

**Submission  
No 202**

## **INQUIRY INTO COAL SEAM GAS**

**Organisation:** National Toxics Network Inc.

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## **NSW Inquiry Into Coal Seam Gas**

### **Legislative Council General Purpose Standing Committee No.5**

**Submission prepared by:**

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Network, on behalf of the National Toxics Network Inc.**

**September 2011**

## **National Toxics Network Inc.**

The National Toxics Network (NTN) was constituted in 1993 and has charity status. It is a community-based network of experts working on a wide range of toxic chemical pollution issues across Australia, New Zealand and the South Pacific. NTN representatives sit on various national advisory bodies and community consultative committees in relation to international chemical conventions, hazardous waste, contaminated sites, industrial, agricultural and veterinary chemical regulation.

NTN is the Australian focal point for the International Persistent Organic Pollutants Elimination Network (IPEN) and also participates in the work of the international Pesticide Action Network (PAN). NTN is a supporting member group of the Australian Environment Network (AEN), Climate Action Network Australia (CANA) and the Lock the Gate Alliance.

*For further details about the National Toxics Network please visit [www.ntn.org.au](http://www.ntn.org.au)*

## **Dr Mariann Lloyd-Smith**

Mariann Lloyd-Smith is a Director of the research group, BioRegion Computer Mapping & Research Pty Ltd (BRCM) and the Co Chair of the International POPs Elimination Network (IPEN), a public interest chemical safety network, representing 800 organisations in over 100 countries.

Mariann gained her PhD from the Faculty of Law at the University of Technology (UTS), Sydney and has worked in the area of chemicals policy and waste management for over two decades. For ten years, Mariann was the coordinator of the National Toxics Network Inc. and now serves as one of its Senior Advisors. Mariann has published widely on chemical issues and was an author of Australia's national management plans for POPs waste.

Mariann was a member of the National Advisory Body on Scheduled Waste, used as a model of participatory democracy in chemical issues. She has been instrumental in the development and implementation of a range of information systems to support environmentally sound chemical management, including the co-development of the model for Australia's National Pollutant Inventory. Mariann is a member of the Technical Advisory Group for the national industrial chemical regulator, NICNAS - National Industrial Chemical Notification and Assessment Scheme. Trained as a negotiator in chemical disputes, she has assisted residents with their negotiations over contaminated land and has participated in the international negotiating committees (INCs) for the Stockholm, Rotterdam and Basel Conventions, the Intergovernmental Forum on Chemical Safety and the Strategic Approach to International Chemical Management (SAICM).

Mariann has presented at UNITAR capacity building and training workshops, both in Geneva and in the Pacific region. Dr Lloyd-Smith is a member of the UN Expert Group on Climate Change and Chemicals and recently coauthored NTN's report on the chemical impacts of hydraulic fracturing in the Australian shale and coal seam gas industry.

*For further information contact Dr Mariann Lloyd-Smith: [biomap@oztoxics.org](mailto:biomap@oztoxics.org)*

## Overview

The National Toxics Network (NTN) welcomes the opportunity to make a submission to the Standing Committee No.5 *Inquiry into Coal Seam Gas in NSW*. Our expertise is specifically in the area of chemicals, pollution and community engagement so we will provide detailed information on these issues as they relate to the Terms of Reference.

The social and environmental impacts of coal seam gas (CSG) mining are significant issues of concern to communities around the world, including Australians, and specifically the communities and individuals faced with CSG developments in their regions.<sup>1</sup>

NTN representatives have spoken at public forums on coal seam gas in NSW during 2010/2011 including events in Casino, Murwillumbah, Lismore, Byron Bay and Laurieton where collectively, thousands of citizens have turned out to be better informed about the CSG industry and to voice their concerns about the possible impacts to their individual properties, communities and environment.

NTN produced a technical report (May 2011) titled *Hydraulic Fracturing in Coal Seam Gas Mining: The Risks to Our Health, Communities, Environment and Climate*. The report is fully referenced and freely available on our website. It is a living document and has been updated several times as new information becomes available. Some of the information provided in this submission is taken directly from the report.

The social and environmental impacts of coal seam gas mining cuts across many challenging areas including: climate change and greenhouse gas emissions; sustainable/renewable energy; chemical use; hazardous waste disposal; air, soil and water pollution; land and water use.

After careful consideration of the chemical pollution issues associated with CSG, NTN recommends that a NSW moratorium be placed on the use of all chemicals involved in the exploration and production of coal seam gas until all of the chemicals used (or proposed for use) have been fully assessed for their health and environmental hazards and their specific cumulative risks as used in coal seam gas mining. This assessment should be conducted by the federal industrial chemicals regulator the National Industrial Chemical Notification and Assessment Scheme (NICNAS).

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<sup>1</sup> Stop Coal Seam Gas Now <http://www.youtube.com/watch?v=93hRPRxXFg4&feature=related>

## Key findings

(NB. Not listed by order of priority but as they relate to the Terms of Reference and sequence of information in this submission)

1. The approach to risk assessment in CSG operations on a project-by-project basis does not take into account the *cumulative impacts* on water and air quality.
2. The disposal of salt and treatment of contaminated produce water is a significant challenge in CSG operations. Limited assessment has been made of the options for treatment and capacity of wastewater facilities and landfills to manage this hazardous waste.
3. Treatment of contaminated produce water using membrane filtration has significant limitations, as it cannot remove all contaminants, particularly organic compounds with low molecular weight.
4. There is no requirement for the assessment and monitoring of the *cumulative load* of chemicals used in CSG operations, or their potential to contaminate sediment, plants, aquatic species and /or animals prior to release of contaminated produce water. A chemical-by-chemical approach to risk assessment is also in contradiction with the current *National Water Quality Management Strategy* which recommends moving away from relying solely on chemical specific water monitoring to a more integrated approach using direct toxicity assessments (toxicity bioassays which assess overall toxicity of the water) and biological monitoring to fully assess the cumulative (additive and synergistic) impacts of complex mixtures of chemicals.
5. NTN's scientific literature review of chemicals used by the CSG industry has found that only 2 out of the 23 most commonly used fracking chemicals in Australia (that we could ascertain) have been assessed by NICNAS, the federal regulator of industrial chemicals. Of the 2 assessed chemicals, neither has been specifically assessed for its use in CSG mining activities.
6. BTEX chemicals are commonly found in the products used in the drilling stage of hydraulic fracturing and BTEX chemicals are also components of the volatile compounds found naturally in the coal gas seams. The fracking process itself can release BTEX from the natural-gas reservoirs, which may allow them to disperse into the groundwater aquifers or to volatilise into air. People may be exposed to BTEX chemicals by drinking contaminated water, breathing contaminated air or from spills on their skin.
7. After hydraulic fracturing is completed, a mixture of hazardous chemical compounds remains underground. These chemicals are distributed over time and space making them difficult and unpredictable to manage into the future, and potentially causing impacts to landscapes and future uses of the land and water.
8. The lack of disclosure on Material Safety Data Sheets of the full chemical identity of chemical ingredients used in products for CSG mining makes it impossible to realistically assess their risks and their possible impacts to the environment and human health.

9. There is an assumption that natural gas derived from CSG can act as a transition fuel because it is a 'cleaner' fossil fuel than coal however, there appears to be limited independent data on which to base this assumption. The total greenhouse gas emissions associated with CSG need to be accounted for in a thorough life cycle analysis.
10. Air pollution associated with CSG sites including emissions from well pads, compressors, gas plants, and waste sites must undergo continuous monitoring for volatile organic compounds and hydrogen sulfide. The data should be provided to regulators and be made publically available. Facilities unable to eliminate toxic emissions should be required to cease operations. All new applications should require a full assessment of the risks and hazards to air quality.
11. CSG exploration and extraction as an industrial activity with a potentially significant impact on the environment and community should require public consultation as part of the authorisation procedure.
12. A cost/benefit analysis should be undertaken for each CSG development and include a full life cycle assessment (including greenhouse gas emission, resource consumption and cumulative impacts) to demonstrate the overall costs/benefits for the society.

## Addressing the Terms of Reference

### 1. The environmental and health impact of CSG activities including the:

#### a. Effect on ground and surface water systems

The long-term impacts to surface waters and groundwater aquifers from CSG activities is unknown as the approach to risk assessment on a project-by-project basis does not take into account the *cumulative impacts* to waterways.

CSG activities involve considerable quantities of water as the extraction of gas from coal seams relies on reducing the ground water pressure that keeps the gas absorbed between layers of coal. The amount of water extracted from a CSG well varies depending on the type and depth of the coal seam, but is reported by industry to range between 0.1 megalitres per day (ML/d) and 0.8 ML/d.<sup>2</sup>

When contaminated with the byproducts of the hydraulic fracturing process, the wastewater in CSG operations is referred to as '*produced water*'. Produced water can be contaminated with fracking and drilling chemicals, heavy metals (eg arsenic, mercury, lead, cadmium and chromium IV), other minerals, hydrocarbons like BTEX which occur naturally in coal seam water, as well as radioactive elements like uranium and thorium.

Coal seam water also contains salt. While the amount of salt depends on the location and age of the coal seam, it is typically between five and eight tonnes (5000kg-8000kg) for every megalitre (one million litres) of water.<sup>3</sup> Disposal of salt and treatment of contaminated produce water is a significant challenge in CSG operations.

#### **Produced Water**

A number of options are used to manage produced water, which is effectively waste product of the CSG operation. Waste water can be stored in evaporation ponds where overtime it evaporates into the atmosphere, it can be re-injected into the aquifer, or 'treated' and then released into waterways or sold on to farmers for irrigation. While the Queensland Government prohibits the use of evaporation ponds as the primary disposal means for produced water (unless there is no feasible alternative)<sup>4</sup>, NSW still permits them and is looking at other options.

Evaporation ponds can cover large areas. For example, Metgasco estimates that water by-products from its Casino wells will require approximately 12 hectares of pond area.<sup>5</sup> The water is typically saline and should the ponds fail (e.g. leak) surrounding soil quality and vegetation could be compromised or, in the worst-case scenario, destroyed. If ponds are flooded (due to rain or location of evaporation ponds on flood plains), their contaminants can be released to surface waters.

Evaporative ponds inevitably result in the transfer of volatile or semi-volatile chemicals in the produced water into the atmosphere. Evaporation ponds also need to be remediated and rehabilitated after use because they leave behind a concentration of

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<sup>2</sup> CSG and water: quenching the industry's thirst, Gas Today Australia — May 2009

<sup>3</sup> Arrow Energy: Salt Management

[http://www.arrowenergy.com.au/icms\\_docs/95251\\_Salt\\_Management.pdf](http://www.arrowenergy.com.au/icms_docs/95251_Salt_Management.pdf)

<sup>4</sup> Coal Seam Gas Water Management Policy, Dept of Environment & Resource Management June 2010

<sup>5</sup> Appendix G METGASCO LIMITED, CASINO GAS PROJECT HYDROGEOLOGICAL ASSESSMENT  
[http://www.planning.nsw.gov.au/asp/pdf/06\\_0217\\_rvps\\_cgp\\_ea\\_appendixgpt1.pdf](http://www.planning.nsw.gov.au/asp/pdf/06_0217_rvps_cgp_ea_appendixgpt1.pdf)

contaminated material.

Some CSG companies in Australia are developing and/or operating plants to treat the produced water using membrane filtration such as reverse osmosis in order to sell the water to farmers for irrigation, domestic drinking water supply or cooling of power stations.

Reverse osmosis involves forcing water through a semi-permeable membrane, which filters out a select number of water contaminants. The three mechanisms a molecule can be rejected by the reverse osmosis membrane are size exclusions (or sieving), electrostatic repulsion and hydrophobic adsorption.<sup>6</sup> In general, if the contaminants are larger in size than water molecules, those contaminants will be filtered out. If the contaminants are smaller in size, they remain in the water. Despite consistent reassurances from CSG companies on this issue, the fact remains that reverse osmosis filtration has significant limitations<sup>7</sup> and cannot remove all contaminants, particularly organic compounds with low molecular weight.<sup>8</sup>

The Queensland Gas Company (QGC) is opening a water treatment facility in the Western Downs region in October 2011. While the \$350 million facility will treat 100 megalitres of water used at the Chinchilla gas processing plant, it's unknown what the company will do with the 200 tonnes of salt produced a day, but a company representative has said, "Dumping it will be a last resort".<sup>9</sup>

### **Release of Produce Water into Waterways**

Permits are provided for the release of wastewater produced in association with the fracking process. In one authorisation for one CSG company,<sup>10</sup> the release of treated water into the Condamine River was authorised for a period of 18 months at a maximum volume of 20 megalitres (ML) per day. Over 80 chemical compounds as well as radionuclides<sup>11</sup> were listed in the permit and included a range of persistent, bio-accumulative toxic substances such as nonylphenols, Bisphenol A (BPA), chlorobenzenes, bromides, lead, cadmium, chromium, mercury and BTEX.

There was no requirement for an assessment of the cumulative load or the potential to contaminate sediment, plants, aquatic species and /or animals prior to release.

While release limits were included for the listed compounds in the above authorization, the majority of the limits set were not based on the ANZECC water quality guidelines<sup>12</sup> because many of the chemicals to be released are not listed in the

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<sup>6</sup> Stuart J. Khan Quantitative chemical exposure assessment for water recycling schemes, Waterlines Report Series No 27, March 2010 Commissioned by the National Water Commission.

<sup>7</sup> See A. Bbdalo-Santoyo, J.L. Gbmez-Carrasco, E. Gbmez-Gbmez, M.F. Maximo-Martin, A.M. Hidalgo-Montesinos Spiral-wound membrane reverse osmosis and the treatment of industrial effluents. *Desalination* 160 (2004) 15 I-I 58: Also see Lianfa Song, J.Y. Hu, S.L. Ong, W.J. Ng, Menachem Elimelech, Mark Wilf, Performance limitation of the full-scale reverse osmosis process. *Journal of Membrane Science* 214 (2003) 239–244

<sup>8</sup> <http://www.industry.qld.gov.au/documents/LNG/csg-water-beneficial-use-approval.pdf>

<sup>9</sup> Farms to get treated coal seam gas water, Sam Burgess and Fidelis Rego ABC News 29/11/2010 Available <http://www.abc.net.au/news/stories/2010/11/29/3079368.htm>

<sup>10</sup> Schedule C, Australian Pacific LNG Pty Ltd Environmental Authority (petroleum activities) No. PEN100067807

<sup>11</sup> Radionuclides occur naturally as trace elements in rocks and soils as a consequence of the "radioactive decay" of uranium-238 (U-238) and thorium-232 (Th-232). When radioactive atoms release or transfer their extra energy, it is called decay. The energy they release is called ionizing radiation, which may be alpha particles, beta particles, or gamma rays. When ionizing radiation strikes a living organism's cells, it may injure the organism's cells. There are about 650 radionuclides with half lives longer than 60 minutes. Of these, about 339 are known from nature. For more information see <http://www.epa.gov/radiation/radionuclides/>; Also see [http://www.nesc.wvu.edu/pdf/dw/publications/ontap/2009\\_tb/radionuclides\\_DWFSOM45.pdf](http://www.nesc.wvu.edu/pdf/dw/publications/ontap/2009_tb/radionuclides_DWFSOM45.pdf)

<sup>12</sup> [http://www.mincos.gov.au/publications/australian\\_and\\_new\\_zealand\\_guidelines\\_for\\_fresh\\_and\\_marine\\_water\\_quality](http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality)



ANZECC guidelines or were marked as having insufficient data to set a water quality guideline.<sup>13</sup>

Follow up monitoring was required by the above authorisation but it did not include an assessment of the cumulative load and impact of the chemicals. This chemical-by-chemical approach is in contradiction of the current National Water Quality Management Strategy (NWQMS)<sup>14</sup> which recommends moving away from relying solely on chemical specific water monitoring to a more integrated approach using direct toxicity assessments (toxicity bioassays which assess overall toxicity of the water) and biological monitoring to fully assess the cumulative (additive and synergistic) impacts of the mixture of chemicals on the environment including plants and animals.

The following list provides volumes and quantities of a selection of compounds permitted for release into the Condamine River over an 18-month period in relation to the wastewater permit authorization discussed above. We include this list to illustrate the range and quantity of pollutants that could be expected from some CSG operations.

<b>Chemical compound</b>	<b>Release rate/day</b>	<b>Total</b> (release rate x 20ML x 547.5 days / 18 months)
BPA	200g/ML	2,298KG (2.298 tonnes)
Bromide	7,000g/ML	76,650KG (76.65 tonnes)
Total Chlorobenzenes	1,840g/ML	20,148KG (20.148 tonnes)
Monochloramine	3,000g/ML	32,850KG (32.85 tonnes)
Nitrate	50,000g/ML	5,475,000KG (5,475 tonnes)
Uranium	20g/ML	219KG
Toluene	800g/ML	8,760KG (8.76 tonnes)
Xylene	600g/ML	6,570KG (6.57 tonnes)
Ethylbenzine	300g/ML	3,285KG (3.285 tonnes)
Benzene	1g/ML	10.95KG
Cyanide	80g/ML	876KG
Lead	10g/ML	109.5KG

<sup>13</sup> The authors note that the Australian Centre for Mining Environmental Research, an industry consultancy has published their own list of TRIGGER VALUES FOR TOXICANTS in the document; Batley, GE, Humphrey CL, Apte SC and Stauber JL (2003). A Guide to the Application of the ANZECC/ARMCANZ Water Quality Guidelines in the Minerals Industry. (Australian Centre for Mining Environmental Research: Brisbane). However, the document is not in the public domain hence the trigger values, the data used or the methodology cannot be assessed.

<sup>14</sup> <http://www.environment.gov.au/water/policy-programs/nwqms/>

## Impacts on Groundwater

*'The drawdown of ground water heads within coal seam gas aquifers is a necessary process and an unavoidable impact associated with the de-pressurisation of the coal seam.'*<sup>15</sup>

CSG drilling and fracking activities can impact the groundwater in different ways. There can be significant losses in pressure within the aquifer or in overlying and underlying aquifers and impacts may be experienced well beyond the perimeter of the gas fields.

Industry predicts groundwater drawdown for the Arcadia Valley and Fairview CSG fields within the Bowen Basin, Queensland of up to 15 metres by 2013 and 65 metres by 2028. For the 4 bore wells situated in and around the fields, it was estimated they would experience 7 to 25 metres drawdown in the groundwater level by 2028. For the Roma CSG field in the Surat Basin, industry predicted minor inter-aquifer transfer and only a 3-metre drawdown at the edge of the gas field.<sup>16</sup>

Drill holes or fractures may intersect with one or multiple aquifers potentially mixing groundwater from different strata or altering the groundwater chemistry through exposure to the air, gas, fracking chemicals and drilling fluids or the release of natural compounds like BTEX.<sup>17</sup>

## Methane Water Contamination

Methane can contaminate bores and water wells near gas wells.<sup>18</sup> An analysis of 60 water wells near active gas wells in the US, found most were contaminated with methane at levels well above US federal safety guidelines for methane. The majority of water wells situated one kilometre or less from a gas well, contained water contaminated with 19 to 64 parts per million (ppm) of methane. Wells more than a kilometre from active gas had only a few parts per million of methane in their water. The study used chemical and isotopic analyses to identify the high levels of methane in well water as being produced in the deep shale, released by gas drilling activities. The low-level, background methane from the more distant water wells came from methane-generating bacteria living in shallow rock.

### **b. Effects related to the use of chemicals**

NTN's scientific literature review of chemicals used by the CSG industry has found that only 2 out of the 23 most commonly used fracking chemicals in Australia (that we could ascertain) have been assessed by NICNAS, the federal regulator of industrial chemicals. Of the 2 assessed chemicals, neither has been specifically assessed for its use in CSG mining activities.

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<sup>15</sup> Groundwater (Deep Aquifer Modeling) for Santos GLNG Project – Environmental Impact Statement 31/3/2009

<sup>16</sup> Groundwater (Deep Aquifer Modelling) for Santos GLNG Project – Environmental Impact Statement 31/3/2009

[http://www.glng.com.au/library/EIS/Section%206/06%2006%20Groundwater%20\(Section%206.6\)%20FINAL%20PUBLIC.pdf](http://www.glng.com.au/library/EIS/Section%206/06%2006%20Groundwater%20(Section%206.6)%20FINAL%20PUBLIC.pdf)

<sup>17</sup> Shenhua Watermark Coal Pty Ltd, Review of Environmental Factors Exploration Drilling and Associated Activities -EL 7223 February 2011 GHD-RPT-EXP-DRL-007 [1] Revision 1

<sup>18</sup> Osborn, SG, A Vengosh, NR Warner, RB Jackson. 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. Proceedings of the National Academy of Sciences, U.S.A. doi: 10.1073/pnas.1100682108. <http://www.nicholas.duke.edu/cgc/pnas2011.pdf>

## BTEX chemicals

BTEX is shorthand for a group of compounds: benzene, toluene, ethylbenzene and xylene. In October 2010, traces of BTEX chemicals were found at an Arrow Energy fracking operation in Queensland. Arrow Energy confirmed that benzene, toluene, ethylbenzene and xylene (BTEX) had been found in well water associated with its coal-seam gas operation at Moranbah, west of Mackay.<sup>19</sup>

On 27<sup>th</sup> August 2011, Arrow Energy released monitoring results<sup>20</sup> of samples taken over three days from monitoring bores constructed around coal seam gas (CSG) dams. BTEX chemicals were found in 5 of 14 shallow bores at Arrow's Tipton West and Daandine gas fields, approx 25 kilometres from Dalby. Some bores detected benzene at levels between 6 to 15 times the Australian drinking water standard. The drinking water standard is set at 0.001 milligram per litre or, approximately 1 part per billion (ppb). Australian water regulators acknowledge that *'No safe concentration for benzene in drinking water can be confidently set. However, for practical purposes the concentration should be less than 0.001 mg/L (approximately 1ppb), which is the limit of determination.'*

An underground coal gasification project run by a Cougar Energy, near Kingaroy Queensland, was also temporarily shut down when benzene and toluene were detected.<sup>21</sup> The QLD Department of Environment and Resource Management has laid charges on three counts of breaching conditions of environmental authority.<sup>22</sup> Queensland has since banned the use of BTEX chemicals in fracking fluids. The NSW Government announced it would examine banning the use of BTEX chemicals in 'situations, which may pose risk to groundwater'.<sup>23</sup>

BTEX chemicals are commonly found in the products used in the drilling stage of hydraulic fracturing. However BTEX chemicals are also components of the volatile compounds found naturally in the coal gas seams. The fracking process itself can release BTEX from the natural-gas reservoirs, which may allow them to disperse into the groundwater aquifers or to volatilise into air. As a consequence, people may be exposed to BTEX by drinking contaminated water, breathing contaminated air or from spills on their skin.<sup>24</sup>

BTEX compounds can contaminate both soil and groundwater. BTEX chemicals are hazardous in the short term causing skin irritation, central nervous system problems (tiredness, dizziness, headache, loss of coordination) and effects on the respiratory system (eye and nose irritation). Prolonged exposure to these compounds can also negatively affect the functioning of the kidneys, liver and blood system. Long-term exposure to high levels of benzene in the air can lead to leukemia and cancers of the blood.<sup>25</sup>

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<sup>19</sup> Contamination fear fails to stop project, <http://www.theaustralian.com.au/national-affairs/contamination-fear-fails-to-stop-project/story-fn59niix-1225950389968>

<sup>20</sup> 26/08/2011 - [Arrow Energy advises of monitoring results](http://www.arrowenergy.com.au/page/Media_Centre/Latest_News/)

[http://www.arrowenergy.com.au/page/Media\\_Centre/Latest\\_News/](http://www.arrowenergy.com.au/page/Media_Centre/Latest_News/)

<sup>21</sup> Cancer chemical found at western Queensland gas site, <http://www.couriermail.com.au/business/cancer-chemical-found-at-gas-site/story-e6f9eqmx-1225940922665>

<sup>22</sup> Cougar Energy charged with three counts of breaching conditions of environmental authority, The Courier-Mail July 02, 2011 <http://www.couriermail.com.au/news/queensland/cougar-energy-charged-with-three-counts-of-breaching-conditions-of-environmental-authority/story-e6f9e0of-1226085900407>

<sup>23</sup> Tough New Rules for Coal Seam Gas Exploration 19.12.2010 News Release, Premier of NSW

<sup>24</sup> Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Interaction Profile for Benzene, Toluene, Ethylbenzene and Xylene (BTEX). U.S. Department of Health and Human Services, Public Health Service.

<sup>25</sup> Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Interaction Profile for Benzene, Toluene, Ethylbenzene and Xylene (BTEX). U.S. Department of Health and Human Services, Public Health Service.

## Fracking Fluids

*“Chemicals are used at most stages of the drilling operation to reach and release the natural gas from gas coal seams – to drill the bore hole, to facilitate the actual boring, to reduce friction, to enable the return of drilling waste to the surface, to shorten drilling time, and to reduce accidents. After drilling has been completed, hydraulic fracturing is used to release the trapped gas by injecting approximately 2.5 million litres or more of fluids, loaded with toxic chemicals, underground under high pressure.”<sup>26</sup>*

Fracturing fluids or ‘fracking fluids’ consist of water, sand and chemicals that are combined and injected into the coal seam at high pressure. The fracking fluids include chemicals and additives that aid the fracturing process (e.g. viscosifiers, surfactants, pH control agents) as well as biocides that inhibit biological fouling and erosion.

The *US Ground Water Protection Council and Interstate Oil and Gas Compact Commission* describes the contents of fracking fluids;

*“The addition of friction reducers allows fracturing fluids and sand, or other solid materials called proppants, to be pumped to the target zone at a higher rate and reduced pressure than if water alone were used. In addition to friction reducers, other additives include: biocides to prevent microorganism growth and to reduce biofouling of the fractures; oxygen scavengers and other stabilizers to prevent corrosion of metal pipes; and acids that are used to remove drilling mud damage within the near wellbore area. These fluids are used to create the fractures in the formation and to carry a propping agent (typically silica sand) which is deposited in the induced fractures to keep them from closing up.”<sup>27</sup>*

While CSG mining companies argue that the full identity and composition of fracking fluids cannot be publicly disclosed as the information is a trade secret and involves commercial-in-confidence data, the identity of the types of chemicals used in fracking fluids is publicly available.<sup>28</sup> (See **Appendix 1** for a list of chemicals used in fracking fluid products identified by the *US Ground Water Protection Council and the Interstate Oil and Gas Compact Commission*).

A recent review on the use of chemicals in fracking<sup>29</sup> lists nearly a thousand products involved in natural gas operations (including CSG and shale gas) in the USA. Only a small percentage of these chemicals have CAS Registry Numbers<sup>30</sup> listed on their Material Safety Data Sheets (MSDS). Without a CAS number it is very difficult to search for specific health and environmental data about a chemical.

MSDS are a limited source of information on chemical hazards as they often provide only rudimentary human health data and little, if any, information on the environmental fate of the chemical or its effects on the environment and ecosystems.

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Health Service.

<sup>26</sup> Theo Colborn, Carol Kwiatkowski, Kim Schultz, Mary Bachran, Natural Gas Operations from a Public Health Perspective, *International Journal of Human and Ecological Risk Assessment*, September 4, 2010. Available at: [http://www.endocrinedisruption.com/files/NaturalGasManuscriptPDF09\\_13\\_10.pdf](http://www.endocrinedisruption.com/files/NaturalGasManuscriptPDF09_13_10.pdf)

<sup>27</sup> <http://fracfocus.org/chemical-use/what-chemicals-are-used> Fracfocus is joint project of the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission

<sup>28</sup> <http://fracfocus.org/chemical-use/what-chemicals-are-used>

<sup>29</sup> Theo Colborn, Carol Kwiatkowski, Kim Schultz, Mary Bachran, Natural Gas Operations from a Public Health Perspective, *International Journal of Human and Ecological Risk Assessment*, September 4, 2010. Available at: [http://www.endocrinedisruption.com/files/NaturalGasManuscriptPDF09\\_13\\_10.pdf](http://www.endocrinedisruption.com/files/NaturalGasManuscriptPDF09_13_10.pdf)

<sup>30</sup> CAS registry numbers are unique numerical identifiers assigned by the Chemical Abstracts Service to every chemical described in the open scientific literature.

A review of 980 chemical products used in the gas industry in the USA found that <sup>31</sup>:

- A total of 649 chemicals were used in the 980 products. Specific chemical names and CAS numbers could not be determined for 286 (44%).
- Less than 1% of the total composition of the product was reported on the MSDS for 421 of the 980 products (43%), less than 50% of the composition was reported for 136 products (14%), and between 51% and 95% of the composition was reported for 291 (30%) of the products. Only 133 products (14%) had information on more than 95% of their full composition.

The issue of the lack of disclosure of the full chemical identity on product MSDS is similar in Australia. In 2010, it was reported that a coal seam gas-drilling site near Lismore NSW, run by Metgasco, was permitted to use fracking after supplying only a generic list of hazardous materials safety guidelines.<sup>32</sup>

A review of MSDS provided by the CSG companies and verified by industry sources<sup>33</sup>, provides a general list of the type of chemicals used in fracking fluids in Australia. (See Table 1)

**Table 1. Types of Chemicals Commonly Used in Fracking Fluids in Australia**

*(NB This summary of chemicals and their uses was consolidated from the MSDS provided by the CSG companies and verified by industry sources in Australia)*

Additive Type	Main Compound(s)	Purpose
Diluted Acid	Hydrochloric Acid, muriatic acid	Dissolves minerals
Biocides	Glutaraldehyde, Tetrakis hydroxymethyl phosphonium sulfate	Eliminates bacteria in water that produce corrosive products
Breaker	Ammonium persulfate/ sodium persulfate	Delayed break gel polymer
Corrosion Inhibitor	n,n-dimethyl formamide, methanol, naphthalene, naphtha, nonyl phenol, acetaldehyde	Prevents corrosion of pipes
Friction Reducer	Mineral oil, polyacrylamide	Reduces friction of fluid
Gel	Guar gum	Thickens water
Iron Control	Citric acid, thioglycolic acid	Prevent metal oxides
KCl	Potassium chloride	Brine solution
pH Adjusting Agent	Sodium or potassium carbonate	Maintains pH
Scale Inhibitor	Ethylene glycol	Prevents scale deposits in pipe
Surfactants	Isopropanol, 2-Butoxyethanol	Affects viscosity of fluid
Crosslinker	Ethylene glycol	Affects viscosity of fracking fluid

<sup>31</sup> Chemicals in Natural Gas Operations, Health Effects Spreadsheet and Summary TEDX 2011, Available at <http://www.endocrinedisruption.com/chemicals.multistate.php>. The Endocrine Disruption Exchange (TEDX) maintains a publicly available database of the potential health effects of chemicals used during natural gas operations. It is available for download in an Excel file format for easy searching and sorting

<sup>32</sup> <http://www.smh.com.au/environment/toxins-found-at-third-site-as-fracking-fears-build-20101118-17zfv.html>

<sup>33</sup> Australian Petroleum Production & Exploration Association Ltd (APPEA), Chemicals that may be used in Australian fracking fluid Available at <http://www.appea.com.au>

### **c. Effects related to hydraulic fracturing**

Hydraulic fracturing or ‘fracking’ is the practice of using high-pressure pumps to inject a mixture of sand, water and chemicals into bore wells in order to fracture rocks and to open cracks (‘cleats’) present in the coal seams thereby releasing natural gas in the process. A well can be repeatedly ‘fracked’ and each gas field incorporates many wells.

CSG industry representatives in Australia repeatedly claim in their literature, media and at public forums that fracking chemicals are ‘safe’ because they are similar to ‘food additives’ and are used in ‘household products’. NTN believes these claims are false and misleading for several reasons.

A number of the chemicals used in fracking fluids would never be permitted as food additives or household products due to their toxicity. Most importantly, there has been no comprehensive hazard assessment of the chemical mixtures used in fracking fluids or their impacts on the environment or human health.

In Australia, a review of a selection of CSG companies’ environmental authorisations identified 23 compounds commonly used in fracking fluids (*See Table 2*). Australia’s industrial chemical regulator, the National Industrial Chemical Notification and Assessment Scheme (NICNAS) has assessed only 2 out of the 23. Yet, hydraulic fracturing in Australia does involve the use of large quantities of fracking fluids.

For example, environmental authorisations by Queensland regulators identified that in one CSG operation, approximately 18,500kg of additives were to be injected during the hydraulic fracturing process in each well, with only 60% of these recovered and up to 40% of the hydraulic fracturing fluid volume remaining in the formation, corresponding to 7,400kg of chemicals per injection well.<sup>34</sup>

The fluids that return to the surface within a specified length of time are referred to as ‘flowback’. As well as the original fluid used for fracturing, flowback may also contain other fluids, chemicals and minerals that were present in the fractured formation such as heavy metals and hydrocarbons.<sup>35</sup> Toxic substances like lead, arsenic, barium, chromium, uranium, radium, radon and benzene can be mobilized by drilling and fracking activities, rendering flowback fluids hazardous.

#### **Drilling Chemicals**

CSG activities also require the use of drilling chemicals. Chemicals commonly used at Australian drill sites include calcium sulfate, anionic surfactants, ethylene glycol monobutyl ether, polyacrylamide polymers and petroleum distillate flocculants. Drilling fluid additives are generally claimed as trade secrets and their contents are typically described as carrier fluids, anionic water-soluble polymers, activators, emulsifiers and neutralizers. Hydrocarbons are also used at the drill sites and surrounding areas and include lubricants, rod grease, petrol and diesel for small plant equipment.<sup>36</sup>

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<sup>34</sup> Coal Seam Hydraulic Fracturing Fluid Risk Assessment. Response to the Coordinator-General Requirements for Coal Seam Gas Operations in the Surat and Bowen Basins, Queensland. Golder Associates 21 October 2010

<sup>35</sup> <http://fracfocus.org/chemical-use/what-chemicals-are-used>

<sup>36</sup> For more information see <http://www.amcmud.com/amc-drilling-fluids-and-products.html>

**Table 2. NICNAS Status of Chemicals Used in Fracking Fluids**

*(NB The following list of chemicals and CAS numbers was compiled from MSDS provided by three CSG companies based in Queensland and NSW)*

Chemical	CAS RN	AICS Status*
Tetramethylammonium Chloride	75-57-0	Pub/NA
Potassium carbonate	584-08-7	Pub/NA
Methanol	67-56-1	Pub/NA
Isopropanol	67-63-0	Pub/NA
Propargyl alcohol	107-19-7	Pub/NA
Formamide	75-12-7	Pub/NA
Ethoxylated 4-nonylphenol	26027-38-3	Pub/NA
Heavy aromatic naphtha	64742-94-5	Pub/NA
Pine oil	8002-09-3	Pub/NA
Naphthalene	91-20-3	Pub/NA; PEC Candidate list
Citric acid anhydrous	77-92-9	Pub/NA
Hemicellulase Enzyme Concentrate	9025-56-3	Pub/NA
Tetrakis(Hydroxymethyl) Phosphonium Sulphate	55566-30-8	Pub/NA
Sodium persulfate	7775-27-1	Pub/Ass; Declared PEC
Guar gum	9000-30-0	Pub/NA
Ethylene glycol	107-21-1	Pub/NA
Sodium hydroxide	1310-73-2	Pub/NA
Diethylene glycol	111-46-6	Pub/NA
2-Bromo-2-nitro-1,3-propanediol	52-51-7	Pub/NA
Alcohols, C12-14	80206-82-2	Pub/NA
Tris(2-hydroxyethyl) amine	102-71-6	Pub/NA; PEC Candidate list
2-Butoxyethanol	111-76-2	Pub/Ass; Declared PEC
Cristobalite (silica)	14464-46-1	Pub/NA

\*AICS = Australian Inventory of Chemical Substances; Pub = public AICS; NA = not assessed; Ass = assessed; PEC = priority existing chemical

Other chemicals commonly listed in fracking chemical products but without CAS numbers include the following. Without CAS numbers the identity of the chemical cannot be assured:

- Alkanes / Alkenes (Multiple CAS)
- Oxylalkylated alcohol(s)
- Fatty alcohol
- Oxylalkylated alkanolamine(s)
- Silicone(s)
- Surfactant(s)

### Health and Environmental Risks of Some Fracking Chemicals

*(NB The following information was compiled from publically available sources including the International Program on Chemical Safety, INCHEM, [www.inchem.org](http://www.inchem.org), US Agency for Toxic Substances & Disease Register, [www.atsdr.cdc.gov](http://www.atsdr.cdc.gov), Material Safety Data Sheets and NICNAS literature).*

Health data and sources for 560 fracking chemicals is available for download at <http://www.endocrinedisruption.com/chemicals.multistate.php>

### Tetrakis (hydroxymethyl)phosphonium sulfate (THPS)

Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) acts as a biocide, that is a chemical that is toxic to microorganisms and is used as anti-fouling agent. THPS has

shown mutagenic potential (in vitro) and cancer potential in rats (No Observable Adverse Effect Level (NOAEL) 3.6 mg/kg). Repeated skin exposure to THPS resulted in severe skin reaction and caused skin sensitization in guinea pigs. THPS was also identified as a severe eye irritant in rabbits.<sup>37</sup> Little is known about the effects of the break down products of THPS. The reported acute toxicity values for algae are less than 1 mg/litre (No Observable Effect Concentration (NOEC) of 0.06mg/litre). No exposure information is available for either humans or organisms in the environment; hence no quantitative risk assessment has been made.<sup>38</sup>

### **Sodium Persulfate**

Exposure to sodium persulfate via inhalation or skin contact can cause sensitization, i.e., after initial exposures individuals may subsequently react to exposure to very low levels of that substance. Exposure to sodium persulfate causes skin rashes and eczema as well as allergies that may develop after repeated exposures. Sodium persulfate is irritating to eyes and respiratory system and long-term exposure may cause changes in lung function (i.e. pneumoconiosis resulting in disease of the airways) and/or asthma.

### **Ethylene Glycol**

Exposure to ethylene glycol via inhalation or skin contact can irritate the eyes, nose and throat. It is a human respiratory toxicant. Among female workers, exposures to mixtures containing ethylene glycol were associated with increased risks of spontaneous abortion and sub-fertility.<sup>39</sup> Ethylene glycol is a teratogen (i.e., an agent that causes malformation of an embryo or foetus) in animal tests. Ethylene Glycol is on the U.S. EPA list of 134 priority chemicals to be screened as an endocrine disrupting substance (EDC).

### **2-Butoxyethanol**

2-butoxyethanol was declared a Priority Existing Chemical (PEC) under Australia's regulatory National Industrial Chemicals Notification and Assessment Scheme.<sup>40</sup> The assessment of 2-butoxyethanol shows that it is highly mobile in soil and water and has been detected in aquifers underlying municipal landfills and hazardous waste sites in the US. It is recommended that waste 2-butoxyethanol not be disposed of to landfill because of its high mobility, low degradation and its demonstrated ability to leach into and contaminate groundwater.

While high doses of 2-butoxyethanol can also cause reproductive problems and birth defects in animals, it is not known whether 2-butoxyethanol can affect reproduction or cause birth defects in humans. Animal studies have shown exposure to 2-butoxyethanol can cause hemolysis (destruction of red blood cells that results in the release of hemoglobin). The International Agency for Research on Cancer has not classified 2-butoxyethanol as to its human carcinogenicity as no carcinogenicity studies are available.

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<sup>37</sup> NTP Study Reports, Abstract for TR-296 - Tetrakis(hydroxymethyl)phosphonium sulfate (THPS) (CASRN 55566-30-8) and Tetrakis(hydroxymethyl)phosphonium chloride (THPC) (CASRN 124-64-1)

<sup>38</sup> Environmental Health Criteria 218 Flame Retardants: TRIS(2-BUTOXYETHYL) PHOSPHATE, TRIS(2-ETHYLHEXYL) PHOSPHATE and TETRAKIS(HYDROXYMETHYL) PHOSPHONIUM SALTS United Nations Environment Programme, the International Labour Organisation, and the World Health Organization, and produced within the framework of the Inter-Organization Programme for the Sound Management of Chemicals. World Health Organization Geneva, 2000

<sup>39</sup> Adotfo Correa, Ronald H. Gray, Rebecca Cohen, Nathaniel Rothman, Faridah Shah, Hui Seacat and Morton Com, Ethylene Glycol Ethers and Risks of Spontaneous Abortion and Subfertility, American Journal of Epidemiology Vol. 143, Issue 7 Pp. 707-717.

<sup>40</sup> Declared Priority Existing Chemical (PEC). Full report at [www.nicnas.gov.au/Publications/CAR/PEC/](http://www.nicnas.gov.au/Publications/CAR/PEC/)



## Ethoxylated 4-nonylphenol

Ethoxylated 4-nonylphenol (NPE) is a persistent bioaccumulative endocrine disruptor, which has been detected widely in wastewater and surface waters across the globe. Canada classified NPE metabolites as toxic.<sup>41</sup> The European Union classifies nonylphenol as very toxic to aquatic organisms, which may cause long-term adverse effects in the aquatic environment.<sup>42</sup> In the aquatic environment, NPE metabolites can cover organisms with a soap-like coating that inhibits them from moving and causes the organism to become stupefied and lose consciousness. NPE also disrupts normal hormonal functioning in the body and thus are considered endocrine disrupting chemicals. NPE mimics the natural hormone estradiol and binds to the estrogen receptor in living organisms. Exposure to NPE changes the reproductive organs of aquatic organisms.<sup>43</sup> Sexual deformities were found in oyster larvae exposed to levels of nonylphenol (NP) that are often present in the aquatic environment.<sup>44</sup> A 2005 study found that exposure to NP increases the incidence of breast cancer in lab mice.<sup>45</sup> The intermediary chemicals formed from the initial degradation of NPE are much more persistent than the original compound.

## Naphthalene

Based on the results from animal studies, which demonstrated nasal and lung tumours in lab animals, the International Agency for Research on Cancer (IARC) concluded that naphthalene is a possible human carcinogen, and the US Department of Health and Human Services (DHHS) concluded that naphthalene is reasonably anticipated to be a human carcinogen.

Naphthalene causes lung toxicity in mice, either by injection or inhalation. Naphthalene can cause cataracts in humans, rats, rabbits and mice. Animal studies suggest that naphthalene is readily absorbed following oral or inhalation exposure. Although no data are available from human studies on absorption of naphthalene, the detection of metabolites in the urine of workers indicates that absorption does occur, and there is a good correlation between exposure to naphthalene and the amount of 1-naphthol excreted in the urine.

Humans accidentally exposed to naphthalene by ingestion develop haemolytic anaemia (damage or destruction of red blood cells). Symptoms of hemolytic anemia include fatigue, lack of appetite, restlessness, and pale skin. Exposure to large amounts of naphthalene may also cause nausea, vomiting, diarrhea, blood in the urine, and a yellow color to the skin.

## Methanol

Methanol is a volatile organic compound, which is highly toxic to humans. Methanol causes central nervous system depression in humans and animals as well as degenerative changes in the brain and visual system. Chronic exposure to methanol,

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<sup>41</sup> Environment Canada 2001 Nonylphenol and its Ethoxylates: Priority Substance Lists Assessment Report. Minister of Public Works and Government Services

<sup>42</sup> European Union 4-Nonylphenol (branched) and Nonylphenol Risk Assessment Report. Institute for Health and Consumer Protection, European Chemicals Bureau Volume 10,

<sup>43</sup> Gray, M., and C. Metcalfe. 1997. Induction of Testis-Ova in Japanese Medaka (*Oryzias Latipes*) Exposed to p-Nonylphenol. *Environmental Toxicology and Chemistry*, No. 16, Issue 5, p. 1082.

<sup>44</sup> Nice, H., D. Morrill, M. Crane and M. Thorndyke. 2003. Long-term and Transgenerational Effects of Nonylphenol Exposure At a Key stage in the Development of *Crassostrea gigas*. Possible Endocrine Disruption? *Marine Ecology Progress Series*, Vol. 256, p. 293.

<sup>45</sup> Acevedo, R., P. Parnell, H. Villanueva, L. Chapman, T. Gimenez, S. Gray, and W. Baldwin. 2005. The Contribution of Hepatic Steroid Metabolism to Serum Estradiol and Estriol Concentrations of Nonylphenol Treated MMTV-neu Mice and Its Potential Effects on Breast Cancer Incidence and Latency. *Journal of Applied Toxicology* Volume 25, Issue 5, pages 339–353, September/October 2005

either orally or by inhalation, causes headache, insomnia, gastrointestinal problems, and blindness in humans and hepatic and brain alterations in animals. Methanol is highly mobile in soil. In water, the degradation products of methanol are methane and carbon dioxide. Methanol also volatilizes from water and once in air, exists in the vapor phase with a half-life of over 2 weeks. The chemical reacts with photochemically produced smog to produce formaldehyde and can also react with nitrogen dioxide in polluted air to form methyl nitrite.<sup>46</sup>

### **Isopropanol**

Isopropanol is reproductive toxin and irritant. It is a central nervous system depressant and prolonged inhalation exposure of rats can produce degenerative changes in the brain.<sup>47</sup>

### **Formamide**

Formamide is a teratogen with the potential to affect the unborn child. The substance is irritating to the eyes and the skin and may cause effects on the central nervous system. It can be absorbed into the body by inhalation, through the skin and by ingestion. It is harmful by all exposure routes.

## **US Analysis of Fracking Chemicals**

A US analysis of chemicals used in fracking based on health data obtained from the MSDS as well as government toxicological reports, and the medical literature for the 362 chemicals with CAS numbers found<sup>48</sup>:

- Over 78% of the chemicals are associated with skin, eye or sensory organ effects, respiratory effects and gastrointestinal or liver effects. The brain and nervous system can be harmed by 55% of the chemicals. Symptoms include burning eyes, rashes, coughs, sore throats, asthma-like effects, nausea, vomiting, headaches, dizziness, tremors, and convulsions.
- Between 22% and 47% of the chemicals were associated with possibly longer-term health effects such as cancer, organ damage, and harm to the endocrine system.
- 210 chemicals (58%) are water-soluble while 131 chemicals (36%) are volatile; i.e., they can become airborne. Because they can be inhaled, swallowed, and also reach the skin, the potential for exposure to volatile chemicals is greater.
- Over 93% of the volatile chemicals can harm the eyes, skin, sensory organs, respiratory tract, gastrointestinal tract or liver, 86% can cause harm to the brain and nervous system, 72% can harm the cardiovascular system and blood, and 66% can harm the kidneys.

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<sup>46</sup> EPA 749-F-94-013a CHEMICAL SUMMARY FOR METHANOL prepared by OFFICE OF POLLUTION PREVENTION AND TOXICS U.S. ENVIRONMENTAL PROTECTION AGENCY, August 1994

<sup>47</sup> International Agency for Research on Cancer (IARC) - Summaries & Evaluations ISOPROPRANOL

<sup>48</sup> Chemicals in Natural Gas Operations, Health Effects Spreadsheet and Summary TEDX 2011, Available at <http://www.endocrinedisruption.com/chemicals.multistate.php>. The Endocrine Disruption Exchange (TEDX) maintains a publicly available database of the potential health effects of chemicals used during natural gas operations. It is available for download in an Excel file format for easy searching and sorting

In May 2011, the *US House of Representatives Committee on Energy and Commerce* released their report identifying 750 chemicals that were used in fracking fluids between 2005 and 2009.<sup>49</sup> They stated:

*'Some of the components used in the hydraulic fracturing products were common and generally harmless, such as salt and citric acid. Some were unexpected, such as instant coffee and walnut hulls. And some were extremely toxic, such as benzene and lead.'*

They noted that the most widely used chemical in hydraulic fracturing as measured by the number of compounds containing the chemical was methanol. Methanol was used in 342 hydraulic fracturing products, and is a hazardous air pollutant and on the candidate list for potential regulation under the US *Safe Drinking Water Act* due to its risks to human health.

Other widely used chemicals were isopropyl alcohol (used in 274 products), 2-butoxyethanol (used in 126 products), and ethylene glycol (used in 119 products). Between 2005 and 2009, hydraulic fracturing products contained 29 chemicals that were either known or possible human carcinogens, regulated under the US *Safe Drinking Water Act* for their risks to human health, or listed as hazardous air pollutants under the *Clean Air Act*. These 29 chemicals were components of more than 650 different products used in hydraulic fracturing.<sup>50</sup>

A chemical and biological risk assessment for natural gas extraction by the Chemistry and Biochemistry Department from the State University of New York in March 2011 identified chemical products in widespread use, including in exploratory wells, that pose significant hazards to humans or other organisms, "...*Because they remain dangerous even at concentrations near or below their chemical detection limits. These include the biocides glutaraldehyde, 2,2-dibromo-3-nitrilopropionamide (DBNPA) and 2,2 dibromoacetone nitrile (DBAN), the corrosion inhibitor propargyl alcohol, the surfactant 2-butoxyethanol (2-BE), and lubricants containing heavy naphtha.*"<sup>51</sup> (See **Appendix 2** for health and environmental effects)

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<sup>49</sup> United States House of Representatives Committee On Energy And Commerce, Minority Staff, April 2011 Chemicals Used In Hydraulic Fracturing. <http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf>

The list of the chemicals used in fracking fluids is available in Annex A.  
<sup>50</sup> United States House of Representatives Committee On Energy And Commerce, Minority Staff, April 2011 Chemicals Used In Hydraulic Fracturing <http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf>

<sup>51</sup> Chemical and Biological Risk Assessment for Natural Gas Extraction in New York. Ronald E. Bishop, Ph.D., CHO, Chemistry & Biochemistry Department, State University of New York, College at Oneonta, Sustainable Otsego March 28, 2011. <http://www.sustainableotsego.org/Risk%20Assessment%20Natural%20Gas%20Extraction-1.htm>

## **f. Effect on greenhouse gas and other emissions**

Industry and government frequently contend that natural gas is a cleaner than coal 'transition' fuel and when used in tandem with renewable energy can play a complementary role in reducing carbon emissions.<sup>52</sup>

At first glance, natural gas looks beneficial when compared with coal at the point of combustion: 80% less acid rain (sulphur dioxide), 60% less greenhouses gases (CO<sub>2</sub>) and no mercury or particulates (soot).<sup>53</sup>

In Australia, greenhouse gas emissions from the external processing and power generation activities for Liquid Natural Gas (LNG) are reported as significantly lower than for coal. Overall, industry claim coal delivery and power generation activities produce 43% more greenhouse gas emissions than LNG per GJ (gigajoule) of energy delivered. Diesel and fuel oil produce approximately 10-15% more greenhouse gas emissions than LNG, and hence sit between coal and gas in terms of emissions.<sup>54</sup>

However, it must be acknowledged that the predicted advantage of natural gas over coal holds only when it is burned in modern and efficient plants. Nevertheless, to effectively assess the impact of natural gas obtained from CSG or shale gas activities compared to other forms of energy production, it is essential to quantify and assess the total greenhouse gas emissions from extraction to combustion, rather than look only at the point of combustion.

US research demonstrates that the energy required for the liquefaction, transport and re-gasification in LNG, may add up to 20% additional CO<sub>2</sub> to natural gas production.<sup>55</sup>

Coal seam gas however cannot be assumed to have an emissions profile that is similar to conventional natural gas. In fact, there are indications that when measured across the entire lifecycle, CO<sub>2</sub> emissions from unconventional gas sources such as CSG are higher than from conventional gas sources. Due to the paucity of emission records and research, just how much higher the CO<sub>2</sub> emissions might be is a contested issue.

A key factor when assessing greenhouse emissions from an energy source is how the lifecycle analysis has been performed. For example, what assumptions have been used and what is the quality and origin of the input data. Currently there is only very limited publicly available information for an in-depth life cycle assessment of CSG versus other forms of natural gas extraction.

The difference in the overall emissions associated with CSG versus conventional natural gas over the lifecycle of the fuel will principally depend on the attributes of the reservoir and the extraction method used. CSG not only differs from conventional gas extraction in terms of drilling (horizontal) and extraction processes (hydraulic

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<sup>52</sup> Australia Pacific LNG Project, Volume 5: Attachment 30: Greenhouse Gas Assessment – Gas Fields and Pipeline

<sup>53</sup> Fulton, M., Mellquist, N and S. Kitasai, (2011) Comparing Life Cycle Greenhouse Gas Emissions from Natural Gas and Coal, March 14, Deutsche Bank, Climate Change Advisors  
[http://www.dbcca.com/dbcca/EN/\\_media/Comparing\\_Life\\_Cycle\\_Greenhouse\\_Gas.pdf](http://www.dbcca.com/dbcca/EN/_media/Comparing_Life_Cycle_Greenhouse_Gas.pdf)

<sup>54</sup> Australia Pacific LNG Project, Volume 5: Attachment 30: Greenhouse Gas Assessment – Gas Fields and Pipeline

<sup>55</sup> Paulina Jaramillo, W. Michael Griffin, H. Scott Matthews, "Comparative Life Cycle Carbon Emissions of LNG Versus Coal and Gas for Electricity Generation" (paper presented at Green Design Reading Group at Carnegie Mellon University, Pittsburgh, PA, February 12, 2005),  
[http://www.ce.cmu.edu/~gdrg/readings/2005/10/12/Jaramillo\\_LifeCycleCarbonEmissionsFromLNG.pdf](http://www.ce.cmu.edu/~gdrg/readings/2005/10/12/Jaramillo_LifeCycleCarbonEmissionsFromLNG.pdf)

fracturing), but additional emissions are generated from transportation and treatment of water and chemicals, as well as the removal of waste products.

The principle emissions during extraction of CSG which need to be accounted for in a thorough life cycle analysis, can be divided into:

- Use of fossil fuels for the engines of the trucks, drills, pumps and compressors used to extract the gas onsite, and to transport equipment, resources and waste on and off the well site;
- Fugitive emissions of natural gas that escape unintentionally during the well construction and production stages;
- Methane emissions from leaking wells; and
- Intentional vented emissions expelled during the extraction process and flaring.

The documents relied on by the Australian industry for their assessments of comparative carbon footprints, readily admit that greenhouse emissions from the extraction, processing and product transport for LNG are higher than for coal, and confirms that:

*“Resources for unconventional sources such as shale formations, tight sands, and coal bed methane are generally more costly and energy intensive to develop due the need for advanced drilling techniques, such as horizontal drilling, and are also often characterized by smaller concentrations and steeper decline rates.”*<sup>56</sup>

A report by the University of Manchester’s Tyndall Centre, which assessed the climate impacts of shale gas, indicates that between 4,300 and 6,600 truck visits occur during preproduction for a 6 pad well arrangement. To produce 10% of the UK gas production would result in a total of 2-4 million truck visits.<sup>57</sup>

Another key question to be examined is the extent of fugitive emissions, especially methane. According to a recent European Parliamentary report<sup>58</sup> on the impacts of shale gas extraction *“Fugitive methane emissions alone from hydraulic fracturing processes can have a huge impact on the greenhouse gas balance. Existing assessments give a range of 18 to 23 g CO<sub>2</sub>- equivalent per MJ from the development and production of unconventional natural gas”*. The emissions due to methane intrusion of aquifers are not yet assessed and will vary depending on the methane production of the well.

Methane is a powerful greenhouse gas, with a global warming potential 72 times more powerful than that of carbon dioxide over a 20-year horizon and 25 times more powerful than that of carbon dioxide over a 100-year horizon.

The Australian gas industry acknowledges that methane is the most important greenhouse gas fugitive emission (e.g. pipe leaks, leaking wells) in CSG projects, but also claims that the emissions of methane are relatively minor.<sup>59</sup>

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<sup>56</sup> Life Cycle Assessment of GHG Emissions from LNG and Coal Fired Generation Scenarios: Assumptions and Results Prepared for: Center for Liquefied Natural Gas (CLNG) Feb 3, 2009 [http://www.energy.ca.gov/lng/documents/2009-02-03\\_LCA\\_ASSUMPTIONS\\_LNG\\_AND\\_COAL.PDF](http://www.energy.ca.gov/lng/documents/2009-02-03_LCA_ASSUMPTIONS_LNG_AND_COAL.PDF)

<sup>57</sup> Wood. R., et al: 2011, *Shale gas: a provisional assessment of climate change and environmental impacts*. A report commissioned by the Cooperative and undertaken by researchers at the Tyndall Centre, University of Manchester

<sup>58</sup> Impacts of shale gas and shale oil extraction on the environment and human health (2011), Directorate-General for Internal Policies, Policy Department A, Economic and Scientific Policy, European Parliament.

<sup>59</sup> Australia Pacific LNG Project, Volume 5: Attachment 30: Greenhouse Gas Assessment – Gas Fields and Pipeline

It is this issue of fugitive methane emissions that lead a team of researchers from Cornell University to the conclusion that the greenhouse gas footprint of natural gas obtained by high-volume hydraulic fracturing from shale formations, which in many aspects is similar to CSG, is at least 30% more, and perhaps even twice as great as those from conventional gas.<sup>60</sup> They concluded that the carbon footprint of shale gas is comparable to coal when compared over 100 years. The Cornell research put the size of the methane fugitive emission at up to 7.9% over the lifetime of a well, with much of the leakage during initial drilling, completion and during transmission, storage and distribution. This figure is hotly contested by industry, which claims that methane leakage is minimal, despite the fact that the US EPA has recently revised its methane emissions estimations upwards. For instance, estimates for well venting were increased by a factor of 11 and well completion by a factor of 172.<sup>61</sup> Given these new figures, the Cornell research figures seem much more realistic.

The experience of landowners with wells on their properties also puts claims of minimal methane leaks in doubt. Wells have been seen to leak with bubbling gas being clearly evident around the wellhead. CSG engineers also admit there are small leaks all along pipeline, but dismiss them as 'tiny'.

Using conservative estimates the Tyndall Centre research found that if half of all the shale gas resources on earth were exploited, the additional cumulative emissions over the time period 2010-2050 would be between 46-183 giga tons of CO<sub>2</sub>, equating to an additional atmospheric concentration of CO<sub>2</sub> of 3-11 ppm.<sup>62</sup>

A recent study<sup>63</sup> estimates the life cycle greenhouse gas (GHG) emissions from the production of Marcellus shale natural gas and compares its emissions with national average US natural gas emissions produced in the year 2008 and electricity from coal production.

The life cycle GHG emissions of Marcellus shale natural gas are estimated to be 63–75 g CO<sub>2</sub>e/MJ of gas produced with an average of 68 g CO<sub>2</sub>e/MJ of gas produced. The study states natural gas from the Marcellus shale has generally lower life cycle

GHG emissions than coal for production of electricity, but acknowledges significant uncertainty in Marcellus shale GHG emission estimates due to uncertainty in production volumes, construction and transportation as well as variability in flaring. In estimating GHG emissions, it includes GHG emissions of carbon dioxide, methane and nitrous oxide, converted to carbon dioxide equivalents according to the global warming potential (GWP) factors reported by IPCC.

Importantly the study uses the 100-year GWP factor rather than 20-year GWP. Within the Life Cycle Analysis framework, the impacts are distributed across the total volume of gas produced during the lifetime of the well but when they are calculated over 20 years, the CO<sub>2</sub> figures are much higher.

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<sup>60</sup> Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, Methane and the Greenhouse-Gas Footprint of Natural Gas from Shale Formations, *Climatic Change Letters* In press April 2011

<sup>61</sup> EPA, ["Greenhouse Gas Emissions Reporting from the Petroleum and Natural Gas Industry, Background Technical Support Document"](#), 30<sup>th</sup> November 2010  
[http://www.epa.gov/climatechange/emissions/downloads10/Subpart-W\\_TSD.pdf](http://www.epa.gov/climatechange/emissions/downloads10/Subpart-W_TSD.pdf)

<sup>62</sup> Wood, R., et al: 2011, Shale gas: a *provisional assessment of climate change and environmental impacts*. A report commissioned by the Cooperative and undertaken by researchers at the Tyndall Centre, University of Manchester

<sup>63</sup> Jiang et al., Life cycle greenhouse gas emissions of Marcellus shale gas, *Environ. Res. Lett.* 6 (2011)

The sources of GHG emissions considered in the LCA include: emissions from the production and transportation of material involved in the well development activities (such as trucking water); emissions from fuel consumption for powering the drilling and fracturing equipment; methane leaks and fuel combustion emissions associated with gas production, processing, transmission, distribution, and natural gas combustion.

The study has some significant limitations. It makes no reference to fugitive emissions from wellheads during exploration and does not include any GHG emissions outside preproduction and production processes. The authors note that while natural processes or development actions such as hydraulic fracturing might lead to emissions of the shale gas external to a well, particularly in the case of poorly installed well casings, all external leaks are not included in this study. This would also mean emissions from post-production leaking wells are not included.

The study also assumes all produced water disposal is via deep well injection and hence the study does not include emissions from energy intensive Reverse Osmosis treatment of CSG wastewater. There is also no reference to emissions from compressing or liquefying the gas, which is very energy-intensive and is the fate of most new CSG projects in Australia.

The study acknowledges there may be significant GHG emissions as a result of flaring and venting activities that occur during all stages of exploration and production, but acknowledges considerable uncertainty in assumptions related to production rates, ultimate recovery and emissions related to well completion. For example, single well longevity is unknown, and as the study acknowledges, there isn't adequate experience to assess the average well production.

The study used a hybrid combination of process activity emission estimates and economic input–output life cycle assessment estimates to calculate the preproduction GHG emission estimates while emissions from production, processing and transport were adapted from the literature.

The EIO-LCA (CMU GDI 2010) model in its estimates of GHG emissions from the construction and the production of the drilling mud components and hydraulic fracturing fluid uses data originally compiled from surveys and forms submitted by industries to governments for national statistical purposes. The model acknowledges considerable uncertainty related to sampling, response rate, missing/incomplete data, estimations to complete forms, etc. The model also notes in the list of Uncertainty and Assumptions that the major uncertainties are due to assumptions using old, incomplete or aggregated data. (CMU GDI (Carnegie Mellon University Green Design Institute 2010 Economic input–output life cycle assessment (EIO-LCA), Assumptions, Uncertainty, and other Considerations with the EIO-LCA Method)

The Jiang study concludes that the fugitive emissions rate would need to be 14% before the overall life cycle emissions including those of electricity generation would be greater than coal. However, if the data is converted to the 20-year GWP the break-even point is reduced to 7% because of the higher impacts attributed to methane. If the study is then adjusted for Australian circumstances to include emissions rates for water treatment with energy intensive reverse osmosis, emissions from compressing or liquefying the gas and emissions from all external leaks, including methane leaks from exploration and post production wells, the conclusion of positive benefits of unconventional gas would be seriously in doubt.

The assumption that natural gas from CSG can act as a transition fuel also needs to be challenged. Rather than substituting for coal, it is likely that CSG will simply satisfy increasing energy demand and hence, increase associated emissions, and contribute to further reducing our ability to keep global temperature changes below 2°C. The Tyndal research went as far as contending that the investment required for the exploitation of unconventional gas sources could further delay rapid carbon reductions, because this *‘investment would be much more effective if targeted at genuinely zero- (or very low) carbon technologies.’*

When the overall lifecycle of CSG and shale gas is taken into account acknowledging all the uncertainties, including the accuracy of emissions factors for fugitive methane released during extraction, processing and transportation, then the assumption that this form of gas provides an effective transitional fuel to a cleaner, greener future is uncertain.

### **g. Relative air quality and environmental impacts compared to alternative fossil fuels.**

In July 2011, the community-based organisation, the Global Community Monitor, released the report, *Citizen Investigation of Toxic Air Pollution from Natural Gas Development*.<sup>64</sup> Air samples were collected from neighbours of natural gas operations as well as targeted sampling sites including the well pad, compressor station, gas separation plant, dehydrator and waste disposal site. Analysis detected 22 toxic air contaminants associated with natural gas development, resulting in significant air pollution.

The report identified the following sources of air pollutants:

<b>Sources</b>	<b>Air pollutants</b>
Fracking compounds	Air pollution caused by fracking compounds during their use, storage, or waste disposal.
Pits	Waste from drilling, fracking or production, which may be stored or disposed of in open-air pits to allow some of the toxic material to evaporate into the air.
Land application (including land farming)	Waste from drilling, fracking, or production may be spread on the ground or otherwise applied to the land (eg sprayed as dust suppression on roads).
Flaring	Unwanted gases in the exploration and production processes are burned off in the open air using flares. These produce toxic gases as a result.
Venting	During various stages of gas exploration, production and maintenance, gases are vented directly into the air rather than contained or flared. Venting can release large volumes of toxic gases.
Fugitive emissions	Leaks in pumps, valves, compressors, pipes and tanks can result in significant air pollution releases because of the large number of components in gas processing.
Compressors	Where the gas from the wells is collected and then compressed into smaller volumes, the compressors may release a range of toxic gases.
Condensate tanks	Some wells produce semi-liquid gases along with natural gas

<sup>64</sup> Citizen Investigation of Toxic Air Pollution from Natural Gas Development July 2011, Global Community Monitor, [www.gcmmonitor.org](http://www.gcmmonitor.org)



	that are stored in tanks, which can leak various toxic gases.
Dehydrators	These systems are needed to remove water from natural gas and can release toxic gases in the process.
Gas processing plant	The last stage of gas production involves the refining of the raw gas into the final product. This occurs at large gas processing plants, which have many sources of air emissions.
Additional waste disposal sites	Wastes from various stages of gas production and processing may be sent to treatment sources including landfills, injection sites and wastewater treatment sites, which can also release air pollution.

## Air Sampling Results

A total of 22 toxic chemicals were detected in the nine air samples, including four carcinogens, toxins known to damage the nervous system and respiratory irritants. The levels were between three to 3,000 times higher than levels established by public health agencies to estimate increased risk of serious health effects and cancer based on long-term exposure.

- **Benzene:** a known carcinogen, was found at high concentrations in four air samples at levels between 6.3 and 47 µg/m<sup>3</sup>. These levels are 48.5 to 800 times higher than the level set by the US EPA of 0.13 µg/m<sup>3</sup> to estimate increased cancer risk from long-term exposure. Levels of benzene in one of the nine samples, collected near the local Elementary School, exceeded the level set by the U.S. EPA for benzene (30 µg/m<sup>3</sup>) to estimate increased risk of non-cancer health effects.
- **Acrylonitrile:** a human carcinogen, was found in five samples at levels between 7.9 and 30 µg/m<sup>3</sup>. These levels are 790 to 3000 times above the U.S. EPA level of 0.01 µg/m<sup>3</sup>, set to estimate an increased risk of cancer from long term exposure. All of these levels correspond to what EPA would consider an “unacceptable cancer risk” in that long-term exposure is associated with a cancer risk of greater than 100 in a million. Acrylonitrile is also a respiratory irritant, causing degeneration and inflammation of nasal epithelium. Levels of acrylonitrile in the five samples exceeded the level set by U.S. EPA for risk of increased non-cancer health effects from long term exposure (2 µg/m<sup>3</sup>) by 3 to 15 times.
- **Methylene chloride:** a human carcinogen, was found in five samples at levels between 7.9 and 17 µg/m<sup>3</sup>. These levels are 3 to 8 times higher than the level set by the U.S. EPA (2.0 µg/m<sup>3</sup>.) to estimate an increased risk of cancer from long-term exposure.
- **Ethylbenzene:** a human carcinogen, was found in five samples at levels between 5.1 to 22 µg/m<sup>3</sup>. These levels are 12 to 55 times higher than the level set by the US EPA (0.4µg/m<sup>3</sup>) to estimate increased cancer risk cancer from long-term exposure.
- **Xylene:** were found at a level of 100 and 154 µg/m<sup>3</sup>. These levels exceed the U.S. EPA’s level for estimating increased non-cancer health risks of 100 µg/m<sup>3</sup>.
- **Hydrogen sulfide:** was found in one sample at 370 µg/m<sup>3</sup> which is more than 185 times above the long term level set by the U.S. EPA (2 µg/m<sup>3</sup>) to estimate increased risk of serious health effects. Long-term exposure to hydrogen sulfide is associated with an elevated incidence of respiratory infections, irritation of the eye

and nose, cough, breathlessness, nausea, headache, and mental symptoms, including depression. The World Health Organization's Guideline Value for exposure to hydrogen sulfide is 7 µg/m<sup>3</sup> over a 30-minute period.

These results demonstrate that local communities, workers and the environment are at risk of exposure to multiple air pollutants from natural gas operations. At the levels detected, the individual exposures can cause an increased risk of cancer and other serious health effects. There are no health-based standards for exposure to multiple chemicals either in US or Australia.

As well as high levels of the toxic BTEX, two cancer-causing chemicals were found at very high levels, acrylonitrile and methylene chloride. Acrylonitrile was detected in five out of the nine samples.

Acrylonitrile is not listed by the Australian Petroleum Production and Exploration Association (APPEA) as one of the ingredients of fracking compounds.<sup>65</sup> However, APPEA does list acrylic copolymers for use as a lubricant. An acrylic polymer must include 85% acrylonitrile units<sup>66</sup> whereas an acrylic copolymer may also include other toxic components like methyl acrylate, methyl methacrylate, styrene, vinyl chloride and or butadiene.

The air pollution identified in this report indicates an urgent need for all current natural gas development sites including well pads, compressors, gas plants, and waste sites to undergo continuous monitoring for volatile organic compounds and hydrogen sulfide and to provide that data to regulators and the public. Those facilities unable to eliminate toxic emissions should be required to cease operations. All new applications should require a full assessment of the risks and hazards to air quality.

### **Impacts on landscape compared to solar power plant**

A recent European Parliamentary report on the impacts of shale gas extraction and experiences in North America<sup>67</sup> reports that:

*“The development of gas shales requires well pads allowing for the storage of technical equipment, the trucks with compressors, chemicals, proppant, water and containers for waste water if these are not delivered from local water wells and collected in ponds. A typical multi-well pad size in Pennsylvania during the drilling and fracturing is about 4-5 acres (16,200-20,250 m<sup>2</sup>). After partial restoration the production pad size might average between 1 – 3 acres (4,050-12,150 m<sup>2</sup>).*

*For comparison, if such an area (~10,000 m<sup>2</sup>) would be occupied by a solar power plant, about 400,000 kWh of electricity could be generated per year, corresponding to about 70,000 m<sup>3</sup> of natural gas per year if this would be converted to electricity at 58% efficiency. The typical gas production of wells in the Barnett shale (Texas, USA) amounts to about 11 Mio. m<sup>3</sup> per well in the first year, but only about 80,000 m<sup>3</sup> in the 9th year and about 40,000 m<sup>3</sup> in the 10th year [Quicksilver 2005]. In contrast to*

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<sup>65</sup> Australian Petroleum Production & Exploration Association Ltd (APPEA), Chemicals that may be used in Australian fracking fluid, <http://www.appea.com.au>

<sup>66</sup> Halliburton Patent 7799744, Polymer-Coated-Particulates, <http://www.docstoc.com/docs/58860687/Polymer-Coated-Particulates---Patent-7799744>

<sup>67</sup> Impacts of shale gas and shale oil extraction on the environment and human health (2011), Directorate-General for Internal Policies, Policy Department A, Economic and Scientific Policy, European Parliament

*fossil energy extraction, the solar power plant generates electricity for more than 20 years. At the end of its life time the solar plant can be substituted by a new one without additional land consumption”.*

**2. The economic and social implications of CSG activities including those which affect:**

**a. Legal rights of property owners and property values**

Anecdotal information told to NTN by individuals and communities living in regions such as SE QLD where CSG gas fields are well established indicate they are no longer able to peacefully enjoy the amenity of their own properties due to the levels of noise (trucks and compressors), vibrations, air and water pollution and intrusion into their privacy as a result of the establishment of CSG wells. They also indicate the value of their properties has declined and they are unable to sell their properties.

**APPENDIX 1: Chemicals used in fracking fluid products identified by the US Ground Water Protection Council and the Interstate Oil and Gas Compact Commission**

Chemical Name	CAS	Chemical Purpose	Product Function
Hydrochloric Acid	007647-01-0	Helps dissolve minerals & initiate cracks in rock	Acid
Glutaraldehyde	000111-30-8	Eliminates bacteria that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	012125-02-9	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Quaternary Ammonium Chloride	061789-71-1	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Tetrakis Hydroxymethyl-Phosphonium Sulfate	055566-30-8	Eliminates bacteria in the water that produces corrosive by-products	Biocide
Ammonium Persulfate	007727-54-0	Allows a delayed break down of the gel	Breaker
Sodium Chloride	007647-14-5	Product Stabilizer	Breaker
Magnesium Peroxide	014452-57-4	Allows a delayed break down the gel	Breaker
Magnesium Oxide	001309-48-4	Allows a delayed break down the gel	Breaker
Calcium Chloride	010043-52-4	Product Stabilizer	Breaker
Choline Chloride	000067-48-1	Prevents clays from swelling or shifting	Clay Stabilizer
Tetramethyl ammonium chloride	000075-57-0	Prevents clays from swelling or shifting	Clay Stabilizer
Sodium Chloride	007647-14-5	Prevents clays from swelling or shifting	Clay Stabilizer
Isopropanol	000067-63-0	Product stabilizer and / or winterizing agent	Corrosion Inhibitor
Methanol	000067-56-1	Product stabilizer and / or winterizing agent	Corrosion Inhibitor
Formic Acid	000064-18-6	Prevents the corrosion of the pipe	Corrosion Inhibitor
Acetaldehyde	000075-07-0	Prevents the corrosion of the pipe	Corrosion Inhibitor
Petroleum Distillate	064741-85-1	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for borate or zirconate crosslinker	Crosslinker
Potassium Metaborate	013709-94-9	Maintains fluid viscosity as temperature increases	Crosslinker
Triethanolamine Zirconate	101033-44-7	Maintains fluid viscosity as temperature increases	Crosslinker
Sodium Tetraborate	001303-96-4	Maintains fluid viscosity as temperature increases	Crosslinker
Boric Acid	001333-73-9	Maintains fluid viscosity as temperature increases	Crosslinker
Zirconium Complex	113184-20-6	Maintains fluid viscosity as temperature increases	Crosslinker
Borate Salts	N/A	Maintains fluid viscosity as temperature increases	Crosslinker
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Crosslinker

Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Crosslinker
Polyacrylamide	009003-05-8	“Slicks” the water to minimize friction	Friction Reducer
Petroleum Distillate	064741-85-1	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for polyacrylamide friction reducer	Friction Reducer
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Friction Reducer
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Friction Reducer
Guar Gum	009000-30-0	Thickens the water in order to suspend the sand	Gelling Agent
Petroleum Distillate	064741-85-1	Carrier fluid for guar gum in liquid gels	Gelling Agent
Hydrotreated Light Petroleum Distillate	064742-47-8	Carrier fluid for guar gum in liquid gels	Gelling Agent
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Gelling Agent
Polysaccharide Blend	068130-15-4	Thickens the water in order to suspend the sand	Gelling Agent
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Gelling Agent
Citric Acid	000077-92-9	Prevents precipitation of metal oxides	Iron Control
Acetic Acid	000064-19-7	Prevents precipitation of metal oxides	Iron Control
Thioglycolic Acid	000068-11-1	Prevents precipitation of metal oxides	Iron Control
Sodium Erythorbate	006381-77-7	Prevents precipitation of metal oxides	Iron Control
Lauryl Sulfate	000151-21-3	Prevent formation of emulsions in fracture fluid	Non-Emulsifier
Isopropanol	000067-63-0	Product stabilizer and / or winterizing agent.	Non-Emulsifier
Ethylene Glycol	000107-21-1	Product stabilizer and / or winterizing agent.	Non-Emulsifier
Sodium Hydroxide	001310-73-2	Adjusts the pH of fluid	pH Adjusting Agent
Potassium Hydroxide	001310-58-3	Adjusts the pH of fluid	pH Adjusting Agent
Acetic Acid	000064-19-7	Adjusts the pH of fluid	pH Adjusting Agent
Sodium Carbonate	000497-19-8	Adjusts the pH of fluid	pH Adjusting Agent
Potassium Carbonate	000584-08-7	Adjusts the pH of fluid	pH Adjusting Agent
Copolymer of Acrylamide, Sodium Acrylate	025987-30-8	Prevents scale deposits in the pipe	Scale Inhibitor
Sodium Polycarboxylate	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Phosphonic Acid Salt	N/A	Prevents scale deposits in the pipe	Scale Inhibitor
Lauryl Sulfate	000151-21-3	Used to increase the viscosity of the fracture fluid	Surfactant
Ethanol	000064-17-5	Product stabilizer and / or winterizing agent.	Surfactant

Naphthalene	000091-20-3	Carrier fluid for the active surfactant ingredients	Surfactant
Methanol	000067-56-1	Product stabilizer and / or winterizing agent.	Surfactant
Isopropyl Alcohol	000067-63-0	Product stabilizer and / or winterizing agent.	Surfactant
2-Butoxyethanol	000111-76-2	Product stabilizer	Surfactant

**APPENDIX 2:** Chemical products in widespread use and dangerous at concentrations near or below their chemical detection limits.

Taken from Chemical and Biological Risk Assessment for Natural Gas Extraction in New York. Ronald E. Bishop, Ph.D., CHO, Chemistry & Biochemistry Department, State University of New York, College at Oneonta, Sustainable Otsego March 28, 2011.

(<http://www.sustainableotsego.org/Risk%20Assessment%20Natural%20Gas%20Extraction-1.htm>)

**Glutaraldehyde:**

Glutaraldehyde (CAS No. 111-30-8) is a biocide used widely in drilling and fracturing fluids. Along with its antimicrobial effects, it is a potent respiratory toxin effective at parts-per-billion (ppb) concentrations (70); a sensitizer in susceptible people, it has induced occupational asthma and/or contact dermatitis in workers exposed to it, and is a known mutagen (i.e., a substance that may induce or increase the frequency of genetic mutations) (70, 71). It is readily inhaled or absorbed through the skin.

In the environment, algae, zooplankton and steelhead trout were found to be dramatically harmed by glutaraldehyde at very low (1 – 5 ppb) concentrations (72).

**DBNPA:**

2,2-Dibromo-3-nitrilopropionamide (DBNPA) (CAS No. 10222-01-2) is a biocide finding increasing use in drilling and fracturing fluids. It is a sensitizer, respiratory and skin toxin, and is especially corrosive to the eyes (73). In the environment, it is very toxic to a wide variety of freshwater, estuarine and marine organisms, where it induces developmental defects throughout the life cycle. In particular, it is lethal to “water fleas” (*Daphnia magna*), rainbow trout and mysid shrimp at low (40 to 50 ppb) concentrations, and is especially dangerous to Eastern oysters (74). Chesapeake Bay oysters are killed by extremely low (parts-per-trillion, ppt) concentrations of DBNPA, well below the limit at which this chemical can be detected.

**DBAN:**

Dibromoacetonitrile (DBAN) (CAS No. 3252-43-5) is a biocide often used in combination with DBNPA, from which it is a metabolic product (with the release of cyanide). Its human and environmental toxicity profiles are similar to that of DBNPA, except that DBAN is also carcinogenic (75). DBNPA and DBAN appear to work synergistically. In combination, the doses at which these biocides become toxic are significantly lower than when they are used separately. In other words, it takes much less of these chemicals to exert toxic effects when they are used together, although the specific degree of potentiation has not been publicly reported.

**Propargyl Alcohol:**

Propargyl alcohol (CAS No. 107-19-7) is a corrosion inhibitor that is very commonly used in gas well construction and completion. This chemical causes burns to tissues in skin, eyes, nose, mouth, esophagus and stomach; in humans it is selectively toxic to the liver and kidneys (76). Propargyl alcohol is a sensitizer in susceptible individuals, who may experience chronic effects months to years after exposure, including rare multi-organ failure (77). It is harmful to a variety of aquatic organisms, especially fathead minnows, which are killed by doses near 1 ppm (78).

## **2-BE:**

2-Butoxyethanol (2-BE), also known as ethylene glycol monobutyl ether (EGBE) (CAS No. 111-76-2), is a surfactant used in many phases of gas exploration and extraction. It comprises a considerable percentage of Airfoam HD, commonly used for air-lubricated drilling (79). Easily absorbed through the skin, this chemical has long been known to be selectively toxic to red blood cells; it causes them to rupture, leading to hemorrhaging (80). More recently, the ability of EGBE at extremely low levels (ppt) to cause endocrine disruption, with effects on ovaries and adrenal glands, is emerging in the medical literature (81). This chemical is only moderately toxic to aquatic organisms, with harm to algae and test fish observed with doses over 500 ppm (80).

## **Heavy Naphtha:**

Heavy naphtha (CAS No. 64741-68-0) refers to a mixture of petroleum products composed of, among other compounds, the aromatic molecules benzene, toluene, xylene, 1,2,4-trimethylbenzene and polycyclic aromatic hydrocarbons including naphthalene. It is used by the gas industry as a lubricant, especially in drilling muds. This material is hazardous to a host of microbes, plants and animals (82). Several of the mixture's components are known to cause or promote cancer. If released to soil or groundwater, several components are toxic to terrestrial and aquatic organisms, especially amphibians, in which it impedes air transport through the skin.

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