

**Management of Waste Fluids from Natural Gas Exploration and Production:  
Comparison of New York State and Delaware River Basin Commission Regulations**

**by**

**Ronald E. Bishop, Ph.D., CHO**

**for**

**The Delaware Riverkeeper Network**

**Summary:**

New York State's regulatory regime for natural gas development was compared with that of the Delaware River Basin Commission (DRBC), based on the following criteria: definitions of natural gas development waste fluids, ultimate objectives of regulatory requirements, control of regulatory compliance processes, and resources / historical record.

Based on this analysis, New York State's efforts to regulate the natural gas industry have been compromised by diffuse, incomplete and incoherent regulations, a legislated inability to focus on environmental conservation, a general lack of compliance process control, and severe paucity of resources. As a result, state regulatory effectiveness over the last twenty years has been questionable.

The Delaware River Basin Commission proposes regulations which are cohesive and coherent, although they are incomplete. These new regulations are necessary to meet anti-degradation standards for federal Special Protection Waters within New York State, because New York's current regulatory program does not guarantee that those standards will be met. New guidance documents which might address some of New York's regulatory

deficiencies are in draft form. DRBC staff members have little experience with regulating the natural gas industry, and appear not to be tasked with inspection or enforcement duties. Although most implementation of gas industry regulations will probably be carried out by New York's Bureau of Oil and Gas Regulation field agents, these agents' ability to robustly enforce new DRBC regulations in addition to their own is doubtful.

Therefore, it is recommended that the DRBC should wait for the finalization of New York's Supplement to the Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program (SGEIS) before completing its own Natural Gas Development Regulations. In addition, the DRBC should put new mechanisms in place to assist state regulators with financial and human resources.

It is further recommended that the DRBC make the following changes to its proposed regulations:

**§ 7.5 (h) (1) (iv) (A) (1) (i):** Make in-basin disposal waivers dependent on docket amendment rather than agency approval, to include public comment on circumstances where disposal within the basin may pose less risk than transport outside the basin.

**§ 7.5 (h) (1) (iv) (C) (2):** Correct the language of this paragraph by inserting "tests on" before "flowback/production water samples...".

**§ 7.5. (h) (2) (ii) (D):** Limit the chemical repertoire for drilling muds and hydraulic fracturing fluids to those additives with benign (or at least, fully tested) characteristics;

**§ 7.5 (h) (2) (ii) (G - H) & 7.5 (h) (2) (iv) (B):** Reject the use of centralized wastewater storage facilities for flowback fluids. Use of any open pits will result in human and environmental exposure to hazardous chemicals;

**§ 7.5 (h) (2) (iii) & 7.5 (h) (1):** Consider all drill cuttings and drilling fluids (not just those from high volume / hydraulic fracturing projects) to be wastes of concern which should be regulated, since they contain many of the additives used in hydraulic fracturing fluid;

**§ 7.6 (c):** Require that tests on waste fluids be based on disclosure of additives used in gas extraction processes, in addition to standardized parameters;

**§ 7.6 (c) - (e):** Include tests for radon (Rn), hydrogen sulfide (H<sub>2</sub>S) and 4-nitroquinoline-1-oxide (4-NQO) in the required battery of analyses. Although these chemicals are not used as drilling or fracturing additives, they are widespread in flow-back fluids and/or groundwater: Rn as an infiltrating gas from radioactive shale, H<sub>2</sub>S as a metabolite of sulfate-reducing microbes prevalent in hydrocarbon-rich rock strata, and 4-NQO as a drilling process by-product.

It is hoped that these recommendations will contribute to effective regulation of natural gas development in the Delaware River Watershed.

## **Introduction**

With respect to natural gas exploration and production, the primary responsibility of the Delaware River Basin Commission is “to protect the water resources of the Delaware River Basin during the construction and operation of natural gas development projects” (1). From the New York State Legislature, “It is hereby declared to be in the public interest to regulate the development, production and utilization of natural resources of oil and gas in this state in such a manner as will prevent waste; to authorize and to provide for the operation and development of oil and gas properties in such a manner that a greater ultimate recovery of oil and gas may be had, and that the correlative rights of all owners and the rights of all persons including landowners and the general public may be fully protected, and to provide in similar fashion for the underground storage of gas, the solution mining of salt, and geothermal, stratigraphic and brine disposal wells.” (2). Also, “It is declared to be the public policy of the state of New York to maintain reasonable standards

of purity of the waters of the state consistent with public health and public enjoyment thereof, the propagation and protection of fish and wild life, and the industrial development of the state, and to that end require the use of all known available and reasonable methods to prevent and control the pollution of the waters of the state of New York.” (3)

These policy statements illustrate very different perspectives of the Delaware River Basin Commission and the New York State Legislature: the Commission aims solely to protect the waters of the Delaware River Basin from pollution, while the Legislature charges its Department of Environmental Conservation with dual responsibilities to fully exploit hydrocarbon resources and to protect citizens’ rights to reasonably pure water – with the dominant focus on industrial development. One objective of this investigation will be to evaluate how those different perspectives may influence the management of waste fluids generated by natural gas development in the Delaware River Basin.

New York has a complex history in regulating gas development. The first domestic gas well was drilled in Canadaway Creek near Fredonia in 1821 (4, 5), New York was the first state to require the plugging of abandoned wells in 1879 (4, 5), and the first New York law to protect public water supplies from contamination was passed in 1885 (6). No particular state entity existed to monitor compliance or enforce these laws, although an 1882 amendment to the well plugging law offered half of any collected fines to informants who reported violations (4). New York’s Fisheries, Game and Forest Commission was formed in 1895 (7), and the New York State Health Department was created in 1901 (6). The Fisheries, Game and Forest Commission was reorganized as the Department of Conservation in 1910 – 1911 (7). Legislation was adopted in 1933 to allow leasing of state lands for oil and gas drilling. In 1949, the Comprehensive State Water Pollution Control Act was passed.

The Delaware River Basin Commission (DRBC) – the first-ever interstate watershed compact – was formed in 1961 by Delaware, New Jersey, New York, Pennsylvania, and the federal government, consolidating the authority and duties of some 43 state, 14 interstate,

and 19 federal agencies (8). Two years later, New York repealed all previous oil and gas legislation and amended Conservation Law to consolidate the Conservation Department's control of that industry's future development in the state, and in 1966 the Department began to keep records on oil and gas wells (4). On April 22, 1970 (the first Earth Day), the New York State Department of Environmental Conservation (DEC) was created from the old Conservation Department, elements of the Health Department and a variety of other state commissions (7). The state's Environmental Conservation Law, including language related to the DRBC as well as to oil and gas regulation, was extensively recodified in 1972 (4).

In 1978, New York passed the State Environmental Quality Review Act (SEQRA), which was revised in 1987 and again in 1996 (9). This law required all state agencies to consider the environmental impact of all activities which they carried out or permitted, issuing environmental impact statements as needed. In response, the DEC's Division of Mineral Resources (DMN) prepared a Generic Environmental Impact Statement on Oil, Gas and Solution Mining (GEIS), issued as a draft in 1988 and finally adopted with revisions in 1992 (10). Although not accompanied by a "rules package" (11), this document became the primary guide for permit conditions attached to new oil and gas well projects until now (5). In roughly parallel efforts, the DEC is currently revising a supplement to the GEIS (dSGEIS) (12) to address new technologies and issues of scale related to horizontally-drilled high-volume hydraulically fractured (HV/HF) gas well projects, and the DRBC has issued draft natural gas development regulations (13). A second objective of this investigation will be to evaluate historical regulatory performance as a possible predictor of future success.

The primary aim of this investigation is to compare the draft regulations for natural gas development proposed by the Delaware River Basin Commission to cognate New York State environmental law, regulations and guidance documents, specifically as they relate to wastewater generated by natural gas development. Any issues with waste fluids which are not addressed by these regulations will also be identified.

## **Methods and Materials:**

For relevant DRBC regulations, the draft Natural Gas Development Regulations (12) and New York Environmental Conservation Law related to the DRBC compact (14) were reviewed. For relevant New York State regulations, New York Environmental Conservation Law (Chapter 43-B of the Consolidated Laws of New York State) (ECL) related to mineral resources (15), water pollution control (16), waste transportation (17) hazardous substances (18), and enforcement (19) were reviewed, along with Title 6 of the Official Compilation of New York Codes, Rules and Regulations (NYCRR) (20), Chapter IV, Parts 360 (Solid Waste Management Facilities), 364 (Waste Transporter Permits) and 371 (Identification and Listing of Hazardous Wastes), Chapter V, Parts 550 – 559 (Oil and Gas), and Chapter X, Part 750 (State Pollutant Discharge Elimination System Permits). In addition, the GEIS (10), dSGEIS (12) and the DEC’s Spill Guidance Manual (21) were consulted for permit conditions and potential mitigation measures.

Financial and human resources were evaluated using annual reports and other data published online by New York State DEC, the DRBC, ProPublica, and the Interstate Oil and Gas Compact Commission.

Effectiveness of regulatory elements was assessed by the following rubric:

1. Definitions of natural gas development waste fluids,
2. Ultimate objectives of regulatory requirements,
3. Control of regulatory compliance processes, and
4. Resources and historical record.

## **Results:**

1. Definitions of natural gas development waste fluids:

Throughout the entirety of New York State ECL Article 23 (“Mineral Resources”), and related regulations (6 NYCRR Parts 550 – 559), there is no definition of brine, wastewater, drilling mud, flowback, production water or any other form of hydrocarbon development waste. The term “waste” is defined only as:

- a. Physical waste, as that term is generally understood in the oil and gas industry;
- b. The inefficient, excessive or improper use of, or the unnecessary dissipation of reservoir energy;
- c. The locating, spacing, drilling, equipping, operating, or producing of any oil or gas well or wells in a manner which causes or tends to cause reduction in the quantity of oil or gas ultimately recoverable from a pool under prudent and proper operations, or which causes or tends to cause unnecessary or excessive surface loss or destruction of oil or gas;
- d. The inefficient storing of oil or gas; and
- e. The flaring of gas produced from an oil or condensate well after the department has found that the use of the gas, on terms that are just and reasonable, is, or will be economically feasible within a reasonable time.” (22)

There is, however, passing reference to brine: “The department shall have power to: ... Require the drilling, casing, operation, plugging and replugging of wells and reclamation of surrounding land in accordance with rules and regulations of the department in such manner as to prevent or remedy the following, including but not limited to: the escape of oil, gas, brine or water out of one stratum into another; the intrusion of water into oil or gas strata other than during enhanced recovery operations; the pollution of fresh water supplies by oil, gas, salt water or other contaminants; and blowouts, cavings, seepages and fires.” (23) And in the related regulations: “Brine is synonymous with salt water.” (24)

The definitions section just mentioned also defines pollution as “the throwing, discharging, draining, running, flowing or pumping of any organic or inorganic materials onto the surface lands or waters or into subsurface waters in such volume or manner as to make these lands and waters unfit for human or animal consumption or usage.” (25)

We find the disposition of drilling fluids from the New York regulations on prevention of pollution or migration: “For purposes of this subdivision, drilling muds are not considered to be polluting fluids.” (26)

New York state environmental law regarding water pollution control (Article 17) includes the following definitions:

“5. ‘Industrial waste’ means any liquid, gaseous, solid or waste substance, or a combination thereof resulting from any process of industry, manufacturing, trade, or business from the development or recovery of natural resources, which may cause or might reasonably be expected to cause pollution of the waters of the state in contravention of the standards adopted as provided herein.

“13. ‘State Pollutant Discharge Elimination System’ or ‘SPDES’ means the system established pursuant hereto for issuance of permits authorizing discharges to the waters of the state.

“17. ‘Pollutant’ means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand and industrial, municipal, and agricultural waste discharged into water; and ballast which may cause or might reasonably be expected to cause pollution of the waters of the state in contravention of the standards adopted as provided herein.

“19. ‘Toxic pollutant’ means those pollutants, or combination of pollutants, including disease-causing agents which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly through food chains, will, on the basis of information available to the department, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, including malfunctions in reproduction, or physical deformations, in such organisms or their offspring.” (27)

Oil and gas development wastes are defined in the section of New York code related to solid waste as exempt from being declared hazardous: “The following solid wastes are not hazardous wastes: ...drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil, natural gas or geothermal energy.” (28)

There are no references to hydraulic fracturing fluids in New York ECL or Codes, but some can be found in the 9<sup>th</sup> chapter of the GEIS, section F: “Stimulation”. There, stimulation fluids are broadly defined as (1) water-gel “fracs” and (2) foam “fracs”. In section H: “Waste Handling and Disposal”, limited information about drilling, fracturing and produced fluids is presented, with brief discussions of acid, chlorides, gelling agents, surfactants and heavy metals. (29) Pits, tanks, and “pitless drilling” (direct discharge to land) are also described in this section.

Overall, then, New York’s laws and regulations for the handling of natural gas development waste are diffuse (spread over multiple sections of law, regulations and guidance documents, incomplete (lacking even a definition or group of definitions for this waste) and incoherent: in some sections suggesting that this waste is polluting and potentially hazardous, and in others exempting it from being declared hazardous.

In contrast to the diffuse, incomplete and sometimes contradictory definitions of gas development waste fluids in New York law, regulations and guidance documents, the draft DRBC regulations provide concise definitions for centralized wastewater storage facilities, drill cuttings, drilling fluid, flowback, high volume hydraulically fractured wells, hydraulic fracturing fluids, impoundment, non-domestic wastewater, pollutants, production water and wastewater – none of which are contradictory – all in one section. (30) In a later section of the same document, prospective dischargers of natural gas wastewater are required to ensure compliance with U.S. EPA’s primary and secondary standards for the following parameters: Total Dissolved Solids, Chloride, Strontium, Barium, Sulfate, Iron, Nitrite, Fluoride, Manganese, Zinc, Nitrate as N, Aluminum, Copper, Lead, Cyanide-Total,

Chromium, Arsenic, Thallium, Selenium, Antimony, Silver, Cadmium, Beryllium, Mercury, gross-alpha, gross beta, pH, radium-226 + radium-228 and uranium. (31)

Comparing the effectiveness of New York's vs. the DRBC's regulations related to natural gas waste fluids on the basis of the two jurisdictions' definitions alone, it appears that regulation by the DRBC offers considerable advantages over regulation by New York State. In fact, it is difficult to envision a concise, complete and coherent regime of oil and gas regulations ever being developed in New York without extensive revision of state environmental law.

## 2. Ultimate objectives of regulatory requirements:

Along with policy statements, annual reports can provide insight about what activities are most important to public agencies. The last publically available annual report to the legislature by the Division of Mineral Resources within New York's DEC was made in 2008. Reported details included the quantities of oil and gas produced and their market value (\$488 million), related local property taxes (\$14.6 million), state revenues from oil and gas (3.1 million), well-plugging financial security (\$24.7 million), permit fees (\$908 thousand) and the status of the account for plugging abandoned and orphan wells (\$378 thousand); information for many of these categories was available by county and town (32). There was no mention of waste fluids in the report, but there was a significant section on the division's ongoing difficulty in dealing with abandoned and orphan oil and gas wells.

The DRBC's last publically available annual report was for 2008. Reported details included hydrologic highlights, renewed focus on maintaining water quality in the lower Delaware Valley, watershed project partnerships, the PCB control program, the first "state of the basin" multi-jurisdictional study, and concerns regarding drilling in the basin for natural gas (33). With respect to natural gas drilling, specific concerns were related to water consumption and related effects on flow, the potential release of pollutants

(sediments as well as chemicals), forest fragmentation, and the storage, treatment and disposal of waste fluids (33).

Comparing the tone and content of these two annual reports, New York's regulatory program appears to be largely occupied with promoting extraction and sale of gas, while the Delaware River Basin Commission appears to be largely occupied with issues of water quality and sustainability. There was no mention of process wastes in New York's report, and although groundwater contamination caused by some old abandoned wells was noted, no mitigation efforts or outcomes were presented there (32). The DRBC report offered specific concerns, but not specific mitigation strategies, for potential impacts of gas development in the basin including impacts from poorly handled process wastes (33). Nevertheless, the themes suggested by New York's and the DRBC's policy and purpose statements regarding natural gas development (1 – 3) are reflected in the two agencies' annual reports (32, 33) and can be summarized as follows: New York State focuses primarily on production and the Delaware River Basin Commission focuses on protection.

### 3. Control of Regulatory Compliance Processes

This rubric point is based on the idea that supervising the means to an end can be an effective way to ensure that the desired end result is achieved. The New York State DEC and the DRBC may employ regulations and/or permit conditions to control compliance processes related to waste fluids from gas development. Since New York oil and gas regulations contain scant references to waste fluids (24, 25), regulations related to State Pollution Discharge Elimination System (SPDES) permits and regulated waste transport permits were consulted along with the GEIS.

The regulations for SPDES permits do not specifically address gas development wastes except to exempt "water, gas or other material that is injected into a well, except a disposal well, to facilitate production of oil, gas, salt or geothermal resources..." from requiring any permit (34). However, SPDES permits have been used for the direct discharge of gas production brines onto land or into surface streams (35).

Gas development wastes, defined as regulated waste (27, 36), are covered by all the provisions of New York's regulated waste transport regulations – provided the transport is not by waterway, rail or air (37). These provisions require extensive documentation of waste category, source, volume, routing, destination, and compliance history of the permit applicant (38). They also prohibit public disclosure of any proprietary information (39). These provisions may, however, allow for road spreading of flow-back fluids (35), also permissible by the granting of beneficial use determinations (40).

Other process control is available to New York's DEC through the use of permit conditions, generally guided by the GEIS. Use of this mechanism has generally been limited to requiring gas development operators to have approved brine disposal plans prior to drilling new wells (35).

The DRBC draft regulations for natural gas development require project sponsors to maintain extensive documentation of waste sources, volume measurement, transportation, and ultimate disposition (41). They also mandate the monitoring of surface water and ground-water within 2000 feet of a high-volume hydraulically fractured gas well pad, in addition to additional steps related to wastes, such as sampling procedures, analytical methods, composition, treatability, re-use options, and storage (42). Any sponsors of treatment and disposal facilities with the Delaware River Basin are also subject to the most stringent controls (43). And all these regulatory sections prohibit the direct discharge of gas development wastes – or even domestic wastes – anywhere in the Basin.

Overall, the DRBC draft regulations for natural gas development exert greater compliance process control than New York's regulations in every aspect except for ground transportation.

#### *4. Resources and Historical Record*

In 2008, the 19 field agents in New York's Bureau of Oil and Gas Regulation performed 2445 inspections which yielded 84 enforcement actions for a total of \$10,500 in fines – an average of \$125 per citation (32, 44). Meanwhile, they noted chronically insufficient resources to plug old, abandoned oil and gas wells; at the current rate of progress, they will need more than 280 years to identify and seal the existing backlog of abandoned wells (32). The DEC has also signed memoranda of understanding with some county health departments to the effect that county staffers are now responsible for initial investigations of complaints regarding oil and gas operations in their localities (45). The Bureau of Oil and Gas Regulation currently has only 16 field agents (44, 46), so with over 13,000 oil and gas wells to monitor (47), the typical agent is responsible for more than 800 wells.

The DRBC has 46 staff members (48) and an annual budget of \$6.2 million (49). However, their role in regulating natural gas development dates only to 2008 (33), and their performance as a lead agency has already been challenged by litigation (50). None of the DRBC staff appear to be responsible for inspections or enforcement (48). Instead, the agency appears to operate principally by contributing technical, financial and legal expertise to state regulators. In view of New York's difficulties with regulating the gas industry (above), it is doubtful that any assistance which fails to supplement financial and human resources can succeed in protecting that state's portion of the Delaware River Basin.

#### *5. Issues with Proposed DRBC Regulations*

**§ 7.5 (h) (1) (iv) (A) (1) (i):** As proposed, this section makes permits to dispose of process wastes within the Delaware River Basin available by agency approval, which could leave such decisions vulnerable to political pressures on agency staff. While conditions could exist that would make transport of such wastes more hazardous than their in-basin disposal, the decision in each case should be made publically, with input from informed and concerned residents of the watershed.

**§ 7.5 (h) (1) (iv) (C) (2):** The language of this section is incomplete.

**§ 7.5. (h) (2) (ii) (D):** New York State regulations currently under review permit a large repertoire of chemical additives to be used for natural gas production (51), and many of them are hazardous or their safety has not been established (52). Although several energy companies are investigating safer alternatives to the most egregious chemicals, there is no regulatory pressure for all companies to adopt the most benign additives which would meet their operational requirements, or to fully test those for which environmental or health hazards are unknown.

**§ 7.5 (h) (2) (ii) (G - H) & 7.5 (h) (2) (iv) (B):** New York State regulations currently under review require the handling and storage of flowback and “produced” fluids in tanks, except in situations where enormous volumes must be accommodated, such as centralized collectors for a number of well pads within a 4-mile radius; for these applications, permits for open impoundments are proposed (53). However, the use of any open pits should be expected to result in human and environmental exposure to hazardous chemicals, as determined by the states of Colorado and New Mexico prior to their banning the use of pits for process wastes from natural gas production (54, 55).

**§ 7.5 (h) (2) (iii) & 7.5 (h) (1):** New York State regulations define drilling fluids as non-polluting fluids, regardless of their actual composition (26). However, as illustrated in Table I, they contain many of the same constituents as hydraulic fracturing fluids. In addition, drilling “muds” may contain potentially hazardous constituents not used in hydraulic fracturing fluids, but which have been detected in flowback fluids from gas wells (56); these include the toxic elements cadmium and selenium (57). Since New York appears unlikely to re-write its code of regulations and begin to regulate drilling fluids, there is a need for the DRBC to address these concerns specifically.

**Table I: Additive Functions in Shale Gas Extraction**

<u>Additive Type</u>	<u>Examples</u>	<u>Purpose</u>	<u>Used In</u>
Friction Reducer	heavy naphtha, polymer microemulsion	lubricate drill head, penetrate fissures	drilling muds, fracturing fluids
Biocide	glutaraldehyde, DBNPA, dibromoacetonitrile	prevent biofilm formation	drilling muds, fracturing fluids
Scale Inhibitor	ethylene glycol, EDTA, citric acid	prevent scale buildup	drilling muds, fracturing fluids
Corrosion Inhibitor	propargyl alcohol, <i>N,N</i> -dimethylformamide	prevent corrosion of metal parts	drilling muds, fracturing fluids
Clay Stabilizer	tetramethylammonium chloride	prevent clay swelling	drilling muds, fracturing fluids
Gelling Agent	bentonite, guar gum, "gemini quat" amine	prevent slumping of solids	drilling muds, fracturing fluids
Conditioner	ammonium chloride, potassium carbonate, isopropyl alcohol	adjust pH, adjust additive solubility	drilling muds, fracturing fluids
Surfactant	2-butoxyethanol, ethoxylated octylphenol	promote fracture penetration	drilling fluids, fracturing fluids
Cross-Linker	sodium perborate, acetic anhydride	promote gelling	fracturing fluids
Breaker	hemicellulase, ammonium persulfate, quebracho	"breaks" gel to promote flow-back of fluid	post-fracturing fluids
Cleaner	hydrochloric acid	dissolve debris	stimulation fluid, pre-fracture fluid
Processor	ethylene glycol, propylene glycol	strip impurities from produced gas	post-production processing fluids

**§ 7.6 (c):** Due to the high cost of attempting to test for every possible additive chemical (51), drilling operators as well as regulators might benefit from the tailoring of test protocols to chemicals and by-products which may reasonably be anticipated to be found in aquifers near well pads and compressor stations. However, some mechanism for securing the intellectual property rights of well service companies will need to be put in place for this approach to become feasible and enforceable.

**§ 7.6 (c) - (e):**

The standard panel of water tests in this section omits three important analytes: radon (Rn), hydrogen sulfide (H<sub>2</sub>S) and 4-nitroquinoline-1-oxide (4-NQO). Although these chemicals are not used as drilling or fracturing additives, they are widespread in flow-back fluids and/or groundwater.

Radon is a radioactive gas which the U.S. Geological Survey found at levels above 300 pCi/L in every ground-water sample they tested within the Delaware River Basin (58). This gas is presumed to infiltrate from radioactive shale formations such as the Marcellus shale (59), and it should be monitored during any process which disturbs such structures. Radon is considered the second leading cause of lung cancer, after tobacco smoking (60).

Rock strata beneath the earth's surface are populated by microscopic organisms, and the advent of air-lubricated drilling (without biocides) has introduced a risk of contaminating surface (fresh) water zones with bacteria and other microbes from deeper (brine) layers, where they often flourish. Of particular concern are sulfate-reducing bacteria, especially *Desulfovibrio desulfuricans*, a facultative anaerobe that thrives in fresh water where some sulfate (such as is present in pyrite or hematite) is available (61).

These bacteria are especially prevalent and aggressive in oil and gas producing regions, where they avidly form living black, sticky films in water wells and other structures (62). There they produce hydrogen sulfide (H<sub>2</sub>S), characterized by a "rotten eggs" smell. Rock strata rich in gas are often also rich in this bacterium, and exposure to hydrogen sulfide along with methane raises significant health concerns –neurological syndromes in humans and, in livestock, elevated birth defect rates and diminished herd health. At high concentrations, hydrogen sulfate is lethal (63).

One chemical compound consistently encountered in flowback fluids from Marcellus gas wells in Pennsylvania and West Virginia was 4-nitroquinoline-1-oxide (4-NQO) (64). This is one of the most potent carcinogens known, particularly for inducing cancer of the mouth (65). It is not used as a drilling additive and is not known to occur naturally in black shale. No studies have been published to date with respect to chemical interactions which

might account for its consistent presence in flowback fluids. In any event, 4-NQO is dangerous at parts-per-trillion (ppt) concentrations, well below its levels reported in gas well flowback fluids (64).

## **Conclusions and Recommendations**

New York State's efforts to regulate the natural gas industry have been compromised by diffuse, incomplete and incoherent regulations, a legislative mandate to focus on petroleum production more than on environmental conservation, a general lack of compliance process control mechanisms, and a severe shortage of financial and human resources.

The Delaware River Basin Commission proposes regulations which are cohesive and coherent, although they are incomplete. These new regulations are necessary to meet anti-degradation standards for federal Special Protection Waters within New York State, because New York's current regulatory program does not guarantee that those standards will be met. New guidance documents which might address some of New York's regulatory deficiencies are in draft form. DRBC staff members have little experience with regulating the natural gas industry, and appear not to be tasked with inspection or enforcement duties. Although most implementation of gas industry regulations will probably be carried out by New York's Bureau of Oil and Gas Regulation field agents (*DRBC draft Natural Gas Development Regulations § 7.1 (i)*), these agents' ability to robustly enforce new DRBC regulations in addition to their own is doubtful.

Therefore, it is recommended that the DRBC should wait for the finalization of New York's Supplement to the Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program (SGEIS) before completing its own Natural Gas Development Regulations. In addition, the DRBC should put new mechanisms in place to assist state regulators with financial and human resources.

It is further recommended that the DRBC make the following changes to its proposed regulations:

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It is hoped that these conclusions and recommendations will promote effective regulation of the natural gas industry in the Delaware River Basin, and foster the greatest possible protection for our precious land and water resources.

## References:

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