requesting an extension of the due date for a submission to the review

Melissa Haswell -Elkins to: csg.review@chiefscientist.nsw.gov.au 23/04/2013 05:44 PM

History: This message has been replied to and forwarded.

Chief Scientist of New South Wales

Dear Professor O'Kane,

I have been working over the last month on the aggregation of evidence on the public health and wellbeing concerns and potential benefits and risks associated with coal seam gas mining in NSW with a group of students studying environmental health in the Master of Public Health program. Because their work is very timely and relevant to your current review, I am exploring the possibility that their report could be collated and used either directly or indirectly as a contribution to your process.

This poses some logistical processes that have delayed us slightly. Would it be possible to receive an extension of time on the due date to Monday May 6 in order to make our submission? That would be much appreciated if it is possible.

Many thanks and kind regards,

Melissa Haswell

Associate Professor Melissa Haswell
Muru Marri Indigenous Health Unit
School of Public Health and Community Medicine
310 Samuels Building
University of New South Wales
UNSW Sydney 2052 Australia
61-2-9385-3324

RE: submission for the Chief Scientist Review of Coal Seam Gas Mining in NSW

Melissa Haswell -Elkins to: csg.review@chiefscientist.nsw.gov.au 08/05/2013 10:24 PM

History: This message has been replied to and forwarded.

Dear Rebecca,
Thank you so much for the extension of deadline for submission of our report.
Please find attached a submission from 12 postgraduate students and myself for the Chief Scientist's review of the evidence regarding health impacts of coal seam gas in New South Wales.
You may place the report under my name (Melissa Haswell-Elkins and colleagues).
Please don't hesitate to ring me on my mobile 0415 568 536 if there is anything else I can assist with or clarify for the Chief Scientist.

kindest regards
Melissa Haswell

Associate Professor Melissa Haswell
Muru Marri Indigenous Health Unit
School of Public Health and Community Medicine
310 Samuels Building
University of New South Wales
UNSW Sydney 2052 Australia
61-2-9385-3324

From: rebecca.radford@chiefscientist.nsw.gov.au [rebecca.radford@chiefscientist.nsw.gov.au] on behalf of csg.review@chiefscientist.nsw.gov.au [csg.review@chiefscientist.nsw.gov.au]
Sent: Friday, 26 April 2013 10:00 AM
To: Melissa Haswell-Elkins
Subject: Re: requesting an extension of the due date for a submission to the review

Dear Professor Haswell-Elkins

Thank you for your email of 23 April, apologies for the delay in responding.

We are more than happy to extend the deadline to Monday 6 May to ensure we receive your submission.

Kind regards
Rebecca Radford

Office of the NSW Chief Scientist & Engineer
Level 49 MLC Centre | 19 Martin Place | Sydney NSW 2001 | GPO Box 5477 | Sydney NSW 2001
T: 02 9338 6786 | F: 02 9338 6760 | E: csg.review@chiefscientist.nsw.gov.au
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From: Melissa Haswell-Elkins <m.haswell@unsw.edu.au>
To: "csg.review@chiefscientist.nsw.gov.au"

<csg.review@chiefscientist.nsw.gov.au>
Date: 23/04/2013 05:44 PM
Subject: requesting an extension of the due date for a submission to the review

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Chief Scientist of New South Wales

Dear Professor O'Kane,

I have been working over the last month on the aggregation of evidence on the public health and wellbeing concerns and potential benefits and risks associated with coal seam gas mining in NSW with a group of students studying environmental health in the Master of Public Health program. Because their work is very timely and relevant to your current review, I am exploring the possibility that their report could be collated and used either directly or indirectly as a contribution to your process.

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School of Public Health and Community Medicine
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61-2-9385-3324

Haswell-Elkins and Environmental Health students at SPHCM.pdf

2013

Examination of the evidence of potential health and wellbeing risks and impacts of Coal Seam Gas Mining: Submission to the Chief Scientist of New South Wales

Contributors

The authors of this report were twelve students of PHCM9612 Environmental Health offered through the postgraduate public health program of the School of Public Health and Community Medicine at the University of New South Wales.

The Course Convenor. Associate Professor Melissa Haswell-Elkins, collated the student information, checked the reports for general accuracy and performed light editing where needed for consistency and quality.

Editorial assistance and reference management in this work was provided by Marcia Grand Ortega and Sarah Gaskin.

For further information or to provide comment on this document, please contact:

Associate Professor Melissa Haswell-Elkins
Muru Marri Indigenous Health Unit
School of Public Health and Community Medicine
University of New South Wales
Telephone 02-9385-3324
Email: m.haswell@unsw.edu.au

This work was completed with no external funding and represents the view of the twelve participating students. There were no conflicts of interest involved in this exercise. It is provided to the Chief Scientist in good faith to assist in her review of the evidence regarding the potential concerns, risks and impacts on public health associated with the coal seam gas mining industry.

Table of Contents

Foreword to the NSW Chief Scientist from the Course Convenor

This report presents a partial review and analysis of some health risks and impacts associated with coal seam gas mining conducted by students of Environmental Health at the School of Public Health and Community Medicine at the University of New South Wales.

The School is recognized among Australia's leading contributions to ensuring maximum public health and wellbeing into the future. This is achieved through three core activities; namely:

- teaching and learning to prepare the public health workforce for critical current and future challenges,
- research that enhances decision-making, practice and policy that places the protection of public health and wellbeing at the top of priorities,
- service that enables our expertise and deep understanding of what makes the public healthy to directly benefit Australia and the world as a whole.

Prominent among the School's contribution is the Master of Public Health, Master of International Public Health and Master of Health Management Programs that enrolled over 250 students in 2013. The postgraduate public health elective, PHCM9612 Environmental Health, draws students from each of these programs and from environmental management and health and safety science. It is taught both internally and externally through a combination of workshops, annually updated course notes, weekly sessions and on line communication.

The Course's first two marked assignments embed group work activities on urgent environmental health priorities to enhance students' capacity to work collectively to:

- brainstorm the array of potential public health concerns and risks;
- search, collect and analyse relevant evidence and identify gaps on the above; and
- synthesise, assess and/or recommend on how best to proceed in line with health promoting/protecting manner.

In 2013, coal seam gas mining was chosen as the focus of this work for many reasons, e.g.:

- the growing evidence base from which risk and concerns could begin to be assessed;
- the breadth of concerns it raises across many basic requirements for good health;
- its potential impact on both severity of and capacity to respond to climate change;
- its enormous local topicality given the large number proposals before the government; and
- the significant engagement and response among the public and health organisations.

The Scenario we created, i.e. that the students were requested by a network of health organisations concerned about CSG to review the evidence in order to support the NSW Chief Scientist, essentially became a reality. This gave students a real sense of their ability to make a difference to government policy and decision-making processes.

This Report should be viewed in the context that its primary purpose was a learning and assessment exercise. While the class included highly knowledgeable and experienced public health practitioners from Australia and overseas and medical doctors, most had limited prior engagement with the issues raised by unconventional gas, climate change, pollution, toxicology, etc. While entering into all of these 'big issues' at once was somewhat overwhelming for some, it was also a unique opportunity to first establish a clear understanding of the big picture of human health and environmental sustainability, and then progress to learning in depth about a specific challenge.

Thus this report is fresh in its view and written by people deeply embedded in the core values and principles of public health and community medicine. These include:

- the equivalent priorities of physical, mental, social and societal wellbeing;
- the preference of promotion and prevention over cure and 'fixing problems' whether they be felt among individuals, groups, communities or society as a whole;
- the necessity of ensuring health and safety for the most vulnerable; and crucially
- the paramount status of intergenerational equity because of the enormous environmental deficit being passed on to today's children and future generations.

At the same time, there are also limitations in the report, especially related to time. The students had four to five weeks to research their topic area and prepare a brief report and three weeks to examine and synthesise the information from the 21 reports from their classmates with their own research into an Executive Summary. This was in addition to covering weekly topics of this course, and for some, the requirements of three to four other courses; for others, demanding full time jobs and often one or more additional courses.

Also making this exercise on CSG different from many typical assignments is the extremely rapid pace of information accumulation – with some pivotal reports on unconventional gas released even within the five week period. Some students were able to continue incorporating new reports and information into their paper up to the due date, while others only had limited time to stay on top of important information, especially from the 'grey' literature (e.g. information from reputable sources but not yet within the academic peer-reviewed literature which can take years).

The opportunity to have work included in this report provided as a submission to the Chief Scientist was discussed in class and individually. Inclusion in this report relied on students actively 'opting in' to having their name, topic and/or executive summaries included, and it had no bearing on their mark in a positive nor negative way. Twelve students opted in.

The students created a document that uses peer reviewed evidence and trustworthy government and independent institute reports on coal seam gas mining directly where possible. They incorporate information from other unconventional gas mining experience where relevant. Where not possible, they have combed the available information from Senate Inquiries, discussion and commentary from reputable sources, policy documents, websites, etc. to ensure that vital aspects of the risk picture were not being missed.

Where information was missing, but legitimate health concerns were clear, the students used informal causal pathways analysis – that is, harvesting knowledge from similar situations where health loss has occurred and applying this to the current situation where the same likely causative factors were present. This is a sophisticated way of building on what we already know from vast public health research experience about the physical, mental, social and societal determinants of what makes people healthy or not healthy.

These extensive processes were necessary because there has been virtually no concerted funding effort to comprehensively investigate or assess the health impacts of CSG mining on local, regional, state or national level. We hope that the research-poor situation in the United States is not replicated here in Australia; this requires funding bodies to enable these studies to be done in a manner that fully and proactively protects health and wellbeing.

Personally, in all my years of teaching, I have rarely observed such intensity of interest and consistent quality in a brief student task. It has been a pleasure to observe these adult scholars apply their skills and expertise in public health and medicine to understand and communicate within a fast moving area of science, medical and public health intelligence and health advocacy.

We commend the NSW government for the key announcement in February 2013 of "Tough New Rules" which according to our Premier Barry O'Farrell ***"These actions clearly place public health and safety at the heart of all CSG activities"*** (Premier Barry O'Farrell, press release, February 19, 2013). The call for an independent review of coal seam gas activities in New South Wales with a focus on the impacts on human health and the environment of the process and industry by the Chief Scientist, and her subsequent call for assistance from the public has led to substantial efforts among academic groups, scientific, medical and public health organisations. This submission, from postgraduate scholars at the University of New South Wales, is offered to the Chief Scientist to assist her very important work in potentially ensuring the wisest use of 23% of the state's land in the 21st century. The information presented seeks to assist in the following two items within the terms of reference:

1. identify and assess any gaps in the identification and management of risk arising from coal seam gas exploration, assessment and production, particularly as they relate to human health, the environment and water catchments
2. identify best practice in relation to the management of CSG or similar unconventional gas projects in close proximity to residential properties and urban areas and consider appropriate ways to manage the interface between residences and CSG activity

It is the students' and my sincere hope that our work supports a state policy on this high impact industry that ensures protection of physical and mental health and psychological, social and economic well being of all people of New South Wales, including our youngest people and generations to come. On behalf of this group of students, I thank you for the opportunity to share this important work and for making this "scenario" a valuable reality.

Associate Professor Melissa Haswell-Elkins
Muru Marri Indigenous Health Unit
School of Public Health and Community Medicine
University of New South Wales

Part 1. Individual Executive Summaries, Assessments and/or Recommendations

Each student presented a unique perspective in their way of summarizing on their understanding of the various health and wellbeing risks and impacts of coal seam gas mining in NSW. Eleven are presented here from student who wanted their work to become part of a submission to assist the Chief Scientist of NSW. No adjustments were made to the words of the students, apart from correcting a few spelling errors, and the only modification made was to provide some format consistency.

Please note that the references to report chapters provided in these Executive Summaries were made from the original student report containing seven chapters and 22 topics in 92 pages of text. In the Part 2 of this report, we have consolidated the twelve topics written by the students who wished to 'opt in' their papers to this report into four sections. Hence we apologise for the unavoidable mismatch, but feel certain that other contributors to the Chief Scientist call for assistance will have provided detail on the areas not included.

ORIGINAL FULL REPORT

Chapter		*Topic*
1 Water	A	Hazards of Fracking Fluid used in Coal Seam Gas mining
	B	Potential risks from produced water
	C	Potential impacts on aquifers and water supply
2 Gas emissions and air pollution	A	Air Pollutants and their health risks
	B	Indirect effects of air pollutants on health in non-urban areas
	C	Indirect effects of air pollutants on health in non-urban areas
	D	Contribution of methane gas emissions to climate change
3 Land use	A	Potential risks of soil contamination
	B	Impact on the availability and allocation of land for other uses
	C	Healthy planning in the Coal Seam Gas industry
	D	Risks to food security
4 Potential risks to biodiversity	A	Biodiversity and natural heritage risks and concerns
	B	Possible impacts on plant and animal life
5 Psychosocial wellbeing and mental health	A	Concerns and risks for the wellbeing of farmers and their families
	B	Concerns and risks to the psychosocial wellbeing of urban residential communities
	C	Concerns and risks to the wellbeing of Young People
6 Economic impacts	A	Macroeconomic and socioeconomic impacts of the industry
	B	Community/Household level impacts + changing social dynamics (Microeconomics)
	C	Economic analysis of possible environmental and agricultural impacts
	D	Economic costing of potential health impacts in New South Wales (NSW): a conceptual approach
7 Risks to workers in the industry	A	Causing Serious "Grief"? The psychosocial impact of coal seam gas (CSG) mining for workers
	B	Occupational accidents of the mining industries

PART 2 OF THIS REPORT

Chapter		*Topic*
1 Chemical pollution risks to water, air and soil	1 A	Hazards of Fracking Fluid used in Coal Seam Gas mining
	3 B	Potential risks of fracturing fluids contaminating
	2 A	Air Pollutants and their health risks
	2 D	Contribution of methane gas emissions to climate change
2 Negative impacts on land: food security, biodiversity and landscape	3 A	Risks to food security
	3 C	Impact on the availability and allocation of land for other uses
	4 A	Biodiversity and natural heritage risks and concerns
	4 B	Possible impacts on plant and animal life and resulting pharmaceutical potential and geographic disease profiles
3 Psychosocial and mental health concerns: farmers, youth and CSG workers	5 A	Concerns and risks for the wellbeing of farmers and their families
	5 C	Concerns and risks to the wellbeing of Young People
	7 A	A Causing Serious "Grief"? The psychosocial impact of coal seam gas (CSG) mining for workers
4 Will health losses overcome economic gains?	6 D	Economic costing of potential health impacts in New South Wales (NSW): a conceptual approach

Executive Summary 1

Purpose. Coal Seam Gas (CSG) industry offers the promise of increased job opportunities, government revenue and a cleaner energy source. CSG has been operating in Queensland for more than ten years and has recently started explorations in New South Wales (NSW). CSG proposals in NSW initiated a robust discourse across various stakeholders about the positive and negative consequences of the industry. Much less is known about its potential health impacts and a comprehensive review is lacking. The purpose of this document is to compile and review available information in both academic and gray literatures regarding the health concerns surrounding the CSG industry.

Methodology. The class of PHCM9612 (Term 1, 2013) conducted an extensive literature review. In a workshop held at the start of the semester, the class was introduced to the topic of CSG in NSW. Guided by the social determinants of health, seven general areas of health concerns were then identified. Each area of concern was allocated to at least two individuals who then focused on a different sub-topic of that area. This resulted to each member of the class reviewing a unique topic. Individual reports were then compiled to produce this document.

Findings. This document is divided into seven chapters. There are at least two sub-topics per chapter. Summary of key findings are as follows:

Chapter 1: Water – Hazards of fracturing fluid (FF), Potential risks from produced water and Impacts on aquifers and water supply. FF is used to maximize the yield of CSG from the wells. It is also one of the most controversial components of the process because of two reasons. First is the non disclosure of the exact chemical composition of the FF. Second is the scarcity, but not absence, of data for health effects of the specific chemicals used. Reports of exposure from FF found that the most common symptoms were those relating to endocrinologic, neurologic, and dermatologic systems on both humans and livestock.

Hydraulic fracturing requires large amounts of water which is in short supply in Australia. The situation is aggravated by occurrence of more droughts and warmer summers attributed to climate change. This leads to the concern of water supply insecurity and its accompanying consequences. Furthermore, produced water from the industry has been shown to contain copious amounts of salt and several toxic chemicals aside from those used in FF. These were attributed to the possible liberation of naturally occurring toxins in the ground due to the fracturing process. Such pollutants are argued to potentially reach the groundwater aquifers or evaporate to the atmosphere. This then adds to the threat on water security (amount and safety).

Chapter 2: Gas emissions – Air pollutants, Health effects to urban and non-urban population, and Methane gas. Various substances found in the emissions warrant health concerns. Ozone resulting from interaction of sunlight and volatile chemicals from well sites contributes to smog formation and could directly affect the respiratory system. Particulate matter from engines is expected to increase as a result of industry-related traffic and machine use. Volatile organic compounds such as benzene, a known carcinogenic, have been identified in CSG mining areas. There is also the burden of overall air pollution which unevenly affects human and animal populations.

Increased noise pollution (from industry processes and increased traffic) has also been identified to adversely affect the general wellbeing of nearby residents. However, no active investigation has been done. It also causes restlessness among livestock that is arguably more sensitive to smaller noise levels. CSG activities have also been associated with increased bushfire risk as illustrated in the past summer seasons. Several old and faulty wells were documented to be burning within high risk areas.

CSG industry in Australia mines for methane, a natural gas considered as a cleaner energy source which helps address climate change issues. The irony is that methane itself is a potent greenhouse gas, much more than carbon dioxide. The problem is the unaccounted amount of methane gas which escapes from the wells, both the expected (from the initial well establishment and drilling process) and unexpected (from faulty or dried-out wells).

Chapter 3: Land use risks and concerns – Soil contamination, Competition for alternative land use, Healthy planning, and Food security. Soil contamination could originate both from the introduced FF and from the liberated, soluble substances that come with the produced water. In addition, the high salinity of produced water coupled with the possible mechanical topsoil degradation would render the land non-viable for growing crops. These are scenarios observed from industry spills and open evaporative pits. Non-viability of land for agriculture and livestock use poses risks to long-term food security.

Soil contamination threatens human health through direct skin absorption of chemicals, effects on agricultural produce, and consequences on livestock. Furthermore, properties like low soil absorption provides chemicals high mobility thus increasing the risk to reach and pollute groundwater. This contributes to the threat to water security.

Health impact assessments (HIA) are inadequately accomplished as part of industry planning, if done at all. Inputs from public health experts are seldom included. While this could be attributed to the contrasting priorities, lack of funding and organisational and government commitments to HIAs are also identified causes.

Chapter 4: Potential risks to biodiversity – Biodiversity and natural heritage concerns, and Impacts on (non-agricultural) plant and animal life. There are two important concepts that highlight the connection of humans and changing environment. First is *solastalgia* which is a form of melancholia felt by people when their home environment in changing in a profoundly negative way. Second is *biophilia* which in essence is love of nature. These two concepts provide a theoretical framework on how the changing environment brought by CSG exploration (with its potential harmful effects to local ecology and uncertain land recovery) affects the local residents through a perceived violation of natural beauty and heritage of their homes. These are substantiated by related theories like stress recovery, attention restoration, and restorative environment which explain the positive physiological effects of natural environments.

Loss and fragmentation of natural habitats is another concern which threatens biodiversity. The relatively short lifespan of gas wells coupled with the planned volume of wells to be built necessitates wide land areas for clearing. This is in addition to the noise and chemical pollutions that affect smaller living animals, including endangered species, which arguably have a lower tolerance level than humans. This could result to direct animal health concerns or changing animal behaviours that could endanger human populations (i.e. proliferation or migration of disease vectors).

Chapter 5: Risks and concerns to psychosocial wellbeing and mental health – Farmers and their families, Urban residential communities, and Young people. Changing of the landscape to suit CSG industry affects the psychosocial wellbeing of farmers beyond *solastalgia*. The land use compensation of CSG companies to the farmers compared to the estimated income per well is perceived as a form of inequity. Aside from this, farmers have the perspective that the lands which they have long cared for are suddenly entered by strangers to explore minerals. This impression of intrusion builds a deeper sense of frustration and powerlessness among land owners. These add to the stress they are already experiencing in dealing with natural challenges for farming like drought. Such experiences have been shown to result in depression.

Surrounding residential communities are also affected through increased traffic of heavy vehicles, potential environmental and noise pollution, and concern for decreased property value. While there have been significant successes such protection of vineyard areas, the equity question remains how different the issue is compared to lands tending other crops. Population dynamics is also affected through the constant flow of both short and long-term migrant workers (and their families) in the communities. Such movement presents another range of concern pertaining to the welfare and development of young people, and the adequacy of infrastructure and services to meet the increased demands.

Chapter 6: Economic impacts – Macro- and micro-socioeconomic concerns, and Economic valuation of land use and health impacts. Economic growth, cleaner energy alternatives, energy security and job creation are the most significant arguments promoting CSG industry in NSW. The extent of each claim varies and the costs of such benefits are often not cited. For example, while job opportunities will definitely be available, there is ambiguity as to who (local versus non-local) will be employed. Furthermore, the demand and duration of human resource to manage CSG wells varies, and it decreases from the well construction to maintenance phase. Moreover, this increase of jobs in the mining industry doesn’t account for the potential jobs lost and overall economic loss from alternative industries (e.g. tourism/agriculture/local businesses) replaced by land use change. It also doesn’t account for economic loss from current and long-term agricultural produce and livestock potentially compromised by environmental pollution.

The incongruity between government and health professional group statements raises much concern. Measuring the economic value of possible health impacts of the CSG industry in NSW is a challenge because of the technical ambiguity of classifying the range of health issues as primary or secondary, where secondary effects are excluded from assessments. Furthermore, there is need for further information on CSG related materials such as the components of FF chemicals and their potential health effects.

Chapter 7: Risk to workers in the industry – Psychosocial impacts and occupational hazards. It is understandable that workers within the industry would have second thoughts in taking any action that would endanger their own job security. It comes to no surprise that occupational and mental health concerns of CSG workers are minimally represented. Aside from the issue of conflicting interest, cultural values such as "machoism" reduce the intensity of health concerns. In addition, the possibility of an ethical dilemma is real such that one would rather face occupational hazards (e.g. exposure to crystalline silica) rather than have no job at all. Furthermore, the psychosocial wellbeing of workers, particularly of those facing and dealing with the angers and frustrations of local communities is an unexplored area.

Preventive measures to protect workers from occupational hazards are in place as part of safety regulations. However, the extent of protection it offers against undisclosed company chemicals is problematic.

Figure 1 is a simplified mapping of the identified mechanisms where the CSG industry generates health and wellbeing concerns. The number superscripts indicate the chapter where the topic is found. Indeed, these pathways are more complex and inter-related than represented such that one topic is discussed in more than one chapters. Table 1 summarizes the findings of this health sector assessment for CSG industry in NSW. Actual references for the collected evidence are available within the full report. This also lists the range of knowledge gaps needed to better understand the health concerns.

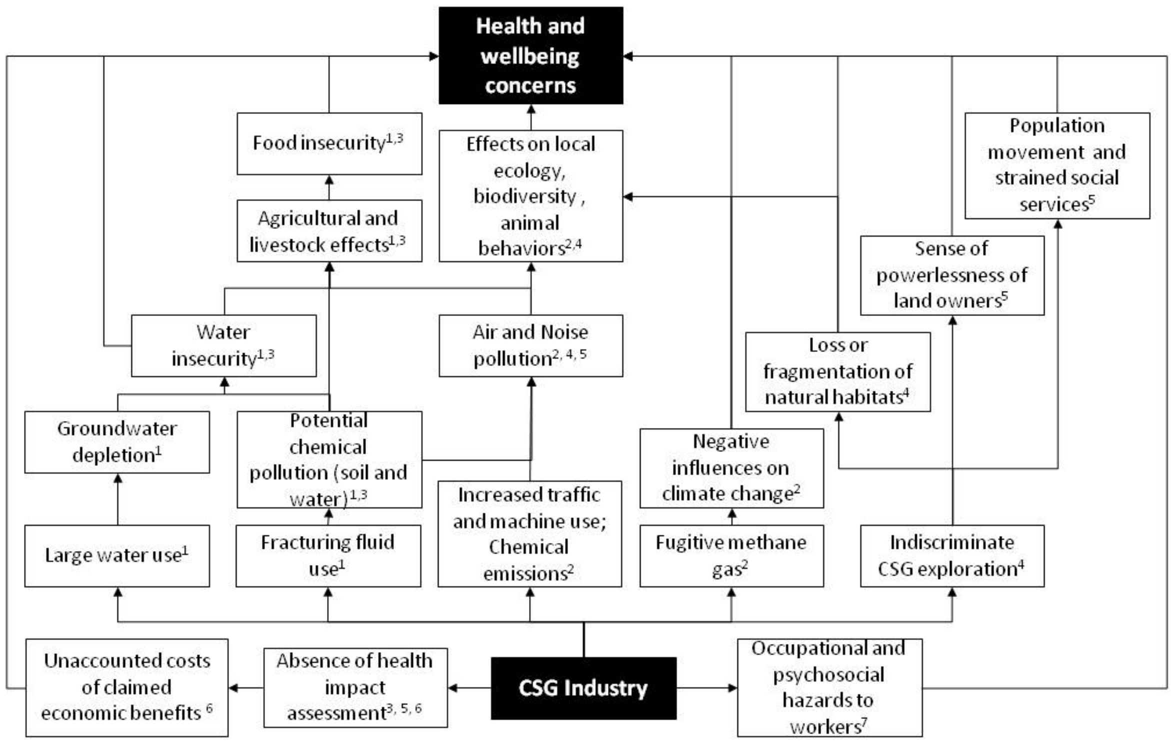

Figure 1. Conceptual map of CSG leading to health and wellbeing concerns

Conclusion. Project proposals, be it from the CSG industry or any other, reflects maximum effort in identifying all potential benefits from the project. However, in identifying all potential risks and the total price to pay to reap such benefits, the intensity of effort is often obscured by conflict of interests. This report discloses the wide landscape of health concerns surrounding CSG industry in NSW.

In the study conducted by Hendryx and Ahern (2009) in the Appalachian coal mining regions in the US between 1979 to 2005, significant health disparities were identified among areas with different degrees of mining activities. Their study concluded that the human cost outweighs the economic benefits of the mining industry. Currently, there is insufficient evidence to confirm or disprove whether a similar outcome awaits NSW. With a decade of existence in Queensland, government and other stakeholders should have an active and joint effort to investigate CSG activities and concerns for human health. The opportunity for empirical investigation is present which would pave the way towards a better informed stakeholder dialogue and eventual decision making.

Overall, there are sufficient knowledge gaps and potential health and wellbeing impacts identified that justify a moratorium on the rapid expansion of CSG exploration in NSW. Until further information becomes available, creation of a comprehensive risk management plan to place the potential health risks within acceptable limits remains a challenge.

References

Hendryx, M., & Ahern, M. M. (2009). Mortality in Appalachian Coal Mining Regions: The Value of Statistical Life Lost. Public Health Reports, 124, 541 - 550.

Table 1. Health sector assessment summary

CSG related factors and activities	Potential health impacts	Chapters cited (See full report for evidence)	Knowledge gaps for evidence-based actions
Fracturing fluids	Various toxicologic effects	1, 3, 4	Health effects of chemical components; Effects on local ecology (biodiversity), species with lower threshold of sensitivity than humans; Effects on agriculture and livestock
Occupational hazards	Spill of pollutants causing various toxicologic effects; Direct worker trauma; Health and wellbeing risks of industry workers	1, 7	Health effects of chemical components Safety precautions; Risk management plan; Paucity of data possibly due to conflicting interests
Produced water	Salinity; Various toxicologic effects	1, 3, 4	Chemical analysis of produced water; Effects on local ecology (biodiversity), species with lower threshold of sensitivity than humans; Effects on agriculture and livestock; Sustainable disposal or treatment mechanisms
Depletion of groundwater	Water security for agriculture, livestock and other domestic uses	1, 3	Complex dynamics of surface and ground water movement in aquifers; Conflicting estimates of CSG industry water use
Ozone, particulate matter, volatile organic compounds, Radon	Respiratory system effects; Cardiovascular system effects; Smog and its consequences	2	Extent of concentration of resulting ozone from natural gas processing; Link between CSG drilling and health effects through air quality monitoring; Health effects from chronic, low level exposure; Unknown health effects of other gaseous emissions
Fugitive methane gas	Potent greenhouse gas	2	Unaccounted and uncontrolled methane gas escape
Noise pollution	Wellbeing effects	2, 4	No active investigation; Effects on local ecology (biodiversity), species with lower threshold of sensitivity than humans; Effects on livestock
Increased bushfire risk	Direct injury	2	Continuing CSG activities during summer seasons in high risk areas
Soil pollution	Food insecurity; Indirect through food and livestock;	3, 4	Substance uptake of agricultural plants and livestock; Health effects of chemical components; Land recovery and rehabilitation plan; Long-term viability of land for agricultural use; Effects on local ecology (biodiversity), species with lower threshold of sensitivity than humans
Exploration based on deposits without regard to farmers or residents	Negative effects to psychosocial wellbeing	4, 5	Issues of inequity; Insufficient research in the area of CSG industry and psychosocial wellbeing and living impacts on affected populations (farmers, residential communities, young people)
Economic benefits	Questionable sustainability and unaccounted opportunity costs across the sectors	6	Unaccounted loss of jobs from other sectors due to land use change; Variable amount and duration of jobs depending on the life cycle of a well; Questionable job benefactors (local versus non local); Absence of health impact assessment and ambiguity of classifying primary versus secondary health effects

Executive Summary 2

Overview

Over the last decade there has been growing concern around the subject of climate change and global warming and the ongoing impact these changes are going to have on humanity. There is now an undeniable reality that consumption of fossil fuels with the ongoing generation of greenhouse gasses (GHG) is bringing us to a point of no return, where global temperatures will ultimately rise to levels where life as we know it will be unsustainable. Weather patterns are already changing causing flooding in some regions and devastating long term droughts in others. Environmental pressures are increasing with rapid loss of plant and animal species and irreversible changes to ecosystems, all of which impact both directly and indirectly on health and wellbeing. Since every economy is dependent on energy, most of which is derived from non-renewable fossil fuels, attention is turning to other sources of energy, including renewable supplies. It is within this context that Coal Seam Gas (CSG) mining is experiencing a boom, proponents highlighting the advantages, including smaller environmental footprint, less GHG production, minimal disruption to local communities as compared with large mining projects and an economic windfall for governments as well as local communities and businesses not to mention the provision of cheaper energy.

As an industry, CSG activities have been occurring in Australia for the last 16 years primarily in Queensland with greater recent focus in New South Wales (NSW). These activities which include forcing high pressure mixtures of sand, water and fracking fluid (chemical mixture and water) into superficial bedrock to release mainly combustible methane has been occurring in the United States for several decades with varying results and increasing concern on the impact to health and environment. These concerns stem mainly from the use of vast quantities of fresh water, chemical mixtures the content of which remain trade secrets, slow but seemingly irreversible changes to landscapes and natural habitat, contamination of ground water supplies, soil contamination and loss of arable land and the slowly increasing evidence of negative health impacts both physical and mental of local communities exposed to CSG activities.

In Australia over the last 5 years, there has been rapid expansion of the industry, where research has not kept pace with new developments, resulting in decisions taken without reliable or proven evidence, the potential consequences of which being detrimental to both the environment and human health. Further to this, there is a perception that economic gains have been put ahead of community health and environmental concerns, with minimal consultation and feedback from energy companies in relation to their activities, impact on agriculture, overall economic benefits, land recovery and reuse and overall health impacts on those communities affected.

In view of the above, it was the purpose of this report to review the available evidence in relation to potential risks posed by CSG activities to health and wellbeing. The scope was reasonably broad, with seven key areas identified from which risks could be ascertained. The method of identification of these seven areas were determined by looking at what the broader impact from CSG activities may be both locally and regionally, the possible long term ramifications at a local and global level and the connections between environment, health, economy and social issues that may all be impacted by these activities. To this end the report is subdivided into seven chapters covering the topics of water, gas emissions and air pollution, land use, effects on natural heritage and biodiversity, impacts on mental health and psychosocial wellbeing, economic impact and lastly the effects on workers within the industry.

The context of this report should be viewed as health pertaining to the entirety of wellbeing and which include physical, mental, social, economic and environmental aspects of health. In reading this report, it should be recognised that many of the identified risks cannot for convenience sake be separated, and are indeed many times interlinked and overlap.

Sources of Potential Risks to Health

The following will be covered in greater detail within the body of the report but are highlighted to draw them to the attention of the reader as focus points. These include risks to health arising from:

- **Water usage and contamination.**

As already mentioned most of the chemicals used in the CSG process are unknown and the threat of direct contamination to fresh water sources from fracking fluid remains real. Secondly, contamination through improper management of produced water also poses a threat to health both directly through chemical exposure, as well as indirectly through soil, crop and livestock exposure. On both counts chemicals used in the CSG processes as well as those occurring naturally and released by mining activity have been found to be toxic to humans and animals and pose a serious threat to health. Lastly, CSG requires huge quantities of fresh water, 300 gigaliters by some estimates and since Australia already has a chronic water shortage, this poses serious issues of sustainability around water supply for general human consumption and agriculture.

- **Air pollution and gas emissions.**

CSG activities are known to release chemicals harmful to health into the air, including volatile organic compounds and heavy metals. Secondary pollutants such as sulphur and carbon dioxide are also produced from the diesel engines of trucks and generators. Although not in Australia, evidence from studies in Colorado suggest that residents living in close proximity to CSG mining are at greater risk of ill health than those further away, suggesting a definite link between exposure and disease. Further to this, there is now evidence to conclude that fugitive methane gas emissions are higher than originally thought, and put in doubt the argument that CSG will help limit GHG emissions. Methane is also a highly volatile and flammable gas increasing the risks to both health and environment from direct exposure as well as increasing fire hazard.

- **Soil contamination and loss of arable land.**

Contaminated soil poses both a direct risk to health from inhalation or ingestion of dust containing hazardous chemicals and indirectly from consumption of food grown in contaminated soil or which has been irrigated with improperly treated waste water. Issues of agricultural sustainability and food security pose real risks to long term health especially in the context of climate change and although there is now an improved policy pertaining to protection of water sources and agricultural lands in NSW, it still does not cover land reuse and recovery. Compounding the obvious risks to health are the planning issues surrounding land use. To date, environmental impact studies have included only brief health impact assessments and then usually with little public health input for those communities effected by CSG activities directly, or from the effects which may occur regionally over time.

- **Loss of biodiversity and natural heritage.**

Although not in direct relation to CSG, links have been made to loss of natural habitat and ill health. Given the greater context of climate change and global warming in which CSG is occurring, there exists a real threat to health over time from the irreversible changes which CSG mining brings. There exists also a real indirect risk to health from changes to local ecosystems, where the risk of increasing vector borne diseases arises, changes in migratory patterns of birds carrying disease and also from loss to the pharmaceutical industry for research and development of new medicines.

- **Psychosocial issues within affected communities.**

To date, most of the impact has been on farming communities already considered to be vulnerable to mental health problems. There now exists a genuine risk from CSG activities that an increased burden will be placed on farmers from financial inequity, disenfranchisement and exclusion from decision making processes resulting in greater mental ill health. Further to this, as CSG mining encroaches on urban communities, there is risk to health from noise pollution, increasing road traffic, loss of sense of community and sleep disturbances. Lastly, the effects which may occur in young people cannot be ignored. As population dynamics change, there is increased pressure on available resources such as schooling and health services. Changes to family dynamics also raise the risks for increasing risky behaviours in young people, such as increased drinking, drug taking and unprotected sex, all of which lead to increased physical and mental ill health.

- **Economic inequity.**

The risks to health arise here indirectly from a potential for economic inequity to exist within communities where a labour shortage may develop, labour costs increase and prices of good rise. The indirect effect on health would most certainly be from socioeconomic differences resulting in mental health issues and possibly physical ill health from increasing risk taking behaviours and poor nutrition.

- **Industrial activities.**

Little has been said on the possible risks to health of workers who are part of CSG mining. As with any industrial activity there exists a real risk to health from exposure to chemicals and dusts as well as from accidents. Decreased psychosocial wellbeing could also come about as their exposure to triggers of mental ill health such as shift work, isolation, noise and dust increases the risk of depression, anxiety and increases risk taking behaviour.

Risks Arising from Uncertainty

The detail of the report is as comprehensive as the evidence allows. As mentioned, CSG activities are reasonably new in Australia, and consequently there exists uncertainties surrounding their full impact on both health and the environment, both now and into the future. For this reason, collectively, the uncertainties themselves pose a risk to health since they form gaps in our knowledge and understanding preventing us from fully quantifying the overall risk to health and wellbeing in relation to CSG activities. These are mentioned here as knowledge of them could inform further studies and are therefore important in this regard and in understanding the limitation of the presented evidence in this report. These include but are not limited to:

- lack of full disclosure of the chemical constituents of fracking fluid
- effects on both surface and ground water from removal of large quantities of water from the Artesian Basin
- long term effects on land use and agriculture
- the viability of land rehabilitation and potential for reuse
- impact of CSG on agriculture and long term food security
- understanding and quantifying the long term fugitive gas emissions in the context of climate change and in comparison with other GHG producers
- greater impacts on psychosocial factors effecting mental health
- direct effect on physical health, including increased risk of carcinogenesis and mutagenesis
- understanding of the real economic impact, especially on small or rural communities already under economic pressure
- lack of full disclosure from mining companies and incomplete government planning procedures

Where to from Here?

There are two things of which we can be certain. Firstly, there is very real evidence that climate change is actively shaping our future, being visible through global warming and increasingly adverse weather events. Secondly, thriving economies require energy. Since changes in climate and ultimately our environment will directly influence and effect our health and wellbeing, we should be seriously questioning our reliance on non-renewable fossil fuels. While the need for energy is most certainly driving the rapid expansion of CSG mining, the evidence of its long term effects on the environment in which we live and indeed on our health has not kept pace. Consequently there is much anecdotal evidence to suggest links to ill health and environmental degradation but not specifically so. It is invariably this lack of strong evidence that large industries hide behind despite the obvious facts. Ultimately, common sense should prevail above economics and where there is potential for harm, extra precaution should be taken until further evidence to the contrary is obtained. Within the global warming context we would do well to slow down and evaluate what our long term priorities are before we jump from the frying pan into the fire.

Executive Summary 3

With available supplies of conventional energy resources such as coal diminishing, there is increasing pressure to realise new energy sources. One such energy source is coal seam gas (CSG), which is conventional natural gas, or methane, trapped in coal seams or other rock formations insufficiently porous for normal extraction of the gas. In order to extract the CSG, a process called hydraulic fracturing, or 'fracking', is carried out, where water mixed with chemicals and sand is injected into the coal seam at high pressure to disturb the rocks, causing the gas to be released. As fracking is a new industry, little research has been conducted regarding the potential costs or benefits of utilising this technology, however rapid expansion of CSG mining is occurring regardless.

To date, the question of health impacts caused by the effects of CSG mining on the environment has been largely ignored in the debate surrounding this energy source. The authors have therefore conducted a literature search of significant scope, in order to assess the extent of current knowledge in this area, and to determine if any conclusions can be drawn regarding the impact of CSG mining on environmental public health.

One of the main environmental health concerns arising from the fracking process relates to the chemicals used in fracking fluid. Many of these chemicals are toxic, and research outlined in Chapter one indicates that only two of the many chemicals used in fracking fluid have been studied by the Australian industrial chemical regulator (NICNAS), and that therefore their effects on ecological and human health are unknown. Limited small-scale studies in the United States of America have indicated that exposure to fracking fluid in humans may be detrimental to health. Chapter six also outlines research which demonstrates that there is a risk of direct harm to the physical health of CSG mine workers through exposure to fracking fluid, as well as other occupational hazards. Furthermore, as described in Chapter three, studies have demonstrated that the chemicals in fracking fluid can be detrimental to the health of livestock, meaning that contamination of agricultural land due to CSG mining could threaten Australia's food security. Finally, Chapter four presents research which indicates that the chemicals used in fracking fluid can have significant negative effects on native flora and fauna, an important source of novel pharmaceuticals.

Fracking processes result in the production of large quantities of contaminated groundwater, or 'produced water', which contains heavy metals, volatile organic compounds and many other toxins. Disposal of produced water can be achieved using evaporation ponds, reinjection into the aquifer, or, following treatment, release into surface waterways or in agriculture. In Chapter one, a study of the literature demonstrated that produced water may be a risk to human health, as the most common method of treatment, reverse osmosis, does not remove carcinogenic compounds such as benzene, which are then released into the environment. Furthermore, in Chapter two, research cited indicates that evaporation of volatile organic compounds from disposal ponds can cause hazardous air pollution at the site. As described in Chapter three, fracking poses a significant risk of soil contamination through incorrect disposal of produced water, or leaks of fracking fluid. Inhalation, ingestion of soil particles or foodstuffs grown in soil particles, or absorption through the skin can introduce these dangerous chemicals and heavy metals into the human body, causing disease. Finally, Chapter four outlines research that indicates that the evaporation ponds used to dispose of produced water could contribute to the spread of vector borne diseases, impacting on human health.

CSG mining is a highly water intensive process. Huge amounts of water are used in fracking fluid and the generation of produced water necessitates a depletion of aquifers. In Australia, the main source of water for CSG mining is the Great Artesian Basin (GAB), which is a critical water supply for the ecosystem and many rural communities. Research cited in Chapter one demonstrates that there is therefore a threat that fracking will result in water scarcity, as well the contamination of human drinking water with fracking fluid or produced water. In addition, as outlined in Chapters three and six, depletion of the GAB and other water resources, relied upon for irrigation for farming, could threaten Australia's food security, as well as the livelihoods of farmers and regional communities, both important social determinants of health.

Other potential health impacts of CSG mining relate to gas emissions and associated air pollution. A study of the literature presented in Chapter two indicates that sulphur dioxide, ozone, nitrous oxide, volatile organic compounds and particulate matter are all produced as a result of CSG mining. Such pollutants are known to have negative effects on human health. In a study conducted in New South Wales, "a total of 22 toxic chemicals were detected in the nine air samples, including four carcinogens, toxins known to damage the nervous system and respiratory irritants. The levels were between three to 3,000 times higher than levels established by public health agencies to estimate increased risk of serious health effects and cancer based on long-term exposure" Lloyd-Smith, et al. (2011). However, it is also important to consider research cited in Chapter two, which indicated that replacing coal with methane as a fuel source results in decreased overall levels of air pollutants.

In addition, research presented in Chapter two states that up to eight per cent of the CSG itself, methane, is released into the atmosphere as a result of fracking, almost twice as much as conventional gas drilling. Further research outlined in Chapter two states that leaking methane from CGS wells can ignite, causing bushfires, which can have a huge impact on both physical safety and mental health in humans. Furthermore, methane is known to be at least 25 times more potent than carbon dioxide as a greenhouse gas, although it has a shorter half-life in the atmosphere. Evidence described in Chapters two and six outlines industry claims that electricity generated with CSG results in 70 per cent fewer greenhouse gas emissions than electricity generated with coal. However, when methane leaked from the CSG wells is considered, other research described in Chapter two state that the overall impact of CSG on climate change is very similar to that of coal. Research presented in Chapter four outlines evidence that climate change is altering the geographical distribution of diseases, and therefore CSG mining may contribute to increasing incidence of tropical diseases in Australia.

The vast number of wells required to extract CSG and associated infrastructure such as roads also has implications for public health. As described in Chapter three, research indicates that CSG mining in agricultural areas can cause severe disruption to almost every aspect of the farming processes involved in grazing livestock and cropping, and leaves arable land unusable afterwards. According to research outlined in Chapter three, arable land constitutes a very small percentage of Australia, yet is the location of the largest CSG deposits. Excessive CSG mining therefore has the potential to threaten Australia's food security, which is one of the essential determinants of health, through utilisation of agricultural land for other purposes. Land clearance and subsequent habitat fragmentation caused by CSG mining may also result in a loss of biodiversity, which is important for public health as a source of novel pharmaceuticals, as described in Chapter four. Finally, changes to the landscape as well as pollution caused by CSG mining can have a negative impact on tourism, as outlined in research presented in Chapter six. This can be detrimental to the economy of affected communities, leading to negative mental and physical health outcomes, as employment is a determinant of health. To address these issues, land use planning is an important process to ensure that the competing interests of agriculture, mining and the health of the community are balanced when making decisions that affect the environment, which has not been adequately utilised to date.

In Chapter five, anecdotal evidence is described which indicates that CSG mining has a negative impact on the mental health of farmers and communities in proximity to the mines. Research outlined in Chapter four indicates that the loss of natural heritage by caused by CSG may contribute to 'solastalgia', distress caused by negative changes to a person's surrounding environment and a resultant feeling a loss of ownership of land and powerlessness, which can lead to negative health outcomes. Further research also suggests that a loss of open space and countryside can lead to poor mental health, as can the noise associated with mining activities in urban areas which causes sleep disturbance and stress. Stress can also contribute to an increased susceptibility to physical disease. Research presented in Chapters five and six indicates that in more remote areas, changes to community caused by CSG mining, such as the fly-in-fly-out employment model, may have an impact on the physical and mental health of young people, other community members and the workers themselves. Chapter six also describes research which states that CSG mining may have a greater negative impact on the health of Aboriginal and Torres Strait Islander people.

Economically, research presented in Chapter six outlines the benefits CSG mining may have for Australia's energy security, economic growth and individual employment. As access to energy and employment could both be considered social determinants of health, it may be that CSG mining may generate positive health outcomes. Conversely, in Chapters two and six, CSG mining is shown contribute to climate change through greenhouse gas emissions, and research outlined in Chapter six links climate change to increasing severe weather events. Such events, such as flooding, result in significant economic losses. Further research cited in Chapter six indicates that the economic cost associated with illnesses caused by CSG may negate any positive health outcomes associated with a boost to the economy.

In conclusion, the authors have demonstrated through our review of the current literature that there is relatively little peer-reviewed evidence regarding the impact of CSG mining on public health. We have shown that there is a clear need for immediate testing of the chemicals used in fracking fluid and the air pollutants produced by CSG mining. Further research is required regarding methane leaks and the impact on climate change and fire risk, biodiversity, water quality, food and water security. Most importantly, research is required on the direct physical and mental health impacts of CSG mining. As described in research presented in Chapter six, a health impact assessment and cost of illness study should be conducted in order to determine whether CSG mining has an effect on health. This research should then be utilised to drive policy reforms that protect the health of both the environment and the people who live and work in it. In the meantime, given how little we know about CSG mining, the precautionary principle should prevail.

References

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Coal Seam Gas (CSG) mining is a growing, contentious issue in Australia. The practice of hydraulic fracturing (fracking) introduces and releases many harmful substances to the environment. With most activity occuring in Queensland and NSW the industry's activities are threatening agricultural lands and encroaching on residential areas. Mounting community concerns regarding their health and well being are providing resistance; these community concerns have led to some degree of precaution being applied by state governments in the form of moratoriums and codes of conduct. To date however, risk assessments performed, such as in Tara QLD (Queensland Health 2013), have failed to adequately address these concerns; and have merely revealed the scarcity of adequate data.

Consistent throughout this report is the lack of specific data; of appropriate epidemiological investigations, of baseline air studies, of chemicals used, of the long term effects of chemicals known to be used. Despite this scarcity of data, this report shows that CSG activities do pose a significant threat to human health through a variety of exposure pathways to many known hazards. Water contamination and scarcity, air pollution, soil contamination, threatened food security, threats to biodiversity, the concept of solastalgia, community disruption, hazards to workers, contributions to climate change and the economic impacts are all outlined in this report.

Chemicals
Despite demands within state legislation for full disclosure of all chemicals used, a complete analysis of all hazards and their concentrations has not been conducted, as described in chapters 1 to 4. The concept of proprietary information has been used in the US to avoid disclosure, despite government demands and is presumably occurring here. Much of our awareness of potential chemical hazards relies on studies in the US, in particular Colborn, Kwiatkowski, Shultz and Bachran (2011), which through fortuitous events, was able to isolate 944 chemical traces, of which only 353 had any applicable data. Of these one quarter were known carcinogens and/or mutagens; three quarters were known irritants affecting skin, eyes, respiratory and gastrointestinal systems and sensory organs; half carried the potential to affect the immune, cardiovascular, renal and nervous systems; and over a third were endocrine disruptors. The drilling phase is no exception. Though banned in NSW and QLD, BTEX chemicals, volatile known carcinogens, are a significant factor as they are released from the seams themselves during the extraction process.

Notably there is a significant discrepancy in the number of chemicals disclosed in Australia by the APPEA (55 compared to 944) and what has found by Colborn et al (2011) to be used in the US. Whilst regional differences in depth of extraction could potentially mean less chemical usage in Australia the reality will be uncertain until full disclosure occurs. Significantly of the disclosed chemicals used in Australia only two of them have been assessed by the relevant authorities and these by very different exposure pathways than those presented by CSG. Long term exposure is virtually unknown to the majority of these chemicals. Despite state government demands, there remains no national requirement for disclosure.

This report found very few human studies of potential toxicity due to CSG activities. None of the contributors to this reports found examples of biomarker assessment in residents anywhere; despite investigations such as the Tara risk assessment of residents reporting symptoms such as headaches, skin and eye irritation, nose bleeds.

Water

CSG activities will have a significant impact on Australias water now and in the future, as chapter 1 investigates. The chemicals used in the process, mobilization of heavy metals and disruption to aquifers carries carry significant threats, and the large volume required potentially threaten the Great Artesian Basin; an integral underpinning of a large percentage of Australia's productive land. Produced water from wells carries the threat not only of the chemicals injected as fracking fluid but also heavy metals and toxins such as Benzene released from the seams themselves. Direct contamination to surface and underground water, and also soil and air contamination of various volatile compounds is a major concern. PH imbalance, altered conductivity and salinity due to high concentrations of salt present also damage freshwater ecosystems and surrounding soils. Though not explored in this reports salination, already a major issue in Australia will be exacerbated by CSG extraction by the sheer quantity of salt produced. The recycling of produced water from wells for other uses such as food production carries risk as treatment options may not remove all contaminants. The use of either evaporative pits or aquifer recharge are both shown to carry risks.

With estimates for water demands from the industry potentially above 300 gigalitres/year CSG threatens water systems in a time of increased demand due climate change and increased food production requirements.

Air

As explored in chapter 2, air quality is shown to be adversely affected by CSG activities. Sulphur dioxide, ozone and particulate matter, which can carry other toxins further, are of particular concern. Studies reported have demonstrated higher concentrations of non-methane hydrocarbons, polycyclic aromatic hydrocarbons and C02 around drilling sites then nearby locations. Radon, itself connected with lung cancer is a significant marker as it demonstrates recent activity as it has a short half life, has been found to be significantly higher near drilling sites. Methane, the major constituent of natural gas has negative health impacts and significantly has a 105 times higher warming impact than CO2. It has been estimated that 8% of the gas available is lost into the atmosphere, as fugitive emissions, potentially negating claimed benefits of the industry towards reduced greenhouse gas emissions.

The link has been made in the US between poorer health and cancer risk and those living near sites and indeed high levels of harmful chemicals. However though the hazard and dose have been demonstrated the link to disease has not been made. Significantly the lack of baseline data has made it hard to prove the link to CSG activities.

As chapter 2 reports the lack of adequate fugitive methane monitoring affects more than health impacts; as, if properly considered, the carbon price liabilities could threaten the economic viability of the industry. Industry claims of major climate benefits are questioned, however despite uncertainty, the report found some benefit to the use of gas over other fossil fuels. However the industry remains a contributor to climate change with significant green house gas emissions, and its practices place communities at continued risk of harm due to climate change.

Land
Chapter 3 demonstrates that through waste water mismanagement such as evaporative pits, the flowback affect, produced water usage and gas release surrounding them, soils are at risk of contamination with many toxins. These include chemicals used in fracking fluid including volatile organic compounds, and heavy metals; including those most known to affect human health; lead, mercury, arsenic and cadmium. As acknowledged by the NSW and QLD governments, food production and security is threatened, through pollution, increased salination and the acidification of soils due to methane release mentioned in chapter 2, as has the potential for loss of agricultural jobs. Organic food production is particularly threatened with exposure to many chemicals. Direct loss of productive land due to infrastructure imposition threatens up to 8% of available land. This is of particular concern considering that most gas fields are underneath prime agricultural lands of NSW and QLD. Cropping lands are of most concern both for toxicity transmission and inability for adequate rehabilitation. However, experiences in the US have shown the sensitivity of livestock to contaminants associated with CSG. In Australia change to stock movements, noise pollution and increased dust covered crops have been of significant concern to graziers.

Biodiversity
Whilst residential areas, once threatened, are being protected by legislation, more distant fragile ecosystems are coming under threat. Chapter 4 explains that whilst there have been some improvements in air capturing practices, CSG threatens wildlife, through direct toxicity, habitat destruction, increased fire risk, with threatened species under increased threat of extinction. Loss of biodiversity threatens potential discoveries of compounds that could aid human health, and a disruption to delicate balances that would alter ecosystems. Land clearance of between 1 and 2 hectares per well plus new road networks result in significant alterations to the landscape, and with added disruption due to noise pollution, is resulting in species being forced from habitations. Changes to water management, the release of endocrine disruptors and salinity in fresh water systems, lead to increased vector spread; including birds carrying the H5N1 virus; mosquitoes, with conditions favouring species that carry malaria; and fruit bats, the reservoir of Nipah virus, brought closer to human habitation.

Psychosocial
Aside from outlined physical health threats there is significant potential for increased mental health issues to result from the imposition of CSG practices on communities and the workers involved. As explored in chapter 5, the concept of Solastalgia, dominates in this regard with a clear link between CSG and the destruction of natural heritage and the significant disempowerment resulting from its blatant imposition on landowners. Marginalization of farmers is apparent; witnessing the contamination and salination of their land with no consultation. Farmers face stress due to financial concerns caused by decreased land values exacerbated further by inherent inequity; only receiving 0.5% of profits of a lucrative short term industry as compensation for something that could permanently damage their land.

Residential areas also face loss of value of their property particularly in the lower socio-economic urban settings targeted.

The rapid expansion of populations due to the influx of workers for the industry burdens existing infrastructure and amenities compromising the well being of community members. Unless rapid development catches up with the influx, health outcomes are expected to fall, with decreasing activity levels, and disrupted community security and decreased communal trust linked to such influxes.

Workers
Workers in the CSG industry face risks to their health, as explored in chapter 7, including direct toxin exposure, and broader impacts from changed social structures; particularly the transient fly in fly out scenario. Silicosis, is seen as a significant threat that may not become apparent until 5-20 years post exposure. Social isolation and disengagement with community, family conflict, shift work demands and prolonged noise and dust exposure lead to increased stress levels, increased substance abuse, risk of STI's and mental illness exacerbations. Hostility from the local community, with 75% opposed to the practice on agricultural land, adds to workers marginalisation. Workers themselves are not immune to solastalgia, facing a sense of powerlessness due to unknown risks within the industry and witnessing first hand alterations to land. These risks are increased in minority groups such as Aboriginal and Torres Strait Islanders.

Economics
The imposition of CSG extraction is built upon the promise of economic growth. Whilst this report, in chapter 6, does not question that income will be generated, it reveals that the situation may not be a clear cut economic benefit.
There is an unsubstantiated potential for vast revenue collection by the state governments. However, incentives to the industry of royalty holidays and reductions until 10 years post initiation may mean that governments may miss the majority of earnings as production is significantly greater in the first few years of a well. There are no assurances on where, or what the revenue would be spent on.

A reduction in domestic energy prices may be negated by export links to the international market and a corresponding link in prices. The promise of employment creation may not be long lived, and instead may just see the introduction of transient skilled workers. Certainly, beyond the short lived construction phase, where local jobs may be available, ongoing maintenance requires scant labour, easily accommodated by a non-resident workforce. Some workers camps are largely self sufficient, therefore not providing any benefits to local economies, but placing demands on services. Any initial boosts to economies with accommodation and food requirements may be offset by longer term losses to the community with residents relocating away from the mine sites, due to fear of adverse health effects. Further, problems such as: the creation of a two speed economy, negatively impact local residents with higher wage structures and reduced labour availability and a potential loss of jobs in other areas such as the tourism sector. Added strain on health services, education, transport and law and order services; and increased housing prices, marginalizing communities, are all further potential negatives from the industry on local communities.

Cost of illness estimations are shown to be very difficult, as chapter 6 outlines; particularly due to the lack of disclosure of chemicals and the difficulties in classifying potential health effects. But the potential of short and long-term health effects and their cost to society need to be factored in any balanced financial appraisal.

Recommendations

Our findings demonstrate a multitude of hazards introduced by this industry and reveal a recurring theme in all areas explored; the lack of robust quantitative and qualitative data regarding hazards and their risk. This situation requires immediate attention. All hazards must be revealed to enable an assessment of their risk. Right now communities and ecosystems are being exposed to hazards, for questionable gain, that have not been adequately assessed for their potential immediate and long-term harm.

Specifically:-

-Communities and ecosystems must be protected from harm and food production not threatened for the short term potential gains of CSG.

-All chemicals and their concentrations used in both the drilling and operational phases of activity must be declared to enable a thorough risk assessment.

-Robust epidemiological studies should be conducted to investigate communities concerns.

-Baseline data must be collected, particularly regarding air, water and soil quality, and community well being to enable direct impacts to be studied.

-Public health consultation must be included in all assessment procedures

-Waste currently being produced must be dealt with in a way that does not place communities at risk now or in the future.

-In the absence of adequate studies proving the safety to communities the precautionary principle must be applied; moratoriums should be placed on further development of this industry until an adequate assessment is conducted.

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Executive Summary 5

Overview
Environmental Health encompasses the assessment and control of those environmental factors that can potentially affect health (WHO, 1999). It demonstrates the link between the health of our environment and the health of populations and individuals. Further, it provides the framework and tools for assessing the potential health effects of changes to the environment, be they natural or anthropogenic, local or global. Where possible it relies on data and evidence to assess risk and create health-supporting environments (WHO, 1999).

The increased use of natural gas has led to mining of "unconventional" gas reserves such as coal seam gas (CSG); accessing such gas requires different processes to conventional gas mining, including fracking, and poses different risks to workers, the environment, and the population (Colborn, Kwiatkowski, Schultz, & Bachran, 2011). There are significant community concerns in Australia regarding CSG mining (Carey, 2012). This report addresses some of the major health concerns which have been raised as potential complications of CSG mining. These span the full biopsychosocial scope of human health and wellbeing, from acute medical effects, though psychological impacts, to changes in culture and society, locally if not globally. Where possible we identify those sub-groups of the population who are at greatest risk.

We discuss the potential risks to health, separated by the environmental medium though which they may act. However, this is an arbitrary separation, useful for analysis, but the effect of CSG mining on health is likely to be greater than the sum of the parts discussed below. We recognise there are potential benefits of CSG mining; where possible these are balanced against the risks. There remain significant gaps in the literature regarding CSG mining which highlights the need for further research. Lastly, we provide a series of recommendations to minimise the potential impact of CSG mining on health.

Direct Health Risks
Worker Health & Safety
There are well-documented risks to workers in the natural gas industry, as well as health risks specific to those mining CSG such as toxicity from fracking fluids and silicosis from sand inhalation. Many of these may be shared by the wider community. The psychological health risks to workers are relatively under-represented in both the media and the scientific literature - these risks are discussed in detail in chapter 7A. In addition there are occupational risks specific to mining workers such as explosions – these are covered in chapter 7B.

Risks to Health through Environmental Damage

Water Pollution
The access to clean water is recognised as an essential requirement for human health (WHO, 2002). Water pollution has been calculated to contribute to over 1.5 million deaths worldwide each year (ibid). In Australia, water scarcity is as critical to future health and quality of life as water quality. CSG mining has the potential to impact on health through three distinct water related mechanisms (discussed in detail in chapter 1): contamination

from fracking fluids, the composition of which is largely unknown; contamination from produced water; and depletion of aquifers / competition for a scarce resource. The re-use of water, further exacerbates the risk of environmental damage.

Air Quality
Clean air is recognised as an essential requirement for human health (WHO Regional Office for Europe, 1999). Air pollution has been calculated to contribute to over 1 million deaths worldwide each year (Zhang & Smith, 2003). In the context of CSG mining, the global perspective, including the benefits of natural gas, need to be considered, as well as local health risks. CSG mining has the potential to impact on health through three distinct mechanisms (discussed in detail in chapter 2): risk of air pollution; direct health effects through changes of air quality in urban areas; and indirect effects though changes through gas release in non-urban areas. The impact of natural gas and CSG mining on climate change is discussed in chapter 2D, highlighting the importance of fugitive emissions is measuring both global effects and health risks.

Land Contamination
The importance of a connection to the land in the health of traditional communities is consistent worldwide and well documented. In fact, land is important for all human health. Arable, and liveable, land is a scarce resource in Australia. CSG mining has been identified as a direct competitor for agricultural land, and has the potential to impact on health through multiple mechanisms (discussed in chapter 3): human effects of soil contamination; agricultural effects of soil contamination; competition for a scarce resource; and subsequent risks to food security. The impact of CSG mining on the land has, to date, been significantly underestimated.

Ecosystem Damage
Human health is inextricably linked to the health of our ecosystems (Parkes & Weinstein, 2004) even though the direct mechanisms are not always clear. Pollution of water, air, and land not only has direct effects on human health, but also has the potential to act indirectly through damage to ecosystems. These impacts are generally difficult to quantify, though the concept is well proven. In chapter 4 we report on the impact on animal health and the risks to health associated with a reduction in biodiversity and geographical changes to disease vectors. These effects are somewhat unpredictable and demonstrate the difficulties in assessing the full potential impact of CSG mining.

Risks to Health through Social Damage

Natural Heritage
As described in chapters 3C, 4A, and elsewhere, the removal of, and from, natural heritage has been associated with poor health outcomes. Restrictions on land use, eg in national parks, have arisen in recognition of this. Solastalgia (see chapter 4) also explains some of the effects of CSG mining on the wellbeing of farmers. Damage to the land from CSG mining is likely to have significant, and underestimated, effects on the psyche of the nation; the broader importance of the environment is a recurring theme in the report.

Psychological Impacts
There are likely to be significant psychological impacts on the health of Australians through disruption of family and community life, marginalisation, uncertainty, and perceived threats to life and livelihood. These effects are likely to be most strongly felt by nearby communities; we discuss the risks to faming communities and urban communities due to CSG mining in chapter 5. We note it is difficult, if not unnecessary, to separate the psychological impacts from medical effects, and that some factors, such as noise, will contribute to both. Both medical and psychological effects are likely to have greater impact on young people; this is discussed in details in chapter 5C.

Economic Impacts
Natural gas is a multi-billion dollar industry in Australia and may reduce Australia's reliance on imported energy sources. However, in a global market, this is unlikely to constrain prices. Employment gains are likely to be short term and necessarily a benefit to local communities. The macroeconomic impact of CSG mining is discussed further in chapter 6A. The complex community and microeconomic effects are discussed in detail in chapter 6B. There are significant economic impacts of the risks to environment and agriculture described above; we attempt to quantify these in chapter 6C. Finally, we provide in chapter 6D a framework for comparing the economic (and other) benefits of CSG mining with the direct negative effects on health.

The Big Picture
The figure below demonstrates the scope of impact of direct, environmental, and social risks to health associated with CSG mining and the magnitude of that impact. This provides a holistic perspective of the health effects of CSG mining. The environmental factors are weighed by their likelihood as well as the severity of effect. Benefits, where proposed, are also incorporated (as negative risk) where possible. The units are arbitrary – specific assessment of QALY impact would be required. The strength of the evidence is discussed in relevant chapters and not represented here. This chart highlights the difficulty in weighing local risks against national and global benefits.

Gaps and Limitations
The scope of this report is limited to the potential impact of CSG mining on the health of Australians. As such, it does not purport to be a thorough assessment of the risk of CSG mining in other locations, though the evidence and many of the recommendations are broadly applicable. Differences in technical methods, environmental sensitivity, governmental regulations, and cultural approaches to the mining of unconventional gas are likely to alter the impact of CSG mining. In particular, the risk benefit analysis for CSG (and other forms of unconventional gas) mining in developing nations may be significantly different; we leave this issue unresolved.

We have addressed the most significant health risks, both direct and indirect, and have highlighted the important role of damage to the environment as a cause of poor health. However, there are some areas which require further attention to supplement the evidence contained in this report. These include, but are not limited to: assessment of the local economic benefits; assessment of the global health effects of natural gas; the physical health risks to workers; effect on Indigenous communities and their health; risks associated with nitrogen compounds; specific risks to animal health and biodiversity; and health impacts of mine accidents.

High quality evidence on the effects of CSG mining on health is limited due to the short time period in which studies have occurred; poor understanding of the chronic effects of low-level exposure; a focus on individual toxins at the expense of combined exposure risk; and the dominance of a medical model of health. There is no established method for comparing the local environmental impacts with the potential global benefits of natural gas use. However, we recognise that this is unlikely to impact on the decision to permit CSG mining in Australia.

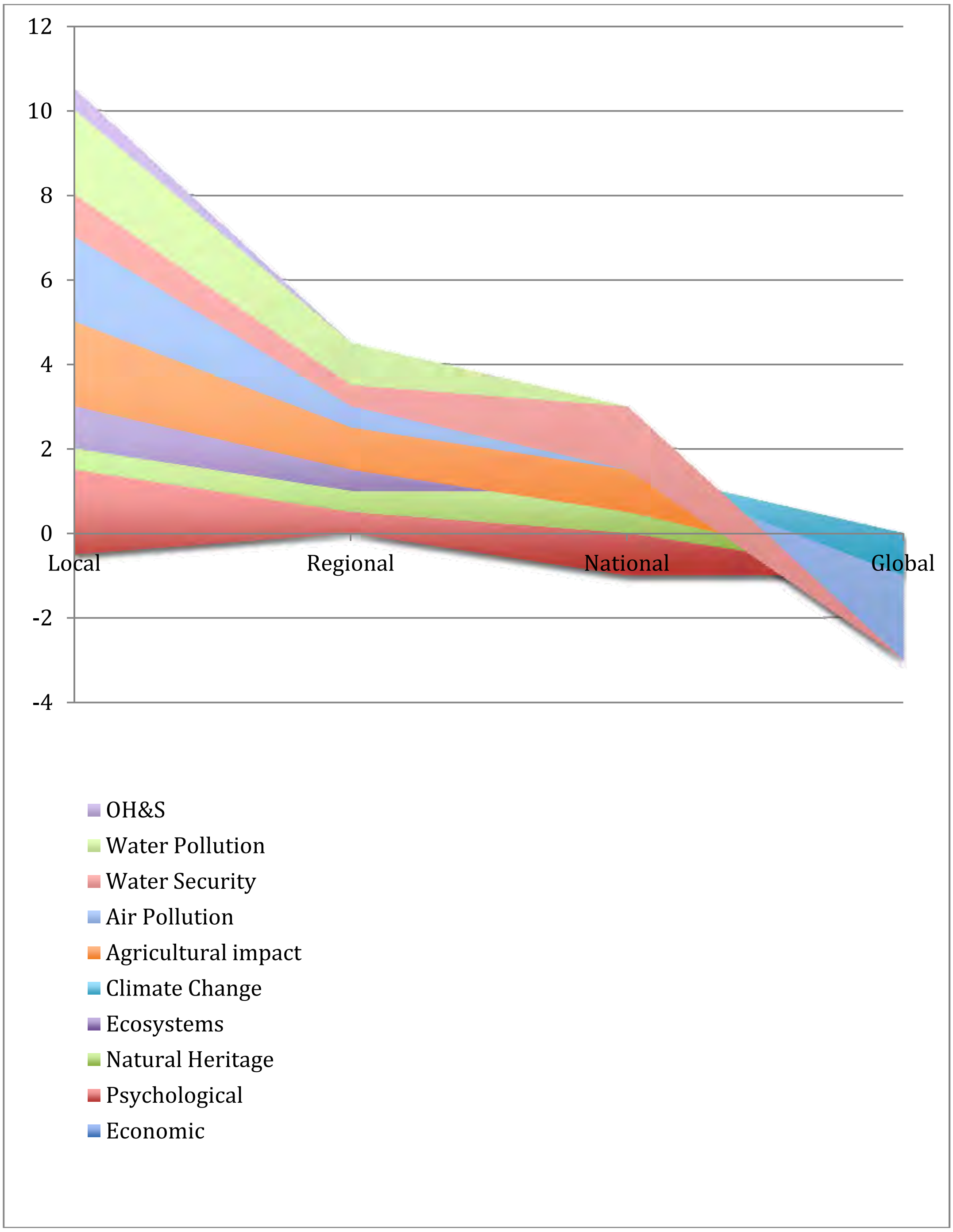

Figure 1: Weighted risks to health by mechanism of effect

Recommendations

A limited number of focussed recommendations are covered in the relevant chapters. The table below provides an overview of these, and highlights the relevant agent or authority who is likely to have responsibility. The details can be found in the main text. Certain common themes emerge, such as the urgent need for more research and improved regulation. It is clear that industry has a significant role, which is likely to require significant regulation and oversight.

The precautionary principle – "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNEP, 1992) is the over-riding recurring theme. There is insufficient evidence to draw any definitive conclusions about the risks, benefits, or safety of CSG mining on the health of Australians. However, there are significant concerns regarding potentially irreversible damage to the environment and proven links to poor health from this damage. We advise extreme caution, enhanced oversight, expanded research, and improved community involvement as CSG mining expands in Australia.

Recommendation	**Health impact**	**Responsibility**
Technology		
improve water recycling	reduced mining costs, reduced water costs for farmers, improved water security	industry
utilise a closed loop system	less air pollution	industry
improve environmental decontamination	minimise harm from pollution, recover land for use, reduce impact on ecosystems	industry, agriculture, science, local government
enhance mine safety	lower worker / community risk	industry (with gov't regulation)
reduce mining footprint	retain land for agriculture, reduce effects on ecosystems and biodiversity	industry

Research		
identify non-toxic alternatives	minimise toxicity	industry, mining science
investigate chronic effects of toxins	minimise toxicity, mediate potential diseases	medical science
investigate effect of toxins on crops / stock	minimise toxicity, mediate potential loss of productivity	agricultural science
identify (in)-appropriate mine sites	reduce pollution	industry, environmental science
improve environment modelling	better identification and quantification of risks, understanding of global impact	environmental science
better modelling of economic impact	accurate cost-benefit analysis	government

Monitoring		
of worker health	OH&S, early identification of symptoms	industry, federal government
of water and air quality (incl baseline)	early warning, feedback, improved evidence base, strengthens links to health	landowners, environmental science
of animal health	may predict human illness, impact on food security	farmers, agricultural science
of population health (incl baseline)	stronger evidence base, identifies unknown toxins or undiscovered pollution	state government, public health
Regulation		
ensure OH&S standards	less risks to workers and community through accident reduction	federal government
control fracking fluid composition	minimise toxicity of pollution	federal government
restrict mine placement in sensitive areas	minimise pollution, protection of natural heritage	government
establish independent CSG authority	indirect benefits through a co-ordinated approach	federal government
introduce a compensation scheme	less psychological and economic effects, esp on farmers	industry, government

Cultural change		
involve public / env't health experts	avoidance of predictable concerns, harm minimisation, scientific approach	industry, government
encourage voluntary disclosure (eg fugitive emissions)	community confidence, less conflict & psychological impact	industry
enhance community involvement	less psychological impact, early detection of symptom clusters, better planning	industry, public health, community groups, government
healthy land use planning	reduced risk of pollution	local & state government

Table 1: Recommendations and intended health impact

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Executive Summary 6

Introduction

Coal seam gas (CSG) mining is poised for massive expansion in Australia despite many unknown health and environmental risks. This executive summary presents an overview of the findings from a collaborative exercise conducted by postgraduate students enrolled in the Environmental Health course elective of the Masters in Public Health and/or International Public Health at the University of New South Wales, Sydney, Australia. Using a desktop review process of the published and grey literature, the document aims to examine the available evidence for the potential risks to human health and wellbeing associated with CSG mining. The assessment includes a specific exploration of several areas considered to be key determinants of health and wellbeing.

Summary of key findings

Water

The impact of CSG mining on water quantity and quality is a fundamental concern, posing a risk for both direct and indirect health effects. CSG mining, in particular the process of hydraulic fracturing (fracking), not only utilizes vast quantities of water, but also chemicals and silica-based sand (collectively known as fracking fluid). In addition, this process generates a "flowback" creating vast amounts of "produced water" containing not only fracking fluid but also the natural salts and minerals, heavy metals, benzene, aromatic hydrocarbons and radioactive substances found naturally in coal seams.

The potential for health impacts may occur via several routes linked to water. Given the vast water requirements for hydrofracking, freshwater reserves (such as the Great Artesian Basin) may be at risk of depletion in the long term, interrupting the supply of water for human consumption. In addition, aquifers may be contaminated by both fracking fluid and produced water, thereby potentially contaminating surface water, groundwater and drinking water supplies with toxic chemicals. Produced water and its management pose further risks with volatile organic compounds (VOCs) potentially increasing ground level ozone (a known respiratory irritant), chemical exposure via spills (during transport), and risks associated with the use of evaporation ponds, such as overflow and air contamination. Such water may also be inadequately treated and used for irrigation, thereby contaminating soil and crops, and potentially entering the food chain.

There is limited data on the specific health effects of these chemical exposures in the context of CSG in Australia, with only 2/23 commonly used fracking chemicals formally assessed by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS). Furthermore, proprietary issues preventing transparent disclosure of chemical data, hampers a thorough scientific assessment of risk. Although the use of the BTEX (Benzene, Toluene, Ethyl benzene and Xylene) chemicals in fracking fluid has been banned in Australia, the process of fracking itself releases BTEX from underground sediments. Available toxicology data for common chemicals used in fracking fluid provide evidence for potential effects on the central nervous system, cardiovascular, renal and immunological systems. In addition, many are mutagenic, carcinogenic and/or have the potential to act as endocrine disruptors. Produced water also contains heavy metals including mercury, cadmium and arsenic with known adverse effects on human health.

Gas emissions and air pollution

All phases of the mining process are likely to contribute to air pollution with potential increases in particulate matter, sulphur dioxide and ozone due to high industrial activity. CSG mining activities in Queensland have been linked to the release of BTEX chemicals and other VOCs in air. Gas flares, burning and fugitive emissions (methane and carbon dioxide) further contribute to air pollution. Although there is no direct evidence for the health impacts of CSG-related air pollution in Australia, such pollutants are well recognised to contribute to significant increases in cardio-respiratory disease and mortality. Furthermore there is evidence for the presence of chemicals in air samples around CSG mining that are known carcinogens, respiratory irritants and potentially damaging to the CNS. Evidence from the United States also suggests poorer health outcomes in residents close to shale mining sites where hydrofracking is used.

The assessment of the health impacts of such air pollution and gas emissions is hampered by the absence of effective, unbiased monitoring systems and the difficulty in understanding cumulative effects of such exposures. It is also possible that if CSG is indeed a “greener” fuel, an overall decrease in particulate matter may be experienced that will offset some of the potential health impacts. However, CSG mining’s claim to be a “cleaner” source of energy is under debate with the recognition of associated high levels of fugitive emissions (methane and CO_2) that could negatively impact on climate change, with long-term implications for human health.

Land use risks

Several concerns related to land use arise in consideration of CSG mining and human health. Firstly, the direct effects of exposure to contaminated soils needs to be considered. The “flowback” of fracking fluid and associated produced water, as well as spillage/overflow from evaporation ponds and wastewater mismanagement can result in contamination of soil. Human exposure to contaminated soil can occur via several pathways such as inhalation of VOCs, direct ingestion, absorption, and via the food chain.

Secondly, the indirect effects on health and wellbeing linked to loss of land and livelihoods are an important consideration. Large losses of agricultural land due to CSG mining industry may impact significantly on food production. Although co-existence of CSG mining and grazing may be achievable, cropping may be significantly affected. Associated risks to food production include chemical contamination of crops and meat via contaminated soils and irrigation water. Furthermore, stock and crop rotation may be limited when areas of farmland are disrupted by mining infrastructure.

There is some recognition of these risks evident in NSW land policy and regulations aimed at protecting strategic agricultural land from mining impacts. However, there has been scant recognition of the importance of including public health professionals in land planning and policy development.

Risks to biodiversity
CSG mining threatens Australia's rich biodiversity and natural heritage, with potentially irreversible land loss. There is a growing body of evidence that such changes have direct and indirect impacts on human health. High levels of human distress termed "solastalgia" related to environmental changes have been described in Australia. Furthermore, the absence of open space and natural countryside has been linked to negative health outcomes. The "biophilia hypothesis" further supports the positive impact of nature on health and wellbeing. In this regard, Aboriginal communities (with their close connection to the land) may be more vulnerable to the effects of land destruction.

The impact of CSG mining on biodiversity may have additional indirect effects on human health in the long-term. The first is the potential for loss of crucial plant biodiversity that may impact on future sources of new pharmaceutical products. Secondly, mechanisms of wastewater management, such as evaporation ponds, could theoretically increase the risk of zoonotic infections via increased exposure to potential reservoirs of infection such as aquatic avian species (avian influenza) and or vector borne diseases via increases in mosquito breeding sites.

Risks to psychosocial wellbeing and mental health
CSG mining in NSW is likely to increasingly encroach on prime agricultural land and urban communities. Negative psychosocial impacts for farmers and their families have already been linked to the loss of land and livelihoods. Furthermore, the psychological stress of negotiating with gas companies, a sense of powerlessness and frustration may increase the risk of mental illness.

For urban residents, rapid expansion of the industry and lack of transparency creates public anxiety. Furthermore, environmental impacts may threaten the mental health of residents around gas fields with increased noise and light resulting in sleep disturbances. In addition, disempowerment, community conflict, uncertainty and loss of control all impact on psychosocial wellbeing. Mental health of residents may also be adversely affected by economic impacts and fear of unknown health risks. Youth may experience particular health vulnerability in this regard. Social and family life may be disrupted by mining infrastructure, work arrangements, and loss of recreational and park facilities. Increased exposure to high-risk behaviours and STIs may also be associated with influxes of young miners and community disruption.

Economic impacts
CSG mining offers the prospect of vast economic benefits with the potential for improvements in health indirectly linked to tax revenues, increased funds for services and individual economic prosperity. Modelling of the economic impact suggests CSG is likely to create substantial growth in Gross State Product for NSW. It is also predicted to provide increases in employment. However, employment may not be sustainable with different workforces employed short-term across various phases. There is a paucity of data for the economic impact at local/community level. Economic losses may be experienced through loss of personnel to the mining industry, impacting on local business. Local economic losses may also occur if residents move, and/or tourism revenue is lost due to environmental degradation and contamination. Furthermore, negative psychosocial impacts of CSG can

affect productivity. Such economic losses have the potential to impact on health in relation to service delivery, individual healthy behaviours and access to care.

A key weakness in NSW 's cost benefit analysis of CSG mining is the inclusion of only primary health impacts related to noise and air pollution with no inclusion of morbidity and mortality data. Although there is no direct data for CSG mining, coal mining in the USA was associated with health costs that outweighed the economic benefits of mining activities, an important consideration in cost benefit analyses.

Risks to workers in the industry

Workers in the CSG mining industry are at risk for several negative health impacts. The gas industry is associated with high fatalities linked to blowouts, explosions, gas flaring and accidents. In addition workers face the likelihood of potentially higher exposures to the toxic chemicals in fracking fluid with associated health effects (as discussed under water and air exposures). Field evidence indicates that workers can be exposed to dust with high levels of crystalline silica contained in fracking sand. This poses a risk, not only for silicosis as outlined in Chapter 7, but is also associated with increased risks for tuberculosis, lung carcinoma, chronic obstructive pulmonary disease, autoimmune and renal disease (National Institute for Occupational Safety and Health, 2012). Additional risks include transport-related accidents linked to high truck volumes.

In addition to physical health risks, CSG workers may experience psychosocial impacts know to be associated with the mining sector. Although specific CSG data is not available, evidence from the mining sector has relevance. This includes the psychosocial impacts of "fly in fly out" work associated with family conflict, isolation, increased suicide risk and substance abuse. In addition, mining camps are associated with social isolation and stress that may exacerbate or trigger mental illness. Furthermore, prolonged exposure to dust and noise and other site-related factors negatively impact psychosocial wellbeing. Conflict between miners and local communities poses an additional risk for employee mental health. Finally, the uncertainty related to health risks associated with CSG mining has the potential to create stress and anxiety amongst industry workers.

Limitations of the report

The methodology used by students conducting this desktop review was not standardised and it is thus possible that data is not fully representative or comprehensive. The relative paucity of good quality health data in the peer-reviewed literature may have necessitated an over-reliance on opinion pieces and anecdotal evidence in the public domain, with its attendant risk of bias. Nevertheless, this collaboration is a potentially useful contribution to the available evidence and serves to highlight gaps requiring further research and discussion.

Conclusion and key recommendations

Although good epidemiological data specific to the health risks of CSG mining is lacking, there is sufficient evidence to suggest numerous mechanisms by which CSG poses a risk to human health and wellbeing. Furthermore, these risks are potentially associated with serious health outcomes resulting in significant morbidity and mortality. This is a situation wherein the precautionary principle should be readily invoked. The purported benefits of CSG mining need to be weighed against the potential for significant harms using an informed public health lens. In this context the following recommendations are proposed:

- Increased inputs of public health professionals in Australia in all stages of the CSG mining process.
- The implementation of a well-designed national surveillance systems for monitoring health outcomes in relation to CSG mining.
- Urgent disclosure and assessment by NICNAS of all chemicals used in the industry to permit accurate risk assessments.
- Implementation of environmental monitoring and regulatory frameworks aimed at specifically protecting health, with enforcement of nationally determined criteria.
- Development and implementation of a standardised national process for conducting a health impact assessment on all current and future CSG mining operations, with specific inclusion of cumulative impacts as recommended by Doctors for the Environment Australia (DEA) (2012).

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Executive Summary 7

This report is a comprehensive research project looking at the potential impacts of the coal seam gas (CSG) mining industry in Australia to the health and wellbeing of its citizens. It is commissioned by an alliance of Australian professional and voluntary health organisations, the National Collaborative Health Network (NCHN), in response to the call for submissions to the Chief Scientist regarding review of proposed CSG mining operations in NSW (NSW Chief Scientist and Engineer, 2013). Targeted mining zones include special interest areas such as Sydney's water catchment area of Illawarra, farming and residential districts in Camden and Campbelltown, prime agricultural land in Gloucester, and the natural heritage areas of Pilliga Forest and Fullerton Cove.

The main purpose of this document is to highlight the detrimental effect that CSG mining will have on the NSW environment and population health should it continue in its current form and under current working practices. The greatest identifiable threats relate to potable surface water, groundwater and aquifer systems; the air and climate; food security and land integrity; ecological biodiversity; livestock and pets; and to the physical and mental health of local residents.

The evidence for this assertion is presented in corresponding sections. Where possible peer-reviewed high-quality studies directly relevant to CSG mining in Australia are presented to substantiate claims. Where there is an absence of pertinent local research, credible overseas studies on similar mining practices are utilised such as those relating to methane extraction from coal beds and shale strata in the United States, as well as relevant reports, government inquiries, grey literature, websites, magazine and newspaper articles that highlight specific points. Despite best efforts several contentions lack fully validated evidence. However crucial knowledge gaps and topics warranting further research are carefully identified.

Finally a series of recommendations has been formulated based on identified hazards from the findings of this report, which if fully implemented are believed to prevent or mitigate environmental and health risks to the public. These recommendations include improved monitoring and testing protocols of mining activities and the surrounding environment (baseline and ongoing measures); enforced disclosure of all mining products; the banning of evaporation pits, treated wastewater disposal in surface waters, and chemical use in environmentally sensitive areas; enforced exclusion zones from residential areas, water catchments and key agricultural sites; full stakeholder participation and collaboration before mining activities are approved beyond these limits; and a preliminary trust fund to be set aside by mining companies for land reclamation and to finance cleanup following spills.

Methodology

The report has been divided into seven sections selected via brainstorming and consultation with NCHN representatives. Assigned specialists have then undertaken research into each field. Section 1 deals with risks to water sources, in particular contamination from fracturing fluid, produced and treated water and water depletion. Section 2 covers greenhouse gas (GHG) emissions and air pollutants. Section 3 deals with land risks in particular soil contamination, and reductions in food security and useable land. Section 4 is concerned with probable impacts to biodiversity. Section 5 covers psychosocial wellbeing and mental health. Section 6 encompasses potential macroeconomic and microeconomic adverse effects. And Section 7 discusses impacts to the mining workforce. Specific concerns related to the NSW special interest areas are covered in the relevant sections.

CSG mining background

CSG mining has undergone significant growth in recent years due to domestic energy demands and an ever-increasing Asian market (Section 6). This mining boom has the potential to generate large revenues, employment and improve people's lives through increased government tax-spending on infrastructure and services. Methane, the fuel produced from this activity and distributed in its compressed form as liquefied natural gas (LNG), has been touted as a cleaner transition fuel in the global movement to renewable energy sources.

However its controversial extraction processes, the hefty consumption of water and incursion into arable land, the production of pollutants and toxic by-products, and management of this waste have caused grave concern among residents, scientists and various citizen groups. It is believed that significant reform is needed to make CSG mining safe for the public and the environment, and to ensure the ongoing viability of water reserves and the grazing and agriculture industries. These concerns, and recommendations for reform, are summarised in the ensuing paragraphs.

Water, land and biodiversity issues

Misgivings regarding water and land integrity emanate from the practice of hydraulic fracturing or "fracking" (Section 1 and 3). Fracking is the means for releasing adsorbed methane gas in impermeable coal seams. It incorporates fracturing coal beds by drilling and pumping fracking fluid (FF) under pressure, placing proppant (a substance such as sand) to keep the fractures open, and retrieving entrapped fluids to reduce the hydrostatic pressure that keeps the methane adsorbed. Wells and pipelines are assembled to remove the gas, and to recover drilling fluids and the water surrounding the coal beds. A major problem is that FF is made up of many toxic chemicals that have not been researched or disclosed for proprietary reasons. Of those identified, the majority are harmful ranging in effects from mild irritation to skin and mucous membranes, to long-term endocrine and organ damage and some even have teratogenic, mutagenic and carcinogenic activity.

Lack of product disclosure hampers proper testing, monitoring and management of exposures. In the U.S. CSG mining exemptions against key protection policies such as the Safe Drinking Water Act and Clean Air Act adds to concerns (Section 2, p.28; American Academy of Pediatrics, 2013). In fact farmers may be in breach of food standards due to contamination of livestock from these chemicals, for which the CSG industry is not accountable. It has been noted that affected meat has ended up in the food chain and on supermarket shelves without being able to be adequately tested due to non-disclosure loopholes (Bamberger and Oswald, 2012; American Academy of Pediatrics, 2013).

In addition to FF chemicals, fracking releases naturally-occurring toxins from coal bed waters ("produced" water) such as the BTEX group of hydrocarbons, heavy metals, radioactive substances, salts and brine. Both fracking fluid and produced water can be very harmful and cause serious long-term health effects depending on their constituents, which to a degree is determined by the local geology. There is accumulating evidence of wildlife losses, pet and livestock disease and death, and human illness from exposure to these substances.

Contamination of soil, surface and groundwater does occur despite industry precautions. This may be from well-casing failure, drilling through aquifers, migration of fluid, but most often is from spills and open pool storage overflow. Storage, treatment and disposal of wastewater generates ongoing concern due to its high volume, toxicity profile, and incomplete treatment by reverse osmosis. Spills in natural habitats can cause plant stress and death and alterations in biodiversity (Section 4). Freshwater ecosystem disruption can eradicate species, redistribute vector-borne disease and distress nature lovers.

Agricultural concerns include: chemical soil contamination from FF and produced water which can enter the food chain through exposed vegetables and grazing animals; dispersion of dust onto grazing land from unsealed roads and heavy traffic flow; increased salinization of soil which can also impact on food security; destruction of arable land through CSG mining infrastructure such as wells, roads and pipelines with subsequent erosion; subsidence; competition for natural resources; and interruption of crop and grazing rotations and harvesting (Section 3). In the face of growing demands for food and unstable weather patterns due to climate change the added burden of CSG mining has affected farmer's livelihoods and wellbeing and caused many to sell up and leave (Section 5 and 6).
Other water issues relate to reduced water supply to landowners and townships from high use in mining (Section 1). This is a major obstacle where water is scarce. Effective depletion of useable water can also occur through contamination or when drained aquifers associated with the coal seams are recharged from interconnected water systems. Methane gas itself is a potential contaminant that easily migrates to water bores and seeps into surface water from below ground (Section 2). This renders the water undrinkable. Many documentaries, newspaper reports and web articles highlight this phenomenon. Although the possibility of catastrophic water loss or contamination has been posited, it is believed that water impacts will be localised and cumulative, proportional to the scale of mining operations.

Risk to the air

The promise of methane being a cleaner fuel has come under increased scrutiny for a number of reasons (Section 2). Firstly it is a potent greenhouse gas (GHG) with 100 times the global warming potential of carbon dioxide over 20 years (or 25 times over 100 years). When the emissions of diesel engines of LNG compressors and transport vehicles are added (typically 1,000 large truck journeys per well lifetime) the load becomes significant. Finally between 1 and 8% of methane is lost to the atmosphere from venting, underground gas migration, well leaks and incomplete flaring (constituting a serious fire hazard). Reliance on fossil fuels also stunts innovation and research in alternative energy use.

Aside from methane, CSG mining produces various air pollutants including sulphur dioxide, nitrous oxide, particulate matter, volatile organic compounds (VOCs) and ground level ozone

(Section 2). The latter formed from the interaction of sunlight, particulate matter, diesel exhaust and other VOCs creates smog and is a potent respiratory irritant linked to increased hospitalisations and death in vulnerable groups. Certain volatile hydrocarbons such as the BTEX chemicals found in coal seams are highly toxic and are readily vaporised and absorbed. These pollutants can also infiltrate the soil and water.

Another concern that disproportionately affects miners is silica inhalation from sand used as a proppant during fracking (Section 7). This can lead to chronic, acute or accelerated silicosis a condition marked by respiratory symptoms and failure, disability and even death.

Psychosocial and mental health issues in residents and miners

Psychosocial and mental health concerns can stem from marginalisation, loss of control, rapid demographic change in communities and from transformation of the landscape (Section 5 and 7). Both landowners and miners are prone to experiencing marginalisation, disempowerment and isolation. This is facilitated in the former group by lack of communication, collaboration and involvement in mining decisions that affect their property and is exacerbated by landowner fears of the unknown, the future, and from perceived threats to their health, land and livelihoods. Miners often endure animosity and conflict from residents, difficult shift work, regular travel and time away from family and supports, and struggle to engage in community life. For both, family problems, drug and alcohol issues, depression and anxiety are common manifestations.

Influx of workers for labour-intensive CSG exploration and well assembly can significantly alter community dynamics and networks. This can lead to loss of amenity, security and recreation. Demand for rental property and services could also affect local disadvantaged groups. Known effects from mining worker in-migration include increased crime rates, unaffordable housing, human resource drain due to more lucrative mining wages, alcoholism, and increases in sexually transmitted diseases.

Transformation of the environment through mining infrastructure and heavy traffic can impact on biophilia (the love of natural surrounds) and create a loss of sense of place, identity and home (solastalgia). This can have a significant effect on stress levels, mental recuperation, outlook and resilience. Both miners and locals are prone to this condition.

Economic issues

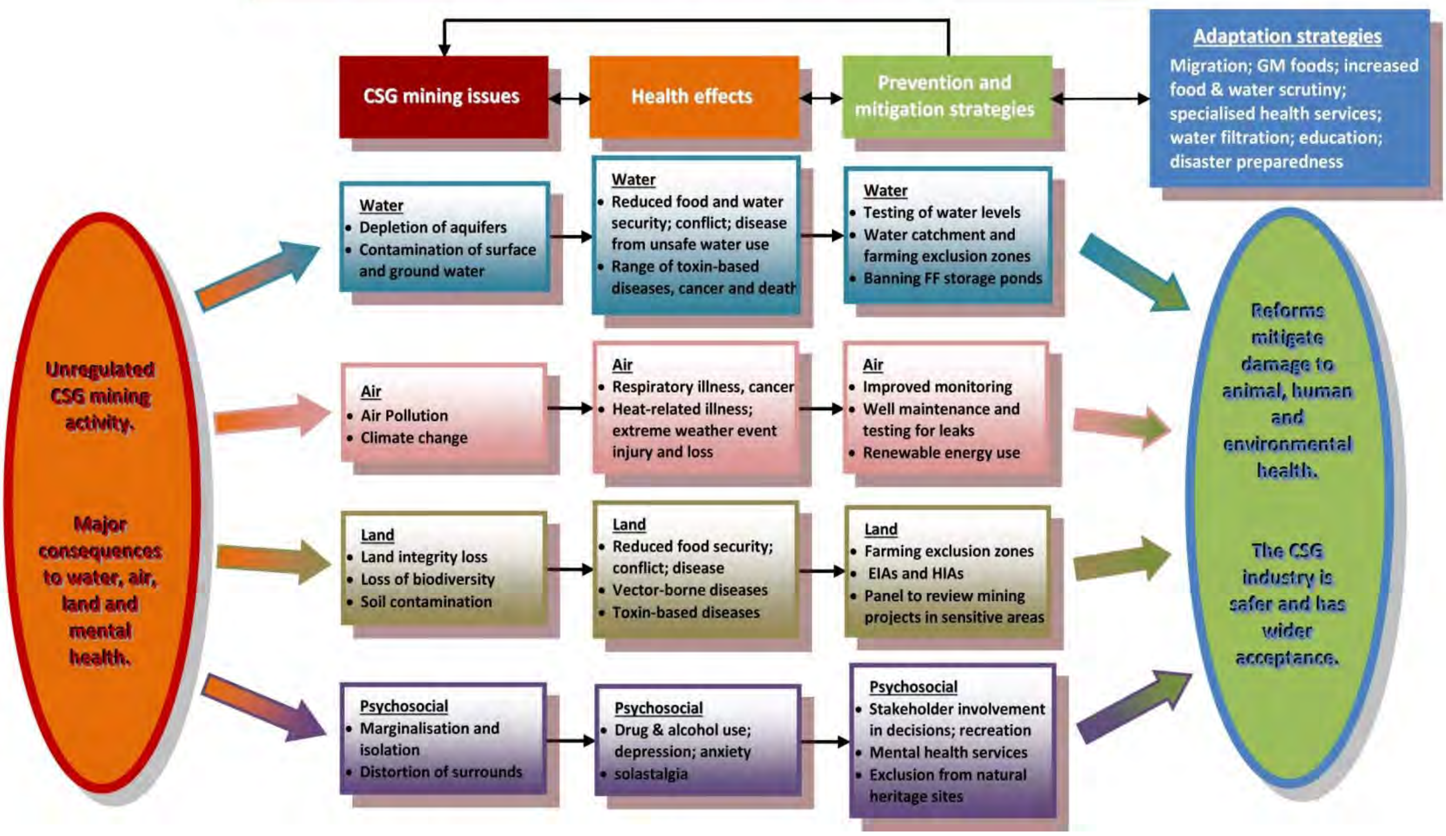
Besides the undeniable benefits of a CSG mining boom it is important to consider long-term macroeconomic and microeconomic impacts, and weigh up the consequences to the enduring life-sustaining agricultural industry from the ephemeral CSG industry (Section 6). Regional variations in geology, hydrology, local enterprise, transport and infrastructure make quantitative or even general projections extremely difficult.
That being said it is indisputable that CSG mining can generate many billions of dollars in revenue. However if the industry is unchecked this will come at the cost of local tourism, natural resources, farming livelihoods (already farmers are selling-up and leaving), land devaluation, and potentially long-term health and environmental effects (from water and soil contamination, to water and arable land depletion). Projections need to encompass

likely increases in demand for food (both domestically and internationally), the presumed impacts of climate change and the lost opportunity for developing and up-scaling renewable energy sources. For this reason strong regulation of CSG mining now can prevent significant adverse outcomes in the future and support the sustainability of other vital industries.

Summary

A range of CSG mining issues have been identified that pose significant threats to the environment, animal welfare and, vitally, human health. The key areas of concern relate to water, air, land, and psychosocial well-being (Figure 1). If these issues are not dealt with adequately it is feared that long-term irreparable damage will be done. A range of prevention and mitigation strategies have been identified which will be expanded further under the recommendations heading on the next page.

Figure 1: CSG Mining health effects and potential reforms



The executive summary concludes with a series of major and minor recommendations that are presented in the table below. If the majority of these proposals are adopted it is believed that the maximal benefit of the CSG industry will be achieved whilst restricting its long-term impacts.

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Recommendations

Table 1: CSG mining issues and related major and minor recommendations.

CSG mining issue	Recommendations
Lack of monitoring and accountability **FF proprietary protection** **Chemical use, storage and disposal** **Mining in sensitive areas** **Lack of stakeholder consultation & involvement** **"Mine and go" practices** **Reliance on fossil fuels** **Domestic CSG prices may rise to export parity levels**	**<u>Major recommendations</u>** • Baseline and regular ongoing monitoring and testing of mining practices and the surrounding environment (water sources and streams, air and soil). • Enforced disclosure of all mining products. • The banning of evaporation pits, treated wastewater disposal in surface waters, and chemical use in environmentally sensitive areas. • Enforced 2km exclusion zones from residential areas, water catchments and key agricultural sites. • Full stakeholder participation and collaboration before mining activities are approved beyond these limits. • Preliminary trust fund to be set aside by mining companies for land reclamation and to finance cleanup following spills. • Fund research into renewable energy sources from a proportion of CSG mining revenues. • Reserve a percentage of methane production for domestic use at capped prices (a domestic gas reservation policy).
Water	
Lack of environmental impact studies and emergency response plans **Water depletion** **Well failures and leaks**	**<u>Minor recommendations</u>** • Environmental Impact Assessments, Environmental Management Plans, Emergency Response Plans and waste management plans to be completed for each new mining zone site. • Regular local bore level measurements and setting of trigger drop levels for investigation and action. • Well innovation, research and redesign; regular well maintenance and testing for leaks.
Air	
Fugitive air emissions **Many potential pollutants** **Pollution from compressors**	**<u>Minor recommendations</u>** • Closed loop well systems with capture of fugitive gases; regular well maintenance and testing for leaks. • Radon testing as screening measure for other air pollutants. • Use electric rather than diesel-powered LNG compressor stations.
Land	
Lack of environmental impact studies and emergency response plans **Mining in sensitive areas**	**<u>Minor recommendations</u>** • Environmental Impact Assessments, Environmental Management Plans, Emergency Response Plans and waste management plans to be completed for each new mining zone site. • Panel of experts in soil science, hydrology, ecology and public health to OK mining in ecologically sensitive areas.
Psychosocial	
Marginalisation & isolation **Depression and anxiety**	**<u>Major recommendations</u>** • Create discussion forums, support groups and recreational activities for residents and miners; encourage employment from local communities as much as is possible; enable resident participation in mining industry meetings. • Improve mental health literacy and services in affected communities.

Executive Summary 8

Coal seam gas is an unconventional gas source, mined from deposits surrounding coal beds. Retrieval requires drilling a multitude of vertical wells, linked together by a network of roads and pipelines, and may involves injection of hydraulic fracturing fluid ("Fracking") to liberate gas from rock formations. It is an industry established in Australia since 1996 and expanding rapidly, increasing by 30% per year in the 5 years from 2003-2008. Despite this, there is little to no evidence on the environmental and health impact of this industry. It is therefore impossible to fully assess the risk to human health. This report was compiled from a literature review by a group of environmental health students, after identification of the six main areas of the industry which may negatively impact on health. Recommendations for action follow each area.

Water

Water is a central concern around the expanding CSG industry, and its link to health and wellbeing is indisputable. The risks are real and include contamination of water sources with hydraulic fracturing fluids, the problem of dealing with "produced" water, and water security. Due to the geological sites of gas deposits in Australia, fracking is not currently a common practice, however, it is predicted to increase to 40% of mines in Queensland in the future. Of greatest concern is that these potential toxins remain mostly unknown, with only two of twenty-three most commonly used fracking chemicals assessed by NICNAS, the national body for regulation of industrial chemicals. A US study found that less than 50% of chemicals used in fracking were disclosed, yet most were known to affect skin and sensory organs, and respiratory and gastrointestinal systems. A large proportion were also known to affect almost every other body system or be known carcinogens and mutagens. Significant health effects after exposures, including death, have been documented in livestock across the US, while case reports of humans there and in Australia with non- specific syndromic conditions continue to emerge. The long term health effects are yet to be studied however any substance known to be carcinogenic has no safe exposure level.

Water produced by the mining process may reach a quantity of 120,000 gigalitres over the next 25 years. Produced water contains salts, heavy metals including lead and arsenic, and toxins, including BTEX chemicals (benzene, toluene, ethyl benzene and xylene), known to cause leukaemia. BTEX chemical have been banned from fracking fluid in Australia, however they can occur naturally in the coal seam and be extracted with produced water. The concern is how this huge quantity of water is managed. Currently it is either stored in evaporation ponds, re-injected into the aquifer or treated and added to waterways or used for crop irrigation. There are obvious risks to human and animal health with spillage and contamination and also with treating methods not removing all toxins, notably BTEX chemicals.

In one of the driest continents on earth, water security is at risk from the CSG industry. Although Queensland's state government has set rudimentary "trigger points" where measured falls in water reservoirs will mean CSG companies have to "make good" to affected communities in an unspecified manner, they otherwise have free reign over water usage. There are no studies into sustainable usage for this emerging industry, even as populations are predicted to depend more greatly on groundwater with climate change and increasing drought.

Recommendations:
There need to be baseline studies on the quality of water aquifers in order to monitor potential contamination and studies on the sustainability of water usage by the CSG industry in order to regulate to protect against depletion and contamination of water for drinking, agriculture and sustaining natural ecosystems.

Emissions and Air Pollution
The World Health Organisation has deemed clear air as essential for human health and wellbeing. The extraction of coal seam gas poses many threats to this, with emissions of fugitive methane, volatile chemicals, particulate matter and collateral emissions from diesel engines all a cause for concern. Sulphur dioxide is particularly harmful to the respiratory system, and increased ozone concentrations downwind of mines has immediate respiratory effects in addition to contributing to smog, high concentrations of which are linked to higher hospital admissions and increased mortality. Diesel fumes have recently been classified as carcinogenic to humans and contribute to respiratory disease and lung cancer. The initial claims that gas is a greener energy source than coal are still in doubt due to fugitive methane emissions from well sites, which have recently been found to be larger than first reported. The greenhouse gas effect of methane is 25 times greater than CO_2, which will make the CSG industry climate change footprint approximately the same as coal over the next two decades, a time when reduction targets are to be met to stop irreversible warming and the associated health consequences.

Alarmingly there are no baseline measurements of air quality or accurate monitoring of fugitive emissions from which to measure the effect of this industry.

Recommendations:
Again, accurate baseline data is required ideally prior to construction of mines to truly known the impact of industry. There need to be new agencies and legislation created to cover the industry and avoid current loopholes and exemptions which exist. This should be created at a federal level.

Land use
The issue of land use in regards to CSG mining involves many potential risks to health. Soil contamination with industrial chemicals (many of which remain unknown secondary to lack of legislation requiring their disclosure), volatile organic compounds, salts and heavy metals all risk health through inhalation as dust or gas, or ingestion through foods grown in contaminated soil. Salinity is a huge issue with approximately 100kg per well per day requiring disposal. The actual health effects of soil contamination remain unknown with an absence of research. The planning of land use and availability for other uses, primarily agriculture has a direct effect on health. Recent reports have concluded agriculture to be incompatible with CSG mining, with many of the largest deposits being found under arable land. Land use planning has a strong influence on public health outcomes, however there has been a lack of consultation with public and environmental health experts in production

of new policy regarding planning of CSG mining locations. There is also a distinct absence of consideration for land reutilisation following the productive lifetime of mines, a relatively short period of approximately 30 years. Experience from coal mining has shown sites to be irrevocably destroyed for future farming. These compounding issues signal a grave threat to food security both locally and for export needs.

Recommendations:
Heath impact assessments need to be mandatory for new mining developments. Public or environmental health expertise must be incorporated into committees which influence land use planning in regards to mining developments. The issue of land reutilisation needs to be researched and addressed adequately in policy. There must be a legislated national requirement to disclose all components of industrial chemicals.

Risk to biodiversity
In regards to biodiversity, Australia has a lot to lose. Approximately 85% of mammals and flowering plants, 94% of reptiles, and 45% of birds are native to the landmass, and can't be found anywhere else on earth. CSG development poses a direct documented threat to biodiversity through land clearance for wells and road networks, which also cause habitat fragmentation. Research has shown environmental noise pollution from drilling and fracking can cause endangered bird species significant stress or to avoid their habitats, and deer populations to decline from changes to habitat selection. The obvious risk of water contamination has also been linked to deaths among several wild species, and health problems in domesticated animals. Landscape changes also pose a risk to health by changing the patterns of vector borne diseases and limiting biodiversity may reduce the potential for discovery of novel pharmaceuticals.

Recommendations:
Planning and development must consider natural ecosystems and monitor the effect on them. Industry should invest in conservation to fulfill their social responsibility.

Psychosocial wellbeing and mental health
The negative effect on psychosocial wellbeing and mental health from the coal seam gas industry is often evident in media, yet again is an issue which is under researched. Mining in general can marginalise farmers in the rural setting, who are already a vulnerable population after long periods of drought, flooding, and bush fires. In regards to coal seam gas, farmers have little rights to refuse companies access to their land. They may then be paid only a minimal fraction of the profits from each well, and also incur land devaluation secondary to mining infrastructure, often forcing them to sell and move. From this, the sense of inequity and injustice and loss of control, assumed rights, livelihood and tradition all impact on psychosocial wellbeing and mental health. 'Solastalgia' is a concept coined to capture the essence of the relationship between ecosystem health and human health and the poorer mental health outcomes that occur with loss of control over either. Both farmers and other residents are susceptible to this as has been seen in the Hunter Valley region. Secondary to drilling and transit of heavy machinery, residents are also at risk of sleep disturbance, circadian rhythm disruption and consequently a wide range of symptoms from inattentiveness to depression and decreased academic performance.

Recommendations:
Studies on psychosocial impact specifically to farmers and residents in close proximity to mining are needed. Companies must invest in treatment and support measures if links are demonstrated.

Economic impacts
The royalties and taxes from coal seam gas mining should be significant income for governments, however to date no modeling has occurred. Currently no royalties are paid until the 5th year of production and lower rates until the 10th, meaning states will lose billions of dollars in the initial most productive years of mining. Low royalties to landholders, for example $5000 per well, where profit may exceed $800,000 per well per year, may be insufficient to cover lost production or land devaluation. Small towns may receive a boom from the industry, however there may be limited long term job creation due to the industry being quite low in required human resources once wells are completed. There are also concerns over creation of a two speed economy between mine and non- mine workers, leading to service competition and housing in-affordability. The industry has made no guarantees against a fly in/out workforce. Risk to community income from tourism is significant, for example in rural Gloucester tourism contributes $28 million per year to the economy. Whilst data about how economic changes may impact health are rare, the economic cost of potential health effects secondary to CSG industry is completely unknown.

Recommendations:
Independent research on energy needs and true economic benefit are needed. The industry needs increased transparency. Also needed is modeling of state benefits from tax and royalties and independent cost benefit analyses and heath impact assessments.

Risk to industry workforce
Occupational health and safety for the workforce of the CSG mining industry is an important, albeit neglected issue. The industry currently employs over 7,300 employees directly, with over 20,000 contractors involved in mid 2012. Physical health hazards include dust inhalation and risk of respiratory illness and silicosis, exposure to fracking toxins, a high risk of explosion incidents, and increased risk of transportation accidents. Furthermore, workers and their families' psychosocial wellbeing may be affected by shift work and isolation of camp environments, and conflict and marginalisation secondary to fly-in, fly-out conditions. Workforce culture may stigmatise psychosocial impact, with one report of 41% of employees failing to complete mental health screening questionnaires. Adding to concern is the notion of 'double burden' where in addition to direct physical and psychosocial impacts, mine workers are also susceptible to the wider indirect health affects and "solastalgia" as described above.

Recommendations:
The CSG industry needs to be primarily responsible for the health and well being of its work force by providing medical cover. This obligation should be supported in legislation. Workers should be encouraged to form or become part of a trade union to collectively protect their personal rights to health and safety.

Executive Summary 9

Introduction

Coal Seam Gas (CSG) mining activities in Australia provides an alternative to traditional fossil fuels as a source of energy with a possible reduction in greenhouse gas emissions. The rapid development of this industry has not only provided economic opportunities but also created potential risks to ecology and human health. These effects are multifactorial and affect both rural and urban populations. Fuelling the concerns are the effects on water, food security and human health. This has been aggravated by the knowledge that this is a vast water consuming industry, the largest deposits of coal seam gas being found on agricultural land and the increasing proximity of mining sites to residential and urban communities. Compounding these concerns is also the lack of transparency regarding the chemicals used in the fracking process and the very limited research done to establish both the direct and indirect health and ecology impacts. A review of the limited existing literature was therefore done as a group class exercise to examine the possible effects of the CSG mining process on population health in Australia.

Effects on water

Australia's already limited water supply is being compromised by CSG mining activities. The industry utilises large amounts of water estimated at 300 gigalitres of water per year and wells in Queensland are predicted to increase from 4000 to 30,000 over the next two decades (p.10). Although CSG mining in Australia is shallower, there is greater water production and subsequently more likelihood of contamination of the water table. Produced water contains volatile organic compounds, radioactive substances and carcinogenic compounds which are either disposed of using evaporation ponds or recycled and added into waterways or used for irrigation in agriculture. There is potential for spillage, leaks and overflow during heavy rainfall. Reverse osmosis, the most common method used for removal of salts and chemical constituents from produced water is not always effective as it only targets specific sized organic compounds. BTEX for instance goes undetected. Although BTEX has been banned, it is naturally found in the coal gas seams and can be released during the fracking process into the groundwater or aquifer or may be vaporised into atmosphere with the risk of causing leukaemia. Produced water also causes ground level ozone production with subsequent respiratory symptoms. Salinity from produced water can lower the permeability of soil to air and water, reducing nutrient availability and causing death to plants and damaging aquatic species. Therefore CSG mining processes effects on water are potential risk of water scarcity, increased risk of toxicity to humans through contamination of the water table and damage to plants and aquatic species.

Gas emissions and air pollution risks

Research exists demonstrating a relationship between air pollution from CSG released toxins and ill health (p.24). Production of ozone and increased particulate matter causing smog occurs as a result of processes during CSG mining. Although improved technology to capture waste products, reduce flowback and subsequent evaporation is now being used, calm winds and air inversions increase the likelihood that potential toxins could reach levels harmful to health. Ozone and smog are major causes of respiratory symptoms requiring admission and evidence exists showing a linkage with increased mortality and premature deaths worldwide yearly. They have also been shown to affect plant photosynthesis adversely.   There is also risk of bushfires as majority of the fumes from the CSG process are flammable. Methane's greenhouse gas emissions are at least 47% less than for coal (p.34). However baseline studies on emissions need to be done before the development of gas fields otherwise the carbon price liabilities of fugitive emissions may make the CSG industry in Australia economically counterproductive.

Land use risks and concerns
As reported in Chapter 3, CSG exploration and production have moved nearer to urban populations and arable land. This is of concern because 5% of Australia's agricultural land mass is arable land. Intensive mining is associated with ground and surface water contamination, soil erosion and contamination, air pollution, noise pollution and habitat destruction. Heavy metals which are harmful to both human and animal health such as lead, arsenic, mercury and cadmium are found in produced water and Lead and Arsenic have been reported at sites near Pillaga. Salinity in produced water potentially degrades topsoil and kills vegetation. Mines have a short lifespan of 30 years and land can never be used for agriculture once mining activities cease. Limited land for food production and the possibility of unsafe food from possible chemical pollutants further threatens food security, subsequently decreasing Australia's ability to export food. Loss of farming livelihoods relates to loss of quality of life for those farmers whose lands have been used for mining. Most importantly, there is a lack of public health expertise on the advisory panel of experts regarding land use planning and CSG mining activities. Thus, CSG activities pose a threat to land use by competition for and destruction of agricultural land.

Potential risks to biodiversity
CSG mining's major impact on biodiversity is its effect on land clearance contributing to the decline of threatened species and habitat fragmentation. Evidence also exists that noise pollution causes animals and birds to change their habitat causing an alteration in the ecosystems. The creation of evaporation ponds could also result in an outbreak of zoonotic diseases and endemic vector borne diseases. CSG mining thus has the potential to destroy the ecology, alter the geographical distribution of diseases and cause a decline of Australia's peculiar fauna.

Risks and concerns to psychosocial wellbeing and mental health
Evidence from Chapter 5 shows that mental illness and stress have been very commonly reported within the coal mining districts. A study conducted in Western Australia showed an association between dryland salinity and an increased risk of hospitalisation and depression. Noise and environmental pollution by contaminants, loss of land, conflict with the officials of the mining industry and community lead to stress, anger, anxiety and sadness for land owners and members of the community. Long shift hours for workers also causes stress and anxiety. These invariably lead to poor mental health, susceptibility to infections and risk of noncommunicable diseases. Environmental threats have the potential to adversely affect the wellbeing of young people which is already being compromised by mental illness. Disruptions to family and community, poor parental mental health as a result of social effects of the mining industry have the ability to affect the academic performance, reproductive ability, social relationships, and increase the risks of diabetes and mental illness in young people. Solastalgia is also most commonly experienced by land owners and farmers who have been lost their lands due to CSG exploration.

Economic impacts of CSG

It is expected that the CSG industry will lead to increased energy security, economic growth and local employment opportunities. While there may be economic benefits from CSG, a critique is that a majority of the research relating to benefits is funded by the mining companies themselves. Contrary to opinions of employment opportunities, the potential for long term jobs is limited because the industry is a low human resource industry. Increased short term employment in the mining industry potentially impacts negatively on the local economy by creating a limited labour supply and higher price of labour. Energy security would also only result from the state implementing a domestic gas reservation policy that ensures a portion of CSG for domestic use. There may also be a reduction in the tourism industry due to land clearance and noise pollution. The actual measurement of the economic value of possible health impacts is impaired because of the technical difficulty in classifying the primary or secondary effects of CSG mining and the need for information on the actual composition and use of the fracturing fluids.

Risks to workers in the industry

Mental illness affects up to 20% of the Australian community annually (p.92). Miners are therefore likely to experience mental illness due to the risk factors associated with the industry like drug and alcohol abuse, and social isolation. Family conflicts, strained social relationships and engagement in substance abuse have also been documented as common among FIFO or DIDO workers. Workers face increasing community hostility and conflict and long shift hours which impacts negatively on their mental health. Aboriginal and Torres Strait Islanders face the possibility of conflicts between the choice of economic benefits of mining employment and loss of their traditional land. Occupational risks include silicosis due to dust inhalations, mining explosions and transportation accidents.

Gaps

The major limitation of this study was the scarcity of data and literature on the direct effects of CSG mining on health and the environment. Consequently a number of extrapolations have been made based on research findings from similar mining procedures in other regions. From the report identified gaps which need to be addressed are:

- Urgent need for focused scientific research exploring causal relationships between CSG mining and human health and the environment.
- Implementation of national policies regulating the composition and disclosure of fracking fluids
- Inclusion of public health expertise in the advisory process relating to CSG activities
- Collaboration between the community, health, mining personnel and policy makers to guide and support the process.
- Ensuring bioregional planning policies that would not allow compromise of the landscape.
- Adequate research on the economic benefits of CSG activities on the community.

Considering the potential adverse effects to human health and the ecosystem, the Precautionary Principle must be applied until substantive evidence-based decisions are reached about the health impacts of CSG mining.

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Coal Seam Gas (CSG) mining has only had a short 16 year history in Australia, however not many issues have divided the country so profoundly and caused such outrage as it has. The rhetoric on both sides of the debate is persuasive. CSG mining has the potential to add billions of dollars to the Australian economy which could be funneled into many key areas including health, education and infrastructure development. On the other hand, the potential ramifications of this industry on our environment, natural resources, current industries and, most crucially, on the health of everyday Australians, cannot be ignored. The paucity of rigorous, unbiased evidence detailing the answers to many of the issues raised in this debate is a considerable problem that does nothing to assuage the fears of Australians.

What we have endeavored to do in this report is build a comprehensive, unbiased review of the literature to date. It aims to assist in providing a clearer picture of the impacts CSG mining has on the health and wellbeing of the Australian population. This paper will discuss the key areas under current debate within the CSG industry including water; gas emissions and air pollution; effects of land use including soil contamination & the impact on food security and biodiversity as well as the complex and multifaceted economic considerations. This report will also discuss the psychological impact the CSG mining has not only on farmers, land owners, business people and everyday Australians but also on CSG workers and their families. The overall theme of this report is the interconnectedness of these varying issues and the 'flow on effect' damage to one has on others.

The primary area that features heavily in the CSG debate is the issue of water, which is featured as Chapter One of this report. Considerable debate has raged in the media and scientific circles as to the impact of CSG mining on, not only, the amount of water being used but the quality of water being left behind. Figure 1 (as highlighted in Topic 1a) gives a succinct summary of the complex issues surrounding water and CSG production.

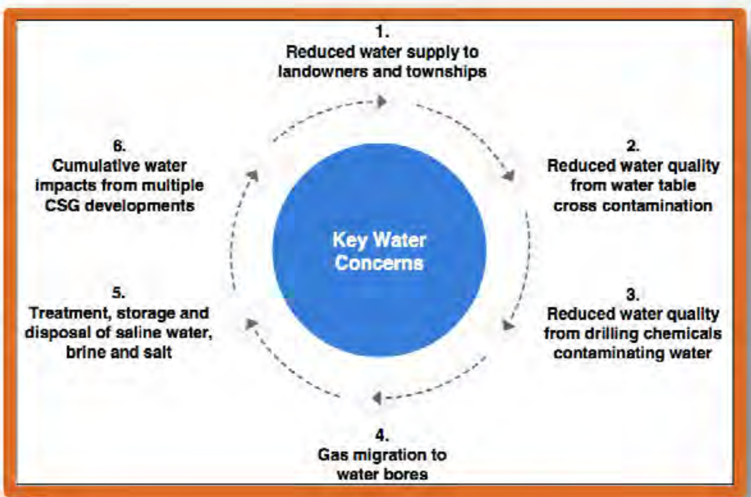

Figure 1: Key CSG water concerns (JP Morgan Asia Pacific Equity Research, 2010)

This report will highlight the potentially profound health effects of many of the chemicals used in the fracking fluids and then found in the byproducts of the mining- the ‘produced water’ (as detailed in topic 1 B). It also describes some of the processes being implemented to mediate these effects, including ‘aquifer recharge,’ and reverse osmosis. These practices do however have their limitations. It will also detail the enormous amounts of water that is used within the CSG mining process (over 300gigalitres per year) and the impact the use of this water will have on crucial water basins including the Great Artisan Basin. This is particularly poignant in a country that is so often plagued by drought and water insecurity.

As detailed in Chapter 2, the chemicals used in CSG mining that have the potential to contaminate the water sources also have the capacity to contaminate the air. This chapter discusses air pollution and gas emissions and features some of harmful chemicals commonly released in CSG production. It highlights the disturbing paucity of evidence regarding the effects these chemicals are having on local populations. It also details some newly emerging research detailing the increasing emissions of methane and radon gases (both highly toxic) and the impact of ‘fugitive emissions.’

> “Exploration for, or production of, gas has the potential to severely disrupt virtually every aspect of agricultural production on cropping lands and, in extreme circumstances, remove the land from production.” (Rural Affairs and Transport References Committee, 2011)

These same pollutants again feature in Chapters 3 and 4, which continue to highlight the interconnectedness of these key issues. In Chapter 3 we explore the land used in CSG mining and the impact it has on soil contamination, and the impact on agriculture and food security. It is here that the broader impacts of contaminated water, soil and air as well as a decline in the amount of water available is shown to have a far reaching impact. The potential effect CSG mining could have on the agricultural industry cannot be ignored. Neither can its potential effect on biodiversity as highlighted in Peduzzi and Harding’s (2013) persuasive article.

From here, we move into critically examining one of the key arguments made by the mining industry in favour of CSG mining. The potential economic rewards of CSG mining as shown in Chapter 6 are not disputed. The potential revenue generated for the state and commonwealth governments could be substantial. However, when that is viewed in line with the potential economic effects, in particular on the agricultural industry, the issue becomes more complex. The potential impacts on the industry as a whole but also at a micro level on the individual farmers is explored.

We have strived throughout this report to highlight not only the research behind the key issues surrounding CSG mining in Australia but also paying special attention to how these issues relate to the health and wellbeing of the population. As is demonstrated throughout the report, all the issues interconnect and highlight the possible ramifications of toxic chemical exposure on humans and animals. Along with the physical health problems detailed throughout this report, special attention has been paid in Chapters 5 & 7 to the psychological impacts CSG mining could have on the community. These chapters make an important contribution to the understanding of the 'invisible' effects of CSG mining on the population, which is detailed particularly well by Hossein et al (2013). The concept of 'solastalgia' is woven through a number of chapters and is used to describe the loss of a 'sense of place' and identity (Albrecht et al., 2007).

As mentioned, the report aimed to provide a comprehensive review of the available literature on CSG mining in Australia. Overall this report highlights the great discrepancies and holes in the current knowledge base. As mentioned, CSG mining is an incredibly lucrative 'money earner' for the Australian Government which will help provide government funded services to the wider community. It has the potential, however, to come at quite a considerable cost. Contamination to our soil, water and air through the use of toxic chemicals appears to be a very real threat. However, this review has thrown into sharp relief the lack of robust evidence either supporting or refuting many claims made by both sides of this argument. Should the question now be: with the current lack of knowledge should we be playing Russian roulette with the very environment that sustains us? Some of the evidence is clear but there are too many unknowns. This report clearly shows the need for more high quality robust information to enable the government and the people of this country to make an informed decision around CSG mining.

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Part 2. Twelve Individual Topic Reports on different concerns and risks associated with coal seam gas mining

In this section, we present twelve topic reports prepared by students who researched different aspects of the risks and concerns that were first identified in their initial readings and discussions in class. As explained on page 8, these represent a subset of the 22 topic reports that were shared by the students in order to prepare their executive summaries.

The topic reports are organized into four chapters. Reference lists relating to the topics are provided at the end of each. For the Chief Scientists' convenience, these lists include both those cited in the chapters, as well as additional references that were located that may be useful for her review and assessment.

1. Chemical pollution risks to water, soil and soil

In this chapter:

- Hazards of fracking fluid used in Coal Seam Gas mining
- Potential risks of fracturing fluids contaminating soil
- Air pollutants and their health risks
- Contributions of methane gas emissions to climate change

1 A: Hazards of Fracking Fluid used in Coal Seam Gas mining

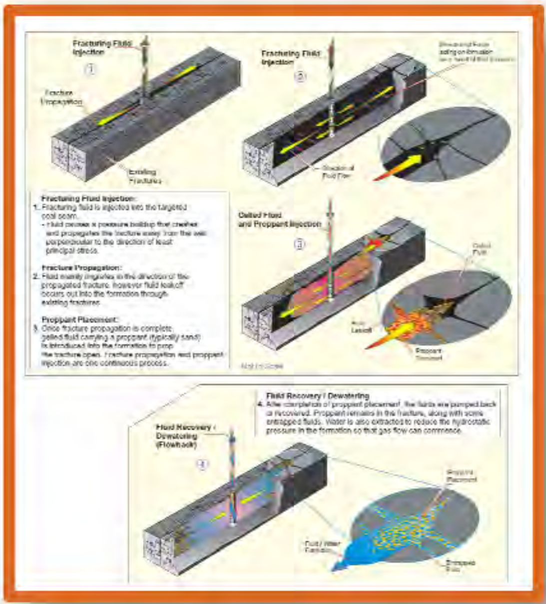


Figure 1.1: Graphical representation of the hydraulic fracturing process in coalbed methane (coal seam) wells (US EPA, 2004, p.ES-5).

i. Introduction

Rapid development of the coal seam gas (CSG) industry in Australia has produced opportunities for societal improvements through revenues generated, but also risks to ecological and human health through the toxic chemicals utilised for methane production, the by-products of extraction processes and waste management of those substances. Chief among environmental health concerns are impacts on water resources (Figure 2; Group Against Gas, 2011), in particular depletion and contamination of aquifers and groundwater for drinking, agriculture and sustaining natural ecosystems. The hazards posed by the chemicals in fracking fluid (FF) are particularly relevant to water issues and will be the focus of this section of the Report.

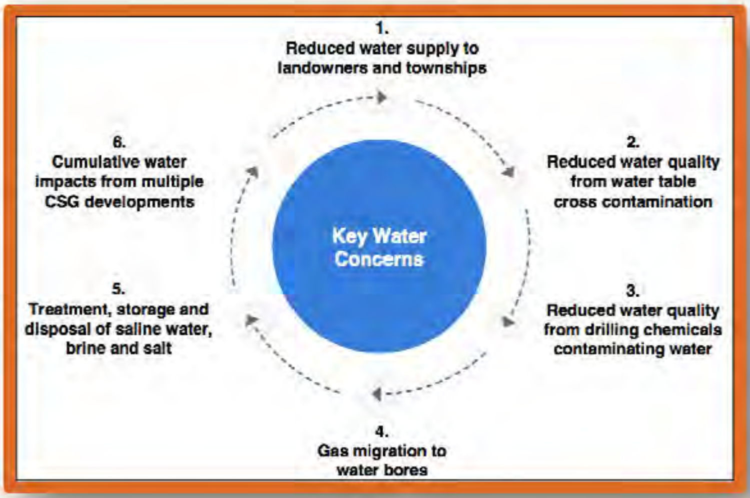


Figure 1.2: Key CSG water concerns (JP Morgan Asia Pacific Equity Research, 2010, p.10. In, Rutovitz, Harris, Kuruppu and Dunstan, 2011, p.28).

A tension exists between economic pressure to capitalise on Australia's vast natural gas resources (Figure 3), credited by some with helping Australia through the Global Financial Crisis (Department of Resources, Energy and Tourism, 2012), and tampering with vital water resources such as the poorly understood Great Artesian Basin (GAB; Figure 4), which could produce unintended consequences for generations to come (Carey, 2012). Lack of disclosure of fracking procedures and chemicals, combined with incidents of toxic spills, surface water contamination, livestock losses and syndromal symptoms arising among people living near to coal seam gasfields (Bamberger & Oswald, 2012; McCarron 2013) are among the many concerns raised about this industry by community members, doctors, researchers in Australia.

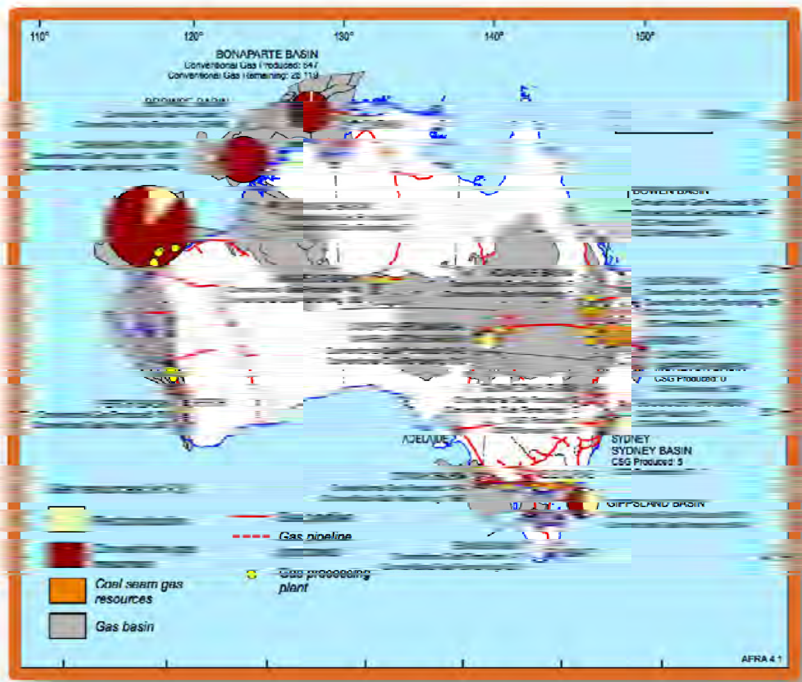


Figure1.3: Location of Australia's gas reserves and infrastructure (Rutovitz et al., 2011, p.70).

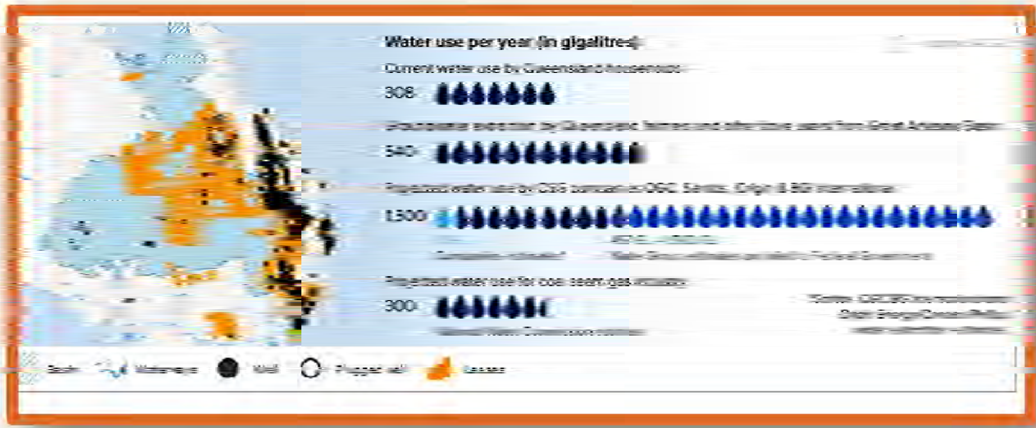


Figure1. 4: CSG mining collocation with the GAB (blue stripes) and water usage rates (ABC News 2011).

ii. Risks posed by hydraulic fracturing

Mechanisms by which FF can cause contamination include: drilling through aquifers; seepage due to fracturing strata above or below the coal seam especially from horizontal drilling (Figure 5); enhanced migration of fluids along cleats following reduction of hydrostatic pressure; spills of flow-back fluid; well and pipe failures; insecure or degraded cement well-casing; and retrieved fluid treatment and storage issues (Figure 6; Rutovitz et al., 2011, p.37-38; Lloyd-Smith and Senjen, 2011; Entrekin, Evans-White, Johnson and Hagenbuch, 2011; Bateman 2010).

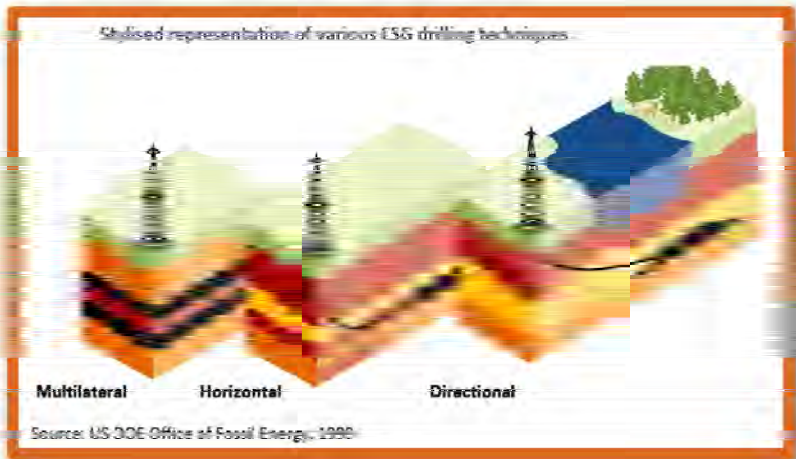


Figure 1.5: CSG drilling techniques (Rutovitz et al., 2011, p.21).

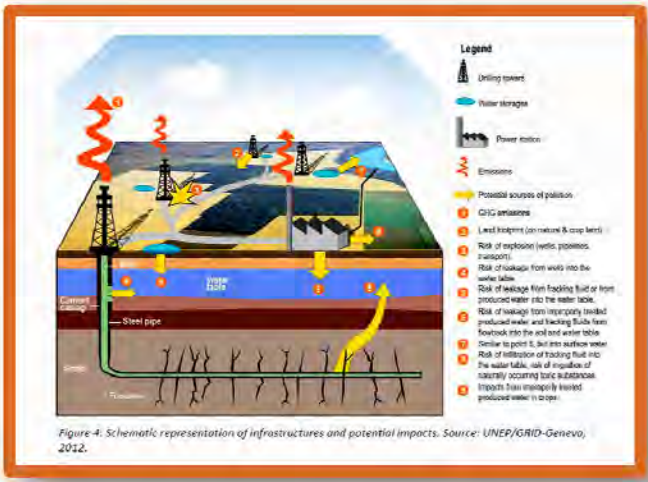


Figure 1.6 :Environmental impacts and potential hazards from CSG mining (UNEP-GEAS, 2012, p. 6).

Well blowouts and casing failures due to microbial action, cement carbonation or shrinkage are a well-known industry hazard (Mavroudis,2001, p.8). Cement carbonation leading to corrosion is a particular issue in CSG mining due to the high concentrations of bicarbonate and aqueous carbon dioxide in associated waters (Taulis and Milke, 2007). Foreseeably in such cases the pumps in active wells can propagate toxins to any height along the well (Figures 1.7 and 1.8).

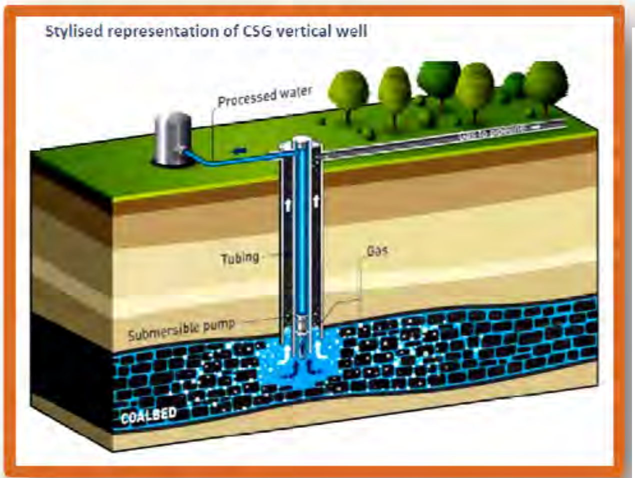
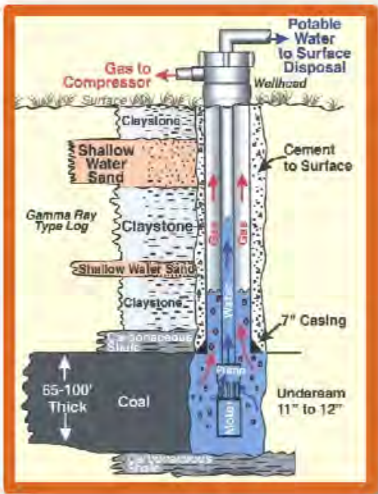


Figure1. 7 (left): A "producing" CSG vertical well (Rutovitz et al., 2011, p.22)

Figure 1.8 (right): Close-up of a producing CSG well (Johnson, 2004, p.2).



Having established the toxicological principle of potential exposure pathway, it is necessary to determine whether toxic substances in high enough dose are made accessible through CSG mining practices, which the CSG industry often says is not the case (Legislative Council, 2012a, p.70; APPEA, no date). However, although large amounts of pumped and retrieved water dilute chemical constituents, many of the chemicals involved are highly toxic even at very low doses (Figure 1.9). These chemicals will be examined in more detail shortly.

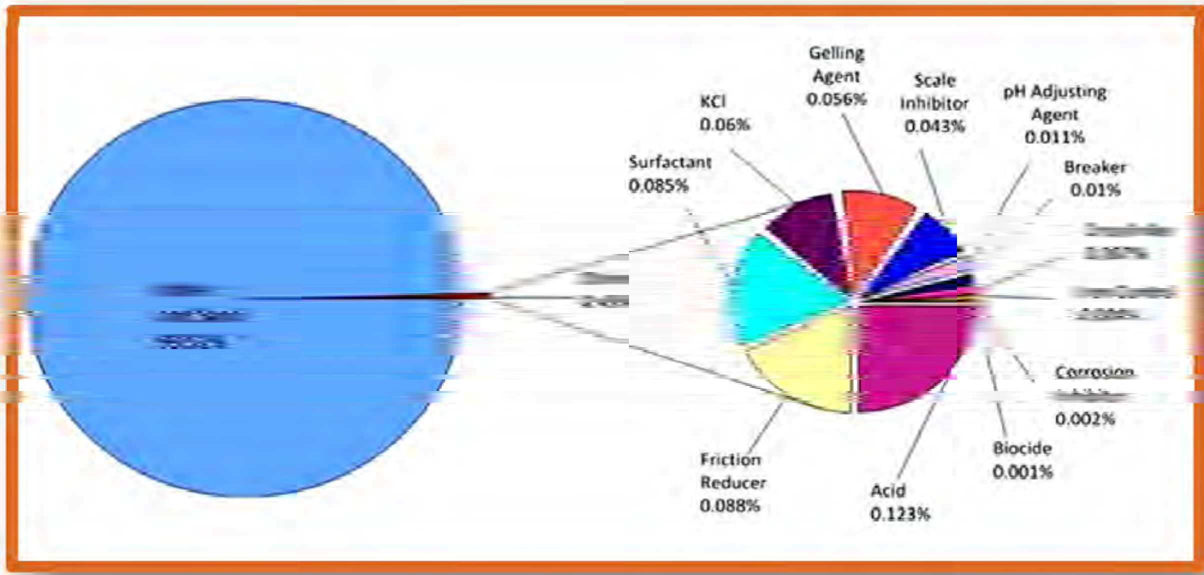


Figure 1.9: Products used in fracking (Shelley, 2011, p.9).

iii. Regional considerations

Firstly it is important to qualify that there are significant differences between methane mining operations in the U.S. and Australia, and even between Queensland and NSW. In the U.S. the majority of unconventional gas deposits are within shale strata which are deeper, more impermeable, and require a higher proportion of hydraulic fracturing (typically 80-90% of wells) to extract methane (NSW Legislative Council, 2012a,b; Rutovitz et al., 2011). As choice of chemicals is dependent on local geology, it is possible that U.S. fracking fluid preparations and toxicity profiles are different to Australia.

In Australia CSG mining is shallower with greater water production and reportedly less need for hydraulic fracturing in some cases. The reduced depth may make contamination of the overlying water table more likely (Rutovitz et al., 2011). In Queensland approximately 8% of wells drilled by 2011 were fracked, but the need for more frequent fracking, between 10% and 40% of wells, over time is anticipated (Rutovitz et al., 2011). In some parts of NSW the fracturing rates are even less with one company (Metgasco) foregoing it (NSW Legislative Council, 2012a), however fracking rates in the Sydney basin Camden Gas Project have been much higher (85%) (Doctors for the Environment Australia, n.d.). New techniques such as multi-lateral in-seam wells may reduce the need further. Perhaps the NSW moratorium on fracking practices is having positive benefits.

Another area of progress in NSW is adaptation of best-practice procedures. Utilising the longer history of U.S unconventional gas mining and environmental incidents, spraying of wastewater on dirt roads has stopped, open storage pits of produced water have been banned, as also BTEX chemicals, and dumping of treated water into streams (Rutovitz et al., 2011). Several open forums and government inquiries have seemingly enhanced communication and accountability. Despite these promising adaptations, issues of mistrust, ongoing toxic chemical use, and fear of water contamination are ever-present.

iv. Chemical Toxicity

A range of chemicals are used in CSG mining procedures which fulfill a number of roles (Table 1.1 overleaf). In the U.S. proprietary issues from chemical suppliers preclude full disclosure of certain product information. This has led to a startling situation whereby some companies are injecting and disposing fluids into the ground without comprehension of their potential risks to human health and the environment (U.S. House of Representatives, 2011).

Types of Chemicals Commonly Used in Fracking Fluids in Australia

Note: This summary of chemicals and their uses was consolidated from the MSDS provided by the CSG companies and verified by industry sources in Australia.

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

Table1.1: Common FF chemicals (Lloyd-Smith and Senjen, 2011, p.8).

In Australia only 2 of the 23 most commonly used fracking chemicals have been assessed by the national industrial chemical regulator, NICNAS (Lloyd-Smith and Senjen, 2011). In the U.S., it is even less. In one study on the composition of 944 products used in natural gas operations, 43% of them disclosed less than 1% of their contents (Colborn, Kwiatkowski, Shultz and Bachran, 2011). Yet 75% of the 353 chemicals that could be traced were known to affect the skin, eyes, other sensory organs, respiratory and gastrointestinal systems; 40-50% could affect the brain/nervous system, kidneys, cardiovascular and immune systems; 37% could affect the endocrine system; and 25% were known to be carcinogenic and mutagenic (Colborn et al., 2011). The more toxic substances tended to be volatile, able to vaporise and cross the blood -brain barrier.

A unique opportunity to test drilling chemicals occurred due to a well blow-out during the drilling stage before fracking began, and they were found to be just as toxic (Colborn et al., 2011). Exposed individuals suffered respiratory distress, nausea and vomiting and required evacuation from their homes.

It was noted that various systems, most notably the endocrine system are sensitive to very low levels of such chemicals, in the order of parts-per-billion. Affected individuals may display subtle, delayed unpredictable effects that can be passed onto their offspring such as fertility issues and sex-related disorders. Entrekin et al., (2011) cautioned that most contaminants are assessed through single-species acute and chronic toxicity laboratory tests with standardised test organisms, but more complex testing of FF mixtures is warranted to predict effects in the real world.

v. Human and animal Toxicity

There were few confirmed toxic exposures among people, but it is likely subtle effects may have been overlooked in certain cases, or that testing was poorly timed or inadequate. Bateman in his article revealed non-specific syndromal symptoms of chronic dizziness, headache, tingling/neuropathy and idiopathic haemorrhaging (nosebleeds) with one case of an endocrine tumour (2010, p.8). Interestingly like symptoms in complainants near active CSG sites in Tara Queensland are consistent with low-grade exposures, but due to the generality of symptoms and lack of clinical findings, exposure cannot be confirmed (Hutchinson, 2013; Queensland Health, 2013).

More obvious are the findings across 6 U.S. states of hair loss, neurological disorder, gastrointestinal upset, spontaneous abortions and death among livestock following confirmed contamination from FF holding tank spills and wastewater impoundment leaks (Bamberger & Oswald, 2012). Their human counterparts also suffered with burning eyes, headaches, endocrine, respiratory, sensory and dermatological symptoms in keeping with the chemical profiles of some products.

vi. Conclusion

Having established potential exposure pathways, the presence of highly toxic chemicals including mutagens and carcinogens that do not require threshold dose-response curves, and examples of toxicity in animals and humans despite industry precautions, it can be concluded that CSG operations can be harmful. It is time that a national moratorium on CSG activities be enacted pending research on FF chemistry and its long-term effects on humans.

3 B: Potential risks of fracturing fluids contaminating soil

This section investigates the potential for soil contamination and its impacts from the coal seam gas (CSG) industry and in particular the process of hydraulic fracturing or 'fracking'. It considers the risks associated with standard operating practices and the increased risks of unsafe practice, focusing on the potential adverse effects to humans.

i. Context

CSG extraction is a controversial issue in the state of NSW, regarding existing and proposed activities, with many potential sites being on highly productive agricultural land.
In September 2012 the NSW state government lifted a moratorium, placed in 2011, on hydraulic fracking in NSW[12]. In its place it imposed a code of conduct demanding full disclosure of all chemicals used and their concentrations and potential health effects to the community [3] (NSW Code of Practice for Coal Seam Gas Fracture Stimulation Activities 2012: 7).

ii. Route of introduction

Through the mismanagement of fluids, the 'flowback' effect, and in particular the practice of using open, evaporative pits [4] (see Appendix 1) for waste management CSG risks the introduction of toxic substances including heavy metals, chemicals, hydrocarbons and even radioactive substances to the environment (Lloyd-Smith & Senjen 2011). The drilling process itself is associated with many harmful chemicals (see Appendix 2).

Areas irrigated with inadequately treated wastewater are at risk of contamination, with some substances known to be too small for filtration (Lloyd –Smith & Senjen 2011). Additionally spills are alarmingly common[5] (Carey 2012)

iii. Chemicals

It is impossible to fully assess the risk to human health due to CSG activities, as virtually no studies have been conducted (Carey 2012). The CSG industry claims that because very low concentrations of the chemicals are used they therefore pose little threat to health (APPEA

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[1] The NSW government had declared that it would be premature to lift its' moratorium until the chemicals used in fracking are tested by NICNAS (Williams 2012: 51)

[2] Community concerns have since forced the state government to place further regulations in relation to where companies are allowed to explore and extract natural gas.

[3] The NSW state government has also commissioned an Independent (IESC) to fully explore the potential impacts of the process.

[4] The NSW Code of Practice CSG does not explicitly prohibit the use of open pits (2012: 8), whilst QLD prohibits them unless there is no feasible alternative (Dept of Environment and Resource Management 2010 in Lloyd-Smith and Senjen 2011: 15)

[5] with 45 compliance related issues in 6 months in QLD alone, including 33 incidents involving inappropriate discharge of contaminated water.

2012: 1 & Colborn et al 2011). However, this has to balanced with the sheer volume of fluid used; up to 2.5 million litres per well, 60% of which returns with volatile organic compounds, high concentrations of ions, heavy metals and radioactive substances from the coal seam (Carey 2012). Aside from the individual chemicals, combination effects have not been studied.

The lack of transparency of companies in disclosing the constituents of the fluids used in both standard unconventional natural gas extraction and hydraulic fracturing, severely hinders accurate assessment (Colborn et al 2011). US attempts to make companies fully disclose constituents of fluids used have been unsuccessful, with companies claiming trade secrecy should prevail (Carey 2012).

The main investigation into the chemicals used was conducted by TedX in the US[6], (which they declare, due to the inadequate data, far from exhaustive), they found 944 products used in the process, comprised of a reported 632 chemicals, of which only 353 were identifiable by CAS numbers (Colborn et al 2011). 210 of these chemicals were volatile, with greater exposure risk due to their potential to become airborne and potential for entering the food chain (see figure 1)

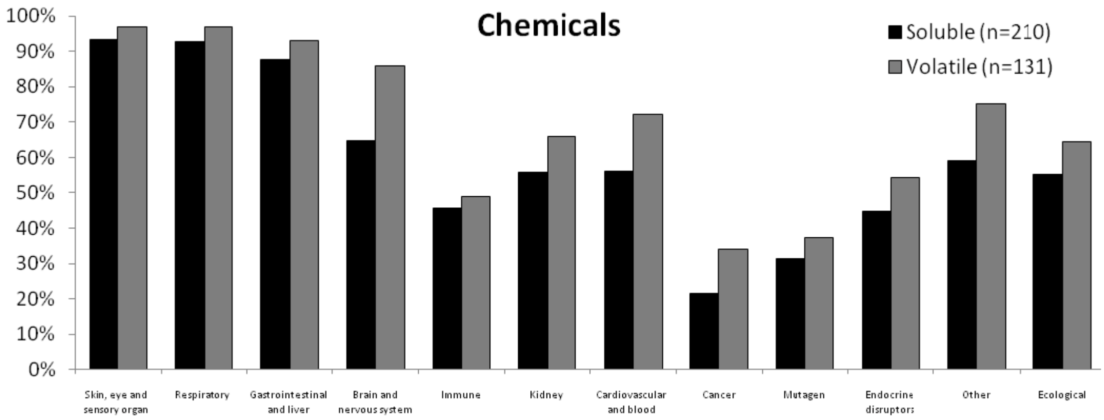

Figure 3.1: Profile of potential human health effects of soluble and volatile

Notably of the volatile chemicals
-93% can harm eyes, skin, sensory organs, respiratory tract, gastrointestinal tract or liver
-86% can harm the brain or nervous system
-72% can harm blood or cardiovascular system
-66% can cause renal damage
(TedX 2011: 3)

Overall: (see Appendix 3)
-55% of the chemicals can harm the brain and nervous system, with common acute effects like burning eyes, rashes, coughs, sore throats, asthma like symptoms, nausea, vomiting, headaches, dizziness, tremors and convulsions
-Up to 47% were associated with long-term effects including cancer, organ damage and harm to the endocrine system (see figure 2).

[6] based on available MSDS's, a 2007 New Mexico study of evaporative pit contents and the analysis of a major spill during the drilling phase of a new project

- Notably only 10% had no reported adverse health effects (figure 2)(Colborn et al 2011).

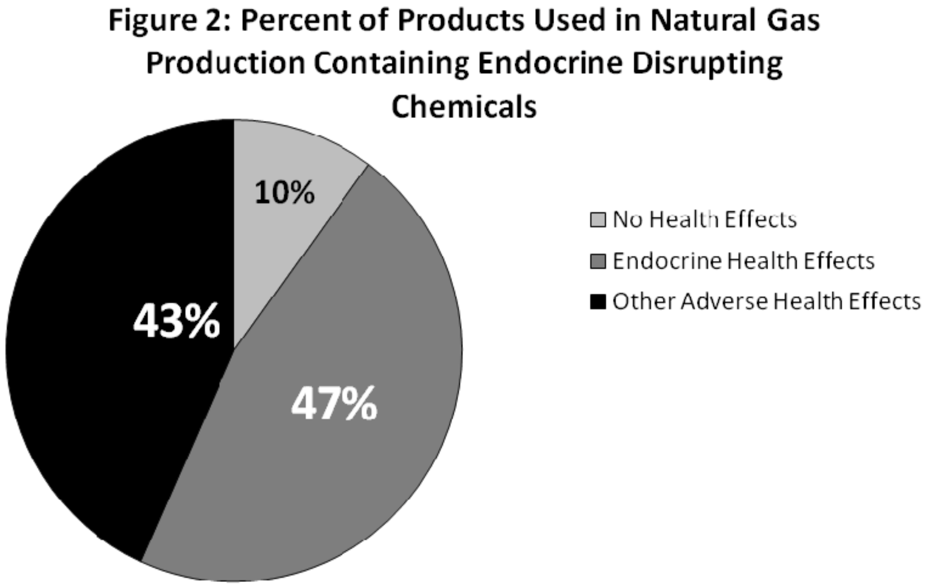

Figure 3.2: Potential Health Effects of 980 products used in the US CSG industry (TedX summary 2011: 3)

iv. Australia

Despite regulations demanding full disclosure in Queensland and New South Wales, it remains uncertain what chemicals are actually used.

The National Toxics Network (NTN) reported in 2011 on 23 listed chemicals used in CSG fracking based on MSDS from 3 companies working in NSW/QLD (Lloyd Smith & Senjen 2011). Of these 23 chemicals 13 are listed on the Australian Petroleum Production Exploration Association (APPEA) site as being used currently in the industry (APPEA 2013). [7]

Of these only 2 have been assessed by NICNAS.

-2-Butoxyethanol: has been investigated in relation to its presence in cleaning products, industrial and domestically; its environmental exposure levels were thus calculated to be low[8] (sub PPM) (NICNAS 1996). 2-Butoxyethanol has a higher biodegrability, suggesting it has a lower potential to cause harm to ecosytems, but its high mobility and low absorption in the soil means that it can readily leach into groundwater (NICNAS 1996). Studies related to periodic exposure have demonstrated adverse dose dependent human effects, through

[7] Carey (2012: 3) has pointed out that as there is no national requirement for full disclosure it remains unclear what chemicals are actually being used.

[8] The CSG industry though introduces the risk for greater concentrations than assessed to be released to the environment.

inhalation, direct ingestion, absorption through direct contact and absorption through the skin of vapours[9] (NICNAS 1996).

Sodium Persulfate: was assessed based on its presence in bleaching products used in hair care products[10]. It is harmful to humans through inhalation and contact with skin, eye and respiratory irritant, and known to have sensitizational properties, with subsequent exposures causing effects even at very low doses (NICNAS 2001). Long-term exposure may cause changes to respiratory function, with known direct human effects including contact urticaria, rhinitis, bronchitis and asthma (Lloyd-Smith 2011; NICNAS 2001). There is currently no exposure standard in Australia and no threshold due to the sensitization effects (NICNAS 2001). The potential harmful effects due to ingestion were not assessed by NICNAS.

The National Toxins Network (Lloyd-Smith & Senjen 2011) investigated the health and environment risks of another 7 identified chemicals, 3 remain listed by the APPEA:

-Tetrakis (hydroxymethyl) phosphonium sulfate (THPS)– has been found to possess mutagenic and carcinogenic potential in rodent studies, however it is unknown what risks it poses to humans or animals when in the environment (Lloyd-Smith & Senjen 2011).

-Isopropanol; -is a central nervous system depressant, reproductive toxin and irritant, though suspected there is insufficient data as to its' carcinogenicity (IARC 1999).

-Ethylene Glycol;-Is a known endocrine disruptor and respiratory toxicant with immediate acute dermal and mucosal irritant effects (Lloyd-Smith & Senjen 2011). Studies have shown links between exposure and congenital malformations, spontaneous abortions and subfertility (Correa et al 1996: 6 & Cordia et al 1997).

The four others they investigated but not currently listed by the APPEA (2013) include:

-Methanol (found to be a constituent in over 76 products used for CSG in the US (Colburn et al 2011) is a highly toxic volatile organic compound with known CNS depression, degenerative cerebral changes and blindness (Lloyd-Smith & Senjen 2011)
-Formamide; a teratogen harmful by all exposure routes, it is an irritant and may have CNS effects (Lloyd-Smith & Senjen, 2011)
-Napthelene; has known carcinogenetic properties in animal studies and causes haemolytic anaemia on ingestion as well as nausea, vomiting, jaundice and diarrhea (IARC 2001)
-Ethoxylated 4-nonylphenol (NPE); a common ingredient in CSG fluids, it is a known bioaccumulative endocrine disrupting chemical to humans and animals, causing feminisation

[9] the studied human effects include skin and airway irritation, headache and nausea, and with ingested exposure respiratory difficulty, shock, coma and haemoglobinuria (NICNAS 1996: 66). It is a potentially lethal substance, however there have been no documented human deaths (NICNAS 1996: 67)
It has not been studied for its carcinogenic potential.

[10] As a hair care ingredient sodium persulfate is expected to degrade rapidly when released into the environment through sewerage systems however even in regard to domestic usage NICNAS (2001: 56) declares there are inadequate studies regarding repeated exposure and also its' carcogenicity.

of fish at levels below normal monitoring (Lloyd-Smith & Senjen 2011, Peduzzi & Harding 2012)

v. *BTEX*

BTEX (Benzene, toluene, ethylbenzene and xylene) is a group of chemicals known for their potential to significantly harm human health. CSG practices have been shown to introduce these substances to the environment at levels high enough to cause significant harm, in the US and here in Australia (Lloyd-Smith & Senjen 2011).

While BTEX chemicals are banned in NSW and QLD, concerns remain particularly regarding benzene[11]; due to the large numbers of diesel generators involved, the increased traffic of large diesel vehicles and the use of petroleum products used in drilling the wells (Williams et al 2012). BTEX chemicals can also be released by the fracking process; forming some of the volatile compounds found naturally in coal seams (Lloyd-Smith & Senjen 2011).

vi. *Soil*

Soil contamination is a threat to human health, posing various routes of entry:
-Inhalation as dust
-Inhalation of volatiles
-Direct ingestion
-Absorption
-Ingestion of foodstuffs grown in contaminated soil

vii. *Food contamination- heavy metals*

Produced water from CSG wells is known to contain the heavy metals that pose the most significant risk to human health: lead [12], mercury, cadmium and arsenic[13] [14][15], with clear exposure-response relationships seen (Jarup 2003).

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[11] Benzene was identified as a priority existing chemical by NICNAS in 1998, due to the exposure risk to the public through vehicular exhaust fumes and occupational risk exposure. Benzene is absorbed by all routes of exposure with no threshold for its' carcinogenicity & genotoxicity; though there is a cumulative increased risk for leukaemia but given that there is no safe level, it is recommended that any exposure be avoided (NICNAS 2001: 34)

[12] Direct association has been demonstrated between environmental pollution and human toxicity to lead (Lin et al 2001: 838) and other heavy metals (Latascu et al 1996: 106).

[13] Arsenic is ranked as the No.1 hazardous substance according to ATSDR, however there are no morbidity or mortality studies of human exposure to soil at hazardous sites (Chou & De Rosa 2003: 383)

[14] Chronic exposure to Arsenic is a major threat to human health, with symptoms appearing 6months to 2 years post initial exposure including generalized weakness, appetite and weight loss, and anemia; involving the respiratory system, gastrointestinal system, liver, spleen, genitourinary system, hemopoietic system, eyes, nervous system, and cardiovascular system (Ramman et al 2001: 692).

[15] Arsenicosis has been shown due to consumption of animal products such as milk, eggs and meat raised in areas of contamination (Datta et al 2012: 61).

Lead and Arsenic have been reported at sites near the Pilliga, with further open holding ponds approved by the state government. A newspaper article suggested that there was no clear management plan to deal with the problem (Cubby 2013).

Ingestion of food, both vegetable and animal, produced in contaminated areas places humans at risk of adverse health effects[16] [17] [18][19].

Salinity has the potential to directly kill vegetation and degrade topsoil allowing it to wash away (Kelly 2012: 4). Companies estimate that for every mega litre of water 4-8 tonnes of salt will need disposal, approximately 100kg per well per day (Arrow Energy in Lloyd-Smith & Senjen 2011, Williams, Stubbs & Milligan 2012).

viii. Global climate change

In addition to the threats caused by current management strategies, there is increased risk to human health due to the effects of global climate change on CSG activities. In particular, adverse weather events causing changes to the source receptor pathway leading to increased toxic exposure through migration of toxins, altered soil characteristics and hydrology (Balbus 2012).

ix. Conclusion

Despite a dearth of assessments of the chemicals used in the process CSG poses a significant risk to environmental health through soil contamination. Chemicals that have been disclosed have the potential to significantly harm human and ecological health. The process of open evaporative pits to store contaminants, and the frequency of spillages in the industry, in particular, place communities at risk for lasting harm.

The precautionary principle should prevail in regards to this industry: existing regulations must remain in place, greater safety measures must be introduced to waste management, the full disclosure of all chemicals must be enforced and studies conducted to enable the full impacts of this industry to be assessed before further harm is caused.

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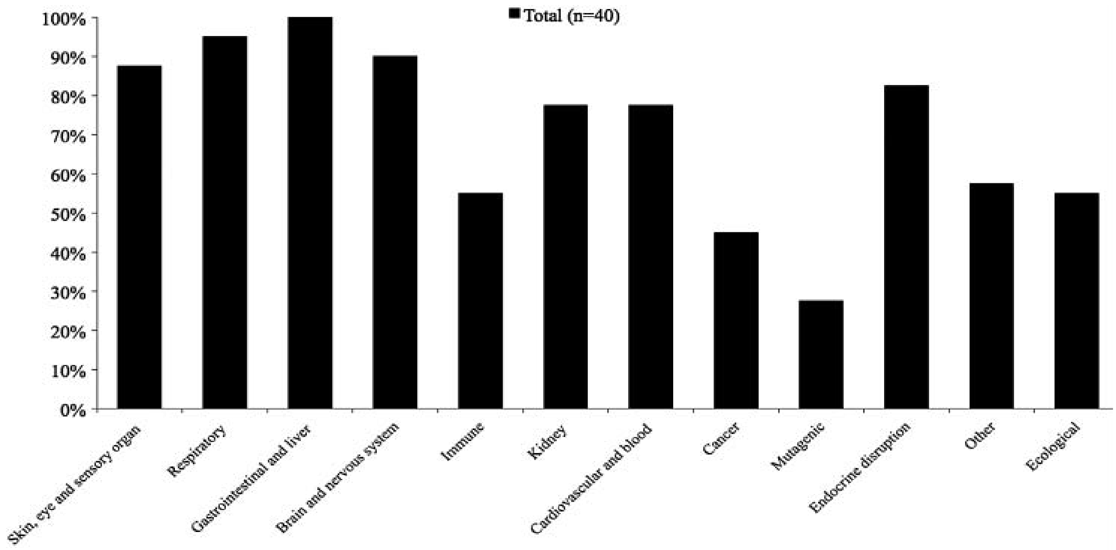
[16] Toxicity in vegetables grown in contaminated soils has been demonstrated, with most metals toxic to humans increasing in leafy and fruity vegetables; lead in particular increasing in root vegetables (Hermanescu et al 2011: 2 & Zhuang et al 2009: 1559).

[17] Rodrigues, Pereira, Duarte & Romkens (2012: 31-35) have demonstrated the human health risks associated with animal products grazing on heavy metal contaminated land associated with mining; recommending that offal consumption in particular be avoided.

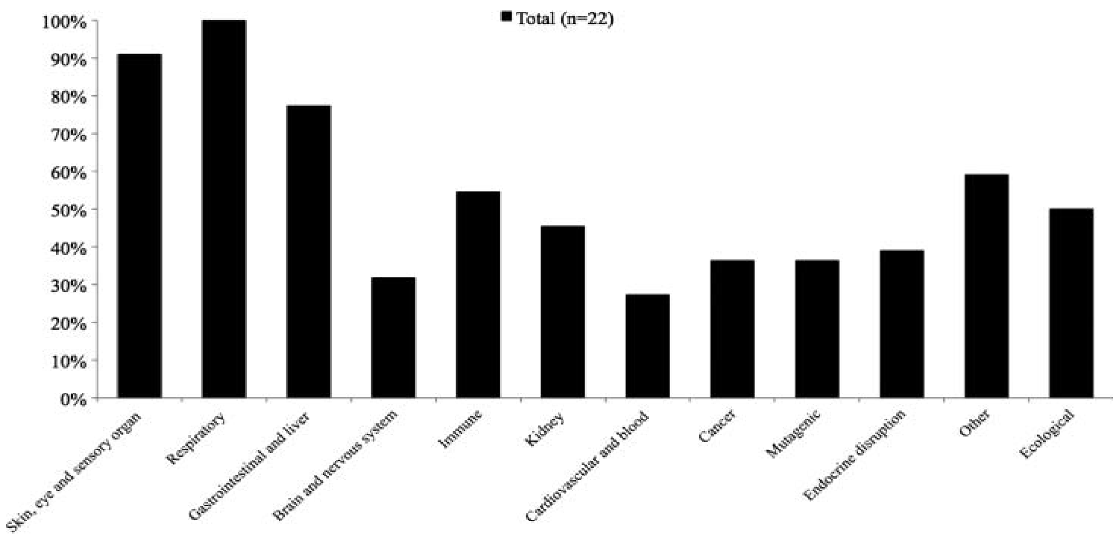
[18] Ratel & Engel (2009: 7893) have demonstrated the vulnerability of animal products to contamination by exposure to volatile organic compounds.

[19] Cattle have been found to be the species of most concern as they are more likely to ingest soil, making them more prone to lipophilic substances that are not taken up by plants, however poultry and swine are also vulnerable. (Fries 1995: 78-84).

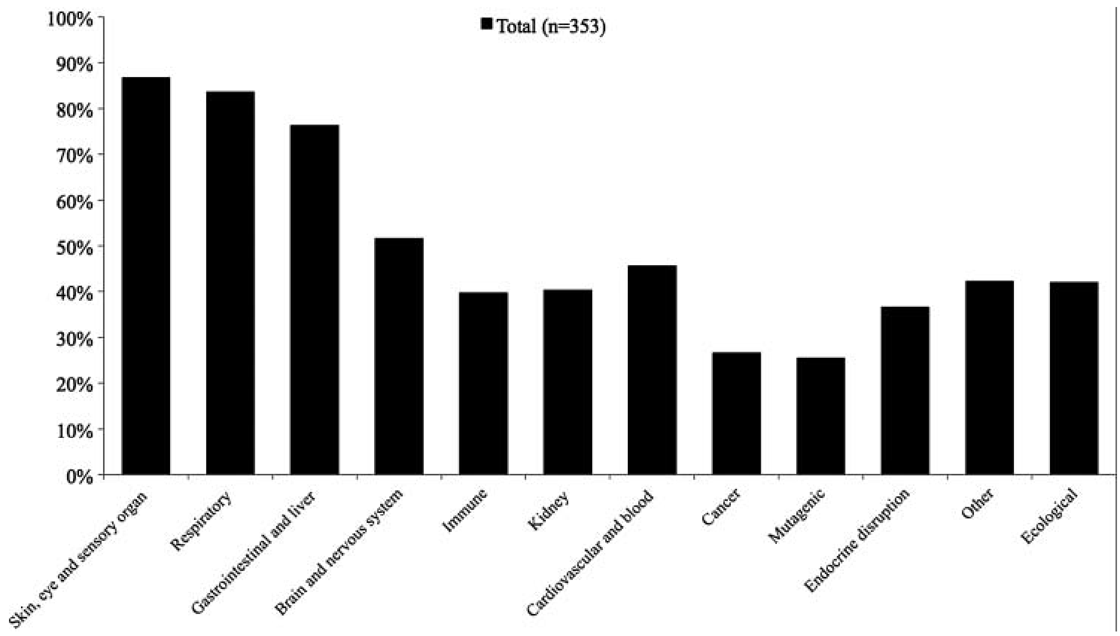
Appendices



Appendix 1: Health effects of 40 chemical traces found in evaporation pits in New Mexico (Colborn 2011: 1048)



Appendix 2: Profile of potential human effects of identifiable chemicals used in the drilling process



Appendix 3: Profile of potential health effects of 353 identifiable chemicals (those with CAS numbers) used in the US CSG operations (TEDX summary 2011: 3)

2 A: Air Pollutants and their health risks

i. Background

The increased use of natural gas has led to mining of “unconventional” gas reserves such as coal seam gas (CSG); accessing such gas requires different processes to conventional gas mining and poses different risks to workers, the environment, and the population. (Colborn, Kwiatkowski, Schultz, & Bachran, 2011). Apart from natural gas itself, mining of CSG also extracts natural salts, heavy metals, benzene and other aromatic hydrocarbons, and radioactive materials, all of which pose a risk to health (McKenzie, Witter, Newman, & Adgate, 2012).

In addition, there are emissions from diesel engines and materials used in gas extraction (McKenzie, Witter, Newman, & Adgate, 2012; NTN, 2011). Though many are unknown, over 1000 chemicals have been identified or reported as in use during the CSG extraction process and more than 75% of these have known potential health effects, especially on the skin, mucous membranes and respiratory system. Up to 25% are thought to have carcinogenic properties (Colborn, Kwiatkowski, Schultz, & Bachran, 2011); there is no safe level of exposure for such chemicals.

Clean air is considered an essential requirement for human health and wellbeing (WHO Regional Office for Europe, 1999). This paper addresses the issue of air pollution due to CSG mining and the potential human health effects of associated pollutants; it concentrates less on air quality or the airborne transmission of toxins, though the distinction is academic and minimal. Ultimately it attempts to answer the question, does CSG mining impinge on our right to clean air?

ii. Sulphur dioxide

Sulphur dioxide (SO_2) is particularly harmful to the respiratory system, especially during exercise or physical activity (and hence particularly affecting children and outdoor workers). Short terms SO_2 pollution increases the risk of hospital admissions while continued exposure at high levels aggravates asthma and COPD, increases respiratory symptoms, and reduces lung function (EPA, 2009). In addition, SO_2 a precursor for particulate matter and acid rain, though these have not been demonstrated near CSG wells (Rahm, et al., 2012).

iii. Ozone

Ozone results from the interaction between sunlight and many of the VOC released at well sites. Spikes in ozone levels often occur many km downwind of the release point, as the chemical reaction takes time; the processing of natural gas has the been shown to increase ozone concentrations downwind (Olaguer, 2012; Kemball-Cook, et al 2010). In addition to the immediate medical effects – mainly respiratory symptoms (Nolan, Hoppert, Ewart, Collins, & Salay, 2011) - ozone also contributes for smog; the health effects of this are well known and include higher hospital admissions during periods of smog (Colborn, Kwiatkowski, Schultz, & Bachran, 2011). High ozone concentrations have been directly linked to increased mortality (Katsouyanni, 2003).

iv. Particulate matter

Particulate matter is usually released from diesel engines / generators and truck exhausts; diesel fumes were recently classified as carcinogenic to humans by the WHO (Rahm, et al., 2012). It is also released during venting of gas. Exposure to particulate matter increases the risk of stroke, cardiovascular disease, and both acute and chronic respiratory disease including lung cancer (Nolan, Hoppert, Ewart, Collins, & Salay, 2011). Importantly, particulate matter aids the transfer of other toxins over long distances and is a significant component of smog. Both ozone and particulate matter have been linked to sudden cardiac death (Ensor, Raun, & Persse, 2013). Excess particulate matter is calculated to account for over 1 million premature deaths worldwide each year (Katsouyanni, 2003).

v. The Big Picture

The burden of poor health from air pollution due to CSG mining is likely to be unevenly distributed. People from lower socio-economic backgrounds have consistently been shown to have both higher rates of exposure to particulate matter and other toxins as well as higher morbidity from such exposures (Zeger, Dominici, McDermott, & Samet, 2008). Though most wells have thus far been located in rural or agricultural areas, wells within 500m of residential areas are becoming increasingly common; this is likely to increase exposure to polluted air and to date, most of these wells have been placed in disadvantaged areas (McKenzie, Witter, Newman, & Adgate, 2012).

The argument for the use of natural gas as a cleaner “transition” fuel is not yet settled, but is important to consider. Where the use of natural gas has directly replaced coal as a fuel source, such as Pennsylvania in the USA, there has been a corresponding decrease in air pollutants, including particulate matter, heavy metals, and sulphur dioxide (Conca, 2013). In addition, indoor air pollution is a significant component of morbidity and mortality in the developing world, accounting for over 1% of global deaths annually (Zhang & Smith, 2003). The replacement of traditional solid fuels with natural gas has reduced this aspect of pollution and has potential to significantly benefit those most disadvantaged internationally (Corvalan, Galecio, & Salim, 2003).

vi. Gaps and Uncertainties

CSG mining is exempt in the US from the Clean Air and Clean Water Acts (Carey, 2012). Hence, there is generally an absence of baseline air quality assessments and identifying appropriate comparator sites has proven difficult. Much of the research investigates the ambient air concentrations of methane or carbon dioxide at the expense of other pollutants. It is assumed these are useful markers of other potentially toxic compounds but evidence for this is scant. Though selective sampling has shown elevated levels of toxic chemicals, there is insufficient evidence of dangerous levels at sites of human exposure.

Further studies are needed to demonstrate a causal link between CSG drilling, air quality, and health; the regulatory framework in Australia provides a good opportunity for air quality and health status assessment before and after drilling. This lack of evidence is due to the short time period in which studies have occurred; poor understanding of the chronic effects of low-level exposure; and a focus on individual toxins at the expense of combined exposure risk. As wells near residential areas becomes more common, this evidence base should improve. Further, the likely effects of air pollution may change from chronic to acute conditions, from average to peak exposure effects, and from public health concerns to medical diseases; all three are likely to bring the issue to public attention.

There is scant evidence, and none of high quality, addressing the balance between local adverse health effects and the potential benefits of natural gas in reducing the use of other "dirtier" fossil fuels, in terms of air pollution. Though recent research suggests that use of natural gas has no significant effect on greenhouse gas emission (eg Stephenson, Valle, & Riera-Palou, 2011), the effect on ozone, sulphur compounds, and particulate matter emissions is unclear. From a global perspective, this research is vital as any potential benefits of air pollution reduction are likely to be in developing countries and distant from the immediate effects of gas drilling. There is no mechanism for balancing probable local effects with potential global ones.

vii. Reducing Air Pollution

Improvements in the methods used in CSG mining have already reduced the amount of methane and other toxins released during the mining process (Nolan, Hoppert, Ewart, Collins, & Salay, 2011). A closed loop system is now required in environmentally sensitive areas; the waste products are captured and removed for treatment minimising flowback and subsequent evaporation (ibid). Indeed, new EPA laws (which take effect Jan 2015) require much higher rates of gas capture (EPA, 2011). However, technological and safety improvements may reduce air pollution independent of health and environmental concerns.

Calm winds and air inversions increase the likelihood that potential toxins will reach levels which could be harmful to health. This was demonstrated by (Colborn, Schultz, Herrick, & Kwiatkowski, accepted 2012) who showed a negative relationship between toxin level and average daily wind speeds. Extended periods of sunshine increase the risk of ozone toxicity (Katsouyanni, 2003). Such information should be utilised to aid the appropriate selection and operation of well sites to minimise air pollution.

viii. Conclusion

It appears beyond doubt that CSG mining results in the release of potential toxins into the air despite improving technology and environmental standards. Similarly, there is good evidence that the air pollution in which these toxins play a major role is associated with poor health, both locally and globally. However, we do not yet have the evidence to demonstrate a significant change in air pollution or a subsequent effect on human health near CSG mining.

To add to the difficulty in assessing health impact, even a small benefit to air quality in the developing world is likely to outweigh the local health effects from CSG mining in Australia, though this is a scientifically difficult and politically fraught idea to prove. While employing the precautionary principle is tempting, it does not diminish the importance of further research and modelling. Based solely on the impact on air pollution, the jury is still out on coal seam gas.

2 D: Contribution of methane gas emissions to climate change.

Concerns surrounding the coal seam gas (CSG) industry's environmental impacts have been receiving a heightened state of media and political focus. Public outrage is questioning the ability of CSG activities to coexist with the community without compromising the health and wellbeing of the community (appendix 3). The national collaborative health network (NCHN) has been requested by the NSW Government to identify potential risks arising from four current and proposed CSG activities within NSW and QLD, review the existing academic literature on those risks and provide an informed assessment.

This paper will discuss the contribution of CGS activities to climate change and the growing body of evidence that fugitive gas emissions can no longer be overlooked.

A changing climate is projected to have significant impacts on human health and wellbeing;
'The rich will find their world to be more expensive, inconvenient, uncomfortable, disrupted and colourless: in general more unpleasant and unpredictable, perhaps greatly so. The poor will die.' (Smith, K. 2008)

According to WHO (2013) heatwaves across Europe in 2003 resulted in 22,000 excess deaths and at least 2,000 premature deaths in the UK alone. Climate change also has indirect effects on the population including increased frequency of extreme weather events, water borne disease, food borne disease, vector borne disease, diabetes, hypertension, obesity and respiratory illness (McMichael *et al,* 2006).

Aboriginal and Torres Strait Islanders are particularly vulnerable to climate change related health impacts, such as vector and food-borne disease and temperature-related illnesses (Nelson *et al*, 2009) as are the elderly, young and chronically ill.

Future demand for health services will be drastically impacted in caring for these groups in a changing climate and any measure to reduce GHG emissions and reduce the impact of climate change must be taken seriously.

CSG promises large economic benefits and a reduction in greenhouse gas (GHG) emissions from energy production (APPEA, 2013) compared to traditional coal-fired power stations. The Queensland Government (2010) estimates that by 2030, 40,000 wells (Australia Pacific LNG project EIS, 2010) will be in production, 16.3 million tonnes of LNG in exports for 2014-2015 and 18,000 jobs directly and indirectly created in Queensland alone. The National economically recoverable coalbed resources (CSG) were estimated to be 930 billion cubic meters (bcm) in 2010 (Geoscience Australia, 2012) with first Australian commercial extraction beginning in 1996. The Australian Petroleum Production & Exploration Association Ltd (APPEA) website claims that 'CSG can help reduce greenhouse emissions in Australia and in countries buying Liquefied natural gas (LNG) made from Australian CSG' and 'Electricity generated using gas produces up to 70% fewer greenhouse gas emissions than some existing coal generation technology, meaning coal seam gas has a significant role to play in reducing greenhouse gas emissions.'

Therefore the transition of the world's energy supplies from GHG intensive to low carbon sources of energy seems a logical step to minimise global GHG emissions and the impacts of climate change (IPCC 2007). The importance of transitioning from coal-fired combustion to natural gas as an important GHG mitigation measure has been highlighted by the Intergovernmental Panel on Climate Change (IPCC) (IPCC 2007). Natural gas has a critical role as a transition fuel as it has a significantly lower GHG intensity (fig 1) than other fossil fuels such as black coal (Pace Global Energy Service 2009). At the point of combustion, natural gas is roughly half as carbon-intensive as coal (Fig 1). Appendix 2 outlines efficiency and carbon intensity data of 'gas versus coal' power generation.

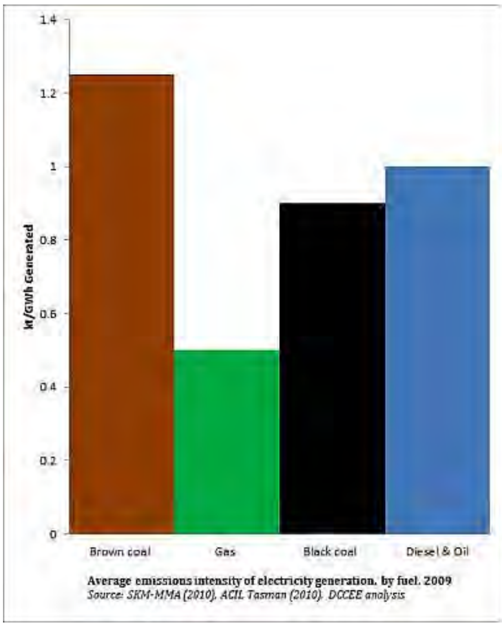


Figure 2.2: *Average emissions intensity of electricity generation by fuel, 2009. (APPEA)*

Maher *et al* (2012) in a submission to the *Department of Climate Change and Energy Efficiency* outlined the use of a pioneering measuring device to assess large-scale complex fugitive gas emissions from coal seam gas mining. Maher *et al* (2012) recorded elevated levels of methane in the air above the Tara gasfield in Queensland, in the order of three times higher than background values. Pitt *et al*, (2012) states that 'fugitive emissions' are emissions that are uncontrolled (appendix 6). This uncontrolled release is the driver of concerns as an alternative to coal and problematic for operators to mitigate (appendix 6). The high level of uncertainty over fugitive gas emissions has led to growing debate over the true GHG footprint of LNG from CSG extraction.

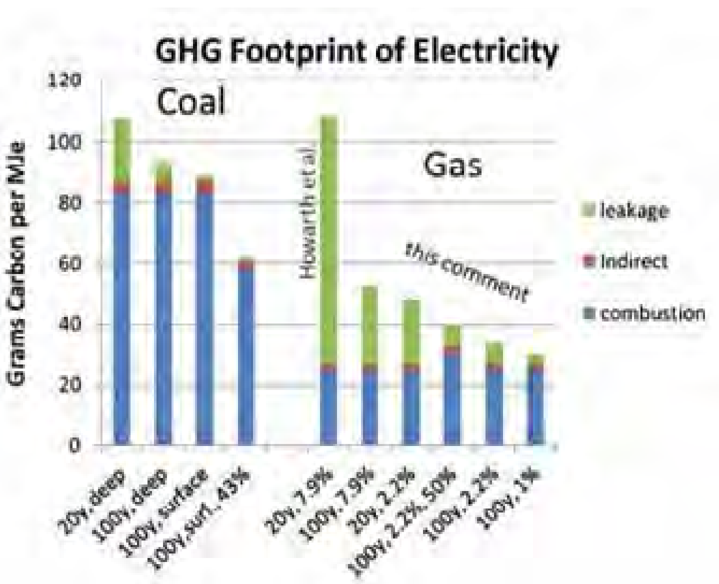


Figure 2.3: *Carbon emissions calculated for coal and gas under various scenarios (Cathles, L, 2012)*

Maher *et al* (2012) states that measurement of fugitive emissions from CSG fields is more complicated then tradition gas fields due to the decentralised infrastructure, and large number of wellheads when compared to conventional gas fields. Current approaches rely mostly on average emissions from individual components (such as pumps, valves, pipelines, etc) used in the production process, these data are primarily from USA studies. The estimates are based on studies performed in the USA that may not be directly applicable to Australia and do not account for diffuse soil fluxes. This early data provided by Maher *et al* (2012) supports the findings in the USA by Howarth *et al* (2012) and Cathles, L (2012).

A leakage rate of 7.9% brings the footprint of CSG activities and natural gas over a 20 year period to be approximately even (Howarth *et al,* 2012). Current estimations of fugitive emissions from coal seam gas wells in Australia use a factor of 0.12% (Doctors for the Environment Australia, nd) well below those estimated and observed by Howarth *et al,* 2012 and Maher *et al,* 2012. Appendix 4 summarises estimates of fugitive emissions from gas production.

Methane is the primary component of natural gas (83% raw, 90% after processing - appendix 1) its release into the atmosphere every year is estimated to be about 550 million tonnes (IPPC, 2007). Natural emissions represent about 40% of total methane emissions. Non-energy related anthropogenic emissions account for 38% and energy-related methane emissions 20% (IPPC, 2007). 550 million tonnes equates to the equivalent of one-fourth of all global greenhouse-gas emissions (IPPC, 2007).

Methane is a more potent greenhouse gas than CO2, about 25 times (Maher et al, 2012), yet has a shorter lifetime in the atmosphere about fifteen years versus approximately 150 years for CO_2. Methane is a significant driver of short-term warming, and reducing methane emissions can lessen the rise in global temperatures. Methane emissions plateaued during 1998-2006, from 2007 an upward trend is occurring (fig 3).

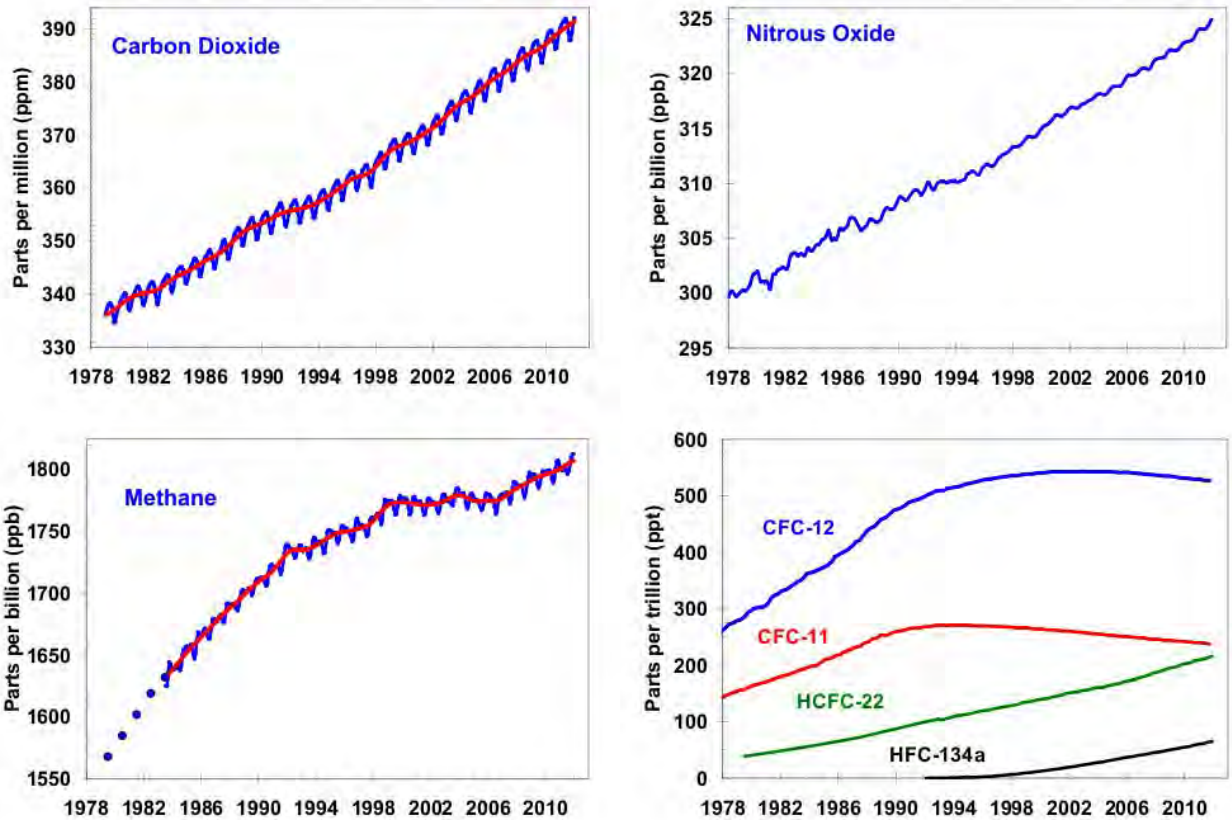


Figure 2.4: Global average abundances of the major, well-mixed, long-lived greenhouse gases - carbon dioxide, methane, nitrous oxide, CFC-12 and CFC-11 - from the NOAA global air sampling network are plotted since the beginning of 1979. These gases account for about 96% of the direct radiative forcing by long-lived greenhouse gases since 1750 (Butler, 2012).

The US EPA is introducing legislation to significantly curb air emissions from unconventional gas fields, and this is expected to result in an almost 95 per cent reduction in volatile organic compounds emissions (Bradbury *et al*, 2013).

The large and growing body of data on emissions from unconventional gas production in the USA is in marked contrast to the situation in Australia. Until Maher *et al* (2012) there was insufficient public information about methane emissions associated with unconventional gas production (CSG) in Australia. The only previous study of fugitive emissions being the reticulated gas supply of Sydney and Brisbane (Day *et al,* 2012). Numerous political and commercial authorities discount USA data (appendix 4) due to differing scenarios (appendix 5), the Australian industry consists of CSG extraction (Maher *et al,* 2012). This is a matter of some public policy concern, given the projected large scale rapid growth in production of CSG. The current code of practice (Queensland Government, 2010) and data collected do not allow authorities to quantify fugitive emissions (Day *et al,* 2012) or implement appropriate mitigation (appendix 6) measures.

Results from Maher *et al* (2012) demonstrate the need for baseline studies before the development of gas fields due to fugitive emissions on the scale foreshadowed in recent studies (Maher et al, 2012; Pitt et al, 2012; Clark et al, 2011; Howarth et al, 2012), would dramatically increase the climate change impacts of CSG, thereby reducing its green credentials over the currently more polluting than coal. The ramification to Australia is if properly measured and accounted, the carbon price liabilities of these fugitive emissions may make the CSG industry in Australia economically untenable.

In regards to the 4 current and proposed activities, the potential for climate change impacts are significantly similar in all settings (regardless of their urban or rural nature) to propose a general baseline monitoring program and accounting as outlined in (Maher et al, 2012; Pitt et al, 2012; Clark et al, 2011; Howarth et al, 2012) that would be addressed using a thorough EIS (Day *et al,* 2012) and ongoing monitoring programs.

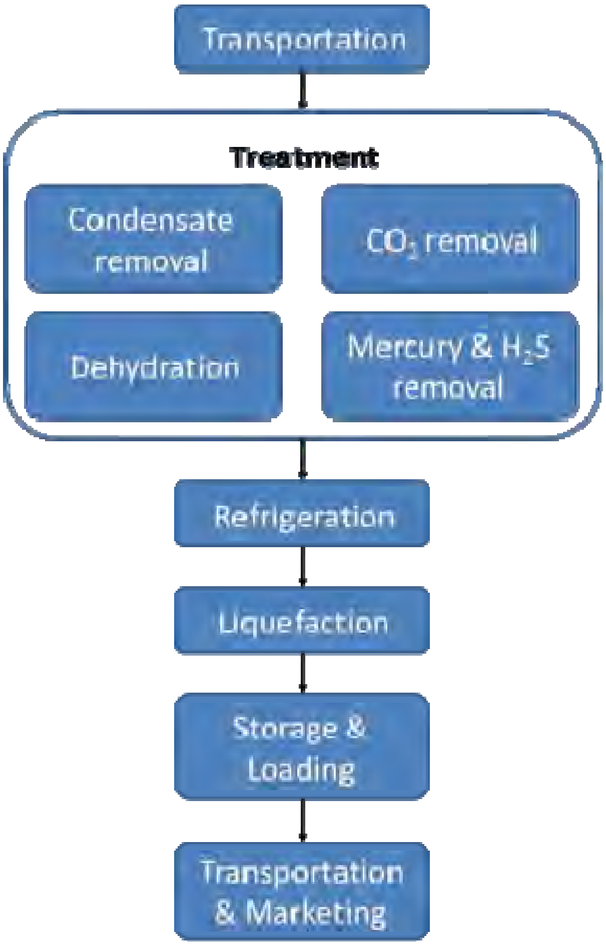
At this point in time there is insufficient data to draw conclusions as to whether CSG operations impact the health and wellbeing of the community in regards to climate change, there are a number of reports in progress to address these uncertainties due for release in 2013. The current lifecycle upper estimates inclusive of fugitive emission by Fulton *et al* (2011) have determined that total GHG emissions to be at least 47% less than for coal.

While there is clear uncertainty surrounding emissions (Doctors for the Environment Australia, nd), it appears that CSG does still hold potential to reduce the GHG emissions of energy production and assist in the transition to other cleaner, renewable energy sources.

Appendix 2.1

LNG process.

The gas is first extracted and transported to a processing plant where it is purified by removing any condensates such as water, oil, mud, as well as other gases such as CO2 and H2S. An LNG process train will also typically be designed to remove trace amounts of mercury from the gas stream to prevent mercury amalgamating with aluminium in the cryogenic heat exchangers. The gas is then cooled down in stages until it is liquefied. LNG is finally stored in storage tanks and can be loaded and shipped.



A typical LNG liquefaction and export terminal exporting 4.5 million tonnes of LNG can be expected to produce in the order of 1.2 million tonnes equivalent carbon dioxide of direct emissions. The greenhouse gas emissions associated with the combustion of 4.5 million tonnes of LNG is approximately 12 million tonnes equivalent carbon dioxide.

Source: http://en.wikipedia.org/wiki/Liquefied_natural_gas

Appendix 2.2

Table 1: Electricity generation GHG intensities – base case (units: tonnes CO2-e/MWh) (Clark *et al*. 2011)

OPERATION		COAL SEAM GAS		BLACK COAL		
		BASE CASE		BASE CASE		
		OCGT	CCGT	SUBCRITICAL	SUPER CRITICAL	ULTRA SUPER CRITICAL
Assumed average efficiency (%)		39	53	33	41	43
Extraction and processing		0.15	0.11	0.03	0.02	0.02
Transport		0.01	0.01	0.03	0.03	0.03
Processing and power generation in China		0.59	0.43	0.96	0.78	0.74
Totals		0.75	0.55	1.03	0.83	0.79
Ranges	Min	0.64	0.49	0.75	0.61	0.58
	Max	0.84	0.64	1.56	1.26	1.20

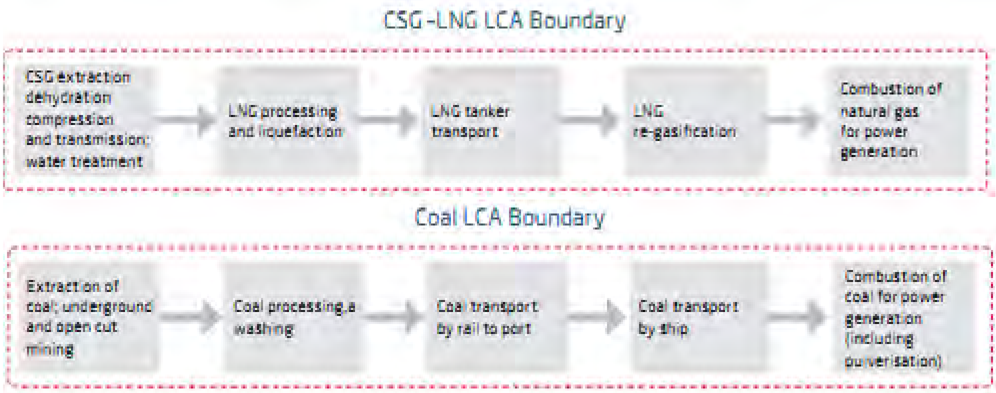
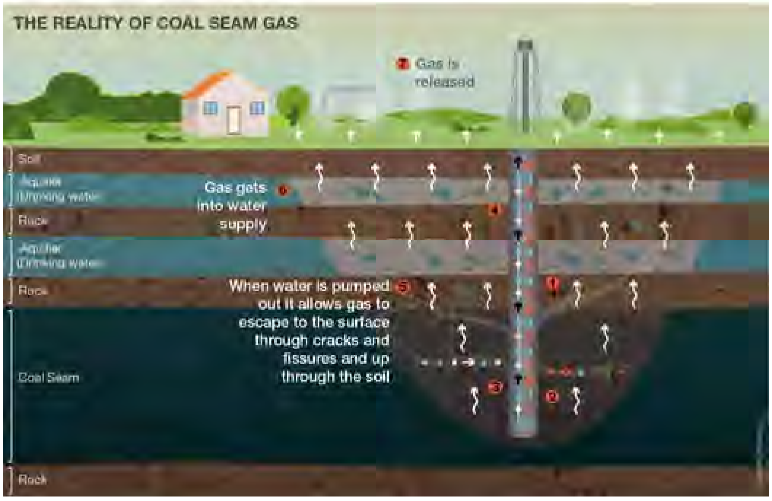


Figure 1: High level Life cycle analysis for local extraction, processing and combustion in China (Clark *et al*. 2011)

Appendix 2.3

Dirtier then coal? (*Source:* Getup! Action for Australia. *Dirtier than coal?)*
Simple infographic used by the political activist group Getup! To highlight to gap between the industry and political account of CSG versus the reality of data outlined by Maher et al (2012) in the Tara gasfield in Queensland.



Daily Telegraph newspaper April 2013
Polling figures reported in the Daily Telegraph newspaper April 2013 appear to support for the CSG industry in NSW has collapsed. According to the report, in February 2011, 44% of people in NSW supported CSG and 42% opposed it. Now, 58% oppose the industry and only 27% support it.

Gas firms accused of sacred site damage
By Cleo Fraser and Tony Bartlett April 05, 2013 5:06PM dailytelegraph.com.au
A QUEENSLAND Aboriginal tribe has accused three gas companies of desecrating sacred sites on a central Queensland island.
"These companies are totally ignorant about the environmental and cultural heritage damage they cause." Spokeswoman for the Gurang tribe, Cherissma Blackman.

Appendix 2.4

Summary of estimates of fugitive emissions from gas production (expressed as a percentage of total production) (Day *et al*, 2012)

Study	Emissions Estimate (% of total production)	Notes
Kirchgessner et al., 1997	1.42	Emissions measurements were made for the U.S. conventional natural gas industry.
Howarth et al., 2011	3.6 to 7.9	Related to the shale gas industry in the US. Conclusions were based on estimates and assumptions rather than direct measurements.
USEPA	2.2	This value was calculated from U.S. gas production data (also used by Cathles et al., 2012).
Pétron et al., 2012	1.68 to 7.7	Estimates were calculated from atmospheric measurements of methane and other hydrocarbons in a (tight-gas dominant) gas field in Colorado.
Clark et al., 2011	0.1	Estimate used for comparing CSG with other fuels. Figure based on industry 'accepted practice'.
Hardisty et al., 2012	1.3 to 4.38	Recalculated life-cycle analysis for CSG from Clark et al., (2011) using revised fugitive emissions estimates reported since their first study.

Day *et al* (2012) states:

'A comprehensive data set relating to the true scale of fugitive emissions from the CSG industry does not yet exist. Estimates for unconventional gas in general range from 0.1 to almost 8% of total production (Table 4.2).

Only two of the estimates (Kirchgessner et al., 1997 and Pétron et al., 2012) are based on measurements of emissions.'

Appendix 2.5

Summary of key differences between CSG, shale gas and tight gas. Day *et al* (2012)

	CSG	Shale Gas	Tight Gas
Source Rock	Coal seams	Low permeability fine grained sedimentary rocks	Various source rocks have generated gas that has migrated into low permeability sandstone and limestone reservoirs.
Depth	300-1000 m	1000-2000+ m	> 1000 m
Gas Occurrence	Physically adsorbed on coal organic matter	Stored within pores and fractures but may also be adsorbed on organic matter.	Within pores and fractures
Gas Composition	Usually > 95 % methane. Small amounts of CO_2 and other gases may be present.	Mostly methane but may also contain significant quantities of higher hydrocarbons (condensate).	Mostly methane.
Extraction Technology	This is described in Section 2.3. Hydraulic fracturing is sometimes required. Currently less than 10 % of wells in Australia require this treatment but this may increase as lower permeability seams are targeted.	Hydraulic fracturing and horizontal wells are usually necessary.	Large hydraulic fracturing treatments and/or horizontal drilling are required.
Water Usage	Water must be pumped from seams to reduce reservoir pressure and allow gas to flow. If hydraulic fracturing is necessary, water is required for the fracturing process.	Water is required for hydraulic fracturing	Water is required for hydraulic fracturing.
Extraction Challenges	Removal of seam water and its subsequent disposal.	Overcoming low permeability. Minimising the amount of water required for hydraulic fracturing. Reducing infrastructure footprint.	Reducing infrastructure footprint.

Appendix 2.6

Methane leakage sources and possible mitigation measures, Day *et al* (2012)

Source	Mitigation Method
Venting from exploration wells, well completions and workovers	Capturing vented gas for sale Capturing gas entrained in water from wells Flare gas if it cannot be used Minimise periods where venting is unavoidable
Venting from compressors and pneumatic devices	Use electrically powered rather than gas powered compressor stations Flare waste gas where possible Avoid the use of gas actuated pneumatic systems
Leaks	Equipment maintained to a high standard Regular leak testing and repairs

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2. Potential health risks associated with altered land use: food security, biodiversity and landscape

In this chapter:

- Risks to food security
- Impact on the availability and allocation of land for other uses
- Biodiversity and natural heritage risks and concerns
- Possible impacts on plant and animal life and resulting pharmaceutical potential and geographic disease profiles

3 A: Risks to food security

i. Background/introduction:

In the current volatile arena surrounding climate change prevention and mitigation, the sustainability and security of Australia's food sources are increasingly a topic in the media and academic publications (Haines et al., 2007; Woodruff, McMichael, Butler, & Hales, 2006). Both nationally and internationally, there are already growing concerns around long-term sustainability of food production (Millar & Roots, 2012; Owens, 2012; Robertson & Swinton, 2005). There is significant pressure on farmers to develop more ecological farming practices and on the industry to continue producing the food for a growing population (Foley et al., 2011; Haines et al., 2007; Woodruff et al., 2006). It is within this climate that the farming industry and environmental protection groups have become wary allies following decades of battles over harmful agricultural practices including salinisation and soil erosion (Lawrence, Richards, & Lyons, 2012). What is the issue that has brought them together? Coal Seam Gas (CSG) mining and, in particular, the impact CSG activities will have on the environment and, therefore, on future food security. This paper aims to delve into the facts behind the rhetoric and determine how CSG activities will impact on food security in Australia and how this will impact on the health and wellbeing of the population.

ii. Food Security in Australia:

In Australia, over 61% of the land mass is used for agricultural purposes. Of this land, approx. 95% is used for non-specific grazing and the remaining 5% is arable land or productive land for cropping (Department of Agriculture Fisheries and Forestry, 2010; Kerr, 2012). Australian farmers produce approx. 93% of the current food supply in the country and exports over 60% of its produce to overseas markets (Department of Agriculture Fisheries and Forestry, 2010; Lawrence et al., 2012; Millar & Roots, 2012). Globally food demands are expected to double by 2050 as the population continues to grow (Robertson & Swinton, 2005). This increasing demand will see the need for extensive changes to current agricultural practices to ensure sustainability and growth to meet this demand both nationally and internationally (Spiertz & Ewert, 2009). It is within this climate that CSG has entered with a whole new set of potential problems for farmers.

iii. CSG in Australia

CSG production is still a relatively new industry in Australia. Production first commenced in Queensland in 1996 (Carey, 2012). Originally CSG activities were concentrated in rural and remote areas away from large populations and arable land (Fainstein, Harman, & Dickson, 2002). In more recent times however, CSG exploration and production have moved closer to urban populations and, importantly for this paper, closer to arable land. It is unfortunate that some of the country's largest deposits of coal seam gas to date have been found under prime agricultural land (Owens, 2012). It has been noted in the literature that it is forecast that CSG operations will occupy less than 1% of Australia's farmland (DAFF, 2012) however it should be very carefully noted that a majority of the CSG sites currently being explored or in operations are in the very valuable arable lands as opposed to the more general grazing lands (Owens, 2012). CSG production is expanding at a rapid rate. The Australian Energy Resource Assessment highlights that "in the 5 years to 2008, [gas production] has increased by 32% each year" (Geoscience Australia and ABARE, 2010).

iv. Impacts of CSG development on food security

> "Exploration for, or production of, gas has the potential to severely disrupt virtually every aspect of agricultural production on cropping lands and, in extreme circumstances, remove the land from production." (Rural Affairs & Transport References Committee, 2011)

Most reports and academic papers detailing the potential effects of CSG production will mention the possible impacts on food security and agriculture (Carey, 2012; Millar & Roots, 2012; Rural Affairs & Transport References Committee, 2011). The difficulty is finding tangible examples and scientific data to support these claims. The most notable risks surrounding CSG are more universal then agriculture and will be discussed in greater depth in other papers. They will be mentioned here however, specifically from a food security standpoint. The most definable risks to food security through CSG production are associated with water. In 2007-08 agriculture was the major user of water in Australia consuming 6,989 gigalitres (Department of Agriculture Fisheries and Forestry, 2010). CSG mining also requires the use of large amounts of water; over 300 gigalitres each year (ABC online, 2012). The question is, is this sustainable when Australia is the driest continent on earth? The impacts on the water table and the aquifers that supply many farms and properties with water for irrigation and livestock could be profound (Owens, 2012). The possible impact of chemical contamination into those same water supplies also needs to be taken into consideration (Carey, 2012). This could have a profound impact on the quality of the meat and crops produced on this land (Carey, 2012). The economic ramifications would be large, with potential to cause impacts on the health of not only the local residents but the wider Australian and international communities.

Food security in these times of climate change is a major issue even without the additional risks of CSG activities. There is already a growing push on the need for agricultural practices to be more sustainable, more ecologically focused and better placed to meet the growing demand of an increasing population (Foley et al., 2011). CSG activities on this land add an additional burden onto an already struggling system. Along with the obvious potential impacts of increased levels of toxicity in meat and produce grown in CSG areas following contamination of soil and ground water, there is also the broader and more calamitous impact of a decreasing food source (Owens, 2012). Combined with other changes, this has the potential to fundamentally alter what food we eat and where this food comes from.

Land access is also a significant issue as agricultural regulations tighten. CSG activities bring heavy vehicles, increasing infrastructure including pipelines onto properties. Additional land is also cleared to make way for this infrastructure. These activities themselves can impact heavily on the agricultural practices on the land. Farmers, particularly those with organic status, must also protect crops from chemicals and toxins that can be brought in purely through increase in vehicle movement through and close to the properties (Owens, 2012). This can also include increasing dust, possible chemical contamination from transportation and excess people on the land (Millar & Roots, 2012). Numerous gas wells on the property and access roads can also effect movement of stock and crop rotations (Kerr, 2012).

It is also worth noting that it is also *where* current CSG activities are planned that makes the agricultural industry nervous. As mentioned, CSG activities have been around for almost 20 years but it is only in the last couple of years that production has moved onto the extremely productive arable lands[20]. Experiences from open cut mining (though vastly different processes) have shown that whilst grazing land has been rehabilitated following completion of mining activities, arable or cropping lands were not able to be (Lawrence et al., 2012).

v. Gaps in the data:

The difficulty with much of this information is that it is currently extrapolation based on the limited available evidence. Further research into implications for the water table as well as water and soil contamination will have a profound impact on the viability of CSG use in conjunction with agriculture (Carey, 2012). The literature from both sides of the debate is based on hypothesis and conjecture. The CSG industry, for example, purports that whilst harsh chemicals are used in fracking fluids, the effects to people, livestock and the environment are minimal. However, as Dr. Gavin Mudd from Monash University said in a recent *4 Corners* report when discussing groundwater, "they [mining company] can't say there's impact, they can't say there's no impact, there's no data" (Carney, 2013).

As is the fundamental problem with current CSG activities, there simply isn't the robust evidence either way about whether these mining activities will have a definite long-term effect on agricultural practices. The question really is what we are willing to risk? Do we focus on an extremely profitable industry that is forecasted to only last a generation or on one that has the potential to ensure our survival for generations to come?

[2020] The policy shift in NSW banning CSG activities on 'strategic agricultural land' will go some way to mitigate the potential effects on the agricultural industry (NSW Government, 2013).

3 C: Impact on the availability and allocation of land for other uses

The development of the coal seam gas (CSG) mining industry in Australia is progressing at lightning speed. The availability and allocation of land for this industry is a contentious issue, and one that may have serious adverse health effects. For instance, will mine sites encroach on agricultural and grazing lands to a degree as to threaten food security? Or what will be the utility of these former-farming lands once mining has finished? Will the land be irreversibly destroyed for any further use? Will food produced from this land be safe? These are just some questions that are only beginning to be explored in the literature, despite CSG activities in Australia for the last 16 years.

A Senate Standing Committee interim report on the impact of CSG noted that "exploration for, or production of gas has the potential to severely disrupt virtually every aspect of agricultural production on cropping lands and, in extreme circumstances, remove the land from production" (Rural Affairs & Transport References Committee, 2011). That land availability may be placed at risk by CSG mining is clear in public concern, and also government reaction. Both New South Wales and Queensland governments have recently produced policies regarding land use - The *Strategic Regional Land Use Policy* (NSW) (NSW Government, 2012) and the *Strategic Cropping Land Act 2011* (QLD). The NSW policy aims to identify and protect valuable water resources and agricultural lands from the impacts of mining. The "Land and Water Commissioner" will now oversee exploration activities and there is a requirement for an Agricultural Impact Statement in the initial stages, considering subsidence, reduced soil fertility and possible contamination. According to the policy, there are two categories of strategic agricultural land – biophysical strategic agricultural land and critical industry clusters. The first is characterised by high soil fertility and a high level of access to water, and covers an area of more than 20 hectares in size, whereas critical industry clusters are concentrations of highly productive industries that contribute to the identity of a region and provide significant employment opportunities (Legislative Council, 2012). Mapping is underway in the Upper Hunter, New England, Central West and Southern Highlands, and the majority of the state to be commenced over the next two years. The policy also covers aquifer interference. Unfortunately it does not cover the issues of land recovery and reuse.

The final report of the NSW Legislative Council's inquiry into CSG raises the question of coexistence with agriculture. They report that less than 6% of the arable land in Australia is left for food production (Legislative Council, 2012). Competition already stems from spread of coastal cities and towns, and they assert the short-term gains of the CSG industry will seriously sacrifice prime agricultural land forever (Legislative Council, 2012). The notion of coexistence seems better suited to grazing rather than cropping, where modern farming practices such as laser leveling and GPS controlled routes, cannot occur with wells interspersed on the land. A comprehensive report on the issues of CSG by John Williams Scientific Services (Williams, Stubbs & Milligan, 2012), has emphasized the importance of good bioregional planning and recommends that it is essential to establish only land based activities which allow the landscape to indefinitely maintain its function.

The unfamiliarity of CSG companies with the land they come to occupy is a source of anger for many landowners, and it may also influence estimation of environmental impact. A report from Doctors for the Environment Australia (2011a) cited one landowner who asserted, based on his knowledge of his land topography, drainage and erosion patterns, that 38 acres in 250 would be required for proposed gas wells. This is much larger than the single acre in 250 estimated by the gas company. A website developed by rural people where farmers can calculate their land loss from gas infrastructure calculates that up to 8% loss is possible just to gas wells and roads, not accounting for electricity and pipe lines, compressor and venting infrastructure and holding ponds (Basin Sustainability Alliance, 2012).

Another important issue in food security is food safety. If availability of land for food production is limited, food security is further threatened if what is produced is unsafe from pollutants from CSG industry. A report from Bamberger & Oswald (2012) looked at impacts of gas drilling on animal health in the USA and found that animals are sensitive to contaminants released by drilling. They cite documented cases in several states where gas extraction industry has been linked with serious health effects and deaths of livestock. They also highlight that despite these associations there is a severe lack of research into adverse effects on animals, or testing of produce. Recently in Pennsylvania cattle had to be quarantined after contacting drill wastewater from a leaking holding pond (Doctors for the Environment, 2011a). Apart from contamination, Australian farmers report that cattle are unable to settle with flared wells every 400 metres across the land and are unable to eat dust covered grass with ongoing ground disturbance from new unsealed roads and industry trucks (Rural Affairs & Transport References Committee, 2011).

Residential landholders may not have to tolerate CSG infrastructure on their property, however there are potential health effects related to adjacent production facilities, increased traffic, and air and noise pollutants (Rural Affairs & Transport References Committee, 2011; Bryner, 2003). Furthermore, loss of farming livelihoods will negatively affect rural towns built upon farming industry and quality of life in these areas (Doctors for the Environment Australia, 2011b) Land allocation policy must also take this into account.

There is a paucity of conversation or data in the literature regarding reuse of land where coal seam gas mining has taken place. With mines having a relatively short lifetime of approximately 30 years, the utility of these sites once drained of gas is of great importance. The rehabilitation of water storage pond sites and residual pipelines are serious causes for concern. The Senate's Interim Report (Rural Affairs & Transport References Committee, 2011) recommends that the requirement to restore pipelines, and well and dam sites needs to be identified in individual agreements with landholders and in policy conditions of production and exploration. This is not covered in the newly released land use policies of either NSW or Queensland. The Senate review committee recommends that the Commonwealth and states establish an independently managed trust funded by gas companies to make provision for long term maintenance of mine sites (Rural Affairs & Transport References Committee, 2011).

In conclusion, the risk to health with loss of agricultural land seems logically clear. Not only may it threaten Australia's food security, it may also lessen our ability to supply food to other countries in the future. The role of the government needs to be emphasised in the responsibility for land availability and allocation. There are numerous other large gaps in the available data around the health impact of this issue. The few published reports cite individual submissions from landholders or anecdotal evidence for the affect on food security and health. With the precautionary principle in mind, research and legislation needs to catch up to the CSG industry's progress before the sustainable industry of agriculture is irrevocably damaged and we incur the health impacts.

4 A: Biodiversity and natural heritage risks and concerns

i. Introduction

Australia is a nation and a continent rich in biodiversity and natural heritage. As many as 84% of mammals, 85% of flowering plants, 94% of reptiles and 45% of birds are endemic to Australia and can be found nowhere else on the planet (State of the Environment Advisory Council, 1996). Although late entrants, we are part of this biodiversity and rely on it to sustain our lives and wellbeing. Increasingly there are unsustainable demands being made on this biodiversity including, rapid urbanization, increasing clearing of natural vegetation for agricultural purposes, diverting of important water sources and industrial activities such as mining, with increasing destruction of natural habitat and heritage (State of the Environment Advisory Council, 1996). The evidence from multiple sources is now undeniable - changes to biodiversity, habitat and natural heritage have a direct and indirect impact on human health in varying degrees depending on the impact to biodiversity.

One such source of change is from mining and in particular Coal Seam Gas (CSG) mining, which has centered discussion around the impact on the environment and the spillover effect on health and wellbeing especially in relation to water resource management and contamination from chemicals (Sherriff, Wilson, & Steed, 2010; National Water Commission, 2010), loss of arable land, exposure to chemicals, gasses and other contaminants used in CSG mining processes (Colborn, Kwiatkowski, Schultz & Bachran, 2011; Doctors for the Environment Australia, 2011a) and mental health issues arising either directly or indirectly from disruption to family and community life, land use conflicts and inability to plan for the future (Anglicare Southern Queensland, 2012); while little has been said about the possible impact that loss of natural heritage has directly on health, if any impact at all. The following discussion will attempt to draw a direct link between loss of natural heritage from CSG activities and adverse health outcomes.

ii. The effects of loss of natural heritage and landscape on health

The Australian Natural Heritage Charter (2002) defines natural heritage as comprising the natural living and non-living components of our world that we inherit including biodiversity and geodiversity and which demonstrate natural significance. In other words, areas of natural beauty and significance that are worth preserving for the enjoyment of ourselves and future generations and that are intrinsically part of the local biodiversity. The Ottawa Charter (WHO, 1986) describes health as a resource which includes the ability to change or cope with changes in the environment. Using this as a starting point, it stands to reason that if people are unable to cope or manage with environmental changes or pressures, especially those where they have little or no control, then they are unable to reach their full health potential. We may even consider them unwell.

The concept of solastalgia was first introduced by Glenn Albrecht in 2003, who noticed a direct relationship between environmental degradation and loss of natural heritage (environmental stress) in the Hunter region of NSW from open cast coal mining (Albrecht, Sartore, Connor et al,. 2007) and high levels of human distress which included loss of sense of place, identity and worsening levels of physical and mental health and wellbeing, especially when those environmental changes occurred in relation to home environments. This was worsened when those affected felt powerless to change the outcome. An environment distress scale developed by Higginbotham et al. (2007) confirmed this link between environmental stress and solastalgia. This was further discussed in a policy brief by COHAB Initiative (2010), where populations devoid of open spaces and natural countryside were more prone to mental and physical ill health as well as experiencing a loss of "sense of place". As a point of interest, given their strong connection with the land, this could be amplified in Australia's Aboriginal communities and help to explain why forced removals to "other" places of natural beauty were never able to satisfy those dispossessed of their land.

Another concept worth reviewing in relation to this discussion is the Biophilia Hypothesis. Simply put, Biophilia is that affection that people have with all things living – the love of nature, natural environments and living systems first suggested by Edward O. Wilson in 1984. In their study, Grinde and Patil (2009) came to the conclusion that interaction with nature, even through visual contact, offers positive outcomes on health and wellbeing and that where there is a nature deficit the opposite is true. This substantiates what anecdotal evidence suggests, that areas of natural beauty, heritage areas and wilderness landscapes all play a positive role in maintaining human health and wellbeing.

Further to the above, in a research report conducted by WWF and Equilibrium (Stolton & Dudley, 2010), which looked at the contribution that natural heritage areas make toward health and wellbeing, several other theories were briefly explored, including the Stress Recovery Theory, the Attention Restoration Theory and Restorative Environment Theory which all pointed to natural environments and landscapes playing a crucial role in overall mental and physical wellbeing. Although some may argue the theoretical nature, in their study Maller, Townsend, Prior, Brown, & St Leger (2005) published evidence in support of the links between nature and human health. These included the positive physiological effects on health when people interact with nature, specifically, improved recovery from mental fatigue, improved ability to cope with stress and recover from illness, improved concentration, an affiliation with nature and an improved outlook on life and overall satisfaction with life lived.

From the above brief discussion, it can be argued that exposure to and interaction with nature, all of which form our natural heritage plays a vital role in overall human health and wellbeing and that our health is interlinked with and not separate from the natural environment, that disruptions to that environment have direct implications to health cannot be ignored.

iii. The Coal Seam Gas Context

From the above there is arguably a link between good health outcomes and our natural environment. The point often made however, from supporters of CSG is that the overall impact on natural heritage and landscapes is small when compared to say open cast mining (Anglicare Southern Queensland, 2012), the intimation being that the possible effects on health will be smaller also. This is not true. The initial environmental footprint may be small, but over time this gradually increases, to the point that the natural landscape is irreversibly changed, with little prospect of rehabilitation. A good example of this is the change in landscape of the Elm Grove Well Field in Louisiana USA between 1984 and 2011 (UNEP GEAS, 2012). Within the CSG context, this loss of natural habitat and landscape is usually associated with a sense of place and belonging, home and community, where those affected have little control over the changes that are occurring around them. There is a deep sense of loss and powerlessness, the consequences of which are a definite lack of health and wellbeing as evidenced by the solastalgia exhibited by affected individuals in the documentary *The Gas Rush* (ABC Four Corners, 2011). In this regard, there is evidence enough to link the solastalgia phenomenon directly with CSG operations. And while there is growing evidence to support poor health outcomes directly associated with the processes of CSG, such as chemical exposures, gas leaks, pollution of water sources, et cetera, there is still little evidence that suggests that CSG, whilst directly causing loss of natural heritage, leads to ill health.

iv. Conclusion

There is a direct link between loss of natural landscapes, wilderness areas and natural heritage with negative health outcomes. We have looked briefly at some of this evidence and associated emerging theories that support this link, with the current consensus that for people to remain both physically and mentally well, they must have a meaningful interaction with the natural environment. Currently there is enough evidence to link CSG operations to destruction of landscapes and natural heritage with the solastalgia phenomenon, but not to the point where loss of natural heritage specifically from CSG activities can be directly associated with decreased *physical* health outcomes. There appears to be a gap in the research, most of which is focused on the more obvious direct health outcomes originating from CSG processes. However, considering the above discussion, it is quite likely that it is only a matter of time before those health care matters associated with natural heritage loss do come to light. Finally, if at least only from anecdotal evidence there can be little doubt, that CSG activities have an overall negative impact on health and wellbeing especially if those effected feel they have little ability to adapt to the changing environment around them, the effects of CSG mining on natural heritage causing ill health coming to light is only a matter of time.

4 B: Possible impacts on plant and animal life and resulting pharmaceutical potential and geographic disease profiles

Biodiversity, or the variety of life on earth, is important to human health for many reasons, including as a source of novel pharmaceuticals and as a reservoir of disease. Any process that impacts on biodiversity therefore has implications for public health research and practice. The emergence of the coal seam gas industry in Australia, particularly in New South Wales and Queensland, is therefore of concern to public health, as it has the potential to negatively impact biodiversity. There are multiple issues associated with coal seam gas extraction that can affect biodiversity, including land clearance, noise pollution, water contamination and the use of water evaporation ponds to dispose of water used in the extraction process.

Coal seam gas is conventional natural gas, or methane, trapped in coal seams or other rock formations insufficiently porous for normal extraction of the gas (Peduzzi and Harding, 2013). Therefore in order to extract the coal seam gas, a process called hydraulic fracturing, or 'fracking', is carried out, where water mixed with chemicals and sand is injected into the coal seam at high pressure to disturb the rocks, causing the gas to be released (Peduzzi and Harding, 2013). The same process applies to shale gas and other unconventional gas sources.

Vital pharmaceutical compounds have been discovered in diverse plant, animal and microbial species for millennia, with the extraction of quinine from bark of *Cinchona* species a recent example (Chivian and Bernstein, 2010; Cragg and Newman, 2013). The advantage of naturally occurring compounds over synthetic chemicals is that they have evolved to have highly specific biological activities. These compounds usually occur in a limited range of plant species (De Luca et al., 2012). As there are many species in existence that have not yet been studied, which may contain compounds that are the key to successfully treating human disease, it is clear that nature will continue to be an important source of novel pharmaceuticals (Cragg and Newman, 2013; De Luca et al., 2012). Preserving biodiversity is therefore essential, as maintaining the greatest possible number of species gives the best chance of discovering the next *Penicillium notatum*, which will improve the health of millions of people.

One of the most important aspects of coal seam gas extraction that has the potential to negatively impact biodiversity, and therefore human health, is land clearance. The coal seams containing gas are located close to the surface of the earth, usually between 100 – 1200 meters, unlike conventional gas which is found at much deeper levels, therefore it is more economical for the mining companies to drill several vertical wells, rather than one horizontal well (Peduzzi and Harding, 2013). In addition, the wells have a short lifespan of only 5 – 15 years, meaning new wells must be drilled regularly. This necessitates the clearance of large areas of land, approximately one to two hectares per well to make way for the well machinery, in addition to creating new road networks (Peduzzi and Harding, 2013). In Queensland, an estimated 600 wells were drilled in 2010-11, with this number expected to increase annually (DEEDI, 2012). It is well documented that land clearance has a negative impact on biodiversity, and can contribute to the decline of threatened species (Burgman, 2007; Chivian and Bernstein, 2010). The huge network of wells can also contribute to habitat fragmentation, which is another major factor threatening Australian biodiversity (Burgman, 2007). If land clearance and habitat fragmentation occur in areas with threatened species, which today applies to much of Australia, including farmland, this may therefore result in the loss of species with the potential to contribute to the development of new pharmaceuticals.

Another aspect of fracking that can affect the biodiversity of the surrounding area is the significant amount of noise pollution associated with the extraction of coal seam gas, resulting both from the wells themselves and associated truck transport (Rahm, 2011). Studies have shown that the noise from natural gas drilling activities can cause endangered bird species to avoid their normal habitats, and increase stress in those that remain (Blickley et al., 2012). Further studies have shown that fracking activity causes mule deer populations to decline significantly through changes to habitat selection and a decrease in survival rates (Sawyer, et al. 2006; 2009). Changing the range of species that inhabit an area can significantly alter the ecosystem, which may contribute to the loss of threatened species, and therefore reduce the availability of compounds that may be of benefit to human health.

Contamination of the environment with water from coal seam gas extraction is another serious threat to biodiversity. Water produced through the extraction of coal seam gas is typically treated to remove contaminants and stored in brine ponds for disposal (Leather et al., 2013). There is a significant amount of salt found in the water produced by fracking, which has the potential to contaminate the surrounding landscape and increase salinity. This is especially relevant in Queensland where the large amount of rain that falls in the wet season makes it effectively impossible to isolate treatment ponds (Leather et al., 2013). Contamination of the surrounding environment from evaporation ponds has been liked to sudden deaths in deer, fish, amphibians and songbirds, as well as significant health problems such as impaired reproductive and neurological function in many domestic animal species (Bamburger and Oswald, 2012). Saline water is known to inhibit plant growth and threatens species living in freshwater ecosystems and can therefore contribute to a loss of biodiversity in the area surrounding the well (Burgman, 2007; Canedo-Arguelles, 2013; Peduzzi and Harding, 2013; Ramirez, 2010). Furthermore, chemicals found in fracking fluid include endocrine disrupting molecules, which can cause feminisation in fish, even at very low levels (Peduzzi and Harding, 2013). This process causes an imbalance in the ratio of male to female fish, and could therefore cause native fish populations to decline. The effects of water contamination on biodiversity, may, like land clearance and noise pollution, reduce the number of species available to study, and therefore reduce our potential sources of life saving drugs.

Fracking may also affect human health by changing the geographical distribution of diseases in Australia. Evaporation ponds such as those utilised for produced water in coal seam gas extraction are very attractive to aquatic birdlife (Ramirez, 2010). The attraction of large numbers of birds to evaporation ponds may result in the spread of diseases such as avian influenza, as increased availability of ponds to waterfowl has been linked to the spread of H5N1 avian influenza in other countries (Desvaux, S., et al., 2011). Outbreaks of waterborne diseases are also known to be increased by the creation of man-made water systems such as irrigation ditches, which provide breeding opportunities for vectors such as mosquitoes (Dudgeon, D. et al., 2006; Kochtcheeva and Singh, 2000). Furthermore, deforestation has been linked to changes to the distribution of flying foxes, which carry viruses such as Nipah virus, causing them to come into closer contact with people and thereby spreading disease (Chivian and Bernstein, 2010). Nipah virus is closely related to Hendra virus, which is present in flying foxes in Queensland. Coal seam gas extraction therefore could contribute to an outbreak of zoonotic disease.

In the key coal seam gas extraction centres of New South Wales and Queensland, it is possible that the creation of evaporation ponds could also contribute to the spread of endemic vector borne diseases such as Ross River Fever. It has been demonstrated that emissions resulting from coal seam gas will contribute to climate change (Peduzzi and Harding, 2013). Research suggests that climate change will cause the geographical distribution of vector borne disease to change in Australia, possibly involving the introduction of malaria and dengue (Harley et al., 2011; Kochtcheeva and Singh, 2000). In addition, deforestation is known to affect mosquito populations, resulting in a predominance of species that can transmit malaria (Chivian and Bernstein, 2010). Therefore it is possible to speculate that coal seam gas extraction may contribute to Australia's disease burden by promoting the spread of vector born diseases via the provision of breeding grounds and the emission of greenhouse gases. The effects of changes to biodiversity that increase vector breeding sites and the numbers of waterbirds may however be mitigated by recent changes to policy that restrict the development of coal seam gas wells within two kilometres of homes in New South Wales (NSW Government, 2013).

Coal seam gas mining therefore has the capacity to have a serious impact on biodiversity in Australia. As well as being disastrous for the environment, this could cause a severe effect on human health. The development of new drugs relies on the largest possible range of species available from which to isolate novel pharmaceutical compounds. In addition, aspects of fracking such as evaporation ponds can contribute to the spread of disease in the community. It is therefore important that the negative effects of fracking on biodiversity are also considered as deleterious effects on human health.

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3. Psychosocial and mental health concerns: farmers, youth and CSG workers

In this chapter:

- **Concerns and risks for the wellbeing of farmers and their families**
- **Concerns and risks to the wellbeing of young people**
- **A causing serious 'grief'? The psychosocial impact of coal seam gas (CSG) mining for workers**

5 A: Concerns and risks for the wellbeing of farmers and their families

Coal seam gas mining (CSGM) in Australia is expanding and since the mid nineties when the first wells began operating we have seen have seen this industry growing substantially. CSGM has been operating largely in Queensland and in more recent years explorations and mining have began to take place in NSW. With recent concerns and a vast amount of debate over the states proposal to mine agricultural land in NSW, questions have to be asked regarding the health impacts and wellbeing of communities where CGSM is rampant. This report will look closely on the psychosocial impacts and the concerns of farmers and their families where CSGM will be taking place and in situations where CSGM has already taken place.

i. Concerns

The mining sector can be seen to have marginalising effects on farmers in the rural setting. This marginalisation of the rural life can impact on the environment, climate change, economics and the psychosocial and wellbeing of farmers. McManus & Connor (2013) suggest that mining can cause the decline of food production, threaten rural industries and can cause the loss of commercial industries. Environmentally there is the potential of damage to biodiversity, farming land damage and loss, water and aquifer destruction, and the risk of polluting the air and water. Income inequality, human health and wellbeing can all have adverse affects on rural communities. Mining companies are competing for resources in NSW that already have longstanding rural production, such as viticulture, pastoralism, breeding farms, dairy farms and high-grade stock-feed cropping, with all of which depend on land and water supply for this to occur (Connor, Albrecht, Higginbotham, Freeman & Smith, 2004).

ii. Evidence supporting concerns

Evidence and predictions are emerging from Queensland where CSGM on agricultural land has been in operation much longer than NSW. Surat Basin is an agricultural-rich area in QLD where CSG is produced. The Department of Natural Resources and Mines in the *Surat*

Underground Water Impact Report (2012) states that there are some 21000 water bores used for agricultural use and urban consumption and out of this 528 bores are expected to experience declines more than the trigger threshold in the bore water levels and this will be due to water used for CSG extraction. The senate interim report 2011 (cited in Carey, 2012) states "there is a risk that residues of chemicals used in fracking may contaminate groundwater and aquifers for human or stock consumption or irrigation…It is acknowledged that in one case in Australia, fracking resulted in damage to the Walloon Coal Measures, causing leakage between that and the Springbook aquifer" (pg.29). Methane leakages from CSGM have been reported though limited support of these findings has been reported. However, a recent study from scientists at the Southern University who conducted a study in Tara, QLD gas field's which are surrounded by farming and agricultural land stated "there was a significant relationship between the number of wells within a 3km of sampling sites and the maximum radon concentration over a 24hr period" (Tait, Santos, Maher, Cyronak & Davis, 2013, pg.3102). Increase methane levels and leakages can have devastating effects, such as increasing fire risk, air pollutants and an increase in greenhouse gas emissions, which can all contribute to climate change.

Coal seam gas lies under some of NSW most arable farming lands and according to Lawrence, Richards & Lyons (2013) in the past where open cut mining has occurred on farming and agricultural land these areas have been able to be brought back to their previous condition, however this is not the case with CSGM where water will be salted and chemicals used in the CSGM extraction have the potential to poison the water used for agriculture leading to arable farming land being damaged. When farming land is lost, financial burden plague the farmer and their families who are dependent on their agricultural business. Farmers receiving below adequate subsidies for CSGM on their properties are an issue seen within the agricultural community in Australia. Hepburn (2012) states, "Many farmers receive $5000 per year for each well that is drilled, however the profit that the well makes can be between $800,000 to $1million a year. This sense of financial inequity, particularly as the mining process may actually decrease the value of the land, generates further frustration and discontent" Hepburn (2012) also goes on to say that many farmers are not wanting compensation but rather want coal seam gas mining to be banned from their land so that they are able to work and farm the lands as they always have.

iii. How the concerns relate to the psychosocial health and well being of farmers

Australian farmers are an already vulnerable population having been through a decade long drought, flash flooding, bush fires and financial burdens which are all associated to climate change. One farmer noted in a recent study that "the mining issue is really doing our heads in. Thinking you own a property for life and then a mining company comes in and makes you sell and leave your community is far more stressful than dealing with Mother Nature" (Hossain, Gorman, Chapelle, Mann, Saal, & Penton. 2013. pg.33). The psychosocial impacts and the psychological distress farm owners are experiencing from CSGM being introduced is becoming more apparent, with limited research beginning to be conducted in this area. Higginbotham, Freeman, Connor & Albrecht (2010) states "that a common theme is residents' concern about the about the present and future health implications of the expansion of coal mining and combustion in the Upper Hunter Valley" (pg. 261).

Solastalgia is a term, which can be used to describe the impact of CSGM and ones psychological state. Solastalgia is the concept of environmentally induced distress. It is the distress that is produced by an environmental change, which will impact the people that are directly connected to their home environment (Albrecht et.al. 2007). Albrecht et.al also goes on to state “solastalgia captures the essence of the relationship between ecosystem health, human health and control (hopelessness and powerlessness) and negative psychological outcomes” (pg.98).

This term can be applied to the abundance of farmland owners who have been devastated by the CSG industry and will lead to a continuous problem with the expansion of the CSG industry and the mental health outcomes of these affected farmers. “They are often told: the resource is there, and you have no rights to stop us obtaining it. The injustice and powerlessness that this engenders contributes to solastalgia and poorer mental health outcomes”. (Doctors for the Environment Australia, 2007).

The powerlessness many farmers are feeling could be leading to a higher rate of mental health illnesses. Higginbotham states that coal mining radically changes the lifestyle of communities, with medical practitioners within the coal mining districts reporting mental illness and stress on a more common basis (as cited in Hossain, et.al. 2013). A recent study conducted in Western Australia about the relationship between environmental degradation and mental health found that there was an association between dryland salinity and an increased risk for hospitalisation and depression (Speldwinde, Cook, Davies & Weinstein. 2009).

iv. Gaps in the data

There have been no studies, which have examined the relationship between coal seam gas mining and psychosocial impact on farmers in NSW to date. Therefore, only limited studies, which were referred to in this report have been directly associated with CSGM and farmers increased risk of psychological impacts. Studies from other states and countries have been referred to, as this has been the only available evidence. Though many farming communities have expressed outrage and concerns for psychological health impacts there is a need for further studies in this field to confidently assess the true extent of the CSGM on the psychosocial state of farmers in NSW.

v. Conclusion

Coal seam gas mining can have a negative impact on rural farmers and agricultural businesses. This report has highlighted several salient issues from environmental, economic and health impacts, in particular the psychosocial impacts CSGM can have on these farmers. Precautions and further investigations must be put into place before we risk irreversible damage to the bio-diversity, land and communities that CSGM could affect.

5 C: Concerns and risks to the wellbeing of Young People

i. Introduction

Coal seam gas mining in Australia and parts of the world has increased in a bid to address the global energy demand (Peduzzi & Harding, 2012). Many concerns have also been raised about the potential impacts of the extraction process on population health. Environmental issues like climate change, air and water pollution have been shown to have the potential to adversely affect the well being of young people (12 – 24 years) (Australian Institute of Health & Welfare, 2011) and young people themselves are also acutely aware of and concerned about these issues (Australian Youth against Coal Seam Gas Mining, Tucci et al., 2007). Young people are particularly vulnerable to changes and factors influencing all aspects of their development as this period of their lives defines their identity formation and future health and social behaviour (AIHW, 2011). Although much research has not been done on the health impacts on youths, this paper will attempt to examine the possible psychosocial impacts of coal seam gas mining on both the young people resident in these communities and those migrating to these communities in Australia in relation to the effects of population change in communities, parental mental health, family disruptions and sexual health.

ii. Population dynamics

Population dynamics associated with mining communities involve both in and out migrations with consequences on existing social amenities and community security. Local residents are reliant on the social support of their communities and friendship networks. In-migration results in insufficient existing public and private social infrastructure like housing, educational and recreational facilities, healthcare services and systems and water and electricity supplies (Ednie, 2003, Petkova, Lockie, Rolfe and Ivanova, 2009 in Shandro et al. 2011). Population movements in mining regions also involve an influx of men and young people. The subsequent growth in population causes disruption to community security and safety with locals losing their sense of community in relation to neighbourhood friendships, sporting, recreational activities and sense of trust. Increased crime rates have also been associated with population growth in mining regions (Carrington, Hogg and McIntosh, 2011). Whilst not limited to environmental factors alone, lack of recreational facilities and lack of trust in neighbourhoods contribute to physical inactivity in young people (Gill, King, Webb and Hector, 2005). Physical activity is essential to achieve health and wellbeing in youths both now and in their adult lives .Physical inactivity has been shown to be associated with increased risk of developing diabetes, cardiovascular diseases and obesity (AIHW, 2011). The limited or absent recreational or park facilities and lack of community security that accompanies population growth in these mining regions is a predisposing factor for physical inactivity in young people which in turn could put them at risk for the development of chronic illnesses like diabetes and mental disorders and consequently reduced quality of life and increased financial burden on the nation.

iii. Sexually transmitted infections (STIs)

Young people are prone to developing sexually transmitted infections with the subsequent long term effects of its complications. There is a high prevalence of STI's amongst young people and single adults (World Health Organisation (WHO), 2007). Furthermore, migrant workers are among the population at risk of developing STI's. Complications following STI include infertility in both sexes, risk of developing genital cancers and the double risk of acquiring and transmitting HIV (WHO, 2011). The incidence of STI's particularly Chlamydia infection has been found to be on the increase amongst young people in Australia (AIHW, 2011). Mining workers especially the fly-in fly-out (FIFO) type are at risk of developing STI's because of their risky behaviour of excessive alcohol intake and engagement in unprotected sexual intercourse. In a study by Goldenberg, Shoveller, Ostry and Koohoorn (2007) the prevalence of STI's particularly Chlamydia have tripled due to the oil industry in British Columbia, Canada. Young males who migrate to live and work in this mining community were predisposed to STI's and HIV because of high levels of financial remuneration, bouts of excessive alcohol intake which lead to loss of inhibition, imbalances in gender,(more men than women) and transience of workers. HIV rates were also found to be high in oil drilling sites in Africa as a result of migration of young adults both male and female to those communities in search of employment (Udoh, Mitchell, Sandfort and Eighmy, 2009). Unsafe sexual practices in young people at these mining regions therefore have implications for both physical and mental wellbeing with possible effects on reproductive ability, acquisition of chronic illnesses and impaired social relationships.

iv. Family Disruptions

The family unit helps shape and determine the young person's suitable adaptability to adult life and its environments and also serves as a support during crisis. Family relationships also have an influence on the educational achievement of a young person and their adaptation to society. Well integrated family relationships are associated with reduced incidence of drug and alcohol use and 'risky behaviour' (AIHW, 2011). Disruptions in the normal family fabric like the absence of a father have been found to be a trigger for future social problems in young people (Walper & Beckh, 2006). In a study carried out by Brereton and Forbes (2004) on Australians who had family members working at the mines, it was reported that regular, long uninterrupted shifts of the miners affected families adversely. Low et al. (2012) go on to state that mental problems like depression, excessive alcohol intake and use of illicit drugs has been linked to the emotional turmoil young people undergo when their family network is disturbed. In addition, the emotional factors involved in changing residences or surroundings has also been found to affect a young person's health and puts them at risk of developing chronic diseases like asthma and diabetes. The absence of the father at home contributes to the poor educational achievement poor relationships with peers and society and the use of drugs, cigarette smoking and alcohol (Kostos & Flynn, 2012). The extent therefore to which young people become fully functional and contribute positively to society as a whole, depends on the level of family support and relationships.

v. Parental Health and young people's mental well being

Contrary to common perception, the well-being of young Australians is already compromised. (Eckersley, 2008, Muir & Powell, 2012). Mental health disorders are the largest contributors to burden of disease amongst young people in Australia with 25% of them experiencing some form of mental disorder in 2007 (AIHW, 2011). Depression affects 3 to 5 % of children and young adults with a tendency to cause poor academic performance, poor relationships with family and friends, dysfunctional growth and social development and may even lead to suicide (Bhatia & Bhatia, 2007). Both mine workers especially shift workers and local residents in a mining community at some point, experience some amount of anxiety, depression or stress as a result of either the work schedules or loss of sense of ownership of land and community therefore caring for or living with a parent with poor mental health may be physically demanding and emotionally draining rendering the affected young people prone to poor academic performance and indulgence in alcohol and drug use (Hargreaves, Bond, O'Brien, Forer and Davies, 2008). Furthermore, a positive family history of mental disorders, stressful life events and chronic illness are risk factors for the development of mental illness in youths (Bhatia & Bhatia, 2007). Indeed, young people who are in good physical and mental health make better educational achievements, are able to obtain gainful employment, form strong social relationships and are better citizens overall (Muir & Powell, 2009).

vi. Conclusion

This paper has not examined the possible direct effects of the chemicals on the young people; but looking at the social effects on young people, coal seam gas mining has a tendency to affect both the physical, mental and social health of young people who are the future generation. The disruptions to community and family that are associated with coal seam gas mining have the potential to affect the academic performance, reproductive ability, social development and relationships and physical and mental health of young people. Consequently, the socio-economic impacts of an unhealthy workforce and population would be immense on a nation. Therefore if a healthy population is expected, then the present society should ensure that a healthy physical and social environment is maintained for the young people. Focused research on the health, psychosocial and economic impacts on youth in relation to coal seam gas mining must be undertaken to better advice policy governing this activity and ensure a healthy and productive future generation

7 A: Causing Serious "Grief"? The psychosocial impact of coal seam gas (CSG) mining for workers

i. Background

The use of new technologies to access "unconventional" gas reserves is growing globally. Australia is no exception, with coal seam gas (CSG) mining poised for rapid expansion in Queensland and New South Wales (NSW) (Carey, 2012). This proposed expansion is occurring amidst widespread national and international debates about the associated environmental and health risks (Ewen, Borchardt, Richter & Hammerbacher, 2012; Howarth, Ingraffea & Engelder, 2011). In Australia, encroachment of CSG activities onto agricultural and residential land, and specific concerns regarding the impact of hydraulic fracturing ("fracking") lie at the heart of the current debate (Carey, 2012; Carey, 2013).

To date, the voices of CSG workers have been noticeably absent in this debate. The current workforce is already substantial with 7,343 direct employees and over 20,241 contractors reported in mid-2012 (Australian Petroleum Production & Exploration Association [APPEA], 2012). There will be a need for exponential growth in this workforce (with various skills) in all phases of future development including exploration, construction and production (Santos, 2010). Such workers face the well-documented dangers associated with the natural gas industry (American Public Health Association [APHA], 2012) as well as "lesser-known" risks specific to CSG, in particular the process of "fracking". Such risks include potential exposure to toxins (in fracking fluid) and inhalation of silica-based fracking "sand" (APHA, 2012; Ewen et al.,2012). Whilst there is increasing attention focussed on the physical hazards of CSG, the psychosocial wellbeing of CSG workers has received minimal consideration. This paper aims to explore the psychosocial impact of the industry on primarily "blue-collar" employees as part of a broader exploration of worker health and safety in CSG mining.

ii. Psychosocial impact of mining – what do we know?

Despite a growing recognition of the importance of worker "wellbeing" in the mining and resources sectors, there is a paucity of data available on the impact of the industry on the mental health of miners. (Australasian Centre for Rural and Remote Mental Health [ACRRMH], 2011a; Kelly et al.,2012). Much of the available data are not specific to CSG but may have relevance and serve to highlight potential impacts.

iii. Risk of mental illness

It is estimated that up to 20% of the community in Australia will suffer from a diagnosable mental illness over the period of a year (Kelly et al.,2012). Furthermore, risk factors for mental illness include drug and alcohol abuse, social isolation and chronic illness (ACCRMH, 2011a; Kelly et al., 2012). As such, miners including those employed in CSG, are likely to experience rates of mental illness at least equal to those of the general community, with substantial impact on worker wellbeing and productivity (ACRRMH, 2011b); Bowers, 2011) As has been highlighted in other mining sectors, CSG employees may be operating in a culture of "machoism" wherein mental illness is often stigmatised, resulting in a failure of recognition of illness and barriers to seeking care (Kelly et al., 2012; Bowers, 2011). This is clearly illustrated in health data from the NSW minerals industry, indicating that 41%

of mine employees undergoing regular health checks, fail to complete the aspects related to mental health screening (Kelly et al., 2012).

iv. Structural and organizational factors

Structural and organisational factors further impact on mental health in the mining industry. There is evidence that shift work may have a negative impact on physical health, family relationships and mental health of miners (Mclean, 2012) Living in a "camp" environment creates social isolation, causing stress and exacerbating (or triggering) mental illness, whilst also being associated with poor health-seeking behaviour (Mclean, 2012). "Fly-in fly-out" (FIFO) and "drive-in drive-out" (DIDO) employment is increasingly common in the mining sector, including CSG (Santos, 2013). A growing body of evidence highlights both negative and positive impacts of such arrangements (Bowers, 2011; Torkington, Larkins & Gupta, 2011). Qualitative research amongst FIFO and DIDO mineworkers highlights experiences of family conflict, feelings of isolation, difficulty engaging in community activities and substance abuse (Torkington et al., 2012). Furthermore, prolonged exposure to noise, dust and other site-related environmental factors contribute to worker discomfort and negatively impact on psychological wellbeing (Grassroots Environmental Education, 2012).

v. Workers and the local community

The relationship between workers and the local community is an important factor in psychosocial wellbeing. Some communities believe that miners have brought increased crime, sex work and other socially "damaging" practices to their towns (Carrington, Hogg, McIntosh & Scott, 2011; Scott & Minichiello, 2013). This animosity may further contribute to social isolation and stress, with development of an "us and them" situation (Hossain et al., 2013). Sharma and Rees (2007) further highlight the experience of female partners of miners in remote towns, in which marginalization, isolation and patriarchy contribute to poor mental health.

As CSG mining increasingly encroaches on urban settings and agricultural lands, it is unclear what impacts this will have on relationships with the local communities (Carey, 2013). Considering that 75% of NSW voters are reported to be against CSG mining on agricultural land (Nichols & Manning, 2013), workers are likely to face increasing community hostility and conflict, with negative impacts on employee mental health (Hossain et al., 2013).

vi. "Double burden" for CSG workers?

In addition to specific work-related stressors, employees are also community members and must deal with the broader community-related repercussions of CSG. As such they could be facing a "double burden" of psychosocial impacts. As described by Albrecht et al. (2007), "solastalgia" (the distress that occurs in relation to environmental changes) has been described in miners themselves and may significantly impact on wellbeing.

i. The stress of unknown health risks?

Perhaps less well-recognised is the potential psychological impact of the ongoing uncertainty pertaining to health and safety risks for CSG employees. There is growing concern regarding community and worker exposure to a number of hazards such as toxic chemicals in fracking fluid and silica-based fracking sand, with potentially significant health impacts (APHA, 2012; Carey, 2012, Tillet, 2013). However, the absence of reliable scientific evidence has hampered the public health and regulatory response to these risks (Mitka, 2012; State of Queensland, 2013). Furthermore, the constituents of fracking fluid are considered proprietary information, making a thorough and accurate assessment of risk extremely difficult (Carey, 2012; Doctors for the Environment Australia [DEA], 2012). This situation may contribute to a sense of powerlessness, with increased stress and anxiety amongst workers regarding current and future health impacts.

ii. Aboriginal and Torres Strait Islander communities

Aboriginal and Torres Strait Islander workers may be disproportionately affected by the psychosocial impacts of the mining industry (Menzies School of Health Research, 2012). In addition to the risks discussed above, these workers may already face social disadvantage and discrimination that increases vulnerability to mental illness (ACRRMH, 2011a, ACRRMH, 2011b). Aboriginal community members may face conflict between the economic benefits of employment in mining, and their commitments to family and protection of traditional land (Albrecht et al., 2007; Menzies School of Health Research, 2012). Furthermore, the lack of availability of culturally appropriate mental health services may act as barriers to seeking care (ACRRMH, 2011a; Kelly et al., 2012). Despite the potential for increased vulnerability, there is also great resilience and knowledge in these communities, which needs to be incorporated into the CSG debate and in formulating measures to reduce potential harms.

iii. Next steps

The paucity of specific data for the CSG industry prohibits a scientifically robust assessment of psychosocial impacts. However, the “precautionary principle” should apply to worker health and safety, as has been recommended more broadly in the CSG debate (Carey, 2012; DEA, 2012; Finkel & Law, 2011; APHA, 2012). In addition, it is essential that baseline data specific to workers in CSG mining is obtained, and these impacts are monitored. Workers should be protected against potential harms by ensuring access to culturally appropriate mental health services and encouraging mental health literacy (ACRRMH, 2011a; Kelly et al., 2012). Transparent communication is essential in helping to address community and worker health concerns. Furthermore, industry regulations protecting workers should be further developed, monitored and enforced by independent regulators (Carey, 2012; Finkel & Law, 2011).

iv. Conclusion

The health and safety of workers is an important component of the CSG debate. Available evidence suggests that CSG mining may directly and indirectly impact on the psychosocial wellbeing of its workers. It is essential that we act now to reduce potential harms, gather reliable data for the future and ensure the voice of the worker is heard in the national discourse. Importantly, this constitutes just one element to be incorporated into a comprehensive assessment of worker health and safety in the CSG industry.

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4. Will health losses overcome economic gains?

In this chapter:

- Economic costing of potential health impacts in New South Wales (NSW): a conceptual approach

6 D: Economic costing of potential health impacts in New South Wales (NSW): a conceptual approach

i. Introduction

CSG is classified as a natural, unconventional gas (≥95% methane) found in coal seams where extraction is maximized through the use of hydraulic fracturing technology. Considered as a cleaner energy source for Australia, modern CSG extraction was first used in Queensland in 1997 (Commonwealth Scientific and Industrial Research Organisation, 2012a, 2012b). CSG exploration has recently started in NSW and this resulted to a vigorous expression of concerns from various stakeholders. Guided by World Health Organization (2003) social determinants of health, the health sector (i.e. PHCM9612 class) embarked on critically examining 7 key areas of concern: water, land biodiversity & natural heritage, land usage, gas emissions, psychosocial, economic impacts, and worker health & safety. This paper discusses the economic impacts area. Figure 1 illustrates how this topic is further subdivided, and the specific focus of this paper is on the economic valuation of potential health impacts. While actual cost estimation is not attempted, a conceptual approach on how one arrives at a certain figure is discussed. This paper has four parts: introduction, valuation of health impacts, costing framework, and conclusion.

ii. Valuation of Health Impacts

Cost-benefit analysis (CBA) is a commonly used tool in comparing options for development. The New South Wales Government (2012) CBA guideline for CSG proposals has received a substantial amount of criticisms from both civilian and professional groups (Public consultation, 2012). Analysis of the guideline reveals poor emphasis on health impacts exemplified by its suggested methodology for value estimation limited only to air and noise pollution. This implies that other concerns (i.e. fracturing fluid) can be conveniently omitted. Furthermore, while techniques in calculating effects from air pollution are available, it is worthwhile to note that it is specific for attributable premature mortalities (Muller, Mendelsohn, & Nordhaus, 2011). It does not account for morbidities.

A fundamental problem rests in the CBA scoping which includes primary impacts (direct and indirect) and excludes secondary impacts. While the said exclusion is acceptable as explained by Boardman, Greenberg, Vining, and Weimer (2006), the challenge is the technical ambiguity of classifying the range of health issues as primary or not. This is partly attributable to the scarcity, though not absence, of evidence demonstrating exposure-disease correlation.

Palmer et al. (2010) discuss the potential health impacts (even after mine-site reclamation) secondary to environmental contamination from mountaintop mining. This is separate from direct occupational exposure which illustrates how the CBA scoping enables it to overlook broader public health effects. The American Public Health Association (2012) enumerates the range of indicative environmental health concerns involving pollution (ground and surface water, air, noise and light), wastewater treatment, community mental health and wellness, occupational health and local health systems. An important public health-oriented article is the ecologic comparison study in the US by Hendryx and Ahern (2009). They compared data from counties in the Appalachian regions grouped according to intensity of coal mining activity from 1979 to 2005. It was found that higher mining activities were related to poorer health outcomes and that the human cost outweighs the economic benefits of coal mining. However, care should be taken in applying this finding to CSG on two points. First, considering that the Appalachian mining started in early nineteenth century, it is near impossible to determine if such health disparities were present before the industry as well as how health concerns were incorporated and addressed during the regional development. Second, these areas practiced underground and surface coal mining techniques which are arguably different from modern CSG technology using hydraulic fracturing.

Queensland Health (2013) issued a summary risk assessment regarding health complaints (i.e. headaches, eye irritations, nosebleeds, skin rashes) of residents from the Tara region. It was basically a desk review of secondary reports including some clinical and environmental monitoring data. It concluded that a clear link could not be established between the health complaints and CSG industry. While the report does have its merits such as the recognition of mental health support, it has several inherent weaknesses. First, the methodology used for a summary risk assessment is weak as it utilizes commissioned reports with questionable approach and absence of declaration of competing interests. Second, there is lack of baseline or time-trend data regarding the incidence rate of complaints which is vital in analysing the syndromic manifestations against another variable (i.e. CSG). Third, the clinical investigation performed was limited. Randomized selection of an adequate sample of the affected residents would have provided a more reliable finding. Fourth, environmental monitoring showed a few substances (e.g. benzene, a confirmed carcinogen) exceeding the reference criteria but was considered insufficient to produce acute health effects. However, impacts from chronic, subclinical exposure remain unknown. Fifth, recognizing that low frequency noise and vibrations were a concern, the report implies that no action is to be done. It is only when concerns continue that additional assessments will take place. Overall, it appears that in addressing health concerns of CSG, Queensland Health is taking a passive stance.

Within the context of public health, economic evaluation is a comparison of consequences and costs of two or more health care interventions (Fox-Rushby & Cairns, 2005). This implies that for the case of CSG in NSW, CBA (as a type of economic evaluation) for health is inappropriate to use. Conceptually, an alternative method to estimate valuation of health effects involves a two-step approach. This includes a health impact evaluation (HIA) which is then followed by a cost of illness (COI) study. It is worthwhile to note that in their special report, the International Energy Agency (2012) did not include such an evaluation as part of the 'golden rules' for unconventional gas production.

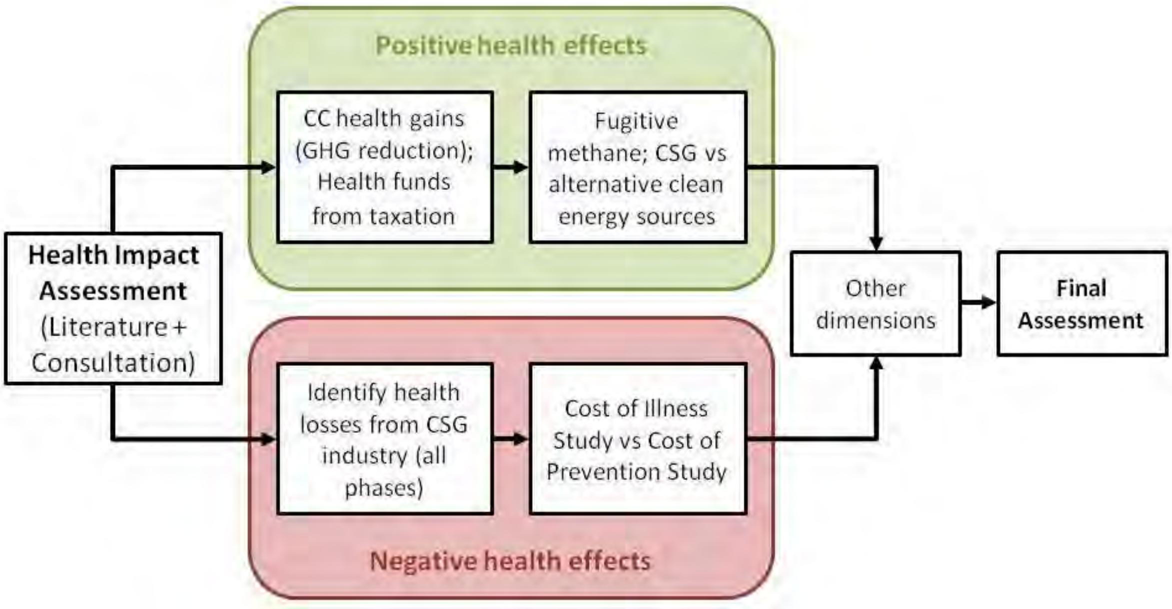
HIA is predominantly a predictive research tool which estimates health consequences of new projects but is not without flaws (Parry & Stevens, 2001). The second stage of HIA (which is scoping and assessment) collects and analyses evidence through literature review and consultations with key stakeholders. Parry and Stevens (2001) note the frequent absence of detailed description of quality assessment criteria and search strategies among published HIAs.

COI studies measure and identify all expenses for a specific disease. Byford, Torgerson, and Raftery (2000) narrates several arguments against COI researches. One of which is that prevention costs may actually be more expensive than COI results. Furthermore, cost of prevention is not routinely included in COIs and thus requires a separate study.

ii. Costing Framework

Figure 2 represents a conceptual costing framework. The process starts with HIA which explores both positive and negative health effects of the CSG industry. Discussion of the positive side includes income from industry taxation which could be allocated to health services. It also involves the issue of climate change (CC) which has multiple harmful effects to human health. In their review, McMichael, Woodruff, and Hales (2006) reiterated that CC is largely due to anthropogenic greenhouse gas (GHG) emissions. Use of cleaner energy sources definitely offers health benefits (Armstrong, 2012). Considering that Australia's CO_2 emission from fuel combustion has consistently increased reaching 383.5 million tonnes in 2010 (International Energy Agency, 2013), initiatives for cleaner energy sources (e.g. CSG) is imperative. However, CSG industry is not entirely GHG-free as evidenced by the escape of fugitive methane gas (about 20 times more global warming potential than CO_2 in 100 years) in the CSG production process (Australian Government, 2012). Moreover, in terms of GHG reduction, CSG is not the only available cleaner alternative and CO_2 reduction computations should not consider it so.

Figure 6.2. Conceptual costing framework



Discussion of the negative side must cover the whole process of CSG. This includes extraction (site preparation, drilling and casing, well completion), transport, processing, storage, combustion, waste disposal, and site remediation phases (American Public Health Association, 2012; Epstein et al., 2011). It also concerns two population groups: CSG workers vulnerable to potential work place contamination and trauma, and the domestic population vulnerable to potentially contaminated biota (through bioaccumulation process), land (through food), water, and air. Pursuant to the holistic definition of health, psychosocial concerns arising from overall environmental use change (Poisel, 2012) and the changing community structure (Hossain et al., 2013) add to the total disease burden

The technique of hydraulic fracturing in CSG makes use of the 'fracturing fluids' which has received much critique in terms of health risks. While it differs in exact mixture across wells, it is generally 97- 99% water and sand plus 1-3% chemical additives. Some the additives are similar to domestic chemicals but some are not associated with household use (Commonwealth Scientific and Industrial Research Organisation, 2012b). Over the life of a well, an estimated 100,000 gallons of chemical additives could be used (American Public Health Association, 2012). Commonwealth Scientific and Industrial Research Organisation (2012b) reports that the extent of human health risks of these require further study. Curiously, NSW Government (2012) fact sheet claims that as these chemicals are used in diluted form they present negligible ecological or human risks. Analysis from the US identified about 650 chemicals used in hydrofracking, 59 of which were involved in natural gas, and 40 had the potential to cause multiple adverse health effects (Bushkin-Bedient, Moore, & The Preventive Medicine and Family Health Committee of the Medical Society of the State of New York, 2013). A sample selection of CSG companies has been reviewed in Australia by the National Toxics Network (NTN) leading to the identification of 23 commonly used compounds in fracturing fluids. The country's industrial chemical regulator, the National Industrial Chemical Notification and Assessment Scheme (NICNAS) has only assessed two (Lloyd-Smith & Senjen, 2011). A list of selected chemicals with their corresponding human health effects is available in Appendix 1.

After identification of the possible diseases from all phases of the CSG production, valuation involves a prospective COI study. This includes three general steps. First, estimate the extent to which the two population groups are exposed, and of those exposed (with respect to dose-response relationship) how many would likely develop the disease. For completion, literature review must account for baseline prevalence trend of similar diseases as we are only concerned with the possible increase attributable to CSG (i.e. incidence rate). Second, of those who develop disease manifestations, estimate the number of cases likely to exhibit mild from severe symptoms as these have different cost equivalents. Third, estimate the cost for both mild and severe cases. In this step, one must account for at least three different cost classifications as done by Scott, Scott, Turley, and Baker (2004): direct medical, direct non-medical, and indirect (i.e. loss of productivity). Summation of these should lead to an estimate of the COI. A similar process from the perspective of illness prevention could be done for the cost of prevention study. Final assessment should then result by balancing out the negative from the positive to obtain the net health effects.

It could be argued that there are other dimensions worth exploring. First, the observed increase in cost of living strains the household budget to maintain a healthy lifestyle (Hossain et al., 2013). Second, at the community level, the increase in population secondary to migration of non-resident workforce pressures the availability of local health services (Hossain et al., 2013). Third, theoretically speaking, having mild symptoms from multiple causative agents could possibly result in increased patient suffering more than its mere summation. Fourth, inter-generational health effects and people to people transmission must be ruled out. Lastly, after making all the technical computations, the ‘reduction’ of health issues to mere numbers must be balanced by giving due consideration to ethical principles. Specifically, to the principle of beneficence that dictates ‘do no harm’ (The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1978) which is in line with the precautionary principle.

iii. Conclusion

The primary interest of this paper is the insufficient attention given to potential health effects (and equivalent economic costs) of a rapidly expanding industry. The incongruity between government and professional group statements raises much concern. Measuring the economic value of possible health impacts of the CSG industry in NSW is a challenge based on two key points. First is the technical ambiguity of classifying the range of health issues as primary or secondary effect for inclusion in the published CBA or HIA scoping. Second is the need for further information on CSG processing, particularly on the composition and use of fracturing fluid chemicals. However, this does not imply that nothing could be done. As discussed by Parry and Stevens (2001), HIA can be accomplished at different extensiveness, and the option to do a mini HIA remains open. Furthermore, evidence is available for likely diseases attributable to CSG production. Considering that the industry has been operating in Queensland for more than a decade, government in coordination with relevant stakeholders should be able to conduct a thorough, proactive investigation on various health effects possibly associated with the industry. Why this has not been achieved at this point leaves room for further debate and is beyond the scope of this paper.

Appendix 6. 1: Selected identified chemicals in fracturing fluids and available human health data, excerpt from Bushkin-Bedient et al. (2013) and Lloyd-Smith and Senjen (2011)

Fracturing fluid chemical	**Human health data**
Tetrakis (hydroxymethyl) phosphonium sulfate (THPS)	No exposure information is available for either humans or organisms in the environment hence no quantitative risk assessment has been made
Sodium Persulfate	Irritant to eyes and respiratory system; Long-term exposure may cause changes in lung function (i.e. pneumoconiosis resulting in disease of the airways) and/or asthma; May cause skin rashes; May develop eczema and allergies after repeated exposure
Ethylene Glycol (antifreeze)	Eye, nose and throat irritant; Human respiratory toxicant; Increased risks of spontaneous abortion and sub-fertility; Teratogenic
2-Butoxyethanol	May cause reproductive problems and birth defects in animals; No carcinogenicity studies are available
Ethoxylated 4-nonylphenol	Persistent bioaccumulative endocrine disruptor
Naphthalene	Possible human carcinogen; Exposure to large amounts of naphthalene may also cause nausea, vomiting, diarrhea, blood in the urine, and a yellow color to the skin
Methanol	Causes headache, insomnia, gastrointestinal problems, and blindness
Isopropanol	Reproductive toxin and irritant
Formamide	Teratogenic
Ascetic anhydride	Severe irritation to eyes, skin, mucous membrane;
Arsenic	Permanent corneal scarring
Benzene	Carcinogen
Chlorine dioxide	Carcinogen
Formaldehyde	Severe respiratory and eye irritant Carcinogen
Lead	Carcinogen

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