Summary Report

Human Health Risks and Exposure Pathways of Proposed Horizontal Hydrofracking in New York State

As presented in a meeting with officials from the New York State Department of Environmental Conservation and the New York State Department of Health Albany, N.Y. - October 9, 2012

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This document is not intended to be, and should not be construed as, a comprehensive review of all possible public health consequences of gas drilling and fracking operations in New York State, nor are the accompanying citations exhaustive of the available scientific literature.

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1. Horizontal hydrofracking in New York's Marcellus Shale will bring to the surface significant amounts of radioactive wastewater (in the form of both flowback fluid and production brine that flows out of wells during gas production). Levels of Naturally Occurring Radioactive Material ("NORM") are generally higher in the Marcellus Shale than in other shale formations where hydrofracking has been conducted.[1] The extended length of horizontal wells through the Marcellus Shale increases exposure to NORM and consequently increases radiation levels of resulting wastewater.[2] Levels of total radium in the wastewater from eleven existing vertical gas wells in New York averaged 8,433 pCi/l.[3] This figure exceeds by more than 1,000-fold the EPA's maximum contaminant level for drinking water (5 pCi/l for combined R-226 and R-228).[4] Federal law requires only infrequent testing for radioactivity in public drinking water systems. If radioactive pollutants were to contaminate public water supplies, discovery of the problem prior to widespread human consumption is unlikely.[5] Exposure to radium can result in anemia, cataracts, cancer (especially bone cancer), and death.[6]

Pathway: direct exposure of workers handling contaminated equipment and water
Pathway: spills or leaks >public or private water supplies > human ingestion
Pathway: spills or leaks > streams or ponds > livestock > human ingestion
Pathway: spills or leaks > streams or ponds > agricultural use > human ingestion

2. Processing radioactive, chemical-laden wastewater through water treatment plants will increase contaminant loads of downstream surface waters. Publicly owned treatment works (POTWs) typically discharge effluent into nearby rivers, lakes, or bays.[7] Assuming the challenges of reducing radiation and

[1] Rowan, E.L., Engle, M.A., Kirby, C.S., and Kraemer, T.F., 2011, Radium content of oil- and gas-field produced waters in the northern Appalachian Basin (USA)—Summary and discussion of data: U.S. Geological Survey Scientific Investigations Report 2011–5135
[2] Personal communication with Elisabeth Rowan, author of the USGS study.
[3] Rowan, E.L., Engle, M.A., Kirby, C.S., and Kraemer, T.F., 2011, Radium content of oil- and gas-field produced waters in the northern Appalachian Basin (USA)—Summary and discussion of data: U.S. Geological Survey Scientific Investigations Report 2011–5135, p. 27
[4] http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/basicinformation.cfm
[5] Environmental Working Group and Physicians, Scientists and Engineers for Healthy Energy, "Ten Problems with New York's Shale Gas Drilling Plan," 13 June 2010
[6] http://www.atsdr.cdc.gov/toxprofiles/tb144.pdf
[7] http://www.epa.gov/npdes/pubs/pretreatment_program_intro_2011.pdf

chemical contaminants to acceptable levels can be overcome, the resulting discharge of large amounts of effluent barely meeting attainment standards will increase ambient contaminant levels, affecting aquatic life and eventually the food chain. EPA has announced plans to issue standards for wastewater from hydrofracking in 2014.[8] High bromide levels in fracking wastewater are especially problematic since they can react during water treatment to form brominated trihalomethanes, which are definitively linked to bladder and colon cancers and suspected to play a role in birth defects.[9]

Pathway: discharge > marine animals > food chain > human ingestion
Pathway: discharge > chlorination > downstream use for drinking water > human ingestion of carcinogenic disinfection byproducts

3. Radioactive sludge from drilling sites or POTWs will contaminate landfills. New York State permits disposal of radioactive drill cuttings and mud ("sludge") in solid waste landfills.[10] Disposal of the radioactive sludge will result in contamination of the disposal site for thousands of years (the half-life of radium-226 is 1600 years).[11] All landfill membranes fail over time,[12] and leaching or flooding can result in contamination of nearby ponds, streams, or groundwater.[13] Radium-226 emits gamma radiation, which can travel long distances through air, thus raising risks for cancer in surrounding communities. [14]

Pathway: landfill > leakage or runoff > streams or ponds > livestock > human ingestion
Pathway: landfill > leakage or runoff > streams or ponds > agriculture > human ingestion
Pathway: landfill > leakage > drinking water contamination > human ingestion
Pathway: landfill > radium exposure > air > human inhalation

4. Vehicles transporting radioactive chemical-laden waste (liquid or solid) increase the risk of human exposure and/or contamination of the environment in the event of accidents. Trucks carrying wastewater to processing plants or recycling facilities, or carrying sludge to landfills pose a potential threat in the event of accidents. Unlike within the nuclear energy industry, the gas industry is exempt from tracking vehicles carrying radioactive waste. Vehicles carry no warning signs or instructions in the event of emergencies. Police and emergency

[8] http://www.epa.gov/hydraulicfracture/#wastewater
[9] Boorman GA, Drinking water disinfection byproducts: review and approach to toxicity evaluation, Environmental Health Perspectives 1999 Feb;107 Suppl 1:207-17.
[10] NYS DEC Revised Draft SGEIS 2011, Page 5-129
[11] http://www.epa.gov/radiation/radionuclides/radium.html
[12] US EPA Solid Waste Disposal Criteria, August 30, 1988
[13] http://www.epa.gov/osw/nonhaz/municipal/landfill.htm
[14] http://www.atsdr.cdc.gov/toxprofiles/tb144.pdf

responders will not be aware of contents, increasing the chances of inadvertent exposures.

Pathway: direct exposure of drivers, passengers and emergency workers
Pathway: runoff into ponds or streams > livestock > human ingestion
Pathway: runoff into ponds or streams > agricultural use > human ingestion
Pathway: runoff into surface drinking water supplies > human ingestion

5. Spreading radioactive, chemical-laden wastewater on roads will expose drivers, passengers and pedestrians, and contaminate nearby surface water, land and agricultural fields. The most common use of radioactive wastewater from gas drilling is road spreading.[15] Radioactive particles may become airborne as trucks and passenger vehicles travel along roads, contaminating nearby fields, homes, schools and playgrounds. Rain or snowmelt can carry radiation off road surfaces where it can migrate into groundwater, or into nearby streams or ponds used for irrigation or as a water source for livestock.[16]

Pathway: discharge > migration into groundwater > human ingestion
Pathway: discharge > runoff into ponds or streams > livestock > human ingestion
Pathway: discharge > evaporation > airborne particles > human inhalation
Pathway: discharge > evaporation > airborne particles > ponds or streams > agricultural use > human ingestion
Pathway: discharge > evaporation > airborne particles > agricultural land > crops > human ingestion

6. Storage of radioactive, chemical-laden wastewater in closed containment tanks can result in groundwater and surface water contamination. Closed containment tanks sometimes used for storage of wastewater can corrode over time, resulting in leaks, and may overflow or rupture if they exceed capacity.[17] Leachate from landfills is a frequent cause of groundwater contamination.

Pathway: leakage or spill > migration into groundwater > human ingestion
Pathway: leakage or spill > runoff into ponds or streams > livestock > human ingestion
Pathway: leakage or spill > runoff into ponds or streams > agricultural use > human ingestion

[15] NYS DEC "An investigation of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Wells in New York State," P. 32.
[16] "Hazardous Waste from Horizontal Hydrofracking," Report of E. Ivan White to DOH and DEC, October 2012
[17] http://www.epa.gov/oust/fsprevnt.htm

7. Natural gas from Marcellus shale contains high levels of radon. The uranium- and thorium-containing shale formations from which natural gas is extracted continuously emit radon. This radon mixes with and stays in the gas as it is transported, via pipeline, from wellheads to homes. Whenever natural gas is burned, radon and its decay products are released into indoor air and can be inhaled.[18] According to the US Geological Survey, radon-222 levels in gas samples from the Marcellus region in Pennsylvania ranged from 1 to 79 pCi/L with a median of 32 pCi/L.[19] This figure is eight-fold higher than the EPA threshold for remediation of radon in indoor air (4 pCi/L).[20] Radon exposure is the second-leading cause of lung cancer in the United States and the leading cause of lung cancer among non-smokers.[21] Moreover, the breakdown products of radon include lead, which can settle onto interior surfaces. Lead is a neurological poison with no safe threshold level of exposure. Low levels of lead exposure are associated with cognitive deficits in children and increased blood pressure in adults. Lead is a probable human carcinogen.[22]

Pathway: radon exposure of workers at drill sites
Pathway: consumer use > human inhalation
Pathway: consumer use > breakdown products > lead exposure in homes > human ingestion (hand-to-mouth behavior of children)

8. Use of silica in hydrofracking operations exposes workers—and, possibly, proximate neighbors—to respirable crystalline silica. Hydraulic fracturing sand is 99% silica.[23] Breathing silica can cause silicosis, a progressive, incurable lung disease that reduces the lungs' ability to take in oxygen and which contributes to disability and risk of premature death.[24] Silica dust is also a known cause of lung cancer and a suspected contributor to autoimmune diseases, chronic obstructive pulmonary disease and chronic kidney disease.[25] The National Institute for Occupational Safety and Health has found that worker exposure to crystalline silica during fracking operations cannot be adequately mitigated with personal respiratory protection.[26]

Pathway: handling silica > direct worker exposure
Pathway: dust from handling silica > airborne particles > air currents > human inhalation among residents living near fracking operations

[18] U.S. Centers for Disease Control, Agency for Toxic Substances & Disease Registry, Case Studies in Environmental Medicine, Radon Toxicity, June 1, 2012.
[19] Rowan, E.L., and Kraemer, T.F., 2012, Radon-222 Content of natural gas samples from Upper and Middle Devonian sandstone and shale reservoirs in Pennsylvania: Preliminary data: U.S. Geological Survey Open-File Report 2012–1159, P. 6
[20] Ibid, P. 4
[21] http://www.epa.gov/radon/healthrisks.html
[22] http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf
[23] NIOSH [1986] Occupational respiratory diseases. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-102
[24] http://www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.html
[25] 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.
[26] E. Esswein et al., Worker exposure to crystalline silica during hydraulic fracturing, NIOSH, May 23, 2012,

9. On-site diesel-powered machinery (trucks, compressors, pumps, generators) contaminates proximate air and contributes to the formation of ground-level ozone (smog) that contaminates regional air. Diesel exhaust is composed of vapors, gases, and fine particles emitted by diesel-fueled compression-ignition engines.[27] Exhaust from large numbers of trucks and on-site machinery at fracking sites contributes to the increased production of ground-level ozone. Exposure to diesel exhaust and smog is a known cause of asthma in children and lung cancer in adults. In addition, these air pollutants are linked to bladder and breast cancers, stroke, heart attack, cognitive decline and premature death. In pregnant women so exposed, these air pollutants are linked to preterm birth and lowered birth weight.[28]

Pathway: direct worker exposure
Pathway: airborne particles > humans in proximity to drilling operations
Pathway: airborne particles > prevailing winds > additional humans

10. Flaring operations contaminate air with hazardous air pollutants. Flaring (the practice of burning off the initial flow of natural gas from a new well) releases hydrogen sulfide, methane and BETEX chemicals (benzene, toluene, ethylbenzene, and xylene) into the air.[29] Because many of these compounds are known to cause cancer and other serious health problems, the EPA has banned flaring, but the new rule will not go into effect until 2015.[30] The process also releases radon, a known cause of lung cancer.[31]

Pathway: direct worker exposure
Pathway: airborne particles > humans in proximity to drilling operations
Pathway: airborne particles > prevailing winds > additional humans

11. Diesel transport vehicles contaminate air in rural communities. An average gas well, with multistage fracturing, can require 320 to 1,365 truck loads to transport the water, chemicals, sand, and other equipment—including heavy machinery such as bulldozers and graders—needed for drilling and fracturing. This increased traffic creates a risk to air quality as engine exhaust that contains air pollutants such as nitrogen oxides and particulate matter are released into the atmosphere.[32] In many areas of New York where drilling is proposed, homes and

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[27] Pandva RJ, Solomon G, Kinner A, Balmes JR, Diesel exhaust and asthma: hypotheses and molecular mechanisms of action, Environmental Health Perspectives, 2002 Feb: 110 Suppl 1:103-12
[28] American Lung Association, "Health Effects of Ozone and Particle Pollution," *State of the Air, 2011;* M.C. Power et al., "Traffic-related Air Pollution and Cognitive Function in a Cohort of Older Men," *Environmental Health Perspectives* 119 (2011): 682-87; U.S. Centers for Disease Control, *Summary Health Statistics for U.S. Children: National Health Interview Survey*, 2006 and "Premature Birth," 2010.
[29] http://www.hsph.harvard.edu/research/niehs/files/penning_marcellusshale.pdf
[30] http://www.epa.gov/airquality/oilandgas/pdfs/20120417presentation.pdf
[31] http://www.atsdr.cdc.gov/toxprofiles/tp145.pdf
[32] OIL AND GAS: Information on Shale Resources, Development, and Environmental and Public Health Risks, Report to

businesses are located close to roadways, increasing potential exposures for inhabitants.

Pathway: diesel exhaust > air particles > human inhalation

12. Mixtures of hydrofracking chemicals, interaction of chemicals with NORM and reaction of chemicals with natural materials under heat and pressure may cause unknown synergistic reactions resulting in altered chemical compounds. The ability of synthetic chemicals to spontaneously form new compounds when exposed to sunlight, water, air, radioactive elements or other natural chemical catalysts was first identified in 1943 by engineers at the Rocky Mountain Arsenal near Denver, CO, when 2-4,D - type compounds were discovered in the arsenal's holding ponds.[33] Synergistic catalysis is a new field of chemical study involving the simultaneous action of two chemical catalysts to create a new chemical bond.[34] Potential health risks of resulting chemicals are unknown.

13. Well casing/cement failures will contaminate drinking water supplies. All well casings/cement systems (structures for isolating wells from adjacent areas) will fail over time. Such failures provide migration routes for fracking fluids, methane, and other hydrocrabons, and return fluids.[35] Thousands of previously-drilled oil or gas wells (abandoned, plugged, or operating) penetrate the Marcellus shale in target regions.[36] If gas wells establish connections with natural fractures, faults, or improperly plugged, dry or abandoned wells, a pathway for gas or contaminants to migrate underground would likely be created, posing a risk to water quality.[37]

Pathway: hydrofracking chemicals > migration up through secondary wells > groundwater > human ingestion
Pathway: hydrofracking chemicals > migration through failed casings > groundwater > human ingestion
Pathway: hydrofracking chemicals > leach into groundwater > human ingestion

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Congressional Requesters by the U. S. Government Accounting Office, September 2012, p. 33.
[33] Walker TR, Ground-Water Contamination In The Rocky Mountain Arsenal Area, Denver, Colorado, Bulletin of the Geological Society of America, June 1960.
[34] Allen AE and MacMIllan DWC, Synergistic catalysis: A powerful synthetic strategy for new reaction development, Chem. Sci., 2012, 3, 633
[35] Watson TL and Bachu S, Evaluation of the Potential for Gas and CO2 Leakage Along Wellbores, Society of Petroleum Engineers, Drilling & Completion, March 2009, p. 115
[36] Bishop, RE, History of Oil and Gas Well Abandonment in New York, Digest of Independent Science on Hydrofracking, July 2012.
[37] OIL AND GAS: Information on Shale Resources, Development, and Environmental and Public Health Risks, Report to Congressional Requesters by the U. S. Government Accounting Office, September 2012, p. 46.

14. Health impacts from hydrofracking will disproportionately burden sensitive populations. Children, the elderly and those with compromised immune systems will be more adversely affected by all exposures.[38] Asthmatics and those with cardio-pulmonary disease will be more adversely affected by air pollution.[39] Children and unborn fetuses will be more adversely affected by exposure to endocrine-disrupting chemicals frequently used in hydrofracking fluids.[40] Individuals on medication may experience interactions from exposure to hydrofracking chemicals, silica dust or contaminated water.[41]

Pathway: air contamination > human inhalation
Pathway: food chain contamination > human ingestion
Pathway: drinking water contamination > human ingestion[42]

15. Multiple forms of stress are associated with hydrofracking operations, and these have real and significant health consequences. Increased noise, traffic, community turmoil, concern about water and air contamination, economic boom and bust, fear of radiation exposure, loss of rental housing for low-income families,[43] and the near-perpetual process of hydrofracking can adversely impact the health of local populations. Stress-related symptoms include headaches, nausea, chest pain, insomnia, dry mouth, agitation, abdominal pain, depression, anxiety symptoms, acute stress disorder and post traumatic stress disorder. Traffic-related noise pollution alone raises risk of heart attack and high blood pressure in adults and is associated with cognitive deficits in children.[44]

16. Health impacts related to hydrofracking will significantly increase health care costs in New York—as it has in other states.[45] Costs related to acute effects from hydrofracking operations include doctor visits, laboratory tests, medications, emergency room visits and hospitalizations due to acute medical disorders, acute exacerbations of existing chronic diseases (asthma, chronic obstructive lung disease [COPD], congestive heart disease), exposure to radioactive materials, ingestion of contaminated water, inhalation of contaminated air, traffic accidents involving heavy-duty trucks, and trauma from on-site accidents in a highly dangerous industrial process. Specific areas of concern include but are not limited to:

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[38] http://www.epa.gov/region7/air/quality/pmhealth.htm
[39] http://www.epa.gov/airnow/asthma-flyer.pdf
[40] Diamanti-Kandarakis *et al*, Endocrine-Disrupting Chemicals: An Endocrine Society Scientific Statement, Endocrine Reviews, June 2009
[41] Audouze K, Juncker AS, Roque FJSSA, Krysiak-Baltyn K, Weinhold N, et al. (2010) Deciphering Diseases and Biological Targets for Environmental Chemicals using Toxicogenomics Networks. PLoS Comput Biol 6(5): e1000788.doi:10.1371/journal.pcbi.1000788
[42] Among women of childbearing age, the pathway progresses to transplacental exposure and further exposure through breast milk during lactation.
[43] J. Gever, "Special Report: Gas Drilling Brings Stress, Social Ills," *Medpage Today*, Dec. 5, 2011
[44] World Health Organization, *Burden of Disease from Environmental Noise*, 2011
[45] Environment America Research and Policy Center, *The Costs of Fracking*, Fall 2012

- **Neurological systems:** developmental disorders involving cognitive, behavioral and psychosocial disorders among children
- **Endocrine disruptors**: affecting hormonal and metabolic processes, leading to infertility, early puberty and other reproductive issues affecting both men and women [46] [47]
- **Immuno-suppressants:** decreasing the immunological defenses of the general population leading to greater vulnerability to existing and emerging infectious agents
- **Mutagens and carcinogens:** leading to a greater incidence of all cancers especially among children, adolescents and young adults
- **Other chemicals** which do damage to the renal systems, gastrointestinal system and cardiac and respiratory systems, as well as skin, eyes, ears, and nasopharyngeal tissues [48]

Quantifiable costs of chronic disease such as asthma, cancer, or heart disease resulting from exposures related to hydrofracking must be calculated, as has already been done for coal. As of 2002, the total annual cost associated with exposure to environmental chemicals for children alone was $54.9 billion.[49]

17. Many health impacts related to hydrofracking may not be evident for years. Medical conditions with longer latency periods such as asthma, cancer and heart disease resulting from exposure to chemicals in air and water will present themselves over time. The developmental effects of endocrine disruption on developing fetuses or small children may not be evident for years. Chromosome damage from exposure to radiation may impact future generations. The full extent of risks associated with shale oil and gas development is unknown, in part, because studies do not generally take into account potential long term, cumulative effects.[50]

18. Local medical professionals in areas where hydrofracking is contemplated are ill equipped to recognize or treat symptoms related to radiation exposures or exposures to hazardous chemicals in water or air. Recognizing the fingerprints of unusual chemical exposures and knowing the possible treatment options is not within the purview of conventional medicine. Diagnosing and treating radiation-related medical conditions is a specialty.

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[46] Colborn T, Kwiatkowski C, Schultz K, Bachran M, (2011) Spreadsheet of products, chemicals and their health effects (excel); TEDX, The Endocrine Disruption Exchange

[47] Finkel ML, Law, A; The Rush to Drill for Natural Gas: A Public Health Cautionary Tale (2011), Am. J Public Health, Vol 101(5):784-785 (effects of Endocrine Disruptors)

[48] Colborn T, Kwiatkowski C, Schultz K, Bachran M, (2011) Natural Gas Operations from a Public Health Perspective, Human and Ecological Risk Assessment: *An International Journal*, 17:5, 1039101056

[49] Landrigan PJ, Schechter CB, Lipton JM, Fahs MC, Schwartz J, Environmental Pollutants and Disease in American Children: Estimates of Morbidity, Mortality, and Costs for Lead Poisoning, Asthma, Cancer, and Developmental Disabilities, Environmental Health Perspectives, 110:7 July 2002

[50] OIL AND GAS: Information on Shale Resources, Development, and Environmental and Public Health Risks, Report to Congressional Requesters by the U. S. Government Accounting Office, September 2012, p. 32

19. Non-disclosure agreements may obstruct efforts of public health officials to obtain accurate data in areas where hydrofracking is currently taking place. Non-disclosure agreements with private landowners and disclosure exemptions are preventing doctors from being able to effectively treat their patients and protect the public's health.[51] Non-disclosure agreements frequently forbid parties from revealing any information about personal health, air quality, water quality, or even the existence of the non-disclosure agreement itself.

20. Conflicts of interest may affect veracity of scientific findings. Many documents referenced in the DEC's rdSGEIS emanate directly from the oil and gas industry, from consultants paid by the oil and gas industry, or are the results of industry-sponsored academic studies.[52] Financial relationships can create conflicts of interest between researchers' obligations to abide by scientific and ethical principles and their desire for financial gain. Studies have found that industry-funded science can result in findings that benefit sponsors, poor study design, withholding of negative data from publication, and other problems.[53]

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[51] Statement of Jerome Paulson, MD, Director of Mid-Atlantic Center for Children's Health and the Environment, Washington DC., quoted in "Silencing Communities: How the Fracking Industry Keeps Its Secrets" Truthout, May 2012.
[52] NYS DEC Revised Draft SGEIS 2011, Bibliography
[53] Johnson J, Conflicts of Interest in Biomedical Research, The Hastings Center, http://www.thehastingscenter.org/Publications/BriefingBook/Detail.aspx?id=2156