MORE RECENT STUDIES CONTINUE TO DEMONSTRATE SERIOUS HARM FROM FRACKING

Overview

This handout provides the reader with highlights of some of the studies published since the Wheeler Panel considered hydraulic fracturing in Nova Scotia.

"Hydraulic fracturing is part of a larger process of extracting, processing and transporting natural gas. Taken together, it is referred to as unconventional natural gas development (UNGD). UNGD sites include well pads, where the hydraulic fracturing occurs, compressor stations, metering stations, and processing plants, all of which release emissions."[i]

The studies provide no grounds for re-opening the public debate, let alone lifting or weakening a moratorium. The evidence continues to point to significant increases in greenhouse gas emissions, air and water pollution, and adverse health effects especially in fetuses and infants.

But at the same time, there is enormous amount of missing information. Much of this attributable to a petro-chemical industrial complex that has been permitted to engage in UNGD using a multitude of chemicals for which there has never been proper analysis of potential risks; and to do so without ever having to establish baseline conditions. Even with this lack of certainty, there is abundant research indicating that fracking is not worth the risk.

There is no reasonable basis for re-visting the existing legislative moratorium on hydraulic fracturing

Very truly yours,

NOFRAC

Mark Tipperman

To better understand the concerns raised, some basic familiarity with the following contaminants is required: (i) volatile organic compounds and ozone[1]; and (ii) methane[2].

Toxins

In an exhaustive study of substances employed in UNGD activities, the authors found there were 1021 chemicals associated with hydraulic fracturing, but there were only 240 chemicals for which there were reproductive and development toxicity information. Furthermore, only 126 chemicals had reproductive toxicity information and only 192 had developmental toxicity information. Drinking water standards were found to exist for only 67 of the 240 chemicals. In the same study the researchers concluded: "a greater proportion of chemicals in wastewater were linked to reproductive and developmental toxicity compared with fracturing fluids themselves." [ii]

"[H]ydraulic fracturing contaminants…include diesel exhaust particulate and gases, volatile organic compounds and other hydrocarbons… crystalline silica, used …in kiloton quantities, and methane escaping from the borehole and piping."[iii]

Water Quality

About 50% of all fracked wells that were stimulated in 2014 were found to be located within two to three kilometers of at least one public or private water well.[iv]

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[1] A brief overview from the Netherlands Ministry of Infrastructure and Water Management: "Emissions of volatile organic compounds (VOC) must be reduced in order to control peaks in the concentration of ozone in the lower atmosphere. Ozone… results from the breakdown of hydrocarbons in the presence of sunlight and NOx…Ozone is a key component of smog. High ozone concentrations may cause damage to crops and health problems in humans, for example.

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[H] concentrations of volatile organic compounds (such as those that can occur in the workplace) may also have a direct effect on health. Prolonged exposure to high concentrations of these substances may damage the nervous system, for example, also called Organic Psycho-syndrome. Furthermore, there are also volatile organic compounds with carcinogenic or mutagenic properties." https://rwsenvironment.eu/subjects/air/volatile-organic/

[2] A brief overview from the U.S. Department of Environmental Protection: "Methane (CH4) is a hydrocarbon that is a primary component of natural gas. Methane is also a greenhouse gas (GHG), so its presence in the atmosphere affects the earth's temperature and climate system….[E]mission sources include landfills, oil and natural gas systems, agricultural activities, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial processes.

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Methane is more than 25 times as potent as carbon dioxide at trapping heat in the atmosphere [measured over a 100 year period]. Over the last two centuries, methane concentrations in the atmosphere have more than doubled, largely due to human-related activities. Because methane is both a powerful greenhouse gas and short-lived compared to carbon dioxide, achieving significant reductions would have a rapid and significant effect on atmospheric warming potential." https://www.epa.gov/gmi/importance-methane

Spills at UNGD sites are common place. Looking at the records maintained by four States in the U.S. with extensive UNGD activities, the annual rate of spills per well were 1.1% in Colorado, 3.1% in New Mexico, 12.2% in North Dakota and 4.3% in Pennsylvania. The spill rates in New Mexico and North Dakota are increasing – very significantly in North Dakota. And these annual rates do not include spill at any location other than the well site.[v]

There is also reason to be very concerned that the number of domestic wells contaminated by UNGD activity is being under-reported. According to an investigation conducted by the non-profit Public Herald, from 2004 through 2016, there were 9,442 complaints about conventional and unconventional oil and gas activities, that were. received by the Pennsylvania Department of the Environment ("PA DEP"). PA DEP considered 4,108 to be "water supply" complaints but hundreds of others were categorized as "gas migration, spill response, pollution, or leaking wells" that may also affect domestic water but the agency only reported only 284 instances of water supplies affected by unconventional gas activities. During a recent four year period when something over 10,000 unconventional wells were drilled, there were an average of three oil and gas complaints every business day. The number of complaints were found to be increasing even as drilling activities declined in Pennsylvania.[vi]

In a thorough examination of Pennsylvania births, domestic water systems and shale gas wells, the authors concluded that the results "suggests that shale gas development is systematically impacting public drinking water quality. These results are striking considering that our data are based on water sampling measurements taken after municipal treatment. Furthermore, our estimated water quality impacts are likely to be understated as they do not include sampling of chemicals that are not regulated under the Safe Drinking Water Act.[vii]

The water produced by UNGD has volatile organic compounds "which are known to induce varying levels of toxicity upon exposure. When spilled, these contaminants can migrate through the soil and contaminant groundwater**.** The researchers evaluated various spill sizes and their effect on groundwater at different depths. "The results showed that benzene and toluene were expected to reach human health relevant concentration in groundwater." [viii] Similarly, other researchers found: "the dominant source of organic compounds to shallow aquifers was consistent with surface spills of disclosed chemical additives" at UNGD wells that were the subject of safety violations.[ix]

A study of 550 water samples taken from public and private water wells that access water in aquifers above the large Barnett Shale region of Texas, were rife with many volatile organic compounds that are used in hydraulic fracturing.[x]

Contamination of groundwater from UNGD volatile organic compounds, has been demonstrated to occur from upward movement of the contaminants to the elevation of the drinking water supply.[xi] In another situation, "natural gas and other contaminants migrated laterally through kilometers of rock at shallow to intermediate depths, impacting an aquifer used as a potable water source. The incident was attributed to Marcellus Shale gas development."[xii]

Flowback and produced water (collectively referred to as "FP Water") generally have s total dissolved solids ("TDS") that constitute 5% to 25% of the mass of FP Water. TDS are mostly

sodium and chloride salts. As a result, "TDS is commonly referred to as salinity." Similarly, levels of naturally occurring radioactive materials ("NORMs") in UNGD FP Water is "expected to be 1.5 times higher than in conventional hydrocarbon waste streams" and the NORMS "become concentrated within precipitates that form during evaporation treatment and in the sludge collected by filtration, sedimentation, or separation."[xiii]

Rock from the Marcellus Shale region released radium within hours or days after exposure to the increasingly saline wastewater produced by hydraulic fracturing. The leached radium included highly radioactive radium-228. The UNGD wastewater becomes increasingly saline as it moves through the fractured rock.[xiv]

Wastewater from hydraulic fracturing in the Bakken region of North Dakota, produces wastewater with a very high saline content, toxic elements and increased levels of radioactive materials that can adversely affect water quality. "[W]ater contamination from brine spills is remarkably persistent in the environment, resulting in elevated levels of salts and trace elements that can be preserved in spill sites for at least months to years." Even worse, the spills lead to the accumulation in soils and sediment of radioactive materials that may "remain for thousands of years."[xv]

The saline content of FP water increases quickly, with most of the fluids injected into the well for drilling and fracturing remaining in the shale. This however, is no blessing as increasing levels of brine contain "naturally occurring constituents of the formation brines, among which are halides, heavy metals, metalloids, naturally occurring radioactive materials (NORM), and other contaminants such as ammonium and iodide." These substances create risks to the environment and human health.[xvi] It is at best difficult to manage FP Water containing these and introduced contaminants.

FP with increased amounts of the halides (iodide, chlorine and bromide) and ammonium can lead to the development of "toxic brominated and iodinated DBPs [disinfection byproducts] in downstream drinking water utilities."…. "[H]alting the disposal of hydraulic fracturing fluids alone will not reduce the risks associated with discharge of …[FP water] to surface waters." Treatment of FP does not remove halides or ammonium.[xvii]

Releases of treated FP waters to "surface water… by centralized waste treatment (CWT) plants pose risks to aquatic and human health." Surface water releases of FP waters 10 to 19 kilometers upstream from a reservoir in western Pennsylvania resulted in sediment contained high "concentrations of salts, alkaline earth metals, and organic chemicals" that probably were derived from the Marcellus Shale formation.[xviii] Another study also concluded that treated FP Water has been found to present serious risks. Levels of radioactive materials in sediment near the discharge from a water treatment plan in Pennsylvania, were more than two times the levels that are required to be disposed of "in a licensed radioactive disposal facility. Radium is a known human bone, liver, and breast carcinogen." Likewise, samples of sediment by a FP disposal well in West Virginia were found to contain high levels of radium, and water samples from the watershed disclosed "high levels of endocrine disrupting chemical activity…and numerous chemicals associated with hydraulic fracturing…".[xix]

In Alberta where 100's of spills of FP Water are reported each year, samples of FP Water were found to contain "a previously unidentified class of aryl phosphates, including diphenyl phosphate

(DPP), triphenyl phosphate (TPP), and others... Many of these aryl phosphates break down into DPP." DPP will move rapidly through groundwater and "may pose an environmental risk to aquatic ecosystems if released into the environment."[3] [xx]

"Gas may also contaminate aquifers by passing through leaking casings or along the well annulus, from abandoned oil and gas wells, or potentially along…faults or fractures…following hydraulic fracturing and drilling." Damaged cement around oil wells that may enable the migration of gas, was found among 30% of 15,000 wells within the first five years and among 50% of 15,000 wells within 20 years.[xxi]

Also methane released by gas well blowouts may impact domestic water supplies and may do so for an extended period of time. Blowouts occur about once for every 1,000 wells. Some of the well blowouts are enormous, such as Deepwater Horizon in the Gulf of Mexico. In some blowouts, the gas does not escape to the surface of the earth, but instead forms fractures that adversely impact groundwater by the insertion of large volumes of methane. In this study published in 2018, the researchers evaluated methane levels in 14 monitoring wells established for an enormous gas well blowout that occurred in 1965. Almost 50 years after the blowout, methane levels in 12 of the 14 wells were above the hazard level established by the U.S. Department of the Interior. The researchers concluded the continued presence of methane at those high levels, was likely the result of ongoing gas leaks from the underground gas that began with the blowout.[xxii]

Air Quality

Levels of volatile organic compounds ("VOCs") over a one year period, in a Utah basin with UNGD, were equivalent to that generated by 100 million motor passenger cars driving an average of 20,000 km a year. Looking at this data and other data gathered from the basin, the authors concluded there is strong evidence between oil and gas releases, toxins released into the air and substantial ozone in the air. The study also concluded that the levels of aromatic VOCs in the oil and gas region studied, was equal to or exceeded that found in "the most heavily polluted inner cities." The high levels of VOCs adversely affect human health because of long term presence of benzene and the generation of ozone resulting in non-attainment of air quality standards.[xxiii]

The U.S. Environmental Protection Agency (http://www.epa.gov/air-emissionsinventories/national-emissions-inventory) "attributes 64% of point source VOC emissions in Colorado to oil and gas extraction activities, and in Weld County, Colorado for 90% of the point source VOC emissions." After eliminating other potential sources of the high levels of the VOC benzene, researchers concluded the source was: "fugitive emissions or gas venting during O&NG production or distribution and emissions from condensate tanks."[xxiv]

Researchers in Maryland looked at the levels of ethane, which is a marker for methane emissions. They found levels had been reduced for about ten years, leveled off when fracking operations in Pennsylvania and West Virginia began and then began to increase. The authors concluded that the

[3] The European Chemicals Agency considers Triphenyl Phosphate to be "very toxic" to aquatic life, with potentially long-lasting effects. https://echa.europa.eu/substance-information/-/substanceinfo/100.003.739

increases in ethane was attributable to natural gas activities in the upwind States of Pennsylvania and West Virginia. The authors studied emissions in Maryland and as a control, in Georgia.[xxv]

"Nitrogen oxides (NO *X* = NO2 + NO), which is comprised of a family of highly reactive and toxic gases, is another major air pollutant that is increasing in regions of shale O&NG activity … NO pollution has both atmospheric and public health implications as these compounds have long been reported to be a major precursor of tropospheric ozone." Researchers found that levels of NO pollution have significantly increased in four major U.S. shale areas and reductions in NO pollution in another had ceased. The study concluded "[i]t is likely that the practice of gas flaring and oil operations in these regions is increasing ambient NO, although urban populations and distribution, as well as the location and fuel types of operating power plants may be contributing…"[xxvi]

Scientists ran tests to determine the extent of airborne contaminants arising from FP Water in the Permian Basin, as well as the transition of the contaminants into particulate matter ("PM"). The concentration of total volatile carbon (hydrocarbons evaporating at room temperature) averaged 29 mg of carbon per liter. Based on the mean average PM that resulted from formation observed in these tests, the researchers concluded: "the estimated formation of PM from evaporated flowback wastewater in the State of Texas is in the range of estimated PM emissions from diesel engines used in oil rigs. Evaporation of flowback wastewater, a hitherto unrecognized source of secondary pollutants, could significantly contribute to ambient PM concentrations."[xxvii]

Methane and Climate Change.

No citation is required to confirm the very grave risk to all life forms from climate change. Direct contributors to climate change are the so-called greenhouse gases. Methane is a formidable greenhouse gas and a significant constituent of natural gas.

Large amounts of natural gas including its component methane are released into the atmosphere by UNGD activities. In one study, the scientists concluded the loss into the atmosphere of natural gas produced, was between 8.4% and 15.9%.[xxviii]

Reductions in carbon dioxide emissions over a 20 year period will have little or no impact on the progression of climate change. However reductions in methane emissions will have an immediate impact. Over a 20 year period, the impact from methane is 86 times greater than the impact from an equal volume of carbon dioxide. Further, "…the total greenhouse gas footprint of shale gas is substantially greater than that of the other fossil fuels when methane emissions are included…" In a study of methane emissions, the author determined that methane constituted 28% of fossil fuel emissions in the U.S. in 1980 and 42% in 2013, with the increase resulting from the increasing use of natural gas and especially from shale gas starting in 2009."[xxix]

Other studies reached similar conclusions. "U.S. methane emissions have increased by more than 30% over the past decade, which would represent a major contribution to the global increase of methane concentrations" and led the authors to suggest that the U.S. emissions could be 30-60% of the world-wide increase in the methane in the atmosphere.[xxx]

Health.

Looking at some of the contaminants found near UNGD wells, the following observations were made: "volatile organic compounds including benzene, associated with short-term effects of headache and dizziness and long-term effects of aplastic anemia and leukemia (ATSDR [Agency for Toxic Substances and Disease Registry], 2015); toluene, associated with headaches, sleepiness, confusion, and possible permanent neurological damage (ATSDR, 2011a) ethylbenzene, associated with symptoms of eye and throat irritation and a possible carcinogen (ATSDR, 2011b) and xylene, associated with eye, nose, throat, and skin irritation and possible long-term neurologic effects (CCOHS, 2017). Other compounds with documented adverse health outcomes include particulate matter, associated with asthma attacks, acute bronchitis, and reduced lung function (OSHA, 2013), methylene chloride, associated with cancer (ATSDR, 2011c), and hydrogen sulfide, associated with eye, nose, and throat irritation and asthma (ATSDR, 2011d)…"

In the same published study, the authors focused on 74 standard health assessments generally prepared by nurse practitioners, with a physical exam conducted where warranted, and in each case reviewed by a board certified physician. 51 of the assessments were found to be prepared for individuals who lived within 1 km of unconventional natural gas wells. Only those symptoms that could not be explained by other evidence or circumstances and began or became worse after exposure to UNGD began were included in the analysis. The study found "[t]he most commonly reported symptoms in this sample of adults were sleep disruption, headache, throat irritation, stress/anxiety, cough, shortness of breath, sinus problems, fatigue, nausea, and wheezing."[xxxi]

"Exposure to aromatic VOCs has been linked to cancer, respiratory effects, and endocrine disruption… Benzene, the simplest aromatic VOC, has…[h]ealth effects associated with benzene exposure include leukemia, anemia and other blood disorders and cancers, immune system impairment, decreased respiratory function, and neural tube defects in newborn babies."[xxxii]

Other researchers followed up an earlier study they published in 2012 by re-interviewing people who had been interviewed for the authors' earlier publication. The subjects were located within two miles of oil and gas wells in five States. The results reported were: (i) for people**,** "…the most common health impacts at the time of the interviews fell under the categories of neurological, respiratory, vascular, dermatologic, and gastrointestinal problems…"; (ii) for animals people keep as companions, including dogs, cats and horses, "the most common health impacts at the time of the interviews fell under the categories of gastrointestinal, reproductive, respiratory, neurologic, and dermatologic problems, and sudden death…"; and in animals raised for food, "…the most common health impacts at the time of the interviews fell under the categories of reproductive, neurologic, gastrointestinal, decrease in milk production, respiratory, and growth problems…" The authors concluded that "health impacts dropped for families and animals moving out of intensively drilled areas or remaining in areas where drilling activity decreased. In the cases of families that remained in the same area and for which drilling activity either remained the same or increased, no change in health impacts was observed."[xxxiii]

"A rise in respiratory disease with proximity to the process has been reported in nearby communities and both silica and diesel exposures at the worksite are recognized respiratory hazards." *** "[B]ased on the traffic volume associated with each drill site and the number of drill sites in any locale, it is

possible at least to compare the effects to that of large traffic volume highways which are known to produce some respiratory effects in surrounding areas."[xxxiv]

Many chemicals employed in oil and gas activities "are associated with adverse reproductive outcomes such as miscarriage, preterm birth, and decreased fertility (2). Exposure to hydraulic fracturing fluids specifically has been shown to result in respiratory, gastrointestinal, dermatological, neurological, immunological, endocrine, reproductive, and other adverse health outcomes in humans and wildlife." The endocrine disrupting chemicals may have cumulative effects that are present even when the individual chemicals are present at levels that by themselves would have no discernible effect. The results of the authors' study of the effects of endocrine disrupting chemicals on prenatal mice led them to "suggest adverse health outcomes that may be observed in humans and animals in areas impacted by extraction operations…"[xxxv]

Many of the substances employed in UNGD including the air pollutants generated are carcinogenic and associated with leukemia and lymphoma. The scientists who conducted this study of pollutants, concluded the study supports the notion that exposure to UNGD may increase the risk of leukemia in children.[xxxvi]

A number of studies have shown the likelihood of an adverse impact on fetuses.

Reporting the results of a study of birth records in Pennsylvania, the authors noted: "…there is increasing evidence that the fetus is vulnerable to a range of maternal pollution exposures…"; (ii) the results of their research was "…evidence for impacts of hydraulic fracturing on human health, based on a large-scale analysis of vital statistics records from more than 1.1 million births in Pennsylvania" *** and "suggest[s] that the introduction of fracking reduces health among infants born to mothers living within 3 km of a well site during pregnancy. For mothers living within 1 km, we find a 25% increase in the probability of low birth weight…and significant declines in average birth weight and in an index of infant healt; and (iii) "…[s]tudies based on large administrative databases have consistently shown that low birth weight is a risk factor for numerous negative outcomes, including infant mortality, attention deficit hyperactivity disorder, asthma, lower test scores, lower schooling attainment, lower earnings, and higher rates of social welfare program participation…"[xxxvii]

The authors of a study of 9,384 mothers who delivered 10,496 babies, noted that "[UNGD]… pollutants, most consistently PM, NO [nitric oxide] , SO [sulfur oxides], and ozone, have been associated with adverse birth outcomes including low or reduced birth and preterm birth. PM and ozone are regional air pollutants, so women living long distances from unconventional natural gas development could experience effects." The researchers found that exposure to unconventional natural gas activities increase the risk of preterm birth and high risk pregnancies.[xxxviii]

"[S]hale gas development increased the incidence of low birth weight and small for gestational age in the vicinity of a shale gas well by 24 percent and 18 percent, respectively."[xxxix]

In a study of pregnancies in the Barnett Shale formation area in Texas, the researchers found an increased risk of preterm birth during the first two trimesters of pregnancy, with the connection between hydraulic fracturing and preterm birth seeming to be strongest in the case of extremely

preterm births. The authors concluded the results were additional evidence of adverse impacts to fetuses related to the mothers living near UNGD activities, with the strongest evidence of adverse effects for extremely premature births.[xl]

In a study that looked at UNGD effects in 29 Pennsylvania counties, with 5,649 UNGD wells, the scientists found: (i) "…children and adolescents exposed to newly spudded UNGD wells within their zip code have 1.25 … times the odds of experiencing an asthma-related hospitalization compared with children who did not live in these communities…"; (ii) for the children and adolescents living within a zip code with 11 or more wells, the odds of hospitalization for asthma were 1.39 as much as those living outside those zip codes; and (iii) for those children and adolescents exposed to the highest levels of VOCs in the area studied, the odds of hospitalization were 1.42 times as much as those residing in the areas with the lowest levels of VOCs.[xli]

Another Marcellus Shale formation study found UNGD activities "were statistically associated with increased risk of mild, moderate, and severe asthma" attacks, respectively requiring medication, emergency room treatment and hospitalization."[xlii]

Another published study that was not limited to a specific population or geographic area, included these findings: (i) "UOG [unconventional oil and gas] operations emit air pollutants linked to adverse respiratory effects throughout their lifecycle…"; and (ii) five of the contaminants arising from UNGD activities, namely ozone, PM, silica dust, benzene, and formaldehyde, "…are associated with increased respiratory problems in children: asthma prevalence and incidence, chronic and acute respiratory symptoms, adverse lung function and development, and airway inflammation. It is also reasonable to conclude that young children with fragile, developing respiratory systems who experience frequent exposures to these pollutants are at particularly high risk for respiratory tissue injury leading to irreversible pulmonary damage and chronic respiratory diseases."[xliii]

If the above described risks were not enough, a paper reviewing the "literature indicates that oil and gas activities produce noise at levels that may increase the risk of adverse health outcomes, including annoyance, sleep disturbance, and cardiovascular disease."[xliv]

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