To: Earthworks

Re: Petition to the United Nations to enact a global ban on fracking

Date: September 27, 2019

The Endocrine Disruption Exchange (TEDX) is a US 501(c)3 non-profit organization dedicated to compiling and disseminating scientific evidence on the health and environmental effects of exposure to chemicals that interfere with hormone (endocrine) action, otherwise known as endocrine disrupting chemicals (EDCs). A major concern with endocrine disruptors is that they are associated with adverse health effects at very low concentrations, particularly when exposure occurs prenatally or in early childhood.

In 2005 TEDX became aware of the large number of chemicals used during unconventional oil and gas operations (UOG; which includes drilling, hydraulic fracturing, and associated activities). We were concerned that these chemicals could be endocrine disruptors, and that potential exposure and hazards were not being disclosed to the public. In 2011 we published the first study identifying such chemicals, including over 100 potential EDCs, as a public health threat. We also made this research publicly available through an online database, in order to inform stakeholders, including the public, advocacy groups, and government agencies.

UOG utilizes horizontal drilling to penetrate tight geological formations (e.g. shale), and it uses hydraulic fracturing (fracking) to create openings in the rock that release the target hydrocarbons to the surface. Fracking requires millions of gallons of water and chemicals, and thousands of pounds of proppants *per well*. In addition, UOG releases tons of polluting chemicals into the air and produces millions of gallons of wastewater over the lifetime of a well.

As UOG unlocks vast shale resources in the US, it is contributing to the industrialization of rural areas as well as encroaching on urban centers. Large populations are now exposed to harmful chemicals where they live, work, and play. The proximity of oil and gas facilities, such as refineries, near minority or low-income residences is often considered an environmental justice issue. Research suggests that UOG wells are also disproportionately located in disadvantaged communities. Further, certain subpopulations are more susceptible to the health harms of UOG, including children, the elderly, and those with compromised immune function.

Before epidemiological research studies were conducted on the health effects of exposure to UOG, TEDX identified 353 chemicals used during UOG and searched the literature for known health effects of those chemicals. We found the following:

- Nearly 75% could have skin/eye/sensory organ, respiratory, and gastrointestinal effects
- Approximately 40–50% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys
- Over 30% could affect the endocrine system
- 25% could cause cancer and mutations[1]

More recently, the US Environmental Protection Agency (EPA) compiled a list of over 1000 chemicals used in fracking[2]. Elliott et al. analyzed these chemicals and found 49 of the chemicals were known, probable, or possible human carcinogens[3]. A previous Elliott et al. study identified 95 fracking chemicals potentially associated with adverse reproductive and developmental effects[4]. In addition to chemicals introduced during the processes of drilling and fracking, UOG contributes to air and water pollution by releasing chemicals into the environment from 'native' underground sources. These pollutants also have multiple negative impacts on health and the environment. Now that nearly a decade has passed since TEDX's first published study, over 200 original research papers have been published on the health effects of UOG.

Adverse Health Effects of UOG

Research on fracking and health is growing rapidly. TEDX maintains the FrackHealth Database, an online resource providing information on the peer reviewed studies of fracking and various health endpoints[5]. Figure 1 displays the number of studies published each year since 2011, including human, animal, in vitro, and health impact assessments, as well as reviews. As of August 2019, 200 studies are included in this database.

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[1] Colborn T, Kwiatkowski C, Schultz K, Bachran M. 2011. Natural gas operations from a public health perspective. Hum Ecol Risk Assess 17(5):1039-1056, doi: 10.1080/10807039.2011.605662.

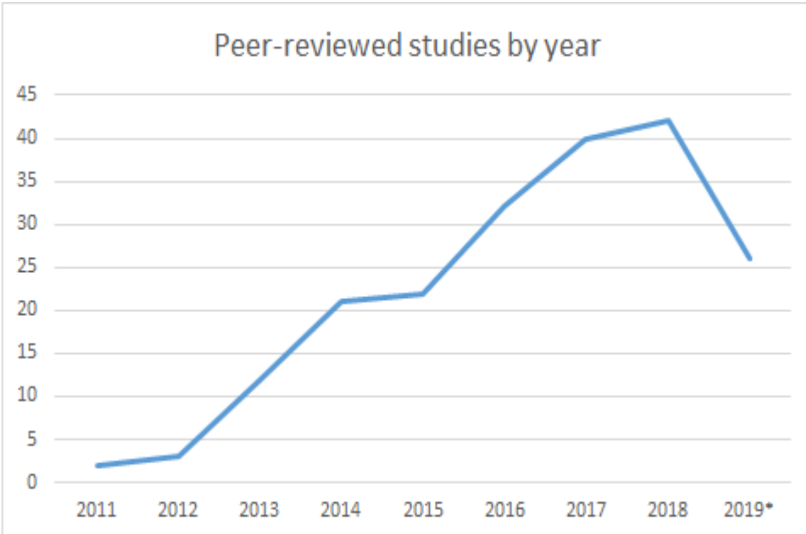
[2] US Environmental Protection Agency. 2016. Hydraulic Fracturing for Oil and Gas: Impacts from the Hydraulic Fracturing Water Cycle on Drinking Water Resources in the United States. Report #EPA-600-R-16-236Fb. Available at www.epa.gov/hfstudy.

[3] Elliott EG, Trinh P, Ma X, Leaderer BP, Ward MH, Deziel NC. 2017. Unconventional oil and gas development and risk of childhood leukemia: Assessing the evidence. Sci Total Environ 576:138-147, doi: 10.1016/j.scitotenv.2016.10.072.

[4] Elliott EG, Ettinger AS, Leaderer BP, Bracken MB, Deziel NC. 2017. A systematic evaluation of chemicals in hydraulic-fracturing fluids and wastewater for reproductive and developmental toxicity. J Expos Sci Environ Epidemiol 27(1):90-99, doi: 10.1038/jes.2015.81.

[5] FrackHealth Database. The Endocrine Disruption Exchange. Available at: https://endocrinedisruption.org/audio-and-video/fracking-related-health-research-database/search-the-database.

Figure 1. Number of UOG peer-reviewed health studies by year of publication



*Includes studies through August, 2019

Human epidemiological research

Here we summarize studies conducted with human subjects, assessing the association between UOG and adverse health effects. Various metrics have been used to define exposure to UOG, including distance from UOG operations, duration of exposure, well count, and stage of well development. Health outcomes include recorded individual level data (e.g. from birth certificates or hospitalizations) and self-reported symptoms collected from surveys and interviews. On the whole, results from epidemiological research suggest that living or spending substantial amounts of time (school, work) near UOG contributes to adverse health outcomes.

Birth Outcomes

The largest body of epidemiological research looks at potential developmental effects from prenatal exposure to oil and gas operations. There are currently 11 epidemiological studies addressing adverse birth outcomes among pregnant mothers living in close proximity (less than 1 km to 10 miles) to fracking operations. These studies have identified significant associations between well pad proximity and altered birth weight[6,7,8], small for gestational age[9,10], infant

[6] Stacy SL, Brink LL, Larkin JC, Sadovsky Y, Goldstein BD, Pitt BR, Talbott EO. 2015. Perinatal outcomes and unconventional natural gas operations in southwest Pennsylvania. PLoS ONE 10(6):e0126425, doi: 10.1371/journal.pone.0126425.

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[8] Hill EL. 2018. Shale gas development and infant health: Evidence from Pennsylvania. J Health Econ 61:134-150, doi: 10.1016/j.jhealeco.2018.07.004.

[9] Stacy et al. 2015

[10] Hill 2018

mortality[11,12], preterm birth[13,14,15,16], and birth defects[17,18,19,20]. Ten out of the 11 studies report that fracking may be associated with poor infant health.

Notably, some effects of prenatal exposure to EDCs can be immediately apparent (i.e. altered fetal growth and development), while others can influence the development of diseases and disorders later in life. For example, outcomes such as preterm birth and small for gestational age have been associated with learning disabilities, lower IQ, and behavioral problems in children as they mature. Unfortunately, such longitudinal research is rare, as it is costly and time consuming to conduct.

Hospitalizations

There are five studies suggesting an association between increased hospitalization rates and living near fracking operations. Respiratory complaints (asthma, pneumonia, general complaint) were the most common cause for hospitalization[21,22,23]. Additional research reported positive associations between well density and genitourinary hospitalizations[24,25], as well as inpatient prevalence rates for cardiovascular, neurological, and dermatological conditions, and oncology visits[26].

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[11] Busby C, Mangano JJ. 2017. There's a world going on underground —infant mortality and fracking in Pennsylvania. J Environ Prot 8(4):381-393, doi: 10.4236/jep.2017.84028.

[12] Whitworth KW, Marshall AK, Symanski E. 2017. Maternal residential proximity to unconventional gas development and perinatal outcomes among a diverse urban population in Texas. PLoS One 12(7):e0180966, doi: 10.1371/journal.pone.0180966.

[13] Casey JA, Savitz DA, Rasmussen SG, Ogburn EL, Pollak J, Mercer DG, Schwartz BS. 2015. Unconventional natural gas development and birth outcomes in Pennsylvania, USA. Epidemiology 27(2):163-172, doi: 10.1097/ede.0000000000000387.

[14] Whitworth et al. 2017

[15] Hill 2018

[16] Whitworth K, Marshall A, Symanski E. 2018. Drilling and production activity related to unconventional gas development and severity of preterm birth. Environ Health Perspect 126(3):037006, doi: 10.1289/EHP2622.

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[20] McKenzie LM, Allshouse W, Daniels S. 2019. Congenital heart defects and intensity of oil and gas well site activities in early pregnancy. Environ Int:104949, doi: 10.1016/j.envint.2019.104949.

[21] Peng L, Meyerhoefer C, Chou SY. 2018. The health implications of unconventional natural gas development in Pennsylvania. Health Econ doi: 10.1002/hec.3649.

[22] Rasmussen SG, Ogburn EL, McCormack M, Casey JA, Bandeen-Roche K, Mercer DG, Schwartz BS. 2016. Association between unconventional natural gas development in the Marcellus Shale and asthma exacerbations. JAMA Intern Med 176(9):1334-1343, doi: 10.1001/jamainternmed.2016.2436.

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[25] Jemielita T, Gerton GL, Neidell M, Chillrud S, Yan B, Stute M, Howarth M, Saberi P, Fausti N, Penning TM, et al. 2015. Unconventional gas and oil drilling is associated with increased hospital utilization rates. PloS One 10(7):e0131093, doi: 10.1371/journal.pone.0131093.

[26] Jemielita et al. 2015

Cancer

There are few studies evaluating cancer as a health effect of UOG, perhaps due to the longer latency period between exposure to environmental chemicals and diagnosis. Increased incidence of urinary bladder cancer has been reported in Pennsylvania counties with UOG compared to those with no activity[27]. McKenzie et al. concluded that Colorado children with acute lymphocytic leukemia were more likely to live near oil and gas wells[28]. However, no increases in childhood cancer were found in Pennsylvania counties with UOG[29].

Determining risk from exposure to known or suspected carcinogens has been used to understand the potential of UOG chemicals to cause cancer. For example, benzene, a recognized carcinogen, is one of the most frequently detected chemicals in air near UOG sites[30]. A health risk assessment using air data collected near UOG operations found elevated cancer risk with increasing proximity to UOG, due almost exclusively to benzene concentrations[31]. In addition to air pollution, exposure to carcinogens in fracking fluids and wastewater may increase cancer risk[32].

Respiratory system

Impacted respiratory function can occur immediately with acute exposure to UOG activity. Residents exposed to high levels of UOG activity, as determined by well data, had increased odds of asthma exacerbations[33]. A related study by Koehler et al. looked at additional activity metrics (compressor stations, impoundments, flaring events) and confirmed an association with

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[27] Finkel ML. 2016. Shale gas development and cancer incidence in southwest Pennsylvania. Public Health 141:198-206, doi: 10.1016/j.puhe.2016.09.008.

[28] McKenzie LM, Allshouse WB, Byers TE, Bedrick EJ, Serdar B, Adgate JL. 2017. Childhood hematologic cancer and residential proximity to oil and gas development. PLoS ONE 12(2):e0170423, doi: 10.1371/journal.pone.0170423.

[29] Fryzek J, Pastula S, Jiang X, Garabrant DH. 2013. Childhood cancer incidence in Pennsylvania counties in relation to living in counties with hydraulic fracturing sites. J Occup Environ Med 55(7):796-801, doi: 10.1097/JOM.0b013e318289ee02.

[30] Bolden AL, Schultz K, Pelch KE, Kwiatkowski CF. 2018. Exploring the endocrine activity of air pollutants associated with unconventional oil and gas extraction. Environ Health 17(1):26, doi: 10.1186/s12940-018-0368-z.

[31] McKenzie LM, Blair BD, Hughes J, Allshouse WB, Blake N, Helmig D, Milmoe P, Halliday H, Blake DR, Adgate JL. 2018. Ambient non-methane hydrocarbon levels along Colorado's northern Front Range: Acute and chronic health risks. Environ Sci Technol 52(8):4514-4525, doi: 10.1021/acs.est.7b05983.

[32] Xu X, Zhang X, Carrillo G, Zhong Y, Kan H, Zhang B. 2019. A systematic assessment of carcinogenicity of chemicals in hydraulic-fracturing fluids and flowback water. Environ Pollut 251:128-136, doi: 10.1016/j.envpol.2019.04.016.

[33] Rasmussen et al. 2016

asthma exacerbations[34]. Respiratory symptoms reported by residents living near UOG include coughing, wheezing, shortness of breath, and increased prevalence of asthma[35,36,37,38].

Other health effects

A study of cardiovascular health in adults found an association between increased UOG activity and several indicators of cardiovascular health (augmentation index, blood pressure, inflammatory markers)[39]. Self-reported cardiac conditions from residents in the Marcellus Shale include irregular heartbeat, high blood pressure, and heart palpitations[40,41,42,43]. Studies of self-reported conditions in residents living in close proximity to UOG include a variety of other symptoms as well. Examples include neurological symptoms (headaches, dizziness, and seizures), dermatological conditions (rashes, burning or itchy skin, and dermatitis) and other symptoms (nosebleeds, nausea, eye irritation, muscle aches, and fatigue)[44,45,46,47,48,49,50,51,52].

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[34] Koehler K, Ellis JH, Casey J, Manthos D, Bandeen-Roche K, Platt R, Schwartz B. 2018. Exposure assessment using secondary data sources in unconventional natural gas development and health studies. Environ Sci Technol 52(10):6061-6069, doi: 10.1021/acs.est.8b00507.

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[41] Saberi et al. 2014

[42] Rabinowitz et al. 2015

[43] Weinberger et al. 2017

[44] Tustin AW, Hirsch A, Rasmussen S, Casey J, Bandeen-Roche K, Schwartz B. 2016. Associations between unconventional natural gas development and nasal and sinus, migraine headache, and fatigue symptoms in Pennsylvania. Environ Health Perspect 125:189-197, doi: 10.1289/EHP281.

[45] Saberi P, Propert K, Powers M, Emmett E, Green-McKenzie J. 2014. Field survey of health perception and complaints of Pennsylvania residents in the Marcellus Shale region. Int J Environ Res Public Health 11(6):6517-6527, doi: 10.3390/ijerph110606517.

[46] Steinzor N, Subra W, Sumi L. 2013. Investigating links between shale gas development and health impacts through a community survey project in Pennsylvania. New Solut 23(1):55-83, doi: 10.2190/NS.23.1.e.

[47] Elliott et al. 2018

[48] Rabinowitz et al. 2015

[49] Denham et al. 2019

[50] Jemielita et al. 2015

[51] Ferrar et al. 2013

[52] Weinberger et al. 2017

Indirect health impacts

Generally, the exposure metrics used above favor air pollutants as a key contributor to impaired health. There are also non-chemical stressors, including noise pollution, traffic, and other community stressors, that could be impacting health on their own or in combination with chemical exposure. Also, risks from fires or explosions on well pads pose a safety issue that is not well studied[53,54].

Noise

There is a growing body of evidence that UOG activities produce noise at high enough levels that it may be harmful to health. Research from the Colorado School of Public Health documented noise levels at a residential UOG site where mitigation noise measures were in place. They found both daytime and nighttime levels exceeding 50 dBA, a threshold above which adverse health effects may be seen[55]. Additional research measured noise levels during different phases of development (drilling, fracking, flowback, production) and found exceedances during all four phases[56]. Environmental noise exposure has been associated with annoyance, sleep disturbance, and cardiovascular disease[57].

Traffic

Increased volume of traffic at oil and gas locations is a big concern for nearby communities. The risk of injury rises with increased trucking activity, especially during pad development, although additional traffic will continue for the life of the pad. Data shows that Colorado counties with increased oil and gas operations have more trucking accidents per capita than those with less activity, with higher populations and well density impacting injury numbers[58]. Similarly, heavily drilled counties in Pennsylvania had higher rates of motor vehicle accidents when compared to control group counties[59].

Socio-environmental stress

Many social stressors are brought on by the underlying uncertainty surrounding oil and gas development, especially in areas with no previously existing extraction activities. Concern over quality of life, health effects, environmental contamination, and property values begin when drilling is proposed, and conflicting information around these impacts can lead to stress and

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[53] Blair BD, McKenzie LM, Allshouse WB, Adgate JL. 2017. Is reporting "significant damage" transparent? Assessing fire and explosion risk at oil and gas operations in the United States. Energy Res Soc Sci 29:36-43, doi: 10.1016/j.erss.2017.04.014.

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[59] Graham J, Irving J, Tang X, Sellers S, Crisp J, Horwitz D, Muehlenbachs L, Krupnick A, Carey D. 2015. Increased traffic accident rates associated with shale gas drilling in Pennsylvania. Accid Anal Prev 74:203-209, doi: 10.1016/j.aap.2014.11.003.

community tension[60,61]. Landowners and community members have reported anxiety, depression, and feelings of isolation and powerlessness[62,63]. Also, studies suggest changes in behavior including increased alcohol use[64] and reported cases of sexually transmitted diseases[65,66].

Laboratory research

Laboratory research is a critical component of the total body of evidence available to answer the question of whether UOG affects human health. It is used precisely because it helps scientists predict human outcomes in the natural environment and can lend support to findings from epidemiological studies. In particular, it can address the limitations of such research with regard to exposure timing (i.e. during prenatal development), dose, and control of covariates.

In laboratory experiments using rodent models, exposure to UOG chemicals resulted in numerous adverse impacts. Specifically, male rodents exposed prenatally to a mixture of chemicals used during hydraulic fracturing were shown to have increased testosterone, decreased sperm counts, and heavier testes and thymus[67]. Effects in female rodents included hormone suppression, changes in uterine, ovary, heart, and body weights, and disrupted folliculogenesis[68]. Additionally, recent research found altered mammary gland development[69], impaired immune system development and function[70], and altered adult energy expenditure in

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[60] Hirsch JK, Bryant Smalley K, Selby-Nelson EM, Hamel-Lambert JM, Rosmann MR, Barnes TA, Abrahamson D, Meit SS, GreyWolf I, Beckmann S, et al. 2017. Psychosocial impact of fracking: a review of the literature on the mental health consequences of hydraulic fracturing. Int J Ment Health Ad 16(1):1-15, doi: 10.1007/s11469-017-9792-5.

[61] Fisher MP, Mayer A, Vollet K, Hill EL, Haynes EN. 2018. Psychosocial implications of unconventional natural gas development: Quality of life in Ohio's Guernsey and Noble Counties. J Environ Psychol 55:90-98, doi: 10.1016/j.jenvp.2017.12.008.

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[70] Boulé LA, Chapman TJ, Hillman SE, Kassotis CD, O'Dell C, Robert J, Georas SN, Nagel SC, Lawrence BP. 2018. Developmental exposure to a mixture of 23 chemicals associated with unconventional oil and gas operations alters the immune system of mice. Toxicol Sci 163(2):639-654, doi: 10.1093/toxsci/kfy066.

light and dark cycles[71,72] in prenatally exposed female mice. Notably, many of the effects are related to the endocrine system and occurred at low exposure concentrations. Such effects can have widespread and long lasting implications for overall health.

Environmental Pollution

The population exposed to environmental pollution associated with UOG is not limited to the frontline communities living near UOG sites. Air and water pollution can occur throughout the UOG extraction and supply chain, with local, regional, and even global impacts.

Air pollution

Numerous studies attest to the fact that UOG creates air pollution. A recent study identified 61 Hazardous Air Pollutants (HAPs) associated with upstream oil and gas operations (drilling, fracking, production)[73]. The US EPA defines HAPs as chemicals known or suspected to cause cancer or other serious health effects. Emissions data from compressor stations located along natural gas pipelines in New York detected 39 chemicals known to be human carcinogens[74]. In addition to HAPs, many endocrine disrupting chemicals have been detected near upstream operations. A review of 48 peer-reviewed studies reported over 200 chemicals in the air, including alkanes, alkenes, alkynes, aromatics, aldehydes, and polycyclic aromatic hydrocarbons (PAHs)[75]. Thirty-four of these chemicals are EDCs, shown to impact hormone function or hormone mediated outcomes.

Pre-drilling activities rely on trucks and heavy machinery to build out the roads and well pads. Associated air pollution during this stage includes diesel exhaust, nitrogen oxides (NOx), and particulate matter[76]. Also, thousands of diesel truck trips are required to deliver the chemicals and water used during drilling and fracking, exposing individuals living along these routes to pollutants. Diesel exhaust emits toxic chemicals including benzene, toluene, ethylbenzene, and xylene (BTEX) and is a major contributor to particulate pollution, associated with cardiovascular

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[71] Balise VD, Cornelius-Green JN, Parmenter B, Baxter S, Kassotis CD, Rector RS, Thyfault JP, Paterlini S, Palanza P, Ruiz D, et al. 2019. Developmental exposure to a mixture of unconventional oil and gas chemicals increased risk-taking behavior, activity and energy expenditure in aged female mice after a metabolic challenge. Front Endocrinol 10(460), doi: 10.3389/fendo.2019.00460.

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disease and respiratory conditions such as shortness of breath, pulmonary inflammation, and aggravation of asthma symptoms[77,78].

Ozone

Many air pollutants associated with UOG are ozone precursors, volatile organic compounds (VOCs) that mix with NOx in sunlight to form ozone. UOG emits both VOCs and NOx. Once emitted, these compounds can travel downwind, contributing to ozone formation in cities near shale plays. In the US, this has led to both urban and rural areas being out of compliance with current US standards[79,80]. A report by the Clean Air Task Force quantified the health impacts from ozone produced by the US oil and gas sector. They attributed 750,000 summertime asthma attacks in children and 500,000 missed school days per year to ozone resulting from oil and gas pollution[81].

Even relatively low levels of ozone can cause health effects in humans. In the short term, ozone can cause difficulty breathing, coughing and sore throat. It can also make the lungs more susceptible to infection and can continue to damage the lungs even when the symptoms have disappeared. In the long term, ozone can inflame and damage the airways, aggravating lung diseases including asthma, emphysema, and chronic bronchitis[82]. Children are particularly vulnerable because their lungs are still developing until about age 18, and they don't process chemicals as efficiently as adults because their immune and metabolic systems are not fully developed. As their lungs grow in the presence of ozone, children may suffer from decreased lung function and immune response making them more susceptible to lung infections[83]. Women exposed to higher ozone during pregnancy have been shown to deliver preterm, low birth weight babies with decreased lung function[84].

Climate change

UOG associated air pollution contributes greenhouse gases, especially methane and carbon dioxide, that are key drivers of climate change. Methane is the largest contributor to the UOG greenhouse gas footprint. Methane has a greater global warming potential over time than carbon dioxide, and new research shows a correlation between increasing atmospheric levels of

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methane and US shale gas development[85]. Methane escapes directly from UOG through venting as well as indirectly through fugitive emissions at wellheads, storage tanks, compressors, pipelines, and storage facilities[86]. Data gaps make estimating methane emissions difficult, with conflicting research reporting leak rates ranging from 3-12% of total production[87]. While tighter regulations forcing technological improvement could result in decreased methane emissions, these reductions may be offset by the sharp increases in new wells drilled using higher intensity UOG methods. As the scale of oil and gas extraction increases, the impacts on climate change will follow suit.

Further, the natural gas industry is one of the top emitters of carbon dioxide in the US[88]. These emissions begin with transportation and extend through processing, refining, and burning fossil fuels for electricity and heat. Transportation is an anthropogenic source of carbon dioxide in the atmosphere, and thousands of truck trips are needed to haul water, proppant, and chemicals for fracking and remove the produced water that will surface for the life of the well. Also, heavy equipment is used to establish roads and the well pad, and large generators and compressors are needed during drilling and fracking. A large contributor to UOG carbon dioxide emissions is flaring at the wellhead, a common practice in locations lacking adequate pipeline capacity such as the Permian Basin in Texas and New Mexico[89].

Water pollution

UOG operations can contaminate ground and surface water through multiple pathways such as faulty well casings, spills, and leaks[90,91]. Spills and leaks of fracking chemicals and produced water occur on pads, and also during transport of fluids to and from the well site. Contaminants have been detected in private water wells in close proximity to UOG operations in Pennsylvania

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and Texas[92,93,94]. Spill data from over 30,000 wells across four states reported hydrocarbon spills at 2-16% of wells each year, most within the first few years when production volumes are highest[95]. Due to differences in reporting, this is likely an underestimation of the spill rate.

Wastewater

It is estimated that over 900 billion gallons of wastewater are generated each year from oil and gas production in the US[96]. This includes the initial flowback of the fracking fluid as well as the produced water that surfaces for the life of the well. Current management and disposal practices include deep well injection, storage in impoundments, recycling for reuse in UOG, and treatment in industrial or municipal facilities[97]. There is limited reuse of wastewater outside of oil and gas production (beneficial reuse), but interest is mounting. Wastewater has been used in some areas for crop irrigation, livestock watering, and road spreading for dust suppression or deicing[98,99].

There is limited knowledge on the chemicals found in wastewater and their potential toxicity. A review of original studies characterizing oil and gas wastewater identified over 1000 chemicals, but this is likely an underestimate due to a lack of established analytical methods[100]. In vitro

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100 Danforth et al. in press

testing on wastewater samples from wells and disposal sites have found hormone disruption, other endocrine related effects, and mutagenicity[101,102,103,104,105,106].

The majority of the identified chemicals have no toxicological hazard data, so risk estimates from human exposure to wastewater may be based on only a few well-studied chemicals. For example, naturally occurring radioactive materials (NORM) are a known component in wastewater, including the carcinogen radium. Radium leaches out of wastewater and has been detected in sediment downstream from spill sites and water treatment plants[107,108]. Long-term exposure to radium, as well as exposure to other chemicals of concern in UOG wastewater including benzene, PAHs, and heavy metals, can increase excess lifetime cancer risk[109]. Based on this limited knowledge, caution should be used in exploring options to re-use UOG wastewater, particularly in light of the many more millions of people who will then be at risk.

Conclusions

It is clear that the scientific evidence on adverse health effects from UOG is increasing steadily, with little evidence to the contrary. Cancer, hormone disruption, respiratory problems, and more, are all risks faced by millions of people worldwide as a result of exposure to UOG. Of particular concern are threats to vulnerable populations such as children born or living near UOG. A recent study demonstrated that in the US alone, 17.6 million people live within 1,600m (~1 mi) of at least one active oil and/or gas well[110].

As if this weren't enough, the scale of UOG operations is growing, posing threats to even more people. As the industry has evolved, the number of wells per unit area has increased, with up to 50 horizontal wellbores that can now extend 2 miles in any direction. These large capacity well

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109 Elliott et al. 2017

110 Czolowski E, Santoro R, Srebotnjak T, Shonkoff S. 2017. Toward consistent methodology to quantify populations in proximity to oil and gas development: a national spatial analysis and review. Environ Health Perspect 125(8):086004, doi: 10.1289/EHP1535.

pads require more chemicals, water, sand, and truck trips, and produce more waste. Compared to conventional wells, this can be as much as 50 times more water and associated fracking chemicals - up to 20 million gallons per well. Thousands of tons of sand must be mined and transported to the pad, and millions of gallons of hazardous wastewater must be transported off the pad, stored, and disposed. Industrial activity on the well pad now lasts for months or years, leading to increased air pollution from diesel and truck engines. Larger scale operations mean higher risk of spills, water contamination, air pollution, truck hazards, etc.

Amplifying this risk is the fact that in many areas, UOG is now being conducted in close proximity to large populations, bringing it closer to more people in their homes, schools, hospitals, and businesses. Efforts to find uses for UOG wastewater, such as dust suppression or deicing of roads, similarly threatens to expose a greater number of people to the hazards of UOG. As these industrial sites expand, they also pose threats from large scale weather events caused by climate change. Damage to UOG facilities, storage tanks, and other equipment can spread industrial toxic waste throughout communities trying to recover from natural disasters.

The pace of science simply cannot keep up with the pace of UOG expansion. Thus, we have all become subjects in a worldwide experiment to see what happens *after* exposure to UOG. Yet we did not consent to participate in this experiment, and we cannot opt out. Neither can future generations who have no voice in their fate. We who can speak for ourselves have a right to stop this experiment before there are no unexposed control subjects. In all our decisions, we must put human and ecological health above the economic benefits of UOG, and our full effort into the safer energy sources that already exist today.