

Hot Topic: Hydrofracking and Radiation Exposure

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DUKE UNIVERSITY
MEDICAL PHYSICS
GRADUATE PROGRAM

Why is this important?

- Over the past two decades the United States government has supported increased exploration and production of natural gas to try and reduce the dependence on imported fossil fuels
- The method that is being used is hydraulic fracturing.
- Environmental concerns surrounding drilling for gas have increased due to the expansion of shale gas drilling operations.
- Without rigorous scientific studies, the gas drilling boom sweeping the world will remain an uncontrolled health experiment.

Hydraulic fracturing

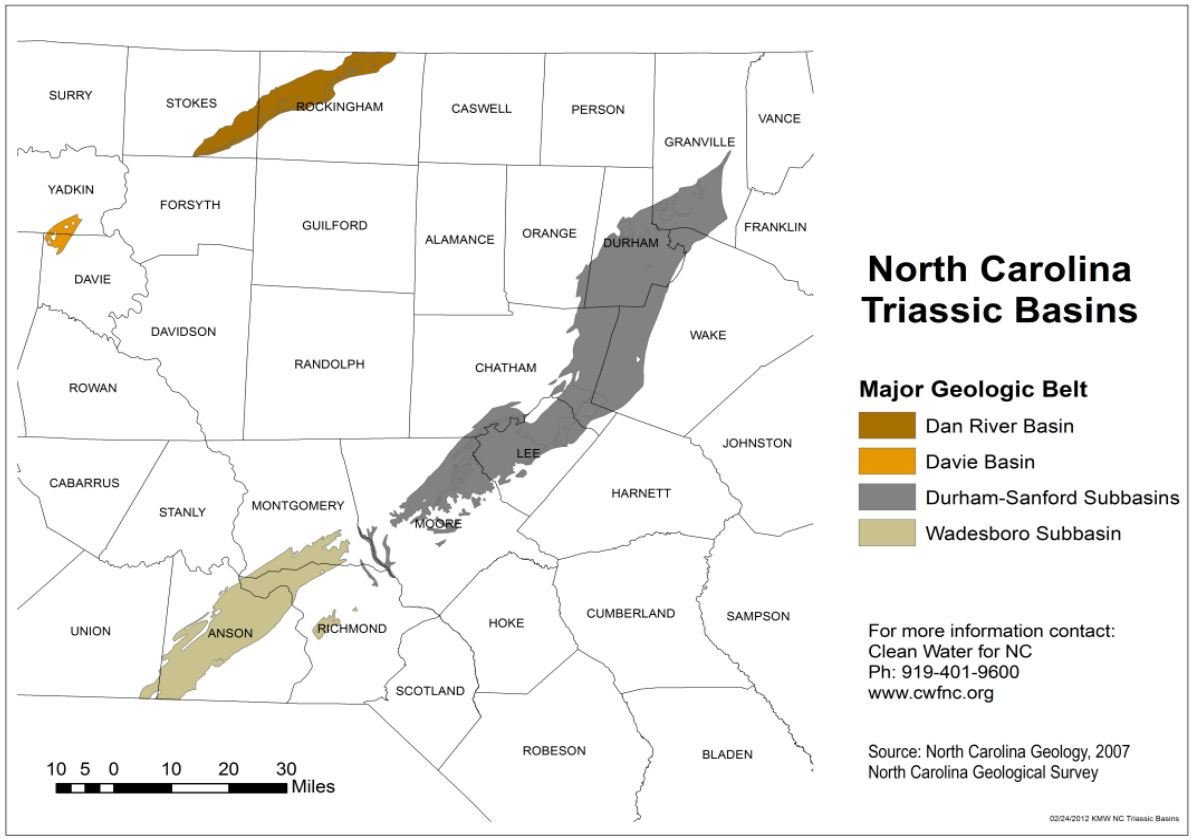
- Hydraulic fracturing, also called hydrofracking, produces fractures in the rock formation that stimulate the flow of natural gas or oil.
- Wells may be drilled vertically hundreds to thousands of feet below the land surface and may include horizontal or directional sections extending thousands of feet.
- Fractures are created by pumping large quantities of fluids at high pressure down a wellbore and into the target rock formation.
- Water and sand represent between 98 and 99.5 percent of the fracturing fluid. The other 1-2% of the fluid includes chemical additives used to condition the water.

Radiation Exposure

- During the fracking process many naturally occurring radioactive materials are released. Radioactive materials, including uranium, thorium, and radium, exist naturally in soil and rock.
- The dominant isotope, Uranium-238, forms a long series of decay products that includes the key radionuclides radium-226, and radon-222.
- Radium can be taken into the body by eating food, drinking water, or breathing air. About 20% of the radium will remain in the body and enter the bloodstream. A considerable fraction is specially deposited in bone and teeth.
- Radium-226 decays to form radon-222, which is a gas. Essentially all air contains radon, which is responsible for most of the dose that Americans receive each year from natural background sources

Geology of North Carolina

- The North Carolina Geological Survey (NCGS) has concluded that a viable reserve of natural gas may underlie parts of the Triassic basins of North Carolina. Recoverable gas is thought to exist in the Sanford sub-basin and possibly the Dan River sub-basin



How much gas is there?

- "The USGS estimates the mean undiscovered natural gas resources in the Deep River Basin in North Carolina to be 1,660 billion cubic feet of gas and 83 million barrels of natural gas liquids. Based on the 2010 average daily natural gas consumption volume in North Carolina of 811 million cubic feet per day, the USGS mean estimate of 1.66 trillion cubic feet could meet the state's natural gas demand for 5.6 years."-Dr. Ken Taylor
- "For the Dan River-Danville Basin, the mean undiscovered resources are 49 billion cubic feet of gas and no natural gas liquids. The USGS assessment combined both the North Carolina and Virginia portions to calculate one estimate for the entire basin. Based on the 2010 average daily natural gas consumption volume in North Carolina of 811 million cubic feet per day, the USGS mean estimate of 49 billion cubic feet could meet the state's natural gas demand for 60 days" –Dr. Ken Taylor

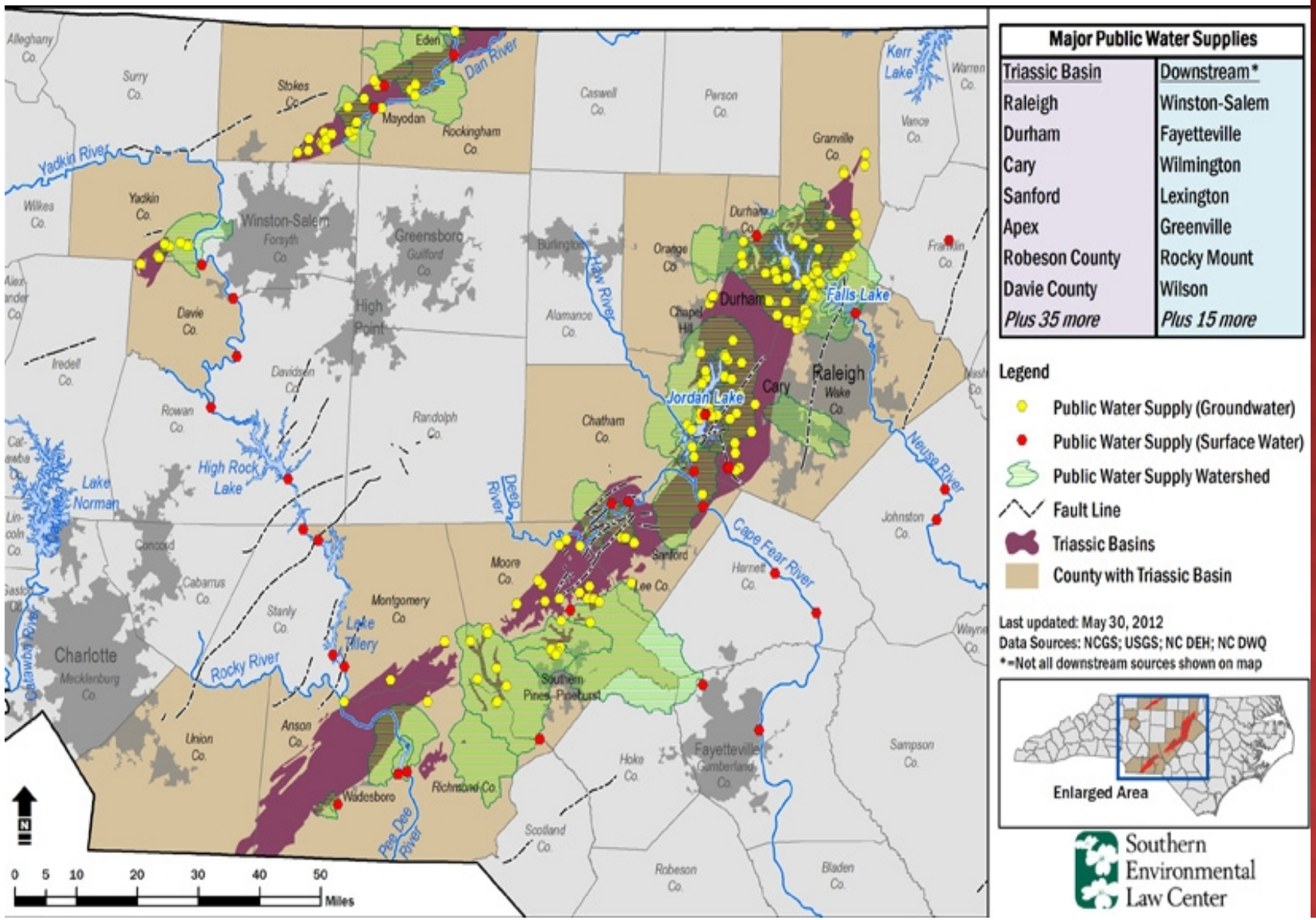
Radiation and Air Quality

- One of the main concerns with hydraulic fracturing is the release of benzene and other aromatic hydrocarbons to the atmosphere from routine operations of the fracking process.
- The inhalation risk is associated primarily with the release of radon. Radon gas is a carcinogen, and exposure to radon is the largest source of public exposure to ionizing radiation in the U.S.
- The primary hazard associated with radon arises from the inhalation of its short-lived decay products, which are charged ions that readily attach to dust particles. Chronic exposure can lead to asthma and chronic obstructive pulmonary diseases (COPD).
- The EPA standards under the Clean Air Act limit uranium in the air. The maximum dose to an individual from uranium in the air is 10 mrem

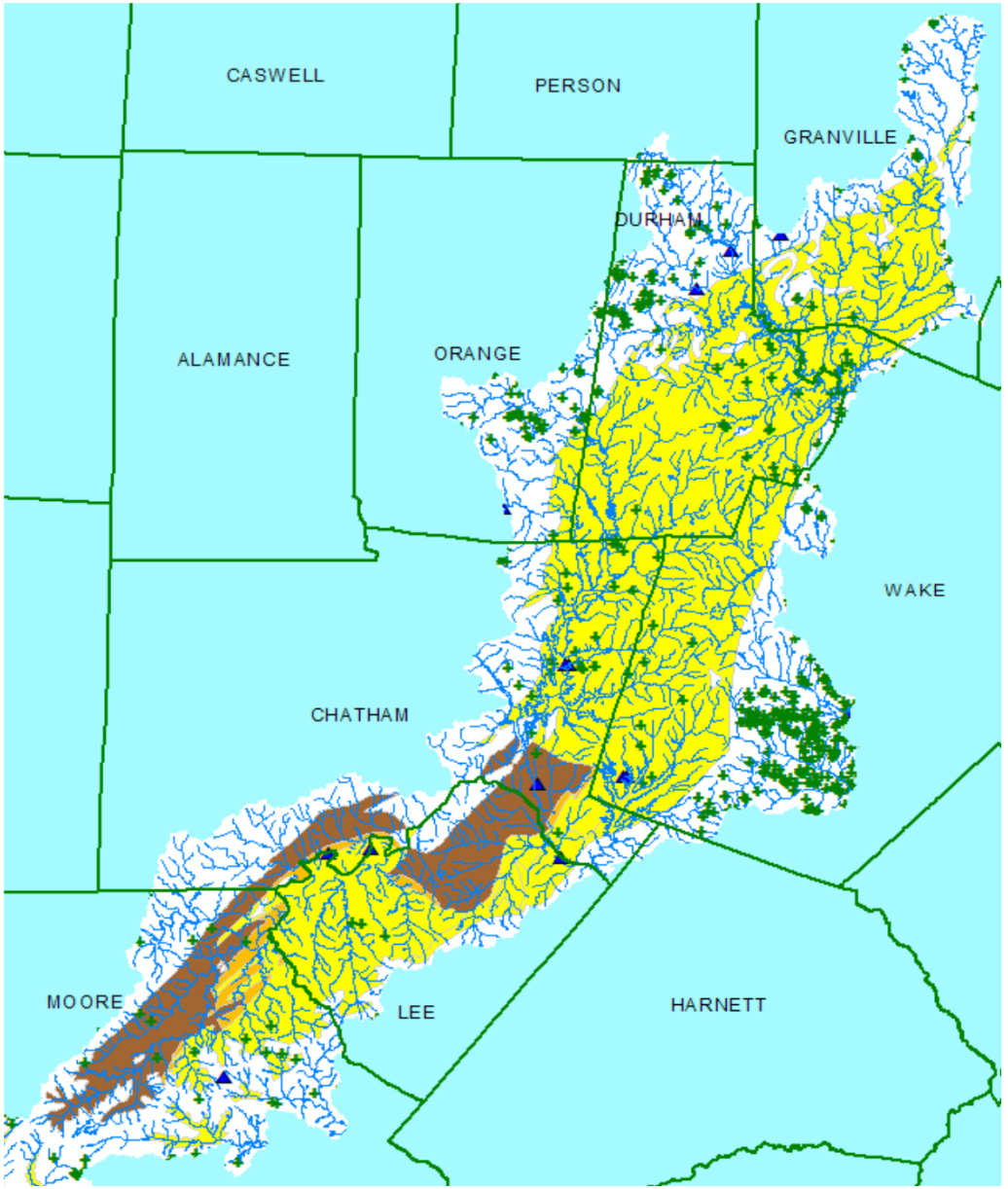
Radiation and Water Quality

- Hydraulic fracturing requires between 3 and 5 million gallons of water per well. To put this in perspective, a number of small cities in North Carolina withdraw 5 million gallons per day to serve their water system customers.
- Water supply wells of up to 1,000 feet deep have been found in North Carolina's Triassic Basins and the depth to which freshwater extends is unknown. Some of the shale that might be tapped for natural gas in the Triassic Basins of North Carolina lies at depths of 3,000 feet or less.
- In Pennsylvania the shale gas resource lies at depths of roughly 10,000 feet or more and the deepest water supply wells are generally no more than 600 feet deep

- A report issued by the Southern Environmental Law Center shows that hydrofracking for natural gas in North Carolina could directly impact the water supply for 1.1 million people, and an additional 1.3 million people downstream.



- The areas encompassing the Sanford and Durham Sub-basins of the Deep River Triassic Basin are shown in yellow, orange and brown. Public water supply systems' water sources are shown with surface water intakes indicated by blue triangles and groundwater wells indicated by the green crosses.



- The maximum contaminant level of uranium in drinking water is 30 micrograms/liter. The maximum contaminant level developed by the U.S. Environmental Protection Agency for radium (as radium-226 and radium-228, combined) in drinking water supplies is 5 pCi/L.
- The New York's Department of Environmental Conservation (DEC) analyzed 13 samples of water, contaminated by the hydraulic fracturing of the shale during the extraction process. The DEC found that the resulting water contained levels of radium-226, some as high as 267 times the limit for safe discharge into the environment and more than 3000 times the limit safe for people to drink.
- A New York Times expose in 2011, released secret EPA documents that illustrated how this water is sometimes sent to sewage plants that are not designed to process the dangerous chemicals or radiation which in some instances are used in municipal drinking supplies or are released into rivers and streams that supply drinking water.

Hydrofracking Waste

- Wastewater associated with shale gas extraction can contain high levels of total dissolved solids, fracturing fluid additives, metals, and naturally occurring radioactive materials.
- Disposal by injection into fractured rock presents difficulty in predicting the fate and transport of the injected wastewaters.
- Federal and state regulators do not require most sewage treatment plants that accept drilling waste to test for radioactivity. At least 12 sewage treatment plants in three states accepted gas industry wastewater and discharged waste that was only partly treated into rivers, lakes and streams.
- In Pennsylvania of more than 179 wells producing wastewater with high levels of radiation, at least 116 reported levels of radium or other radioactive materials 100 times as high as the levels set by federal drinking-water standards. At least 15 wells produced wastewater carrying more than 1,000 times the amount of radioactive elements considered acceptable

Health Effects

- When understanding and determining the health risk involved with hydrofracking we must know the hazard and the exposure.
- Children are more vulnerable to environmental hazards because they eat, drink, and breathe more than adults on a pound for pound basis. Research has also shown that children are not able to metabolize some toxicants as well as adults due to immature detoxification processes
- According to the U.S. EPA, studies have shown that toluene can cause an assortment of developmental disorders in children born to pregnant women that have been exposed to toluene.

- Chemicals used in fracking have been linked to breast cancer and reproductive health problems. The Institute of Medicine released a report in December 2011 that links breast cancer to exposure to benzene.
- According to the U.S. Committee on Energy and Commerce, fracking companies used 95 products containing 13 different known and suspected carcinogens between 2005 and 2009 as part of the fracking fluid that is injected in the ground.
- More than 75% of the chemicals used in fracking could affect the skin, eyes, and other sensory organs, and the respiratory and gastrointestinal systems. Approximately 40-50% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys; 37% could affect the endocrine system; and 25% could cause cancer and mutations. More than 40% of the chemicals have been found to have ecological effects, indicating that they can harm aquatic and other wildlife.



Workers/Community Exposure

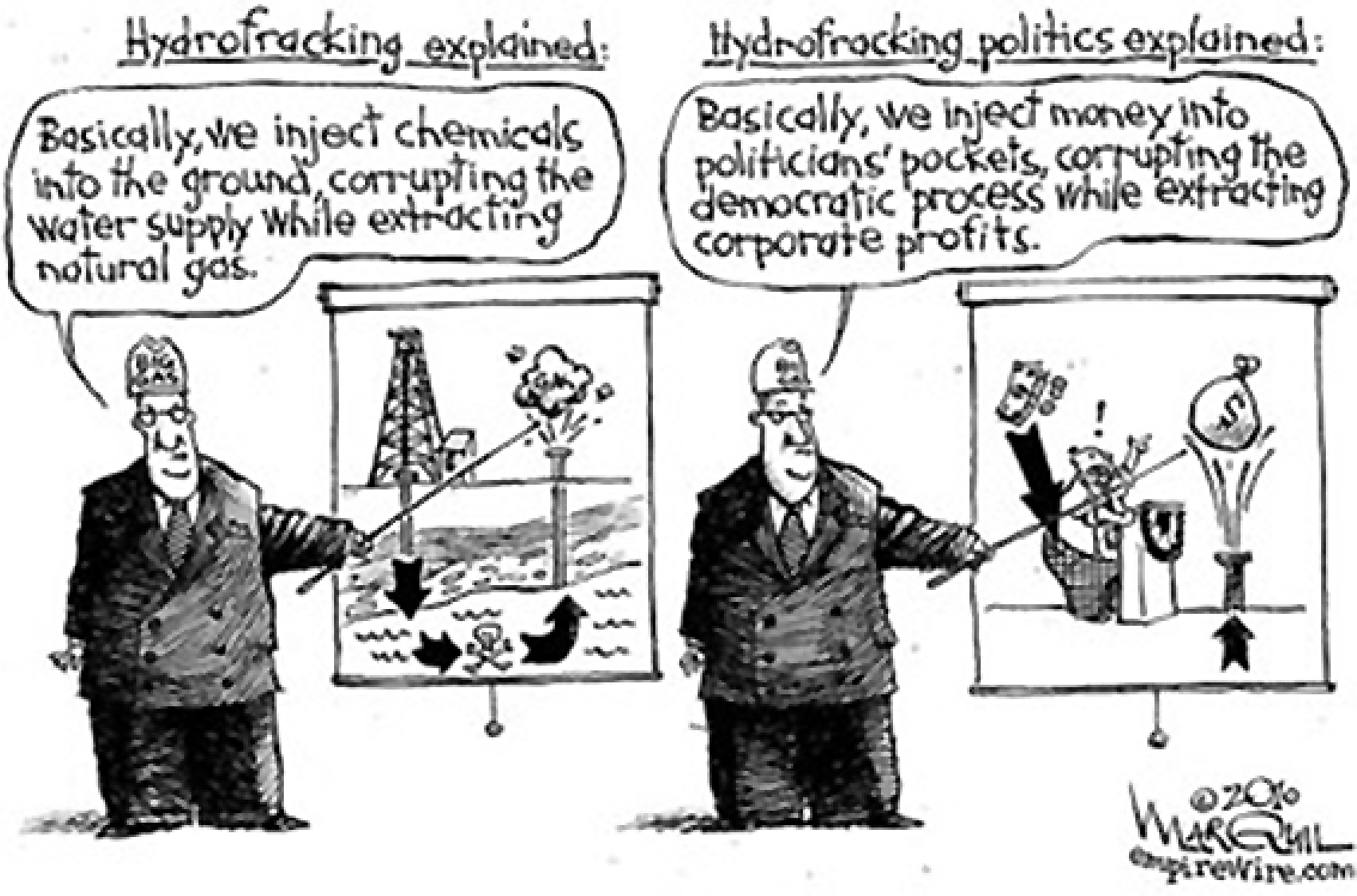
- The occupational limit for a radiation worker is 5,000 mrem/year. If a worker does not reach 500 mrem/year then they do not require a device to measure their exposure to radiation. The amount of radiation to the community cannot exceed 100 mrem/year.
- According to a letter sent today from the AFL-CIO, Mine Workers (UMWA) and the United Steelworkers (USW) to the top federal safety agencies working in the hydraulic fracturing industry exposes workers to high levels of crystalline silica, putting them at risk of developing silicosis, lung cancer and other debilitating diseases.
- A study by NIOSH found that 47 percent of all oil and natural gas workers breath air that exceeds the safe breathing limits for silica dust.

- The State of Louisiana, Department of Environmental Quality has recently issued a notification concerning a potential health hazard associated with handling pipe used in oil and gas production that may be contaminated with radioactive scale from naturally-occurring radioactive materials (NORM).
- There is a concern about the possible inhalation and/or ingestion of scale particles contaminated with radium-226 and possibly other radioactive material that may become airborne during welding, cutting or reaming of pipe containing the radioactive scale.
- According to one study by the CDC National Institute for Occupational Safety and Health (NIOSH), workers in the oil and natural gas industries are seven times as likely to die on the job as workers in other industries. The three most common types of fatal accidents that those working for well-servicing companies fall victim to are motor vehicle accidents (29 percent), being struck by objects (20 percent), and explosions (8 percent).



Thanks

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- Fred and Alice Stanback


Hydrofracking explained:
Basically, we inject chemicals into the ground, corrupting the water supply while extracting natural gas.
Hydrofracking politics explained:
Basically, we inject money into politicians' pockets, corrupting the democratic process while extracting corporate profits.
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Hot Topic, Hydrofracking and Radiation Exposure

Over the past two decades the United States government has supported increased exploration and production of natural gas to try and reduce the dependence on imported fossil fuels. In keeping with the rush to produce more natural gas, technological advances have permitted the gas industry to drill deeper and expand wider, tapping into gas reserves with greater facility and profitability. The method most often used to release previously unattainable gas deposits from deep within the ground is hydraulic fracturing. This technique is performed by drilling vertically down through the earth then drilling horizontally and injecting thousands to millions of gallons of water loaded with undisclosed toxic chemicals and sand into the shale in order to release the gas. Environmental concerns surrounding drilling for gas have increased due to the expansion of shale gas drilling operations. Controversy surrounding the impact of drilling on air and water quality has pitted the gas industry against individuals and groups concerned with environmental protection and public health. Complete evidence regarding health impacts of gas drilling and the waste created cannot be obtained due to incomplete testing and disclosure of chemicals. The radiation exposure that can occur during hydraulic fracturing and its possible effects will be discussed. Without rigorous scientific studies, the gas drilling boom sweeping the world will remain an uncontrolled health experiment.

Introduction

Hydraulic fracturing, also called hydrofracking, produces fractures in the rock formation that stimulate the flow of natural gas or oil. Wells may be drilled vertically hundreds to thousands of feet below the land surface and may include horizontal or directional sections extending thousands of feet. Fractures are created by pumping large quantities of fluids at high pressure down the well and into the target rock formation. Each time a well is fracked it can take up to 5 million gallons of fresh water. This water will never be available for drinking and is permanently removed from the hydrological cycle. Once the injection process is completed, the internal pressure of the rock formation causes fluid to return to the surface through the wellbore. This fluid is known as flowback or produced water and may contain the injected chemicals plus naturally occurring radioactive materials. Some of the materials that may be included in the flowback are arsenic, barium, strontium and radium. The flowback is typically stored on site in tanks or pits and then can be taken to underground injection wells or wastewater treatment plants where it is eventually discharged to surface water, potentially contaminating the receiving body. Up to 85% of the fluid can remain in the ground, potentially contaminating groundwater[1].

The process of hydrofracking begins with building the necessary site infrastructure including well construction. Vertical well sections may be drilled hundreds to thousands of feet below the land surface and lateral sections may extend 1000 to 6000 feet away from the well. Fracturing fluids may be composed primarily of water and a proppant (such as sand) to keep the fractures open. Water and sand represent between 98 and 99.5 percent of the fracturing fluid. The other 1-2% of the fluid includes chemical additives used to condition the water. Chemicals are added to increase the density and weight of the fluids in order to facilitate boring, to reduce friction, to assist the return of drilling detritus to the surface, to shorten drilling time, and to reduce accidents[2].

Combinations of chemicals are added to the “muds” used to drill the wellbore hole. After drilling, hydraulic fracturing is done to break up the zone in which the gas is trapped and make it easier for the methane to escape, increasing a well’s productivity. The exact makeup of fracturing fluid varies from company to company and may also be adjusted based on conditions at the individual well site. Any single fracturing fluid generally contains between 6 and 12 chemical additives. Some chemicals that

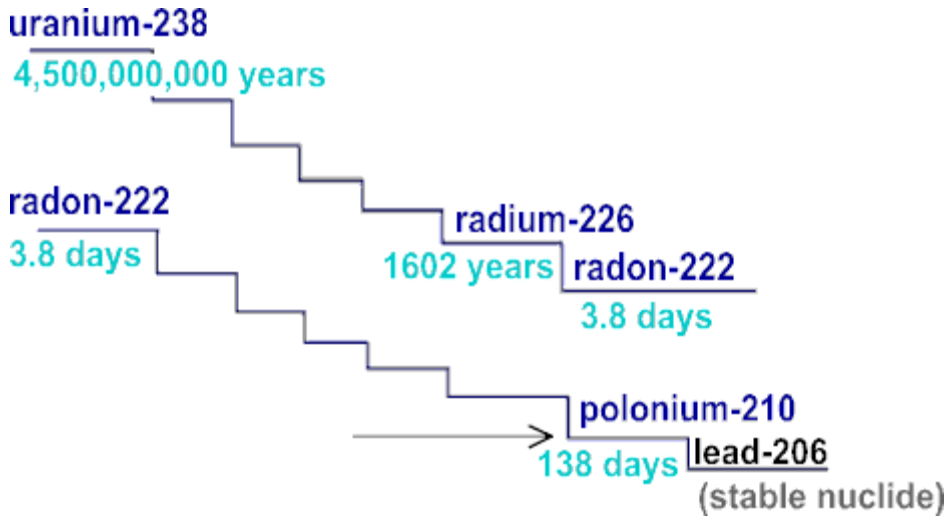
have been used in fracturing fluids, such as diesel fuel, have raised concern because of potential health impacts[2].

The North Carolina Department of Environment and Natural Resources (DENR) believes the production of natural gas by means of hydraulic fracturing can only be done safely in North Carolina if the state adopts adequate safeguards in the form of regulatory standards specifically adapted to conditions in the state and invests sufficient resources in compliance and enforcement. Development of appropriate standards will require additional information on North Carolina's geology and hydrogeology to identify conditions under which hydraulic fracturing can be done without putting the state's water resources at risk. Standards and a strong compliance and enforcement program are needed before issuing permits for hydraulic fracturing in North Carolina's shale formations.

Radioactive Elements Released in Hydraulic Fracturing

Many naturally occurring radioactive materials are released during the hydrofracking process. The earth itself is a source of terrestrial radiation. Radioactive materials, including uranium, thorium, and radium, exist naturally in soil and rock. Water also contains small amounts of dissolved uranium and thorium. The dose from terrestrial sources varies in different parts of the world, but locations with higher soil concentrations of uranium and thorium generally have higher doses. Uranium is a naturally-occurring element found at low levels in virtually all rock, soil, and water. Uranium in soil and rocks is distributed throughout the environment by wind, rain and geologic processes. Uranium has a long radioactive half-life (4.47×10^9 years) so the total amount of it on earth stays almost the same. All uranium isotopes are radioactive[3]. The three natural uranium isotopes found in the environment, U-234, U-235, and U-238, undergo radioactive decay by emission of an alpha particle accompanied by weak gamma radiation. The dominant isotope, U-238, forms a long series of decay products that includes the key radionuclides radium-226, and radon-222 (Figure 1)[4]. Radiation is released during the decay process which continues until a stable, non-radioactive decay product is formed.

Figure 1: Decay Scheme of Uranium-238



The importance of understanding the decay chain of uranium-238 is the development of radium-226 and radon-222. Radium is a radioactive element that occurs naturally in very low concentrations in the earth's crust. Radium exists in soil, rocks, surface water, groundwater, plants, and animals. Radium can be taken into the body by eating food, drinking water, or breathing air. About 20%

of the radium will remain in the body and enter the bloodstream. A considerable fraction is specially deposited in bone and teeth. The amount in bone decreases with time from the exposure, generally dropping below 10% in a few months to 1% and less in a few years. However, the release of the radioactive material from the bone is slow so a portion of inhaled and ingested radium will remain in the bones throughout a person's lifetime. Chronic exposure to radium can induce bone sarcomas[5].

Radium-226 decays to form radon-222, which is a gas. Radon can seep through soil and cracks in rocks into the air and it can also seep through foundations into homes and accumulate into high concentrations. The EPA states that any radon exposure carries some risk; no level of radon exposure is always safe. However, if an occupant's long-term exposure will average 4 picocuries per liter (pCi/L) or higher the EPA recommends that the house is fixed. A pCi is a measure of the rate of radioactive decay. Therefore, at 4 pCi/L, there will be approximately 12,672 radioactive disintegrations in one liter of air during a 24-hour period[6]. Essentially all air contains radon, which is responsible for most of the dose that Americans receive each year from natural background sources. Radon has a short half-life (3.8 days) and its decay emits alpha particles, which is the radiation that presents the greatest hazard to lung tissue[4].

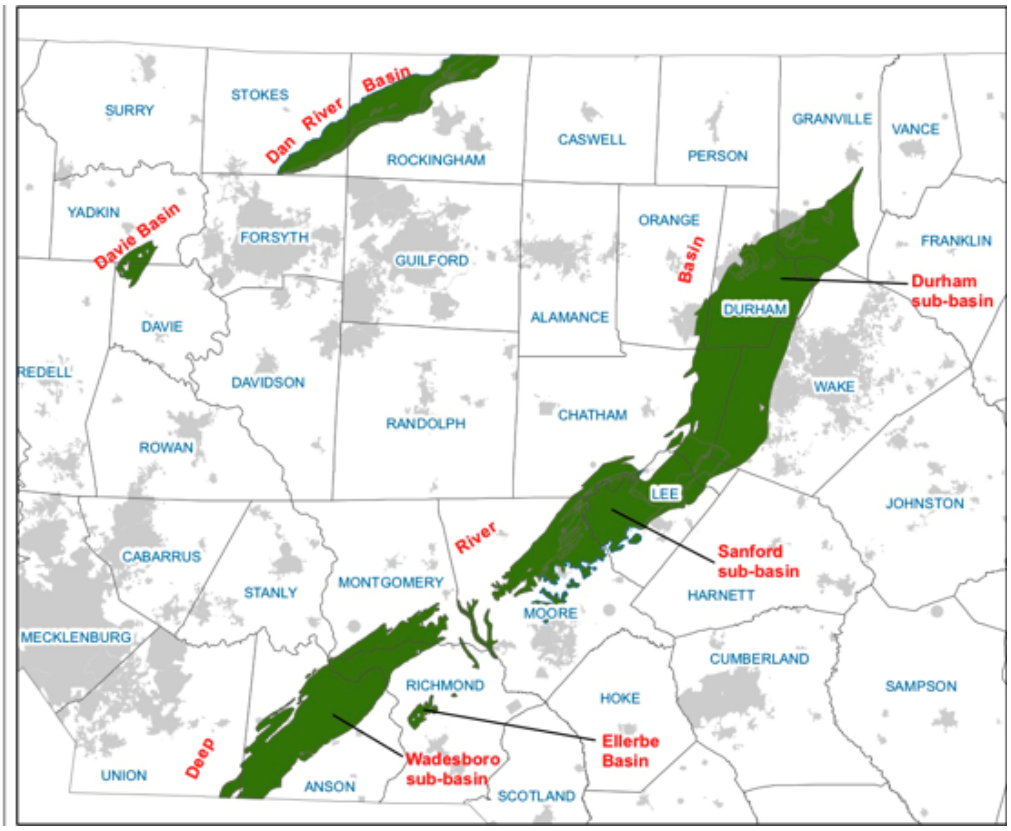
Geology in North Carolina

Using a geology-based assessment method, the U.S. Geological Survey (USGS) estimated a mean undiscovered natural gas resource of 3.9 trillion cubic feet and a mean undiscovered natural gas liquids resource of 135 million barrels in continuous accumulations within five East Coast Mesozoic basins. The area assessed extends across parts of Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, and Massachusetts. The five basins assessed are the Deep River, Taylorsville, South Newark, Dan River-Danville, and Richmond basins. The Deep River and Dan River-Danville basin are within the Piedmont Province of North Carolina and Virginia. These basins were filled with a variety of sediments as they formed, including boulder beds, coarse-grained fluvial to deltaic sandstones, red siltstones, and mudstones. The assessment of the East Coast Mesozoic basins is based on the geologic and geochemical characteristics of the individual total petroleum systems (TPS) that were recognized within the basins[7].

The Deep River Basin is a 150-mile long northeast-trending half-graven with a steeply-dipping eastern border fault in central North Carolina. The basin is divided into three sub-basins, which are the Durham sub-basin, the Sanford sub-basin and the Wadesboro sub-basin. The three sub-basins are filled with about 7,000 feet of Triassic strata including red and gray siltstone, black shale with some beds of gray shale, sandstone, coal and gray sandstone. The black shale extends across ~25,000 acres, at depths of less than 3,000 feet in the Sanford sub-basin. Organic geochemistry and thermal maturation analyses indicate that the black shale is gas-prone.

The North Carolina Geological Survey (NCGS) has concluded that a viable reserve of natural gas may underlie parts of the Triassic basins of North Carolina. Recoverable gas is thought to exist in the Sanford sub-basin and possibly the Dan River sub-basin (Figure 2). The Sanford sub-basin includes Lee, Chatham and Moore counties. The Dan River sub-basin includes Stokes and Rockingham counties. The available organic geochemical and seismic data has caused NCGS to focus on an area of more than 59,000 acres in the Sanford sub-basin as the most promising location for organic-rich shale and coals from which natural gas can be extracted[8].

Figure 2: Map of North Carolinas Triassic Basins[9]



Dr. Kenneth Taylor, lead geologist for DENR, stated his results for how much possible gas there is in North Carolina:

> "The USGS estimates the mean undiscovered natural gas resources in the Deep River Basin in North Carolina to be 1,660 billion cubic feet of gas and 83 million barrels of natural gas liquids. Based on the 2010 average daily natural gas consumption volume in North Carolina of 811 million cubic feet per day, the USGS mean estimate of 1.66 trillion cubic feet could meet the state's natural gas demand for 5.6 years. For the Dan River-Danville Basin, the mean undiscovered resources are 49 billion cubic feet of gas and no natural gas liquids. The USGS assessment combined both the North Carolina and Virginia portions to calculate one estimate for the entire basin. Based on the 2010 average daily natural gas consumption volume in North Carolina of 811 million cubic feet per day, the USGS mean estimate of 49 billion cubic feet could meet the state's natural gas demand for 60 days"[7]

In comparison the Marcellus Shale located throughout Pennsylvania and New York is estimated to have 84 trillion cubic feet of natural gas which could meet the countries natural gas demand for 4 years.

Radiation and Air Quality

The development of shale gas and other forms of natural gas result in significant local air pollution. One of the main concerns with hydrofracking is the release of benzene and other aromatic hydrocarbons to the atmosphere from routine operations of the fracking process. There have been well-documented air quality impacts in areas with active natural gas development, with increases in emissions of methane, volatile organic compounds (VOCs) and hazardous air pollutants. Another concern with air pollution is the creation of ground level ozone. Unconventional natural gas development from hydrofracking increases ozone pollution due to leakage of organic compounds to the air. At each stage of production and delivery tons of toxic VOCs, other hydrocarbons, and methane can escape and mix with nitrogen oxides (NOx) from the exhaust of diesel-fueled, mobile, and stationary equipment, to produce ground-level ozone. Gas field ozone has created a previously unrecognized air pollution problem in rural areas, similar to that found in large urban areas, and can spread up to 200 miles beyond the immediate region where gas is being produced[10].

The inhalation risk from hydrofracking is associated primarily with the release of radon. Radon gas is a carcinogen, and exposure to radon is the largest source of public exposure to ionizing radiation in the U.S. The primary hazard associated with radon arises from the inhalation of its short-lived decay products, which are charged ions that readily attach to dust particles. These particles can then be inhaled into the lungs and deposited on the mucous lining of the respiratory tract. When alpha particles are emitted within the lungs, the cells lining the airways can be damaged, potentially leading to lung cancer over time[11]. Chronic exposure can lead to asthma and chronic obstructive pulmonary diseases (COPD), and is particularly damaging to children, active young adults who spend time outdoors, and the elderly.

The EPA standards under the Clean Air Act limit uranium in the air. The maximum dose to an individual from uranium in the air is 10 mrem[12]. In comparison, a typical plain x-ray film delivers a dose of 1-15 mrem. The state air toxics program requires a source of state-regulated toxic air pollutants to demonstrate compliance with the ambient air levels at the property boundary. Shale gas production often occurs under a lease of property that may be owned and in some cases occupied by another person. If natural gas production occurs on a residential property or farm, the property owner or occupant may be exposed to unhealthy concentrations of toxic pollutants. In 2011, the Environmental Protection Agency (EPA) developed draft standards for air emissions from natural gas exploration and production activities. As proposed, the rules would affect gas wellheads, centrifugal compressors, reciprocating compressors, pneumatic controllers, storage vessels, and sweetening units. Until the proposed rules go into effect, no federal new source performance standards or hazardous air pollution standards apply to emissions from these natural gas exploration and production activities[2]. EPA finalized the rules on April 17, 2012, but the industry is not required to implement all of the provisions of the rules until 2015.

Approximately 37% of the chemicals used in fracking are volatile and can become airborne. More than 89% of these chemicals can harm the eyes, skin, sensory organs, respiratory tract, gastrointestinal tract, or liver. Compared with the soluble chemicals, far more of the volatile chemicals (81%) can cause harm to the brain and nervous system. Seventy one percent of the volatile chemicals can harm the cardiovascular system and blood, and 66% can harm the kidneys. Overall, the volatile chemicals produce a profile that displays a higher frequency of health effects than the water soluble chemicals. In addition, because they vaporize, not only can they be inhaled, but also ingested and absorbed through the skin, increasing the chance of exposures[10].

Adding to this air pollution is the dust created by fleets of diesel trucks working around the clock hauling the constantly accumulating condensate and produced water to large waste facility evaporation pits on unpaved roads. Trucks are also used to haul the millions of gallons of water from the source to the well pad. There can be anywhere from 1,000-2,000 trucks used to deliver the water needed. Along with the water, there are 700-800 trucks that deliver the proppant used in the fracking process.

Radiation and Water Quality

Water quality issues have been associated with oil and gas operations. Hydraulic fracturing requires between 3 and 5 million gallons of water per well. To put this in perspective, a number of small cities in North Carolina withdraw 5 million gallons per day to serve their water system customers. In the Sanford sub-basin, there appears to be much less separation between groundwater used for drinking water and the gas-producing layer than in other gas-producing states. Water supply wells of up to 1,000 feet deep have been found in North Carolina's Triassic Basins and the depth to which freshwater extends is unknown. Some of the shale that might be tapped for natural gas in the Triassic Basins of North Carolina lies at depths of 3,000 feet or less. In Pennsylvania the shale gas resource lies at depths of roughly 10,000 feet or more and the deepest water supply wells are generally no more than 600 feet deep[2].

There are several reports of contamination of drinking water wells and surface aquifers by fracking fluids, particularly in Pennsylvania and in Colorado. A recently published model suggests there may also be a threat of migration of contaminated fracking fluids from depth to surface drinking water aquifers over time through fissures and cracks. At least two recent studies have found higher levels of methane in groundwater near natural gas wells that had been hydraulically fractured. In Pavillion, Wyo., the EPA found methane and organic chemicals consistent with those used in hydraulic fracturing fluids in both monitoring wells and water supply wells[13]. Conditions in Pavillion are not necessarily representative of most shale plays, however; the hydraulic fracturing that occurred in Pavillion involved injection of hydraulic fracturing fluids directly into the same formation tapped by water supply wells. The U.S. EPA is currently pursuing a comprehensive study of groundwater contamination from hydraulic fracturing, and intends to release a preliminary report later this year and a final report in 2014.[14]

A study in Pennsylvania found that water supply wells close to active exploration and production wells in the Marcellus shale have higher levels of dissolved methane than wells farther away. The study did not find components of hydraulic fracturing fluids in any of the water supply wells that were sampled but the study did find methane in water supply wells. The methane had an isotopic signature indicating that it originated from deep, thermogenic sources consistent with a Marcellus shale source, rather than from shallow biogenic sources. The lack of pre-drilling groundwater samples makes it difficult to definitively link the methane to drilling practices. Pre-drilling groundwater samples should be taken in order to defend against any contamination findings. A Groundwater Protection Council study found that most Texas groundwater contamination incidents related to oil and gas activity reviewed were traced to either the production phase of well operations or involved waste management and disposal[2].

A report issued by the Southern Environmental Law Center shows that hydrofracking for natural gas in North Carolina could impact the water supply of 2.4 million residents (Figure 3). Hydraulic fracturing of potential shale gas deposits in the state could directly impact the water supply for 1.1 million people, and an additional 1.3 million people downstream[15].

Figure 3: Map of the water supplies that could be affected by hydrofracking

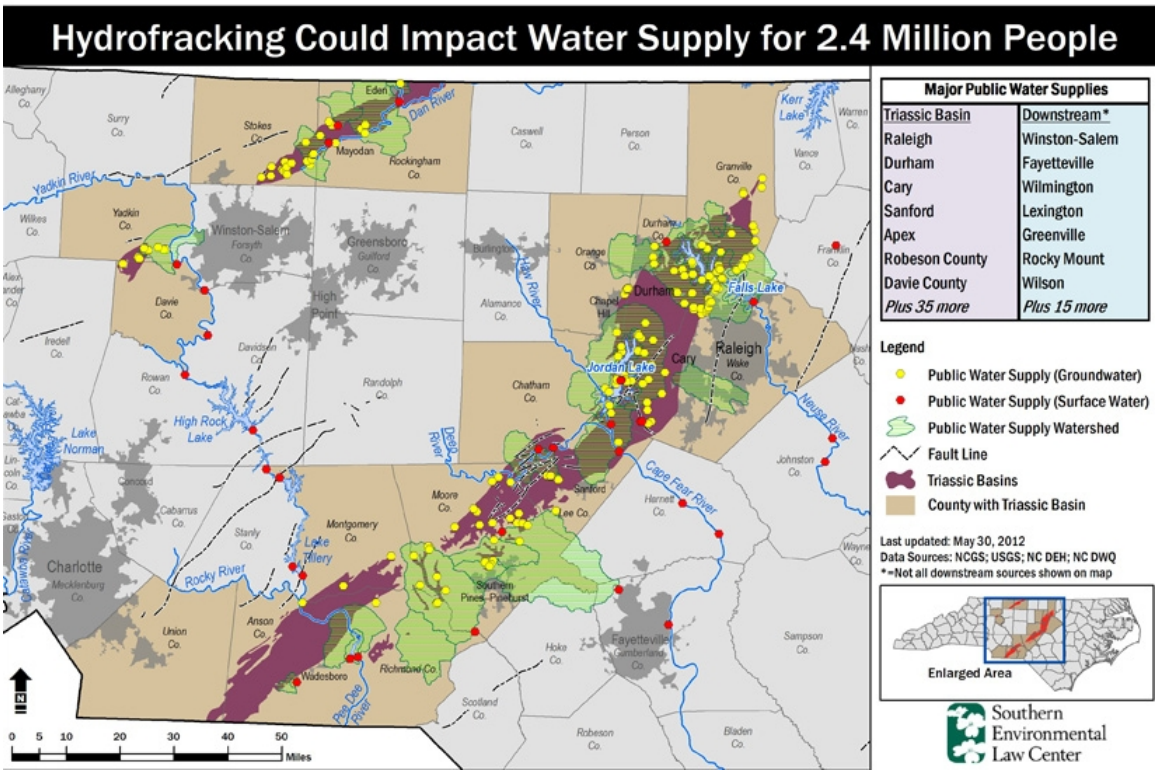
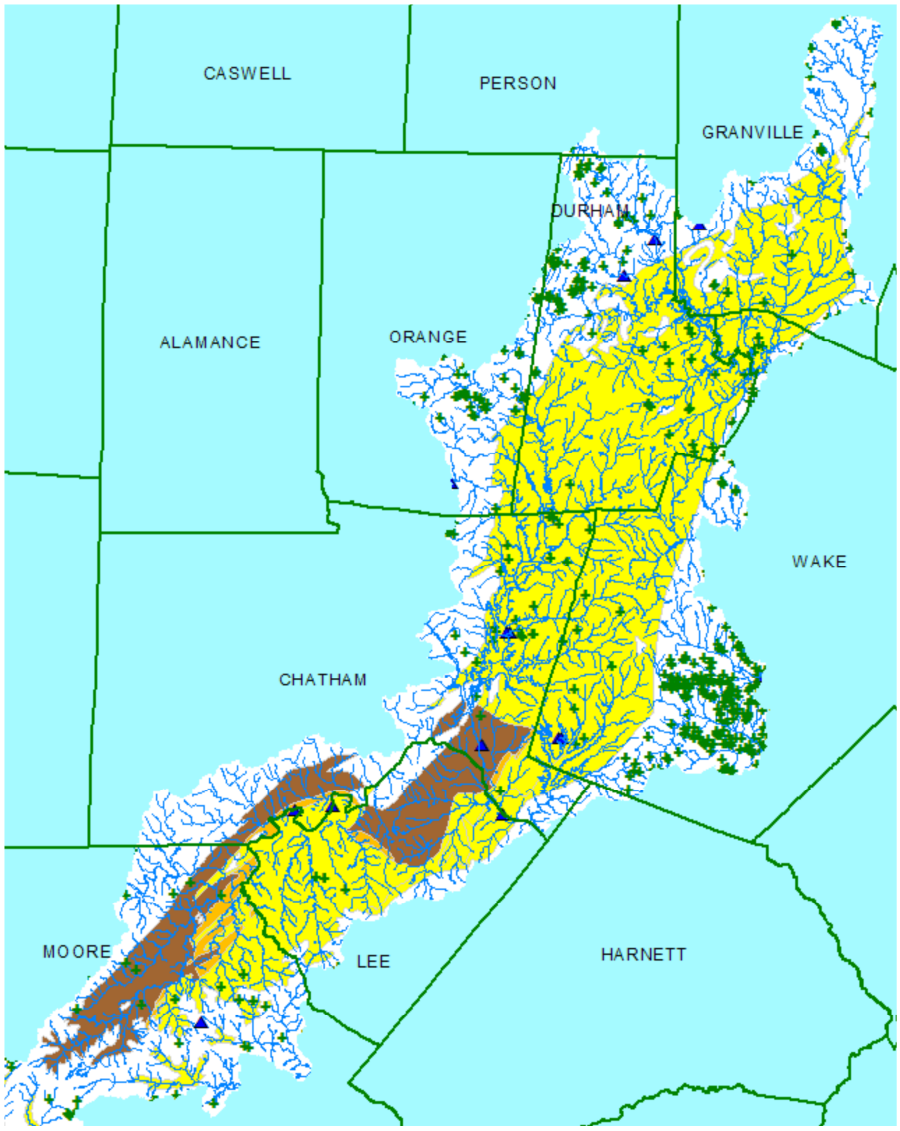


Figure 4: Map of the Sanford and Durham sub-basins and the public water supplies



In Figure 4 the areas encompassing the Sanford and Durham Sub-basins of the Deep River Triassic Basin are shown in yellow, orange and brown within the water resource study area. Public water supply systems' water sources are shown with surface water intakes indicated by blue triangles and groundwater wells indicated by the green crosses[2]. In the Sanford and Durham geologic sub-basins the Deep River and the Haw River merge to form the Cape Fear River. Low flows in the Deep River are supplemented by releases of stored water from several upstream reservoirs. Above the confluence, in the Haw River drainage, Jordan Lake lies inside the western boundary of the Triassic Basin in Chatham County. This reservoir, built and operated by the U.S. Army Corps of Engineers, stores water as a regional water supply source, provides flood control storage and provides water to augment downstream flows in the Cape Fear River.

The city of Sanford, in Lee County, and the Goldston-Gulf Sanitary District are supplied by water withdrawn from the Cape Fear River through a water treatment plant operated by Sanford. The Moore County Public Utilities-Seven Lakes water system distributes groundwater withdrawn from a sub watershed outside of the Triassic Basin to its customers, some of whom reside in the Triassic Basin. Overall in the Sanford geologic sub-basin study area 45 groundwater and surface water sources supply

public water systems. Twenty-four of these sources tap waters within the Triassic Basin. Within Lee County, the city of Sanford also provides water from the Cape Fear River to the Carolina Trace Water System and the town of Broadway. In 2010, these three systems provided water to almost 47,000 of the 58,059 county residents[2]. Residents not supplied by the network of water utilities supplied by the city of Sanford depend on private wells or other groundwater-based community water systems. At least one community water system uses water from wells in the Triassic Basin.

A core element of the Safe Drinking Water Act's (SDWA) Underground Injection Control (UIC) program is settling requirements for proper well siting, construction, and operation to minimize risks to underground sources of drinking water. The Energy Policy Act of 2005 excluded hydraulic fracturing, except when diesel fuels are used, for oil, gas or geothermal production from regulation under the UIC program. The EPA has developed draft UIC Class II permitting guidance specific to oil and gas hydraulic fracturing activities using diesel fuels. This document describes information useful in permitting the underground injection of oil-and-gas-related hydraulic fracturing using diesel fuels where EPA is the permitting authority[16]. While uranium in drinking water is covered under the Safe Drinking Water Act, hydrofracking is exempt from most of the Safe Drinking Water Act. The maximum contaminant level of uranium in drinking water is 30 micrograms/liter. The maximum contaminant level developed by the U.S. EPA for radium (as radium-226 and radium-228, combined) in drinking water supplies is 5pCi per liter (pCi/L). The EPA reports that the average open ocean surface waters contain about 0.05 pCi/liter of radium while coastal waters probably do not generally contain much higher than 1 pCi/liter. Fifty pCi/liter is the level of activity of radium that distinguishes between hazardous and nonhazardous wastes under proposed EPA regulations[17].

The New York's Department of Environmental Conservation (DEC) analyzed 13 samples of water, contaminated by hydrofracking of the shale during the extraction process. The DEC found that the resulting water contained levels of radium-226, some as high as 267 times the limit for safe discharge into the environment and more than 3000 times the limit safe for people to drink. One gas well can produce over a million gallons of contaminated water. A New York Times expose in 2011, released secret EPA documents that illustrated how this water is sometimes sent to sewage plants that are not designed to process the dangerous chemicals or radiation which in some instances are used in municipal drinking supplies or are released into rivers and streams that supply drinking water[18].

Hydrofracking Wastewater

As the number of shale gas wells in the US increases, so too does the volume of shale gas wastewater that requires disposal. Wastewater associated with shale gas extraction can contain high levels of total dissolved solids, fracturing fluid additives, metals, and naturally occurring radioactive materials. Between 9 and 35 percent of the fluid pumped into a well for hydraulic fracturing returns to the surface as "flowback" shortly after fracturing. The EPA is examining the different disposal methods employed by industry to ensure that there are regulatory and permitting frameworks in place to provide safe and legal options for disposal of flowback. During the remainder of the productive life of the well, a much smaller volume of wastewater is generated more or less continuously as the well produces gas. In many states, flowback from a drilling operation can be disposed of by underground injection. Disposal of flowback via underground injection is regulated under the Safe Drinking Water Act's Underground Injection Control (UIC) program.

It is not clear that injection wells would be a feasible option for managing flowback from a gas well in the Triassic Basins of North Carolina. The areas with potential for natural gas development have not

been sufficiently characterized to determine whether the formations would be suitable for disposal of shale gas production wastewater. The sedimentary rocks of these basins generally have very low permeability, and natural fractures are responsible for nearly all of the permeability and groundwater movement in these basins. Disposal by injection into fractured rock presents difficulty in predicting the fate and transport of the injected wastewaters. These conditions suggest that Triassic Basins in North Carolina generally do not have suitable hydrogeologic conditions for disposal by well injections[2].

EPA has exempted "drilling fluids, produced waters, and other wastes associated with the exploration, development or production of crude oil, natural gas or geothermal energy" from regulation under the Resource Conservation and Recovery Act (RCRA) -- the federal statute that regulates hazardous waste. Since some exploration and production wastes may have the characteristics of hazardous wastes, but are not regulated under RCRA, oil and gas-producing states have generally developed specific standards for handling exploration and production wastes. Since North Carolina statutes and rules have not been written to address these particular types of wastes, existing state rules would allow disposal of all RCRA-exempt exploration and production wastes (other than oils and liquid hydrocarbons) in a municipal solid waste (MSW) landfill[2]. Although North Carolina has strong standards for design and construction of both industrial and MSW landfills, those standards were not developed for disposal of hazardous waste.

Federal and state regulators do not require most sewage treatment plants that accept drilling waste to test for radioactivity. More than 1.3 billion gallons of wastewater was produced by Pennsylvania wells over the past three years, far more than has been previously disclosed. Most of this wastewater — enough to cover Manhattan in three inches — was sent to treatment plants not equipped to remove many of the toxic materials in drilling waste. At least 12 sewage treatment plants in three states accepted gas industry wastewater and discharged waste that was only partly treated into rivers, lakes and streams. Of more than 179 wells producing wastewater with high levels of radiation, at least 116 reported levels of radium or other radioactive materials 100 times as high as the levels set by federal drinking-water standards. At least 15 wells produced wastewater carrying more than 1,000 times the amount of radioactive elements considered acceptable[19].

The problem with the hydrofracking waste is that when the chemicals are combined with the naturally occurring radioactive material a mixed waste is created which needs a specific enclosure in order to contain the radiation and also withstand the chemical mixture. Records from disparate corners of the United States show that wells drilled to bury this waste deep beneath the ground have repeatedly leaked, sending dangerous chemicals and waste gurgling to the surface or, on occasion, seeping into shallow aquifers that store a significant portion of the nation's drinking water. In 2010, contaminants from such a well bubbled up in a west Los Angeles dog park . Within the past three years, similar fountains of oil and gas drilling waste have appeared in Oklahoma and Louisiana. In South Florida, 20 of the nation's most stringently regulated disposal wells failed in the early 1990s, releasing partly treated sewage into aquifers that may one day be needed to supply Miami's drinking water[20].

Drilling produces copious amounts of waste, burdening regulators and demanding hundreds of additional disposal wells. There are more than 680,000 underground waste and injection wells nationwide, more than 150,000 of which shoot industrial fluids thousands of feet below the surface. Scientists and federal regulators acknowledge they do not know how many of the sites are leaking. Those wells are changing the earth's geology, adding man-made fractures that allow water and waste to flow more freely. From late 2007 to late 2010, one well integrity violation was issued for every six deep injection wells examined — more than 17,000 violations nationally. Also more than 7,000 wells showed

signs that their walls were leaking. Records show wells are frequently operated in violation of safety regulations and under conditions that greatly increase the risk of fluid leakage and the threat of water contamination[20].

Structurally, a disposal well is the same as an oil or gas well. Tubes of concrete and steel extend anywhere from a few hundred feet to two miles into the earth. At the bottom, the well opens into a natural rock formation. There is no container and waste simply seeps out, filling tiny spaces left between the grains in the rock like the gaps between stacked marbles. Deep well injection takes place in 32 states, from Pennsylvania to Michigan to California. Most wells are around the Great Lakes and in areas where oil and gas is produced, along the Appalachian crest and the Gulf Coast. They also appear in California and in Texas, which has more wells for hazardous industrial waste and oil and gas waste than any other state[20]. Federal rules divide wells into six classes based on the material they hold and the industry that produced it. Class 1 wells handle the most hazardous materials, including fertilizers, acids and deadly compounds such as asbestos, PCBs and cyanide. The energy industry has its own category, Class 2, which includes disposal wells and wells in which fluids are injected to force out trapped oil and gas. The most common wells, called Class 5, are a sort of catch-all for everything left over from the other categories, including storm-water runoff from gas stations.

The EPA requires that Class 1 and 2 injection wells be drilled the deepest to assure that the most toxic waste is pushed far below drinking water aquifers. Both types of wells are supposed to be walled with multiple layers of steel tubing and cement and regularly monitored for cracks. Operators are required to do mechanical integrity tests at regular intervals, yearly for Class 1 wells and at least once every five years for Class 2 wells. In 2010, the regulatory tests led to more than 7,500 violations nationally, with more than 2,300 wells failing. In Texas, one violation was issued for every three Class 2 wells examined in 2010. Such breakdowns can have serious consequences. Damage to the cement or steel casing can allow fluids to seep into the earth, where they could migrate into water supplies. Most well failures are patched within six months of being discovered, EPA data shows, but with as much as five years passing between integrity tests, it can take a while for leaks to be discovered. And not every well can be repaired. Kansas shut down at least 47 injection wells in 2010, filling them with cement and burying them, because their mechanical integrity could not be restored. Louisiana shut down 82 while 114 injection wells were shut down in Wyoming[20].

Another way wells can leak is if waste is injected with such force that it accidentally shatters the rock meant to contain it. A report published by scientists at the Department of Energy's Pacific Northwest National Laboratory and the University of Texas said that high pressure is "the driving force" that can help connect deep geologic layers with shallower ones, allowing fluid to seep through the earth[20]. Most injection well permits strictly limit the maximum pressure allowed, but well operators – rushing to dispose of more waste in less time – sometimes break the rules, state regulatory inspections show. According to data provided by states to the EPA, deep well operators have been caught exceeding injection pressure limits more than 1,100 times since 2008.

The cumulative effect of these exemptions and exclusions has created a federal void in environmental authority over natural gas operations, leaving the responsibility primarily up to the states. Although some states have oil and gas commissions to watch over natural gas production activity, the primary mission of these agencies has been to facilitate natural gas extraction and increase revenues for the states. In addition, when states issue permits to drill, they have not traditionally required an accounting of how the resulting liquid and solid waste would be handled. In short, their focus has not typically been on health and the environment.

Health Risks with Radiation Exposure

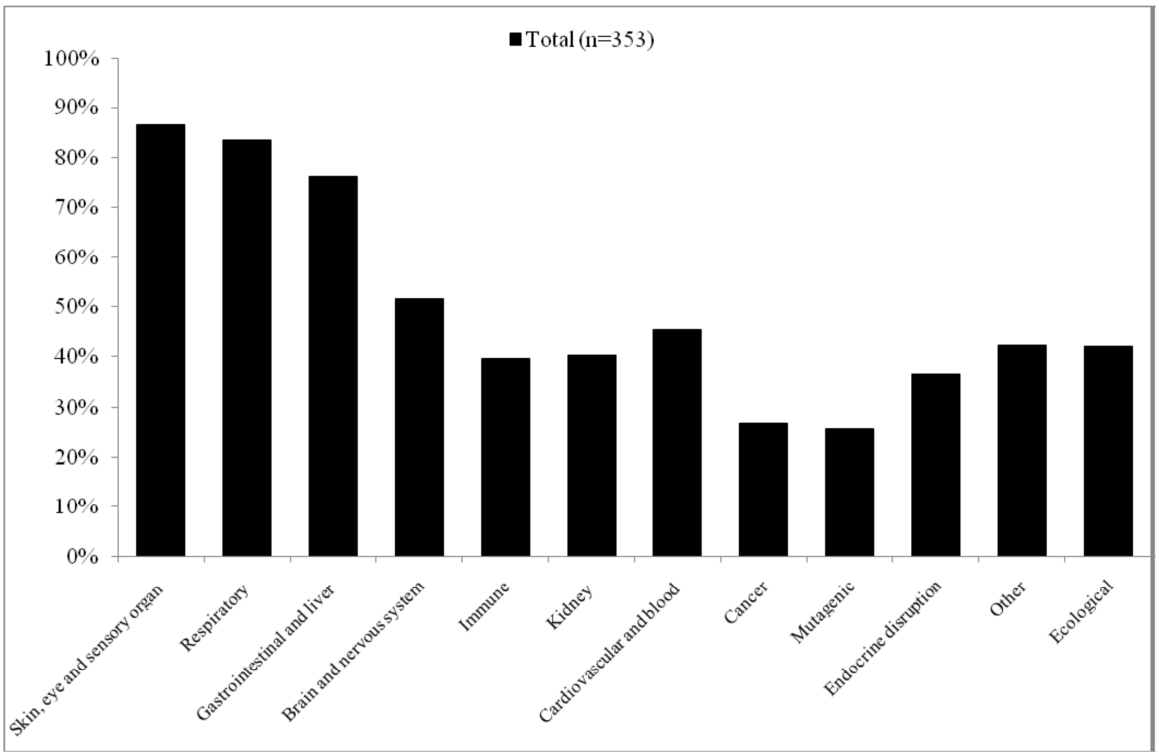
When understanding and determining the health risk involved with hydrofracking we must define the hazard and the amount of exposure. Those that are most at risk to the health effects linked to hydrofracking are children and pregnant women. Children are more vulnerable to environmental hazards because they eat, drink, and breathe more than adults on a pound for pound basis. Research has also shown that children are not able to metabolize some toxicants as well as adults due to immature detoxification processes. Moreover, the fetus and young child are in a critical period of development when toxic exposures can have profound negative effects[21]. Certain compounds, such as toluene, that are released as gas at the wellhead and also found in water contaminated by hydrofracking have the potential to harm pregnant women or women wishing to become pregnant. According to the U.S. EPA, studies have shown that toluene can cause an assortment of developmental disorders in children born to pregnant women that have been exposed to toluene. Pregnant women also carry an increased risk of spontaneous abortion from exposure to toluene[22]. In Wyoming, which contains some of the most active drilling fields in the country, they failed to meet federal standards for air quality due to fumes containing toluene and benzene in 2009.

Chemicals used in hydrofracking have been linked to breast cancer and reproductive health problems. Chemicals linked to cancer are present in nearly all of the steps of extraction—in the fracking fluids, the release of radioactive and other hazardous materials from the shale, and in transportation and drilling related air pollution and contaminated water disposal. According to the U.S. Committee on Energy and Commerce, hydrofracking companies used 95 products containing 13 different known and suspected carcinogens between 2005 and 2009 as part of the fracking fluid that is injected in the ground[22]. These include naphthalene, benzene, and acrylamide. Benzene, which is classified as a human carcinogen, is released in the fracking process through air pollution and in the water contaminated by the drilling process. The Institute of Medicine released a report in December 2011 that links breast cancer to exposure to benzene[23].

From the first day the drill bit is inserted into the ground until the well is completed, toxic materials are introduced into the borehole and returned to the surface along with flowback and other extraction liquids. In the western U.S. it has been common practice to hold these liquids in open evaporation pits until the wells are shut down, which could be up to 25 years. These pits have rarely been examined to ascertain their chemical contents outside of some limited parameters (primarily metals, chlorides, and radioactive materials). The Endocrine Disruption Exchange (TEDX) revealed in their report that extremely toxic chemicals are found in evaporation pits and indeed, these and other similar sites may need to be designated for Superfund cleanup[10]. In the eastern U.S., and increasingly in the West, these chemicals are being re-injected underground, creating yet another potential source of extremely toxic chemical contamination. In other words, what ends up in evaporation pits in the West will in other parts of the country be injected underground.

The technology to recover natural gas depends on undisclosed types and amounts of toxic chemicals. More than 75% of the chemicals used in hydrofracking could affect the skin, eyes, and other sensory organs, and the respiratory and gastrointestinal systems. Approximately 40-50% could affect the brain/nervous system, immune and cardiovascular systems, and the kidneys; 37% could affect the endocrine system; and 25% could cause cancer and mutations (Figure 5)[10]. More than 40% of the chemicals have been found to have ecological effects, indicating that they can harm aquatic and other wildlife.

Figure 5: Profile of possible health effects of chemicals used in natural gas operations



These results indicate that many chemicals used during the fracturing and drilling stages of gas operations may have long-term health effects that are not immediately expressed. To protect public health there should be full disclosure of the contents of all products, extensive air and water monitoring, coordinated environmental/human health studies, and regulation of fracturing under the U.S. Safe Drinking Water Act. Industry representatives have said there is little cause for concern because of the low concentrations of chemicals used in their operations. Nonetheless, pathways that could deliver chemicals in toxic concentrations at less than one part-per-million are not well studied and many of the chemicals on the list should not be ingested at any concentration. Numerous systems, most notably the endocrine system, are extremely sensitive to very low levels of chemicals, in parts-per billion or less. The damage may not be evident at the time of exposure but can have unpredictable delayed, life-long effects on the individual and/or their offspring[10]. The precautionary principle states that if an action of policy has a suspected risk of causing harm to the public or to the environment in the absence of consensus that the action or policy is harmful the burden of proof that is not harmful falls on those taking the action.

Workers/Community Exposure to Radiation

Hydrofracking presents a unique set of dangers to workers, the most pressing being exposed to radioactive materials. It is unclear who would be responsible for addressing the potential health and safety issues related to radiation exposure of hydrofracking workers. The potentially lethal threat to workers and the public that hydrofracking poses is simply unacceptable. Working in the hydrofracking business has the potential for exposure to a wide variety of airborne chemicals. The occupational limit for a radiation worker is 5,000 mrem/year. If a worker does not reach 500 mrem/year then they do not require a device to measure their exposure to radiation. Also the amount of radiation to the community cannot exceed 100 mrem/year[24]. The EPA is working with states and other key

stakeholders to help ensure that natural gas extraction does not come at the expense of public health and the environment. The EPA's focus and obligations under the law are to provide oversight, guidance and rulemaking that achieve the best possible protections for the air, water, and land where Americans live, work, and play. The EPA also invests in improving our scientific understanding of hydraulic fracturing, providing regulatory clarity with respect to existing laws, and using existing authorities where appropriate to enhance health and environmental safeguards.

The occurrence of environmentally high concentrations of radioactivity, specifically radium isotopes in oil field production waters is well documented. It appears that the radionuclides are leached from the clay minerals in the soil. The radium levels observed in most saline flowback from the Gulf Coast Region exceed proposed and existing radium discharge limits. Radium 226 and 228 activity was found in all 41 samples of brines in one survey. Activity ranged from 19 to 2800 pCi/l. Seventy-six percent of the samples tested contained 50 pCi/l of total radium[17]. Flowback samples from Louisiana platforms exhibited total radium activities of 605-1215 pCi/l in a recent study. It has been estimated that flowback from the Leeville Oil Field coastal Louisiana contributed up to 1.76 Curies of radium to the marsh around the field in a 5-year period. It is our understanding that some fields have been in production for 40 years or more. It is therefore possible that the total radium released to the environment at these old fields could be in excess of 10 Curies over the lifetime of the fields[17].

Those helping to pull oil and gas from the ground are regularly exposed to cancer-causing silica dust. According to a letter sent from the AFL-CIO, Mine Workers (UMWA) and the United Steelworkers (USW) to the top federal safety agencies working in the hydraulic fracturing industry exposures workers to high levels of crystalline silica, putting them at risk of developing silicosis, lung cancer and other debilitating diseases. The U.S. Department of Labor's Occupational Safety and Health Administration and the National Institute for Occupational Safety and Health issued a hazard alert on ensuring that employers in hydraulic fracturing operations take appropriate steps to protect workers from silica exposure. Silica sand is a major component of the hydrofracking process. The sand is mixed with large volumes of water and chemical additives and injected under high pressure by drilling into shale rock. Massive quantities of sand are used and workers are at risk of high levels of exposure during multiple points of the hydrofracking process. A study by NIOSH found that 47 percent of all oil and natural gas workers breathe air that exceeds the safe breathing limits for silica dust[25]. In addition to the health hazards, workers in the oil and gas extraction industries face high rates of fatal occupational injuries. Between 2003 and 2009, there were 27.5 deaths per 100,000 workers, a rate more than seven times higher than the fatality rate for all U.S. workers.

The State of Louisiana, Department of Environmental Quality has recently issued a notification concerning a potential health hazard associated with handling pipe used in oil and gas production that may be contaminated with radioactive scale from naturally-occurring radioactive materials (NORM). The concern is the possible inhalation and/or ingestion of scale particles contaminated with radium-226 and possibly other radioactive material that may become airborne during welding, cutting or reaming of pipe containing the radioactive scale. The State of Louisiana is using the term for this material Technologically Enhanced Natural Radiation (TENR), which is a subgroup of a larger group, referred to as naturally occurring radioactive materials or NORM. Contaminated piping from refineries has been found in scrap iron yards in New Orleans, Baton Rouge, and Lake Charles. The State of Mississippi has found contaminated pipe used in the construction of bleachers at schools. The Nuclear Energy Division (NED) has found the concentrations of radium in oil field production ponds to be elevated. Readings made recently in a pipe reaming area at a pipe yard in Houma were such that monitoring of employees would be required if it were a licensed nuclear installation. The magnitude of the problem is difficult to

estimate, but it is not unrealistic to expect contamination at all oil and gas production sites and pipe handling facilities[17].

According to one study by the CDC National Institute for Occupational Safety and Health (NIOSH), workers in the oil and natural gas industries are seven times as likely to die on the job as workers in other industries. The three most common types of fatal accidents that those working for well-servicing companies fall victim to are motor vehicle accidents (29 percent), being struck by objects (20 percent), and explosions (8 percent). Motor vehicle accidents are a leading cause of death among oil and gas industry workers in part because of an exemption from federal highway safety rules that allow truckers to work longer hours than drivers in most other industries[26]. In March 2011, National Transportation Safety Board Chairwoman Deborah A.P. Hersman wrote a letter to the Department of Transportation asking the federal agency to end this exemption. Last December, the Federal Motor Carrier Safety Administration declined, saying the exemption had already "been in place for nearly 50 years. "Other oil and gas industry trucks crash due to poor maintenance. According to the Pennsylvania State Police, 40 percent of 2,200 oil and gas industry trucks inspected between 2009 and February 2012 had to be removed from the road because they were too unsafe to drive[26].

Hydraulic fracturing has become a popular method of gas extraction because of new drilling techniques and the discovery of large shale reserves across the eastern seaboard. The practice of hydraulic fracturing has come under fire recently however, due to a number of environmental concerns concerning the controversial process. Among other dangers, residents living near hydrofracking sites have reported issues like dust problems, air pollution, and contaminated groundwater from fracking fluids. Efforts to force the gas industry to reveal what is included in fracking fluids has been blocked, and a number of states have enacted controls to slow down the spread of hydrofracking until its potential environmental effects have been further researched. Until it becomes safe for the environment, safe for the drinking water and safe for workers, communities are correct in opposing hydrofracking and elected officials have a responsibility to stand up to the gas industry and protect the public from its dangers.

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