DRBC hearing January 23, 2018 **Larysa Dyrszka, MD**

Shale gas development has the potential to cause adverse health impacts.[1] But due to a well-orchestrated set of exemptions this industry received from key federal public health laws[2], these health issues have only recently begun to come to light.[3]

Reports of ill health in impacted people became evident over recent years, despite the lack of involvement from federal and state public health and environmental departments. Lists were generated by activists (List of the Harmed)[4] and surveys compiled (Earthworks' Survey of Health Impacts)[5]. A Health Impact Assessment[6] started in Battlement Mesa Colorado showed that air pollution was a stressor and particularly significant. And there is still no mechanism in place to monitor or track the health and environmental impacts from gas drilling operations, including the economic costs.

In 2012 Congress commissioned a report[7] which found that accidents happen and violations occur in this industry frequently, and even the best regulations have not prevented environmental disasters.

Physicians, Scientists and Engineers for Healthy Energy published an analysis of the peer-reviewed literature in 2015. Their results, as of 2015, indicated that at least 685 papers have been published in peer-reviewed scientific journals that are relevant to assessing the impacts of unconventional natural gas development (UNGD). 84% of public health studies contain findings that indicate public health hazards, elevated risks, or adverse health outcomes; 69% of water quality studies contain findings that indicate potential, positive association, or actual incidence of water contamination; and 87% of air quality studies contain findings that indicate elevated air pollutant emissions and/or atmospheric concentrations.[8] [9] There are, as of yesterday, 1395 peer-reviewed studies on fracking in the PSE for Healthy Energy database.[10]

Concerned Health Professionals of New York just completed the fifth edition of a compendium on the risks and health impacts of fracking. It will be available on our site shortly; meanwhile, the fourth edition

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[1] Shonkoff et al. April 2014. Environmental Public Health Dimensions of Shale and Tight Gas Development. EnvHealthPerspectives. Access at: http://dx.doi.org/10.1289/ehp.1307866

[2] http://www.ewg.org/research/free-pass-oil-and-gas/oil-and-gas-industry-exemptions

[3] Rabinowitz et al. Sept 2014. Proximity to Natural Gas Wells and Reported Health Status: Results of a Household Survey in Washington County, Pennsylvania. EHP. Access at: http://dx.doi.org/10.1289/ehp.1307732

[4] http://pennsylvaniaallianceforcleanwaterandair.wordpress.com/the-list/

[5] Steinzor, N, et al., Investigating Links Between Shale Gas Impacts and Health through a Community Survey Project in Pennsylvania, New Solutions, Vol. 23(1) 55-83 (May 2013). Access at: http://www.earthworksaction.org/files/publications/SteinzorSubraSumiShaleGasHealthImpacts2013.pdf

[6] Witter R, et al, Battlement Mesa HIA 2011 http://www.garfield-county.com/environmental-health/battlement-mesa-health-impact-assessment-draft2.aspx

[7] http://democrats.naturalresources.house.gov/sites/democrats.naturalresources.house.gov/files/2012-02-08_RPT_DrillingDysfunction.pdf

[8] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0154164

[9] https://www.psehealthyenergy.org/our-work/publications/archive/the-science-on-shale-gas-development/

[10] https://www.psehealthyenergy.org/our-work/shale-gas-research-library/

is there,[11] as well as a preview of the fifth edition's water section.[12] The Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking (the Compendium) is a fully referenced compilation of the evidence outlining the risks and harms of fracking. It is a public, open-access document that is housed on the websites of Concerned Health Professionals of New York (www.concernedhealthny.org) and Physicians for Social Responsibility (www.psr.org). For this fifth edition of the Compendium, as before, we collected and compiled findings from three sources: articles from peer-reviewed medical or scientific journals; investigative reports by journalists; and reports from or commissioned by government agencies. Peer-reviewed articles were identified through databases such as PubMed and Web of Science, and from within the PSE Healthy Energy database. The studies and investigations referenced in the dated entries catalogued in Compilation of Studies & Findings are current through December 2017.

Following is an excerpt from the section titled **Emerging Trends: Fracking and the disposal of fracking waste threaten drinking water.**

> "Cases of drinking water sources contaminated by drilling and fracking activities, or by associated waste disposal, are now proven. The U.S. Environmental Protection Agency (EPA)'s assessment of fracking's impacts on drinking water resources confirmed specific instances of water contamination caused by drilling and fracking-related activities and identified the various pathways by which this contamination has occurred: spills; discharge of fracking waste into rivers and streams; and underground migration of chemicals, including gas, into drinking water wells. Independently, researchers working in Texas found 19 different fracking-related contaminants—including cancer-causing benzene—in hundreds of drinking water samples collected from the aquifer overlying the heavily drilled Barnett Shale, thereby documenting widespread water contamination. In Pennsylvania, a solvent used in fracking fluid was found in drinking water wells near drilling and fracking operations known to have well casing problems. In California, state regulators admitted that they had mistakenly allowed oil companies to inject drilling wastewater into aquifers containing clean, potable water. A 2017 study found that fracking wastewater discharged to rivers and streams through treatment plants created dozens of brominated and iodinated disinfection byproducts that are particularly toxic and "raise concerns regarding human health." As we go to press, researchers report on the discovery of opportunistic, pathogenic bacteria in fracking-impacted water wells in Texas and raise questions about fracking's effects on the microbial ecology of aquifers."[13]

And in the section on water contamination, we write:

> "Substantial evidence shows that drilling and fracking activities, and associated wastewater disposal practices, inherently threaten groundwater and have polluted drinking water sources, as confirmed by the U.S. Environmental Protection Agency's 2016 final report on the impacts of fracking on the nation's drinking water. Repudiating industry claims of risk-free fracking,

[11] http://concernedhealthny.org/compendium/
[12] http://concernedhealthny.org/wp-content/uploads/2018/01/Compendium5_0WaterExcerpt_Florida_Launch_FINAL.pdf
[13] Ibid.

studies from across the United States present irrefutable evidence that groundwater contamination occurs as a result of fracking activities and is more likely to occur close to well pads. In Pennsylvania alone, the state has determined that more than 300 private drinking water wells have been contaminated or otherwise impacted as the result of drilling and fracking operations over an eight-year period. As determined by the U.S. Agency for Toxic Substances and Disease Registry, the chemical contamination of some private water wells in Dimock, Pennsylvania posed demonstrable health risks, rendering the water unsuitable for drinking.

"Evidence on instances and pathways of water contamination exist even though scientific inquiry is impeded by industry secrecy and regulatory exemptions. The 2005 Energy Policy Act exempts hydraulic fracturing from key provisions of the Safe Drinking Water Act. As a result, fracking chemicals have been protected from public scrutiny as "trade secrets." The oil and gas sector is the only U.S. industry permitted to inject known hazardous materials near, or directly into, underground drinking water aquifers. At the same time, in most states where fracking occurs, routine monitoring of groundwater aquifers near drilling and fracking operations is not required, nor are companies compelled to fully disclose the identity of chemicals used in fracking fluid, their quantities, or their fate once injected underground.

"Nevertheless, of the more 1,000 chemicals that are confirmed ingredients in fracking fluid, an estimated 100 are known endocrine disruptors, acting as reproductive and developmental toxicants. Adding to this mix are heavy metals, radioactive elements, brine, and volatile organic compounds, which occur naturally in deep geological formations and which can be carried up from the fracking zone with the flowback fluid. As components of the fracking waste stream, these toxic substances also pose threats to surface water and groundwater. A 2017 study found that spills of fracking fluids and fracking wastewater are common, documenting 6,678 significant spills occurring over a period of nine years in four states alone. In these states, between 2 and 16 percent of wells report spills each year. About 5 percent of all fracking waste is lost to spills, often during transport. Spills and intentional discharges of fracking waste into surface water have profoundly altered the chemistry and ecology of streams throughout entire watersheds, increasing downstream levels of radioactive elements, heavy metals, endocrine disruptors, toxic disinfection byproducts, and acidity, and decreasing aquatic biodiversity and populations of sensitive fish species, such as brook trout. New studies documenting changes in the bacterial flora in groundwater following drilling and fracking operations represent an emerging area of concern."[14]

Two years ago NY State DOH Commissioner, Dr Zucker, advised Governor Cuomo not to approve high volume hydraulic fracturing in NY because of the potential health risks, and he based it on the science.[15] The State of Maryland permanently banned fracking after 2 years of study, based on the potential for

[14] Ibid.
[15] http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf

adverse public health and environmental impacts.[16] The EPA HF study has been completed and shows that water has, in fact, been contaminated.[17]

Most importantly, there are many people who have already been impacted in states where gas extraction using high volume hydraulic fracturing is permitted. We must carefully study the scientific information that is fundamental to making informed decisions. As we review the studies already completed, and speak with impacted people, we are increasingly aware that fracking causes stressors on health that cannot be mitigated.

For these reasons (and with more detail provided below) the moratorium on gas extraction using high volume hydraulic fracturing must become permanent. That should include a prohibition on water withdrawals and the importation of fracking waste.

Rulemaking

The Commission is currently proposing to amend its Special Regulations by the addition of a section on hydraulic fracturing in shale and other rock formations, including the wise decision to prohibit high volume hydraulic fracturing in shale and other rock formations. However, the following two provisions: 1) water use for hydraulic fracturing; and 2) the management of produced water from hydraulic fracturing should be more protective. Both the water acquisition from the DRB and the importation of waste from hydraulic fracturing operations into the DRB should be prohibited.

In the Rulemaking Notice, the Commission writes: "The data available on produced water (including flowback) from hydraulically fractured wells in the Marcellus formation indicate that this waste stream is unlike other industrial and domestic waste streams treated and discharged in the Delaware River Basin, and that it poses significant risks to human health and the environment if improperly handled."[18] Yet, the DRBC is proposing a rule that "provides that this material may not be transferred to, treated by or discharged from or to a new or existing wastewater treatment facility located within the Delaware River Basin, at any volume or rate, **except** in accordance with an approval in the form of a docket issued by the Commission to the owner or operator of the wastewater treatment facility or in accordance with a state permit issued pursuant to a duly adopted administrative agreement between the Commission and the host state."[19] There is no good reason to accept fracking waste. It should not only be "discouraged" but prohibited.

The following is from the **Water withdrawals** section in the Rulemaking Notice, and the Commission makes a very good case for prohibition of water withdrawal.

"The acquisition of water for use in HVHF may result in modifications to groundwater levels, surface water levels, and stream flows. The Susquehanna River Basin Commission (SRBC) has reported that for the period 2008 through 2013 an average of 4.3 million gallons of water were injected per fracturing event in natural gas wells within the Susquehanna basin. During the same period, 84 percent of injected water was "fresh" water from surface water and groundwater sources, and the remaining 16 percent

[16] http://thinkprogress.org/climate/2015/05/29/3664098/larry-hogan-maryland-fracking-ban/
[17] https://www.epa.gov/hfstudy
[18] http://www.state.nj.us/drbc/library/documents/HydraulicFracturing/RulemakingNotice113017.pdf p14.
[19] Ibid.

was recycled produced water or flowback water. According to EPA, the median volume of water used per well fracturing event in Pennsylvania between January 2011 and February 2013 was 4.18 million gallons. EPA further reports that in at least 10 percent of cases, the water use in Pennsylvania during the same period was over 6.6 million gallons per well. EPA has reported that in the Marcellus formation in Pennsylvania, 82 to 90 percent of the base fluid used for hydraulic fracturing is fresh water that is naturally occurring and that the remaining base fluids (10 to 18 percent) are reused and recycled produced water. Advances in horizontal drilling technology are leading to longer drill paths and the need for more fracturing fluid volumes for each path. According to SRBC, when the industry began lengthening its lateral well bores in 2013, the average amount of water used per fracturing event increased to approximately 5.1 to 6.5 million gallons per fracturing event. [20]

"Withdrawals from surface and ground water in the amounts required for HVHF may adversely affect aquatic ecosystems and river channel and riparian resources downstream, including wetlands, and may diminish the quantity of water stored in an aquifer or a stream's capacity to assimilate pollutants. Because HVHF operations may significantly increase the volume of water withdrawn in a localized area, they may ultimately upset the balance between the demand on water resources and the availability of those resources for uses protected by the Commission's comprehensive plan, particularly during periods of low precipitation or drought."[21]

"**Consumptive use** - In contrast with most domestic and commercial water use, most water used for HVHF is used "consumptively," meaning it is not returned to the basin's usable ground or surface waters. According to the EPA, water accounts for 90 to 97 percent of all hydraulic fracturing fluids injected into a well for the purpose of extracting natural gas. EPA reports further that produced water, or water that flows from and through oil and gas wells to the surface as a by-product of oil and gas production over a ten-year operations period, makes up only 10 to 30 percent of the fluid injected. Accordingly, EPA estimates that 70 to 90 percent of the water used in high volume hydraulic fracturing is permanently removed from the water cycle. The SRBC's estimate is higher. SRBC reports that approximately 96 percent of water withdrawn by the natural gas industry is consumptively used in the hydraulic fracturing process and that the balance of the water is consumptively used for other activities at the drilling pads, such as well drilling, preparation of drilling muds and grout, dust control, maintenance operations, and site reclamation."[22]

Wastewater handling and disposal, also in the Rulemaking Notice, is well-referenced (see the linked Notice for references) and again, makes a very good case for prohibition of this activity.

"Produced water" (including "flowback" water) refers to any water or fluid returned to the surface through the production well as a waste product of hydraulic fracturing. This material may be stored in tanks or other containers on the pad site before it is transferred for off-site treatment and/or disposal. The composition of produced water depends on the composition of the injected hydraulic fracturing fluid and the composition of the target formation. In the Marcellus region, produced water is generated in large quantities and often contains high concentrations of total dissolved solids (TDS or "salts") and constituents that may be harmful to human health and the environment. Produced water from HVHF in the Marcellus formation has been found to contain: • Salts, including chloride, bromide, sulfate, sodium,

[20] http://www.state.nj.us/drbc/library/documents/HydraulicFracturing/RulemakingNotice113017.pdf pp6-7
[21] Ibid.
[22] Ibid.

magnesium, and calcium; • Metals, including barium, manganese, iron, and strontium; • Naturally-occurring organic compounds, including benzene, toluene, ethylbenzene, xylenes(BTEX), and oil and grease; • Radioactive materials, including radium; and • Hydraulic fracturing chemicals and their chemical transformation products." [23]

"The disposal of produced water poses a significant risk to the water resources of the basin if the wastewater is not properly managed. The concentration of TDS in produced water can be high enough that if discharged untreated to surface water, the potential exists to adversely affect designated uses of surface water, including drinking water, aquatic life support, livestock watering, irrigation, and industrial use. Because produced water contains high TDS and dissolved inorganic constituents that most publicly owned treatment works and other municipal wastewater treatment facilities are not designed to remove, these constituents can be discharged untreated from such facilities; can disrupt treatment processes, for example by inhibiting biological treatment; can accumulate in biosolids (sewage sludge), limiting their beneficial use; and can facilitate the formation of harmful disinfection byproducts. Where produced water has been discharged to domestic wastewater treatment facilities in the past, elevated concentrations of chloride and bromide have been documented in the receiving waters. The discharge of bromide upstream of drinking water intakes has led in documented instances to the formation of carcinogenic disinfection by-products at drinking water utilities."[24]

Of serious concern are the hundreds of chemicals used in gas exploration and production which are not disclosed and which include many toxic chemicals. Dr Theo Colborn[25] has written about the chemicals that are toxic. They include benzene (a known carcinogen), ethylbenzene, toluene (causes miscarriages, placenta previa), xylene, diesel (recently classified by WHO as a carcinogen), naphthalene (a neurotoxin and carcinogen), polynuclear aromatic hydrocarbons (carcinogens), formaldehyde (known carcinogen), 2-Butoxyethanol (hemopoietic dyscrasias; carcinogenesis), and 2-BE is the active component of Corexit which was used as a dispersant in the Exxon Valdez and BP Gulf disasters and is used in all phases of gas extraction.

Waste from fracking operations is exempt from federal oversight.[26] [27]

It has been documented that disposal in underground injection wells has caused earthquakes.[28] [29] [30] [31]

Our Compendium section on water contamination provides forty pages of references,[32] the majority of which show definitive risk of contamination.

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[23] http://www.state.nj.us/drbc/library/documents/HydraulicFracturing/RulemakingNotice113017.pdf p9.
[24] Ibid.
[25] http://endocrinedisruption.org/assets/media/documents/cP02591Colborn20021022coalbedmethane2-BEcommments.pdf
[26] http://www.epa.gov/osw/nonhaz/industrial/special/oil/oil-gas.pdf
[27] Horwitt, D. 2016. Toxic Secrets Companies Exploit Weak US Chemical Rules to Hide Fracking Risks. http://www.pfpi.net/wp-content/uploads/2016/04/PFPI_ToxicSecrets_4-7-2016.pdf
[28] Katie M. Keranen, Heather M. Savage, and Geoffrey A. Abers et al., "Potentially Induced Earthquakes in Oklahoma, USA: Links between Wastewater Injection and the 2011 Mw 5.7 Earthquake Sequence," Geology, vol. 41, no. 3 (March 26, 2013)
[29] http://geology.gsapubs.org/content/early/2013/03/26/G34045.1.abstract
[30] http://www.ldeo.columbia.edu/news-events/wastewater-injection-spurred-biggest-earthquake-yet-says-study
[31] http://stateimpact.npr.org/texas/tag/earthquake
[32] http://concernedhealthny.org/wp-content/uploads/2018/01/Compendium5_0WaterExcerpt_Florida_Launch_FINAL.pdf

Radioactivity

Brown has reviewed the issue of radioactivity in waste.[33]

The International Atomic Energy Agency[34] and the International Commission of Radiation Protection have 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 through RCRA (Resource Conservation and Recovery Act) the materials that come from down-hole which are, in many cases, radioactive. [35]

EPA region 3 reports that radium, measured as gross alpha and beta, in flowback water and produced waste in Pennsylvania wells, is significantly higher than in other shales.

The graphs found here, from a USGS report, illustrate the high radioactivity in Marcellus shale.[36]

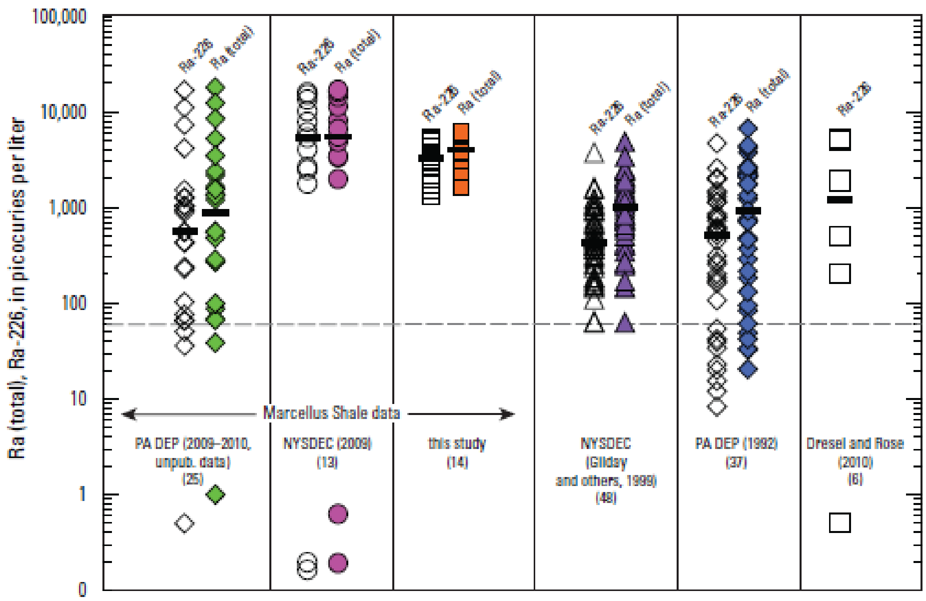


Figure 4. Measured activities for total radium (Ra-226 + Ra-228) and Ra-226 for each of the data sources used in the study. The three datasets for produced water from Marcellus Shale wells are shown on the left; the remaining three datasets are for non-Marcellus Shale wells. The number of points in each dataset is shown in parentheses, and the median values are plotted as heavy black lines. For reference, the dashed line shows the industrial effluent discharge limit (60 pCi/L) for Ra-226 (U.S. Nuclear Regulatory Commission, *http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/Radium-226.html*).

In the 2008 publication of the International Association of Oil & Gas Producers, the authors wrote: "During the production process, NORM flows with the oil, gas and water mixture and accumulates in scale, sludge and scrapings. It can also form a thin film on the interior surfaces of gas processing

[33] Brown VJ. 2014. Radionuclides in fracking wastewater: managing a toxic blend. Environ Health Perspect 122:A50–A55; http://dx.doi.org/10.1289/ehp.122-A50

[34] Recommendations from the International Atomic Energy Agency (IAEA) http://www-pub.iaea.org/MTCD/publications/PDF/TCS-40_web.pdf

[35] Federal exemption http://www.epa.gov/osw/nonhaz/industrial/special/oil/oil-gas.pdf

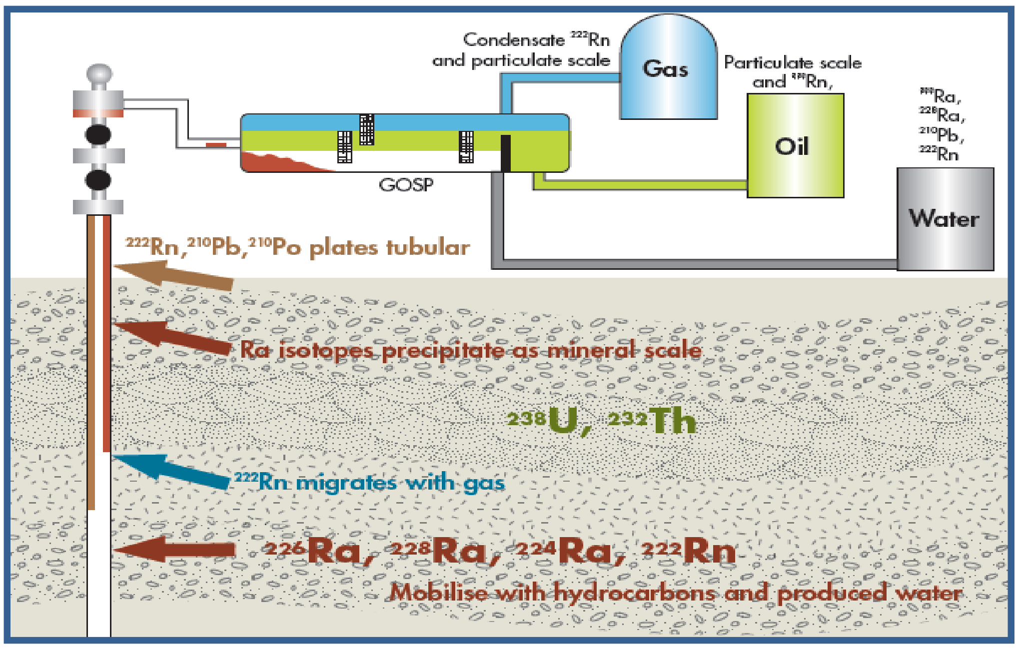
[36] http://pubs.usgs.gov/sir/2011/5135/pdf/sir2011-5135.pdf

equipment and vessels. The level of NORM accumulation can vary substantially from one facility to another depending on geological formation, operational and other factors… NORM may accumulate, *e.g.* at wellheads in the form of scale; at Gas/Oil Separation Plants (GOSP) in the form of sludge; and at gas plants the form of thin films as the result of radon gas decay.

"…radionuclides such as Lead-210 and Polonium-210 can…be found in pipelines scrapings as well as sludge accumulating in tank bottoms, gas/oil separators, dehydration vessels, liquid natural gas (LNG) storage tanks and in waste pits as well as in crude oil pipeline scrapings."[37]

This graph from the same publication shows the origins of NORM, as well as where NORM can accumulate.

Figure 1.1 The origins of NORM, indicating where NORM may accumulate in the recovery process.



In January 2015, PA DEP released their TENORM report[38]. The DEP was quick to issue a press memo assuring that "There is Little Potential for Radiation Exposure from Oil and Gas Development".[39] Upon careful review of the report and the appendices, it was clear that there were elevated levels of radium and radon which needed to be mitigated; some areas should even be posted as radioactive areas, as per OSHA regulations.[40] The report has since undergone changes.

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[37] OGP, "Guidelines for the management of Naturally Occurring Radioactive Material (NORM) in the oil & gas industry" International Association of Oil & Gas Producers, Report No. 412, September 2008 http://www.ogp.org.uk/pubs/412.pdf

[38] http://www.dep.pa.gov/Business/Energy/OilandGasPrograms/OilandGasMgmt/Oil-and-Gas-Related-Topics/Pages/Radiation-Protection.aspx

[39] http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/RadiationProtection/rls-DEP-TENORM-01xx15AW.pdf

[40] https://www.osha.gov/SLTC/radiationionizing/standards.html

In the PA DEP report, wastewater treatment plants reported the following numbers for liquid waste Ra226:

Figure 4-1. CWT Influent and Effluent Liquid Ra-226 Minimum, Maximum, and Average

Wastewater Source	Filtered or Not	Min (pCi/L)	Max (pCi/L)	Ave (pCi/L)
Effluent	Filtered	18.0	14,900	2,100
Effluent	Unfiltered	42.0	15,500	1,840
Influent	Filtered	57.0	14,100	2,350
Influent	Unfiltered	17.5	13,400	1,870

It is clear that workers at wastewater treatment plants handling gas waste are being exposed to high radiation doses. "The maximum gamma radiation exposure rate measured was 502 μrem/hr on contact with the outside of a wastewater tank. Work in proximity of the tank could potentially result in an exposure of 100 mrem in 200 hours of annual exposure or 10 percent of an employee's 2,000-hour occupational year."[41]

The method measuring Radium 226 and 228 and their progeny has recently received scrutiny, and a new set of methods has been developed by the EPA in collaboration with Nelson and Schultz at the University of Iowa[42]. The FPWHFO (flowback and produced water in hydraulic fracturing operations) matrix is considered to be a particularly challenging one due to its extremely high dissolved solids content and its complexity. This new method addresses that complexity.

In brief, the calculations done using the older EPA methods have likely significantly underestimated the radium content of flowback and produced water. Note that the methods used to detect radium in the USGS report[43] and in this recent PA DEP report on radioactivity[44] (using EPA methods 900 - 904[45]) may have underestimated the radium content because of the high salinity in the samples.

The gas which enters the pipeline carries gaseous radon with it; and as radon decays within the pipeline, the solid daughter elements, polonium and lead, accumulate along the interior of the pipes. There is concern that the gas transiting, and being compressed, will have radioactivity levels which will be a risk not only to the workers at these stations and along the pipeline, but potentially also to the residents.

Radon was measured at various locations around POTW plants "…at various indoor locations such as break rooms, labs, offices, etc., …The results ranged from 0.2 to 8.7 pCi/L."[46]

[41] http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-105822/PA-DEP-TENORM-Study_Report_Rev._0_01-15-2015.pdf pg 4-8
[42] http://www2.epa.gov/sites/production/files/2014-08/documents/epa-600-r-14-107_-_gross_alpha_-_gross_beta_508_km_08-08-2014.pdf
[43] http://pubs.usgs.gov/sir/2011/5135/pdf/sir2011-5135.pdf
[44]http://www.portal.state.pa.us/portal/server.pt/community/oil___gas_related_topics/20349/radiation_protection/986697
[45] http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/RadiationProtection/Sampling_and_Analysis_Plan-Part-II-Quality_Assurance_Project_Plan.pdf
[46] Ibid pg 4-3

Radon has a short half-life (3.8 days) but its decay products, lead and polonium, have relatively long half-lives of 22.6 years and 138 days respectively. Lead causes neurologic and hematologic toxicity, and death; polonium causes cancer and death.[47] 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 may cause cancer. "Ninety-nine % of the health effects are caused by radon's daughter products; of most significance are the four short-lived ones, polonium-218 to polonium-214 inclusive, which are referred to as radon daughters, radon progeny, or radon decay products."[48]

Following is a description of the fate of radon in a processing plant; however, similar activities occur at a compressor station. Both compressors and processing plants dot Pennsylvania's landscape. "Radon enters the … piping where it decays into radioactive particulates that are deposited in the piping. During the working lifetime of a … plant, radon is constantly entering the system and adding to the level of radioactive progeny. Most radon progeny are short-lived, so when a … plant ceases operations, the short-lived progeny decay quickly. These short-lived radionuclides are the ones that produce the signature gamma ray spectrum that can be detected easily on the outside of the piping. As the short-lived radon progeny decays, it becomes more and more difficult to detect activity from the outside of pipes and tanks, even though there may be detectable radiation on the inside. As the short half-lived progeny decay away, the only radionuclides remaining are the relatively long-lived 210Pb (T1/2 21 y) and its progeny. 210Pb emits a gamma ray at 47 keV and has a transmission of only about 10to the minus7 to 10to the minus6 through a schedule-40 pipe. Unless the pipe had an access point, internal contamination might not be detectable from the outside."[49]

During production radon usually follows the gas stream. "If the natural gas is fractionated, a disproportionately high percentage of radon can concentrate in the propane streams and to a lesser degree in the ethane streams. Radon-222 produces, through natural decay, several radioactive nuclides (also known as radon progeny). Most radon progeny are short-lived, with the exception of Lead-210 and Polonium-210, which have relatively long half-lives…. Most of the radon decay products (90-99%) are attached to ambient aerosols, airborne particulates or surfaces. This can result in forming thin radioactive films on the inner surfaces of gas processing equipment such as scrubbers, compressors, reflux pumps, control valves and product lines."[50]

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[47] National Academy of Sciences 1988 report: Health Risks of Radon and Other Internally Deposited Alpha-Emitters: BEIR IV, page 5

[48] http://www.inive.org/medias/ECA/ECA_Report15.pdf pg 9

[49] Krieger. 2005. http://radonattahoe.com/TENORM.pdf

[50] OGP. 2006. http://www.ogp.org.uk/pubs/412.pdf

Activity concentration of ^{222}Rn, ^{210}Pb and ^{210}Po in natural gas (Reference 1)

Radionuclide	Reported Range (Bq/m³)
^{222}Rn	5 – 200,000
^{210}Pb	0.005 – 0.02
^{210}Po	0.002 – 0.08

Activity concentration of ^{210}Pb and ^{210}Po in NGL/hydrocarbon condensate (Reference 1)

Radionuclide	Reported Range (Bq/l)
^{222}Rn (NGL)	0.01 – 1,500
^{222}Rn (C3 -liq)	0.01 – 4,200
^{210}Pb	0.3 – 230
^{210}Po	0.3 – 100

[51]

In 2013, samples of natural gas were analyzed for Spectra and submitted to FERC (public record). The results are as follows:

Results of Samples for Spectra Energy

Date	Location	Analyzed[1]	Rn Conc (pCi/L)[2]	MDC (pCi/L)[3]
12/3/2013	Bechtelsville	12/4 - 12/5	29.9 ± 3.2	0.1
	Bechtelsville	12/11 - 12/12	29.4 ± 3.1	0.3
12/3/2013	Blank	12/4 - 12/5	0.16 ± 0.04	0.07
	Blank	12/11 - 12/12	0.19 ± 0.04	0.27
12/12/2013	Staten Island	12/13 - 12/14	20.6 ± 2.2	0.1
	Staten Island	12/23 - 12/24	20.5 ± 2.2	0.5
12/12/2013	Jersey City	12/13 - 12/14	20.7 ± 2.2	0.1
	Jersey City	12/23 - 12/24	20.4 ± 2.2	0.5
12/12/2013	Blank	12/27 - 12/28	-0.16 ± 0.04	6.69
	Blank	12/31 - 1/1/14	1.38 ± 0.15	12.86
12/16/2013	Ramapo	12/17 - 12/18	26.1 ± 2.8	0.1
	Ramapo	12/26 - 12/27	26.4 ± 2.8	0.4
12/16/2013	Mahwah	12/17 - 12/18	23.0 ± 2.5	0.1
	Mahwah	12/17 - 12/18	23.3 ± 2.5	0.4
12/16/2013	Blank	12/27 - 12/28	-0.23 ± 0.05	0.61
	Blank	12/31 - 1/1/14	0.14 ± 0.04	1.23
12/17/2013	Line 9	12/18 - 12/19	41.6 ± 4.4	0.1
	Line 9	12/30 - 12/31	41.8 ± 4.4	0.7
12/17/2013	Blank	12/18 - 12/19	0.22 ± 0.05	0.09
	Blank	12/30 - 12/31	0.60 ± 0.07	0.76

Radon concentrations between 20 and 41 pCi/L are elevated and could have significant human health impacts.

[51] http://www.ogp.org.uk/pubs/412.pdf

Table 3-18. Natural Gas Samples from Production Sites

Sample ID	County	Gas Source	Radon Conc. +/- 2 S.D. (pCi/L)	MDA (pCi/L)
WP 08 RG	Washington	Marcellus Shale	79.6 +/- 0.800	0.300
WP 09 RG	Washington	Marcellus Shale	78.8 +/- 4.20	0.300
WP 22 RG	Tioga	Marcellus Shale	42.8 +/- 0.200	0.100
WP 23 RG	Tioga	Marcellus Shale	39.6 +/- 0.800	0.200
WP 24 RG	Tioga	Marcellus Shale	73.8 +/- 0.400	0.200
WP 25 RG	Tioga	Marcellus Shale	44.4 +/- 2.60	0.200
WP 26 RG	Lycoming	Oriskany Sandstone	19.9 +/- 0.200	0.200
WP 27 RG	Tioga	Marcellus Shale	38.4 +/- 3.40	0.300
WP 28 RG	Tioga	Marcellus Shale	40.8 +/- 5.20	0.400
WP 16 RG	Washington	Marcellus Shale	50.0 +/- 5.20	0.300
WP 17 RG	Washington	Marcellus Shale	49.5 +/- 5.80	0.500
WP 19 RG	McKean	Upper Devonian Shale	18.3 +/- 4.40	0.400
WP 20 RG	McKean	Upper Devonian Shale	88.2 +/- 10.6	0.700
WP 21 RG	Forest	Upper Devonian Shale	92.2 +/- 6.40	0.400
WP 04 RG	Tioga	Marcellus Shale	49.6 +/- 29.6	1.20
WP 05 RG	McKean	Marcellus Shale	148 +/- 15.6	1.50
WP 12 RG	Lycoming	Marcellus Shale	37.6 +/- 33.4	2.20
WP 11 RG	Tioga	Utica	5.70 +/- 1.20	0.500
WP 29 RG	Sullivan	Marcellus Shale	23.4 +/- 4.00	0.240
WP 30 RG	Bradford	Marcellus Shale	25.5 +/- 2.70	0.200
WP 31 RG	Bradford	Marcellus Shale	3.00 +/- 1.20	0.300
WP 14 RG	Jefferson	Marcellus Shale	5.60 +/-0.100	0.140
		Average	**47.9**	
		Median =	**41.8**	
		Standard Deviation	**34.5**	

Note: All results adjusted to account for the fact that Rn was counted in methane, but the scintillation cells were calibrated for Rn in air. Range of α particles is greater in methane than in air. All results divided by 1.054, according to Jenkins et. al., Health Physics, Vol. 106, No. 3, March 2014. [52]

When it enters the environment, radon gas "… can move to air, groundwater, and surface water. Decay products of 222Rn, such as 218Po and 214Pb, are solids that can attach to particles in the air and be transported this way in the atmosphere. They can be deposited on land or water by settling or by rain. Radon will undergo radioactive decay in the environment."[53]

"...radon and subsequent decay product atoms are charged and tend to attach to aerosol particles. Radon progeny are similarly charged, readily aggregate, form clusters, and attach to dust particles in air. The main health problems arise when primarily those radon progeny that are attached to dust particles (termed the attached fraction) are inhaled, deposit in the airway (particularly the tracheobronchial tree), and irradiate nearby cells repetitively with alpha particles as each atom transforms through the decay chain..."[54]

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52 http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-112658/Pennsylvania%20Department%20of%20Environmental%20Protection%20TENORM%20Study%20Report%20Rev%201.pdf

53 http://www.atsdr.cdc.gov/ToxProfiles/tp145.pdf

54 Ibid, pg 16

Regarding workers at gas operations sites and radon exposure, ATSDR notes: " …exposure to high concentrations can occur in any location with geologic radon sources. A list of common occupations that have the potential for high radon and progeny exposure … include mine workers … employees of water treatment plants, and radioactively contaminated sites can include … oil refineries, power plants, and natural gas and oil piping facilities."[55]

The amount of radon released by natural gas operations is not insignificant: "Fishbein (1992) has reported that coal residue and natural gas emissions release 20,000 and 10,000 Ci of 222Rn each year, respectively…"[56]

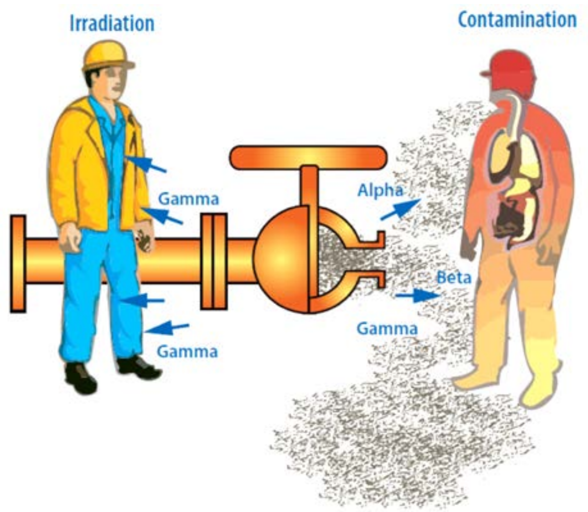
Interestingly, "Regulations regarding the land disposal of radionuclides, as set forth in 10 CFR 61 (USNRC 2008), do not apply to radium, radon, or its daughters...regulation of radon is up to the individual states."[57]

The gathering of information about radon releases has been limited. "There is no information on releases of radon to the atmosphere from manufacturing and processing facilities because these releases are not required to be reported (EPA 1998)."[58] The DRBC regulations as proposed do not address radioactivity.

[55] http://www.atsdr.cdc.gov/ToxProfiles/tp145.pdf, pg 124
[56] http://www.atsdr.cdc.gov/ToxProfiles/tp145.pdf, pg 126
[57] http://www.atsdr.cdc.gov/ToxProfiles/tp145.pdf, pg 118
[58] Op cit, ATSDR, pg 124

As radon decays within the pipeline, the solid daughter elements, polonium and lead, accumulate inside the pipes. PCBs and other contaminants such as black powder,[59] and anaerobic microbials, do as well [60] [61]. PIGs (Pipeline Inspection or Intervention Gauge/Gizmo/Gadget [62]) inspect or clean out the pipe, and become repositories of these toxins. These PIGs, with pipe film, black powder, bacteria, scale and sludge, must be removed from the pipeline, stored and eventually disposed.[63] [64] [65] [66]

An industry video of pipeline cleaning (with PIGs) can be viewed here.[67]



NORM materials may become an inhalation risk when the material is dislodged by mechanical forces, such as wire brushing, pipe rattling *etc.* [68]

At each step, precautions must be taken to avoid contaminating workers and residents.

"Natural gas plant scale typically consists of Rn decay progeny that accumulate on the interior surfaces of plant pipes and equipment ... As a result, the only radionuclides that remain and adhere to the interior surfaces of machinery/pipes are the Rn decay progeny Po-210 and Pb-210. These longer-lived

[59] Baldwin, Richard M. "Black powder problem will yield to understanding, planning." Pipeline and Gas Industry 82 (1999): 109-112. http://muellerenvironmental.com/Documents/100-056-Black%20Powder.pdf and Baldwin, Richard M. "Black powder control starts locally, works back to source." *Pipeline & Gas Industry* (1999): 81-87. http://www.muellerenvironmental.com/Documents/100-058%20Black%20Powder2.pdf
[60] Mueller, Fred, and Mark Null. "Impurities in the Gas Stream." Mueller Environmental Designs, Inc. Technical Document, 2005. http://www.muellerenvironmental.com/public/ProductDocuments.aspx
[61] Zhu, Xiang Y., John Lubeck, and John J. Kilbane. "Characterization of microbial communities in gas industry pipelines." Applied and environmental microbiology 69.9 (2003): 5354-5363. Access at http://aem.asm.org/content/69/9/5354.full.pdf
[62] http://en.wikipedia.org/wiki/Pigging)
[63] http://www.rigzone.com/training/insight.asp?insight_id=310&c_id=19
[64] http://www.pigtek.com/advanced_pipeline_cleaning.php
[65] Tsochatzidis, Nikolaos A., and Konstantinos E. Maroulis. "Methods help remove black powder from gas pipelines." Oil and Gas Journal 105.10 (2007): 52. http://www.desfa.gr/files/dimosieyseis/Tsochatzidis%26MaroulisOGJMar2007.pdf
[66] Lindner, Hubert. "A new cleaning approach for black powder removal." Pigging Products and Services Association, 2006. http://www.ppsa-online.com/papers/2006-Aberdeen-8-Lindner.Pdf
[67] http://www.cleanharbors.com/assets/downloads/videos/video-popup-pipeline-coating.html
[68] http://www.ogp.org.uk/pubs/412.pdf

decay progeny are not readily detected on the outside of pipes. However, Pb-210 and Po-210 emit α and β radioactive particles that may be a potential inhalation or ingestion hazard when pipes and machinery are opened for maintenance and/or cleaning. Access to the internal surfaces of pipes and equipment for surveys of surface α and β activity was not available. However, the facility propenizer equipment opened and sampled during filter change-out is representative of interior conditions… A Pb-210 activity result of 3,580 pCi/g was identified…. The results confirm the build-up of the longer-lived Rn decay progeny in equipment and pipes. The concentration of Pb-210 identified may present a potential inhalation or ingestion hazard during routine system maintenance."[69]

Reviewer 6 of the PA DEP report wrote "…that maintenance workers at midstream facilities can also be exposed to Pb-210 and Po-210 when working on internals of pipe and equipment. Progeny tend to plate out on surfaces where there is turbulence in the flow. That would include pumps, elbows, pig launchers/catchers, etc., in addition to the compressor stations themselves."[70]

He continues: "It is the opinion of this reviewer that the alpha and beta contamination potential (and hazard) on well sites and compressor stations, gas plants, et al., is underestimated because there was no access to equipment internals. Also, Po- 210 does not appear to be considered, and that is an internal hazard. Maintenance workers, on and off site (e.g., at repair shops) could be exposed to significant contamination based on years of experience in the industry."[71]

Conclusion

There is a growing but already significant body of scientific evidence showing harms to public health from gas development.

And yet, despite this evidence, the monetary costs associated with the health impacts--premature death, birth defects, prematurity of birth, cancer, autism, learning disabilities and other problems--have never been entered into an economic analysis of fracking.

Some have supported gas development for the purported economic boost. The contrary is true—the industry will not be a recession buster.[72] From the peer-reviewed literature provided, it is also clear that the economic papers boasting a boon have been industry-sponsored, and have not taken into account the economic loss from existing economies like tourism and agriculture. In addition, the costs of health impacts have never been considered, and those will be significant. And, as former Congressman Hinchey said, the DRBC's mission is the environment, not the economy; "…the DRBC's role is to prohibit and control pollution of the waters of the basin."

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[69] http://www.dep.pa.gov/Business/Energy/OilandGasPrograms/OilandGasMgmt/Oil-and-Gas-Related-Topics/Pages/Radiation-Protection.aspx sec 6-3
[70] http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-112656/Appendix_L-Peer%20Review%20Comment%20and%20Resolution%20Document.pdf Appendix L page 39 of original document
[71] Ibid, pg L-42
[72] http://theconversation.com/the-false-promise-of-fracking-and-local-jobs-36459

The DRBC Compact[73] states: " Whereas some twenty-two million people of the United States at present live and work in the region of the Delaware River Basin and its environs, and the government, employment, industry, and economic development of the entire region and the health, safety, and general welfare of its population are and will continue to be vitally affected by the use, conservation, management, and control of the water and related resources of the Delaware River Basin…"

"Each of the signatory parties covenants and agrees to prohibit and control pollution of the waters of the basin according to the requirements of this compact and to cooperate faithfully in the control of future pollution in and abatement of existing pollution from the rivers, streams, and waters in the basin which flow through, under, into or border upon any of such signatory states, and in order to effect such object, agrees to enact any necessary legislation to enable each such party to place and maintain the waters of said basin in a satisfactory condition, available for safe and satisfactory use as public and industrial water supplies after reasonable treatment, suitable for recreational usage, capable of maintaining fish and other aquatic life, free from unsightly or malodorous nuisances due to floating solids or sludge deposits and adaptable to such other uses as may be provided by the comprehensive plan."[74]

From the references provided, it should be clear that gas exploration and production are inherently polluting and unsafe industrial practices, and have no place in a protected watershed. The Delaware River Basin Commission is responsible for protecting the 13,000 square mile watershed, and the drinking water of millions of people.

Some seven years ago, over 30,000 comments were received by the DRBC opposing gas development of the Delaware River Basin.[75] Today there are many peer-reviewed scientific studies documenting the harms and risks of fracking, including water impacts from withdrawal and waste disposal.[76] [77]

We ask that the DRBC fulfill its mission to protect the Delaware, a critical drinking water supply, and make permanent the moratorium on fracking in the watershed, as well as the prohibition of water withdrawals for an unpermitted industry and also the disposal of its waste.

Respectfully submitted,

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[73] DRBC Compact. 1961. Access at: http://www.state.nj.us/drbc/library/documents/compact.pdf pg2
[74] DRBC Compact. 1961. Access at: http://www.state.nj.us/drbc/library/documents/compact.pdf pg14
[75] https://protectingourwaters.wordpress.com/2011/04/15/30000-oppose-gas-drilling-near-delaware-river/
[76] https://www.psehealthyenergy.org/our-work/shale-gas-research-library/
[77] http://concernedhealthny.org/compendium/