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NATIONAL TOXICS NETWORK SUBMISSION
Inquiry into the impacts on health of air quality in Australia

Air pollution related to unconventional gas exploration and production

It has long been known that urban air pollution levels are associated with increased mortality and cardiorespiratory morbidity and that these health effects occur even at exposure levels below those stipulated in current air-quality guidelines, and it is unclear whether a safe threshold exists.[1]

While air pollution in Australia has historically been sourced to motor vehicle emissions, heavy industry, home heating using wood and electricity generation from fossil fuels, unconventional gas (UG) including coal seam gas activities provides a new and serious source of air pollution.[2]

Unconventional Gas (UG) refers to natural gas from unconventional sources such as shale deposits, coal seams, tight sandstones and methane hydrates. Natural gas consists of methane with other hydrocarbons, carbon dioxide, nitrogen and hydrogen sulfide. UG wells differ from conventional gas in that many wells need to be drilled to extract the gas, many will incorporate horizontal drilling and that the hydraulic fracturing process is likely to be used a number of times over the life of a well.

UG Industry Sources of Air Pollution

The US National Library of Medicine notes that operations at gas fields emit a wide range of pollutants including nitrogen oxides, volatile organic compounds (VOCs), carbon monoxide, sulfur dioxide, and particulate matter. Air emissions come from several sources in gas fields, including equipment engines, drilling rigs, pumpjacks, boilers, heaters, generators, combustion flares, storage tanks, injection pumps, dehydrators, vehicles, and oil and gas skimmers. They note that one of the major sources of air emissions at gas fields are compressor stations that move natural gas through pipelines and gas processing plants.[3]

[1] Tord E Kjellstrom, Anne Neller and Rod W Simpson, Air pollution and its health impacts: the changing panorama *Med J Aust* 2002; 177 (11): 604-608.
[2] UNEP Global Environmental Alert system Gas fracking: can we safely squeeze the rocks? http://na.unep.net/api/geas/articles/getArticleHtmlWithArticleIDScript.php?article_id=93
[3] http://toxtown.nlm.nih.gov/text_version/locations.php?id=150

Gas Processing, which is required to remove impurities before natural gas can be used as a fuel, produces by-products including ethane, propane, butanes, pentanes and higher molecular weight hydrocarbons, hydrogen sulphide, carbon dioxide, water vapor and sometimes helium and nitrogen. These are vented to the atmosphere, providing an important point source of air pollution from the industry.

Flaring (the burning off of natural gas from a new well) is a common practice in the gas fields and represent a direct release of pollutants to air. The emissions include hydrogen sulfide, methane and BTEX chemicals,[4] as well as dioxins and metals such as mercury, arsenic and chromium.[5] The US EPA due to air pollution concerns has banned flaring associated with UG activities after January 2015. [6]

Volatile Organic Compounds (VOCs)
Of particular concern are the VOCs, which are released at all stages of UG production. Raw natural gas contains many toxic non-methane hydrocarbons that surface with the methane and are released during venting and in fugitive emissions at all stages of natural gas production and delivery. Mobile and stationary equipment release VOCs, as well as NOx, CO and particulate matter through exhaust and evaporative emissions. Pit fluids and holding ponds are also a source of VOCs, including the break-down products and mixtures of chemicals that cannot be predicted. Volatile chemicals are used during cleaning and maintenance of well pads and equipment. Volatile chemicals are also injected underground during drilling and hydraulic fracturing (fracking) a percentage of which eventually surfaces.

Many VOCs are toxic. Some are known to cause cancer in animals (eg methylene chloride), or in humans (eg formaldehyde) or are suspected human carcinogens (eg chloroform and bromodichloromethane). VOCs are also key ingredients in forming ozone (smog), which is linked to asthma attacks, and other serious health effects. VOCs help form fine particle pollution (PM2.5). VOC exposure may result in eye, nose, and throat irritation; headaches, visual disorders, memory impairment, loss of coordination, nausea, damage to liver, kidney, and central nervous system.[7]

Benzene, Toluene, Ethylbenzene, Xylene or BTEX are both components of drilling fluids and natural VOCs released from the coal seam. Their short term health effects include skin, eye / nose irritation, dizziness, headache, loss of coordination and impacts to respiratory system. Chronic exposure can result in damage to kidneys, liver and blood system. Benzene is strongly linked with leukemia [8] and other diseases such non-Hodgkin's lymphoma (NHL).

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[4] http://www.hsph.harvard.edu/research/niehs/files/penning_marcellusshale.pdf
[5] Birnur Buzcu-Guven, Robert Harriss, Donald Hertzmark *Gas Flaring And Venting: Extent, Impacts and Remedies* Institute For Public Policy, Rice University , September 2010 http://www.bakerinstitute.org/publications/CARBONFlaring%20paper%20Birnur%20FINALwith%20cover%20secured.pdf ; Also see Canadian Public Health Association, Background to 2000 Resolution No. 3 www.climatelaw.org/cases/country/nigeria/cases/casedocuments/nigeria/report/section7/doc7.1.pdf
[6] http://www.epa.gov/airquality/oilandgas/pdfs/20120417presentation.pdf
[7] http://www.epa.gov/iaq/voc.html
[8] Rinsky, R.A Benzene and leukemia: an epidemiologic risk assessment. *Environ Health Perspect*. 1989 July; 82: 189–191.

The USEPA 2012 presentation on new emissions standards for the gas industry stated that the oil and gas industry is the largest industrial source of VOC emissions in the U.S. Once considered a summertime pollutant, ozone had now become a problem in winter in areas with significant natural gas production. They concluded that air toxics from the oil and gas industry could cause cancer and other serious, irreversible health effects, such as neurological problems and birth defects.[9]

A 2012 study,[10] carried out over 12 month detected 44 hazardous air pollutants at UG drilling sites. The study found a wide range of air toxics including methane, methylene chloride, ethane, methanol, ethanol, acetone, propane, formaldehyde, acetaldehyde and PAHs including naphthalene. They noted a great deal of variability across sampling dates in the numbers and concentrations of chemicals detected. Notably, the highest percentage of detections occurred during the initial drilling phase, prior to hydraulic fracturing on the well pad.

Australia Research

Research by the Southern Cross University[11] used atmospheric radon (^{222}Rn) and carbon dioxide (CO2) concentrations to measure fugitive emissions in the CSG fields of the Tara region, Queensland. They measured a 3 fold increase in maximum ^{222}Rn concentration inside the gas field compared to outside. They suggest that CSG activities may change the geological structure and enhance diffuse soil gas exchange processes. The study notes that emissions include greenhouse gases such as CO2 and methane. While not harmful to human health at low concentrations, methane is a powerful greenhouse gas with a global warming potential 25 times that of CO2 over a 100-year time horizon. These emissions should be accounted for when estimating the net greenhouse gas footprint of CSG operations. The presence of these gases also suggests the release of other gaseous substances, such as VOCs, which can be very harmful to human health.

Impacts On Human Health

A Human Health Risk Assessment of air emissions around US UG activities,[12] concluded that residents closest to well pads i.e., living less that 1/2 mile from wells, have higher risks for respiratory and neurological effects based on their exposure to air pollutants; and a higher excess lifetime risk for cancer. The study took 163 measurements from fixed monitoring station, 24 samples from perimeter of well pads (130-500 feet from center) undergoing well completion and measured ambient air hydrocarbon emissions. Emissions measured by

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[9] Reducing Air Pollution from the Oil and Natural Gas Industry EPA's Final New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants
April 17, 2012 http://www.epa.gov/airquality/oilandgas/pdfs/20120417presentation.pdf

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

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

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

the fenceline at well completion were statistically higher ($p \leq 0.05$) than emissions at the fixed location station (inc. benzene, toluene, and several alkanes.) The assessment was based on the US EPA guidance to estimate non-cancer and cancer risks for residents living greater 1/2 mile from wells and residents living equal to or less than a 1/2 mile from wells. The study may have underestimated risks to human health as it did not measure ozone or particulates. USEPA methods may also underestimate health risks of mixed exposures.

Some have attempted to dismiss this study stating that Australian CSG does not emit the same hydrocarbons however, sampling around CSG activities have shown the presence of BTEX including benzene on which the cancer risk was primarily based. (See VOCs in Tara, Queensland)

A US Health Survey [13] investigated the extent and types of health symptoms experienced by people living near UG in Pennsylvania. Environmental testing was conducted on the properties of a subset of survey participants (70 people in total) to identify the presence of pollutants that might be linked to both gas development and health symptoms. Test locations were selected based on household interest, the severity of symptoms reported, and proximity to gas facilities and activities. In total, 34 air tests and 9 water tests were conducted at 35 households in 9 counties. VOCs were detected in air including 2-Butanone, Toluene, Acetone, Chloromethane, Carbon tetrachloride, Benzene, Trichlorofluoromethane, Methylene Chloride, Dichlorodifluoromethane, n-Hexane, Tetrachloroethylene, 1,2,4-Trimethylbenzene, Ethylbenzene, Trichloroethylene, Xylene and 1,2-Dichloroethane**.** A range of symptoms were reported in the 108 surveys including nasal & throat irritation (60%), sinus problems (58%), eyes burning (53%), shortness of breath (52%), difficulty breathing (41%), severe headaches (51%), sleep disturbance (51%), frequent nausea (39%), skin irritation (38%), skin rashes (37%), dizziness (34%). While the study did not prove that living closer to UG facility causes health problems, they did suggest a strong association, as in general, the closer to gas facilities respondents lived, the higher the rates of symptoms they reported.

Residents of Tara Queensland, adjacent to extensive CSG activities report similar symptoms including severe headaches, nausea, vomiting, nose bleeds, rashes, eye and throat irritations and severe skin irritations. They also report ‘stench events’

VOCs in Tara Queensland

While there has been no comprehensive monitoring of air pollutants in the Tara community near gasfields, one-off samples of ambient air around homes have detected a range of VOCs. These include ethanol, acetone, benzene, toluene, xylene, ethylbenzene, dichlorodifluoromethane, 1,2,4-trimethylbenzene, naphthalene, phenylmaleic anhydride, methyl ethyl ketone, phenol, butane, pentane, and hexane. While this sampling is clearly inadequate to assess emissions and pollution, the detection of VOCs near

[13] Gas Patch Roulette: How Shale Gas Development Risks Public Health In Pennsylvania, October 2012 Earthworks' Oil & Gas Accountability Project www.earthworksaction.org

residences and adjacent to residential water bores indicates the overwhelming need for a comprehensive sampling program to assess air releases. Toluene, a neurotoxin was detected in the air around at least eight Tara homes and in the air over a private bore. In the latter, the level was simply dismissed (by the report's authors) as below levels of concern,[14] yet it is well above the 'Chronic Reference Exposure Limits' used by many states in the USA (eg California, Massachusetts, Michigan) for assessing the impacts of long term exposure.

Community Sampling
Community sampling activities have also detected volatile and semivolatile compounds in water samples taken around Queensland UG activities. VOCs change easily from liquid form to vapor. A sample taken from the top of the well-head, a day after the well had been 'fracked', demonstrated the presence of VOCs, eg bromodichloromethane, bromoform, chloroform, dibromochloromethane, benzene.[15] The US Hazardous Substances Data Bank[16] lists dibromochloromethane as having an estimated half-life of 8.4 months in air, indicating that long-range global transport is possible. The International Agency for Research on Cancer has concluded that chloroform and bromodichloromethane are possible human carcinogens.

Air Testing by NTN in cooperation with local communities took three air samples from around gas extraction activities over an 8-hour period, including one taken adjacent to a residential water bore. The samples were analysed by the National Measurement Institute and were shown to contain ethanol and chlorofluorocarbons (CFCs).[17] Once used as refrigerants and aerosol spray propellant, because of their adverse impact on the ozone layer, CFCs were either banned or heavily regulated under the Montreal Protocol on Substances That Deplete the Ozone Layer. Dichlorodifluoromethane, commonly known as Freon-12 was detected in all samples, as was trichlorofluoromethane (Freon-11), which has the highest ozone depletion potential of any refrigerant. Both these CFCs are recognised as substances that may be formed in natural processes, hence the source of these CFCs remains unknown.

Naturally occurring radioactive materials
NORMs are found in both coal seams and shale, eg uranium, thorium, radium-228 and radium-226.[18] The radioactive material can be released through the drilling process in drill cuttings/muds, flowback water and air emissions. Radon-222 is the immediate decay product of Radium-226 and preferentially follows gas lines. It decays (through several rapid steps) to Pb-210, which can therefore build up as a thin film in gas extraction equipment.

[14] Simtars Investigation of Kogn Water Bore (RN147705) -16 October 2012
[15] Labmark Environmental Laboratories, Certificate of Analysis, Report 331850-W Composite: Roma Water Analysis, Mar 26, 2012
[16] http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB
[17] Australian Government National Measurement Institute, Report of Analysis of Air Canisters Low Level, Report No. RN900555 (2 Feb 2012), Report No. RN893233 (16 Dec 2011), Report No. RN893232 (16 Dec 2011)
[18] Fact Sheet FS-163-97 October, 1997 Radioactive Elements in Coal and Fly Ash: Abundance, Forms, and Environmental Significance, USGShttp://pubs.usgs.gov/fs/1997/fs163-97/FS-163-97.html

The level of reported radioactivity varies significantly, depending on the radioactivity of the reservoir rock and the salinity of the water co-produced from the well. The higher the salinity the more NORM is likely to be mobilized. Since salinity often increase with the age of a well, old wells tend to exhibit higher NORM levels than younger ones.[19] Radium is a known carcinogen[20] and exposure can result in increased incidence of bone, liver and breast cancer. Radon, a decay product of radium can cause lung cancer. Despite the increased rate of radon detected by the SCU study inside the gas fields, there has been no radionuclide analyses or testing for radon in the communities surrounding gas fields.

<u>Particulates and Silica</u>

UG activities result in the formation and distribution of particulate pollution from a range of sources including diesel engines and the use of proppants in hydraulic fracturing. Up to 50,000 kg of proppants may be used per hydraulic fracturing. These consist of either silica or manufactured ceramic polymer spheres based on alumino-silicates, which are injected as part of the fracturing fluid mixture and intended to remain in the formation to hold open the fractures once the pressure is released. Breathing silica can cause silicosis, and exposure to silica dust is a known cause of lung cancer and a suspected contributor to autoimmune diseases, chronic obstructive pulmonary disease and chronic kidney disease.[21]

The US National Institute for Occupational Safety and Health (NIOSH) recently released a Hazard Alert, identifying exposure to airborne silica as a health hazard to workers conducting hydraulic fracturing operations.[22]

NIOSH identified seven primary sources of silica dust exposure during hydraulic fracturing operations:

- dust ejected from thief hatches (access ports) on top of the sand movers during refilling operations while the machines are running (hot loading);
- dust ejected and pulsed through open side fill ports on the sand movers during refilling operations;
- dust generated by on-site vehicle traffic;
- dust released from the transfer belt under the sand mover;
- dust created as sand drops into, or is agitated in, the blender hopper and on transfer belts;
- dust released from operations of transfer belts between the sand mover and the blender; and
- dust released from the top of the end of the sand transfer belt (dragon's tail) on sand movers.

NIOSH acknowledges the serious lack of information on occupational dust exposure in the gas industry, including exposure to diesel particulates. Diesel

[19] http://www.world-nuclear.org/info/Safety-and-Security/Radiation-and-Health/Naturally-Occurring-Radioactive-Materials-NORM/#.UTlc2qXfCcM

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

[21] NIOSH Hazard Review, Health Effects of Occupational Exposure to Respirable Crystalline Silica. National Toxicology Program [2012]. Report on carcinogens 12th ed. U.S. Department of Health and Human Services, Public Health Service.

[22] www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.htm

exhaust is classified as a Group 1 carcinogen by the International Agency for Research into Cancer.[23]

Proppants based on ceramic polymers may also add to air pollution. According to Haliburton's patent[24] acrylic polymers, consisting of 85% of the human carcinogen, acrylonitrile are used for proppant spheres. Acrylonitrile has been detected in US air sampling of gas sites at high levels. Acrylonitrile is also a respiratory irritant, causing degeneration and inflammation of nasal epithelium. Levels of acrylonitrile in the five samples exceeded the level set by USEPA for risk of increased noncancer health effects from long term exposure by 3 to 15 times.[25]

Vulnerable Populations

There are many children living in communities in close proximity to UG activities and at risk from air pollutants.

"Children are not little adults: they have special vulnerabilities to the toxic effects of chemicals. Children's exposure to chemicals at critical stages in their physical and cognitive development may have severe long-term consequences for health. Priority concerns include exposure to air pollutants, pesticides and persistent organic pollutants (POPs), lead, mercury, arsenic, mycotoxins and hazardous chemicals in the workplace." [26]

The unique vulnerability of children to hazardous chemicals is well recognized by WHO, UNICEF and UNEP [27] and newborns can be much more vulnerable than adults to the commonly-used chemicals, eg., up to 164 times more sensitive to the organophosphate pesticides chlorpyrifos.[28] Children's bodies are still developing, their detoxification systems are immature and their protective biological barriers such as the blood-brain barrier are still developing.[29] They are also more at risk because they have higher respiration and metabolic rates than adults, they eat and drink more per bodyweight, and they live life closer to the ground, crawling, digging in dirt and putting objects in their mouths. Being unaware of chemical risks, children are less able to

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[23] http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf

[24] Halliburton Patent 7799744, Polymer-Coated-Particulates, www.docstoc.com/docs/58860687/Polymer-Coated-Particulates---Patent-7799744

[25] Citizen Investigation of Toxic Air Pollution from Natural Gas Development July 2011, Global Community Monitor, www.gcmonitor.org

[26] World Health Organisation (WHO), International Labor Office (ILO), United Nations Environment Program (UNEP) 2006. Helping to Protect Children from the Harmful Effects of Chemicals. International Program on Chemical Safety. http://www.who.int/ipcs/en/

[27] World Health Organization / Children's Environmental Health. http://www.who.int/ceh/en/
Also see IFCS Children and Chemical Safety Working Group. 2005. Chemical Safety and Children's Health: Protecting the world's children from harmful chemical exposures - a global guide to resources, October.

[28] Furlong, C. E., N. Holland, R. J. Richter, A. Bradman, A. Ho and Brenda Eskenazi. 2006. PON1 status of farmworker mothers and children as a predictor of organophosphate sensitivity. *Pharmacogenetics and Genomics* 16:183-190.

[29] Landrigan, P J et al. 1998. Children's health and the environment: A new agenda for prevention research. *Environmental Health Perspectives* 106, Supplement 3:787-794.

protect themselves from exposures and higher skin absorption rates may also result in a proportionally greater exposure.[30]

Maternal exposure to air pollutants is also very important as the placenta is not an effective barrier to chemical transfer from mother to the foetus, and toxins can be transferred through breast milk as well. The timing of chemical exposures is significant. Research has shown that babies and children experience particular “windows of susceptibility” in their development.[31] If exposures occur during critical times, it may contribute to health problems much later in life; for example, exposure to dioxin in utero can produce disabilities in neurological function and learning ability well into childhood.[32] Similarly, early exposure to other endocrine disruptors can affect an individual’s immune function or ability to reproduce. Early exposure to carcinogens can increase the risk of developing cancer later in life.[33]

Some VOCs are endocrine disrupting chemicals and can cause adverse effects at very low-concentrations, eg polycyclic aromatic hydrocarbons (PAHs). Babies with elevated PAHs in their umbilical cord blood were much more likely to eventually score highly on the anxiety/depression scale than those with low PAH levels in cord blood. [34] PAHs were detected in the air around Tara residences, where many children live, yet there has been no assessment of the impact of air pollutants on this most vulnerable population.

Conclusions

Australian guidelines and standards currently do not take into account low-level, chronic exposure associated with endocrine and epigenetic impacts. Nor do they address the impacts of exposure to real world mixtures of air pollutant. To assess the full impacts of UG development, this is essential and needs to be addressed as a priority. Comprehensive health impact assessments taking into account all exposure routes must be carried out before any approval is given for UG activities. Mandatory baseline air quality testing and on-going monitoring of both particulate matter and VOCs during UG activities is crucial. Background levels of existing methane must also be established before any UG activities are undertaken.

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[30] Lloyd-Smith, Mariann; Sheffield-Brotherton, Bro, 'Children's Environmental Health: Intergenerational Equity in Action—A Civil Society Perspective' *Annals of the New York Academy of Sciences*, Vol. 1140:1, pp. 190-200(11) 2008

[31] Olin, S. R. & B. R. Sonawane. 2003. Workshop to Develop a Framework for Assessing Risks to Children from Exposure to Environmental Agents, September 2003. *Environmental Health Perspectives* 111/12: 1524-1526

[32] Pluim, H.J., J.G. Koppe, K. Olie, J.W. van der Slikke, P.C. Slot, & C. van Boxtel. 1994. ‘Clinical laboratory manifestations of exposure to background levels of dioxins in the perinatal period. *Acta Paediatrica* 83: 583-587.; Ollsen A., J.M. Briët, J.G. Koppe, H.J Pluim, & J. Oosting. 1996. Signs of enhanced neuromotor maturation in children due to perinatal load with background levels of dioxins. *Chemosphere*: 33(7), 1317-1326.

[33] Barton, H. A., V. J. Cogliano, L. Flowers, L. Valcovic, R. W. Setzer & T. J. Woodruff. 2005. Assessing Susceptibility from Early-Life Exposure to Carcinogens. *Environ. Health Perspect. 13(9): 1125–1133*

[34] Perera, Frederica P.; Tang, Deliang; Wang, Shuang; Vishnevetsky, Julia (2012). "Prenatal Polycyclic Aromatic Hydrocarbon (PAH) Exposure and Child Behavior at age 6-7". *Environmental Health Perspectives*. doi:10.1289/ehp.1104315. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3385432

The National Environment Protection Measure (NEPM) process is woefully inadequate to address air pollution in Australia. Standards rather than guidelines need to be implemented for a full range of VOCs, criteria pollutants and particulates based on precaution rather than economic convenience. These standards must reflect world's best practice and provide maximum protection for the most vulnerable in our community.

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