DELAWARE RIVERKEEPER NETWORK

May 6, 2015

watersupply@dep.nj.gov
New Jersey Department of Environmental Protection
Trenton, New Jersey

Re: Recommendation on Perfluorinated Compound Treatment Options for Drinking Water

Please find enclosed a technical analysis prepared by Fardin Oliaei, MPA, PhD, and Don Kriens, Sc.D., P.E. of Cambridge Environmental Consulting commissioned by Delaware Riverkeeper Network and submitted on behalf of the organization and its membership on the Drinking Water Quality Institute's document **Recommendation on Perfluorinated Compound Treatment Options for Drinking Water**. Also attached is a PDF containing the Curriculum Vitae for Dr. Oliaei and for Don Kriens, Sc.D., P.E.

Delaware Riverkeeper Network submits these comments advocating that the public be protected from PFNA contamination and that New Jersey's drinking water be required to be treated to a safe level based on the best available scientific evidence and employing the best available treatment technology.

We support all the recommendations and findings made by Dr. Oliaei and Cambridge Environmental Consulting in this technical analysis. We advocate that effective treatment options be employed to remove PFCs from New Jersey's drinking water. We support Cambridge Environmental Consulting's conclusion that the best available technology to remove PFOS, PFOA, and PFNA from water supplies is activated carbon. We support that this technology is economically achievable for municipal drinking water systems. We also support the finding that point-of-use devices can be effectively used to remove PFCs at residences that depend on individual water wells employing granular activated carbon in combination with reverse osmosis to achieve complete removal of PFCs.

Thank you for presenting treatment options for removal of PFCs from drinking water, an essential component of the technical analysis needed to achieve the removal of this toxic compound from New Jersey's drinking water supplies. The added public benefit gained by the use of economical as well as effective treatment can be expected to speed the installation of this urgently needed treatment in the State.

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Sincerely,

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

Attachments:

Technical Analysis of NJ Drinking Water Quality Institute Recommendation on Perfluorinated Compound Treatment Options for Drinking Water.

Curriculum Vitae - Fardin Oliaei, MPA, PhD. and Don Kriens, Sc.D., P.E.

Technical Analysis of New Jersey Drinking Water Quality Institute

Recommendation on Perfluorinated Compound Treatment Options for Drinking Water

prepared by

Fardin Oliaei MPA, Ph.D.

Don Kriens Sc.D., P.E.

Cambridge Environmental Consulting

May 5, 2015

Technical Review of New Jersey Drinking Water Quality Institute's "Recommendation on Perfluorinated Compound Treatment Options for Drinking Water"

prepared by

Cambridge Environmental Consulting

Executive Summary

We reviewed the treatability of PFCs and water treatment technologies that may be implemented at municipal drinking water supplies to remove PFOS, PFOA, and PFNA. Our review includes evaluation of the report "Recommendation on Perfluorinated Compound Treatment Options for Drinking Water" by the New Jersey Drinking Water Quality Institute Treatment Subcommittee, dated April 2015, hereinafter referred to as the Report.

We found that activated carbon treatment offers the best available technology to remove PFCs that is economically achievable at municipal drinking water supplies. Although reverse osmosis technology may provide additional enhanced removal of PFCs, especially carboxylic PFCs, reverse osmosis is unlikely to be cost effective for most municipal installations due to reverse osmosis reject concerns. Our analysis found that advanced oxidative technologies do not effectively remove PFCs, and that ion exchange, or other adsorption technology using resins, would not exceed the removal performance using activated carbon. We also found that point of use (POU) devices employing activated carbon/reverse osmosis technology effectively remove PFOS, PFOA, and PFNA, and are useful in residential settings using individual well water sources.

Introduction

In the U.S. the majority of municipal drinking water treatment systems use conventional water treatment technologies, which typically include flocculation and coagulation, filtration, and disinfection using chlorine or chlorine derivatives. Alternative disinfectants such as ozone are occasionally used which also provide for organics removal, and occasionally municipal systems use advanced technologies such as activated carbon. Conventional drinking water treatment technologies have little effect on PFC removal, including PFOS, PFOA, and PFNA. More advanced technologies are used to remove selective organic compounds and include, but are not limited to, advanced microfiltration technologies, such as ultrafiltration and nanofiltration, advanced oxidation processes, such as ozonation, peroxide, and UV peroxide, and reverse osmosis and activated carbon technologies. A combination of technologies may be applied where superior removals are needed, such as in water reclamation processes. A number of advanced water treatment systems using combinations of advanced technologies are in operation worldwide where recycled domestic wastewater is reclaimed and treated to very high quality. These advanced systems, however, are used at locations where water scarcity is the primary constraint.

PFC compounds have relatively high molecular weights, at least for the higher carbon number PFCs, that leaves them amenable to adsorptive removal technologies such as activated carbon. They are both hydrophobic and hydrophilic, although aqueous solubility varies greatly between PFCs. This duality can reduce carbon adsorption capacity for the carboxylic PFCs to some extent, although the hydrophilic portion of the molecule increases potential removal by membrane (reverse osmosis) and ion exchange technologies.

Cost is a consideration in addition to treatability of PFCs at municipal systems using various advanced technologies. In some drinking water contaminant instances analysis of the economic benefits of reduction in health costs versus the cost of treatment (benefit-cost analysis) may be useful to assess overall social benefit. In addition, cost-effective analysis also helps in determination of the most suitable removal technology. However, economic considerations are beyond the scope of this review. Our analysis is limited to evaluation of the treatability and technical capability of technologies to remove PFOS, PFOA, and PFNA, with limited qualitative comment on their cost-effectiveness.

Evaluation of Treatment Options

Activated Carbon

Although activated carbon (AC) is deemed an advanced treatment technology it has been used in many treatment applications for decades, and is "relatively" cost-effective. AC has been shown to be very effective to remove most PFCs. AC may be used either as a granular activated carbon (GAC) system where carbon is housed in granular form in modules similar to sand filters, or as powdered activated carbon (PAC) where carbon is added in finer granular form to mixed basins, followed by filtration or sedimentation. PAC may involve recycle of carbon with eventual recovery (wasting) of PAC and carbon disposal. Both GAC and PAC systems typically employ pre-filtration via sand or mixed-media filtration. GAC and PAC carbon disposal is typically accomplished by thermal regeneration off-site.

Some studies indicate that powdered activated carbon versus granular activated carbon provides better PFC removal. In a study by Hansen et. al. AC was found to be effective in removal of PFCs in environmentally relevant concentrations in the ng/l range (influent PFNA at 65 ± 5 ng/l). This study found that powdered activated carbon generally showed better adsorption than granulated activated carbon, sulfonates were more stronger adsorbed than carboxylic acids, and PFC adsorption increased with increasing PFC chain length (Hansen 2010). The study found high performance in PFOA removal at 95% using GAC.

A study by Ochoa-Herrera found that PFOS is strongly adsorbed by GAC. PFOA and PFBS were also removed by GAC but to a lesser extent (Ochoa-Herrera and Sierra-Alvarez 2008). Results in this study indicate stronger adsorption to perfluorosulfonates as compared to perfluorocarboxylates at equivalent chain lengths. In a study by Arvaniti, PFOS, PFOA and PFNA were removed by nearly 100% using PAC, but at considerably lesser percent removals using GAC (Arvaniti 2013).

There are a few municipal drinking water treatment systems in operation in the U.S. designed for removal of PFCs, two of which are shown in the case history examples described in the Report (Oakdale, Minnesota and Little Hocking, Ohio). These municipal systems have demonstrated that effective and sustained removal of PFCs is feasible using GAC, and is relatively cost-effective. In addition to those cases, the Minnesota Mining and Manufacturing (3M) Cottage Grove, Minnesota plant also uses a GAC system to remove PFCs from its wastewater discharge to the Mississippi River. A 2006 study found a 79% reduction in PFOA and a 95% reduction in PFOS through the 3M GAC treatment system (Oliaei and Kriens 2006).

In summary, AC has been shown to very effectively remove PFCs, in practice or via research studies, although the form of AC (GAC or PAC) could affect performance in some instances and individual PFCs may be removed at different rates.

Reverse Osmosis

Reverse osmosis and nanofiltration can be very effective to remove PFCs. Reverse osmosis resulted in greater than 99% rejection of PFOS, and nanofiltration resulted in 90-99% PFOS removal in a study by Tang et. al. (Tang 2007). The effectiveness of reverse osmosis treatment is shown by Quinones and Snyder (2009), where a utility using microfiltration and reverse osmosis in wastewater treatment for indirect potable reuse reduced total PFC influent of 80 ng/L and influent PFOS of 41 ± 18 ng/L to no reportable levels (Quinones and Snyder 2009).

In Point of Use (POU) studies in Minnesota GAC and GAC in combination with reverse osmosis were evaluated to determine their effectiveness to remove PFCs. These POU devices are typically under-sink for drinking water, but may also be designed for whole-house treatment, and are primarily used in residential settings treating domestic well water (groundwater). This comprehensive study found that GAC and GAC combined with reverse osmosis were effective to remove PFCs at manufacturer recommendations for water flow rate and volume throughput, although lower chain PFCs were removed at reduced rates using GAC alone (Olson and Paulson 2008). In cases where GAC was shown less effective, reverse osmosis enhanced PFC removal performance. In this study GAC systems alone (without reverse osmosis) showed a loss of performance towards end of the carbon useful life, while combined GAC/reverse osmosis systems did not show a loss of performance at total throughput volumes. We expect that enhanced removal by reverse osmosis is likely due to added capability of reverse osmosis to remove charged ionic species, (inorganic and organic), such as the carboxylic PFCs, through both adsorption and electrostatic repulsion.

Advanced Oxidative Processes

Advanced oxidative processes such as chlorination, ozonation and UV peroxide, have been found very effective in breakdown of organic compounds, including complex organics, but are not expected to provide significant removal of PFCs due to the strength of the C-F bond. In a study by Arvaniti et. al. no significant removal of PFCs was observed using UV and UV peroxide (Arvaniti 2013). As noted in the Report one study showed relatively modest PFOS removals between 10-50%, dependent on the oxidative process used (Ribeiro 2015).

Resin Adsorption/Ion Exchange

Zeolites have been widely used to purify water. One study found that PFOS adsorbs strongly to a NaY80 (Si/Al 80) zeolite, but other zeolites demonstrated poor adsorption (Ochoa-Herrera and Sierra-Alvarez 2008). This study also found that this zeolite adsorbed to PFOS at the same order of magnitude as GAC, although overall GAC provided better PFOS removal. Anion exchange resins were also found effective for PFOS removal in wastewater in a study by Deng et. al., which also noted that sorption rates for PFOS were dependent on their polymer matrix and porosity (Deng 2010).

As described in the Report, one study found that anion exchange removed PFCs by the following performance levels: PFOA at 74%, PFNA >67%, and PFOS >92% (Appleman 2014). However, disposal of resin and brine (reject) needs to be considered. We believe it is unlikely that ion exchange would provide an equivalent level of PFC removal compared to activated carbon at equivalent cost.

Summary of Technology Effectiveness to Remove PFOS, PFOA, and PFNA

We conclude that the best available technology to remove PFOS, PFOA, and PFNA from dilute aqueous streams, economically achievable for large scale municipal drinking water systems, is activated carbon. The choice of carbon form (PAC or GAC) used will depend on site-specific characteristics including levels of natural organic matter present, economics of pretreatment required, and flow.

We also find that reverse osmosis may offer superior removal of PFCs, especially for carboxylic PFCs. Reverse osmosis technology, however, is relatively capital expensive with high energy demand, even at lower total dissolved solids influent concentrations, due to pumping requirements. Reverse osmosis typically has higher operation and maintenance requirements versus AC systems. In addition, as discussed in the Report, reverse osmosis processes produce a large stream of reject water, typically close to 25% of the total influent flow. This reject water must be discharged in some fashion, presumably to surface waters. If applicable, the discharge must meet PFC discharge limitations. Eliminating reverse osmosis reject water via other methods to avoid a surface discharge, such as evaporative techniques, is prohibitively costly and very energy intensive. Therefore, reverse osmosis technology applied to municipal water treatment systems is unlikely to be cost-effective at most locations.

We observe that point-of-use devices (POU) can effectively remove PFCs at individual residences using well water; POU devices using GAC combined with reverse osmosis demonstrate complete removal of PFCs. GAC filter devices without reverse osmosis work very well to remove PFCs, but have a finite life. The addition of a reverse osmosis component considerably extends GAC useful life in POU applications and increases treatment redundancy. In our analysis of costs of under-sink POU devices, we found relatively minor differences in cost between GAC and combined GAC/reverse osmosis systems, with added benefit that GAC/reverse osmosis systems provide redundancy in PFC removal.

References

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Arvaniti O, Andersen H, Hwang H, Antoniou M, Gatidou G, Thomaidis N, Stasinakis A, (2013). Removal of Perfluorinated Compounds from Water with Activated Carbon and Redox Treatments. poster presentation. 13th International Conference on Environmental Science and Technology, Athens, Greece, Sept 2013.

Deng S, Yu Q, Huang J, Yu G, (2010). Removal of perfluorooctane sulfonate from wastewater by anion exchange resins: Effects of resin properties and solution chemistry. Water Research 44(2010) 5188-5195.

Hansen M, Børresen M, Schlabach M, Cornelissen G, (2010). Sorption of perfluorinated compounds from contaminated water to activated carbon. J Soils Sediments (2010) 10:179–185.

Ochoa-Herrera, Sierra-Alvarez R, (2008). Removal of perfluorinated surfactants by sorption onto granular activated carbon, zeolite and sludge. Chemosphere 72 (2008) 1588–1593.

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Olsen P, Paulson D, (2008). Performance Evaluation, Removal of Perfluorochemicals (PFC's) with Point-of-Use (POU) Water Treatment Devices, Water Science and Marketing, May 2008.

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Ribeiro A, Nunes O, Pereira M, Silva A, (2015). An overview on the advanced oxidation processes applied for the treatment of water pollutants defined in the recently launched Directive 2013/39/EU. *Environment International,* 33-51

Tang C, Shiang Fu Q, Criddle C, Leckie J, (2007). Effect of Flux (Transmembrane Pressure) and Membrane Properties on Fouling and Rejection of Reverse Osmosis and Nanofiltration Membranes Treating Perfluorooctane Sulfonate Containing Wastewater. Environ. Sci. Technol. 2007, 41, 2008-2014.

Curriculum Vitae **Fardin Zoe Oliaei**
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Phone: 617-775-5797

PROFILE

- Accomplished scientist with years of experience in creating innovative solutions to challenging environmental problems related to public health, policy development and environmental sustainability.
- Experienced project manager with skills in the application of analytical methods and techniques necessary for working within the framework of state/federal environmental and public health organizations.
- Registered independent consultant in the UNEP and UNIDO experts' roster for U-POPs and New-POPs and implementation of the Stockholm Convention on Persistent Organic Pollutants.
- Rigorous researcher and team leader experienced in spearheading all phases of (planning, budgeting, developing, conducting, and directing) of environmental project management.
- Effective communicator with ability to translate complex scientific data into coherent material in order to inform audiences with varying degrees of knowledge about environmental issues.
- Conscientious professional with experience presenting expert witness testimony in litigation cases involving a wide range of environmental problems and related public health issues.
- Experienced college instructor developing and teaching natural sciences and environmental science and public health policy courses.

EDUCATION

Harvard University School of Public Health, Boston, MA
Audited several courses: Air Pollution; Water Pollution; and Risk Assessment

Harvard University John F. Kennedy School of Government, Cambridge, MA
Master in Public Administration
Concentration: Leadership and International Env. Health Policy and Management

Western Michigan University, Kalamazoo, MI
PhD in Environmental Sciences
- Dissertation title: Acid Rain and Lake Acidification Impacts on Aquatic Life

MS in Biology
- Thesis title: Drinking Water Quality and Waterborne Diseases in Rural Iran

National University of Iran, Tehran, Iran
BS Chemistry, Minor Biology

PROFESSIONAL EXPERIENCE

Cambridge Environmental Consulting, LLC., Boston, MA 2006 - Present
Senior Scientist and President

- “Visiting Professor” at the Iranian National Institute of Oceanography (INIO) - conducted training workshops for INIO staff/scientist and coastal management professionals on the policy aspects of coastal zone management and its implications. The training was tailored to the local cultural characteristics, government structure, resource integrity, and management needs of the country (2012).
- Invited by the Iranian Governor’s Officials to visit and evaluate the environmental impacts of a historically contaminated site caused by the largest landfill located near the Caspian Sea. Developed an integrated solid waste management plan for implementation, including an assessment of all environmental risks, and the development of mitigation efforts required to minimize the adverse impacts on Public health and the environment (2012).
- Participated and presented two papers at Dioxin 2010 - 30th International Symposium on Halogenated Persistent Organic Pollutants (POPs) on 1) Presence of PBDEs in Minnesota Landfills – Environmental Releases and Exposure Potential, and 2) Investigation of PFOS/PFCs Contamination from a PFC Manufacturing Facility in Minnesota – Environmental Releases and Exposure Risks (2010).
- Chaired the “New POPs” Section (Implication of Stockholm Convention of New POPs) of the11th International HCH and Pesticide Forum, Cabala, Azerbaijan (2012).
- Serve as expert witness in environmental litigation pertaining to release of industrial toxic contaminants.
- Conduct evaluations of toxic contaminants (including New POPs) and use dispersion modeling (groundwater, surface water, soils and air) to evaluate contaminants' environmental impacts and public health risks.
- Review and evaluate EPA documents related to the issuance of new source National Pollutant Discharge Elimination System (NPDES) permits to industrial activities.

Women’s Environmental Institute (WEI), St. Paul, MN 2006 - 2012
Principal Scientific Consultant

- Served as a WEI Board Member and later, as the principal scientific consultant, developed environmental justice education program to promote environmental awareness, sustainability, and health disparity.
- Directed and managed projects on environmental issues related to public health and environmental quality.
- Analyzed the effectiveness and efficiency of existing environmental and public health programs for the implementation and administration of programs best fit the affected communities. Identified and presented to public policy makers the problems affecting concerned communities.
- Evaluated the impact of toxic pollutants on the growth and development of exposed children. Developed multimedia outreach programs to inform families about toxic exposure and consequences.
- Developed culturally specific environmental training and educational seminars for exposed communities through different radio stations and newspapers.

Mote Marine Laboratory, Sarasota, FL 2007- 2008
Associate Scientist

- Designed health risk assessment framework to evaluate potential exposure pathways and toxicity effects of contaminants in Florida manatees. Contributed to development of research proposals.
- Evaluated public and environmental regulatory policies and proposed effective mitigation tools

Minnesota Pollution Control Agency (MPCA), St. Paul, MN 1989 - 2006

Senior Scientist, Project Manager, and Emerging Contaminants Program Coordinator

- Developed policy, program analysis methods, and multimedia strategy to assess health impact of toxic chemicals.
- Initiated and led the Emerging Contaminants Program for the competent authority (MPCA).
- Prepared Environmental Impact Assessments (EIS) for major projects in MN and communicated the results, including the potential social, and economic impacts of these projects with authorities and public.
- Represented the MPCA as a scientific expert, liaison, and critical state contact in the PCBs, Dioxin, and emerging contaminants activities of the US EPA, Great Lakes Binational Strategy (GLBNS) and in other related national and international programs.
- Worked closely with diverse array of clientele and stakeholders (federal and state governments, industry, grass root organizations, affected communities, and the state legislators) to develop progressive environmental policies and educational materials.
- Presented at international conferences and gave presentations regarding environmental issues in public meetings, legislative hearings and governmental agencies.
- Managed contracts and secured federal/state grants and awards for health impacts of contaminant in Minnesota.
- Developed statewide air toxics monitoring/bio-monitoring network using mass balance and integrated air exposure-effect models.
- As the technical coordinator and MPCA liaison, built partnership between PCA and other sister agencies (MN Department of Health, MN Department of Natural Resources, and MN Department of Agriculture), USA EPA, and MN university researchers for ongoing efforts to identify, evaluate, control, regulate, and reduce the emerging pollutants with endocrine disruptive characteristics (PFOS and PFOA, PBDEs, and pharmaceuticals).
- Assessed the current regulations and programs already in place that may be addressing reduction of toxic contaminants of concern, identified unregulated emerging contaminants of greatest potential risk to human health and the MN environment, rationale of why these contaminants need to be regulated.

TEACHING EXPERIENCE

Teach biology, chemistry, environmental science, health and policy-related courses (Elements of Health and Wellness, Foundations of Research, Public Policy Planning and Implementation), part-time at:

- **University of Phoenix** – Adjunct Faculty Boston, MA 2010 - Present
- **Regis College** – Adjunct Professor Weston, MA 2012 - 2013
- **Hamline University –** Adjunct Assistant Professor St. Paul, MN 2002 - 2003
- **St. Paul College –** Adjunct Assistant Professor St. Paul, MN 1998 - 2002
- **Inver Hills Community College** – Adjunct Faculty St. Paul, MN 1996 - 2002
- **Minnesota Department of Corrections** Various locations 1998 - 2000
- **Normandale Community College** – Adjunct Faculty Bloomington, MN 1990 - 1998
- **Northland College** – Assistant Professor Ashland, WI 1986 - 1989
- **Western Michigan University** – Teaching Assistant Kalamazoo, MI 1980 - 1985

PROFESSIONAL AFFILIATIONS

- Member, **PCB Elimination Network (PEN)** of the Stockholm Convention 2011 - Present
- Member, **Society of Environmental Toxicology and Chemistry** 1990 - Present
- Member, Board of Directors, **Women's Environmental Institute** 2003 - Present
- Member, **Aquatic Biogeochemistry Research Group,** Harvard University, Harvard School of Public Health (HSPH) 2010 - 2012
- Member, **American Chemical Society** 1992 - 2010
- Member, **Air and Waste Management Association** 1998 - 2010

LANGUAGE SKILLS

- Fluent in English and Farsi (Persian)

PUBLICATIONS

- Brambilla, G., d'Hollander, W. Oliaei, F., Stahl, T., and Weber, R. Pathways and factors for food safety and food security at PFOS contaminated sites within a problem based learning approach, Accepted for publication at Chemosphere, 2014.
- Oliaei, F., Weber, R., Watson, A., and Kriens, D. Review of Environmental Releases and Exposure Risk of PFOS/PFAS Contamination from a PFOS Production Plant in Minnesota. Environmental Science and Pollution Research, 2013.
- Oliaei, F., Weber, R., and Watson, A. Landfills and Wastewater Treatment Plants as Sources and Reservoir of Polybrominated Diphenyl Ether (PBDE) Contamination. Environmental Science and Pollution Research, 2012.
- Weber, R., Watson, A., and Oliaei, F. *The Stockholm Convention Listing of New POPs – Implications and Follow Up Activities.* 11th International HCH and Pesticide Forum, Cabala, Azerbaijan, 2011.
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- Oliaei, F., and Hamilton, C. *PBDE congener profiles in fish with different feeding behaviors from major rivers in Minnesota.* Organohalogen Comp. 64, 356-359, 2003.
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- Pratt G., Gerbec, P., Livingston S., Oliaei F., Bollweg G., Paterson S., and Mackay D. *An indexing system for comparing toxic air pollutants based upon their potential environmental impacts.* Chemosphere 27(8), 1359-1379, 1993.

Don Kriens **Curriculum Vitae**

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AREAS OF EXPERTISE

- Professional engineer - range of civil and environmental engineering projects, and design.
- Exposure and risk assessments for human health.
- Project manager - toxic contaminant cleanup projects.
- Design of water/wastewater treatment systems, hydro-geologic studies, remediation projects, stormwater control, and hazardous waste cleanups (Superfund).
- Industrial technologies and processes, pollution prevention, industrial process chemistry, and application of emerging treatment technologies to industries.
- HAZMAT trained.
- Regulatory enforcement, civil and criminal. Skilled in technical writing and presentation, and negotiation. Knowledge of federal and state environmental regulatory programs.
- Global water scarcity problems, environmental policy and justice, climate change impacts, energy, and engineering economic analysis.
- Modeling exposure and risk of chemicals, including disinfection byproducts and contaminants in drinking water supplies.

EDUCATION

HARVARD UNIVERSITY, Cambridge, MA
Sc.D. Environmental Health
Concentration - Exposure Sciences

HARVARD UNIVERSITY, Cambridge, MA
M.S. Environmental Health

UNIVERSITY OF IOWA, Iowa City, Iowa.
M.S. Environmental Engineering

UNIVERSITY OF IOWA, Iowa City, Iowa.
B.S. Sciences

AWARDS
Bush Foundation Leadership Fellow 2008
U.S. EPA Civil and Criminal Investigation Award
Harvard University Andelot Scholarship
Harvard University Water Initiative Fellow

PROFESSIONAL EXPERIENCE

1978-2008 MINNESOTA POLLUTION CONTROL AGENCY, St. Paul, MN

Principal Engineer

- Lead agency technical expert for water projects. Mentor to engineers, hydro-geologists, and other technical staff.
- Research projects to assess ecological and health impacts of contaminants. Evaluated emerging technologies to resolve pollution problems.
- Conducted major civil and criminal environmental investigations with MN Attorney General staff, U.S. Attorney's Office, USEPA Region V. Expert witness.
- Developed major industrial environmental permits, determined technologies required to comply. Assessed economic impact of regulations.
- Technical expert for water/wastewater treatment, remediation and hazardous waste, water supplies.
- Technical expert for emergency response regarding toxics and resolution. Project manager and/or engineer for remediation of various toxic waste sites.

1996-2008 Kriens Engineering, Oakdale, MN
Consulting Engineer and Owner
- Design of Individual Sewage Treatment Systems. Groundwater (well) analysis and water consulting.

Castek Consulting Engineering Services
Engineer
- Operation, design, and process chemistry evaluations of wastewater treatment plants; air pollution studies; indoor air quality assessments.

TEACHING EXPERIENCE

Harvard University
- Teaching Assistant in water pollution and risk assessment. Lecturer in water scarcity at Harvard Extension School.

Kirkwood Community College, Cedar Rapids, Iowa
- Instructor; wrote courses in chemistry/advanced chemistry of wastewater treatment.

University of Iowa Department of Civil and Environmental Engineering, Iowa City, Iowa
Research Scientist and Environmental Engineering Laboratory Supervisor
- Supervised laboratory conducting biological and chemical analyses, including GC and GC/MS. Conducted field studies. Occasional teaching assistant.

LICENSES AND PROFESSIONAL AFFLILIATIONS

- Registered Professional Engineer
- Individual Sewage Treatment System Designer (Minnesota)
- Certification in air quality inspections (California Air Resources Board)
- Certification in Stormwater Treatment and Erosion Design
- Member, Minnesota Government Engineers Council
- Member, Society of Professional Engineers

PAPERS AND PUBLICATIONS

Listing available on request