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INDEPENDENT REGULATORY REVIEW COMMISSION

From: Collins, Emily A [eac50@pitt.edu]
Sent: Friday, February 12, 2010 4:57 PM
To: EP, RegComments
Cc: Myron Arnowitt
Subject: Chapter 95 Wastewater Treatment Requirements Comments; 39 Pa. Bulletin 6547
Attachments: 2.12.1010 Chapter 95 comments.final.pdf

Dear Environmental Quality Board members,

Please accept the attached comments for Clean Water Action, Earthjustice, Three Rivers Waterkeeper, and the Sierra Club. We are placing a hard copy of the same comments in the mail today.

Sincerely,

Emily Collins

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February 12, 2010

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FEB 19 2010
INDEPENDENT REGULATORY REVIEW COMMISSION

Environmental Quality Board
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Re: Chapter 95 Wastewater Treatment Rulemaking

Dear Environmental Quality Board members,

Thank you for the opportunity to comment on the proposed revisions to Chapter 95 of the Pennsylvania Code noticed in the November 7, 2009 and November 14, 2009 editions of the Pennsylvania Bulletin. The University of Pittsburgh Environmental Law Clinic submits these comments on behalf of our client, Clean Water Action, joined by the Sierra Club, Earthjustice, and the Three Rivers Waterkeeper.

Clean Water Action commends the Department of Environmental Protection (Department or DEP) for acting quickly to propose changes to Chapter 95, with a goal of preserving and protecting Pennsylvania waters from significantly increased loadings of total dissolved solids, chlorides, sulfates, barium, and strontium. While we support the proposal, Clean Water Action suggests a few modest, but important, changes that would improve the final rule significantly. We urge the Environmental Quality Board to act quickly to ensure adequate treatment of wastewaters containing high levels of total dissolved solids. Clean Water Action strongly supports DEP's use of wastewater quality-based effluent limitations combined with the development of water quality criteria for chloride and sulfates that will be protective of aquatic life uses of Pennsylvania's waters. We have attached a summary of our comments as Exhibit 1.

The Department has the necessary statutory authority to set effluent limits for TDS, chlorides, sulfates, barium, and strontium. The DEP has the power to promulgate reasonable regulations implementing the stated policy of the Pennsylvania Clean Streams Law "to prevent further pollution of the waters of the Commonwealth" and "also to reclaim and restore to a clean, unpolluted condition every stream in Pennsylvania that is presently polluted." 35 P.S. § 691.4(3) (2009); *see also id.* § 691.5(a) (giving DEP broad authority to adopt rules and regulations "implementing the declaration of policy in section 4 of th[e] act"); 2 Pa.C.S.A. § 102 (2009). The power to adopt rules that impose effluent limitations on wastewater dischargers beyond the limitations derived from Federal effluent limitation guidelines, the use of best professional judgment, applicable water quality standards, and the Commonwealth's antidegradation policy stems from the following five required factors in the Clean Streams Law:

(1) Water quality management and pollution control in the watershed as a whole;

(2) The present and possible future uses of particular waters;

(3) The feasibility of combined or joint treatment facilities;

(4) The state of scientific and technological knowledge;

(5) The immediate and long-range economic impact upon the Commonwealth and its citizens.

35 P.S. § 691.5(a) (2009). Ultimately, the DEP is free to adopt regulations that are more protective than federal standards. Similarly, the Clean Streams Law empowers DEP to adopt regulations "as may be deemed necessary for the protection of the purity of the waters of the Commonwealth, or parts thereof, and to purify those now polluted, and to assure the proper and practical operation and maintenance of treatment works approved by it." 35 Pa. Code § 691.304 (2009). The Federal Clean Water Act specifically allows states to adopt and enforce "any standard or limitation respecting discharges of pollutants" or any other requirement to control pollution as long as the state rules are not "less stringent than the effluent limitation, or other limitation, effluent standard, prohibition, pretreatment standard, or standard of performance under [chapter 26]…." 33 U.S.C. § 1370(1) (2010).

The proposed changes to Chapter 95 fall squarely within DEP's duties to prevent pollution and restore water quality, and they provide a clear and direct method of managing a growing problem caused by a wide array of discharges including a major new wastewater stream associated with Marcellus Shale gas drilling. The Clean Streams Law provides DEP with the authority and flexibility to adopt wastewater treatment effluent limitations in addition to water quality-based effluent limitations and technology-based effluent limitations to handle newly introduced and otherwise unique wastewater streams such as the high-TDS wastewaters that this rulemaking is designed to address. Indeed, the Clean Streams Law imposes a duty on DEP to adapt its rules and NPDES decision-making to changing wastewater sources and innovative treatment technologies. 35 P.S. § 691.5; 25 Pa. Code § 92.2b (2009). Given the documented water quality impacts of high-TDS wastewater on Commonwealth waters; the growing body of scientific evidence regarding serious threats both to human health and aquatic life posed by TDS, chlorides, and sulfates, as well as barium and strontium; the availability of effective treatment technologies; and the major economic impact on the public in the absence of adequate treatment for these wastewaters – all factors that merit detailed discussion in the preamble to the final rule - the proposed changes to Chapter 95 will provide an effective tool to protect Pennsylvania's waterways while encouraging the use of innovative wastewater treatment technologies.

I. <u>The Department Should Describe the Nature of the Chapter 95 Effluent Limitations in Comparison to Technology-based Effluent Limitations and Water Quality-based Effluent Limitations.</u>

The Preamble to Chapter 95 should clarify the source of the statutory basis for "wastewater quality standards" under the Clean Streams Law. The Preamble should further clarify how the Chapter 95 effluent limitations differ from other state-level effluent limitation guidelines and water quality-based effluent limitations. In Chapter 92, the Department has referred to the requirements of Chapter 95 as "wastewater quality standards" that must be considered in addition to water quality standards and implementation of those standards, "applicable treatment requirements and effluent limitations to which a discharge is subject under [Chapter 92] and the Federal Act," and the "treatment requirements and effluent limitations of [Title 25]."[1] The definition of "applicable effluent limitations or standards" in the Department's regulations includes several categories of limitations beyond technology-based and water quality-based effluent limitations, including "standards of performance, toxic effluent standards and prohibitions, BMPs and pretreatment standards."[2] The definition of "effluent limitation guideline" includes categorical guidelines promulgated by EPA as well as rules published by the Department "to revise or adopt effluent limitations."[3] These various types of effluent limits are separate and distinct concepts, arising under different statutory provisions, subject to different legal requirements, and derived through varying scientific and technical considerations. As DEP has the power to issue a variety of effluent limits and standards, the Department should specify the distinction between the Chapter 95 standards and other applicable effluent limitations and standards. More specifically, the preamble of the final form rulemaking should clearly reflect the Department's authority and duty under the current circumstances to set effluent standards in addition to water-quality and technology-based discharge permit limits.

Similarly, the preamble should be revised to more clearly reflect the foundation for the new effluent standards. While the preamble to the draft rule sheds light on the severity of the TDS problem, the language in the preamble should not be limited to descriptions of water quality concerns rather than the entirety of the considerations required by 35 P.S. § 691.5(a). First, the preamble outlines the problems arising in the Monongahela River, especially a well-publicized series of events in 2008 when water quality standards for TDS and sulfates were exceeded at 17 Potable Water Supply intakes and an another incident involving chloride exceedances at South Fork Tenmile Creek.[4] Second, the preamble cites the possible impacts of TDS on aquatic life in Greene County, where saltwater organisms are developing downstream of Marcellus Shale wastewater facilities. In addition, the preamble should set forth the current state of scientific and technical knowledge on treatment technologies and the economic costs to the community of

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[1] 25 Pa. Code § 92.2a(a). The Department's power to institute wastewater treatment standards in addition to water quality-based effluent limits and technology-based effluent limitations has been in rule for over 30 years. 9 Pa. Bull. 2989, 3180 (September 8, 1979).

[2] 25 Pa. Code § 92.1 (2009).

[3] *Id.*

[4] Additional exceedances of the TDS water quality criteria in the Monongahela River occurred in August, September, and October 2009.

TDS, chlorides, and sulfates impacts without the proposed effluent limits. Consideration of the five rule-making factors set forth in the Clean Streams Law supports adoption of the propose Chapter 95 regulations, and the preamble should make that clear.

II. Chapter 95 Effluent Standards Should Not Replace National Effluent Limitation Guidelines or Best Professional Judgment Duties Unless Specifically Developed As Technology-based Effluent Limitations.

The Department should clarify how the new effluent limitations will interact with pre-existing and possibly forthcoming Federal effluent limitation guidelines,[5] best professional judgment, and water quality-based effluent limitations. Clean Water Action is concerned that dischargers will seek to rely on Chapter 95 to escape required technology-based effluent limits that must be set based on the permit engineer's best professional judgment regarding the level of pollution control achievable using the best available technology.

Clean Water Action's concern that DEP is proposing to use the Chapter 95 changes to replace the need to conduct a BPJ analysis is not unfounded. The Department's High-TDS Permitting Strategy (Permitting Strategy) describes the Chapter 95 changes as "treatment-based water quality management,"[6] which initially appears to comprise a different approach than establishment of state-level effluent limitation guidelines for high-TDS wastewaters. The Permitting Strategy at page 4 states:

> Discharges from a CWT facility treating gas extraction produced waters are subject to the effluent limitations and pretreatment standards established under 40 CFR Part 437. However, additional limits and conditions are needed to address pollutants that were not considered in developing the federal CWT Effluent Guidelines and Standards (ELGs). For example, there is the potential for several pollutants to be found in produced waters (e.g., TDS, radionuclides, chlorides) that were not regulated or considered in the development of the CWT ELGs.

The Department then summarizes the procedure for using BPJ when Federal ELGs do not cover pollutants present in unanticipated wastewater streams treated at centralized wastewater treatment facilities as follows:

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[5] EPA has recently requested comments on the Preliminary 2010 Effluent Guidelines Program Plan, which specifically solicits comment on "whether [EPA] should expand its detailed study of coalbed methane extraction to include all oil and gas exploration, stimulation, and extraction techniques that result in contamination of surface and groundwater, including hydraulic fracturing in all formations. 74 Fed. Reg. 68599, 68607 (December 28, 2009). Comments are due by February 26, 2010. Further, EPA has announced its intent to issue revised effluent limitation guidelines for the Steam Electric Generating Unit Category. *See* 74 Fed. Reg. 55,837, 55,839 (Oct. 29, 2009).

[6] Pennsylvania Department of Environmental Protection, Permitting Strategy for High Total Dissolved Solids (TDS) Wastewater Discharges, April 11, 2009, *available at* http://www.portal.state.pa.us/portal/server.pt/community/marcellus_shale_wastewater_partnership/18683 (last checked February 10, 2010).

for a CWT facility that accepts produced waters or other waste from oil and gas extraction facilities, the permitting authority (DEP) needs to develop technology-based effluent limits to address those pollutants not considered or regulated by the CWT Effluent Guidelines and incorporate these limits in the facility's NPDES permit.[7]

The Department's Permitting Strategy further states that the use of BPJ "requires a great deal of individual professional judgment, takes a great deal of time, and does not result in a level playing field for all CWTs with regard to required treatment levels." Clean Water Action is concerned that these statements in the Permitting Strategy suggest that the proposed changes to Chapter 95 would replace the Department's obligation to use Best Professional Judgment in permitting actions.

Clean Water Action disagrees that the permitting scheme allows DEP to disavow its obligation to use BPJ unless they specify and adequately analyze the Chapter 95 changes as "technology-based effluent limitation guidelines." The development of technology-based effluent limitation guidelines requires careful consideration of available technologies, costs in relation to effluent reduction benefits, engineering aspects of various control techniques, available best management practices, and non-water quality environmental impacts.[8] The preamble to this rulemaking does not currently reflect that DEP took those considerations into account in developing the Chapter 95 changes. If the Department intends the Chapter 95 changes to operate as state-level effluent limitation guidelines as envisioned by 25 Pa. Code § 92.1, DEP must clarify that intent and present the required "best available technology" analysis.

Finally, as Chapter 95 merely seeks to establish wastewater quality standards for TDS, chlorides, sulfates, barium, and strontium, the Department will need to use best professional judgment to set technology-based effluent limits for a host of other pollutants present in Marcellus Shale wastewater. The chemical composition of each stream of Marcellus Shale wastewater presents unique challenges to the Commonwealth that requires the tailored analysis of the BPJ process. Each drilling company uses a proprietary mixture of chemicals for its fracturing fluid. In addition, the chemical composition of the produced water varies from location to location within the overall Marcellus Shale formation. TerrAqua Resource Management, LLC, provided samples from 10 Marcellus Shale drilling operations showed a variety of concentrations for pollutants not covered by the NSPS limits in 40 C.F.R. § 437.31, including aluminum, arsenic, barium, bromide, cadmium, chloride, iron, lead, manganese, silver, Gross Alpha, Gross Beta, Radium 226, Radium 228, and Uranium.[9] Therefore, the Department will need to continue to exercise its best professional judgment in individual permitting decisions regardless of the Chapter 95 rule changes.

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[7] *Id.*

[8] 40 C.F.R. § 125.3(c), (d).

[9] NPDES #PA0233650 Fact Sheet, TerrAqua Resource Management, LLC, Water Tower Square Gas Well Wastewater Processing Facility, Prepared 4/17/09 by Jeffrey J. Gocek, EIT, Environmental Engineering Specialist, Water Management Program – Permit Section, Northcentral Regional Office, Pennsylvania DEP; *see also* DEP Form 26R Chemical Analysis of Residual Waste Annual Report by the Generator Instructions.

III. The Department Should Revise the Preamble to Reflect the Process By Which the Numerical Effluent Limits Were Derived.

Several organizations have questioned the scientific basis for the Proposed Chapter 95 regulations and DEP's attention to economic impacts on dischargers, and they have questioned whether the EQB and the Department have a duty to explore alternate regulatory schemes to achieve the stated goals of this revision. In fact, DEP staff have considered not only the relevant science and economic, they also have contemplated alternate regulatory schemes in the context of the Regulatory Advisory Commission (RAC) process. The preamble should reflect the entire scientific basis and technological considerations that went into the development of the Chapter 95 changes. Regulations promulgated by the EQB must pass a reasonableness test that demonstrates consideration of the conditions in 35 P.S. § 691.5(a).[10]

With respect to economic impacts, the preamble should reflect the legally mandated analysis of economic impacts *to the public*. In considering the Department's imposition of very stringent effluent limitations on an individual discharger, the Pennsylvania Supreme Court has stated that "[t]he economic impact which must be considered under The Clean Streams Law...relates to the impact on the community and public at large, not on the individual discharger."[11] Therefore, the Department should describe the economic impact to the public, the state of technical and scientific knowledge, and the present and possible future uses of the waterways that are threatened without enactment of the rule changes.[12]

In addition, the Department should clarify the process by which it arrived at the 500 mg/L limits for TDS and the 250 mg/L limits on total chlorides and sulfates, and clearly describe any relationship those numbers have to the maximum contaminant levels for the National Secondary Drinking Water Regulations found in 40 C.F.R. § 143.3. In doing so, the Department should specifically clarify whether it is utilizing the authority in 35 P.S. § 691.501 to enact regulations to protect public water supplies.[13]

IV. Reuse and Recycling Treatment Technologies Exist that Can Meet the Effluent Standards in the Chapter 95 Proposal.

The current state of treatment technology, including reuse and recycling processes, reverse osmosis with pretreatment, evaporation, crystallization, and mechanical distillation, is sufficiently advanced to meet the new effluent limits in Chapter 95. In fact, the Department has a duty to develop regulatory measures that encourage the use of the following types of treatment facilities, in descending order of preference: reuse wastewater facilities, wastewater recycling

[10] 2 Pa.C.S.A. § 102.

[11] *Mathies Coal Co. v. DER*, 559 A.2d 506, 511 (1989). 35 P.S. § 691.501 (2009).

[12] 35 P.S. § 691.5 (2009).

[13] 35 P.S. § 691.501 (2009) states: "In addition to the powers and authority hereinbefore granted, power and authority is hereby conferred upon the department, after due notice and public hearing, to make, adopt, promulgate, and enforce reasonable orders and regulations for the protection of any source of water for present or future supply to the public, and prohibiting the pollution of any such source of water rendering the same inimical or injurious to the public health or objectionable for public water supply purposes."

facilities, and treatment and discharge facilities.[14] The effluent limitations in Chapter 95 will encourage the use of more effective treatment technologies and reuse and recycling facilities for wastewater management. To that end, the Department should describe and clarify which technologies it foresees as satisfying the new effluent limits and the types of technologies that were considered during the development of the Chapter 95 revisions.

Several facilities in Pennsylvania and West Virginia are already able to satisfy the effluent limitations in Chapter 95, proving that the technologies are effective, reliable, and economically feasible. For example, AOP Clearwater, LLC, has developed a reuse and recycling wastewater plant in Fairmont, West Virginia.[15] The AOP plant pretreats high-TDS wastewaters to remove solids and other pollutants, separates oil from the water, and then processes the wastewater to remove TDS to concentrations of less than 500 mg/L.[16] AOP Clearwater has estimated treatment costs at 14.3 cents per gallon if 80 percent of wastewater is available for reuse or 12 cents per gallon if the reused water is not available for reuse and discharged.[17] The facility can process up to 210,000 gallons of wastewater per day.[18]

Here in Pennsylvania, the DEP has recently issued a NPDES permit to TerrAqua Resource Management with TDS, sulfate, and chloride effluent limits identical to those proposed in Chapter 95. The company plans to satisfy these limits by using a thermal treatment process. Also, the recently noticed Reserved Environmental Services (RES) draft permit demonstrates that the effluent standards in the Chapter 95 proposal can be met by a reuse and recycling wastewater facility.[19] The RES plant will include treatment in two phases: Phase I will consist of a chemical and physical treatment with a recycling program that will reuse all wastewater, including flowback, pit, and production fluids, for hydraulic fracturing, while Phase II will include installation an evaporator and crystallizer, which will provide physical, chemical and thermal treatment of the wastewater. During Phase I, the RES facility will use up to 3 million gallons of potable water per day to be used to adjust the concentration of chlorides in the recycled water to levels appropriate for fracturing. Phase I will operate for an estimated period of three years while Phase II, the thermal portion of treatment, is constructed. RES proposes to provide all its effluent for reuse during Phase I, which will result in no discharge of wastewater. RES plans to either sell distillate from the evaporator for reuse to drillers or discharge the remaining effluent. In addition, condensate from the evaporator will be sent to a crystallizer

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[14] 25 Pa. Code § 92.2b (stating that the "Department will encourage consideration of the following measures, in descending order of preference, for environmental management of wastes: reuse, recycling, treatment and disposal.").

[15] AOP Clearwater Water Recycling process description *available at* http://aopclearwater.com/The_Clearwater_Process.html (last checked February 10, 2010).

[16] *Id.*

[17] The State Journal, Pam Kasey, "AOP Clearwater to Use Evaporation for Gas Well Drilling Brine," published on February 20, 2009, *available at* http://www.statejournal.com/story.cfm?func=viewstory&storyid=52674 (last checked February 10, 2010).

[18] *Id.*

[19] 40 Pa. B. 33 (January 2, 2010) (NPDES Draft Permit No. PA0254185).

from which salt and any remaining wastewaters will either be reused or properly disposed as residual waste. The RES plant is currently designed to handle up to 1 million gallons per day of produced wastewaters from Marcellus shale fracturing.

While the RES Phase I dilution is used to achieve acceptable chloride levels for flowback reuse in hydraulic fracturing, and excessive water withdrawals may pose environmental problems once recycling and reuse facilities become operational, these facilities show great promise in protecting potable water supplies and aquatic life if physical or chemical separation is used and well pad tank storage (rather than pit storage) of flowback water is required.

Depending on the level of TDS concentrations in wastewater influent, other technologies for the treatment of TDS are also available to meet the effluent limits proposed in Chapter 95. Major David Johnstone, Ph.D., is an Assistant Professor of Civil & Environmental Engineering at the Virginia Military Institute, where he specializes in water quality modeling, environmental engineering, and physical/chemical treatment processes.[20] In a report attached as Exhibit 2, he concludes that evaporation and crystallization may be used to treat TDS concentrations from 20,000 to over 150,000 mg/L, reducing the TDS concentrations to between 50 to 150 mg/L. Membrane technologies, such as reverse osmosis, nanofiltration, ultrafiltration, electrodialysis, and electrodialysis with reversal, may be appropriate for wastewaters with TDS concentrations of less than 50,000 mg/L. If adequate pretreatment is used for flowback water, membranes may be useful for wastewaters with TDS concentrations below 50,000 mg/L. Further, the use of some of these technologies would be beneficial for all industries that produce high-TDS wastewaters.

V. Chapter 95 Should Apply to Existing Dischargers Upon Their NPDES Permit Renewal.

The definition of "new discharge" in 95.10(a) should be clarified to ensure that existing discharges with high levels of TDS will eventually be subject to the limits in Chapter 95. The language as proposed implies that existing discharges from existing sources are exempt from the new effluent limits. Instead, existing dischargers should be brought into compliance with these effluent limits through the NPDES renewal process. This would ensure that all dischargers comply with Chapter 95, while providing a reasonable concession to the realities of modifying existing facilities to comply with new effluent limitations.

Any interpretation of Chapter 95 that does not regulate existing discharges fosters an environment of unfair competition between existing and new dischargers. By favoring old over new facilities, this interpretation would discourage investment in new and more efficient wastewater treatment facilities at a time when Pennsylvania desperately needs more treatment capacity. Further, existing discharges have already pushed several watersheds to their breaking point and allowing them to continue unabated would undermine the purpose of these new effluent limits.

[20] Major Johnstone's C.V. is attached as Exhibit 3.

VI. The Effluent Limits Should Include a Daily Maximum in Addition to a Monthly Average.

In addition to a monthly average effluent limitation, Chapter 95 should include a maximum daily value limitation, which is the standard format found in the federal effluent limitation guidelines. Large swings in pollutant loads in oil and gas wastewater are not uncommon, and having the Chapter 95 effluent limits expressed in this way accounts for that variability. Such daily limits are necessary to prevent unacceptable adverse impacts to aquatic life.

VII. Minor clerical suggestions

In order to enhance the clarity of § 95.10(c)(1), which prohibits the discharge of wastewater from drilling sites, the Department should change the phrase "that is" to either "e.g." or "including, but not limited to." This change would clarify that the list of wastewater types is intended to be non-exclusive. In § 95.10(6), the Department should amend the phrase "new source standards of performance," appearing in a list of different types of federal effluent limitation guidelines, to the more accurate phrase of "New Source Performance Standards (NSPS)." This brings all of the items in that list into a standard format and creates a more appropriate textual disposition.

VIII. The Department Should Promulgate a Bromide Effluent Limit and Additional Water Quality Standards for Chloride and Sulfate.

The Department should continue in its effort to protect Pennsylvania's waters by promulgating a water quality criterion for chlorides and sulfates. By setting new effluent standards in Chapter 95, the Department has taken an important first step in updating the state's water regulations to reflect the challenges posed by the development of the Marcellus Shale formation. Setting new water quality criteria for chlorides and sulfates that are protective of aquatic life and incorporating a wastewater quality standard for bromides is a necessary second step.

Using the same statutory structure as that used for the proposed changes to TDS, chlorides, and sulfates, the Department should develop a wastewater quality standard for bromides. As mentioned in the attached report form Major Johnstone, the Monongahela, Allegheny, and Ohio Rivers are experiencing "significant bromide levels," which poses a significant human health risk to the surrounding communities. As described by Major Johnstone, brominated byproducts have been classified as possible human carcinogens. Chapter 95 revisions could address these concerns by including an effluent limitation for bromides.

Iowa recently reviewed its own water quality standards for total dissolved solids, chlorides, and sulfates. Like Pennsylvania, only the public water supply use enjoyed protection by a chloride water quality standard in Iowa. As an interim measure to regulate in-steam TDS levels, however, Iowa required that, if in-stream chloride concentrations reached an acute threshold of 860 mg/l, or a chronic threshold of 230 mg/L, Whole Effluent Toxicity tests were required. Those threshold levels are the equivalent of EPA's 1988 section 304(a) national criteria. In setting final chloride criteria, Iowa performed a literature review and conducted new toxicity tests on several species that were not considered in EPA's 1988 chloride criteria document. The Iowa Department of Natural Resources determined that the 1988 acute criterion of 860 mg/L and the chronic criterion of 230 mg/L needed to be updated and recalculated based on the following:

> The most recent 304(a) national criteria for chloride were published in 1988. The national criterion for chloride was derived based on the toxicity test data of sodium chloride in laboratory reconstituted water given that it is the only chloride composition with enough data available to allow derivation of a water quality criterion. Also, it is likely that most anthropogenic chloride in ambient water is associated with sodium, rather than potassium, calcium, or magnesium (EPA, 1988).[21]

IDNR found in its literature review that several studies were not considered in EPA's development of the national criteria for chloride and more toxicity data was needed to determine if four particular species were indeed sensitive to chloride. As a result, EPA contracted with the Great Lakes Environmental Center (GLEC) in Columbus, OH and the Illinois Natural History Survey (INHS) at Champaign, IL to perform additional toxicity testing.[22]

Using a statewide default value for hardness and sulfate in the absence of site-specific data, Iowa decided on the following criteria:

- Acute chloride criterion: $254.3(\text{hardness})_{0.205797}(\text{sulfate})_{-0.07452}$
- Chronic chloride criterion: $161.5(\text{hardness})_{0.205797}(\text{sulfate})_{-0.0745}$

After conducting an extensive literature review and developing new sulfate toxicity data, Iowa set a sulfates criteria based on the relationship between sulfate toxicity and water chemistry parameters that included chloride and hardness. In adopting a aquatic life protective water quality criterion for sulfates in Pennsylvania, the Department should account for water chemistry conditions that may significantly change sulfate toxicity. Water chemistry-dependent equations should be considered as well as numerical standards. In setting Pennsylvania's chloride and sulfates criteria, the Department should consider the toxicity data developed by Iowa in conducting the review of its own chloride and sulfate water quality standards. Clearly, the toxicity of both chloride and sulfates is dependent on watershed-specific factors such as water hardness.

While the general format of Iowa's equations may be copied directly, the specific coefficients must be determined based on a scientific review of Pennsylvania's stream ecology. For example, the toxicity of chloride in Pennsylvania might be dependent of the presence of trace

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[21] Iowa Department of Natural Resources, *Water Quality Standards Review: Chloride, Sulfate and Total Dissolved Solids,* (February 9, 2009), *available at* http://www.iowadnr.gov/water/standards/files/ws_review.pdf.

[22] EPA, *Acute Toxicity of Chloride To Select Freshwater Invertebrates.* (September 26, 2008).

metal ions that are found in the state's waters from acid mine drainage. Other chemical factors may be appropriate to include in the specific equations as well.

IX. Conclusion

We support the Department's proposed effluent standards for high-TDS wastewater. The Department should clarify the process by which permit engineers will implement these new limitations into new sources and dischargers, and existing discharges of high-TDS effluent should be rolled into the Chapter 95 wastewater quality standards at the point of permit renewal. The preamble should be revised to reflect and document the thoughtful administrative process that went into the development of these limits and the technology that is expected to satisfy the new limits. As further protection, the new limits should include a daily maximum limit and the Department should promulgate a new water quality standards for chlorides and sulfates that will protect aquatic life. Finally, the Department should consider setting a bromides effluent limitation in Chapter 95 to ensure the significant human health threats associated with brominated byproducts.

Once again, thank you for the opportunity to comment on the proposed revisions to Chapter 95. Please feel free to contact me at (412) 648-1300 with any questions or concerns.

Sincerely,

Matthew Hilliard
Certified Legal Intern

Emily A. Collins
Supervising Attorney

Myron Arnowitt
Pennsylvania State Director
Clean Water Action

Ned M. Mulcahy, Esq.
Executive Director
Three Rivers Waterkeeper

Abigail Dillen, Esq.
Staff Attorney
Earthjustice

Craig Segall
Environmental Law Fellow
Sierra Club

Exhibit 1

Clean Water Action Comments on Chapter 95 Revisions

CLEAN WATER ACTION
PENNSYLVANIA

Proposed Rulemaking on 25 PA CODE Chapter 95, Wastewater Treatment Standards

Summary of Comments from Clean Water Action, joined by Earthjustice, Three Rivers Waterkeeper, and the Sierra Club.

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Overall, we support the proposed effluent standards for high-TDS wastewater. We suggest several modifications to strengthen the proposed rule:

1. The DEP has the necessary statutory authority to set effluent limits for TDS, chlorides, sulfates, barium, and strontium, and should fully detail the basis of the proposal in the Preamble to the proposed regulation.

2. The Preamble to Chapter 95 should clarify the source of the statutory basis for "wastewater quality standards" under the Clean Streams Law, and clarify how the Chapter 95 effluent limitations differ from other state-level effluent limitation guidelines and water quality-based effluent limitations.

3. The proposed Chapter 95 standards should not replace pre-existing and possibly forthcoming Federal effluent limitation guidelines, best professional judgment, and water quality-based effluent limitations.

4. The DEP should clarify in the Preamble the process by which it arrived at the 500 mg/L limits for TDS and the 250 mg/L limits on total chlorides and sulfates.

5. The current state of treatment technology, including reuse and recycling processes, reverse osmosis with pretreatment, evaporation, crystallization, and mechanical distillation, is sufficiently advanced to meet the new effluent limits in Chapter 95. Several facilities in Pennsylvania and West Virginia are already capable of meeting these limits.

6. Chapter 95 should apply to existing dischargers upon their NPDES permit renewal.

7. The effluent limits should include a daily maximum in addition to a monthly average.

8. The DEP should promote additional water quality standards for chlorides and sulfates. DEP should additionally consider an effluent standard for bromides to address public drinking water safety.

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Exhibit 2

Clean Water Action Comments on Chapter 95 Revisions

February 11, 2010

Emily Collins
Supervising Attorney
University of Pittsburgh - Environmental Law Clinic
210 South Bouquet Street
Pittsburgh, PA 15260

Dear Ms. Collins,

Please find my attached letter report concerning the review of the Pennsylvania Department of Environmental Protection's rulemaking proposal to enact TDS, chloride, sulfate, barium, and strontium technology-based effluent limitations on dischargers of more than 2,000 mg/L of TDS. Specifically, the overall scope was to assess the proposed restrictions and to provide insight on possible technologies to achieve the effluent limitations.

Project Tasks

Tasks for this project are as follows:

1. Review wastewater discharge regulations, U.S. drinking water regulations, and the following documents provided by the Environmental Law Clinic:

    - Milavec, P. J. (2008). "Aquatic Survey of Lower Dunkard Creek" – PA Department of Environmental Protection
    - Argent, D. G. and Kimmel, W. G. (2008). "A Comprehensive Ichthyofaunal Survey of Tenmile Creek Watershed: Phase I" – California University of PA
    - Argent, D. G. and Kimmel, W. G. (2009). "A Comprehensive Ichthyofaunal Survey of Tenmile Creek Watershed: Phase II" – California University of PA
    - Gocek, J. J. (2009). "NPDES #PA0233650 Fact Sheet" – TerrAqua Resource Management, LLC
    - Handke, P. (2008). "Trihalomethane Speciation and the Relationship to Elevated Total Dissolved Solid Concentrations Affecting Drinking Water Quality at Systems Utilizing the Monongahela River as a Primary Source During the 3rd and 4th Quarters of 2008" – Pennsylvania Department of Environmental Protection

2. Identify treatment technologies capable of meeting effluent goals of 500 mg per liter of TDS, 250 mg per liter of both chlorides and sulfate all as monthly averages, and 10 mg per liter of both strontium and barium as monthly averages.

3. Provide a letter report summarizing the findings on available treatment technologies and their application in wastewater treatment.

Results and Discussion

The results and discussion are presented in the same order as the tasks listed in the previous section (Task 3 is the preparation of this letter report).

1. Wastewater Discharge Documents Review (Task 1)

The proposed revisions to Chapter 95 of the Pennsylvania Department of Environmental Protection's Wastewater Treatment Requirement restricts end of pipe effluents for new discharges exceeding 2000 mg/L total dissolved solids (TDS) to the following monthly averages: 500 mg/L TDS, 250 mg/L for total chlorides and sulfates, respectively, and 10 mg/L for total strontium and barium, respectively. TDS, chloride, and sulfate are among the list of constituents on the secondary drinking water regulations set forth by the USEPA due to cosmetic and aesthetic effects in drinking water (USEPA, 2002). Recent studies however, suggest that elevated concentrations of these contaminants have detrimental effects to aquatic ecosystems. Surveys of the Tenmile Creek Watershed spanning Washington and Green counties in Pennsylvania indicate impaired water quality due to elevated specific conductance which indicates high TDS exceeding the recommended maximum for healthy fish populations (Argent and Kimble, 2008; Argent and Kimble, 2009). Similarly, a survey of the Lower Dunkard Creek in Greene County, Pennsylvania targeted the Shannopin mine drainage treatment plant as a significant source of TDS. It has been reported that the plant's discharge, under low flow conditions, has caused a stretch of the Dunkard Creek to be uninhabitable to fish life (Table 1).

Results of wastewater samples generated by the drilling of ten gas wells into shale exhibited TDS concentrations that were an order of magnitude greater than those measured in the Lower Dunkard Creek (TerrAqua, 2009). These levels ranged from 27,476 to 217,200 mg/L with an average TDS concentration of 137,819 mg/L. Of the ten sites that were tested, only two of the sites reported sulfate concentrations with an average of nearly 12 mg/L. Meanwhile, eight of the tested sites reported chloride concentrations in the range of 13,455 to 107,696 mg/L with an average concentration of 72,799 mg/L. In addition to the constituents of concern, bromide levels were reported at two of the locations with concentrations of 30.6 mg/L and 479 mg/L, respectively. While bromide concentrations are not currently regulated, they pose a major health concern following the disinfection of drinking water as bromide is easily oxidized by free chlorine resulting in hypobromous acid (Duirk and Valentine, 2007). The hypobromous acid reacts with natural organic matter yielding significant quantities of brominated byproducts which have a higher toxicity than chlorinated byproducts and have been classified as possible human carcinogens (Duirk and Valentine, 2007; Nikolaou, 2004; Cowman and Singer, 1996). A recent study of trihalomethane (THM) speciation for systems on the Monongahela, Allegheny, and Ohio rivers concluded that THM formation was indeed impacted by concentrations of bromide. Of all the systems studied during the fourth quarter of 2008, greater than 85% of total THM formation was comprised of brominated compounds and in some cases, the highest historical THM levels were reported (Handke, 2008).

Key findings from the document review can be summarized as follows:

- Benthic IBI scores ranging from 31.1 to 50.2 for stations along Dunkard Creek indicate an impaired aquatic environment.
- TerrAqua samples of shale wastewaters contain significant concentrations of TDS, chloride, sulfate, barium, and strontium.
- Trihalomethane speciation results (greater than 85% and 76% brominated compounds on a ppb and molar basis, respectively – Appendix A) for drinking waters along the Monongahela, Allegheny, and Ohio rivers indicate significant bromide levels in the rivers. AWWA Information Collection Rule Data Analysis reports that for waters containing greater than 100 μg/L bromide, the nationwide average percentage of total THM species that were brominated was approximately 60% (molar basis).

These findings support the need for more stringent effluent guidelines and effective treatment technologies.

2. Fracture Flowback Wastewater Treatment Technology Review (Task 2)

The overall objective of this task was to identify treatment technologies and processes capable of meeting the effluent goals set forth in the proposed rulemaking 25 Pa. Code Chapter 95 (Wastewater Treatment Requirements). As mentioned in the previous section, the relevant effluent discharge goals for this evaluation can be summarized as follows:

a) Total dissolved solids (TDS) monthly average less than 500 mg/L.
b) Total chlorides monthly average less than 250 mg/L.
c) Total sulfates monthly average less than 250 mg/L.
d) Total barium monthly average less than 10 mg/L.
e) Total strontium monthly average less than 10 mg/L.

In order to identify the treatment technologies and processes capable of meeting these effluent goals, the following approach was taken:

1. Review the scientific literature and identify core technologies and processes capable of treating a wastewater with varying concentrations of TDS.
2. Review fracture flowback water characteristics and water quality measurements to quantify representative concentrations. Data on fracture flowback water after physical-chemical treatment processes will also be included in this review.
3. Summarize reported treatment removal efficiencies of reverse osmosis for treatment of TDS, chloride, sulfate, barium, and strontium and estimate the ability of these technologies and processes to meet the effluent goals.

1. Identify Core Technologies and Processes Capable of Treating Fracture Flowback Water
The following references summarizing core technologies capable of treating wastewater containing dissolved constituents were reviewed:

- Tchobanoglous, G., F. L. Burton, and H. D. Stensel (2003) *Wastewater Engineering: Treatment and Reuse*, 4th ed., Metcalf and Eddy, Inc., McGraw-Hill Book Company, New York.
- Asano, T., F. L. Burton, H. Leverenz, R. Tsuchihashi, and G. Tchobanoglous (2007) *Water Reuse: Issues, Technologies, and Applications*, McGraw-Hill, New York.
- The Dow Chemical Company, Dow Water & Process Solutions, FILMTEC™ Reverse Osmosis Membranes Technical Manual (Form No. 609-00071-1009).
- Afify, A. (2010). "Prioritizing Desalination Strategies Using Multi-Criteria Decision Analysis." Desalination **250**: 928-935.

Candidate technologies for fracture flowback wastewater treatment include membrane and thermal technologies. Membrane technologies include both electrodialysis (ED) and reverse osmosis (RO), each of which requires elements of physical and/or chemical treatment before their application. ED has been reported to treat brackish waters with concentrations of up to 20,000 mg/L. However, at salt concentrations greater than 10,000 mg/L, this method cannot compete with the overall process costs of RO which can achieve similar removal efficiencies (Afify, 2010). Furthermore, since the results presented by TerrAqua report an average physical/chemical treatment effluent of 23,177 mg/L TDS from shale wastewaters, the use of ED will eliminated from further discussion.

The most common thermal technology methods are multistage flash (MSF), multiple-effect distillation (MED), and vapor compression (VC). MSF has the longest track because of its reliability and relatively simple operation. Of the two removal processes mentioned (membrane and thermal), thermal technologies have the ability to treat the largest wastewater TDS concentrations and provide the best water quality (Table 2). The major drawback of thermal methods, however, is that they are energy intensive. Energy costs comprise up to 80% of the overall operation and maintenance costs for thermal technologies compared to only 50-60% for membrane technologies (Afify, 2010). Despite the overwhelming advantage of constituent removal for distillation methods, the remainder of the discussion will analyze the feasibility of using RO as an option to treat shale wastewaters.

2. Review Fracture Flowback Water Characteristics and Water Quality Measurements
Fracture flowback water characteristics and water quality before and after existing wastewater physical and chemical treatment processes are summarized in Table 3. Since the process flow diagrams for RO require elements of physical and/or chemical treatment before its application, the mean treated values from table 3 will be used to identify the viability of RO when available.

3. Treatment Removal Efficiency and Feasibility of Reverse Osmosis
Table 4 summarizes RO removal efficiency ranges for TDS, chloride, sulfate, barium, and strontium. Applying the removal efficiencies from Table 4 to each constituent, wastewater

effluent concentrations were calculated and are summarized in Table 5 (note that the values calculated in Table 4 for TDS, chloride, and barium were based on physical/chemical treated fracture water, whereas sulfate and strontium were based on untreated fracture water).

Comparing the calculated treatment values in Table 5 to the proposed effluent standards:

1. TDS concentration estimates after RO range from 462-1,849 mg/L, well above the proposed limit of 500 mg/L. However, additional dilution (1:4) via combination with other water-wastewater or other means would lower TDS to an acceptable range (< 500 mg/L).
2. Chloride concentration estimates after RO range from 727-872 mg/L, well above the proposed limit of 250 mg/L. However, additional dilution (1:4) via combination with other water-wastewater or other means would lower TDS to an acceptable range.
3. Sulfate (0.1-1.0 mg/L) is well below the proposed limit of 250 mg/L.
4. Barium (0.1-0.2 mg/L) is well below the proposed limit of 10 mg/L.
5. Strontium (after RO range of 14-55 mg/L) is greater than the proposed limit of 10 mg/L. However, the estimate was based on untreated fracture water. Assuming comparable physical and chemical treatment removal as that measured for barium, strontium treatment by RO should also meet the proposed level.

Table 1. Water quality data collected of Lower Dunkard Creek (PA Department of Environmental Protection, 2009).

Station	Conductance (μS/cm)	Sulfate (mg/L)	TDS (mg/L)	Impairment[a] (Benthic IBI)
DC5	661	570	1182	50.2
DC6	4022	6171	9552	31.1
DC7	3596	6398	9238	41.3
DC8A	3581	5878	8752	37.8
DC8[b]	NR	318	NR	NR

[a] Benthic IBI score below "50" indicates an impaired water (Milavec, 2009).
[b] Station not considered due to backup of the Monongahela River into Dunkard Creek.

Table 2. Summary of technologies capable of treating fracture flowback water (Afify, 2010; DOW Water and Process Solutions).

Characteristic	Electro-Dialysis	Reverse Osmosis	Thermal Distillation[a]
Theoretical TDS Limit (mg/L)	< 20,000	< 50,000	20,000 to 100,000+
Pretreatment	Filtration	Extensive	Minimal
Final Water TDS (mg/L)	350-500	350-500	< 10

[a] Includes multistage flash (MSF), multiple-effect distillation (MED), and vapor compression (VC).

Table 3. Summary of fracture flowback water quality analysis (all values are reported in units of mg/L) reported by Gocek, J. J. (2009)[a] from gas wells drilled into shale (ten total sites – nine in Pennsylvania and one in New York).

	Fracture Flowback Water		Treated[b] Fracture Flowback Water	
Constituent	Range	Mean	Range	Mean
TDS	27,476 - 217,200	137,819	NR	23,177
Chloride	13,455 - 107,696	72,799	12,000 – 17,077	14,539
Sulfate	< 1 - 22.3	11.7	NR	NR
Barium	4.07 - 1060	344	4-5	4.5
Strontium	NR	1,381	NR	NR

[a] Gocek, J. J. (2009). "NPDES #PA0233650 Fact Sheet" – TerrAqua Resource Management, LLC, Appendix 3.
[b] Physical-Chemical Systems Treating Gas Well Wastewater (Tri-County and Hart Resource Technologies).
NR – Not Reported

Table 4. Typical RO membrane dissolved constituent rejection percentages.

Constituent	Percent Rejection
TDS[a]	92-98
Chloride[b]	94-95
Sulfate[b]	95-99
Barium[b]	95-98
Strontium[b]	96-99

[a] DOW Water and Process Solutions
[b] GE Osmonics

Table 5. Individual constituent removal estimates using Table 3 RO rejection percentages (all values are reported in units of mg/L).

Constituent	Initial Value	After RO
TDS	23,177 [b]	462 - 1849
Chloride	14,539 [b]	727 - 872
Sulfate	11.7 [a]	0.1 - 1
Barium	4.5 [b]	0.1 – 0.2
Strontium	1381 [a]	14 - 55

[a] Fracture Flowback Water
[b] Treated Fracture Flowback Water

Conclusions and Recommendations

The overall scope of this effort was to review the proposed effluent standards for TDS, chloride, sulfate, barium, and strontium and evaluate potential technologies/processes to treat fracture flowback water. Based on document review and a preliminary estimate of dissolved constituent removals using reverse osmosis (RO) in combination with physical-chemical treatment, I have the following conclusions and recommendations:

1. Bromide may need to be considered or added as a separate constituent for compliance because of drinking water disinfection byproduct formation. If not listed as a separate standard, then perhaps further data analysis of fracture flowback water to determine the ratio of bromide to TDS could be used to evaluate if the TDS standard will suffice as a surrogate for bromide.
2. Reverse osmosis (RO) in combination with physical/chemical treatment and dilution should be a viable solution to meet the proposed effluent standards. However, the feasibility and cost-effectiveness needs to be further evaluated using site locations, fracture water volumes, site specific water concentrations, and available dilution options.
3. High influent concentrations and lower effluent limitations suggest thermal distillation to be the best available technology. Although energy costs make up 60-80% of the operation and maintenance costs for thermal methods compared to 50-60% for membrane technology, it may be plausible to consider the cost-effectiveness of a centralized facility that uses thermal methods rather than RO.

This report is based upon the data and information available at the time of composition. The author reserves the right to modify, change, or develop new conclusions when and if additional information and data is forthcoming. Please feel free to call or write if there are other questions. I may be reached by phone at (540) 460-6483.

Sincerely,

David W. Johnstone, Ph.D.

References

- Afify, A. (2010). "Prioritizing Desalination Strategies Using Multi-Criteria Decision Analysis." Desalination **250**: 928-935.
- Argent, D. G. and Kimmel, W. G. (2008). "A Comprehensive Ichthyofaunal Survey of Tenmile Creek Watershed: Phase I" Final Report for Grant Agreement WRCP – 06169.
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- Asano, T., F. L. Burton, H. Leverenz, R. Tsuchihashi, and G. Tchobanoglous (2007) *Water Reuse: Issues, Technologies, and Applications*, McGraw-Hill, New York.
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- McGuire, M. J., McLain, J. L., Obolensky, A. (2002). "Information Collection Data Rule." Denver, CO, AWWA Research Foundation.
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- Nikolaou, A. D. (2004). "Investigation of the Formation of Chlorination By-Products in Water Rich in Bromide and Organic Matter Content." Journal of Environmental Science and Health A39 (11-12): 2835-2853.
- Tchobanoglous, G., F. L. Burton, and H. D. Stensel (2003) *Wastewater Engineering: Treatment and Reuse*, 4th ed., Metcalf and Eddy, Inc., McGraw-Hill Book Company, New York.
- The Dow Chemical Company, Dow Water & Process Solutions, FILMTEC™ Reverse Osmosis Membranes Technical Manual (Form No. 609-00071-1009).
- USEPA (2002). "National Secondary Drinking Water Regulations." 40CFR143.1 19: 613-614.

Appendix A

Table A. Percentage of the TTHM that were brominated (molar concentration).

Location	Sample	Date	Brominated THM (Molar %)
Charleroi	Not Reported	10/20/08	89
PA American - Pittsburgh	USC Twp Building - 119	11/19/08	92
	PAWC - 145	11/19/08	90
	Independence Booster - 156	11/19/08	91
	Malone Ridge - 136	11/19/08	91
	Independence Booster - 156	11/19/08	80
	Malone Ridge - 136	11/19/08	79
	Homestead PRV - 151	11/19/08	79
	Waterways Plumbing - 138	11/19/08	78
Oakdale Borough	Oakdale Maintenance Garage - 012	10/17/08	88
	Huckleberry's - 003	10/17/08	81
	Oakdale UP Church - 014	10/17/08	87
	405 Clinton Ave - 011	10/17/08	87
Pittsburgh Water and Sewer Authority	Mission Pump St.	11/18/08	90
	Bedford Fire House	11/18/08	87
	1022 Chestnut	11/18/08	85
	Homestead Fire House	11/18/08	83
Oakmont Borough Municipal Authority	255 Unity Tressle - 001	10/07/08	77
	238 McClure Drive - 002	10/07/08	77
	11803 Frankstown Road - 003	10/07/08	81
	Best Wholesale Tire - 004	10/07/08	76
Moon Township Municipal Authority	1935 Hassam Road	10/14/08	80
	1000 Stoop Ferry Road	10/14/08	85
	1700 Beaver Road	10/14/08	85
	Carnot Storage Tank	10/14/08	87
Municipal Authority of the Township of Robinson	Waste Tank Cleaning	11/03/08	97
	Robinson Public Works	11/03/08	95
	Highland Towers	11/03/08	89
	MATR Office[a]	08/04/08	59

[a] Represents 3rd quarter sample as no 4th quarter sample was reported.

Exhibit 3

Clean Water Action Comments on Chapter 95 Revisions

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EDUCATION

Ph.D. Civil Engineering, The University of Akron, 2009
M.S. Civil Engineering, Youngstown State University, 2005
B.E. Civil Engineering, Youngstown State University, 2003

PROFESSIONAL REGISTRATION

- Engineer in Training (2003)

TEACHING EXPERIENCE

Assistant Professor — *August 2009-Present*
Virginia Military Institute, Dept. of Civil and Environmental Engineering

- CE105 – Introduction to Engineering
- CE321 – Environmental Engineering
- CE322 – Water Resources Engineering
- CE410 – Hydrology

Part-time Faculty — *August 2006-May 2008*
Youngstown State University, Dept. of Civil, Environmental, and Chemical Engineering

- CEEGR 3717 – Hydraulic Design
- CEEGR 3716 – Fluid Mechanics
- CEEGR 5877 – Systems Engineering and Construction Management

Graduate Assistant — *August 2005-July 2009*
The University of Akron

- 4300:341 – Hydraulic Engineering
  - Direct instruction of several topics, laboratory supervision, and general assistance (Spring '05 to Spring '08)
- 4300:201 – Statics
  - Direct instruction of several topics and general assistance (Fall '05 to Spring '08)

Graduate Assistant — *January 2004-May 2005*
Youngstown State University, Dept. of Civil, Environmental, and Chemical Engineering

- CEEGR 3717 – Hydraulic Design
  - Junior and senior-level undergraduate teaching (Spring '05)
- CEEGR 2610 – Surveying Lab
  - Sophomore-level undergraduate teaching (Fall '04)

CONSULTING EXPERIENCE

Consultant *August 2005-July 2009*
Envital Ltd.

- Engineering consulting support for hydraulic and environmental projects including the City of Norwalk and the City of Barberton water distribution models.
- Cuyahoga River flow and hydroelectric evaluation.
- Storm sewer inlet analysis.

Inspector *February 2004-August 2004*
Seidler Engineering

- Oversee construction of a new housing development along with the installation of redundant water lines and force main.

Inspector *June 2002-October 2002*
Environmental Quality Management, Inc.

- Oversee the dredging and refurbishing of the Mahoning River in Warren, Ohio.

RESEARCH EXPERIENCE

Research Assistant *August 2005-July 2009*
The University of Akron, Dept. of Civil Engineering

- Laboratory
  - ➢ Conducted research projects on the formation potential of halogenated byproducts in drinking water distribution systems.
  - ➢ Demonstrated ability to statistically design laboratory experiments. Analytical procedures include but were not limited to gas chromatography (GC), fluorescence spectroscopy, and state of the art separation and characterization of natural organic matter fractions.
  - ➢ Use of multiple complex statistical analysis techniques including variations of principle component analysis to analyze three-way arrays created from fluorescence spectroscopy.
  - ➢ Development of innovative and patentable methods using data gathered through designed experiments along with statistical analysis. These methods can be applied to evaluate water treatment operation effectiveness and water quality improvement efforts.

- Field
  - ➢ Performed fire-flow analysis to assess system pressures and hydrant flows using data loggers for use in distribution system calibration and validation of WaterCAD models.
  - ➢ Identified locations and collected water samples throughout distribution systems for water quality analysis and disinfectant byproduct sampling.

- Computer/Software
  - ➢ Analyzed flows and water quality parameters throughout distribution systems using WaterCAD.

- ➢ Design of single pipe and open channel flow using FlowMaster.
- ➢ Design and analysis of water distribution systems using EPANET.
- ➢ Kinetic modeling of water quality conditions and byproducts using Berkeley Madonna/Scientist.

PROFESSIONAL MEMBERSHIP

- Member, American Society of Civil Engineers
- Member, American Water Works Association

JOURNAL PUBLICATIONS

- Johnstone, D. W. and Miller, C. M. (2009). "Fluorescence Excitation-Emission Matrix Regional Transformation and Chlorine Consumption to Predict THM and HAA Formation." *Environmental Engineering Science* ***26*** *(7): 1163-1170.*
- Johnstone, D. W., Sanchez, N. P., Miller, C. M. (2009). "Parallel Factor Analysis of Excitation-Emission Matrices to Assess Drinking Water Disinfection Byproduct Formation During a Peak Formation Period." *Environmental Engineering Science* ***26*** *(10): 1551-1559.*

CONFERENCE PROCEEDINGS AND TECHNICAL REPORTS

- PARAFAC Modeling of Fluorescence Excitation-Emission Matrices to Quantify Chlorine Reactivity with Dissolved Organic Matter, *3rd Annual Conference on Undergraduate and Graduate Student Research*, March 27, 2008.
- Examination of DBP Speciation after Coagulation during a Peak Formation Period, 4th *Annual Conference on Undergraduate and Graduate Student Research,* March 26, 2009.
- "Metro Parks River Flow and Hydroelectric Plant Feasibility Evaluation," Cuyahoga Falls, Ohio (2007).
- "Hydraulic Analysis of Storm Water Inlets during Flood Conditions," City of Warren, Ohio (2007).
- "Barberton Coagulation and Disinfection Byproduct Reduction Assessment," City of Barberton, Ohio (2006).