Submission to the Senate Environment and Communications References Committee regarding the

Beetaloo Cooperative Drilling Program.

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Summary.
Oil and gas exploration and production in the Beetaloo Basin will be detrimental to the health of Northern Territory residents, leading to increased incidence of cancer. Funding from the Industry Research and Development (Beetaloo Cooperative Drilling Program) Instrument 2021 should be ceased until further studies can be carried out to examine the two fold incidence in neoplasms (cancer) reported by Werner *et al,* in children living near similar operations in Queensland (see below).

For some time, scientists have been concerned about Polycyclic Aromatic Hydrocarbons (the most potent carcinogens in cigarette smoke) being released into water supplies and air during unconventional gas mining. Recent publications indicate unconventional gas mining (UG) has resulted in increased cancer incidence in the USA and in Queensland.

Coal consists of a complex mixture of organic chemicals, many having structures likely to cause mutations in DNA and the potential to cause cancer in humans. Polycyclic Aromatic Hydrocarbons, (PAHs) found in coal are amongst the most potent carcinogens known. Fracking chemicals include known human carcinogens eg. benzene, and potentially more potent carcinogens as impurities. A few of these chemicals have been studied and listed as possible carcinogens, but most, including those likely to be the most potent carcinogens, remain untested and therefore are largely not taken into account in assessing potential health risks. Unconventional gas mining (UG) allows large amounts of these chemicals to be solubilised from coal seams and leached out into ground water. Flaring results in coal tar like impurities (including PAHs) being released into air. Fracking chemicals will also be released into the atmosphere and ground water. Unconventional gas mining (UG) poses a new major health risk for Australia, with a possible increase in cancer cases on par with or greater than asbestos.

Present legislated “safe” or maximum contamination levels are close to the level of detection for the few known PAHs listed. Most potent carcinogens found in coal and produce water have not been studied or listed. They are likely to initiate cancer at concentrations that are orders of magnitude below their detectable levels in drinking water. So testing ground or drinking water may be of little use in determining cancer risk.

The health effects reported in USA gas mining areas are now occurring in Australia. Over 100 people living near UG wells at Tara, Qld, have reported symptoms such as skin rashes, dizziness, nausea and nosebleeds, consistent with exposure to fracking chemicals, and elevated levels of benzene have been measured adjacent to UG wells in the area.

**The author's publications include papers in Nature, the Lancet, New England Journal of Medicine, Mutation Research, Neurology, Oncogene, Biochemical Pharmacology and Plant Science. Invited speaker at the Dibble Cancer Research Centre, UDMS, London, and the International Congress for In Vitro Biology, Portland, OR, USA. Over 30 years working as a molecular biologist in Cancer Research at University of Qld and Qld Institute of Medical Research, studying the effects of chemical carcinogens on cultured human cells.*

Cancer resulting from chemical mutagen exposure manefests 10 to 12 years after exposure in adults and 5 years after exposure in children. After more than 15 years shale gas mining in USA, increased bladder cancer has been reported in adults. Unconventional gas mining in Australia has only been carried out for less than 10 years, but there is now preliminary evidence of increased cancer in 5-9 year old children in an UG area in Queensland.

Once a well is drilled, carcinogenic chemicals can leak out for years afterwards, and for UG wells in the catchment of rural water supplies this poses a huge long-term risk to public health.

The flyer, "PAHs:the New Asbestos" describes PAHs and how they cause cancer. A more robust scientific analysis is below:

Chemical Carcinogens, Mutagens and Cancer.

The process of development of human tumors is complex,[1] but the underlying cause of the process is mutation of DNA. "Most evidence points to a multistep process of sequential alterations in several, often many, oncogenes, tumor-suppressor genes, or microRNA genes in cancer cells."[2]

Carcinogens are classified according to their mode of action as genotoxic or nongenotoxic carcinogens. Genotoxic carcinogens initiate carcinogenesis by direct interaction with DNA, resulting in DNA damage or chromosomal aberrations that can be detected by genotoxicity tests eg. Ames Test[3]. Nongenotoxic carcinogens are agents that, at least initially, indirectly interact with DNA. These indirect modifications to DNA structure, amount, or function may result in altered gene expression or signal transduction[4].

A large range of chemical mutagens have been found to cause cancer in animal models.[5] Poly Aromatic Hydrocarbons (PAHs) and their derivatives are among the most potent carcinogens, having structures that resemble the base pair in DNA and readily intercalating and/or covalently bonding to DNA causing mutation.[6,7] The effect of carcinogens in mixtures is complex and synergistic effects often occur.[8] Cancer risks from chemical carcinogens in complex mixtures such as environmental samples can be much greater than for individual chemicals.

Possible CSG Carcinogens

Coal consists of a complex mixture of organic chemicals, many having structures likely to cause mutations in DNA and the potential to cause cancer in humans. PAHs solubilised from coal samples ranged from 1.21 to 28.6 mg/kg, and this did not include compounds 4 rings or larger.[9] Amounts of US EPA specified PAHs extracted from coals in this study range from 0.28 to 6.38 mg/kg. Less than one quarter have been listed as possible carcinogens, the rest remain unstudied, and therefore are not classified by agencies like the International Agency for Research on Cancer(IARC), the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) or the National toxicology Program of the U.S.Department of Health and Human Services (NTP) as carcinogens or possible carcinogens. As they are not classified, the majority of carcinogens in coal and fracking chemicals are not taken into account in assessing potential health risks.

Coal tar is a complex mixture made when coal is carbonised to make coke or gasified to make coal gas. It contains many of the PAH's from coal and is listed by IARC as a Group 1 mixture, carcinogenic to humans, based on sufficient evidence of human and animal carcinogenicity.[10] Fracking chemicals include known human carcinogens eg. benzene, and potentially more potent carcinogens as impurities.[11]

Few of these chemicals, mainly PAH's[12], that can be solublised from coal or occur as impurities in fracking chemicals have been studied and listed as possible carcinogens. Most, including those likely to be the most potent carcinogens, remain untested and therefore are largely not taken into account.

Liberation of Carcinogens by Unconventional Gas Mining.
Unconventional gas mining solublises large quantities of chemicals from coal (production water can range between 0.1 megalitres per day (ML/d) and 0.8 ML/d.48), and uses large amounts of drilling and fracking chemicals typically 18.500 kg.[11] "Geogenic contaminants mobilised from the coal seams during fracking may add to the mixture of chemicals with the potential to affect both ground and surface water quality.[12]" Orem *et al* [13] identified a wide range of phenols, biphenyls, heterocyclic compounds, aromatic amines and aliphatic compounds, typical of those found in coal, in produced water from Wyoming CSG wells. Total PAH's were measured at levels of 23µg/l. Individual PAH's ranged from 0.01 to 18 µg/l.

Under natural conditions, fossil fuels contribute a relatively small volume of PAHs to the environment. Because most coal and oil deposits are trapped deep beneath layers of rock, there is little chance to emit PAHs to the surface environment. For the first time, UG will allow large amounts of these chemicals to be solublised from coal seams and leached out into ground water, and fracking chemicals to be released into our atmosphere. This poses a new major health risk for Australia.

"Safe" levels of Carcinogens.
The dose response curve for the Ames test using varying concentrations of chemical is almost always linear[14] indicating that there is no threshold concentration for mutagenesis. This suggests that, as with radiation, there may be no "safe" threshold for chemical mutagens or carcinogens[15,16] and they need to be considered differently to other chemical toxins where a high threshold amount is needed, for example, to adversely affect the function of a whole organ. Chemical carcinogens on the other hand typically initiate cancer by one molecule causing a DNA mutation in one cell. Arguably there is no "safe level" for genotoxic chemicals like PAHs.

Present legislated "safe" or maximum contamination levels are close to the level of detection for the few known carcinogens listed. For example US EPA Maximum Contamination Level (MCL) for benzene in drinking water is 5ng/l .[17] Inhalation carcinogenic potency (WHO air guidence for Europe [29]) for benzo(a)pyrene is four orders of magnitude higher than Benzene:

PAH – benzo(a)pyrene	$8.7x10^{-2}$	unit risk/(µg/cu. m.)
Benzene	$6x10^{-6}$	unit risk/(µg/cu. m.)

ANZECC/ARMCANZ guidelines (1996) specify a concentration limit of 10 ng/L of benzo(a)pyrene in drinking water. This limit has also been adopted by NHMRC. Based on the ratio above the drinking water MCL for benzo(a)pyrene should be several orders of magnitude lower than 10 ng/L.
Typical water testing limits of quantification (LOQ) values for PAHs range from µg/l[18] to 10 ng/l. So testing ground or drinking water may be of little use in determining cancer risk of water contaminated by PAHs.

Assays for CSG Carcinogens.

Testing of produce water is one possible way of detecting carcinogens released from coal by the mining process, as they will be present at higher concentrations when first released from wells. Orem et al [13] found individual PAHs rangeing from 0.01 to 18 µg/l, in produced water from Wyoming CSG wells, allowing measurement of levels above the LOQ range.

Few reports have so far been published on Australian produce water as most assay results are kept confidential. Stearman *et al* [27] reported values near the detection limit (0.01 µg/l) for several PAHs (eg. Naphthalene 0.01 – 0.046µg/l, µg/l, Benzo[b+k]fluoranthene 0.01 – 0.033µg/l, Dibenz[a,h]anthracene 0.01 –0.014µg/l) from Walloon Coal Measures' CSG waters, as sampled from production wells. The maximum total PAH concentration reported from any single well was 0.083 µg/L. The authors stated "Coal is a heterogeneous material and each coal seam gas field may present a unique inventory of organic compounds needing characterization and assessment to fully understand coal-groundwater interactions and ultimately water quality. Moreover, there is potentially a far wider range of organic compounds mobilized from coals to CSG water beyond the common environmental analytes of this study, including heterocyclic compounds, biphenyls, aromatic amines and non-aromatic compounds." "we do not know how many of these are likely to be carcinogenic and what is the carcinogenic potential of mixtures which can have enhanced carcinogenic potential over their constituents."

It is essential that PAH assays of produce water are carried out routenely at an assay sensitivity, below safe drinking water levels (0.01 µg/L, ANZECC/ARMCANZ drinking water guidelines). Stearman *et al* [30] state, "In some instances, the detection level (DL) of some organic compound classes in CSG water may be too high to adequately assess the occurrence of potentially harmful compounds. Aromatic compounds such as BaP have regulatory limits (0.01 µg/L) 50 times less concentrated than the minimum DL (detection level) of the Bandanna Formation dataset (0.5 µg/L) of this work and the small number of publicly available QLD CSG water organic datasets." So in this publication, the assays were not sensitive enough to detect PAHs at levels that could cause cancer. Assays of with detection levels > 3ng/l are needed, so research laboratory methods (Oream *et al* [13] *)* need to be used for routene assays.

Testing air close to the well may detect measurable levels of fracking chemicals.[20] However most VOC tests do not detect the chemicals of interest, with the exception of benzene, as typically only the top 5 or 10 VOC's are assayed. The more complex carcinogens, (PAHs), may only be detected in the top 20 to 100 VOC's. Assays are often reported as negative, which is misleading as the chemicals of interest were not included in the assay results, and the chemical may still be present.

The Long-term Health Risks of Unconventional Gas Mining.

Over 100 people living near CSG wells at Tara, Qld, have reported symptoms such as skin rashes, dizziness, nausea and nosebleeds, consistent with exposure to fracking chemicals,[21] and elevated levels of benzene have been measured adjacent to CSG wells in the area. Santos and Maher[22] have measured some of the highest levels of methane in the atmosphere in UG mining areas in Queensland. This was consistent with fugitive gas emissions. Whenever wells leak, other chemicals (including carcinogens) will be leaking along with methane, so this data raises the possibility that Australia could have relatively high UG emissions and high air-borne carcinogen levels from UG.

McKenzie *et al*[20] have estimated nearly double the cancer risk from chemical exposure for Colorado residents living less than 1/2 mile form CSG wells compared to those living greater than ½ mile away, based on measurement of air-borne carcinogens.

The health effects reported from UG mining areas in USA are now occurring in Australia. Once a well is drilled, carcinogenic chemicals can leak out for years afterwards, and for wells in the catchment of urban water supplies this poses a huge long-term risk to public health. Chlorination of drinking water can produce chloro-derivatives of PAHs that are even more potent carcinogens,[23] adding to this health risk.

Cancer attributed to UG in USA

Finkel [24] found evidence for increased bladder cancer in data from the Pennsylvania Cancer Registry. The observed number of urinary bladder cases was higher than expected in both sexes in counties with shale gas activity. The increase correlated with the number of producing wells; "in counties with the fewest number of producing wells, the increase was essentially non-existent."

Increased neoplasms in Qld children.

Werner *et al* [25] analysed child and adolescent hospital admission rates in Queensland and compared a coal seam gas area (CSG), a coal minninng area (CHI) and a control area (RLI - no mining). "Adjustment for covariates revealed a 95% increase per year in 'Neoplasms' admission rates in the CSG area relative to the RLI area." This needs further study, but indicates that childhood cancer could be nearly doubled in the UG area. "The CHI area also showed an increase of 94% per year relative to the RLI area." This data points to a carcinogen liberated by both UG and open cut coal mining; PAH's are a prime contender. Again further study is needed.

Conclusions.

Taking values of Relative Inhalation Carcinogenic Potency from World Health Organization Air Guidence for Europe[29], if the cancer risk for benzene is 1, the relative cancer risk for asbestos is 29, and for the PAH, Benzo(a)pyrene, is 14,500. Unconventional Gas Mininng poses a major health risk for Australia, with the potential of increasing cancer levels comparible to asbestos.

More sensitive assays are needed for routine testing of PAHs, and regular testing of produce water for PAHs should be manditory to assess the health risks of UG.

The Australian Institute of Health and Welfare Report[26] on cancer incidence in Australia found that between 1991 and 2009, the number of new cancer cases diagnosed in Australia each year almost doubled; from 66,393 to 114,137. This is likely to be only partly accounted for by increase in population and increased diagnosis; environmental factors are likely to play a major role. Vineis and Xun,[27] describe "The emerging epidemic of environmental cancers in developing countries." Grant[28] has identified air pollutants in particular PAH's as "the likely source of air pollution that affects cancer risk on a large scale, through production of black carbon aerosols with adsorbed polycyclic aromatic hydrocarbons".

These types of studies, the recent data on Australian cancer incidence, and the worldwide rise in air- and water-borne chemical carcinogens[29] should be ringing alarm bells throughout the public health sector about increased cancer from environmental chemicals. The public Health risk of this project needs to be carefully examined before any funding is approved.

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