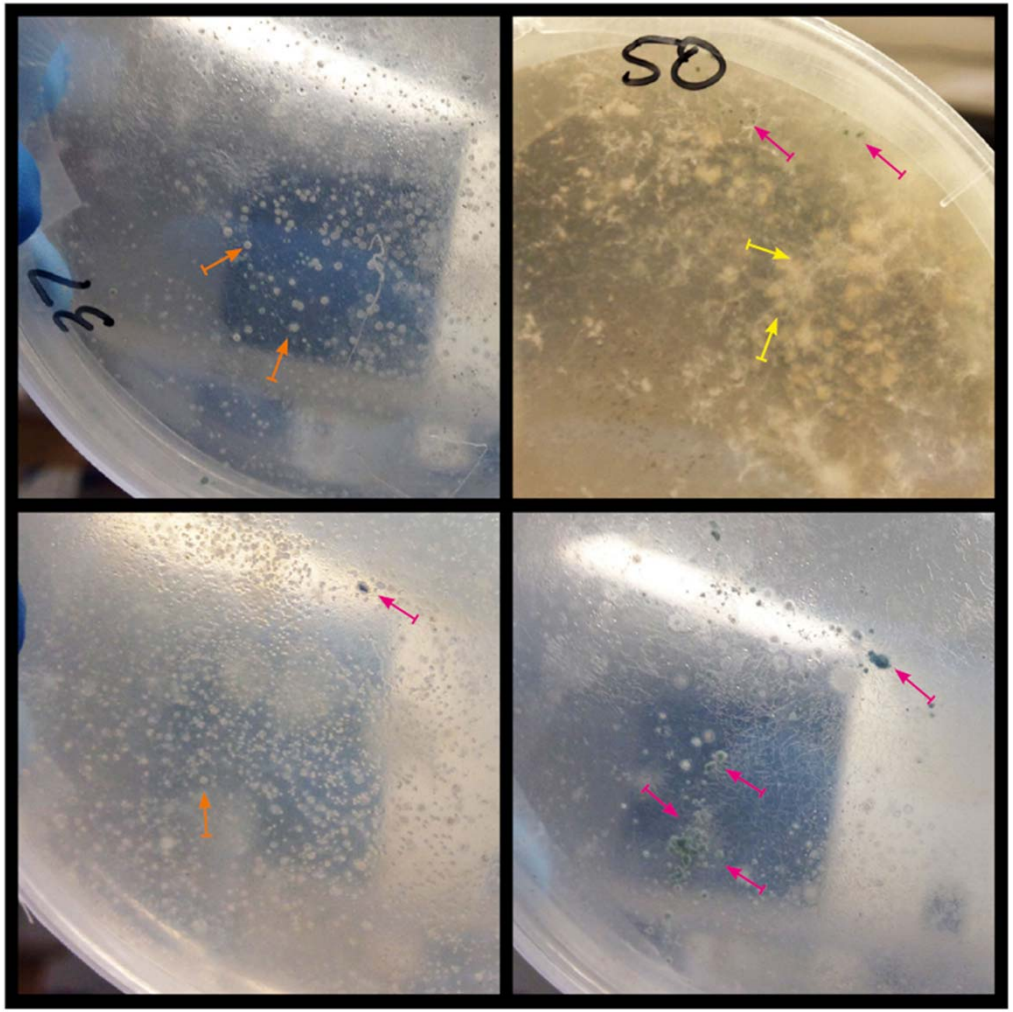
In aquifer microcosms some chemicals were partially degraded, while others did not degrade after incubation.



Key findings – chemical degrading organisms from soil

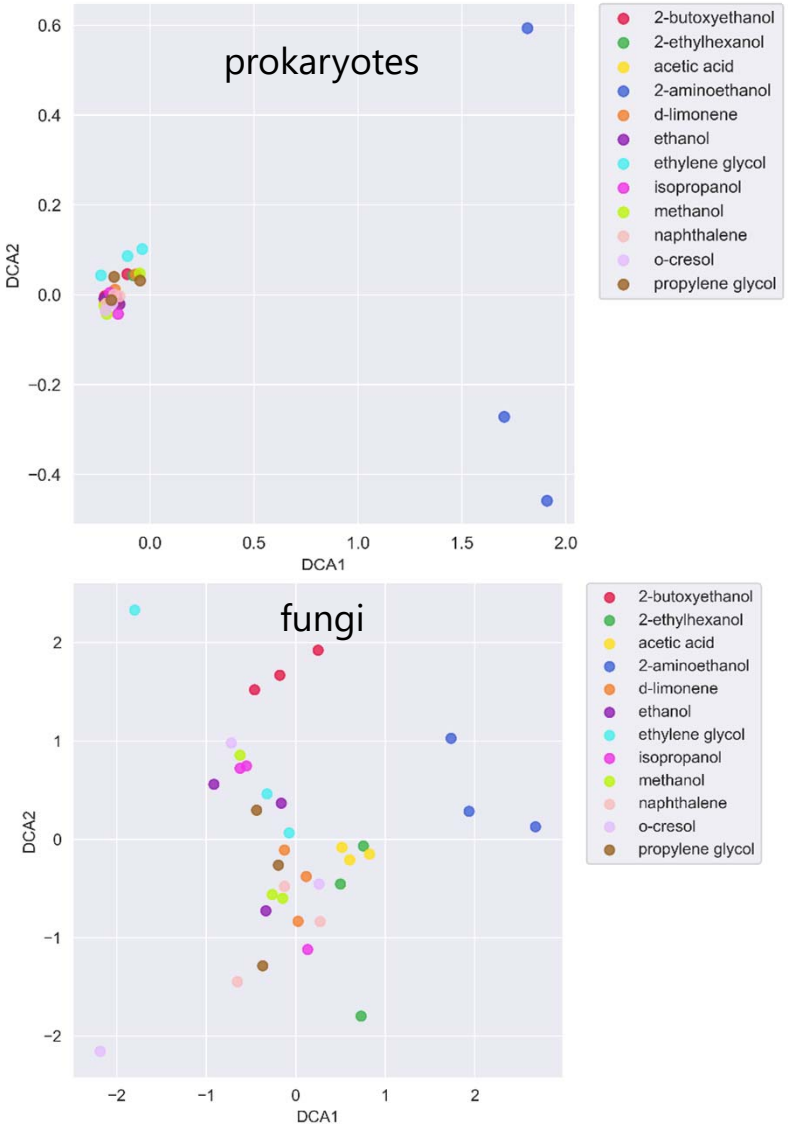
- Most chemicals in soil had identifiable degrading organisms.
- On bronopol, only fungal growth was observed.





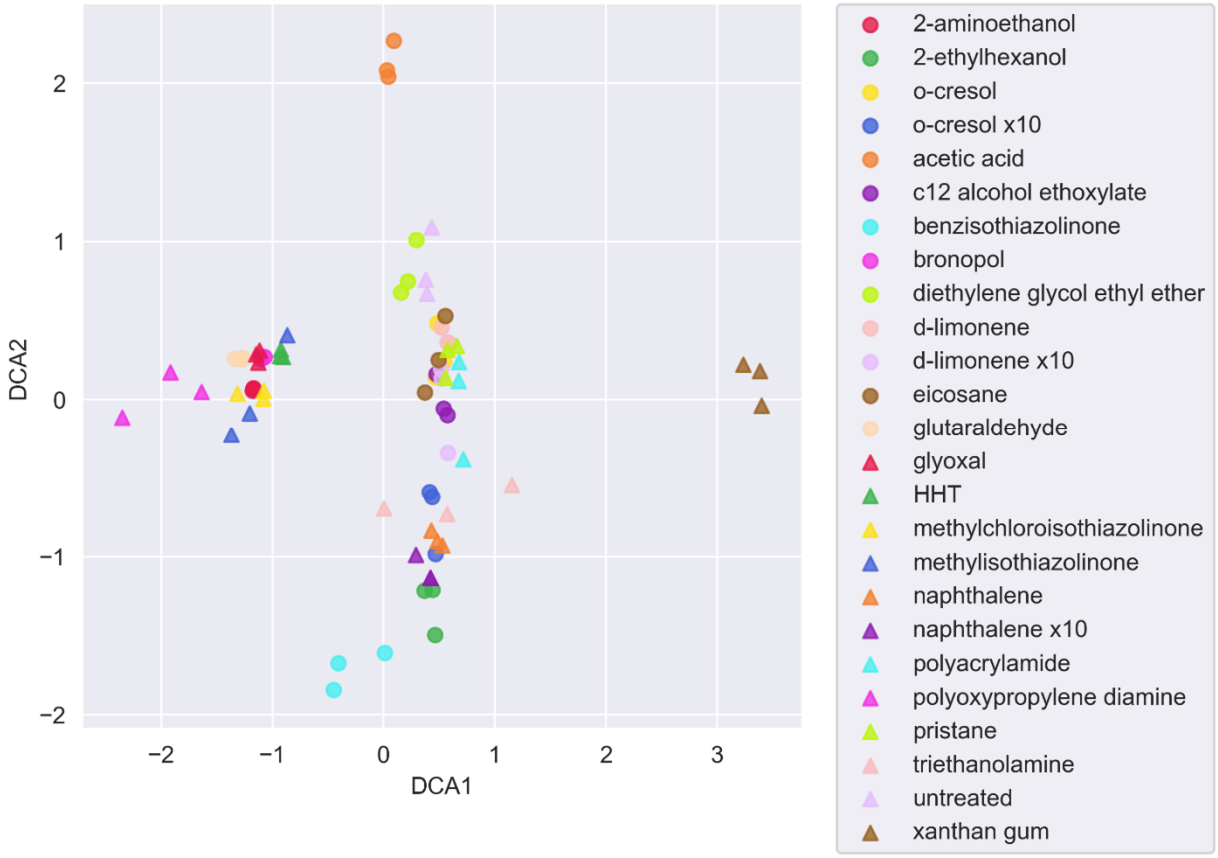
Key findings – effects on soil microbial communities

- The prokaryotic community structure was largely unaltered by exposure to tested chemicals, with the exception of 2-aminoethanol and ethylene glycol.
- In contrast, the fungal community structure was altered by many of the chemicals tested, most markedly, 2-butoxyethanol and 2-aminoethanol. For fungal communities, intra-treatment variation on individual chemicals was also significant.



Key findings – effects on aquifer microbial communities

- Most chemicals had effects on microbial community structure in the aquifer.
- These changes could be a result of increases in catabolising organisms, toxic effects or a combination of both.



Key findings –indicator taxa

- Potential biomarkers of “leaks” were detected for a range of chemicals.
- For soils, biomarker taxa were identified for:
  - 2-aminoethanol, 2-butoxyethanol, acetic acid, isopropanol and o-cresol and ethylene glycol in soil.
- For aquifers, biomarker taxa were identified for:
  - 2-ethylhexanol, acetic acid, benzisothiazolinone, naphthalene, o-cresol, triethanolamine and xanthan gum.

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Discussion – is there an impact to ecosystem services?

- For prokaryotes in soil chemicals appear to readily degrade and impacts on microbial communities appear minimal.

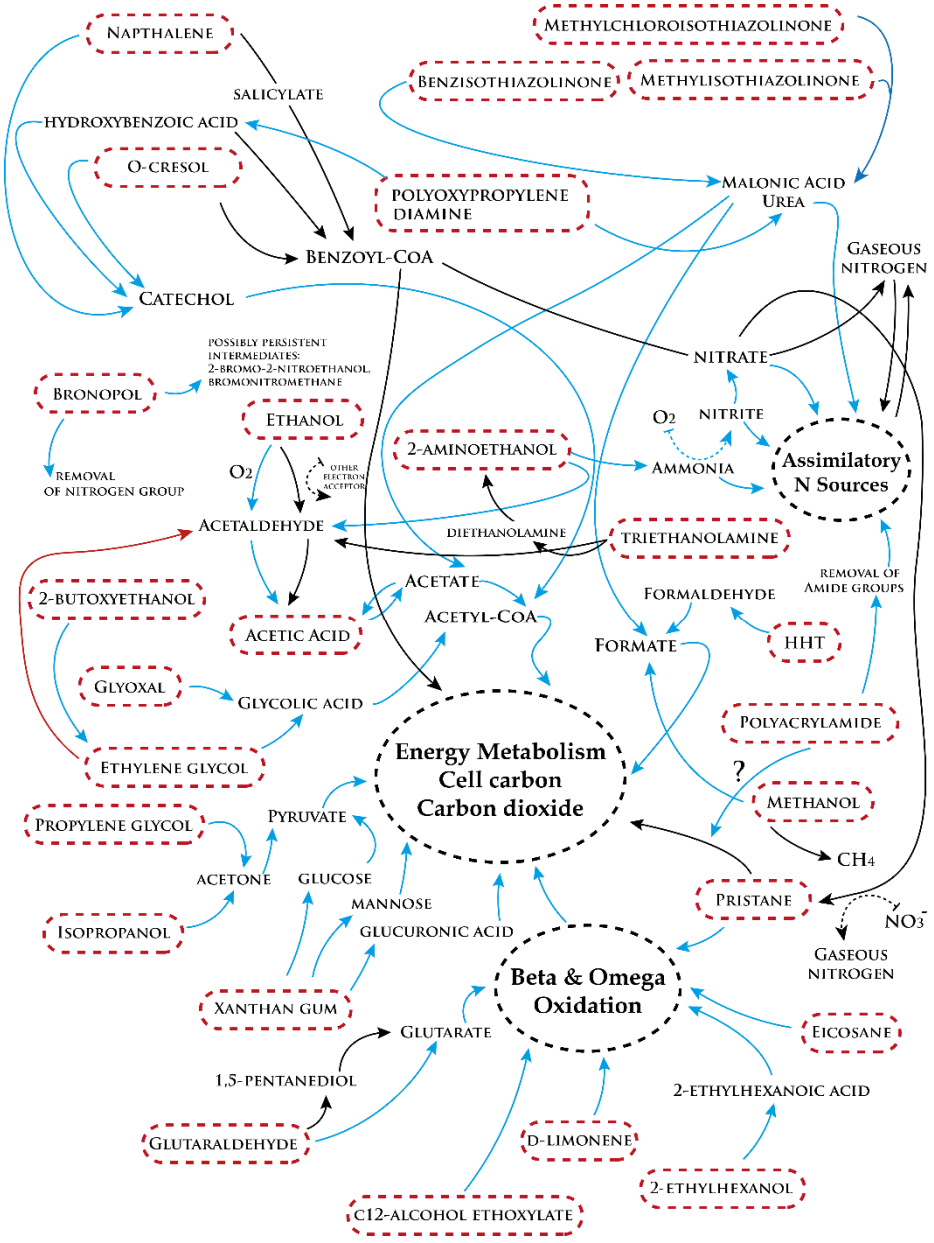
- Demonstrable structural changes to other microbial communities but do these impact ecosystem services? i.e. carbon, nitrogen or other geochemical cycling.

  - Minimal impacts on prokaryotes in soil
  - Greater impact of tested chemicals on fungal communities.
  - Greater impact on aquifer microbial communities.

Discussion – why don't chemicals degrade in the aquifer as readily?

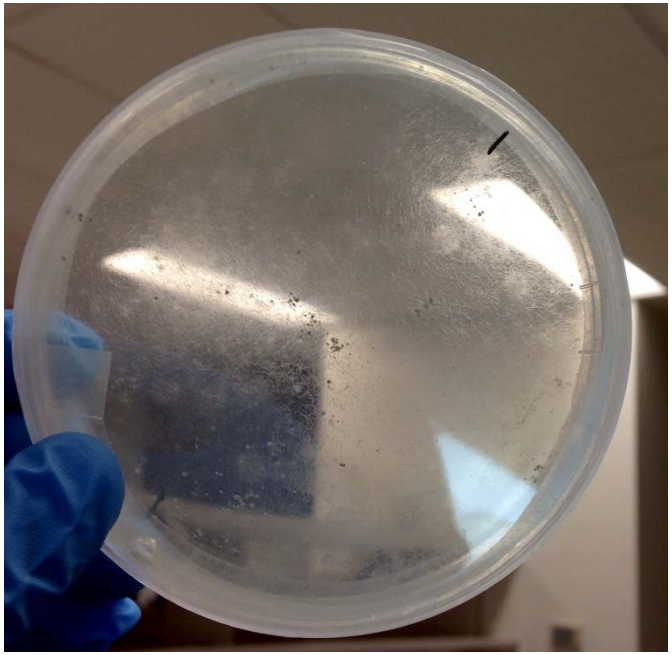
- Microbes with the catabolic potential to degrade these compounds are present in the aquifer.
- Are other nutrient deficiencies preventing the biodegradation of these compounds? (nitrogen and phosphorus limiting cell growth and activity?)

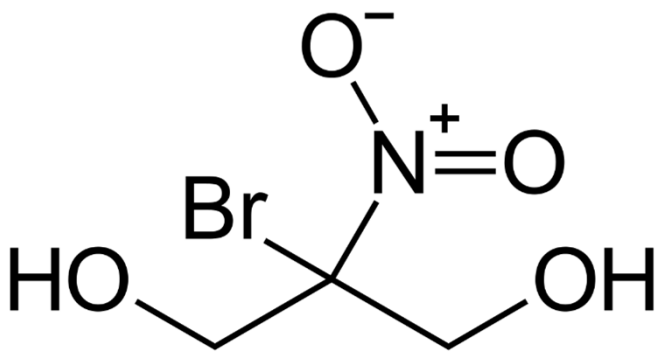
Discussion


NAPTHALENE
METHYLCHLOROISOTHIAZOLINONE
BENZISOTHIAZOLINONE
METHYLISOTHIAZOLINONE
SALICYLATE
HYDROXYBENZOIC ACID
O-CRESOL
POLYOXYPROPYLENE DIAMINE
MALONIC ACID
UREA
BENZOYL-COA
GASEOUS NITROGEN
CATECHOL
NITRATE
POSSIBLY PERSISTENT INTERMEDIATES: 2-BROMO-2-NITROETHANOL, BROMONITROMETHANE
BRONOPOL
ETHANOL
O2
NITRITE
2-AMINOETHANOL
AMMONIA
Assimilatory N Sources
REMOVAL OF NITROGEN GROUP
OTHER ELECTRON ACCEPTOR
ACETALDEHYDE
DIETHANOLAMINE
TRIETHANOLAMINE
2-BUTOXYETHANOL
ACETATE
FORMALDEHYDE
REMOVAL OF AMIDE GROUPS
ACETIC ACID
ACETYL-COA
FORMATE
HHT
GLYOXAL
GLYCOLIC ACID
POLYACRYLAMIDE
ETHYLENE GLYCOL
Energy Metabolism Cell carbon Carbon dioxide
?
METHANOL
PROPYLENE GLYCOL
PYRUVATE
CH4
ACETONE
GLUCOSE
PRISTANE
NO3-
MANNOSE
ISOPROPANOL
GLUCURONIC ACID
GASEOUS NITROGEN
Beta & Omega Oxidation
XANTHAN GUM
EICOSANE
GLUTARATE
1,5-PENTANEDIOL
2-ETHYLHEXANOIC ACID
GLUTARALDEHYDE
D-LIMONENE
2-ETHYLHEXANOL
C12-ALCOHOL ETHOXYLATE

Discussion - bronopol

- Bronopol was bacterocidal at low concentrations.
- Bronopol degrades to a number of microbially recalcitrant intermediates.
- Fungi from the Penola soil are able to grow on bronopol as a sole source of carbon, but further work to characterise its degradation products from this catabolism would be valuable.
- Are other biocides preferable?





Discussion – limitations, synergies and thresholds

- The focus here revealed taxa that can degrade chemicals and effects on microbial communities for *single* chemicals. Are microbial communities are affected by combinations of chemicals – are microbial communities just as resilient with multiple chemicals?
- From the perspective of ecosystem services, the threshold values (i.e. the concentration at which ecosystem services are impacted) of individual chemicals are not known.
- In particular, the threshold values for the biocides would be valuable in order to develop regulations and guidelines for their use.

Final comments

- Tested chemicals degraded in soils rapidly. In the aquifer, partial degradation was observed for some chemicals but not others.

- Soils of SE South Australia contain microbes that can degrade a range of onshore gas-related chemicals.
- Aquifers and soil fungal communities are more prone to impact than soil prokaryotic communities – though we don't know how or if this impacts ecosystem services.

- Species which might be useful to monitor 'environmental health' have been identified.

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Thank you

David Midgley

Senior Research Scientist.

t +61 2 9490 5062

e david.midgley@csiro.au
w gisera.csiro.au

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