Shale Gas Exploration and Production:
Potential Health and Environmental Impacts
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UKRAINE
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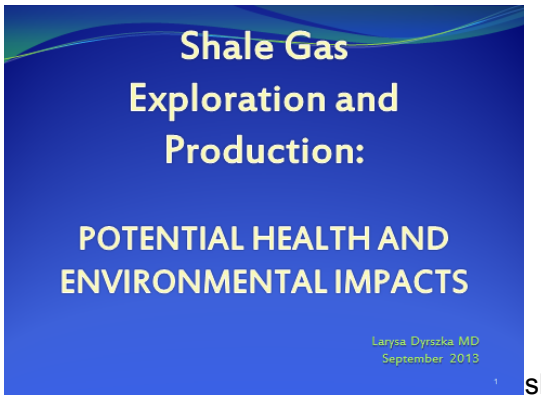

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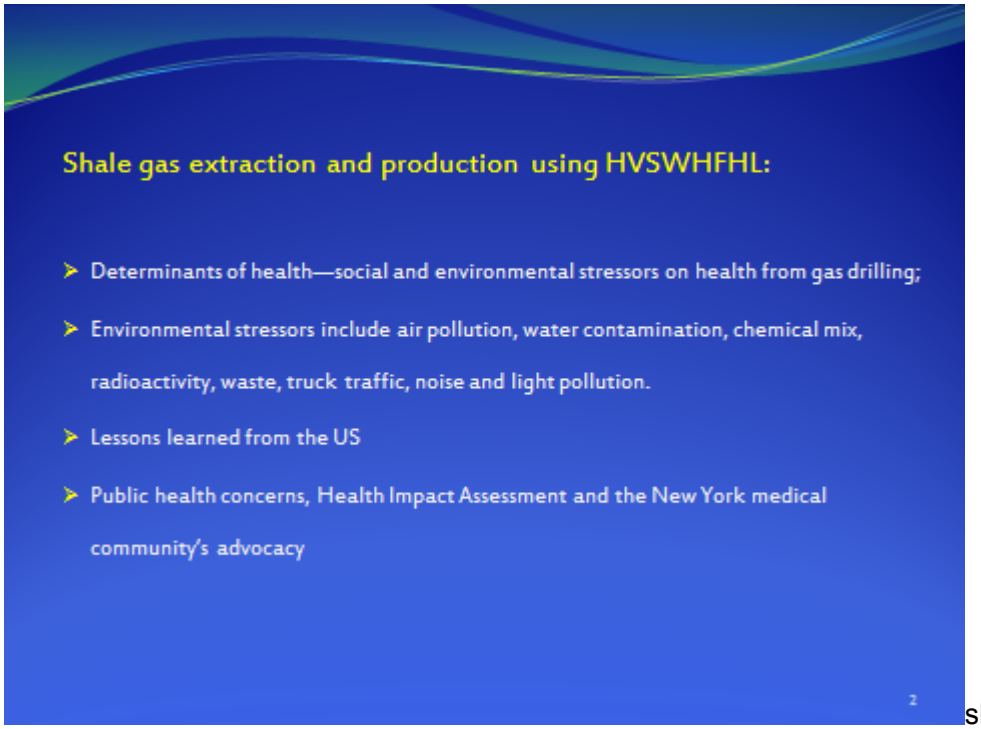

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In this presentation, I'd like to introduce the determinants of health, focusing on the social and environmental stressors from gas drilling. Then I'll review what we know about health impacts of gas drilling in the US, and I'll tell you about the advocacy of the New York medical community.

slide 3

The World Health Organization defines health as *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"* (WHO 1948).

Overall health is influenced by a broad range of both individual and collective factors- and their interactions; these factors are referred to as "determinants of health".

The impacts from each of these determinants vary, but in general the health of a population depends mainly on the combined influence of the social environment and the physical environment. (the yellow and purple in the diagram).

Who specifically might be affected by the shale gas extraction process? And here I mean the entire process, not just fracking.
--people who mine silica sand, or live nearby (from silicosis and cancer)
--people in the areas where gas drilling occurs (stress of rapid industrialization, accidents, crime, air and water pollution)
--people near pipelines (explosions and air pollution)
--people who receive their water from gas drilling areas (water pollution)
--people who are downwind of gas producing or processing areas (air pollution)
--those whose regions receive gas drilling waste
--Marcellus shale gas consumers
--those who are workers in the gas industry
--whose health is already compromised, or who are vulnerable

as well as their animals, water , air and crops.

slide 4

One of the first papers that found air pollution was the greatest risk to human health was from Colorado.

In a follow-up to that study, MacKenzie found that residents living < ½ mile from wells were at greater risk for health effects from gas development than residents living >½ mile from wells. Subchronic exposures to air pollutants presented the greatest potential for illness, with benzene as the major contributor to the risk.

The study by Dr Colborn this year tested air before and after the start of drilling and fracking operations. Once drilling operations started, 44 air pollutants were detected at a house located about 1 kilometer away from a well pad.

The report from a federal agency, the National Oceanographic and Atmospheric Administration, discusses a study in Utah with high level ozone during the winter—something that is not supposed to happen.

Because ozone precursor pollutants are emitted in large quantities by the region's oil and natural gas drillers, the regulators concluded that they were the main contributors to the toxic emissions.

High concentrations of ozone can trigger asthma attacks and inflame conditions for people with bronchitis, emphysema and other respiratory ailments.

Children are especially vulnerable because their lungs continue to grow and enlarge until about age 18. Plus they breathe faster and are closer to the ground. The result of chronic ozone exposure can be brittle lungs like those of an elderly adult.

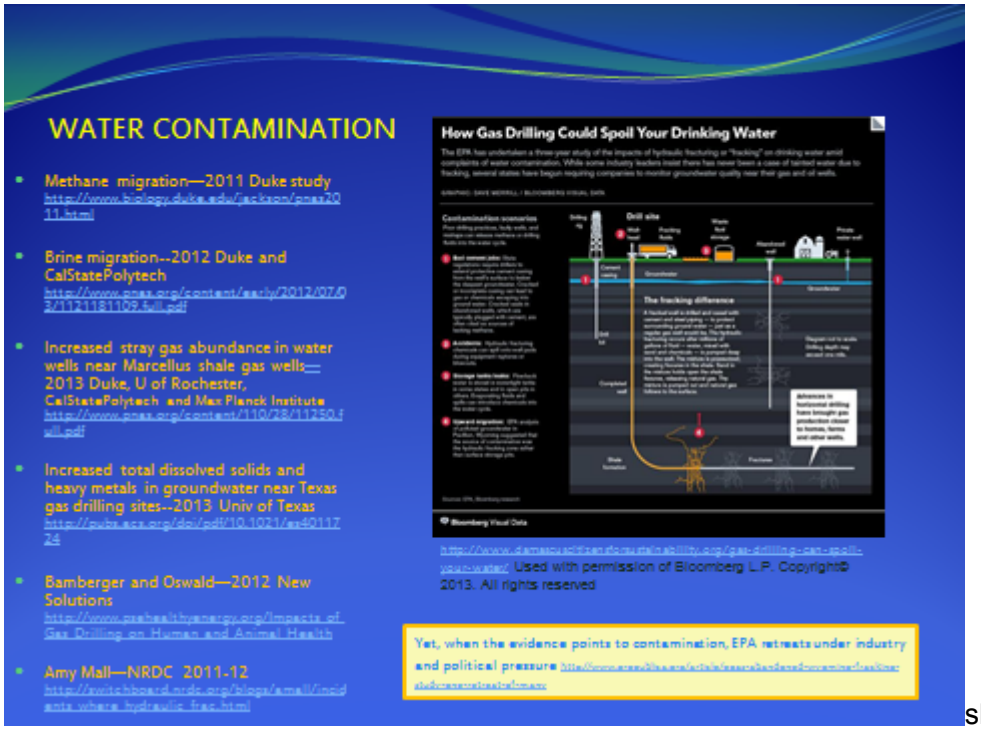
Air pollution has also been shown to be associated with neurodevelopmental disorders, lower IQ in babies born to mothers with polycyclic aromatic hydrocarbon exposure during pregnancy and learning disorders in exposed children.

And the World Health Organization has now classified diesel exhaust as a definite carcinogen, raising additional concerns for workers and other vulnerable groups exposed to diesel exhaust.

Total air pollution in an area of Texas which is heavily drilled, is more than double all the auto and truck exhaust. That area has had a recent increase in the incidence of asthma—to 25%--compared to half that in other Texas cities.

There are also the pipelines, compressor stations, processing plants and power plants that produce extensive air pollution.

Hydrogen Sulfide gas, poisonous and deadly in low concentrations, is released in certain areas during gas drilling operations. Also released are nitrogen oxides, sulfur dioxide, formaldehyde, volatile organic compounds and particulate matter.



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There is growing evidence in peer-reviewed literature from major US universities that water has become contaminated when gas drilling occurs nearby.

In the 2011 paper on methane migration, they found evidence that aquifers overlying the Marcellus shale formations have explosive levels of methane contamination in drinking water and this was associated with shale gas extraction.

In the July 2013 paper, 141 drinking water wells were analyzed across Pennsylvania. They detected thermogenic methane in 82% of drinking water samples, with the highest concentrations in homes <1 km from natural gas wells. Methane is a problem for humans when it displaces oxygen and breathing becomes difficult. People in Pennsylvania have lost consciousness in their homes. In other cases methane accumulated in the home has caused explosions.

In the Texas paper, arsenic, selenium, strontium, barium, and total dissolved solids (TDS) reached their highest concentrations in water coming from areas in close proximity to natural gas wells. Arsenic causes bronchitis, gastroenteritis, skin changes, neuropathy, various cancers, and death. Excessive selenium causes growth retardation, hair and skin changes, and neurological disturbances. Strontium accumulates in bones and can weaken them, and the effects are worse on children's bones. The signs of barium toxicity include low blood potassium, cardiac arrhythmias, respiratory failure, gastrointestinal dysfunction, paralysis, muscle twitching, and elevated blood pressure.

In their recent paper in New Solutions, Bamberger and Oswald researched several cases where chemicals associated with drilling were implicated in negative health outcomes.

They focused mostly on animals because they are the sentinels of disease in humans due to the fact that their reproductive cycles and their lives are shorter.

One of several cases they describe was the death of 17 cows within one hour from direct exposure to hydraulic fracturing fluid. The final necropsy report listed the most likely cause of death as respiratory failure with circulatory collapse. The hydraulic fracturing fluid contained petroleum hydro-carbons and quaternary ammonium compounds plus other toxins.

Two cases provided inadvertent control experiments since herds of cows were kept in different pastures. In brief, cows exposed to gas drilling chemicals had significantly more deaths, stillbirths and congenital malformations.

Two other cases involved deaths and congenital malformations of companion animals and one of the implicated routes of exposure was waste spreading on roads which the animals either drank or licked off their paws; and in the other case it was from an aerated impoundment of waste. In addition, their water had turned after drilling but they had continued to use it.

In one of the homes, a child became ill with fatigue, confusion, abdominal and back pain. After several animals in the household had died, the doctor became suspicious of toxins and testing revealed arsenic in the child. The family then stopped drinking the water despite results which showed the well water was safe and he eventually recovered, having lost a year of school. In these cases, there were 25 wells within two miles of the homes, and there was also the aerated impoundment, and two compressor stations within a mile. While checking for other toxins in these two homes, random urine tests on family members revealed phenol, a metabolite of benzene; symptoms observed by families in both homes included extreme fatigue, headaches,

nosebleeds, rashes, and sensory deficits (smell and hearing). Were it not for the deaths of the animals, the human health effects would not have been found.

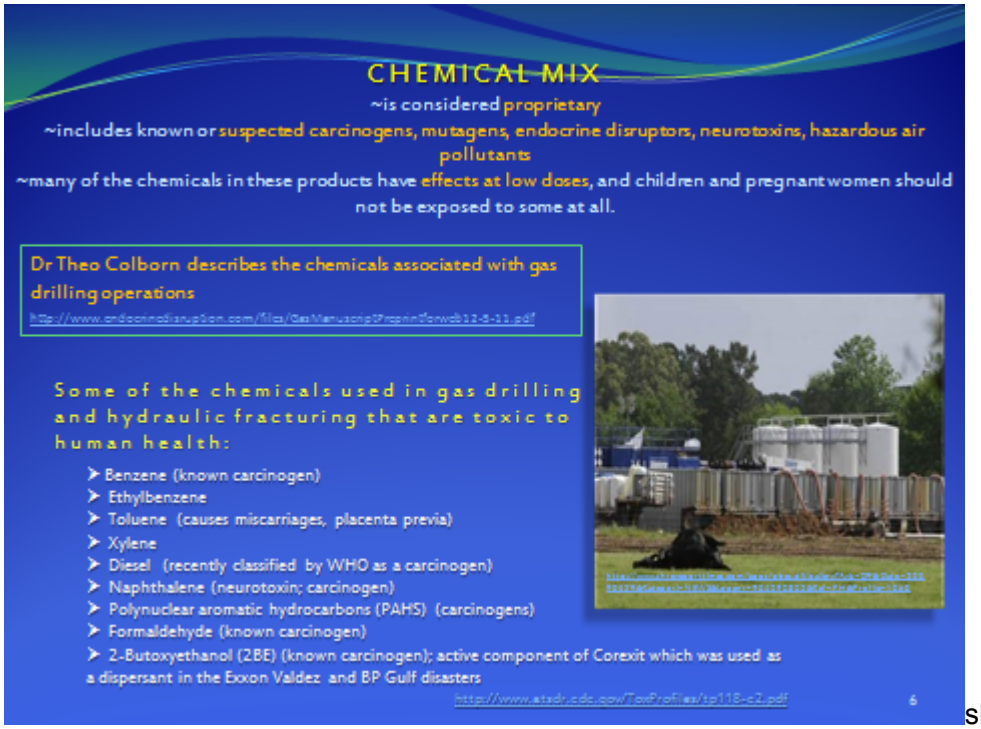
Their study illustrates several plausible links between gas drilling and negative health effects.

The US Environmental Protection Agency (EPA) has studied several cases of water contamination—in Texas, Dimock Pennsylvania and Pavillion Wyoming. Yet, when the evidence points to contamination, EPA retreats under industry and political pressure.

The graphic on the right shows potential gas and fluid movement pathways and how connections can be made from formation layers to aquifers, underground structures and the surface.

There are natural and artificially induced fractures that can act as conduits.
Abandoned wells do the same.
Spills can contaminate water.

Casing is an inch or so thick. It's man-made, sometimes flawed, and doesn't last forever.
6-9% of casings immediately fail, and there's a 60% failure in 30 years.



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The picture on the right is from the incident described by Bamberger and Oswald in their paper -- the deaths of 17 cows within one hour from exposure to hydraulic fracturing fluid. What do we know about the chemicals which are so toxic that they can kill cattle?

Not much because the gas industry calls the formulations “proprietary” and divulging the information might give their competitors an unfair business advantage, and therefore it is kept secret.

In fact, a doctor cannot obtain the chemical blend in the case of an emergency, as happened in the case of a nurse in Colorado who treated a worker with a chemical spill on his clothing. He was OK, she almost died from multiple organ failure and during the time she was in the intensive care unit, her doctor could not obtain the name of the chemical that spilled.

In 2004 **Dr. Theo Colborn**, the scientist who first used the term “endocrine disruptors” began investigating the makeup of drilling fluids. She was motivated by the story of a Colorado resident, Laura Amos, who suspected her adrenal tumor was tied to water contamination from a nearby gas well. To figure out what was in the water, Dr Colborn collected shipping manifests and when a well spill or a blowout at a drilling site occurred, she took water and soil samples and tested them for contaminants. Her group identified 944 products used in natural gas operations in the U.S., from suspected cancer-causing compounds like benzene to the compound called 2-BE. Laura Amos suspects her adrenal tumor was tied to the 2-BE used by the driller.

42% of the products on Dr. Colborn’s list are endocrine disruptors--chemicals that can interfere with the hormonal function of the body and can also interfere with the development of individuals before they are born. Hormones are involved in reproduction, growth, development and metabolism.

Many of the chemicals in these products have severe effects at low doses, and children and pregnant women should not be exposed to some at all.

The damage of endocrine disruptors may not be evident at the time of exposure but can have unpredictable, delayed, life-long effects on the individual or their offspring. One of the first recognized endocrine disruptors was diethylstilbestrol (DES). In the 1950s and 1960s pregnant women were prescribed this synthetic estrogen to prevent miscarriages. Not only did DES fail to prevent miscarriages, but it also caused health problems for many of these women's children. In 1971, doctors began reporting high rates of unusual vaginal cancers in teenage girls. Investigations of the girls' environmental exposures traced the problem to their mothers' use of DES. The girls also suffered birth defects of the uterus and ovaries, and immune system suppression.

Because endocrine disruptors affect the development of the body's vital organs and hormonal systems, infants, children and developing fetuses are more vulnerable to exposure. And as was the case with DES, parents' exposure to certain chemicals may produce unexpected -- and tragic -- effects in their children, even decades later. Some of the drilling and fracking chemicals have been linked to attention deficit and hyperactivity disorder (ADHD), autism, diabetes, thyroid disorders and infertility.

There are no completed studies of the effect of endocrine disrupting chemicals used during fracking and drilling on pregnant women and children.

Here is a very short **list of toxins**—there are many more.

One of these, 2-Butoxyethanol (2BE) (a known carcinogen), is a solvent that, at very low doses (as low as 0.02 parts per million) affects the endocrine system and which causes adrenal, kidney and liver tumors, blood dyscrasias and other human health problems.

Benzene primarily affects the central nervous system (CNS) and the hematopoietic system, resulting in anemia and leukemia. Acute benzene toxicity is characterized by CNS depression. Symptoms may progress from light-headedness, headache, and euphoria to respiratory depression, apnea, coma, and death. Benzene concentrations of about 20,000 ppm are fatal to humans within 5 to 10 minutes. With gas drilling, it is the subchronic exposures to benzene that are most likely to occur, and this was documented in the recent Colorado study by MacKenzie; some of the health problems that might be encountered are rather non-specific, like fever, blood disorders, fatigue, and anorexia. It is too early to study the long-term problems like cancer.

Regarding toluene, evidence suggests that the risk for pregnancy problems, as well as developmental delays and neurobehavioral difficulties, is higher for the children of women who were exposed to high concentrations of organic solvents during pregnancy than for those who have not. (2010 http://www.ncbi.nlm.nih.gov/pubmed/20377315.)

And xylene exposure can occur via inhalation, ingestion, eye or skin contact. The main effect of inhaling xylene vapor is depression of the central nervous system, with symptoms such as headache, dizziness, nausea and vomiting. The effects can begin to occur with exposure to air levels of about 100 ppm. Long-term exposure may lead to headaches, irritability, depression, insomnia, agitation, extreme tiredness, tremors, impaired concentration and short-term memory. Levels of 200 ppm or greater can irritate the lungs, causing chest pain and shortness of breath. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2996004/)

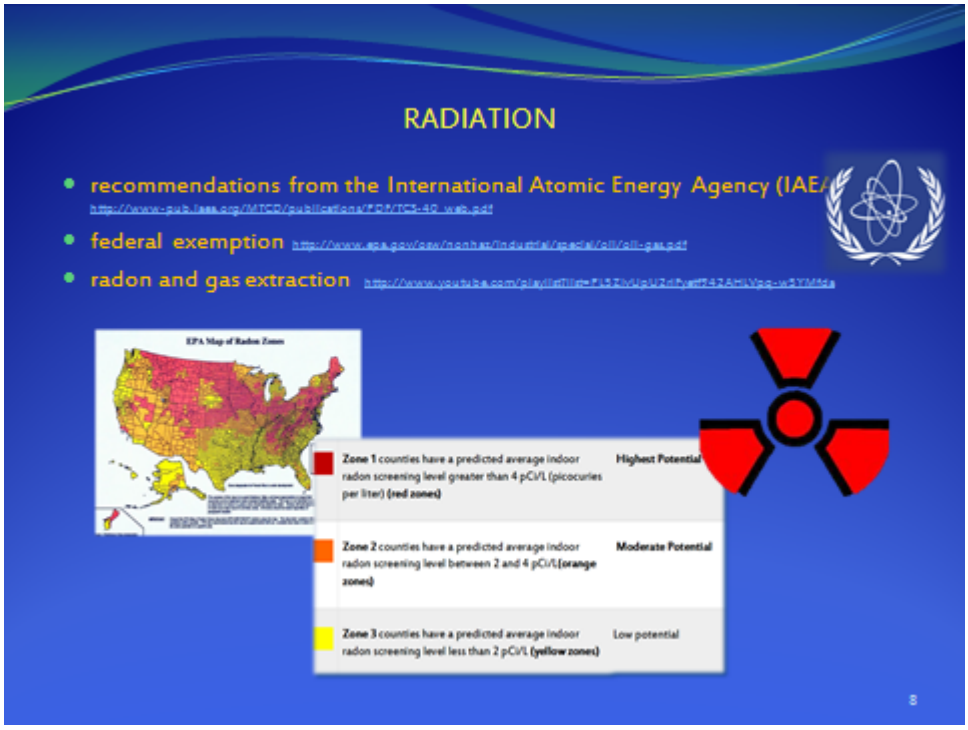
slide 7

In the waste is extremely salty “brine”, at least 5-10X the salinity of the sea.

And also brought up are naturally occurring volatile organic hydrocarbons such as benzene, ethylene, toluene, and xylene, as well as radionuclides which cause cancer, reproductive problems and neurological issues.

Shales, more than any other kind of rock, trap heavy metals such as lead, arsenic, barium, strontium, and chromium. And when shale is fracked, these heavy metals are released and brought to the surface with the gas and produced fluids.

To dispose of the waste--underground injection wells (which cause earthquakes), soil farms, road spreading (as de-icers and dust control), and dispersal into streams and rivers via waste treatment plants are currently used.



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For decades we have known the Marcellus shale to be more radioactive than other shales.

The International Atomic Energy Agency has recommendations regarding radioactivity at oil and gas mining sites, and most countries which are members adhere to the recommendations. The US is a member but has instead exempted from federal oversight the materials that come from down-hole which are, in many cases, radioactive.

The radioactive elements found in Marcellus shales include uranium, thorium, radium, polonium and also radon.

Radon is the leading cause of lung cancer among non-smokers and the second leading cause among smokers. 21,000 lung cancer deaths per year in the US are attributed to radon exposure. Radon and its radioactive decay products enter the body primarily through inhalation. Most of the radon is exhaled prior to radioactive decay but some of the solid radioactive polonium and lead remain in the lungs and are the elements which cause cancer. Although zero is the only “safe” level for radon exposure, mitigation must be done for indoor levels of 4 picoCuries per liter in the US. The World Health Organization recommends mitigation at 2.7 picoCuries per liter (or about 100Bq/m^3.

The map shows radon concentrations in the US.

Areas overlying the Marcellus shale have high indoor radon, on average, already. Residents of many of these counties, with the richest shale deposits, have average radon concentration of 4 picoCuries per liter in their homes already--those areas shown as dark red-- and will be at even greater risk from radon delivered to their gas stoves. The reason for this concern is that the

shale gas taken from the Marcellus formation has high radon concentration—about 30 picoCuries per liter. (For reference, one pCi/L is equivalent to 37 Bq/m^3.)

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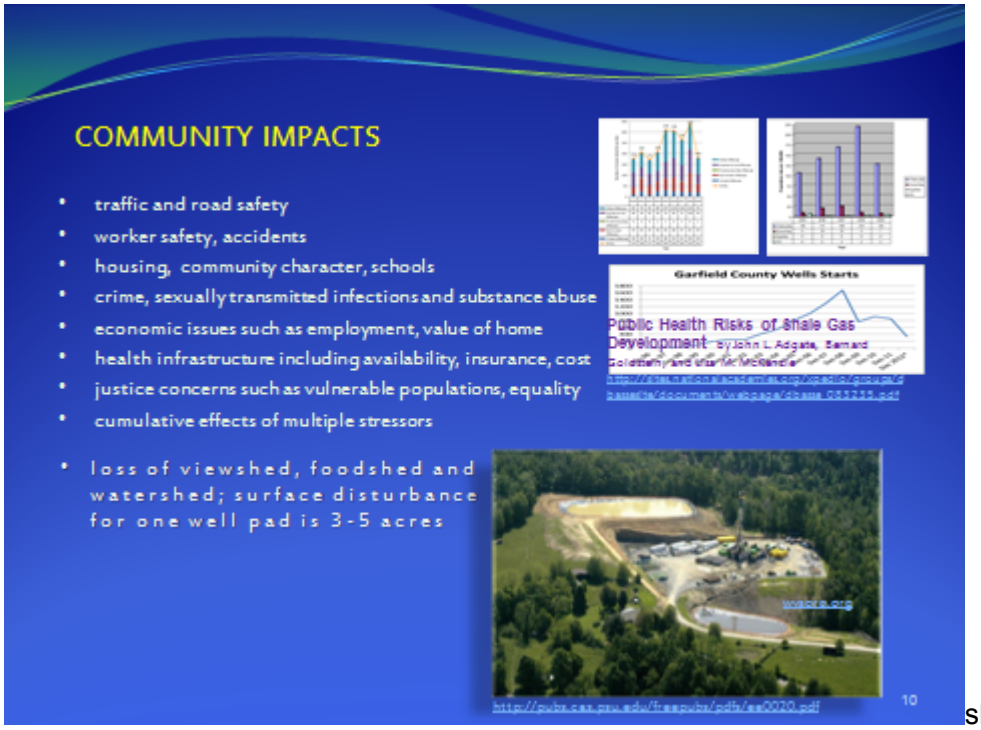
Large quantities of silica sand are used during the hydraulic fracturing process, and it is mined primarily in Minnesota and Wisconsin, and local residents are concerned about their air.

In the course of transport silica dust is released into the air, causing a hazard to those employees involved in handling silica sand.

Silicosis is an incurable but preventable lung disease. In addition to being an occupational lung carcinogen, inhaling silica dust causes chronic obstructive pulmonary disease (COPD), chronic renal disease and various autoimmune diseases. Individuals with silicosis are known to be at higher risk of tuberculosis. And these illnesses can impact the community in which the workers live.

The Occupational Safety and Health Administration has just proposed rules to limit crystalline silica, which would prevent nearly 700 deaths a year.

No health agency has looked at the residents living nearby.



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It is important to recognize that potential impacts could be both positive and negative.

In this particular land use-- shale gas development-- it is clear that the gains are often in the form of a short-term boom for a few, with a resultant bust for the whole community.

A cornerstone of the industrialization that comes with fracking is all the **truck traffic** -- hundreds of trucks a day travel on country roads never built for large trucks or the amount of wear and tear. Accidents are common.

Community character changes, with **increased rate of crime**. There is also a documented **increase in sexually transmitted diseases with the influx of workers** for which the community's healthcare system is not prepared. On the top, the left graph shows police arrests from 2000 to 2009; top right graph shows incidence of sexually transmitted infections from 2005 to 2009. And the lower graph shows the number of wells spudded from 1996 to 2012. As the number of wells increased, so did crime and incidence of sexually transmitted infections. After 2008 the number of wells (and also workers) started to decrease, and so did crime and sexually transmitted infections.

Schools are strained.

Housing becomes unaffordable for some of the residents when workers arrive in a community, mostly because landlords know these new workers will pay a higher rent.

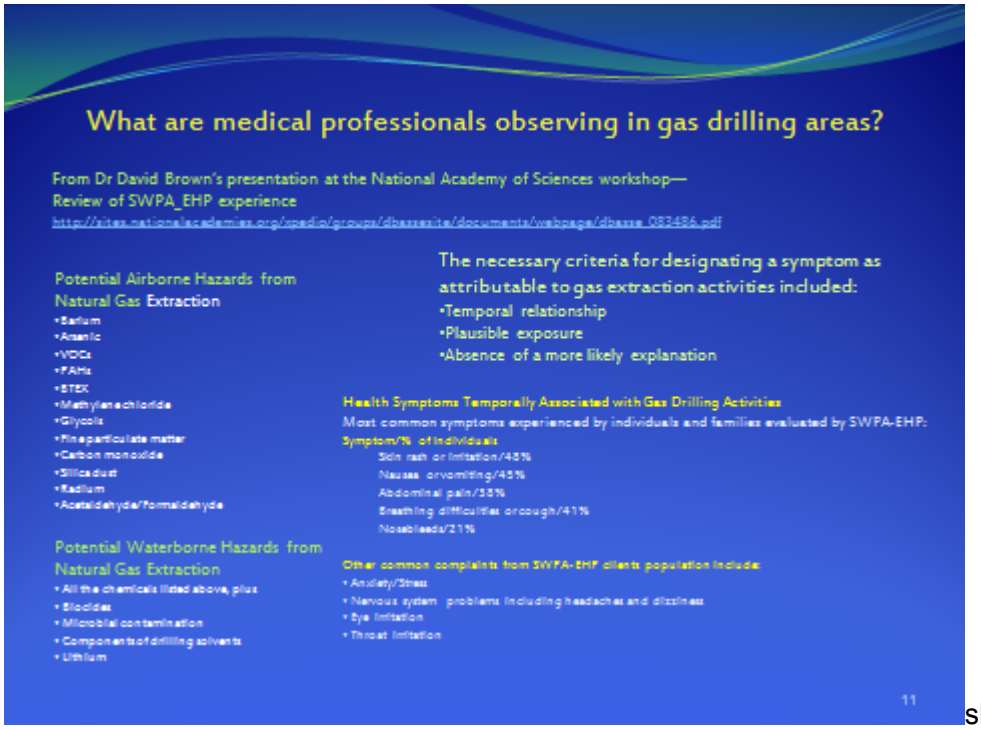
Homes with **water contamination** cannot be sold.

Environmental and social justice concerns include protection of children from environmental risks, and actions to address environmental justice in minority and low-income populations.

Yet, in the US, gas drilling frequently occurs in areas which have underserved, rural populations and near **vulnerable group activities such as schools**.

People already under **stress** from an underlying illness, or poor socioeconomic status, or because they are simply very young or very old and therefore a vulnerable population, suffer environmental impacts less well than people who are not so stressed.

On the bottom right is the surface disturbance from one well being drilled, 3-5 acres. Not only is there a loss of viewshed, but of foodshed and watershed.



slide 11

There are medical professionals who are working in the gas fields who have made observations about the health impacts.

This slide summarizes some of Southwest Pennsylvania's Environmental Health Project's experiences..

They set out to identify the pathways for contamination and the likely chemicals to which individuals are exposed. A review of the literature of air exposures led the toxicologist to produce a list of compounds that have potent physiological impacts and high concentrations of them are found in various phases of the extraction process.

These are the classes of pollutants that are most likely to impact human health through the air pathway:

VOC-volatile organic compounds
PAH-poly-aromatic hydrocarbons
BTEX-Benzene, Ethylbenzene, Toluene and Xylenes

In the short term, these chemicals can cause some of the symptoms listed on the slide. Many of these are known carcinogens or have other long-term health impacts.

The early results from the Southwest Pennsylvania Environmental Health Project study implicate air contamination as the likely cause of three-quarters of the associated illnesses. In some cases, high levels of fracking-related air pollutants were found in the air inside of people's homes.

Dr Brown describes the necessary criteria for designating a symptom as attributable to gas extraction activities, and that includes:
•**Temporal relationship** – Development of symptom (or exacerbation of pre-existing symptom) after onset of gas extraction activities
•**Plausible exposure** – Identifiable exposure source in proximity to the individual experiencing symptoms
•**Absence of a more likely explanation** – Symptoms were not attributed to gas extraction activities if an individual had an underlying medical condition that was as (or more) likely to have caused the symptom

***It is too early to be seeing significant spikes in cancer in our area, although in Texas where gas drilling has been going on for much longer, the breast cancer rate is higher compared to less drilled counties.

Additional concerns:

Published epidemiologic studies relating shale gas production to health are virtually nonexistent which makes it challenging to scientifically validate anecdotal reports, of which there are many.

And doctors are not routinely trained to evaluate for environmental contamination, so they may not ask the questions, nor even be familiar with the chemicals and other possible toxins.

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There is no public health agency in the United States that is seeking and compiling information about people who have been adversely impacted by shale gas development.

Because information about health is not being collected systematically by government agencies, and so is difficult to obtain at best, and suppressed in some cases, grassroots groups are attempting to fill that void.

Grassroots organizers, like Jenny Lisak, have now compiled over 1500 reports of people who have been harmed.

Non-disclosure agreements are common, and prevent important information-sharing, such as this case in Pennsylvania. I know of numerous cases where significant health information cannot be publicly shared since the families signed a non-disclosure agreement. The way that works is that if a family has a legitimate complaint of health or environmental problems, they may receive a settlement from the gas company, like money or water delivery or a new filtration system, but in return for that the family has to sign this document which prevents them from discussing the terms and reasons for the settlement.

Another obstacle that has recently emerged in certain states is the sharing of medical information that doctors receive from industry in order to treat their patients. In Pennsylvania and Colorado, doctors are required to sign a non-disclosure agreement in exchange for life-saving information.

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A series of online educational modules has been developed by Physicians, Scientists and Engineers for Healthy Energy (PSE) to educate medical professionals.

The Southwest Pennsylvania Environmental Health Project (SWPA-EHP) has published a *Medical Toolkit* for medical professionals which focuses on addressing patient concerns and symptoms.

Drs Michelle Bamberger and Robert Oswald, the guest editors of an online journal called New Solutions, recently had an entire volume dedicated to health impacts and gas drilling.

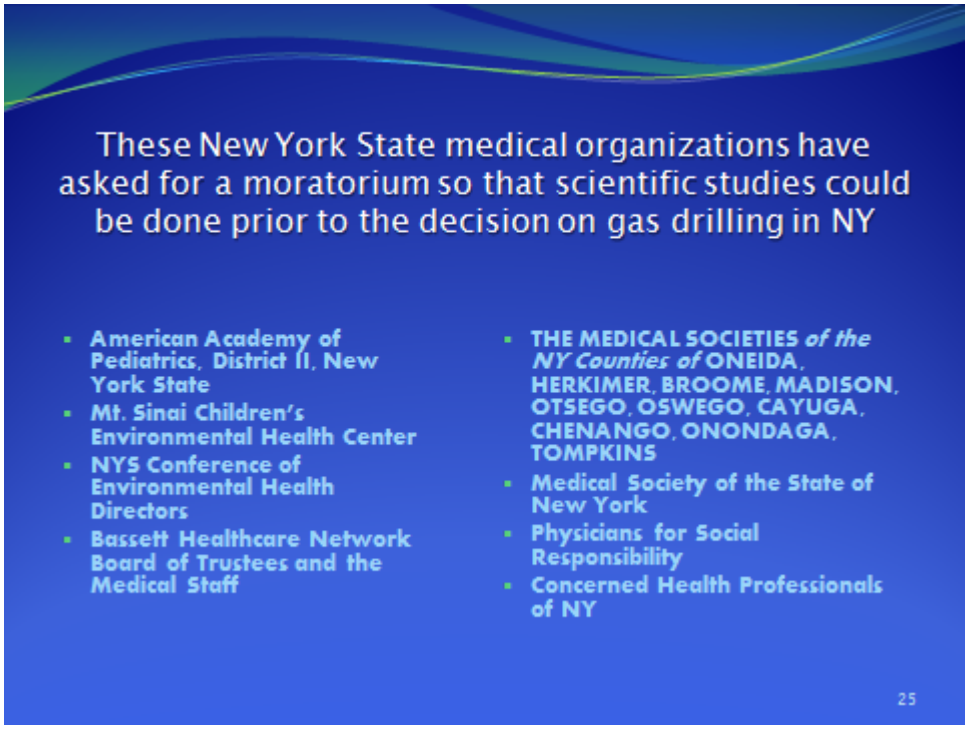
Earthworks Oil and Gas Accountability Project published a survey of symptoms of impacted people and distance from wells.

Drs Adgate, Witter and Wernham were the lead authors on the first Health Impact Assessments on gas drilling.

Dr Sandra Steingraber has been an outspoken advocate for health rights, and she and I co-founded Concerned Health Professionals of New York.

And Dr Theo Colborn has been documenting health impacts of chemicals and air toxins in Colorado since this industry took hold there.

There are more trailblazers…this was just to name a few.



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In the US, doctors mostly work in private practices or in hospitals, and not for the state. Doctors generally organize by region, like New York, and also by specialty, so for example all the pediatricians belong to the American Academy of Pediatrics (AAP), and there are branches in every state. This organization, supported by dues from the members, in turn supports research and has committees that develop best practices which pediatricians follow, like immunization schedules. The AAP has an advocacy committee which advises pediatricians about issues which are important for the health of children. We have gathered as a group and lobbied our legislators in support of certain laws to protect children.

The medical community of New York has become active in its advocacy on the gas issue.

Three years ago there was a moratorium bill introduced in New York. Since I was a pediatrician, I asked my state pediatric society if they would write a letter of support for the moratorium bill, and they did. With a copy of that memo we went to all the state legislators. They were impressed with the letter from a medical group as large as the pediatric society of the state, representing more than 6,000 pediatricians and millions of children across the state. The bill passed with a landslide in both houses and I believe the pediatricians' advocacy helped.

THE MEDICAL SOCIETIES of the Counties that would be drilled first in New York issued a statement asking for precautionary measures until cause and effect relationships are fully established scientifically.

The physicians in the other medical organizations listed here all support a moratorium on natural gas extraction with fracking until further studies evaluate its effects on human health and the environment.

The medical community of NY State has written five detailed letters to Governor Cuomo of New York, and they can all be found on our website www.concernedhealthny.org . Our letters cite growing evidence from Texas, Wyoming, Louisiana, North Dakota and Pennsylvania that documents worsening health metrics among residents living close to gas wells and related infrastructure such as compressor stations and waste pits.

In our letters we support the planning and implementation of a Health Impact Assessment…

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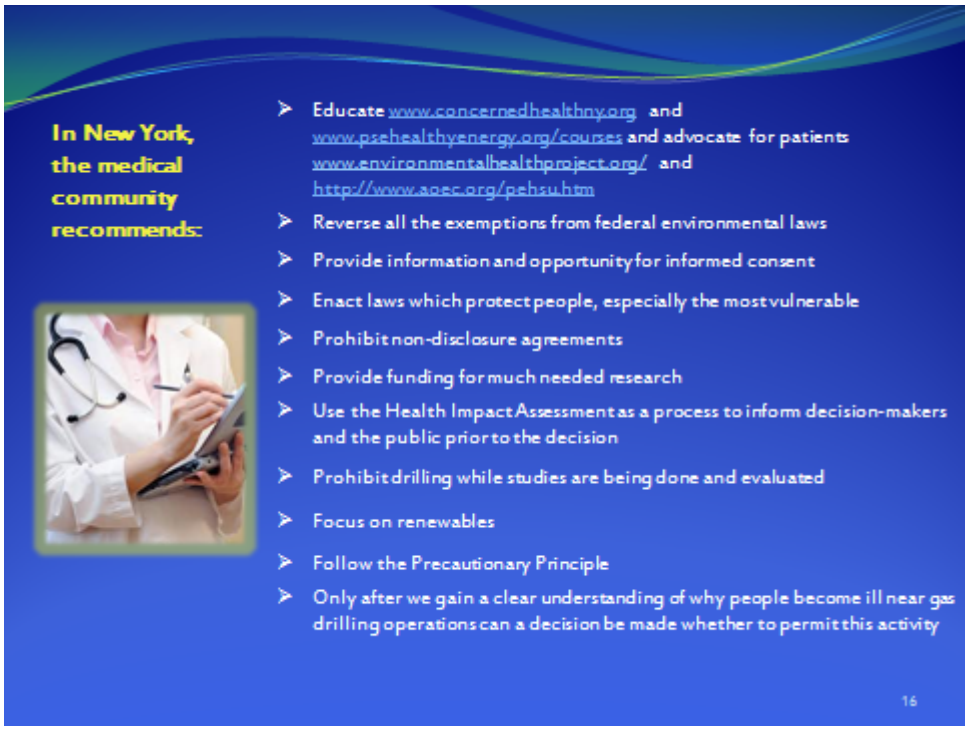
Where gas drilling has not yet begun, there is a process that could bring public health to the table. However, it must be done prior to the development of regulations and certainly before issuing permits. It is particularly important in the case of gas exploration and production because health impacts must be taken into account before deciding whether to go forward with the largest land use decision of our time.

Health Impact Assessment was first described at a conference of the World Health Organization in 1999 and documented in the Gothenburg Consensus paper.

An HIA would add value to the decision whether to permit gas drilling because it would include:

- current health literature and it would provide for the inclusion of future research
- the medical profession
- possible exposure pathways, even if remote.
- direct and indirect impacts
- consideration of all population groups
- recommendations which would improve health outcomes
- a plan for monitoring and evaluation

To date, New York State has refused to order such a study, despite requests from numerous medical organizations.



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This is what the New York medical community recommends:

- Educating (www.concernedhealthny.org and www.psehealthyenergy.org/courses) and advocating for patients (www.environmentalhealthproject.org/ and http://www.aoec.org/pehsu.htm)
- Reversing all the exemptions from federal environmental laws
- Giving people all the information they need to make an informed decision
- Enacting laws which protect people, and not just the industry
- Prohibiting non-disclosure agreements
- Providing funding for much needed research
- Doing a Health Impact Assessment
- Prohibiting drilling while studies are being done and evaluated
- Common sense tells us that we should be focusing on renewables
- Following the Precautionary Principle
- Only after we gain a clear understanding of why people become ill near gas drilling operations can a decision be made whether to permit this activity.

The potential risks to the public's health, and especially to children, from shale gas drilling must be taken seriously. There is sufficient reason for concern even though specific pathways are yet to be determined, and there is a growing body of evidence that those living near gas drilling operations are being exposed to toxins, and we should invoke the principle of precaution to slow down the process so that the federal and state agencies and public health scientists can better evaluate the risks, and determine how to proceed to avoid possible irreversible harm.

A process called the Health Impact Assessment would be useful in determining the potential health effects of the proposed program of gas drilling.

In medicine we follow the principle of informed consent which requires that subjects of a procedure or experiment give their consent. In the case of gas drilling, such detailed information has not been given to the public, and therefore the public is not in a position to give informed consent.

Children in particular need added protections because they will be on this earth for longer than the adult population which is making the decisions. Their cells divide faster and so are subject to damage with each division, they breathe faster and so inhale more pollutants, they don't process toxins like adults--chemicals have a different, more detrimental effect on children, especially endocrine disruptors, because their bodies are still developing.

The health profession is unanimous in their recommendation that this is a good time to push the pause button.

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