October 4, 2017 Submitted electronically and by regular mail

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
WATER RESOURCE MANAGEMENT
DIVISION OF WATER SUPPLY AND GEOSCIENCE

Re: **DEP Docket Number: 13-17-06. Proposed Amendments: 7:10-5.2, 5.3, and 12.30; Proposal Number: PRN 2017-14**

Delaware Riverkeeper Network submits these comments on the Proposed Amendments to N.J.A.C. 7:10-5.2, 5.3, and 12.30, DEP Docket Number: 13-17-06 as described in the Public Notice.

Proposed Maximum Contaminant Levels

Delaware Riverkeeper Network (DRN) supports the proposal to amend the New Jersey Safe Drinking Water Act (SDWA) rules at N.J.A.C. 7:10 to establish a maximum contaminant level (MCL) for perfluorononanoic acid (PFNA) and a MCL for 1,2,3-trichloropropane (1,2,3-TCP). DRN recommends that the MCL for PFNA should be set between 3 and 5 ppt rather than the 13 ppt proposed in this rulemaking. Attached to this comment is a technical analysis prepared by Fardin Oliaei, MPA, PhD, and Don Kriens, Sc.D., P.E. of Cambridge Environmental Consulting ("Cambridge Report") that was submitted to the New Jersey Drinking Water Quality Institute (DWQI) during the Institute's comment period in 2015.

The Cambridge Report evaluates the proposed health based maximum contaminant level (MCL) for PFNA in drinking water developed by the DWQI, as described in the DWQI's report "Health-Based Maximum Contaminant Level Support Document: Perfluorononanoic Acid (PFNA)", dated March 31, 2015. As stated in the Cambridge Report:

> "The criterion should be developed on the basis of a more vulnerable population segment (children), based on animal studies, and epidemiologic evidence that associate negative health effects in children due to PFNA exposures. We propose that the MCL at a minimum be revised to 5 ng/l based on children age group:
> 1-6 (using a mean water ingestion rate), and preferably to 3 ng/l for children age group
> 1-6 (using a 90th percentile water ingestion rate). Using a 90th percentile ingestion rate is consistent with updated EPA default criteria applied to adult exposure assessments."

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(Cambridge Report, Executive Summary).

DRN supports the Cambridge Report conclusion that the safe drinking water standard should be based on the more vulnerable population segment (children). Their analysis uses evidence from animal studies and epidemiologic evidence that associate negative health effects in young children due to PFNA exposures. Exposure of fetuses and young children can cause developmental damage that lasts for a person's entire life or can cause devastating disease later in life. To protect these most vulnerable populations, a stricter standard of 3 to 5 ppt is necessary. DRN advocates strongly that this more protective standard be adopted rather than the 13 ppt that is proposed in this rulemaking.

PFNA is one of a large group of perfluorinated chemicals (PFCs) that has been widely recognized as contaminants of concern. PFCs have spread throughout the world, are persistent in the environment, concentrate in human blood, and have serious negative health effects. ATSDR published a draft Toxicological Profile for Perfluoroalkyls in 2009. The profile includes information on PFNA; scientific studies show that PFNA, a longer carbon chain PFC, is associated with health effects in humans, is more bioaccumulative and toxic than PFOA in rodents and in general causes similar toxic effects as PFOA, but at lower doses.

As summarized in this rulemaking, the DWQI Health Effects Subcommittee Report in 2015 stated that "…exposure to low drinking water concentrations of PFNA increases concentrations in human blood serum that persist for many years after exposure ends". (Page 8). The DWQI Report's description of the toxicological effects of exposure to PFNA are comprehensive and reflect the up-to-date analysis of the top scientists that serve on the DWQI. The DWQI is nationally recognized as a panel with highly developed expertise.

PFNA was first discovered in the Delaware River Watershed in Gloucester County, NJ. The raw groundwater well in Paulsboro near the Solvay plastics manufacturing plant in West Deptford was sampled as part of an occurrence study conducted by DEP in 2009-2010. The Paulsboro groundwater showed an alarmingly high concentration of 96 ppt, higher than any other value we could find worldwide.

In subsequent sampling in 2013 PFNA was found at 140 ppt in raw water and 150 ppt in finished water in the water supply well in Paulsboro. Sampling done of surface water by the Delaware River Basin Commission during monitoring in 2007-2009 revealed PFNA had the highest concentration of PFNA of any PFCs sampled there. The highest level of PFNA (976 ng/L) was found in the lower part of the Delaware River at a river mile in the vicinity of the Solvay plant.

Further investigations in 2013-14 resulted in 5 area municipalities shutting down contaminated wells, people being put on bottled water, and emergency remediation. Through municipal and public advocacy, action was taken at the state level to reconvene in 2014 the Drinking Water Quality Institute that had been shuttered in 2010. The Institute's agenda, at the direction of DEP, was to develop MCLs for three perfluorinated compounds – PFNA, PFOA, and PFOS. PFNA was the first PFC to be studied by the newly reconstituted DWQI; the DWQI recommended the MCL for PFNA in July 2015. New Jersey residents who are being exposed to PFNA in their drinking water have been forced to wait for a mandatory MCL that will

assure safe drinking water. The proposed rulemaking, with DRN's alternative recommended MCL of between 3 and 5 ppt should move ahead immediately to cease the exposure of people to dangerous levels of this toxic compound.

DRN supports the proposal to amend the New Jersey Safe Drinking Water Act (SDWA) rules at N.J.A.C. 7:10 to establish a maximum contaminant level (MCL) for 1,2,3-trichloropropane (1,2,3-TCP). As stated in the proposed rulemaking, 1,2,3-TCP is a chlorinated hydrocarbon that is highly stable, persisting in the environment. 1,2,3-TCP is an extremely potent carcinogen, both mutagenic and genotoxic, making it very dangerous to people who are exposed through drinking water. It has been used as a solvent, a cleaning agent, a degreaser, an agent which is used to make other chemicals, and has been released into the environment as a contaminated byproduct produced by soil fumigants in agricultural applications.

Discovered by New Jersey Department of Environmental Protection (DEP) at contaminated sites in the state and by ATSDR when sampling was done for the Environmental Protection Agency's (EPA) Unregulated Contaminant Monitoring Rule 3 (UCMR3), it is known to be present in dangerously high concentrations in Moorestown, Burlington County, NJ. The DWQI recommended a MCL of 30 ppt for 1,2,3-TCP.

DRN advocates for a stricter standard than the 30 ppt proposed by this rule. The California Department of Public Health has adopted a standard of 5 ppt based on the most current science, after years of study due to extensive water contamination there, primarily related to agricultural practices. (See: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/123TCP.shtml and http://www.waterworld.com/articles/2017/07/ca-state-water-board-sets-max-limits-for-1-2-3-tcp-in-drinking-water.html) There is ample evidence that the more protective standard of 5 ppt is justified and would provide the necessary level of protection. DRN advocates that DEP adopt the more protective MCL of 5 ppt to protect people more fully from the risk of developing cancer.

There are no federal MCLs for PFNA or 1,2,3-TCP and there is no expectation that either of these will be proposed for federal rulemaking in the foreseeable future. The people in New Jersey require MCLs for these toxic contaminants immediately. There have been long delays in regulatory action on both these toxic contaminants; there must be no further delay.

Monitoring Proposals

Delaware Riverkeeper Network (DRN) supports the proposal to amend the New Jersey Safe Drinking Water Act (SDWA) rules at N.J.A.C. 7:10 to establish monitoring requirements for PFNA and other chemicals. DRN supports monitoring and treatment, as necessary, for these contaminants for both public community and public nontransient noncommunity water systems.

Regarding monitoring for PFNA, we object to the proposal to phase in monitoring of the state's water supplies during 2019-2020. One of the most important benefits of the adoption of a MCL is that all water users will be equally protected by the mandatory requirement for water systems to sample for the contaminant and remove it where it is found.

Monitoring for PFNA should begin rapidly in order to locate all water systems that are contaminated with this toxic compound so that PFNA can be swiftly removed from all drinking water. Anything else is unjust and unfairly burdens communities that are not going to be immediately sampled on a regular basis. The communities that are aware now of PFNA contamination, primarily the Delaware River Watershed Gloucester County region, have already been disproportionately burdened by years of exposure to the toxic compound through drinking water and other pathways of exposure. They need immediate implementation of monitoring for PFNA in all size water systems to fulfill their right to know and to establish transparent disclosure of what is in their water. Communities that do not yet know if they have been exposed require that information immediately as well since they could be drinking contaminated water and don't know it.

New Jersey is the most densely populated state in the nation and has a legacy of industrial activity, as well as ongoing industrial operations, and its population and environment are exposed to pollution associated with those activities. It is reasonable to expect that other locations have been exposed to releases of PFNA into the environment and into drinking water sources and some could have long-term exposure like the Gloucester County area. Action to find and remedy the contamination is urgently needed. The proposed monitoring implementation time frame of 2019 and 2020 is not justifiable or timely. The technology and testing methods are available, laboratories can meet the need, and the public deserves timely action. DRN advocates strongly for an immediate implementation of monitoring for PFNA, with a reasonable phase-in period of no more than 3 to 6 months to install equipment and train lab technicians.

DRN advocates for a more rapid monitoring schedule for 1,2,3-TCP based on similar concerns about community exposure.

DRN also supports the proposal to amend the SDWA rules to require public nontransient noncommunity water systems to begin monitoring for radionuclides and advocates for a more rapid implementation than 2019.

Treatment Options

DRN attaches a copy of "Technical Review of New Jersey Drinking Water Quality Institute's Recommendation on Perfluorinated Compound Treatment Options for Drinking Water" dated May 5, 2015 by Cambridge Environmental Consulting (Cambridge Treatment Report). The Cambridge Treatment Report was commissioned by Delaware Riverkeeper Network and submitted to the DWQI in 2015 on behalf of the organization and its membership as a review of the Drinking Water Quality Institute's document "Recommendation on Perfluorinated Compound Treatment Options for Drinking Water".

We support the DWQI Treatment subcommittee's finding that granular activated carbon is used to remove PFCs and that effective treatment is not a limiting factor in implementing the MCL. It was also the conclusion of the Cambridge Treatment Report that the best available technology to remove PFOS, PFOA, and PFNA from water supplies is granular 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.

Attached also is the curriculum vitae for Fardin Oliaei, MPA, PhD. and Don Kriens, Sc.D., P.E. of Cambridge Environmental Consulting.

Thank you for the opportunity to comment on this critically important proposed rulemaking. We urge swift adoption and implementation of the proposals with our recommended changes.

Sincerely,

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

Attachments:

Technical Analysis of NJ Drinking Water Quality Institute Proposed Health-Based Maximum Contaminant Level (MCL) for PFNA in Drinking Water

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

Proposed Health-Based Maximum Contaminant Level (MCL) for PFNA in Drinking Water

prepared by

Fardin Oliaei MPA, Ph.D.

Don Kriens Sc.D., P.E.

Cambridge Environmental Consulting

May 5, 2015

PREFACE

The opinions in this report are stated to a reasonable degree of scientific probability. The methods and principles used in forming these opinions are generally accepted within the scientific community, and are consistent with their regular application within the scientific community. Qualifications of the authors, including publications where applicable, are summarized in the attached resumes. We reserve the right to modify or supplement opinions stated in this report.

Technical Analysis of Proposed NJDWQI Health-Based Maximum Contaminant Level (MCL) for Perfluorononanoic Acid (PFNA)

by

Cambridge Environmental Consulting

Executive Summary

We conclude that the proposed drinking water MCL of 13 ng/L for PFNA is not protective. The criterion should be developed on the basis of a more vulnerable population segment (children), based on animal studies, and epidemiologic evidence that associate negative health effects in children due to PFNA exposures. We propose that the MCL at a minimum be revised to 5 ng/l based on children age group
1-6 (using a mean water ingestion rate), and preferably to 3 ng/l for children age group
1-6 (using a 90th percentile water ingestion rate). Using a 90th percentile ingestion rate is consistent with updated EPA default criteria applied to adult exposure assessments.

Introduction

This is a summary of our analysis and evaluation of the proposed health based maximum contaminant level (MCL) for PFNA in drinking water developed by the New Jersey Drinking Water Quality Institute (NJDWQI), as described in its report Health-Based Maximum Contaminant Level Support Document: Perfluorononanoic Acid (PFNA), dated March 31, 2015, hereinafter referred to as the Report.

The presence of PFNA in New Jersey water supplies is of high concern because of unusual high concentrations in groundwater and surface water within the Delaware River Watershed. According to water sampling analysis conducted by the Delaware River Basin Commission (DRBC), PFNA had the highest concentrations of any PFCs sampled during monitoring of 2007-2009. The highest level of PFNA (976 ng/L) was found in the lower part of Delaware River at Paulsboro, near the Solvay plant. To our knowledge, this is the highest level of PFNA ever reported in surface water, worldwide. PFNA was also found at a very high level (96 ng/L) in a raw groundwater sample at the Paulsboro Water Department in 2009. In 2013 PFNA was found at 140 ng/L in raw water and 150 ng/L in finished water in this well in Paulsboro. To our knowledge this is these are highest levels of PFNA in drinking water reported in studies, worldwide.

Drinking water contamination is one of the most important PFNA human exposure routes. PFNA is known to be persistent and bioaccumulative with a long half-life in humans, and causes some toxic effects similar to PFOA, but at lower doses (ATSDR 2009). Human epidemiologic and animal data suggest potential health risks from drinking water exposures.

The MCL for PFNA was derived by quantifying a point of departure defined as the BMDL (benchmark dose 95th percentile lower confidence interval) in dose-response modeling, using pregnant mice PFNA serum levels (at selected PFNA dose) and increase in liver weights. The benchmark response used was a 10% increase in mean liver weight of pregnant control mice. The analysis is based on a study by Das et. al. 2015, the only study available where dose-response data allows quantification of a BMDL (Das 2015). Using USEPA Benchmark Dose Modeling Software 2.40 a BMDL of 5200 ng/ml was selected as the POD, pursuant to finding the best fit of the model using statistical criteria in the BMD software. We concur with the approach used and also determined a 5200 ng/ml BMDL as a point of departure.

Uncertainty Factors (UFs)

In its interim draft PFNA groundwater criterion the New Jersey Department of Environmental Protection (NJDEP) had proposed a cumulative UF (CUF) of 300. This is revised in the NJDWQI MCL for drinking water to a CUF of 1000. This is based on a UF of 10 for intraspecies differences (human variation), a UF of 10 for extrapolation from non-chronic to chronic, a UF of 3 for incomplete database (notably for the lack of carcinogenic studies), and a UF of 3 (3.16) for extrapolation from animal to human (interspecies) for toxicodynamic differences.

Given that the target tissue is blood serum level we concur that toxicokinetic differences between species (human and test animals) is accommodated and therefore no UF is needed for toxicokinetic interspecies extrapolation. This is consistent with EPA's position: "interspecies differences in TK are defined as differences in the external dose producing the same level of the dose metric in the target tissue of interest in test animals" (USEPA 2014).

A UF of 10 for the lack of data versus a UF of 3 could be viewed as appropriate since there is a lack of carcinogenic test information. If we use a 10 for lack of data then the CUF would be 3000. However, uncertainty values chosen are inherently subject to bias and a resultant calculation can go both ways – either towards a conservative or a less conservative result. We have no scientific basis to assign a more conservative value for lack of data, underscoring use of professional judgment where a UF of 3 and 10 are often equivalently applied in risk assessments for lack of data. In this case we concur with a UF of 3 for lack of data and a CUF of 1000, which is consistent with CUF's commonly applied in other health risk assessments for non-carcinogenic endpoints.

Serum:Water Ratio

We disagree with the use of a central tendency (median) value for the serum:drinking water ratio, presumably using the PFOA ratio of 100:1 and multiplying by a factor of 2, based on limited data that the human half-life of PFNA is at least 2 times that of PFOA. NJDWQI Report also indicates that the half-life of PFOA is higher in children. The central tendency of 200:1 used here is inconsistent with upper percentile exposure values used by USEPA in its assessments. Therefore, 200:1 represents a less protective and non-conservative ratio.

Relative Source Contribution Factor

Although derivation of a RSC based on chemical-specific exposure data improves accuracy, we disagree with the basis used in NJDWQI's analysis to determine an RSC of 0.50 for PFNA. We find that potential PFNA exposures from local sources other than drinking water, such as locally grown vegetables, recreationally caught fish, and indoor contamination, in areas and regions with known PFC contamination, were not fully taken into account.

NJDWQI proposes to use the upper tail (95th percentile) of the U.S. population distribution of PFNA serum concentration (NHANES 2011-2012) as a surrogate for non-drinking water sources, including food, soil, air, water, and consumer products. Although the 95th percentile is an upper percentile of PFNA serum distribution in the normal population (uninfluenced by contaminated drinking water), it is not necessarily representative of individuals exposed to non-drinking water sources of PFCs in known "local" PFC contaminated regions/areas. The variability of national PFNA serum levels is likely due to within-population pharmacokinetic differences. Humans respond differently to the same or similarly dosed chemical exposures based on exogenous and intrinsic factors, as well as life stages, which would affect PFNA serum levels. Therefore, the 95th percentile serum PFNA may not be singularly representative of an upper level of serum concentrations associated with non-drinking water inputs of PFNA. In addition, the 95th percentile serum as a surrogate for non-drinking water inputs is very unlikely to be representative in areas where PFC contamination has been shown to be present.

NJDWQI formulates a basis that non-drinking water PFNA sources in the area/region are negligible because "the most recent data (PFNA analysis of white perch and channel catfish from locations on the Delaware River in the vicinity of communities where drinking water is contaminated with PFNA) do not suggest elevated exposures from recreationally caught fish in communities where PFNA is present in drinking water" (NJDWQI 2015). Based solely on this analysis NJDWQI assumes that the 95th percentile U.S. population PFNA serum level of 2.54 ng/mL represents a reasonable and protective estimate of total non-drinking water exposure. This reasoning is not supportable. First, we note that only two species (white perch and channel catfish) were tested for PFNA in the Delaware River, hardly representative of all recreational fish potentially contaminated with PFNA and consumed. Presumably, analysis was limited to white perch and channel catfish since they are on fish consumption advisories for other contaminants (PCBs) in the Delaware River. In fact, the Delaware River Basin Commission (DRBC) states that data collected for these fish are used to track the progress of PCB TMDLs established by the U.S. EPA in 2003 (DRBC 2012).

A number of fish species need to be tested in rivers to determine the extent of PFC contamination and risk to consumers. Researchers have found widely varying PFC levels in fish within and between species, and bioaccumulation factors for PFCs (PFOS) vary greatly from study to study and among species within studies (Oliaei 2006; MPCA 2010; Oliaei 2012). Researchers have found that PFC concentrations do not necessarily increase with trophic position. In Minnesota the following levels of increasing levels of PFOS have been found in

some of the fish tested: (channel catfish < walleye < carp <bluegill < white bass < smallmouth bass) (McCann 2007). For example, bluegill in Mississippi River locations are generally low in environmental contaminants (PCB, Hg) but have relatively high PFOS levels, generally much higher PFOS levels than fish at higher trophic levels. In Alabama (Bakers Creek and the Tennessee River) PFOS in channel catfish were 7 to 886 times lower than PFOS found in largemouth bass (Sass).

NJDWQI analysis disregards other non-drinking water sources in its calculation of a RSC. In areas with known PFC contamination, researchers have also found a significant positive association between serum PFC (PFOA) levels and home-grown vegetable consumption after adjusting for water (PFOA) concentrations, suggesting that locally grown food may be an important source of exposure (Hoffman 2011). This association was also found in other studies (Bartell 2010; Steenland 2009). We would expect a similar pattern with PFNA.

It is illogical to conclude that the lack of PFNA in only two fish species tested is representative of all non-drinking water inputs (locally grown food, fish consumed, indoor air, etc.) in areas where known PFC contamination has occurred. An RSC of 0.50, based solely on the assumption that background U.S. PFNA serum levels (95th percentile) represent non-drinking water sources, is cursory and overlooks other potential local PFNA inputs.

We conclude that NJDWQI has not supported a data-driven RSC alternative to the default RSC of 0.20, and therefore the default RSC of 0.20 should continue be used in the MCL calculations, until such time data is available to formulate a data-driven RSC.

PFNA Toxicity and Unknowns

PFOA exposures have been associated (probable links) in epidemiologic studies with several health endpoints including increased cholesterol, ulcerative colitis, thyroid disease, reduction in vaccine response, and hyperuricemia (Steenland 2009; Steenland 2013; Lopez-Espinosa 2012; Steenland 2010; Looker 2013). PFCs, including PFOA and PFNA, have been found to be associated with a lower percentage of sperm with coiled tails, a measure of sperm quality (Louis 2015). *In utero* exposure to PFOA has also been found to be associated with lower adjusted sperm concentration and total sperm count (Vested 2013). Although PFNA is a close homologue of PFOA we do not know whether these human health endpoints are also associated with PFNA exposure.

We also do not know whether PFNA causes cancer in test animals because carcinogenic studies have not been undertaken, although PFOA and PFOS have been shown to cause tumors in rats (Sibinski, 1987; Biegel 2001; Thomford 2002). We do have epidemiologic evidence of significant associations between higher PFOA serum levels and testicular, kidney, prostate, and ovarian cancers and non-Hodgkin lymphoma (Vieira 2013). We also know that at least for some testing endpoints, such as reproductive and developmental, that PFNA, a one-carbon higher carboxylate than PFOA, is a more potent toxicant than PFOA (Das 2015; Wolf 2010), which, as the NJDWQI Report states, “is likely related to its greater intrinsic potency and longer

persistence in the body" (NJDWQI 2015).

Studies that include PFNA have found it to be significantly associated with increases in total cholesterol. As stated in the NJDWQI Report; "epidemiologic data provide evidence of consistency, specificity, and exposure-response for PFNA and increased total cholesterol, although data on temporal relationship and strength of an association are limited." The NJDWQI Report further states: "The possibility that PFNA causes increased cholesterol is further supported by evidence from epidemiology studies of PFOA, a closely related compound with similar toxicological effects. The epidemiology database for PFOA includes multiple studies of different designs in the general population, communities with drinking water exposure, and workers with occupational exposure, and suggests that a causal relationship may exist between PFOA and increased cholesterol" (NJDWQI 2015). We note that although a conclusion of causality between PFNA and increased cholesterol cannot be made since the evidence is based on epidemiologic studies, the evidence for the association is nevertheless very strong.

As discussed in the NJDWQI Report, although only one study found evidence of a significant positive association with thyroid stimulating hormone (TSH) and PFNA serum levels (Webster 2014), and 10 other studies found a null association, in our view the Webster study is more meaningful since it was a prospective birth cohort study. Considering the hierarchy of evidence, cohort studies, which establish a temporal relationship between exposures and outcome, are considerably more valuable than cross-sectional studies in determining outcomes.

Applying the MCL to a Vulnerable Group

As stated in USEPA guidance, in part, sensitive life stages should be considered explicitly in the risk assessment when sufficient data are available (USEPA 2005).

PFCs have been shown to be significantly associated with some health effects in children. In a epidemiologic study by Lopez-Espinosa of thyroid function and PFAAs in children living near a chemical plant, serum PFOS and PFNA concentrations were significantly associated with slightly higher levels of thyroid hormone TT_4 in children 1-17 (Lopez-Espinosa 2012). For PFNA the study found that interquartile contrasts of 1.2 to 2.0 ng/mL were both associated with a 1.1% increase in TT_4 (95% CI: 0.7, 1.5) in children 1-17. The association remained after adjustment for PFOS, also found to be associated with increased TT_4 levels. It should be noted that increased TT_4 in this study was not associated with subclinical hypothyroidism. Yet an association between PFNA and increases in thyroid hormones is of concern, considering their importance to cognitive function in children and the adolescent brain. This study also found a significant association between thyroid disease (usually hypothyroidism) and serum PFOA levels (OR 1.44; CI 1.02, 2.03).

Other studies on children have shown health impacts from PFC exposures. Significant increases in total cholesterol and LDL cholesterol were linearly and positively associated ($p < .001$) with PFOA and PFOS serum concentrations in a large study of 12,476 children (Frisbee 2010). PFNA was not evaluated in that study. However, again, as noted in the NJDWQI Report

“epidemiologic data provide evidence of consistency, specificity, and exposure-response for PFNA and increased total cholesterol” (NJDWQI 2015). It is reasonable, therefore, to expect similar associations in increased total cholesterol and PFNA exposures in children.

Given that the carcinogenic potential of PFNA is unknown and that the MCL is based solely on one dose-response study in pregnant mice, we believe that a margin of safety should be applied to the MCL derivation. This is further supported by a finding in another study (with no dose-response data) that suggests a more sensitive endpoint than increased liver weight in the mice study and greater toxicity to the liver (rats) due to histological changes, including necrosis (Stump 2008).

We believe that the MCL should be calculated on the basis of the more vulnerable group of children. This is based, in part, on the potential vulnerability to early childhood exposures of contaminants with later manifestation of health impacts, epidemiologic evidence that PFNA is associated with level of hormones in children, and our inability to observe and quantify developmental exposures and their impact on later life disease incidence.

Accordingly, we propose that the MCL be derived for a children group 1-6 as follows.

Proposed Revision for MCL

Summary of variables used and values

BMDL	POD of 5200 ng/ml
CUF	1000
RSC	0.20
Serum:water ratio	200:1
default adult body weight	80 kg per USEPA
default adult intake	3L at 90th percentile per USEPA
children body weight	16.8 kg
children intake	0.69 L mean, 1.19 L 90th percentile

Adult Calculation

Based on a BMDL (POD) of 5200 ng/l, cumulative UF of 1000, the default RSC 0f 0.20 versus a proposed RSC of 0.50, and a central tendency serum:water ratio of 200:1, we calculate an adult MCL as:

target serum level = $\frac{5200 \text{ ng/ml}}{1000 \text{ UF}}$ = 5.2 ng/ml

Increase in human serum level that can result from drinking water exposure only:

5.2 ng/ml x 0.20 RSC = 1.04 ng/ml (1040 ng/L)

MCL = $\frac{1040 \text{ ng/L}}{200:1 \text{ serum:water}}$ = **5.2 ng/L (5 ng/l) ADULT**

Children (age 1-6)

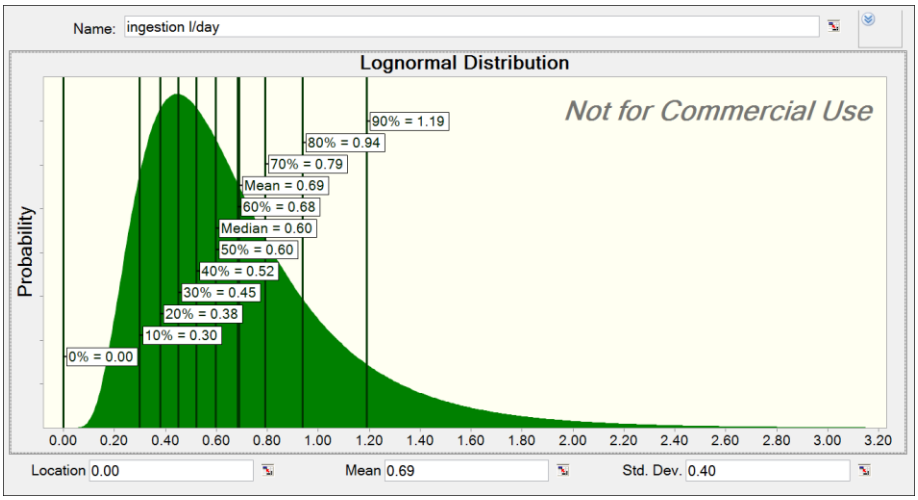
Using a 5.2 ng/L MCL adult, revised EPA default values of daily water intake at 3L/day (90th percentile) and adult mean body weight at 80 kg (EPA 2014), the daily allowable mass intake of PFNA is calculated as:

$\frac{5.2 \text{ ng/L x 3L/day default}}{80 \text{ kg x 0.20 RSC}}$ = 0.975 ng/kg/day allowable daily intake

To extrapolate to children age group 1-6 we use the same allowable mass intake of 0.975 ng/kg/day and calculate a MCL using a mean child body weight of 16.8 kg and mean child water intake of .69 L/day. (These values were determined using EPA 2011 Exposure Factor Handbook data, taking smaller increments of age groups and gender, combined by weighting the means of group increments, and pooling variances to determine means and standard deviations.)

0.975 ng/kg/day x 16.8 kg x 0.20 RSC = **4.75 ng/l MCL (5 ng/l) CHILDREN 1-6**
.69 L/day (mean value)

Following the EPA's default criteria of the 90th percentile distribution of water intake, we found a 1.19 L/day water ingestion rate for children 1-6 at the 90th percentile, based on our derivation of a lognormal distribution of water intakes for this combined age group, as shown in the graph below.



Graph: Lognormal Distribution of Water Intakes for Children Group Ages 1-6

Accordingly,

0.975 ng/kg/day x 16.8 kg x 0.20 RSC = **2.75 ng/l MCL (3 ng/l) CHILDREN 1-6**
1.19 L/day (90th %)

We propose that the MCL be revised to 5 ng/l, and preferably to 3 ng/l, based on protection of children 1-6.

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Technical Analysis of New Jersey Drinking Water Quality Institute

Recommendation on Perfluorinated Compound Treatment Options for Drinking Water

prepared by

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May 5, 2015

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

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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.

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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

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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

200

6 - 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

200

7- 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

198

9 - 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.
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