Health concerns associated with unconventional gas mining in Western Australia: A critical review

Part 1. Based on international experience, what are the potential health concerns associated with the development of shale gas mining in Western Australia?

Part 2. Are these health concerns adequately addressed by two Western Australian governmental reports that contributed to policy decisions on the topic?
“The Reports” reviewed in Part 2

“Hydraulic fracturing for shale and tight gas in Western Australian drinking water supply areas: Human health risk” WA Health Department, June 2015
(referred to as The WA Health Report)

and

“Implications for Western Australia of hydraulic fracturing for natural gas” Western Australian Standing Committee of Environment and Public Health Affairs, Report 42, 2015
(referred to as The WA Parliamentary Report)

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Health concerns associated with unconventional gas mining in WA

Abstract

This paper examines the evidence available from peer-reviewed journal publications regarding the broad array of health concerns associated with unconventional gas mining and whether two Western Australian governmental reports used to contribute to policy decisions on unconventional gas, adequately and accurately address these health concerns. The reports are:

- “Implications for Western Australia of hydraulic fracturing for natural gas” (Western Australian Standing Committee of Environment and Public Health Affairs, Report 42, 2015)
- “Hydraulic fracturing for shale and tight gas in Western Australian drinking water supply areas: Human health risk” (Western Australian Health Department, June 2015).

The literature review identified increasing evidence of multiple potential hazards and exposure pathways posing credible risks to human health, via air emissions, water contamination, psychosocial stress and climate change. Increasing numbers of published studies report associations between negative health and developmental outcomes and nearness of residence to and/or intensity of unconventional gas operations. These significant risks, combined with substantial gaps in understanding, prevent confirmation of the safety of the industry to health and the environment.

Four main concerns emerged from the examination of the two Reports, which prevent them from adequately and accurately assessing the potential risks and benefits of the industry to the health and wellbeing of Western Australians, based on current knowledge.

This paper concludes by urging the Western Australia government to conduct an updated and fully comprehensive review of the potential direct and indirect impacts of proceeding with an unconventional gas industry on human health and wellbeing, both now and in future. Six recommendations are made to maximize the value of such a review.
Executive Summary

This paper examines the evidence available from peer-reviewed journal publications regarding the broad array of health concerns associated with unconventional gas mining and whether two Western Australian governmental reports, used to contribute to policy decisions on unconventional gas, adequately and accurately address these health concerns.

Part 1. Based on international experience, what are the health concerns associated with the development of shale gas mining in Western Australia?

Providing a comprehensive, up-to-date and accurate answer to this question requires continuous attention to rapidly emerging evidence reported in the peer-reviewed literature. The number of papers on the topic of unconventional gas has risen rapidly from very few in 2012 to over 900 today as the pace and breadth of research has expanded dramatically across the United States. While gaps remain, most of the evidence from these studies has heightened, rather than reduced, concerns about potential negative impacts of unconventional gas mining on health and wellbeing.

In December 2016, a comprehensive systematic review of 156 peer-reviewed publications was published, examining the evidence of human exposures to harmful air and water pollutants, health impacts, seismic activity and climate impacts of unconventional gas mining. This review found multiple potential hazards to human health associated with mining and substantial gaps in understanding that prevented confirmation of the safety of the industry, and recommended no new developments in the United Kingdom until research demonstrated its safety. The major concerns identified by this systematic review and other research publications are described below.

There are direct local health concerns associated with living and working in close proximity to all steps of the unconventional gas mining process, not just the hydraulic fracturing (‘fracking’) component. Thus, any sincere examination of the implications requires us to broaden the scope of inquiry to all steps.

These local concerns include potential exposures to air pollutants released during the whole process, including volatile organic compounds, fine silica, oxides of nitrogen, hydrogen sulphide, formaldehyde, ground level ozone and diesel fumes. Local communities may also face stress from an array of changes, including exposure to noise, lights, odours, and dust, as well as worries and fears about health, accidents, declining property values, increased traffic, industrialised landscapes, loss of community cohesion, post-construction job losses, local business loss, and changes to community character.
Findings from various research studies have suggested associations between living close to unconventional gas operations and higher frequencies of negative health indicators, such as lower birth weights, more birth complications, more self-reported symptoms such as migraines, nasal and sinus problems and fatigue, and more hospitalisations due to heart, nerve and asthma conditions. These findings are concerning, and more research is needed to better understand these links.

At a local and regional level, unconventional gas activities near drinking water sources carry the potential for impacts on water quality. Dealing with wastewater from hydraulic fracturing safely remains a major challenge – each method and proposed new solution carries with it potential problems and complications.

At a global level, we are gravely concerned about the unconventional gas industry’s contribution to climate change. Hopes that fracking methods would allow gas to become a ‘safe and clean bridging fuel’—significantly lowering greenhouse gas emissions while we move from coal to renewable energies—are not supported by current knowledge. Current indications are that unconventional gas leads to higher than expected fugitive emissions of methane across all steps of the extraction and delivery process. This, with a more rapid than expected climate change progression, makes immediate steps to reduce emissions of potent greenhouse gases, like methane, a top priority.

Part 2. Are health concerns accurately and adequately addressed by The Reports that contributed to policy decisions on unconventional gas?

The Reports do not appear to have fully and accurately assessed the potential risks and benefits of the industry to the health and wellbeing of Western Australians, based on current knowledge.

There are four major concerns, identified as follows:

Concern 1. The Reports did not accurately and sufficiently acknowledge the recommendations from many professional public health and medical groups, both in Australia and abroad, to apply the Precautionary Principle to unconventional gas mining.

- These groups assert that, given the high degree of uncertainty regarding significant health risks and the extent to which these health risks can be managed, the industry should not be allowed to proceed until long-term safety is demonstrated. This assertion is based on evidence from the peer-reviewed literature and should not be overlooked or dismissed.
• Furthermore, the information contained in the submissions to the Inquiry from a number of health organisations, including the Department of Health’s own submission, do not appear to be adequately understood or considered in the Parliamentary Report. Of particular concern is the lack of legislative power of the Department of Health to guarantee that health considerations are given equal weight to other considerations in the decision-making regarding approvals, regulation, location and management of hydraulic fracturing operations. The submission also highlights the need for the Department of Health to be engaged from the start and granted sufficient power to proactively assess and participate in risk management and communication with sufficient information to provide transparent and accurate information to the community.

Concern 2. The terms of reference and/or scope of the review was not sufficient to capture the health and wellbeing risks associated with the unconventional gas industry. These risks arise from much more than just the hydraulic fracturing aspect of shale and tight gas mining.

• Some examples of insufficiently examined, but important, risks are exposure to chemicals in air and wastewater, including endocrine-disrupting chemicals, and mental health risks from psychosocial stress due to exposure to noise and loss of place and community cohesion.

• The Department of Health identified a number of other significant concerns associated with the unconventional gas industry, including air and soil pollution that needed to be fully addressed after the primary concern regarding the protection of water supplies was fully secured.

Concern 3. The Reports do not reflect current understandings from recent research evidence, which support, rather than refute, risks from unconventional gas activity. Other publications highlight the inadequacy of regulation in the protection of human and environmental health.

• Important examples include two systematic reviews, as well as a paper on asthma exacerbations (Journal of the American Medical Association). Another recent source provided evidence of impacts on drinking water resources, particularly the US EPA’s seminal final report entitled, “Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources,” December 2016. Many instances of proven contamination of water supplies as a result of various stages of the unconventional gas mining processes are described. The conclusion of this report was that contamination of water supplies can and has occurred. Furthermore the report highlights that, due to a lack of documentation and comprehensive data available, the extent to which drinking water resources have been impacted by hydraulic fracturing remains unquantified. Hence despite the extensive experience in the United States, the actual, as opposed to the predicted, safety of the operation to drinking water resources remains unknown.
In its Parliamentary submission, the Department of Health clearly states a position that hydraulic fracturing should not be allowed to occur in priority areas of public drinking water sources or within two kilometres of private drinking water wells, 100 year flood plains and lands with ‘sensitive use’.

Concern 4. Issues of potential bias in the interpretation and communication of knowledge-versus-opinion that favour industry over the communities that will have to bear the risks that industry brings.

In order to address this concern, we urge the government of Western Australia to conduct an independent and rigorous update of the evidence of potential health benefits or risks associated with the entire lifecycle of the industry. This would assist the State in making the best decision on the industry’s future.

This investigation should:

1. Engage the Department of Health as well as additional independent public health experts in defining the scope and terms of reference for the review, ensuring that it is sufficiently wide to include all significant health concerns and risks and the latest international and local evidence.

2. acknowledge that many professional public health and medical groups in Australia, the United Kingdom, the United States and elsewhere, are calling for the Precautionary Principle to be applied to unconventional gas development because of existing scientific evidence and continuing uncertainties regarding the multiple potential risks to people and the environment.

3. refrain from insinuating that the debate is simple and involves only myths and facts and communicate the correct definition of the precautionary principle in the proceedings.

4. accept that appropriate and accurate understanding of the implications of unconventional gas mining for Western Australia requires analysis of evidence from peer-reviewed literature, acknowledging that unproven regulations and untested solutions to challenging issues can place human health at risk. It also requires respectful listening to individuals and families whose lives have been disturbed by anticipated, perceived and actual impacts of gas developments near or within their farms, residences and communities.

5. fully reveal to the community the current evidence of risks and impacts across the entire lifecycle of this industry on health and wellbeing of people and their environment. The risks, and their impacts should they occur, need to be clearly recognised as community-borne costs worthy of compensation and consideration in economic, social and health cost-benefit analyses.
6. equally scrutinize and make public the realistic short-, medium- and long-term economic benefits of the unconventional gas industry to enable accurate comparisons between its full likely costs and benefits. This should also be used to compare the cost-benefit ratios of unconventional gas mining with other potential state developments that may carry greater benefits with fewer potential health and environmental losses.
Health concerns associated with unconventional gas mining in Western Australia: A critical review

Part 1.
Based on international experience, what are the health concerns associated with the development of shale gas mining in Western Australia?

1. Purpose of this critical review

This review aims to increase recognition and understanding of current knowledge from peer-reviewed publications regarding the direct and indirect risks and concerns relevant to shale gas mining operations to the health and wellbeing of potentially affected residents. The paper is aided by a comprehensive systematic review of 156 peer-reviewed papers and reviews of public health impacts of unconventional natural gas development conducted by Saunders, McCoy, Goldstein and Saunders. This work was published in the peer-reviewed journal *Environmental Geochemistry and Health* in December 2016.

This information is then used to examine two important Western Australian documents that appear to be guiding policy and decision making about the future of the shale gas industry in the state. We compare these documents with some of the submissions to the Inquiry from health organisations. We ask the question, do these documents fully and accurately assess the risks and benefits of the industry to the health and wellbeing of Western Australians? Is there certainty that the recommendations made in the reports are sufficient to protect the health and wellbeing of affected communities? We also consider how a green light on shale gas mining in WA may contribute to health challenges of future generations and people beyond the state.

2. Introduction

Until recently, methane (natural) gas used in households and industries around the world has mainly come from areas with large, concentrated deposits of gas that is released relatively easily (i.e., without fracking). As global reserves of these ‘conventional’ sources of gas from accessible locations are dwindling, remaining deposits, such as those located in deep offshore waters, are increasingly complex and expensive to recover. The gas industry is now focused on obtaining gas from ‘unconventional sources’, including gas within deep shale deposits in the Perth and Canning Basins of Western Australia. The government has expressed significant interest in promoting shale gas mining in these locations. As in other states and territories, this has been met with significant community opposition.
Because gas is spread out in low concentrations within shale beds, ‘unconventional gas’ mining requires many more wells and well-heads, and deep, horizontal drilling and fracking to release the gas. Because of the investment needed for these expensive operations, the capacity to link into a large international export market is often required in order for the venture to be commercially viable.

To date, there are few Australian examples of the industry for WA to learn from. Queensland has the most advanced unconventional gas industry, harvesting gas from coal seams that are much shallower than the shale beds in WA. The industry began gaining momentum in 2005, resulting in approximately 4402 wells in production by 2015\(^1\) and continuing. The industry extends across Queensland, in the form of pipelines and compressor stations, and major industrial development expansions for processing, liquefying and shipping gas overseas. The export business raises, rather than lowers, gas prices for Australian consumers—an impact that has already been felt by Queenslanders.

Australian experience with unconventional gas is recent and, therefore, limited. The United States’ experience is now extensive. The US Energy Information Administration estimates that there are currently 300,000 unconventional gas wells in production. It was estimated in 2013 that 15.3 million Americans\(^2\) were living within a mile of at least one unconventional gas or oil well that had been hydraulically fractured at least once since 2000. These extensive operations began despite very few peer-reviewed research publications on possible environmental and health impacts. Now there is a rapidly growing body of literature. In 2015, a count of peer-reviewed publications\(^3\) on environmental and public health concerns relevant to shale and tight gas mining found 685 publications, with over 80% published after 2013.

3. Two important definitions and some background concepts

Two terms need to be defined for the purposes of this paper. First, it is critically important to be aware that the word ‘fracking’ is often used in two different ways.

For the industry and in an engineering sense, ‘fracking’ is most often defined narrowly, meaning only ‘hydraulic fracturing’ – which is just one part of a very complex and multi-step process that finds, extracts, processes and delivers gas from unconventional sources for export or gas for domestic use. In sharp contrast to the engineering definition, communities tend to use the word ‘fracking’ to refer to the entire process that is used to produce unconventional gas, from start to finish.

\(^1\) https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0020/238124/petroleum.pdf
\(^2\) https://www.wsj.com/articles/SB10001424052702303672404579149432365326304
\(^3\) http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0154164
The scope of this paper is aligned with the community definition of ‘fracking’, also referred to as ‘shale gas mining’ or ‘unconventional gas mining’.

Secondly, it is important to remember in investigations such as this, that the definition of ‘health’ that is consistent with the Australian Institute of Health and Welfare (AIHW), refers not just to getting a disease as a result of exposure to chemicals used in hydraulic fracturing. The AIHW glossary defines health as follows:

*Term relating to whether the body (which includes the mind) is in a good or bad state. With good health the state of the body and mind are such that a person feels and functions well and can continue to do so for as long as possible.*

It defines public health as follows:

*Term variously referring to the level of health in the population, to actions that improve that level or to related study. Activities aimed at benefitting a population tend to emphasise prevention, protection and health promotion as distinct from treatment tailored to individuals with symptoms. Examples include provision of a clean water supply and good sewerage, conduct of anti-smoking education campaigns, and screening for diseases such as cancer of the breast and cervix.*

These definitions are consistent with Aboriginal definitions of health, which also emphasize the connection between an individual’s health and their contribution to the wellbeing of the whole community:

*Health is not just the physical well-being of the individual, but the social, emotional, and cultural well-being of the whole community. This is a whole-of-life view and it also includes the cyclical concept of life–death–life (NAHS Working Party 1989:x).*

Importantly, Aboriginal definitions of health consider not just present, but also future life and wellbeing. This is extremely relevant, for decisions made today may affect the health, wellbeing and quality of life of future generations. Indeed, Australians generally also care deeply about the health and wellbeing of current and future children.

The impacts of environmental damage may not be evident immediately and also may add to risks associated with other environmental changes. We must, therefore, consider possible future outcomes.
to make sure we protect the health of today’s children into their adulthoods and beyond. This means that uncertainties regarding any long-term impact should not be ignored or discounted as less important as short-term impacts.

4. What are the main concerns in terms of fracking's effect on health?

The need for shale gas mining to extend across large areas, often brings wells and other parts of the operation close, and sometimes very close, to where people live. Many communities are conscious of the wide array of changes in their physical and social environment brought with unconventional gas mining. Key concerns, for which evidence is growing, are described below.

4.1 Hazards and Potential Risk Pathways

4.1.1. Risks from air pollution

An array of chemicals capable of causing significant health impacts may be released during unconventional gas operations. These include:

1) volatile organic compounds, including BTEX (Benzene, Toluene, Ethylene and Xylene), that occur naturally in the shale, and evaporate from the flowback wastewater after fracking and from flaring excess gas;
2) endocrine-disrupting chemicals;
3) nitrogen oxides;
4) hydrogen sulphide from gas processing;
5) formaldehyde (from the breakdown of escaping methane);
6) diesel fumes from extensive truck movements and
7) ground level ozone, that forms from mixtures of pollutants and which is known to travel large distances.

Workers, and possibly people living very close to hydraulic fracturing operations, may also be exposed to unsafe levels of fine silica due to the large volumes of sand used, increasing the risk of silicosis.

4.1.2. Risks to water quality and water security

Many of the chemicals and chemical types mentioned above, plus additional chemicals such as polyaromatic hydrocarbons (PAHs), heavy metals, naturally-occurring radioactive materials (NORMs) and a wide array of known and unknown chemicals used in drilling and hydraulic fracturing fluid, have
the potential to damage the health of people who are exposed. Workers and community residents may become exposed through contact with water that has been contaminated through the handling of the large quantities of chemicals and wastewater involved. Water security could be affected by the large amounts of water used in each hydraulic fracturing event (many times per well, many wells), contamination of aquifers rendering them unusable for human consumption, and in some places damage to the ecosystem that may reduce the quality of drinking water sources. These concerns would be particularly acute during times of water scarcity and could cause competition with agriculture uses.

A news release on the seminal US EPA report4, “Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources”, released in December 2016, follows:

EPA identified cases of impacts on drinking water at each stage in the hydraulic fracturing water cycle. Impacts cited in the report generally occurred near hydraulically fractured oil and gas production wells and ranged in severity, from temporary changes in water quality, to contamination that made private drinking water wells unusable.

As part of the report, EPA identified certain conditions under which impacts from hydraulic fracturing activities can be more frequent or severe, including:

- Water withdrawals for hydraulic fracturing in times or areas of low water availability, particularly in areas with limited or declining groundwater resources;
- Spills during the management of hydraulic fracturing fluids and chemicals or produced water that result in large volumes or high concentrations of chemicals reaching groundwater resources;
- Injection of hydraulic fracturing fluids into wells with inadequate mechanical integrity, allowing gases or liquids to move to groundwater resources;
- Injection of hydraulic fracturing fluids directly into groundwater resources;
- Discharge of inadequately treated hydraulic fracturing wastewater to surface water resources; and
- Disposal or storage of hydraulic fracturing wastewater in unlined pits, resulting in contamination of groundwater resources.

The report provides valuable information about potential vulnerabilities to drinking water resources, but was not designed to be a list of documented impacts.

4 https://www.epa.gov/hfstudy
Data gaps and uncertainties limited EPA’s ability to fully assess the potential impacts on drinking water resources both locally and nationally. Generally, comprehensive information on the location of activities in the hydraulic fracturing water cycle is lacking, either because it is not collected, not publicly available, or prohibitively difficult to aggregate. In places where we know activities in the hydraulic fracturing water cycle have occurred, data that could be used to characterize hydraulic fracturing-related chemicals in the environment before, during, and after hydraulic fracturing were scarce.

[Author’s note: A most important point in this extract is this final sentence:] Because of these data gaps and uncertainties, as well as others described in the assessment, it was not possible to fully characterize the severity of impacts, nor was it possible to calculate or estimate the national frequency of impacts on drinking water resources from activities in the hydraulic fracturing water cycle.”

This conclusion makes it clear that, despite some 300,000 unconventional gas wells being drilled, hydraulically fractured and operating in the United States, the safety of the operation to drinking water resources is not demonstrated.

Further unknowns and uncertainties regarding water

At times, various ‘solutions’ to problems can actually cause further problems and may not be subject to research before implementation. For example, the siting of multiple wellheads on the same pad, and drilling multi-directionally may both reduce surface footprint. However, the wellheads may not be placed in optimal positions for the location of the ‘sweet spots’ of gas in each direction. This may mean longer distance drilling, and larger water requirements and greater pressures for hydraulic fracturing.

Furthermore, the reuse of flowback water after fracking for additional fracking (recycling) may result in increasingly high concentrations of hazardous chemicals, elevating risks in handling and ultimate disposal. According to Webb et al. (2014), recycling wastewater is not often used because of the increased concentrations of hazardous chemicals. An analysis by Parker et al. (2014) revealed multiple challenges in the treatment and management of fracking-affected water, which is also very expensive.

Any such proposed ‘adaptive management’ changes should be accepted only after extensive consideration of the potential complications and risks they may pose. Additionally, contamination risks to water in agricultural areas should also be seen as potential food safety concerns, as livestock and produce may be affected. Very little research has been done to investigate this possible concern.
4.1.3. Loss of mental health, psychosocial wellbeing and community cohesion

There are many avenues through which the unconventional gas industry can harm mental health and individual and community wellbeing. The initial phase impacts include distress and anxiety due to disagreements that split the community into those who support the industry and those who oppose it. In the 'boom' phase tight-knit communities can feel inundated with strangers coming in, swamping unprepared health and mental health services. Crime may also increase. Such impacts are detrimental to the social cohesion and for some, the moral character, of the community. In the post-construction phase, jobs decline dramatically and housing demand drops. Production ramps up with drilling and fracking, with its 24-hour lights, noise, odours, tree clearing and truck movements - causing some people to feel a deep sense of loss of control, loss of place and loss of peace and a feeling of being trapped and unable to escape. All of these phases present risks of depression, anxiety and increased use of alcohol and other drugs for coping.

There are particularly important concerns when considering the potential psychosocial and spiritual impacts of unconventional gas mining on Aboriginal people and communities. While there are no research publications to date, many Aboriginal and Torres Strait Islander people are leading efforts to protect the environment and health in the face of challenges from mining and climate change.

4.1.4 Risks for children

Since 2013, there has been an increasing focus on the likely vulnerability of developing fetuses and children to environmental hazards as compared to adults. The complex developmental processes that occur during gestation are exquisitely sensitive to chemicals and signals in the uterine environment. There is a growing understanding of the negative impacts of various exposures to the mother during pregnancy on birth outcomes, for example air pollution (PM2.5) and tobacco smoking on birth weight and preterm births, as well as alcohol and other drugs on brain development. Many of the chemicals involved in unconventional gas mining have reproductive and developmental toxicity.

Infants and children continue to face higher risks from toxic exposures due to their higher metabolic and respiration rates, their smaller body size and smaller and immature organs, including the liver, lungs and kidneys that deal with or store many toxins that enter the body. Children also experience greater exposure to toxins in the environment through outdoor play activities, compared to adults.

It is also very important to recognise that infant and child well-being is highly sensitive to psychosocial and community stressors, including noise, negative emotions expressed by others and witnessing aggression and conflict.
Despite this, only a small body of literature specifically examines potentially harmful exposures to air- and water-borne pollutants associated with unconventional gas mining for children. Two reviews by Webb et al. (2014, 2016) identify significant concerns:


### 4.1.5 Greenhouse gas emissions and climate impacts

Unfortunately, early claims that the use of unconventional gas for energy will have positive impacts on greenhouse gas emissions in comparison to coal are no longer justified. The idea that gas makes a good ‘bridging fuel’ to assist the transition from coal to renewable energy sources is not validated. It is now clear that the impacts of gas emissions were underestimated for a number of reasons:

- Compared to what was initially expected, higher proportions of the extracted gas escapes as fugitive emissions. This occurs for reasons of well-casing failures, or leaky pipes and infrastructure or, possibly, fracking-induced channels for gas flow from underground to surface.

- The recognition that methane’s long-term impact on warming is 86 times more potent than carbon dioxide over 20 years.

- The enormous impact of accidents involving well blowouts and leakage from methane storage sites, as exemplified by the 2016 Aliso Canyon disaster, but potentially occurring at many similar sites in future.

### 4.1.6 Insufficiency of regulation to prevent these risks

Regulations on paper are neither sufficient, nor appropriately implemented to prevent damage from the industry – due to human failure, for example. Instances of failure in the United States are presented in
the fourth edition of the “Compendium of scientific, medical and media findings demonstrating risks and harms of fracking” (unconventional gas and oil extraction).

4.2 Evidence from studies measuring health Impacts

As stated previously, studies attempting to measure health impacts of the industry remain relatively few but are increasing, and are mostly limited to physical health consequences. Negative health outcomes that have been found to occur more often in groups of residents with greater exposure to shale gas mining, compared with groups with lower exposure, include:

- Developmental problems during pregnancy and infancy – lower birth weight, small for gestational age, higher frequency of serious birth complications, specific birth defects.

- Hospitalisations – for cardiovascular and neurological disorders and for those with existing asthma conditions (emergency department visits and inpatient stays).

- Symptoms – migraine headaches, chronic nasal and sinus irritation, fatigue, nausea, skin rashes, eye irritation, nosebleeds, and asthma worsening requiring medication changes.

While these findings are associated with unconventional gas activity geographically, they do not provide ‘proof’ of cause and effect. This is to be expected because we lack specific measures of exposure to the chemicals and stressors involved. Research necessary to provide direct causal evidence of effects, such as randomized controlled trials, are unethical and unfeasible in this context. However, an increasing number of studies provide support for a causative relationship between the industry and elevations in these health concerns by demonstrating:

- Plausibility – there are logical links between the health problems being experienced and the kinds of chemicals and distressing experiences associated with living near industry operations.

- Dose-dependence – finding a higher frequency of problems with higher exposure (closer distance to wells, higher densities of wells, more intense gas production).

- Time relationship – showing that the increases in health problems began only after commencement of industry activities in the areas.

- Association still evident after allowing for other causes – for example, controlling for the potential contribution of smoking, socioeconomic status, community age profiles, legacies of other industrial activities in the area, etc.
4.3 Principles regarding public health

Good health is highly cherished. Australian citizens generally believe that their state and national governments make responsible decisions that protect their health above other considerations, even where there is uncertainty. Thus many people assume that the precautionary principle is being applied by government, i.e., that preventive action would be taken in the face of uncertainty; that the proponents of a proposed activity would be required to demonstrate its safety, not the community; that governments would explore a wide range of alternatives to possibly harmful actions; and that government would encourage public participation in decision making⁵.

It should be noted that many public health and medical organisations are calling on governments to apply the Precautionary Principle in this situation, and refrain from allowing unconventional gas mining to occur in Australia until there is sufficient evident demonstrating that it is safe for people and the environment. Among these organisations are:

- Doctors for the Environment Australia⁶
- Public Health Association of Australia⁷
- Australian Medical Association⁸
- National Toxics Network⁹
- Climate and Health Alliance¹⁰, which includes 28 professional health bodies including the Australian Psychological Association, the Australian Council for Social Services, Australian College of Nursing and the Australian Research Alliance of Children and Youth.


⁷ https://www.phaa.net.au/documents/item/726


¹⁰ http://www.caha.org.au/healthy_energy
Part 2.

Critique: Are these health concerns adequately addressed by The Reports that contributed to policy decisions on the topic?

The Reports examined in this critique are the Standing Committee of Environment and Public Health Affairs report 42 entitled, “Implications for Western Australia of hydraulic fracturing for natural gas,” (the WA Health Report) and the WA Health Department’s report entitled, “Hydraulic fracturing for shale and tight gas in Western Australian drinking water supply areas: Human health risk” (the WA Parliamentary Report). Further submissions into the Inquiry by the Department of Health and other public health and environmental health organisations were also reviewed.

Contemporary evidence (summarized in Part 1) was used to assess the adequacy and accuracy of two Western Australian government reports that have thus far contributed to government policy and decision making on unconventional gas in the state. This analysis concludes that The Reports could not fully and accurately assess the potential risks and benefits of the industry in regard to the health and wellbeing of Western Australians, in the light of knowledge now available in 2017.

It is also important to note that clear evidence was provided in submissions to the Inquiry from a range of health organisations including the Department of Health, about potential health risks that are not brought forward in the WA Parliamentary Report. Furthermore, the significant uncertainties regarding the safety of the industry to human health from air pollution, noise, soil contamination, threats to livelihoods and psychosocial stressors and as a result of contamination of drinking water sources and risks to food security.

Justification for this statement of inadequacy and for recommendations going forward includes:

Concern 1. The reports did not accurately and sufficiently acknowledge the recommendation from many professional public health and medical groups, both in Australia and abroad, that the Precautionary Principle should be applied to unconventional gas mining.

Applying the Principle would mean that the industry would not be allowed to proceed until there is sufficient evidence that ensures the safety of people and the environment. This is advisable due to the large number of potentially significant hazards involved in the unconventional gas industry, the emerging evidence of health impacts, and the large number of persisting uncertainties, particularly of potential cumulative (long-term) impacts.
We emphasise, this assessment has been conducted with knowledge available to 2017, which was not available to the Committee and Health Department. Nevertheless, by 2014, public health and medical opinion in the United States, Australia and other countries was increasingly raising serious questions about the uncertainties surrounding the safety of the industry, and many negative incidents had already been reported in the United States in easily accessible locations. Many medical and public health groups, including the Australian Medical Association, Doctors for the Environment Australia, Climate and Health Alliance, Public Health Association of Australia and the National Toxics Network called for a moratorium and/or application of the Precautionary Principle in unconventional gas mining until the large number of uncertainties were resolved.

While there was substantial input and quotations from the industry and engineering associations, notably ACOLA, regarding industry safety to the environment, there was no corresponding voice from public health and medicine reported in the inquiry that appeared to raise and explain the array of human health risks and concerns arising from the industry. Although a range of health concerns were mentioned in the WA Health Report, they were not examined in depth or considered in the WA context.

The most extensive systematic literature review on the public health impacts of unconventional gas mining to date (Saunders et al., 2016) reported the following definition of the Precautionary Principle, updated from its original publication in 2001:

*The Wingspread Declaration on the Precautionary Principle counsels that ‘When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not established scientifically. In this context the proponent of the activity, rather than the public, should bear the burden of proof’ (Science and Environmental Health Network 2016).*

In concluding their review of 156 peer-reviewed publications on exposure pathways [air, water], seismicity, and health, economic and social and climate change impacts associated with unconventional gas mining, the authors [Saunders et al. (2016)] state:

*As the available evidence does not enable a definitive public health judgment, a position shared by the US Centers for Disease Control (Centers for Disease Control and Prevention), we have a duty to pursue and assess that evidence while ensuring that, in the meantime, communities are not exposed to unacceptable risks. Several countries and North American states have banned, or imposed moratoria on, hydraulic fracturing including France, Bulgaria, Germany, Scotland, Wales, New York, Nova Scotia, Newfoundland, Quebec and New Brunswick (Finkel et al. 2015) … Considering the uncertainties surrounding the health, environmental, social, global warming potential and economic
implications of unconventional gas within this internationally recognised framework, it would seem prudent to incentivize further research across all the domains of UNGD related impact, and delay any proposed developments until the products of this investment have been peer-reviewed and assessed.

The Western Australian Department of Health, Doctors for the Environment Australia, the Public Health Association of Australia, Environmental Health Australia and individual medical and health professionals, among others, submitted information to the WA Inquiry that raised many concerns about the impact of the industry on human health. Much of this informed knowledge and the consensus regarding uncertain risks and concerns raised do not appear to have been adequately investigated in the WA Parliamentary report.

While the WA Health Report does raise a number of uncertainties, there is an implied acceptance that health risks can be managed. As the first sentence of the Foreword states, “The Western Australian Health Department continues to be a strong advocate for adoption of a risk management approach for all proposals for new industries, developments or technologies where people live or work close to public water resources, to ensure protection of health”.

It is recognised, however, that the WA Health Report is only one component of a number of submissions and contributions of the Department of Health to the Parliamentary Inquiry. Three of these are publically available, namely:

- Written submission into the Inquiry, October 2013;
- Transcript of the evidence provided by the Executive Director of Public Health and the Principal Toxicologist of the Western Australian Department of Health on February 17, 2014;
- Written submission of additional evidence provided by the Executive Director describing the management of radioactive material in Western Australia.

These documents demonstrate that the following concerns were made known to the Inquiry, including:

- That limitations of the Health Act 1911 do not enable the Department of Health to “act proactively and on a risk management basis”. This situation leaves the Department of Health without legislative power to ensure the protection of health within resource proposals and can, and has, according to the Legislative Assembly (2007, p. 93), led to “a recurring theme of ‘...a failure to place Public Health considerations on the same basis of other considerations’.”
The submission argued that it is imperative that this be corrected and that the Department of Health be consulted and engaged from the start and in decision-making processes. The Department also emphasizes that the absence of legislative power prevents a requirement for its involvement in proactively assessing and preventing risks to water supplies and contamination.

- That “good risk communications with transparent and accountable disclosure of risks” balanced ‘as much as possible’ with Commercial in Confidence needs of the industry is required.

- That P1 and P2 Priority source protection areas for Public Drinking Water Source Areas be identified and off limits to hydraulic fracturing, and that hydraulic fracturing not occur within the EPA separation distance of 2km from private drinking water wells, 100 year flood plains and ‘sensitive land uses’.

- That proposals for the re-use of recycled wastewater be required to comply with existing national guidelines for water recycling and reuse for the protection of the environment and health.

The Department of Health submission also includes a full and accurate definition of the Precautionary Principle, and identifies its relevance to considerations regarding approvals for unconventional gas developments.

It is critical to also consider that risk management approaches are sufficient only where the technical capacity to alleviate all risks exists and is clearly and sufficiently demonstrated. Relying on risk management approaches also requires certainty that a sufficient level of regulation, monitoring, early detection, correction and preventative actions can be operationalised, paid for by appropriate bodies, and sustained over time. Experience documented in the US EPA Final Report regarding impacts of hydraulic fracturing in the United States shows that such a level of assessment, monitoring, detection and correction has not occurred, making it impossible to able to estimate on a wide scale how much contamination of water supplies has resulted from the industry. This raises serious questions about the extent to which people have been exposed to undetected contaminants in water they have consumed, and particularly to endocrine-disrupting chemicals that have the potential to affect human development and reproduction at very low concentrations.

Furthermore, the Physicians for Social Responsibility and Concerned Health Professionals of New York have compiled four extensive editions of “Compendium of scientific, medical and media findings demonstrating risks and harms of fracking” (Unconventional oil and gas extraction) in the United States.
The authors argued that, based on this extensive experience, “regulations have not prevented significant harms; and that some harms are not preventable through regulatory opportunities”.

Even if risk management were theoretically possible, all governments should be asking whether their regulatory agencies have – and will continue to have - the capacity to adequately monitor and respond to the many potentially hazardous chemical, social, mental and physical health risks posed by large numbers of producing and depleted wells. The future security of these regulations will depend on the commitment of future government leadership to place the protection of human and environmental health above that of industry demands, where conflicts exist.

It therefore appears that these evidence-based arguments may have been included in the discussion of ‘exaggerations’ described in the WA Parliamentary Report, rather than as evidence regarding uncertainties that require serious examination. With further evidence accumulating, this is a serious oversight.

**Concern 2. The terms of reference and/or scope of the review were not sufficient to capture the health and wellbeing risks associated with the unconventional gas industry. These risks arise from much more than just the hydraulic fracturing aspect of shale and tight gas mining.**

Item 1.8 identifies that “The Committee is satisfied that the four issues emphasized in its terms of reference: land impact, chemical use, water quality and the legacy of hydraulic fracturing reflect recurring concerns identified in submissions received”. It also indicates that the Committee did its own research. It is not clear why the Committee did not recognize the many additional concerns raised in the literature and in the submissions of many professional health bodies and scientists. These include climate change, chemical exposure, air pollution and psychosocial and community distress presenting risks to mental health.

The need for shale gas mining to sprawl across large areas, often bringing wells and other parts of the operation close and sometimes very close to the places where people live, work, go to school and play is a major and immediate concern. While many other developments introduce a number of community impact concerns, the particularly extensive industrial aspects of the unconventional gas industry and the health concerns that accompany them, are likely a driver of unusually high levels of community opposition. Without clearly articulating and addressing these concerns with residents, who have a diversity of perspectives, and serious attention to the alleviation of psychosocial and physical risks, it is unlikely that a ‘social licence’ will be obtained.
It should be noted that the Department of Health identified a number of significant concerns associated with the unconventional gas industry, including air and soil pollution that needed to be fully addressed after the primary concern regarding the protection of water supplies was fully secured.

**Concern 3. The Reports do not reflect current understandings from recent research evidence which support, rather than refute, risks from unconventional gas activity. Other publications highlight the inadequacy of regulation in the protection of human and environmental health.**

Most of the Health Risk Assessment work within the WA Health Report was done in 2014 and based on government reports rather than peer-reviewed publications, which were sparse at the time. Since 2015, many key publications have helped to advance our understanding, and simultaneously increased confidence in the real possibilities of these risks. The WA Health Report raises many questions that have guided the surge in new research and commentary since 2014, when this research was in its infancy.

Two new publications of particular importance to assessing health risks associated with chemicals in hydraulic fracturing fluid and wastewater are summarized below:


This study examined the carcinogenicity data on a total of 1177 chemicals in fracking fluids and wastewater (US EPA) and 143 chemicals identified in scientific papers reporting air pollutants that were published before 2016. The researchers found that over 80% of these chemicals were not evaluated for carcinogenicity. Among the 119 chemicals that were evaluated, 49 water and 20 air pollutants were possible, probable or known carcinogens and 20 were associated with leukemia/lymphoma, including benzene, 1,3 butadiene, cadmium, diesel exhaust and PAHs.


Summary: This study examined the reproductive and developmental toxicity of 1021 chemicals identified in fracturing fluid, wastewater or both. The researchers found that toxicity information was lacking for 781 (76%). Among the 240 that had been evaluated, 103 were known to have the potential for reproductive toxicity and 95 for developmental toxicity.
The previously mentioned comprehensive systematic literature review by Saunders et al. (2016) highlighted a major gap in our understanding of the interactions between the many chemicals in wastewater produced after hydraulic fracturing. Interactions are not considered in the WA Health Report – not surprisingly because there is still little to no understanding of this complex area, as reported by Saunders et al (2016).

Furthermore, the Health Report states on page 6 that chemical by-products or chemicals within flowback water do not need to be identified, referencing the Department of Mines and Petroleum (2013). Given that many of the air-borne pollutants, notably BTEX chemicals, as well as heavy metals, naturally occurring radioactive materials and polyaromatic hydrocarbons exist in the flowback water, it is unclear how these potentially toxic chemicals will be assessed.

Finally, the WA Health Report does not examine the growing body of concern regarding endocrine-disrupting chemicals involved in unconventional gas mining. Evidence of endocrine-disrupting activity in surface and groundwater in areas with unconventional gas mining raises concerns. These chemicals can interfere with endocrine function at very low concentrations without any signs or symptoms.

Balise et al. (2016) published a systematic review of 45 peer-reviewed publications examining the association between conventional gas extraction processes and the presence and potential impacts of endocrine-disrupting activity. The review concluded that there is moderate evidence for an increased risk of preterm birth, miscarriage, birth defects, decreased semen quality, and prostate cancer that could result from disruption of the estrogen, androgen, and progesterone receptors by chemicals associated with oil and gas production. The authors postulated that unconventional gas mining was likely to pose more risks to reproductive health than conventional gas operations given the many endocrine-disrupting chemicals involved in the hydraulic fracturing process. Key papers include:

**Other peer-reviewed publications not available at the time of The Reports:**

Other examples of systematic literature reviews of particular relevance for human exposures, [direct] human health risks, socio-economic impacts and climate change include the following:


Other important examples of recent papers addressing health impacts of unconventional gas developments include:


The following publication provides the first quantitative evidence of the extent to which farmers’ anxieties about unconventional gas mining (CSG) contribute to the burden of stress and mental health
problems among farmers and so adds to the large literature on the psychosocial impacts of coal and gas mining communities:


Recent publications on potential impacts on drinking water resources

The likelihood and severity of impacts on drinking water supplies were identified as leading considerations for Western Australia’s policy development on unconventional gas mining. There is now a much larger body of research examining this in the peer-reviewed published literature than there was in 2014. Most notable is a seminal report released in its final version by the US EPA in December 2016. The EPA has found scientific evidence that activities in the hydraulic fracturing water cycle can and has impacted on drinking water resources at many steps of the process, including both surface and ground water sources. The report does little to support the suggestion that the risks to drinking water supplies is negligible or manageable with regulatory regimes.

Further, the EPA report highlighted the lack of data available:

Because of ..... data gaps and uncertainties, as well as others described in the assessment, it was not possible to fully characterize the severity of impacts, nor was it possible to calculate or estimate the national frequency of impacts on drinking water resources from activities in the hydraulic fracturing water cycle.

This conclusion makes it very clear that, despite some 300,000 unconventional gas wells being drilled, hydraulically fractured and operating in the United States, the experienced safety of the operation to drinking water resources cannot be properly quantified.

Recognising, even in October 2013, prior to many recent studies, the Department of Health’s submission to the Parliamentary Inquiry clearly states a position that hydraulic fracturing should not be allowed to occur in priority areas of public drinking water sources or within two kilometres of private drinking water wells, 100 year flood plains and lands with ‘sensitive use’.

This advice does not appear to be adequately noted or addressed in the WA Parliamentary Report.
Concern 4. Issues of potential bias in the interpretation and communication of knowledge- versus-opinion that favour industry over the communities that will have to bear the risks that industry brings.

The WA Parliamentary Report carries a perhaps-unintended tone that can be interpreted as disrespectful and lacking in transparency in the discussion about ‘facts’ and ‘myths’. The reality is — as now described in the US EPA’s final report and in the extensive systematic literature review by Saunders et al. (2016) identified above — that there are many uncertainties and unknowns that cannot be ignored. These uncertainties are not myths — they are highly significant to considering the current and future impact of the unconventional gas industry. Examples include: long-term well integrity, how actual gas yields over time influence the rate of well proliferation for commercial viability, GHG emissions and climate impact, behaviour of the mixtures of chemicals involved in water and air-borne emissions as opposed to toxicities of individual chemicals, etc.

It is disappointing that in the four mentions of the ‘Precautionary Principle’ in the WA Parliamentary Report, no definition of the principle is provided. One such mention (Chapter 4, section 4.1.08; page 65) quoted from the Department of Health submission follows:

- All decisions relating to hydraulic fracturing should be transparent with all decision-making being properly supported with scientific evidence and in accordance with the Precautionary Principle.

With the exception of the above statement, each time the Precautionary Principle is mentioned, it is followed by a statement about an expectation of the total elimination and/or exaggeration of risks by precautionary proponents. The Precautionary Principle does not insist that all risks be eliminated and it should not be insinuated that the multiple public health and medical organisations, and the many jurisdictions that have decided not to go ahead at present, are either exaggerating or requiring complete elimination of risks.

The Department of Health submission to the Parliamentary Inquiry, along with those submitted to the Inquiry by other public health and medical organisations, provided the Inquiry with the accurate definition of the Precautionary Principle and simultaneously with reasons why its application is needed in decisions regarding hydraulic fracturing approvals.
Conclusion and Recommendations

The work undertaken towards the WA Parliamentary and Health reports were completed in 2014 and 2015. Since that time, there has been a surge in peer-reviewed publications. The majority of these publications, including two seminal systematic literature reviews and a US EPA report presenting extensively analysed experimental evidence on impacts on drinking water supplies, have only added weight and urgency to our concerns regarding the potential for significant health impacts to be borne by the WA community.

The new evidence includes studies showing associations between the industry and increased presence and concentration of air and water contaminants and psychosocial stressors which may impair health. Children have been identified as potentially at greater risk. In parallel, studies report increased frequency of health impacts, such as frequencies of asthma exacerbations, cardiovascular and neurological conditions requiring hospitalisation, lower birth weights and other birth complications, nasal and sinus symptoms, migraine headaches and increased mental health burden are all associated with living close to industry operations and are gravely concerning.

In order to address this concern, we urge the government of Western Australia to conduct an independent and rigorous update of the evidence of potential health benefits or risks associated with the entire lifecycle of the industry. This would assist the State in making the best decision on the industry’s future. This investigation should:

- Engage the Department of Health as well as additional independent public health experts in defining the scope and terms of reference for the review, ensuring that it is sufficiently wide to include all significant health concerns and risks and the latest international and local evidence.

- Acknowledge that many professional public health and medical groups in Australia, the United Kingdom, the United States and elsewhere, are calling for the Precautionary Principle to be applied to unconventional gas development because of existing scientific evidence and continuing uncertainties regarding the multiple risks to people and the environment.

- Refrain from insinuating that the debate is simple and involves only myths and facts and communicate the correct definition of the precautionary principle in the proceedings.

- Accept that appropriate and accurate understanding of the implications of unconventional gas mining for Western Australia requires analysis of evidence from peer-reviewed literature, acknowledging that unproven regulations and untested solutions to challenging issues can place
human health at risk. It also requires respectful listening to individuals and families whose lives have been disturbed by anticipated, perceived and actual impacts of gas developments near or within their farms, residences and communities.

- Fully reveal to the community the current evidence of risks and impacts across the entire life cycle of this industry on health and wellbeing of people and their environment. The risks, and their impacts should they occur, need to be clearly recognised as community-borne costs worthy of compensation and consideration in economic, social and health cost-benefit analyses.

- Equally scrutinize and make public the realistic short-, medium- and long-term economic benefits of the unconventional gas industry to enable accurate comparisons between its full likely costs and benefits. This should also be used to compare the cost-benefit ratios of unconventional gas mining with other potential state developments that may carry greater benefits with fewer potential health and environmental losses.

Any health (and socioeconomic, international security, environmental) assessments of the implications of further developments to extract unconventional gas (itself a highly potent greenhouse gas) cannot be complete without consideration of the state of the climate. Concentrations of carbon dioxide in the atmosphere are now permanently above 400 parts per million according to the US National Oceanic and Atmospheric Administration\textsuperscript{11} with previously unseen impacts on global stability in temperature, sea level rise, droughts, floods and heat waves. These lead to well-documented direct and indirect health impacts and contribute to the urgency of our response to move to clean, renewable energies. There are large net improvements that would be achieved in reducing greenhouse gas emissions as well as all of the health impacts described in this report by shifting from unconventional gas to existing renewable energies. These improvements dwarf those that might achieved in transitions from coal or ‘clean coal’ to unconventional gas, and arguably at lower cost.

The sooner our decision makers commit and follow through on the actions we need in rejecting continuation of coal, oil and gas production and welcome proven cleaner energies such as wind and solar, the more health benefits will accrue to the people of Western Australia and globally.

We urge the new Western Australian government to conduct an updated and fully comprehensive review of the potential direct and indirect impacts of proceeding with an unconventional gas industry on human health and wellbeing, both now and in future.

\textsuperscript{11} https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html
Bibliography

Peer-reviewed Publications used in the preparation of this report

(arranged by topic area)

1. Peer-reviewed publications and reputable published reports (identified by *) providing general reviews including comprehensive and systematic reviews on a range of health impacts


2. Peer reviewed papers examining associated population health impacts (excluding birth outcomes and papers with specific focus on children)


3. Papers raising further, particular concerns regarding safety for developing foetuses and children


4. Peer-reviewed papers and US EPA report regarding risks to drinking water


Extensively reviewed in:


5. Peer reviewed papers examining air quality


Extensively reviewed in:


6. Peer reviewed papers and CSIRO report examining psychosocial and community wellbeing impacts


7. Peer-review papers and seminal reports examining climate change impacts


