PO Box 173 Bangalow
NSW 2479 Australia
info@ntn.org.au

www.ntn.org.au

Working globally for a toxic free future

Keir Delaney, Secretary,
Environment & Planning Committee
Parliament House, Spring Street,
Melbourne VIC 3002
Email: epc@parliament.vic.gov.au

NATIONAL TOXICS NETWORK SUBMISSION
Legislative Council's Environment and Planning Committee's Inquiry into Unconventional Gas in Victoria

The industrialisation of the rural landscape brought about by unconventional gas (UG) activities with its associated air and water pollution, would significantly damage the Victorian environment and put at risk the health of communities and associated agricultural industries. As this submission will show after a decade in Australia, the UG industry still does not have effective ways to deal with its waste water, its solid wastes (eg salts, drilling muds) or its impact on groundwater aquifers. As the federal government's National Pollutant Inventory demonstrates, industry cannot control its toxic air emissions, which continue to escalate. While improved regulation may to some extent reduce the impacts of hydraulic fracturing (fracking/HF) and other activities of the UG industry, the global alert released in 2012 by United Nations Environment Programme acknowledged that it is impossible to regulate this industry into safety and unintended impacts are inevitable.

'UG exploitation and production may have unavoidable environmental impacts. Some risks result if the technology is not used adequately, but others will occur despite proper use of technology. UG production has the potential to generate considerable GHG emissions, can strain water resources, result in water contamination, may have negative impacts on public health (through air and soil contaminants; noise pollution), on biodiversity (through land clearance), food supply (through competition for land and water resources), as well as on soil (pollution, crusting).

- UNEP Global Environmental Alert System 2012

The recently released New York Department of Health Inquiry[1] into unconventional gas and high-volume hydraulic fracturing (HVHF) concluded that the 'overall weight of the evidence from the cumulative body of information demonstrates that there are significant uncertainties about the kinds of adverse health outcomes that may be associated with HVHF, the likelihood of the occurrence of adverse health outcomes, and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health. '

They noted that an evaluation of the studies revealed critical information gaps and concluded these needed to be filled to more fully understand the connections between risk factors, such as air and water pollution, and public health outcomes among populations

[1] New York State Department of Health, Public Health Review of Hydraulic Fracturing For Shale Gas Development, 2/13/2015 http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

living in proximity to HVHF shale gas operations. The Department concluded that until the science provides sufficient information to determine the level of risk to public health, HVHF should not proceed in their State.

Their major findings are summarised as:

- Air impacts that could affect respiratory health due to increased levels of particulate matter, diesel exhaust, or volatile organic chemicals.
- Climate change impacts due to methane and other volatile organic chemical releases to the atmosphere.
- Drinking water impacts from underground migration of methane and/or fracking chemicals associated with faulty well construction.
- Surface spills potentially resulting in soil and water contamination.
- Surface-water contamination resulting from inadequate wastewater treatment.
- Earthquakes induced during fracturing.
- Community impacts associated with boom-town economic effects such as increased vehicle traffic, road damage, noise, odour complaints, increased demand for housing and medical care, and stress.

1. Chemicals used and released in unconventional gas exploration and production

In Australia a wide range of chemicals are used and released in unconventional gas exploration and production. The chemicals used include drilling fluids, fracking fluids, waste water treatment chemicals and industrial cleaners. They are also many volatile and semi-volatile compounds released to air and water as fugitive emissions.

Hydraulic fracturing (HF) is used in coal seam gas, shale and tight gas production. It involves injecting wells at high pressure with water, proppants, radioactive tracers and chemical additives to fracture the formation and produce new cracks and pathways to help extract the gas.

While chemical additives make up less than 2% of the fracking fluid, this translates to large quantities of chemical additive. An estimated 18,500 kilograms of HF products were used in a CSG HF in Australia with up to 40% not recovered.[2]

The European Parliament report estimates 16 tonnes of acute toxic substances were used to frack tight gas in Lower Saxony, Germany.[3] The US industry fracfocus database reports up to 100 tons of chemical can be added to fracking fluid used in shale gas production depending on depth and pressure requirements. A well may be 'fracked' a number of times.

At a minimum, HF usually requires:

- biocide to prevent bacterial action underground (eg glutaraldehyde, THPS, DBNPA);
- clay stabiliser to prevent clay expanding on contact with water and plugging the reservoir (eg tetramethyl ammonium chloride);
- gelling agent to hold the proppant in suspension (eg mixtures of guar gum, diesel);
- gel stabiliser (eg sodium thiosulphate) and gel breaker (eg sodium persulfate);
- friction reducer to ease pumping and evacuation of fluid (eg polyacrylamide, mixtures of methanol, ethylene glycol, surfactants); and
- buffer fluids and crosslinking agents.

HF may also utilise corrosion inhibitors (eg formamide, methanol, naphthalene, naptha, nonyl phenol); scale inhibitors (eg ethylene glycols); iron control (eg citric acid, thioglycolic acid); pH adjusting agents (sodium or potassium carbonate) and various surfactants to affect

[2] Coal Seam Hydraulic Fracturing Fluid Risk Assessment. Response to the Coordinator-General Requirement for Coal Seam Gas Operations in the Surat and Bowen Basins, Queensland. Golder Associates 21 October 2010
[3] European Parliament Directorate General For Internal Policies, Economic & Scientific Policy Impacts of shale gas & shale oil extraction on the environment & on human health ENVI 2011

fluid viscosity (eg isopropanol, 2-BE.) Large quantities of proppant are used for each fracturing, consisting of sand or manufactured sol-gel ceramic spheres based on alumino-silicates.

More than 750 chemical products containing 650 hazardous substances plus 279 products with trade secrets were identified by the US House of Representatives Committee on Energy and Commerce.[4] These include carcinogens (eg naphthalene), neurotoxins (eg isopropanol), irritants/sensitisers (eg sodium persulfate), reproductive toxins (eg ethylene glycol) and endocrine disruptors [5] (eg nonylphenol). Some of the chemicals were found to be dangerous at concentrations near or below chemical detection limits,[6] (eg glutaraldehyde, brominated biocides (DBNPA, DBAN), propargyl alcohol, 2-butoxyethanol (2-BE), heavy naphtha.)

A number of chemicals used hydraulic fracturing have recently been identified as endocrine disrupters. These include ethylene glycol monobutyl ether, 2-ethylhexanol, ethylene glycol, diethanolamine, diethylene glycol methyl ether, sodium tetraborate decahydrate, 1,2-bromo-2-nitropropane-1,3-diol, n,n-dimethyl formamide, cumene, and styrene. [7]

A quick review of the health impacts associated with some HF chemicals demonstrate they are far from non-toxic and safe for human health or the environment. *The following information was compiled from publically available sources including International Program on Chemical Safety, INCHEM, www.inchem.org, US Agency for Toxic Substances & Disease Register, www.atsdr.cdc.gov, Material Safety Data Sheets and NICNAS literature. Health data for 560 HF chemicals is available for download at http://www.endocrinedisruption.com/chemicals.multistate.php*

Sodium Persulfate - exposure via inhalation or skin contact can cause sensitization, i.e., after initial exposures individuals may subsequently react to exposure at very low levels of that substance. Exposure can also cause skin rashes and eczema. 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.

2-Butoxyethanol - high doses of 2BE can cause reproductive problems and birth defects in animals. Animal studies have shown exposure 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. 2BE was declared a Priority Existing Chemical under NICNAS due high mobility, low degradation and potential to contaminate aquifers.

Ethylene Glycol - known human respiratory toxicant, associated with increased risks of spontaneous abortion and sub-fertility in female workers, can irritate the eyes, nose and throat. It is a human respiratory toxicant, birth defects in animals. Ethylene Glycol is on the U.S. EPA list of 134 priority chemicals to be screened as an endocrine disrupting substance (EDC).

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

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[4] US House of Rep. C'tee on Energy & Commerce, April 2011 Chemicals Used In Hydraulic Fracturing. http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf

[5] WHO State of the Science of Endocrine Disrupting Chemicals (2013) notes there is often no threshold for EDC effects and EDCs are likely to have effects at very low doses and may exhibit non linear dose response curves.

[6] Chemical and Biological Risk Assessment for Natural Gas Extraction in New York. Ronald E. Bishop, Ph.D., CHO, Chemistry & Biochemistry Dept, State University of New York, Sustainable Otsego March 28, 2011. www.sustainableotsego.org/Risk%20Assessment%20Natural%20Gas%20Extraction-1.htm

[7] Kassotis et al Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region, *Endocrinology* doi: 10.1210/en.2013-1697 http://www.endo.endojournals.org

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. Methanol is listed as the most commonly used HF chemical by the United States House of Representatives Committee on Energy and Commerce. [8]

Naphthalene - IARC *'possible human carcinogen'*, US *'reasonably anticipated to be human carcinogen*'. Chronic exposure of workers and rodents to naphthalene has been reported to cause cataracts and damage to the retina. Based on the results from animal studies, which demonstrated nasal and lung tumours in lab animals, US EPA and the International Agency for Research on Cancer (IARC) has classified naphthalene as a Group C, possible human carcinogen. 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.

Glutaraldehyde - highly irritating to the eyes, skin and the respiratory tract of humans and laboratory animals. It has induced skin sensitization in humans and laboratory animals, and caused asthma in occupationally exposed people. In animal tests, glutaraldehyde by inhalation caused lung damage in rats and mice. DNA damage, mutations and some evidence of chromosome damage were found in mammalian cells in culture following treatment with glutaraldehyde. Data indicates that both algae and fish embryos may be particularly sensitive to long-term glutaraldehyde exposure.

Ethoxylated 4-nonylphenol - persistent, bioaccumulative, endocrine disruptor, which has been detected widely in wastewater and surface waters. NPE disrupt normal hormonal functioning in the body and can mimic the natural hormone estradiol and binds to the estrogen receptor in living organisms. Exposure to NPE changes the reproductive organs of aquatic organisms. Sexual deformities were found in oyster larvae exposed to levels of nonylphenol (NP) that are often present in the aquatic environment. A 2005 study found that exposure to NP increases the incidence of breast cancer in lab mice. Canada classified NPE metabolites as toxic. The European Union classifies nonylphenol as very toxic to aquatic organisms, which may cause long-term adverse effects in the aquatic environment. The intermediary chemicals formed from the initial degradation of NPE are much more persistent than the original compound.

Many HF chemicals have not been assessed for their long-term impacts on the environment and human health. In Australia, of the 23 identified as commonly used 'fracking' chemicals, only 2 had been assessed by the national regulator, National Industrial Chemicals Notification and Assessment Scheme (NICNAS) and neither for their use in CSG.[9] The mixtures used in drilling and fracking fluids are also not assessed for toxicity or persistence. These can form new compounds when exposed to sunlight, water, air, radioactive elements or other natural chemical catalysts.

US industry self-reporting on 9,310 individual fracking operations between January 2011 and

[8] Methanol was used in 342 of the 750 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. See 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

[9] Lloyd-Smith, M.M & Senjen, Rye, *Hydraulic Fracturing in Coal Seam Gas Mining: The Risks to Our Health, Communities, Environment & Climate*, National Toxics Network Sept. 2011 www.ntn.org.au

September 2012, noted cancer causing chemicals were used in one out of every three HF operations. While not all companies report and not all chemicals used in the process are disclosed because of 'trade secret' exemptions, industry did report that known carcinogens like naphthalene, benzyl chloride and formaldehyde were used in 34 percent of all HF operations.[10]

Secrecy and Confidential Business Information
Proprietary data and trade secret regimes mean the disclosure of full formulations is usually not possible even by those who use the products. For example, INFLO 150 a friction reducer commonly used in Australia has listed in its active ingredients listed on the material safety data sheet (MSDS):

- Methanol (CAS 67-56-1) at 5-10%
- Ethylene Glycol (CAS 107-21-1) at 10-30% (listed as *animal teratogen on MSDS*)
- Oxyalkylated Alcohols (trade secret) 10-30%

Plus the following with no details on their identity, CAS number or concentration:

- Fatty Alcohol
- Oxylalkylated Alkanolamine(s)
- Silicone(s)
- Surfactant(s)

The US MSDS describes the surfactant as a fluorocarbon surfactants but it is not identified with a distinct CAS number. Fluorocarbon surfactants belong to a group of chemicals, perfluorocarboxylic acids (PFCAs) that can be extremely persistent, capable of long-range transport and are widespread throughout the environment and in wildlife. Many are found in human blood indicating bioaccumulation and concentrations in wildlife high on the foodchain, strongly suggest biomagnification. Some are known to have serious adverse health impacts, e.g. tumourigenic and immunotoxic impacts in laboratory animals. [11]

Discussions with the legal representative of Haliburton, maker of hydraulic fracturing fluids stated that the company is not willing to provide full details of the formulation to either the users or government regulatory bodies.[12]

Drilling Impacts
Even in the 50% of cases where CSG wells are not required to be hydraulically fractured immediately, the industry still has significant chemical usage and releases. As the lifespan of an UG well according to the International Energy Agency is 5 to 15 years with output typically declining by between 50% and 75% in the first year of production, many new wells are required to be drilled to keep a gas field commercially viable. Hence, the impact of the large amounts of drilling fluid components needs to be addressed in an assessment of the impacts of the UG industry

Drilling fluid components include:
• Viscosifiers to increase viscosity of mud to suspend cuttings (eg bentonite, polyacrylamide)
• Weighting agent (eg barium sulphate);
• Bactericides/biocides to prevent biodegradation of organic additives (eg glutaraldehyde);
• Corrosion inhibitors to prevent corrosion of drill string by acids and acid gases (eg zinc carbonate, sodium polyacrylate, ammonium bisulphate);
• Defoamers to reduce mud foaming (eg glycol blends, light aromatic and aliphatic oil, naptha);

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[10] http://ecowatch.org/2013/cancer-causing-chemicals-fracking-operations/
[11] Linda S. Birnbaum and Philippe Grandjean, Alternatives to PFASs: Perspectives on the Science, and The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs) Volume 123 number 5 May 2015 *Environmental Health Perspectives* http://dx.doi.org/10.1289/ehp.1509934
[12] Views expressed by the Haliburton representative presenting at the Helsinki Chemical Forum, April 2014

• Emulsifiers and deemulsifiers to help the formation of stable dispersion of insoluble liquids in water phase of mud;
• Lubricants to reduce torque and drag on the drill string (eg chlorinated paraffins)
• Polymer stabilisers to prevent degradation of polymers to maintain fluid properties (eg sodium sulfite);
• Breakers to reduce the viscosity of the drilling mud by breaking down long chain emulsifier molecules into shorter molecules (eg diammonium peroxydisulphate, hemicellulase enzyme)
• Salts (eg potassium chloride, sodium chloride, calcium chloride);

and in the case of drilling for shale gas:
• Shale control inhibitors to control hydration of shales that causes swelling and dispersion of shale, collapsing the wellbore wall (eg anionic polyacrylamide, acrylamide copolymer, petroleum distillates).

Drilling Muds, Cuttings and Wastes
Drilling muds consisting of drilling fluid, weighting agents, and stabilizing materials need to be disposed of safely. The mud has come into contact with the coal and its contaminants, which mixing with the mud fluid are transported to the surface with the drilling muds. Trials undertaken in Queensland on a proposal for land spraying of drilling by–products identified environmental hazards associated with drilling by–products include potentially toxic additives, salt compounds, heavy metals, hydrocarbons, pH-control additives, and total suspended solids (TSS).[13] The report notes that concentrations of aluminium, boron, iron, manganese, molybdenum, vanadium and mercury exceeded the Australian and New Zealand Environment and Conservation Council (ANZECC) 2000) Guidelines[14] and detectable concentrations of petroleum hydrocarbons were observed in drilling muds. They concluded that the C6–C9 fraction, which include BTEX (benzene, toluene, ethyl benzene and xylenes) may pose a risk from an environmental and human health perspective.

In June 2013, New Zealand milk giant, Fonterra, announced it would no longer accept milk from farms that accept CSG muds and drilling cuttings on their properties, citing both contamination concerns and the extra cost of testing the milk at about $80,000 per year.[15]

2. Risks to Water

Potential risks to ground and surface water have been identified and include:

- leakage of drilling fluids from the well bore into near surface aquifers;
- poor cement jobs on well bore casing, or fracking pressure resulting in cracks in the well casing allowing leakage of fluids;
- contamination from flow back fluid;
- accidental spills of fluids or solids at the surface;
- surface and subsurface blow outs;
- chemicals remaining in the underground from repeated fracking or naturally occurring contaminants finding their way from the producing zone to shallow or drinking water aquifers through fractures in the rock; and/or
- discharge of insufficiently treated waste water into surface water or underground.[16]

Contamination of groundwater
Australian UG company, Shenhua Watermark Coal acknowledge that drill holes may intersect with one or multiple aquifers potentially mixing groundwater from different strata or

[13] Origin's EMP Landspraying While Drilling (LWD) Trial Program OEUP-Q8200-PLN-ENV http://www.aplng.com.au/pdf/Environmental_Management_Plan_Landspraying_While_Drilling_Trial_Program.pdf
[14] http://www.environment.gov.au/resource/australian-and-new-zealand-guidelines-fresh-and-marine-water-quality-volume-1-guidelines
[15] http://www.stuff.co.nz/taranaki-daily-news/news/8813978/Fonterra-rejects-new-landfarm-milk
[16] Potential Risks for the Environment and Human Health Arising from Hydrocarbons Operations Involving Hydraulic Fracturing in Europe. http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf

altering the groundwater chemistry through exposure to air, gas, drilling fluids or release of natural compounds.[17] They also note interconnection of aquifers within the borehole may impact on aquifer levels.

BTEX chemicals have been found in 5/14 monitoring wells in Queensland gas fields; benzene at levels 6 and 15 times Australian drinking water standard.[18] Toluene and methane were also found in private drinking water bore adjacent to gasfields.[19]

Produced water

Produced water is the term used by the industry to describe the waste water produced along with the gas. Produced water from both CSG and shale gas is contaminated with heavy metals, NORMs, fracking or drilling chemicals, volatile and semi volatile organic compounds and high concentrations of salts. For a typical shale gas well, daily produced water volumes range from 300 - 4,500 litres (80 to 1,200 gallons).[20] The amount of produced water from a CSG well varies between 0.1 - 0.8 megalitres (ML) per day.[21]

Produced water tends to be of high salinity and large quantities of salts are a byproduct of CSG production.[22]

Produced water is either reinjected into aquifer formations, used for dust suppression on roads, reused for brick making, sent to holding ponds or partially 'treated' and released into waterways. The treatments to remove contaminants from produced water are limited by the chemicals they can remove, the energy needed and their economic costs. Reverse osmosis filtration has significant limitations and cannot remove many of the organic chemicals used in UG activities. Low molecular weight, non polar, water-soluble solutes such as the methanol and ethylene glycol are poorly rejected.[23]

In Queensland, the UG company, Santos claimed in their original environmental impact statement that they would treat the produced water to Australian standards before disposing of it in local waterways (Dawson Creek). However, Santos found that they were unable to treat the water to Australian standards. (Ammonia was 45 times guidelines, sulphate was 80 times guidelines, boron was 8 times guidelines and total suspended solids were twice guidelines). In late 2012, they requested permission to dump this contaminated water and they were given permission by the Queensland government to pump 12-18 million litres per day of contaminated water into the Dawson Creek.[24]

In Australia, high levels of lead, mercury, chromium, hydrocarbons and phenols have been detected in produced water, seven months after a spill in the Pilliga Forest CSG gas field.[25] In 2011, bromine was detected in treated produced water released by Eastern Star Gas at six times background levels. Methane was also detected at 68 micrograms per litre (ug/l), whereas it was not detected in the upstream control sample.[26]

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[17] 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

[18] Media Release 'Arrow advises of monitoring results' 26 August 2011

[19] Simtars Investigation of Kogen Water Bore (RN147705) -16 October 2012

[20] Bill Chameides, "Natural Gas, Hydrofracking and Safety: The Three Faces of Fracking Water," *National Geographic,* September 20, 2011

[21] CSG and water: quenching the industry's thirst, Gas Today Australia, May 2009

[22] Tim A. Moore, Coalbed methane: A review, *International Journal of Coal Geology* 101 (2012) 36–81

[23] Chemicals unable to be treated successfully include bromoform, chloroform, naphthalene, nonylphenol, octylphenol, dichloroacetic acid, trichloroethylene. See www.industry.qld.gov.au/documents/LNG/csg-water-beneficial-use-approval.pdf; http://www.aquatechnology.net/reverse_osmosis.html ;Stuart J. Khan Quantitative chemical exposure assessment for water recycling schemes, Waterlines Report Series No 27, March 2010 Commissioned by the National Water Commission

[24] The Australian, Big Gas fills state coffers, http://www.theaustralian.com.au/national-affairs/big-gas-fills-state-coffers/story-fn59niix-1226678669963

[25] Flint, C & Hogan, N, THE TRUTH SPILLS OUT: A Case Study of Coal Seam Gas Exploration in the Pilliga, May 2012 Report for Northern Inland Council for the Environment The Wilderness Society Newcastle

[26] Analytical Results ES1118565, 25-AUG-2011 East West Enviroag Project No. EW110647

In 2014, BTEX was detected in the in water from two of AGL's four CSG wells and an above-ground water storage tank at Gloucester in New South Wales; 5 samples included BTEX, one at concentration of 555 ppb. The New South Wales EPA suspended AGL's CSG Waukivory Project.

Flowback

Flowback refers to the 15 - 80% of the hydraulic fluid mixture that returns to the surface. It contains some of the chemicals injected, plus contaminants from the coal seam like BTEX, polycyclic aromatic hydrocarbons (PAHs), naturally occurring radioactive materials (NORMs), heavy metals and other volatile organic compounds (VOCs). Samples taken from the top of the well-head, a day after the well had been 'fracked', detected bromodichloromethane, bromoform, chloroform and dibromochloromethane, as well as benzene and chromium, copper, nickel, zinc.[27] Published studies from USA show that even after treatment, flowback water had dangerous levels of bromine and radium 226. [28]

AGL was criticised after its contractor Transpacific transported 600,000 litres of flowback from its Gloucester projects to be discharged after treatment into Hunter Water's network.

Hunter Water had previously advised both companies it would not accept the discharge. In a table provided to Hunter Water in November 2013, AGL said the flowback water from its fracking for the four wells would contain 450 litres of Tolcide. Tolcide is a biocide used to kill bacteria in the well with the active ingredient, Tetrakis (hydroxymethyl)phosphonium sulfate (THPS). As a biocide, THPS is toxic to microorganisms and its reported acute toxicity values for algae are less than 1 milligram per litre (No Observable Effect Concentration (NOEC) of 0.06mg/litre). Repeated skin exposure to THPS resulted in severe skin reaction and can cause skin sensitization.[29] It has shown mutagenic potential (in vitro) and cancer potential in rats. No exposure information is available for either humans or organisms in the environment; hence no quantitative risk assessment has been made.[30] Little is known about the effects of the break down products of THPS

The presence of the chemical was one reason Hunter Water refused to accept even treated flowback water in its sewer system. Despite letters to reinforce the refusal, AGL's contractor still discharged 600,000 litres of flowback water into its network. AGL then made arrangements to send its flow back water to WORTH Water Treatment Plant in Windsor, however the company has now rejected any more CSG wastewater and AGL appears to have no ready option to dispose of either its flow back or produced water.

Evidence of Water Contamination in the US

In 2011, US EPA investigation of water contamination in 23 drinking water wells near natural gas extraction sites detected high concentrations of benzene, xylenes, gasoline range organics, diesel range organics, and other hydrocarbons in groundwater samples from shallow monitoring wells near pits indicated that they were a source of shallow ground water contamination. They concluded that compounds associated with hydraulic fracturing had contaminated the aquifer at or below the depths used for domestic water supply.[31] Elevated

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[27] Labmark Environmental Laboratories, Certificate of Analysis, Report 331850-W Composite: Roma Water Analysis, Mar 26, 2012 as reported in Lloyd-Smith & M, Senjen, R Halogenated Contaminants From Coal Seam Gas Activities, Proceedings of Dioxin 2012 Conference, Cairns, Australia.

[28] Valerie J. Brown, Radionuclides in Fracking Wastewater: Managing a Toxic Blend, *Environ Health Perspect;* DOI:10.1289/ehp.122-A50;.Also see Warner NR, et al. Impacts of shale gas wastewater disposal on water quality in western Pennsylvania. Environ Sci Technol 47(20):11849–11857 (2013); http://dx.doi.org/10.1021/es402165b.

[29] 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

[30] Environmental Health Criteria 218 Flame Retardants: TRIS(2-BUTOXYETHYL) PHOSPHATE, TRIS(2-ETHYLHEXYL) PHOSPHATE and TETRAKIS(HYDROXYMETHYL) PHOSPHONIUM SALTS World Health Organization Geneva, 2000

[31] http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf

levels of dissolved methane in domestic wells generally increased with proximity to gas wells. A review of complaints in four US states, showed more than 100 cases of pollution being confirmed in Pennsylvania alone.

US EPA Report Assessment of Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resource

In the recently released US EPA report[32] on groundwater contamination they confirmed "specific instances" when fracking "led to impacts on drinking water resources, including contamination of drinking water wells." The report notes that spills occurred between January 2006 and April 2012 in 11 states and included 151 cases in which fracturing fluids or chemicals spilled on or near a well pad but due to the methods used for the EPA's characterization of spills, these cases were likely a subset of all fracturing fluid and chemical spills during the study's time period.

The study notes that the small number of contamination incidents included in the report might not be due to limiting factors, including the lack of pre- and post-fracking data about drinking water resources; the dearth of long-term studies; and "the inaccessibility of some information on hydraulic fracturing activities and potential impacts," most likely held by companies. Unfortunately these provisos did not get reported in the popular media.

Methane in Drinking Water

US studies have shown that methane levels in drinking water are higher in areas with a high density of wells and methane levels increased over time coinciding with the increasing number of wells. Methane contamination of water was evident in 60 water wells near active gas wells in the US.[33] Contamination at 19 to 64 parts per million was above US federal government safety guidelines. The majority were situated one kilometre or less from a gas well. Wells more than a kilometre from active gas wells had only a few parts per million. In a follow up 2013 study, distance to gas wells was found to be the most significant factor. Water wells close to gas-drilling sites had methane levels more than six times higher than more distant wells.[34] Methane was detected in private drinking water bores adjacent to Australian gasfields.[35]

Endocrine disrupting chemicals

In a 2013 study[36] surface and groundwater near sites experiencing high levels of unconventional gas activity in Colorado contained endocrine-disrupting chemicals and showed moderate to high levels of endocrine-disrupting chemical (EDC) activity. Samples taken from sites with little drilling showed little EDC activity. Exposure to EDCs can increase the risk of reproductive, metabolic, neurological, and other diseases, especially in children and young organisms.

Unsustainable water use - water table drawdown

UG activities use very large quantities of water, which compete with human and agricultural needs for water, raising important water equity issues. This is clearly acknowledged by the CBM companies. Australian UG company, Santos notes '*The drawdown of ground water heads within coal seam gas aquifers is a necessary process and an unavoidable impact*

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[32] United States Environment Protection Agency, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources, Office of Research and Development, Washington, D.C. External Review Draft | EPA/600/R-15/047a | June 2015 | www.epa.gov/hfstudy

[33] Osborn, SG, A Vengosh, NR Warner, RB Jackson. 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. http://www.nicholas.duke.edu/cgc/pnas2011.pdf

[34] Jackson et al, Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction *PNAS* 2013 110 (28) 11250-11255

[35] Simtars Investigation of Kogen Water Bore (RN147705) -16 October 2012

[36] Kassotis et al Estrogen and Androgen Receptor Activities of Hydraulic Fracturing Chemicals and Surface and Ground Water in a Drilling-Dense Region, *Endocrinology* doi: 10.1210/en.2013-1697 http://www.endo.endojournals.org

associated with the depressurisation of the coal seam.' [37] There can be significant losses in pressure both within the aquifer, and/or in the overlying and underlying aquifers. Santos predicts groundwater drawdown for their CSG fields within the Bowen Basin, Queensland of up to 15 metres by 2013 and 65 metres by 2028. For the four 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. Significant drawdown of farm bores has already been experienced in the region.

3. Air Pollution From Unconventional Gas Exploration And Production

The National Pollutant Inventory data over the last 5 years has shown the UG industry is a significant source of air pollution including particulates (PM_{10}, $PM_{2.5}$), nitrogen oxides and volatile organic compounds (VOCS), and the quantities are increasing. **W**hile the primary component of natural gas is methane, it typically contains other hydrocarbons such as ethane, propane, butane, and pentanes and may also contain hazardous air pollutants such as BTEX, hexanes, hydrogen sulphide, and carbon dioxide.

Air toxics associated with UG activities can cause serious, irreversible health effects, including cancer, neurological problems and birth defects. [38] In 2013, the World Health Organization[39] declared that outdoor air pollution is carcinogenic.

There are many sources of toxic air pollutants in gas fields and related infrastructure
These include equipment/engines, drilling rigs, boilers/heaters, generators, flares, storage tanks, injection pumps, dehydrators, vehicles and gas skimmers. A major source of air pollutants are the compressor stations that move natural gas through pipelines and gas processing plants.[40]

The following pollutants have been identified with some forming precursors of secondary pollutants such as ozone (O3). [41]

Nitrogen Oxides
NOx are emitted from machinery, compressors, flaring. NOx can react with VOCs to form ground-level ozone, which is linked to asthma attacks and other serious health effects. Nitrogen dioxide can cause respiratory problems, heart conditions and lung damage.

Carbon monoxide - CO is emitted during flaring and from machinery and is poisonous if inhaled, inhibiting the blood's ability to carry oxygen. It can cause dizziness, unconsciousness and even death.

Sulfur dioxide - SO2 reacts with other chemicals to form acid rain and particulate pollution, which can damage lungs and cause respiratory illness, heart conditions and premature death.

Hydrogen sulfide – H2S occurs naturally in some gas formations and can be released when gas is vented or flared, or via fugitive emissions. It is a toxic gas, which is lethal if

[37] Groundwater (Deep Aquifer Modelling) for Santos GLNG Project – Environmental Impact Statement 31/3/2009 http://www.santosglng.com/media/pdf41108/P2_Groundwater%20(Deep)%20FINAL%20PUBLIC.pdf
[38] Reducing Air Pollution from the Oil and Natural Gas Industry EPA's Final New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants, April 17, 2012 http://www.epa.gov/airquality/oilandgas/pdfs/20120417presentation.pdf
[39] International Agency for Research on Cancer, press release no 221 17 Oct 2013 - http://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf
[40] http://toxtown.nlm.nih.gov/text_version/locations.php?id=150
[41] A Kibble, T Cabianca, Z Daraktchieva, T Gooding, J Smithard, G Kowalczyk, N P McColl, M Singh, S Vardoulakis and R Kamanyire Review of the Potential Public Health Impacts of Exposures to Chemical and Radioactive Pollutants as a Result of Shale Gas Extraction: Draft for Comment, PHE-CRCE-002 http://www.hpa.org.uk/Publications/Environment/PHECRCEReportSeries/PHECRCE002/

inhaled at high concentrations.

Volatile organic compounds
VOCs are present during all stages of UG activities including drilling, flaring, from equipment/machinery, hydraulic fracturing flowback, holding ponds. Semi volatile chemicals are injected underground during fracking, a percentage of which eventually surfaces.

VOCs are toxic
Some VOCs cause cancer in animals (e.g. methylene chloride), in humans (e.g. formaldehyde) or are suspected human carcinogens (e.g. chloroform, bromodichloromethane). VOC exposure may result in eye, nose, and throat irritation, headaches, visual disorders, memory impairment, loss of coordination, nausea, damage to liver, kidney, and central nervous system.[42] Some VOCs like formaldehyde and styrene are endocrine disrupting chemicals (EDCs). EDCs are chemicals that may interfere with the production or activity of hormones in the human endocrine system.[43]

VOCs detected near homes adjacent to gasfields
Sampling of air around homes near gasfields has detected a wide range of VOCs many of which are toxic [44] Community sampling around Queensland gas activities also detected dichlorodifluoromethane, a potent chlorofluorocarbons (CFCs), [45]

A more detailed discussion of testing, results and impacts from UG on the Queensland Tara Estates is available later in this submission.

Polycyclic aromatic hydrocarbons
Researchers in 2015 identified polycyclic aromatic hydrocarbons (PAHs) as a significant air pollutant associated with unconventional gas production. [46] They noted that people living or working near active natural gas wells may be exposed to certain pollutants at higher levels than the US EPA considers safe for lifetime exposure. High levels of PAHs were found across the study area with levels highest closest to the wells and decreased by about 30 percent with distance. PAHs are a group of very toxic volatile compounds.

A further study found increased ethane concentrations measured in Baltimore, Maryland and in Washington, DC are probably the result of natural gas drilling in upwind states, notably Pennsylvania and West Virginia, although this drilling is hundreds of kilometres away. Air pollution from hydraulic fracturing may travel hundreds of kilometres

Coal seam drilling releases toxic BTEX (Benzene, toluene, ethylbenzene, xylene)

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[42] http://www.epa.gov/iaq/voc.html
[43] US National Library of Medicine http://toxtown.nlm.nih.gov/text_version/chemicals.php?id=65
[44] These include acetone, acrolein, alpha-pinene, benzene, benzothiazole, chloromemethane, cyclohexane, dichloroflurometh ane, ethanol, ethyl acetate, ethylbenzene, 2-ethyl-1-hexanol, heptane, hexane, heptadecane, hexadecane, 2-methylbutane, methylcyclohexane, methylene chloride, methyl ethyl ketone, 3- methylhexane, 3 methylpentane, naphthalene, pentane, phenol, propene, tetradecane, tetrachlorethylene, 1,2,4,-trimethylbenzene, toluene, vinyl acetate, xylene, ethanol, phenylmaleic anhydride, methyl ethyl ketone.Symptomatology of a gas field, An independent health survey in the Tara rural residential estates and environs - http://www.ntn.org.au/wp/wp-content/uploads/2013/05/Symptomatology-of-a-gas-field-An-independent-health-survey-in-the-Tara-rural-residential-estates-and-environs-April-2013.pdf
[45] Australian Government National Measurement Institute, Report of Analysis of Air Canisters Low Level, Report No. RN900555 (2 Feb 2012), Report No. RN893233 (16 Dec 2011), Report No. RN893232 (16 Dec 2011) as reported in Lloyd-Smith & M, Senjen, R Halogenated Contaminants From Coal Seam Gas Activities, Proceedings of Dioxin 2012 Conference, Cairns, Australia.
[46] Paulik et al., Impact of natural gas extraction on PAH levels in ambient air. *Environ Sci Technol*. 2015 Apr 21 ;49(8):5203-10. doi: 10.1021/es506095e. Epub 2015 Apr 9.

BTEX chemicals are naturally occurring VOCs released from coal deposits and are also found in associated groundwater.[47]

Drilling, fracking and removal of produced water release BTEX from the coal seam. Short term health effects include skin, eye and nose irritation, dizziness, headache, loss of coordination and impacts to respiratory system. Chronic exposure can result in damage to kidneys, liver and blood system.

Benzene is a human carcinogen
Benzene causes (leukemia, non-Hodgkin's lymphoma) and also affects the immune system. It may cause chromosomal aberrations and mutations in human and animal cells,[48] and has been linked to birth defects[49] and sperm abnormalities [50]

Particulates are a serious health hazard
Particulate matter (PM) is released during construction, venting, flaring, diesel exhaust (IARC Class 1 human carcinogen) and via silica based proppants, exposure to which can cause silicosis, lung cancer, autoimmune diseases, pulmonary disease and chronic kidney disease.[51] Chronic inhalation of PM_{10} and is $PM_{2.5}$ can lead to respiratory problems, cancer, heart attacks, strokes, diabetes, asthma, hypertension, renal disease or premature death. PM also provides an effective pathway for other contaminants such as heavy metals and radioactive substances into the broader environment.

Australian government has acknowledge that there is no threshold at which health effects do not occur [52] yet, UG companies are not required to report emissions of either $PM_{2.5}$ or PM_{10} unless they exceed a threshold of 400 tonnes per year, or 1 tonne per hour.

The US National Institute for Occupational Safety and Health (NIOSH) released a Hazard Alert, identifying exposure to airborne silica as a health hazard to workers conducting hydraulic fracturing operations.[53] They identified a range of sources of silica dust exposure during hydraulic fracturing operations. NIOSH acknowledges a lack of information on occupational dust exposure in the gas industry, including exposure to diesel particulates. Diesel exhaust is classified as a Group 1 carcinogen by the International Agency for Research into Cancer.[54]

Synergy between particulates and air pollutants
Particulate matter travels deep into the lung and crosses directly into the bloodstream carrying with it other toxic chemicals. [55] The surface area of the particle is what drives a synergistic response, producing greater than additive response.[56]" Together, the mixture is even more dangerous to health than the added individual risks and importantly, there is no evidence of a safe level of exposure to the combined air pollutants or a threshold below, which no adverse health effects occur.

Gas processing is a key source of air pollution

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[47] http://www.ehp.qld.gov.au/management/coal-seam-gas/btex-chemicals.html
[48] http://www.atsdr.cdc.gov/toxprofiles/tp3-c6.pdf
[49] http://www.ncbi.nlm.nih.gov/pubmed/20923742
[50] http://www.environmentalhealthnews.org/ehs/newscience/benzene-linked-to-sperm-abnormalities
[51] NIOSH Hazard Review, Health Effects of Occupational Exposure to Respirable Crystalline Silica. National Toxicology Program [2012]. Report on carcinogens 12th ed. U.S. Department of Health and Human Services, Public Health Service.
[52] http://www.npi.gov.au/resource/particulate-matter-pm10-and-pm25
[53] www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.htm
[54] http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf
[55] David Brown, Beth Weinberger, Celia Lewis and Heather Bonaparte, Understanding exposure from natural gas drilling puts current air standards to the test. *Rev Environ Health* 2014; DOI 10.1515/reveh-2014-0002 http://www.fraw.org.uk/files/extreme/brown_lewis_2014.pdf
[56] David Brown, Beth Weinberger, Celia Lewis and Heather Bonaparte, Understanding exposure from natural gas drilling puts current air standards to the test. *Rev Environ Health* 2014; DOI 10.1515/reveh-2014-0002 http://www.fraw.org.uk/files/extreme/brown_lewis_2014.pdf

Gas processing removes impurities before natural gas can be used producing many by-products, which are usually vented to the air e.g. ethane, propane, butanes, pentanes, higher molecular weight hydrocarbons, hydrogen sulphide, carbon dioxide.

Flaring generally banned in the USA

The USEPA has banned gas flaring (the burning off of natural gas from a new well) in most cases after January 2015 due to growing concerns over air pollution,[57] but there are no restrictions on UG flaring in Australia. Flaring releases hydrogen sulphide, methane, BTEX [58] and is recognised as a significant source of soot or black carbon pollution.[59]

Australian UG industry reports to the National Pollutant Inventory

Australia is one of the few countries where the UG companies are required to self-report their emissions to land, air and water to the government's National Pollutant Inventory (NPI).[60] The data submitted represents their calculated emissions for a limited list of around 100 chemicals and heavy metals. The latest data from 2013-14 show many thousands of tonnes of toxic chemicals are being released to air by the UG industry.

Confirming that gas treatment was a major source of air pollution, particulate matter (PM) for the Queensland Gas Company's Kenya Processing Plant (ATP620) and Compressor Stations near Tara, Queensland rose from 5,400 kg of PM_{10} and $PM_{2.5}$ in 2011/12 to over 590,000 kg in the 2012/2013 reporting period (100 times more). The total VOCs emitted doubled. In 2013-14, the same facility emitted total PM of 342,000kgs, 710,000 kg of NOx, 410,000kg of CO and total VOCs at 89,000 kg.

While its sister infrastructure, QGC's Windibri Processing Plant (PL201) and Compressor Stations in 2013-14, reported total PM emissions of 1,316,000 kg, showing no real decrease from 2012-2013 reporting period when it emitted 1,324,000 kg PM_{10} and $PM_{2.5}$. In 2013-14, Windibri's total VOCs increased from 76,000 to 91,000 kg.

In 2013-14, in QGC's report for their Ruby Jo field in Tara, the emissions of CO were 1,600,000 kg doubling the figure of 80,000 kg in 2012-13. Nitrous oxides were reported at 810,000 kg, well up from 230,000 kg.

These figures reflect the ongoing steady growth from overall emissions reported by the industry in the last 5 years. From 2010 to 2013, QGC's total releases of PM increased from less than 16,000 kilograms (kg) in 2010 to almost 2 million kg three years later (12 times higher). Carbon monoxide emissions were 17 times higher at over a million kg and the emission of total volatile organic compounds or VOCs had escalated 100 times to 262,000 kg in 2013. As well, in 2013 QGC emitted 62,000 kg of formaldehyde into the air whereas none had been reported in 2010.

Cumulative load across a region

In 2013-14, both CSG or shale gas, emit large quantities of VOCs and other contaminants and while individual projects may report moderate figures, the numerous gasfields and infrastructures in a single region add up to significant numbers. For example, the Santos Big Lake shale gas project at Leigh Creek, SA in 2013-14 reported 670,000 total VOCs, while Santos Merrimelia Gas in Leigh Creek, emitted over 350,000 VOCs, 850,00 CO and 580,000 NOx and Santos's Toolachee Gas in Leigh Creek, released 240,000 kg of VOCs, over 670,000 kg of CO and 450,000 kg of NOx. This results in over 1.25 million kilograms of VOCs released into the Leigh Creek region. Toxic air emissions from UG activities are increasing.

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[57] http://www.epa.gov/airquality/oilandgas/pdfs/20120417presentation.pdf
[58] http://www.med.upenn.edu/ceet/documents_user/MarcellusShale_Penning3.pdf
[59] Stohl, A., Klimont, Z., Eckhardt, S. et al. (2013). Black carbon in the Arctic: the underestimated role of gas flaring and residential combustion emissions. *Atmospheric Chemistry and Physics*. 13: 8833–8855. Also see http://ec.europa.eu/environment/integration/research/newsalert/pdf/349na5.pdf
[60] http://www.npi.gov.au

Australian research on Fugitive emissions

Fugitive non-methane and methane emissions are an issue usually associated with abandoned wells but are evident over the complete gas exploration and production cycle. Australian research[61] measured atmospheric radon (Rn-222 and Rn-220) and carbon dioxide (CO_2) concentrations as a measure of fugitive emissions in the gas fields. The researchers suggest the presence of radon and CO_2 indicates the possible release of other gases, such as VOCs. They suggest that CSG activities such as the depressurisation by groundwater extraction from the coal bed strata change the geological structure and pressures, helping gases to seep through the soil and be released to the atmosphere. They reported a 3-fold increase in maximum radon ^{222}Rn concentration inside the gas field compared to outside with a significant relationship with the number of wells.

In their submission to the Australian government, they also reported hotspots with concentrations of methane (CH4) as high as 6.89 ppm and CO_2 as high as 541 ppm near Tara. Background atmospheric CH4 outside the gas fields were lower than 2ppm.[62] In a later study just published, the same researchers confirmed the widespread enrichment of both CH4 (up to 6.89 ppm) and CO_2 (up to 541 ppm) within the production gas field, compared to outside. The CH4 and CO_2 δ13C source values showed distinct differences within and outside the production field, indicating a CH4 source within the production field that has a δ13C signature comparable to the regional CSG.[63]

Methane Leaks

Further evidence of fugitive emissions is evident in bubbling methane gas reported along 5 kilometre stretch of the Condamine River in Queensland, Australia. The Queensland government's initial investigation [64] notes that four CSG wells were within 5k radius of the gas seep but there was no evidence of fracking within 40 kilometres. Methane was measured at 80% of the lower explosive limit (LEL) (at river surface) equating to 4% gas in air. Another Queensland government study found 26 of 58 gas wells tested leaked methane; one above the lower explosive limit (LEL), 4 at or above 10% of the LEL and 21 with levels between 10-3000ppm. Similar figures were found in surrounding gas fields.[65] Methane is a powerful greenhouse gas with a global warming potential much greater than that of CO2. The IPCC calculated that methane is 34 times stronger as a heat-trapping gas than CO2 over a 100-year time scale. The IPCC report also stated that over a 20-year period, methane has a global warming potential of 86-105 compared to CO2. Its release may also indicate ongoing releases of other gases toxic to human health.

Naturally occurring radioactive materials

Naturally occurring radioactive materials (NORMs) are found in both coal seams and shale, eg uranium, thorium and their progeny radium-228 and radium-226.[66] The level of reported

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[61] Douglas R. Tait, Isaac Santos, Damien Troy Maher, Tyler Jarrod Cyronak, & Rachael Jane Davis, Enrichment of radon and carbon dioxide in the open atmosphere of an Australian coal seam gas field *Environ. Sci. Technol.* http://pubs.acs.org/doi/abs/10.1021/es304538g

[62] Submission on National Greenhouse and Energy Reporting (Measurement) Determination 2012 - Fugitive Emissions from Coal Seam Gas. Submitted 19 October 2012 to Department of Climate Change and Energy Efficiency by Dr. Isaac Santos Southern Cross University, NSW Australia

[63] Damien T. Maher & Isaac R. Santos & Douglas R. Tait, Mapping Methane and Carbon Dioxide Concentrations and δ13C Values in the Atmosphere of Two Australian Coal Seam Gas Fields *Water Air Soil Pollut* (2014) 225:2216

[64] Summary Technical Report - Part 1 Condamine River Gas Seep Investigation, December 2012 Version 1 State of Queensland, Department of Natural Resources and Mines, 2012. http://www.dnrm.qld.gov.au/mining/coal-seam-gas

[65] Investigation report, Leakage testing of coal seam gas wells in the Tara 'rural residential estates' vicinity, The State of Queensland, Department of Employment, Economic Development and Innovation, 2010. http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0011/119675/tara-leakage-csg-wells.pdf

[66] Fact Sheet FS-163-97 October, 1997 Radioactive Elements in Coal and Fly Ash: Abundance, Forms, and Environmental Significance, USGShttp://pubs.usgs.gov/fs/1997/fs163-97/FS-163-97.html; Note in 2014, Santos coal seam gas project was found to have contaminated aquifers with Uranium at 335 micrograms per litre, which is 20 times the Australian Drinking Water guideline of 17 ug/l. See Santos coal seam gas project contaminates

radioactivity varies significantly, depending on the radioactivity of the reservoir rock and the salinity of the water co-produced from the well. The higher the salinity the more NORM is likely to be mobilized. Since salinity often increase with the age of a well, old wells tend to exhibit higher NORM levels than younger ones.[67]

Both radon and radium emit alpha particles, which are most dangerous when inhaled or ingested. Radium is a known carcinogen[68] and exposure can result in increased incidence of bone, liver and breast cancer. When inhaled, radon can cause lung cancer, and there is some evidence it may cause other cancers such as leukemia.[69] Consuming radium in drinking water can cause lymphoma, bone cancer, and leukemias.[70] Radium also emits gamma rays, which raise cancer risk throughout the body from external exposures. Radium-226 and radium-228 have half-lives of 1,600 years and 5.75 years, respectively. Radium is known to bioaccumulate in invertebrates, mollusks, and freshwater fish,[71] where it can substitute for calcium in bones.

UG activities such as drilling, fracking, removal of produced water, earthworks and transport result in radioactive substances being remobilized and relocated either via waste water, 'bonding' with particulates or via resuspension in air. Direct particle fallout, as well as washout from rain then provides an effective pathway for these contaminants to find their way into the wider environment and onto rooftops and into domestic water tanks. Radon-222 a decay product of Radium-226 also follows the gas lines and decays (through several rapid steps) to Pb-210, which can build up as a thin film in gas extraction equipment.

In 2014, Santos coal seam gas project in the NSW Pilliga Forest was found to have contaminated aquifers with Uranium at 335 micrograms per litre, which is 20 times the Australian Drinking Water guideline of 17 ug/l. [72]

As nearly all uranium is in the form of Uranium 238, its detection well above drinking water levels should have prompted immediate testing for radionuclides in the groundwater such as Radium 226 and Radon 222, which are far more harmful to living organisms. Unfortunately, testing for radioactivity did not occur.

Implications for human health

There has been no comprehensive assessment of the health implications of UG air pollutants to residents or workers in Australia. A US based human health risk assessment of air emissions concluded residents closest to well pads i.e., living less that 1/2 mile from wells, have higher risks for respiratory and neurological effects based on their exposure to air pollutants; and a higher excess lifetime risk for cancer. [73]

Children living in close proximity to UG activities are at particular risk from air

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aquifer' SMH 2014 http://www.smh.com.au/environment/santos-coal-seam-gas-project-contaminates-aquifer-20140307-34csb.html

[67] http://www.world-nuclear.org/info/Safety-and-Security/Radiation-and-Health/Naturally-Occurring-Radioactive-Materials-NORM/#.UTIc2qXfCcM

[68] http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=790&tid=154

[69] NRC. Health effects of radon progeny on non-lung-cancer outcomes. In: Health Effects of Exposure to Radon, BEIR VI. Washington, DC:Committee on Health Risks of Exposure to Radon (BEIR VI), National Research Council, National Academies Press (1999). http://www.nap.edu/openbook.php?record_id=5499&page=118

[70] EPA. Radionuclides: Radium [website]. Washington, DC:Office of Radiation and Indoor Air, U.S. Environmental Protection Agency (updated 6 March 2012). http://www.epa.gov/radiation/radionuclides/radium.html#affecthealth

[71] Warner NR, et al. Impacts of shale gas wastewater disposal on water quality in western Pennsylvania. *Environ Sci Technol* 47(20):11849–11857 (2013); http://dx.doi.org/10.1021/es402165b.

[72] Santos coal seam gas project contaminates aquifer, SMH 2014 http://www.smh.com.au/environment/santos-coal-seam-gas-project-contaminates-aquifer-20140307-34csb.html

[73] Lisa M. Mckenzie, Roxana Z. Witter, Lee S. Newman and John L. Adgate, Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment* March 21, 2012

pollutants, due to their unique vulnerability to hazardous chemicals. [74] Children's exposure to chemicals at critical stages in their development may have severe long-term consequences for health. WHO has expressed a priority concern around children's exposure to air pollutants [75]

Maternal exposure to air pollutants carries significant risks as the placenta is not an effective barrier to chemical transfer from mother to the foetus and toxins can be transferred through breast milk as well. The developing fetus is particularly sensitive to environmental factors with *critical windows of vulnerability* during prenatal and early postnatal development, during which chemical exposures can cause potentially permanent damage to the growing embryo and fetus. [76] Early exposure to carcinogens can also increase the risk of developing cancer later in life.[77] In utero and in early infancy, pollutants can cause permanent brain damage at levels of exposure that would have little or no adverse effect in an adult.[78]

A recent study [79]demonstrates that the higher a baby's prenatal exposure to Polycyclic Aromatic Hydrocarbons (PAHs) was, the more white matter of the prefornatl cortex of both hemispheres was reduced and the more acute the behavioural and developmental problems were. Importantly the damage is not isolated to prenatal stages. Postnatal PAH exposure, if measured at age 5, correlated with diminished white matter in areas of the prefrontal cortex of both hemispheres.

A large study from Colorado found that children born in areas with the highest number of gas wells had a 30% increased rate of congenital heart defects compared to children born in areas with no gas wells within 10km. [80]

A study from Cornell University found that babies born within 2.5km of a gas well had lower birth weight and more health problems than babies who were born within 2.5km of a well that was planned but had not been drilled.[81]

The Queensland Government's Health Report[82] into residents' complaints acknowledged that there was *'some evidence that might associate some of the residents' symptoms to exposures to airborne contaminants arising from CSG activities.'*

A recent literature review (August 2014) by Shonkoff, Hays and Finkel summarises the growing body of evidence of the adverse impacts of HF and UG. [83]

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[74] World Health Organization / Children's Environmental Health. http://www.who.int/ceh/en/
Also see IFCS Children and Chemical Safety Working Group. 2005. Chemical Safety and Children's Health: Protecting the world's children from harmful chemical exposures - a global guide to resources, October.
[75] World Health Organisation (WHO), International Labor Office (ILO), United Nations Environment Program (UNEP) 2006. Helping to Protect Children from the Harmful Effects of Chemicals. International Program on Chemical Safety. http://www.who.int/ipcs/en/
[76] Olin, S. R. & B. R. Sonawane. 2003. Workshop to Develop a Framework for Assessing Risks to Children from Exposure to Environmental Agents, September 2003. *Environmental Health Perspectives* 111/12: 1524-1526
[77] Barton, H. A., V. J. Cogliano, L. Flowers, L. Valcovic, R. W. Setzer & T. J. Woodruff. 2005. Assessing Susceptibility from Early-Life Exposure to Carcinogens. *Environ. Health Perspect. 13(9): 1125–1133*
[78] Dr Philippe Grandjean MD & Philip J Landrigan MD, Neurobehavioural effects of developmental toxicity, *The Lancet Neurology*, Volume 13, Issue 3, Pages 330 - 338, March 2014 doi:10.1016/S1474-4422(13)70278-3 http://www.thelancet.com/journals/laneur/article/PIIS1474-4422(13)70278-3/abstract
[79] Peterson et al, Effects of Prenatal Exposure to Air Pollutants (Polycyclic Aromatic Hydrocarbons) on the Development of Brain White Matter, Cognition, and Behavior in Later Childhood *JAMA Psychiatry*. Published online March 25, 2015. doi:10.1001/jamapsychiatry.2015.57 http://archpsyc.jamanetwork.com/article.aspx?articleid=2205842
[80] McKenzie et al., Birth Outcomes and Maternal Residential Proximity to Natural Gas Development in Rural Colorado, *Environ Health Perspect;* DOI:10.1289/ehp.1306722 http://ehp.niehs.nih.gov/1306722/)
[81] Hill, E. (2013). The impact of oil and gas development on infant health in colorado. Cornell Dyson School Working Paper
[82] Queensland Government's Health Report, *'Coal seam gas in the Tara region: Summary risk assessment of health complaints and environmental monitoring data, March 2013'*
[83] Shonkoff SB, Hays J, Finkel ML. 2014. Environmental public health dimensions of shale and tight gas development. Environ Health Perspect 122:787–795; http://dx.doi. org/10.1289/ehp.1307866

These findings included:

- The concentrations of chemicals detected in surface and ground water in areas with intensive natural gas development were in high enough concentrations to interfere with the response of human cells to male sex hormones and estrogen. (Kassotis et al. 2014);
- Fifty-two percent of the chemicals have the potential to negatively affect the nervous system, and 37% are candidate EDCs (endocrine disruptor chemicals) (Colburn et al 2011);
- Residents living <_0.5mile from wells were at a greater risk for health effects from exposure to natural gas development than those living > 0.5 mile from wells. (McKenzie et al. 2012);
- Many non-methane hydrocarbons (NMHCs), which were observed during the initial drilling phase, are associated with multiple health effects. (Colburn et al 2014);
- High photochemical ozone concentrations in the rural Upper Green River Basin in the winter, reporting readings of up to 140ppb, just less than double the U.S. EPA ozone concentration limit of 75ppb. (Schnell et al. 2009);
- Workers experience the most direct exposure; however, silica dust may also be an air contaminant of concern to nearby residents. Silicosis is a progressive lung disease in which tissue in the lungs reacts to silica particles. (Esswein et al.2013);
- Diesel PM (particulate matter) is a well-understood health damaging pollutant that contributes to cardiovascular illness, respiratory disease (eg lung cancer) (Garshick et al.) atherosclerosis and premature death.(Pope 2002);
- Insufficiently treated flowback and produced water that contain concentrations of contaminants associated with shale gas development entered local water supplies, even after treatment. They also found elevated levels of chloride and bromide downstream, along with radium -226 levels in stream sediments at the point of discharge, that were approximately 200 times greater than upstream and background sediments and well above regulatory standards (Warner et al 2013);
- The results of Alley et al. (2011) agree with other reports that samples of fracturing fluids, drilling muds, and flowback and produced waters in wastewater- surface containment ponds contain chemicals that, at elevated doses or certain concentrations have been associated with health effects ranging from skin and eye irritation to neurological and nervous system damage, cancer and endocrine disruption (Colborn et el 2011);
- An analysis of waste obtained from reserve pits indicated the potential for exposure to technologically enhanced naturally occurring radioactive materials and potential health effects from individual radionuclides (Rich and Crosby 2013);
- The researchers did observe a positive association between density and proximity of pregnant mothers to shale gas development and the prevalence of congenital heart defects and possibly neural tube defects in their newborns (McKenzie et al. 2014);

The situation in Tara, Queensland

Despite the knowledge of the significant releases in the Tara region, there has been no comprehensive monitoring of air pollutants. However, single point sampling of ambient air around Tara homes by both industry and government has detected a wide range of VOCs many of which are toxic. These include acetone, acrolein, alpha-pinene, benzene, benzothiazole, chloromemethane, cyclohexane, dichlorofluromethane, ethanol, ethyl acetate, ethylbenzene, 2-ethyl-1-hexanol, heptane, hexane, heptadecane, hexadecane, 2-methylbutane, methylcyclohexane, methylene chloride, methyl ethyl ketone, 3-methylhexane, 3 methylpentane, naphthalene, pentane, phenol, propene, tetradecane, tetrachlorethylene, 1,2,4,-trimethylbenzene, toluene, vinyl acetate, xylene, ethanol,

phenylmaleic anhydride, methyl ethyl ketone.[84]

In sampling undertaken by QGC[85] (ERM Report) and used to dismiss residents' complaints, only 13 air samples were collected in all. A single sample was collected at five Tara properties with two samples at each of the remaining four properties.

While many volatile organic compounds were detected in the air, the ERM report concluded that apart from the benzene exceedance, there were no other exceedances of the air quality screening criteria. Yet in the case of 26 chemicals, the health criterion was set at a level below the detection level used by the laboratories. The ERM report notes that it cannot be categorically stated that concentrations in the samples were also below the relevant criteria value. For example, US EPA Regional Screening Levels for 1,1,1,2-tetrachloromethane is 0.33 µg/m3, whilst the limit of detection used by the different labs varied between 8.3 µg/m3 and 12 µg/m3, well above the health criteria.

In the case where benzene was clearly detected above health risk criteria, it was dismissed stating that *'benzene* was not a compound that is found in CSG and therefore could not be attributed to CSG activities' but rather from a local source such as smoking, etc. This was a surprising when the website of the Queensland Government's Department of Environment and Heritage Protection states that: *"BTEX compounds (benzene, toluene, ethylbenzene, xylene) are found naturally in crude oil, coal and gas deposits and therefore they can be naturally present at low concentrations in groundwater near these deposits".*[86] Benzene had already been detected in monitoring bores at an Arrow Energy fracking operation[87] in Queensland at 6 and 15 times the Australian Drinking Water Guidelines.

The simple dismissal of benzene exceedances is unacceptable when other BTEX chemicals such as toluene, a neurotoxin, were found in the air around a number of Tara homes and in the air above a resident's water bore.[88] The level of toluene in air above the bore was measured at 0.33ppm but was dismissed as below levels of concern yet this level is well above the 'Chronic Reference Exposure Limits' used for long term exposure by California, Massachusetts, Michigan states in the USA.[89]

The total ERM monitoring period was only nine days and the methodology resulted in testing limits of reporting for some chemicals that were substantially higher than the reference air quality criteria. The monitoring was not designed to identify short-term peaks or troughs in air concentrations and in order to assess air contaminants sampling is needed over an extended period of time. This was demonstrated in a 2012 study on air pollution associated with unconventional gas activities. The twelve month study[90] detected 44 hazardous air pollutants at gas drilling sites including a wide range of air toxics, eg methane, methylene chloride, ethane, methanol, ethanol, acetone, and propane, formaldehyde, acetaldehyde, PAHs / naphthalene. Most importantly, the authors noted a great deal of variability across sampling dates in the numbers and concentrations of chemicals detected. Notably, the highest percentage of detections occurred during the initial drilling phase, prior to hydraulic fracturing on the well pad.

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[84] Symptomatology of a gas field, An independent health survey in the Tara rural residential estates and environs - http://www.ntn.org.au/wp/wp-content/uploads/2013/05/Symptomatology-of-a-gas-field-An-independent-health-survey-in-the-Tara-rural-residential-estates-and-environs-April-2013.pdf

[85] Queensland Gas Company Environmental Health Assessment Report Tara Complaint Investigation Report, January 2013 Final REF: 0181432R01 (known as the ERM Report)

[86] http://www.ehp.qld.gov.au/management/coal-seam-gas/btex-chemicals.html.

[87] Media Release 'Arrow advises of monitoring results' 26 August 2011

[88] Simtars Investigation of Kogan Water Bore (RN147705) -16 October 2012

[89] http://oehha.ca.gov/air/chronic_rels/pdf/108883.pdf ; Also see http://environment.gov.ab.ca/info/library/6659.pdf

[90] Colborn T, Schultz K, Herrick L, and Kwiatkowski C. 2012 (in press). An exploratory study of air quality near natural gas operations. *Hum Ecol Risk Assess*

Wieambilla Odour Investigation Results: July - December 2012
The Queensland Government has facilitated adhoc sampling for VOCs in air at the Wieambilla Estate in Tara response to community concerns. They provided Summa canisters[91] with a 1-minute sampling period and passive diffusion samples to residents for use when appropriate. Many VOCs were again detected and while most were below relevant guidelines and the criteria used, the number and type of compounds was diverse.

Summa canister sampling found the following VOCs: hexane, propene, chloromethane, dichlorodifluromethane, methylene chloride, ethanol, acetone, methyl ethyl ketone, acrolein, vinyl acetate. Vinyl acetate exceeded the annual criteria in one case.

Passive samplers also found the following VOCs: pentane, hexane, heptane, tetradecane, hexadecane, heptadecane, cyclohexane, 2-methylbutane, 3-methylpentane, 3-methylhexane, methylcyclohexane, tetrachloroethylene, 2-ethyl-1-hexanol, ethyl acetate, benzene, toluene, xylene, ethylbenzene, 1,2,4-trimethylbenzene, phenol, benzothiazole, naphthalene, alpha-pinene.

Benzene was detected at 0.6 ppb, exceeding their reference value and also above the US EPA recommendations of 0.4ppb, which over a lifetime could cause a risk of one additional cancer case for every 100,000 exposed persons.[92] The benzene result was simply dismissed as an 'outlier'.

In community sampling around UG activities over an eight-hour period, ethanol and chlorofluorocarbons (CFCs) were detected.[93] Dichlorodifluoromethane, a potent ozone depleting chlorofluorocarbon (CFC) was detected in all 3 air samples.

In July 2014, small suite of state government tests taken outside a Tara family residence identified Acrolein at 9.6ppb, more than 100 times higher than acceptable chronic exposure standard.[94] The Texas annual criterion is 0.066ppb. Acrolein is an acute irritant of the eyes, nose, throat, lungs and skin and is reported to be used by the oil and gas industry as a biocide in drilling waters, as well as a scavenger for hydrogen sulphide and mercaptans. Flares are also a possible source of acrolein. Formaldehyde[95] was also detected.

Despite the increased rate of radon detected by the SCU study inside the gas fields, there has been little comprehensive radionuclide analyses or testing in the Tara communities surrounding gas fields. However, limited independent testing has detected worrying levels of beta and alpha radioactivity in Tara residents' water tanks. This represents a significant concern for the children, as they are far more vulnerable to radioactivity than adults with sensitivity to radiation being highest early in life.[96] As has been noted earlier in this paper, particulate pollution provides an effective pathway for radioactive substances into the broader environment, and it is hypothesized that through resuspension of radioactive substances and washout from rain as well as direct particle fallout onto roofs and tanks has resulted in the detection of radioactivity in the water and sediment of Tara residents' water

[91] Summa canister is a stainless steel vessel which when the valve is opened allows the surrounding air to fill the canister and achieve a representative sample. The valve is then closed and the canister is sent to a laboratory for analysis
[92] http://www.anapolschwartz.com/practices/benzene
[93] Australian Government National Measurement Institute, Report of Analysis of Air Canisters Low Level, Report No. RN900555 (2 Feb 2012), Report No. RN893233 (16 Dec 2011), Report No. RN893232 (16 Dec 2011) as reported in Lloyd-Smith & M, Senjen, R Halogenated Contaminants From Coal Seam Gas Activities, Proceedings of Dioxin 2012 Conference, Cairns, Australia.
[94] Submission to the Senate Select Committee on Certain Aspects of Queensland Government Administration related to Commonwealth Government Affairs, 17th November 2014 BY Dr Geralyn McCarron MB BCh BAO FRACGP
[95] Formaldehyde is a suspected human carcinogen. It can affect nearly every tissue in the human body, leading to acute (dermal allergies, asthma) and chronic (neuro-, reproductive, hematopoietic, genetic and pulmonary toxicity and cellular damage) health effects http://www.ehjournal.net/content/pdf/1476-069X-13-82.pdf
[96] http://www.who.int/ceh/capacity/radiation.pdf

tanks.

An assessment of the scope and severity of the Tara region's air pollution is not possible from a review of the adhoc single point data sets that are available, or from industry's reports of the estimated air releases. However, both the real world experience of serious particulate pollution and the consolidation of available information, does paint a worrying picture of the region's air quality and its possible impacts. It requires both an urgent investigation and precautionary management responses to protect human and environmental health.

Observed Health Impacts on Tara Residents

The physical and social impacts on the affected residents have been substantial but the Queensland Government's Health Report[97] into residents' complaints was cursory and included little clinical investigation. The report concluded that it was unable to determine whether any of the health effects reported by the community were linked to exposure to CSG pollutants. This was not a surprising finding and but one that is common in cases of chronic chemical exposures and suspected health effects, especially when no baseline health or environmental data was available. The report did however acknowledge that there was 'some evidence that might associate some of the residents' symptoms to exposures to airborne contaminants arising from CSG activities.'

In response to the Queensland government report which did nothing to allay community concern, in February-March, 2013 a Brisbane based GP, Dr Geralyn McCarron conducted a health survey of residents within the Western Downs gasfields. Her findings were published Australian and New Zealand Journal of Public Health.[98] Full details are also available in her report, "Symptomatology of a gas field."[99] Thirty-five households in the Tara residential estates and the Kogan/Montrose region were surveyed in person and telephone interviews were conducted with three families who had left the area. Information was collected on 113 people from the 38 households. Over half (58%) the residents surveyed reported that their health was definitely adversely affected by CSG, whilst a further 19% were uncertain.

In all age groups, there were reported increases in cough, chest tightness, rashes, difficulty sleeping, joint pains, muscle pains and spasms, nausea and vomiting. Approximately one third of the people over 6 years of age were reported to have spontaneous nose bleeds, and almost three quarters were reported to have skin irritation. Over half of children were reported to have eye irritation. Of particular concern were the symptoms that could be related to neurotoxicity (or nervous system damage), and the frequency with which these symptoms were reported in children.

Approximately a third of the all the children to age 18 were reported to experience paraesthesia (abnormal sensations such as pins and needles, burning or tingling). Almost all the children aged 6-18 were reported to suffer from headaches and for over half of these the headaches were severe. Of people aged 6 years and over, severe fatigue and difficulty concentrating was reported for over half. Parents of a number of young children reported twitching or unusual movements, and clumsiness or unsteadiness.

The people of the Western Downs gas fields had been reporting adverse impacts since 2008 when untreated CSG waste was sprayed on local roads for 'dust suppression.' In 2009, residents reported health impacts such as rashes, nose bleeds, nausea and vomiting which forced people to leave their homes.

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[97] Queensland Government's Health Report, *'Coal seam gas in the Tara region: Summary risk assessment of health complaints and environmental monitoring data, March 2013'*

[98] MacCarron, G. Symptomatology of a gas field 2013 Unconventional Natural Gas Development: Economic Salvation or Looming Public Health Disaster? *Australian and New Zealand Journal of Public Health* 2014.

[99] Symptomatology of a gas field, An independent health survey in the Tara rural residential estates and environs - http://www.ntn.org.au/wp/wp-content/uploads/2013/05/Symptomatology-of-a-gas-field-An-independent-health-survey-in-the-Tara-rural-residential-estates-and-environs-April-2013.pdf

Urine specimens from 16 people living in Queensland's gasfields were tested privately. Testing revealed a mixture of chemical contaminants including phenol, cresol, acetone, polycyclic aromatic hydrocarbons, methyl ethyl ketone, toluric acid, a metabolite of xylene and hippuric acid, a metabolite of toluene. 13 people had mixtures of two or more chemicals in their urine. The chemicals that returned positives in urine samples were not chemicals routinely tested for in normal pathology laboratories. Their reference ranges relate only to occupational exposure to a single chemical toxin, and relate to adult workers whose exposure is limited to a typical 8hour working day. There are no "normal" values or reference values for children exposed 24 hours per day, 7 days per week to a chemical cocktail.

The results of the survey carried out by Dr McCarron may have influenced the gas company, QGC decision two buyout six affected families from Tara.

Conclusion

Australian guidelines and standards currently do not take into account of low-level, chronic exposure particularly to environmental contaminants that demonstrate endocrine and epigenetic impacts. To assess the full impacts of UG development, this is essential and would need to be addressed as a priority. Nevertheless, all the monitoring and regulatory safeguards put in place around unconventional gas exploration and production cannot remove the threat of adverse impacts to water and air quality and to the health of all Victorians. When so much is at risk, the most simple cost benefit analysis would suggest that this is an industry that represents far too great a risk to Victorians and to Victoria's clean, green environment and reputation.