DEPARTMENT OF ENVIRONMENTAL PROTECTION
Hazardous Sites Cleanup Program

RESPONSE TO COMMENTS – Appendices

Ridge Run PFAS HSCA Site

April 18, 2019

Appendix A: Written Commenter #4: Angela Goodwin. Attachments to the August 30, 2018 e-mail.

Appendix B: Written Commenter #5: Tracy Carluccio. Attachments to the e-mail.

Appendix C: Written Commenter #14: Perkasie Regional Water Authority. Four attachments to the August 31, 2018 e-mail

Appendix A: Written Commenter #4: Angela Goodwin. Attachments to the August 30, 2018 e-mail.

Cherry, Timothy

From: Harper, Lena
Sent: Friday, August 31, 2018 7:24 AM
To: Wade, Colin
Cc: Cherry, Timothy
Subject: FW: Comments for Ridge Run contamination
Attachments: 20180830_173448.jpg; 20180830_173502.jpg

Lena Harper | Geologic Trainee
Department of Environmental Protection | Southeast Regional Office
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From: Angela Goodwin [redacted]
Sent: Thursday, August 30, 2018 6:23 PM
To: Harper, Lena <lharper@pa.gov>
Subject: Fwd: Comments for Ridge Run contamination

~~Angela Goodwin~~
[redacted]

-----Original Message-----
From: Angela Goodwin [redacted]
To: lharper <lharper@pa.gov>
Sent: Thu, Aug 30, 2018 5:49 pm
Subject: Fwd: Comments for Ridge Run contamination

1) Our families health, our property values and our community have been compromised and the only thing that would help is public water. Would you buy a home with a contaminated well?

2) The filtration system does not have an alarm system to let us know when the filter needs to be replaced. We could have our water tested and then 6 months later the filter could be bad. We would then be back to dealing with contaminated water and not even know it. We would always be worried about using too much water and the filter needing to be replaced. People have pools and hot tubs that need to be filled occasionally, we would be afraid to do that because of the filters. We will never be able to lead a normal life with the filtration systems.

3) You mentioned that if you shut down wells the contamination could go elsewhere. Well the highest levels are right around Bergey's property, so "A" why are we supposed to be punished for something that we had nothing to do with and not control over, "B" what about new wells going in, you will be drilling new wells to keep checking will the water, new homes go up all the time and what if current residents need new wells, that also can change things.

4) You mentioned at the meeting that after you finish your investigation you will be going after the party you feel is responsible for this. You mentioned that we would then have to go after this party to recoup our lose, but we have reached

out to 7 attorneys and we have not been able to get anyone to represent us. We are too small of an area and they all seem to be representing residents around the Navel Air Force Base. So without public water the residents with contaminated wells really have no value in their properties and no way to recoup any losses, plus we have to hope our health is not affected.

5) Representatives from East Rockhill Township and Perkasie Water Authority were present at this meeting and they mentioned they could bring us public water for under DEP budget amount, but DEP mentioned that private wells are really not their concern, that private wells are the responsibility of the owners. We the owners did not cause this contamination, it would be nice to have our government looking out for us.

6) We all know that the responsible party is Bergey's. I have copies of newspaper articles from back in 1985 and 1986, they had tires piled up for 5,6,7 years. Per the township comments that was not allowed. The year before the fire they were supposed to be cutting them in half and recycling. You can tell from the pictures from the fire they were not. They had over 3 million tires piled up. If there was not so many tires piled up they may not have had to use the spray foam. According to the one article "it really did not help".

7) From what I was told this spray foam was all over my property and the neighbors (we purchased our property in 2000 and the tires were/are in trailers). The previous owner and neighbors had asked the township and fire department about coming back to clean this up but no one responded. As of this point the soils on my property may also be contaminated and I have asked about doing soil testing but I get no response.

8) There is a retention basin behind my property. This basin use to drain on the vacant lot next to my property. Back in 1986 after the fire the EPA monitored the clean-up of Bergeys and the water in the basin. After it was okay they allowed this water to be released. EPA then test the stream that they THOUGHT this water was draining too but it never made it that far. As of this point the soil all around my property could very well be contaminated and we still deal with water running from Bergey's property onto mine.

Public water is in our best interest and should not be what fits in a budget, especially when you are talking about someone's health.

I have attached 2 pictures of plants that I did an experiment on. They were both planted at the same time. I used the same soil in both pots. I gave them the same amount of water at the same time. The only difference was I used bottled water for one and well water for the other. I did not use fertilizer on either one.
Look at the difference between the 2 plants in only a month with little sun. Now think what they would be like after a couple months. So what is happening to our health from our water?

It would be nice if we the residents would have a vote on what you would like to do with OUR properties.

Thank you,
Angela Goodwin
[redacted]
Sellersville, PA

Appendix B: Written Commenter #5: Tracy Carluccio. Attachments to the e-mail.

Cherry, Timothy

From: Harper, Lena
Sent: Tuesday, August 07, 2018 7:21 AM
To: Wade, Colin
Cc: Cherry, Timothy
Subject: FW: Comment Ridge Run PFAS HSCA site, East and West Rockhill Twps., Bucks Co.
Attachments: verbal tesimony PADEP HSCA 7.18.pdf; cvr ltr PFOA mcl cmnt11.19.combinedpdf.pdf; Cvr ltr PQL PFOA cmnt11.19.combined.pdf; cvr ltr PFC treatment cmntcombined11.19.pdf; PFOS cmnt1.31.18.combined.pdf

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From: Tracy Carluccio [mailto:Tracy@delawareriverkeeper.org]
Sent: Monday, August 6, 2018 4:54 PM
To: Harper, Lena <lharper@pa.gov>
Subject: Comment Ridge Run PFAS HSCA site, East and West Rockhill Twps., Bucks Co.

To:
Ms. Lena Harper
Re:
PADEP, Hazardous Sites Clean-Up
UNDER THE ACT OF October 18, 1988
NOTICE OF PROPOSED INTERIM RESPONSE
Ridge Run PFAS HSCA Site, East & West Rockhill Townships, Bucks County, PA

Dear Ms. Harper,
Please find attached a copy of testimony submit by Tracy Carluccio, Deputy Director, Delaware Riverkeeper Network at the PADEP July 11 hearing. This comment may be slightly different than that verbally presented due to shortening the length due to time constraints at the hearing.
Also please find copies of the technical reports commissioned by Delaware Riverkeeper Network regarding:

- PFOA: Recommended MCL; PQL; Treatment Options (3 PDFs)
- PFOS: Recommended MCL; PQL; Treatment Options (1 combined PDF)

Please consider these reports as supporting the testimony made to PADEP at the July 11 Hearing and in the written version of that testimony attached hereto.
Thank you for the opportunity to submit these written comments,
Tracy Carluccio

DELAWARE RIVERKEEPER NETWORK

July 11, 2018

Lena Harper
Environmental Protection Specialist
Pennsylvania Department of Environmental Protection
2 East Main Street, Norristown, PA 19401

TESTIMONY of Tracy Carluccio
Deputy Director, Delaware Riverkeeper Network
to Pennsylvania Department of Environmental Protection (DEP) re.
Hazardous Sites Clean-Up UNDER THE ACT OF October 18, 1988
NOTICE OF PROPOSED INTERIM RESPONSE
Ridge Run PFAS HSCA Site, East & West Rockhill Townships, Bucks County
July 11 Public Hearing
West Rockhill Township, Bucks County

Delaware Riverkeeper Network (DRN) presents this testimony regarding the proposed clean-up of per- and poly-fluorinated alkyl substances (PFAS) above the US Environmental Protection Agency's (EPA) Health Advisory Limit (HAL) combined concentration for Perfluorooctane sulfonate (PFOS) and Perfluorooctanoic acid (PFOA) of 70 nanograms per liter (ng/L) or parts per trillion (ppt).

We have a few points to make today:

First, we do not agree that applying the EPA HAL of 70 ppt is reasonable or protective and using it can mask how much contamination actually exists. In June, the federal Agency for Toxic Substances and Disease Registry (ATSDR) released "minimum risk levels" that reduce the level at which no harm can be expected from exposure down to approximately 7 ppt for PFOS and 11 ppt for PFOA. PFAS is highly toxic and linked to devastating disease such as cancer. Even miniscule concentrations in drinking water can have adverse health effects. Additionally, other states are considering safe drinking water standards that are many times lower than the EPA HAL and more in line with ATSDR's findings.

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New Jersey, for instance, is going to adopt mandatory maximum contaminant levels (MCLs) of 14 ppt for PFOA and 13 ppt for PFOS, dropping the trigger in that state for mandatory treatment by all water suppliers to a much lower and more protective level.

Finally, DRN filed a formal petition with Pennsylvania's Environmental Quality Board (EQB), asking that they set a MCL for PFOA of 1ppt or no greater than 6ppt. The EQB accepted our petition last year and is currently considering setting a MCL. We recently brought to the EQB's attention the final recommendation and findings of the NJDWQI for a MCL for PFOS and submitted DRN's report prepared by an independent toxicologist recommending a MCL of a maximum of 5 ppt or "non-detect" for PFOS.

Based on the most recent science, the trigger for remediation and water replacement for people should be either at non-detect or no greater than 5 ppt for PFOS and between 1 and 6 ppt for PFOA. You refer in your presentation here tonight to identifying 12 wells with PFCs in this area. However, the summary of groundwater sampling that you provided for review shows many more than 12 wells with detections of PFOA and PFOS above 5 or 6 ppt, singly or combined. Using these levels as triggers increases the number of wells that require treatment and substantially changes DEP's evaluation and the cost analysis – both the total cost and the distribution of the capital costs of treatment. This is especially true if PFAS is detected in more wells as sampling continues.

DRN supports DEP's proposed Alternative 4, the piping in of public contaminant-free water, to provide the protection needed. Extending the public water system could be coupled with Alternative 3 by immediately installing whole house filtration systems or continuing the use of bottled water until the piped system is operating. The installation of whole house filtration systems could be used in combination with Alternative 4 to cover outlier wells that are outside the area that would be reasonably served by the extension of the existing water system. Extending the water system and using the bottled water or whole house filters in the meantime will provide immediate long-term relief for an already impacted community.

However, Alternative 3's condition of turning the systems over to the homeowners after 1 year is unacceptable and unfair. The systems should be monitored and maintained by DEP or the responsible party in perpetuity.

DRN supports that action be taken by DEP as swiftly as possible to address the groundwater contamination in the Ridge Run area. The public and DEP are well aware of the highly toxic properties of PFAS and the threat these compounds represent to human health. Contaminated drinking water is the major source of ingestion of PFAS. Because there are numerous individual water wells and at least two – now closed - public water supply wells that are known to be contaminated at this site, because the source of the contamination has not been conclusively defined, because the groundwater aquifer is known to contain the compounds and because these compounds do not break down in the environment but persist indefinitely and can spread over time, because PFAS builds up in peoples' blood, increasing the risk of harmful health effects, and people here do not know how long they've been exposed and at what level, it is critical that action be taken on urgent footing to protect public health and the environment.

Regardless of the solution, it is vitally important that the environmental cleanup of the pollution commences in tandem with the drinking water solution and the source be found and the responsible party be made accountable. That would provide a truly permanent solution.

Thank you for the opportunity to comment on this important contamination issue and thank you for taking action to remedy this egregious pollution problem.

DELAWARE RIVERKEEPER NETWORK

November 19, 2016

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

Re: Comment on the Proposed DWQI Addendum to Appendix C: 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 **Addendum to Appendix C: Recommendation on Perfluorinated Compound Treatment (PFC) 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 PFC 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 the most effective treatment technologies.

We support the recommendations and findings made by Dr. Oliaei and Don Kriens of Cambridge Environmental Consulting in this technical analysis regarding the Addendum to the Treatment Options Report by the DWQI. We support the utilization of the most effective methods of removing PFCs considering the highly toxic properties of the compound.

Dr. Oliaei and Don Kriens recommend that reverse osmosis (RO) is needed to completely remove all PFCs from drinking water to the proposed safe drinking water standard. Dr. Oliaei and Don Kriens also find that RO alone or used after granular activated carbon (GAC) represents the best available technology for this purpose. Delaware Riverkeeper Network supports these findings and advocates for the use of the best available technology with a goal of providing safe drinking water to the public.

Thank you for the opportunity to comment on the Treatment Options to remove PFCs, including PFOA, PFNA, and PFOS.

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Sincerely,

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

Attachments: Technical Review of Proposed DWQI Recommendation on Perfluorinated Compound Treatment Options for Drinking Water, Fardin Z. Oliaei, Don Kriens, Cambridge Environmental Consulting, Nov. 18, 2016

Technical Analyses of New Jersey Drinking Water Quality Institute

Recommendation on Perfluorinated Compound Treatment Options for Drinking Water

prepared by

Fardin Z. Oliaei MPA, Ph.D.
Don L. Kriens* Sc.D., P.E.

Cambridge Environmental Consulting

November 18, 2016

PREFACE

The opinions in this report are stated to a reasonable degree of scientific probability. The methods and principals 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.

** The views expressed in this report do not necessarily reflect those of the Harvard T.H. Chan School of Public Health, Harvard University, of which the author is affiliated as a Research Fellow.*

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

by

Cambridge Environmental Consulting

Executive Summary

We previously reviewed treatment technologies applicable to removal of PFCs at municipal drinking water supplies to remove PFOS, PFOA, and PFNA in our comments to NJDWQI proposed MCL for PFNA in 2015. This review updates our prior analysis of these technologies.

We found that reverse osmosis (RO) is needed to adequately remove all PFCs, including PFOA, PFNA, and PFOS, to proposed MCL standards. There are numerous installations across the U.S. where RO is economically applied to treat groundwater and, in some cases, surface water, as drinking water supplies. We believe that RO alone or RO after GAC (granular activated carbon) represents the best available treatment technology economically achievable to remove PFCs. Depending upon pilot studies and bench testing, nanofiltration (NF) may be a viable substitute for RO. RO preceded by conventional treatment (filtration) represents best technology at public water supplies using groundwater, and conventional treatment/coagulation-filtration followed by RO or a sequence of GAC followed by RO (or NF where applicable) represents best available technology for surface waters.

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 (Queensland, Australia; Los Angeles; Singapore; Windhoek). These advanced systems, however, are used at locations where water scarcity is the primary constraint.

PFC compounds have relatively high molecular weight, at least for 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. Analysis of the economic benefits of reduction in health costs versus the cost of treatment (benefit-cost analysis) would be useful to assess overall social benefit of treatment for PFC at locations containing these contaminants in their water supplies. Cost-effective analysis would help to determine the most suitable removal technology. However, economic considerations are beyond the scope of this review.

Granular Activated Carbon

Granular activated carbon (GAC) has been shown to be very effective to remove most PFCs. GAC systems typically employ pre-filtration via sand or mixed-media filtration.

Some studies indicate that powdered activated carbon (PAC) versus granular activated carbon provides better PFC removal. One study found that powdered activated carbon generally showed better adsorption than granulated activated carbon, sulfonates were more strongly adsorbed than carboxylic acids, and PFC adsorption increased with increasing PFC chain length (Hansen et al., 2010). 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 some municipal drinking water treatment systems in operation in the U.S. designed for removal of PFCs. In Oakdale, Minnesota a GAC system treats water for about 30,000 residents, meeting the current Minnesota drinking water standard for PFOA and PFOA of 300 ng/L (to be updated to the revised EPA standard of 70 ng/L). These limits are much higher than New Jersey's proposed limit of 14 ng/L. The quantitative analytical reporting limit for PFOA in Minnesota is 14 ng/L. Although Oakdale's GAC water is produced at levels below this limit it is unknown whether that GAC facility would meet a limit lower than 14 ng/L. The NJWQI report notes that PFNA is removed to less than detectable with a RL of 5 ng/L at the New Jersey American Water-Logan System, although no data is provided for PFOA.

The Minnesota Mining and Manufacturing (3M) Cottage Grove, Minnesota plant also uses a GAC system to remove PFCs from its wastewater discharge effluent to the Mississippi River. A 2006 study found a 79% reduction in PFOA and a 95% reduction in PFOS at the 3M GAC treatment system (Oliaei and Kriens 2006).

In summary, GAC 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 are removed at different rates.

Reverse Osmosis

Reverse osmosis and nanofiltration are 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 effective to 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. No significant removal of PFCs was observed using UV and UV peroxide in a study by Arvaniti et al., 2013. One study showed only relatively modest PFOS removals between 10-50%, dependent on the oxidative process used (Ribeiro 2015).

Resin Adsoprtion/Ion Echange

Zeolites are 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 et al., 2010). Ion exchange would not provide an equivalent level of PFC removal compared to GAC at equivalent cost.

Further Evaluation of RO versus GAC

Although both GAC and RO remove PFOA, PFOS, and other long chain PFCs to greater than 90%, RO has been shown in full scale and lab studies to remove PFOA to 99%. RO and NF also remove lower molecular weight short chained PFCs like PFBA and PFBS, found in water supplies. The recent Water Research Foundation (WRF) report of 2016 notes that "all PFASs were below the MRLs (maximum reporting limits) in the collected samples immediately following the RO systems, making this the most effective form of treatment evaluated in this study." The study included evaluation of GAC, anion exchange, oxidation, nanofiltration, and conventional water treatment methods (WRF 2016). The WRF study also notes that GAC and anion exchange "were less effective at removing shorter chain PFASs, whereas NF and RO were effective at removing even the smallest PFAS studied". RO and/or NF will assure removal of shorter chain PFBA and PFBS present.

Similar rejection of PFOS (>99%) was shown in a bench testing study of RO efficiency (Tang et al. 2006). WRF also notes in its 2016 report that nanofiltration membrane systems can be less costly and could prove to be just as capable of rejecting PFASs as RO in full-scale plants, as NF has been deemed potentially effective (> 95%) in bench-scale experiments using NF270 membranes (WRF 2016; Steinle-Darling and Reinhard 2008)."

Although GAC has been shown effective to remove PFOA, PFNA, and PFOS, often to > 90%, there are inconsistencies in GAC removal efficiency. In a study using GAC in Amsterdam, PFOA was not effectively removed, with a final mean GAC concentration of 5.3 ng/L (range 0.8 ng/L - 9.4 ng/L) versus a mean influent PFOA concentration of 4.4 ng/L (range 3.8 ng/L– 5.2 ng/L). In that study greater removal of PFOS and PFNA were achieved with a mean final water level of <0.23 ng/L and <0.24 ng/L, respectively, versus influent levels of 6.7 to 10 ng/L for PFOS and 0.5 to 0.8 ng/L for PFNA (Eschauzier et al., 2012). In a study of removal of PFOS and PFOA at a water treatment plant in Spain, treating about 100 million gallons per day of Llobregat surface river water to supply over 1 million inhabitants, RO removed PFOA to a mean of 2.1 ng/L in final water with influent raw water at a mean 6.9 ng/L. GAC removal resulted in a mean of 4.7 ng/L for PFOA in final water. This study found that PFOS was removed to a mean of 0.7 ng/L in final water, whereas GAC removed PFOS to a mean of 22 ng/L in final water, with raw water at 86 ng/L PFOS. Overall, this study found an efficiency of removal of 99% ± 1 for RO and 63% for GAC (Flores 2013).

In testing of 5 RO membranes and 3 NF membranes researchers found that rejection efficiencies (efficiency of removal) for RO membranes were >99% and for NF membranes

ranged from 90-99% (Tang et al., 2007).

PFC removal was studied at two water reclamation plants (treating domestic effluents as influent) in Southeast Queensland, Australia. One plant (plant A), treating about 2 million gallons per day, utilizes de-nitrification, ozonation, coagulation/flocculation, dissolved air flotation and sand filtration and biologically activated carbon filtration processes. The other plant (plant B), treating about 17 million gallons per day, utilizes coagulation/flocculation and sedimentation, ultra-filtration (UF), reverse osmosis (RO), advanced oxidation (peroxide with ultraviolet) and final stabilization and disinfection. In plant A using activated carbon PFCs were detected at all sampling points across the treatment train. In plant B using RO, PFCs were below reporting limits in samples taken from points after RO treatment (Thompson et al., 2010). Reporting limits (RL) ranged from 0.4 to 1.5 ng/L. At PFOA influent levels ranging from 15 to 27 ng/L, PFOA was removed to < RL to 1.4 ng/L in the RO effluent stage of plant B. PFOS was removed to <RL in the RO effluent stage with influent levels ranging from 23 to 39 ng/L. In this study activated carbon (biological) was ineffective to remove PFCs. However, this may have been due to the age of the carbon beds or short contact times.

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

We conclude that the best available technology economically achievable to remove PFOS, PFOA, and PFNA from dilute aqueous streams at public water supplies is reverse osmosis (RO). In some cases GAC may be sequenced ahead of RO, and NF may potentially offer a substitute for RO. GAC followed by RO may be economically applied at Point-of-Use (POU) systems treating well water at residences or, in some cases, at residences receiving municipal drinking water with PFC contaminants. POU systems, in particular those using both GAC and RO, have been successful in Minnesota to remove PFCs, and allow redundancy in assuring continuous removal. Use of RO or GAC/RO is advantageous since additional health benefits may be derived by removal of disinfection byproducts (DBPs) produced during chlorination/disinfection of water supplies. RO is necessary to remove the haloacetic fraction of DBPs in these water supplies.

Given the nature of PFOA to cause long lasting adverse impacts on humans and the uncertainty inherent in toxicological studies to determine a protective MCL, best available technology should be used to assure health protection, irrespective of whether an MCL is 1 ng/L, 6 ng/L, or 14 ng/L.

** The views expressed in this report do not necessarily reflect those of the Harvard T.H. Chan School of Public Health, Harvard University, of which one the author is affiliated as a Research Fellow.*

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November 19, 2016

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

Re: Health-Based Maximum Contaminant Level Support Document: Perfluorooctanoic Acid (PFOA)

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 regarding the Support Document and recommendation by the Drinking Water Quality Institute for a **Health-Based Maximum Contaminant Level for Perfluorooctanoic Acid (PFOA)**. Also attached are two PDFs 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 PFOA contamination and that New Jersey's drinking water be required to be treated to a safe level based on the best available scientific evidence.

We support all the recommendations and findings made by Dr. Oliaei and Cambridge Environmental Consulting in this technical analysis. We advocate that an appropriately protective MCL be recommended to and acted upon by the New Jersey Department of Environmental Protection and agree with Dr. Oliaei's finding that that the proposed drinking water MCL of 14 ng/L for PFOA based on increased relative liver weight is not adequately protective of all population segments. We support Dr. Oliaei's position that the standard may be developed based on an immunotoxic association in children or, alternatively, evidence of developmental effects shown in rodent studies. Both of these approaches provide more sensitive endpoints with quantitative data to develop an MCL, providing greater protection. We support Dr. Oliaei's analysis and final conclusion that the recommended MCL should be lowered to 1 ng/L, or alternatively, should be no higher than 6 ng/L.

Thank you for proposing a recommended MCL for PFOA, an action that is critically needed to remove this toxic compound from New Jersey's drinking water supplies.

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Sincerely,

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

Attached: Technical Analyses of New Jersey Drinking Water Quality Institute Proposed Health-Based Maximum Contaminant Level for Perfluorooctanoic Acid (PFOA) in Drinking Water, Fardin Z. Oliaei, Don Kriens, Cambridge Environmental Consulting, Nov. 18, 2016

Technical Analyses of New Jersey Drinking Water Quality Institute

Proposed Health-Based Maximum Contaminant Level (MCL) for Perfluorooctanoic Acid (PFOA) in Drinking Water

prepared by

Fardin Z. Oliaei MPA, Ph.D.
Don L. Kriens* Sc.D., P.E.

Cambridge Environmental Consulting

November 18, 2016

PREFACE

The opinions in this report are stated to a reasonable degree of scientific probability. The methods and principals 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.

** The views expressed in this report do not necessarily reflect those of the Harvard T.H. Chan School of Public Health, Harvard University, of which the author is affiliated as a Research Fellow.*

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

by

Cambridge Environmental Consulting

Executive Summary

We conclude that the proposed drinking water MCL of 14 ng/L for PFOA based on increased relative liver weight is not adequately protective of all population segments. The criterion may be developed on the basis of epidemiologic evidence of a significant immunotoxic association in children or, alternatively, evidence of significant adverse developmental effects shown in rodent studies. Both of these offer more sensitive endpoints with quantitative data to develop an MCL to assure greater health protection. We calculate an approximate MCL of 0.5 ng/L based on the BMDL determined and the association found between immune suppression and serum PFOA levels in children as reported by Grandjean and Budtz-Jørgensen, or an approximate MCL of 1.0 ng/L based on the BMDL determined in the delayed mammary gland developmental effects in mice studies. Alternatively, we calculate a MCL of 6 ng/L for children group ages 1-6 using the increased liver weight endpoint, with exposure values we determined for mean weight and 90th percentile water intake in that group. We propose that NJDWQI lower the proposed MCL to 1.0 ng/L, consistent with the values found pursuant to the immunotoxic epidemiologic study and/or animal studies showing adverse developmental effects. Excluding use of these values the MCL should be no greater than 6 ng/L to assure protection of children.

Introduction

This is a summary of our analysis and evaluation of the proposed health based maximum contaminant level (MCL) for PFOA 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: Perfluorooctanoic Acid (PFOA), dated June 27, 2016, hereinafter referred to as the NJDWQI Report.

The presence of PFOA in New Jersey water supplies is of great concern because high concentrations are found in groundwater and surface water within the Delaware River Watershed and other locations in New Jersey. According to NJDEP database as of January 2016, of 72 public water supplies (PWS) tested 47% or 66 PWS were found contaminated with PFOA at levels equal to or exceeding the reporting limit (5 ng/l). Thirty-two PWS or 45% had levels exceeding 10 ng/l, and 12 PWS or 17% had levels exceeding 40 ng/l (NJDWQI 2016). Water tested at these PWS includes both raw and finished water; negligible to no removal of PFOA is achieved in the conventional water treatment systems used at these PWS. The affected population was not listed although we would expect it to exceed 1 million. NJDEP has not

published studies of PFOA in private wells, however PFOA has been found at levels exceeding 40 ng/L (maximum >400 ng/L), in 59 private wells within 2 miles of a New Jersey industrial source (NJDWQI 2016 Report, DuPont, 2009).

Drinking water represents a significant portion of total human exposure to PFOA. The relative portion depends significantly upon the concentration of PFOA in drinking water. One study found that drinking water (at 9.66 ng/l) represented 24% of total exposure (Thompson et al 2011). Using NHANES 2003/2004 data, Lorber and Egeghy also determined a relative contribution of drinking water to total intake at 24%. They note that this rate is similar among adults and children (Lorber and Egeghy 2011). Others have found that drinking water represents a much higher portion of total exposure (Noorlander et al. 2011). A 20% contribution to total intake is used as a default value for relative source contribution (RSC) in this risk analyses.

PFOA exists predominantly in anionic form in drinking water sources. PFOA is non-volatile and therefore inhalation exposures to PFOA during showering and bathing and other domestic uses are negligible. PFOA does not cross the skin barrier and therefore PFOA is not absorbed into circulation via the skin, based on skin permeability of PFOA (Franko et al. 2012).

PFOA may escape water via aerosolization. In a laboratory study aerosols generated from deionized, fresh, and ocean waters spiked with PFO were found to have significantly higher concentrations of PFO than the parent water body, ≤ 80 times for ocean waters (McMurdo et al. 2008). Aerosols are produced by breaking waves on surface waters to generate air bubble beneath the surface which, when bursting at the surface, eject aerosol droplets into the atmosphere. This study also suggests that gas-phase evolution of PFOA from the aerosol-bound PFO into the atmosphere likely occurs due to the short aerosol-to-gas phase transfer half-life, about 7 seconds. Aerosol generation may also account for long-range air transport of PFOA, in addition to pathways of atmospheric transport of volatile precursors (8:2 FTOH) and transport of PFOA via the ocean.

Localized surface and groundwater PFOA contamination is primarily caused by wastewater discharges, air transport and deposition from PFOA emission sources, and groundwater plume migration. The extent of PFOA-laden aerosols via short-range air transport and potential direct exposure to humans is unknown but may help to explain, in part, PFOA concentrations in ground and surface waters in some locales proximate to factory sources, such as those found in Minnesota (Oliaei et al 2012).

We calculated that exposure to PFOA from drinking water source aerosols produced during typical showering conditions are likely to be negligible at a range of source water concentrations, based on equations we used in inhalation studies of aerosol particulates during showering (Cowen and Ollison, 2006; Zhou et al. 2010).

Calculation of MCL Using Quantitative Epidemiologic Data (Immunotoxicity)

The National Toxicology Program (NTP) supports a conclusion that PFOA alters human immune function (NTP 2016). A number of studies have shown PFOA immunotoxicity in that PFOA suppresses immune response. Four studies assessing associations with antibody concentrations following vaccination had prospective study designs that allowed temporality assessment. Among these, a prospective birth cohort study in Norway found strong evidence of decreased rubella-induced antibodies with increasing PFOA maternal serum concentrations in 99 pregnant women with a subsequent follow-up of 56 children at 3 years of age (Granum et al. 2013). Although no statistically significant associations were found with responses to vaccines for Influenza Type B or Influenza Type A H1N1, a large prospective cohort study of 411 adults in the mid-Ohio valley found decreasing antibody concentrations following Influenza A H3N2 vaccination (Looker et al., 2014). A large prospective cohort of 656 consecutive singleton births in the Faroe Islands with prospective follow-up of 587 cohort members at ages 5 and 7 years, found a strong association between serum PFC concentrations (PFOA and PFOS) and serum antibody concentrations against tetanus and diphtheria toxoids (Grandjean and Budtz-Jørgensen 2013).

The NJDWQI report acknowledged that "data from other human studies and toxicology studies provides support for biological plausibility of decreased immune system response to vaccines in humans" (NJDWQI Report 2016). The Report cites Fletcher et al. (2009), which "reported several statistically significant associations between several markers of immune function (decreased IgA; decreased IgE in females only; increased anti-nuclear antibody; decreased C-reactive protein) and serum PFOA levels in communities with drinking water exposure to PFOA in a C8 Science Panel status report" (NJDWQI 2016).

There is concordance with animal studies showing suppression of immune response. As noted in the NJDWQI report these include (in mice) decreased absolute and relative spleen and thymus weights, decreased thymocyte and splenocyte counts, decreased immunoglobulin response, and changes in total numbers and/or specific populations of lymphocytes in the spleen, thymus, peripheral blood, and bone marrow" (NJDWQI report).

NJDWQI notes that a "review of epidemiologic studies provides evidence of consistent findings among studies of decreased antibody concentrations following vaccination and PFOA. However, while there is epidemiologic evidence of temporality, evidence of an exposure-response is limited" (NJDWQI 2016). We disagree. We believe that where there is strong, significant epidemiologic evidence that includes quantitative data to enable derivation of a BMDL, such data should be taken into account in derivation of the MCL.

The Grandjean and Budtz-Jørgensen study represents the greatest sensitivity to PFOA thus studied, un-confounded by exposure to other chemical contaminants. In this study regression modeling of PFC concentrations (PFOA and PFOS) as independent variables along with potential confounders of sex, age, and booster type at age 5 and 7, with antibody concentrations as outcome, allowed determination of benchmark response (BMR) and benchmark dose (BMD).

The lower one-sided 95% CL (confidence limit) of the BMD, the BMDL (benchmark dose level), was determined in this study to be approximately 0.33 ng/ml for PFOA and 1.3 ng/ml for PFOS, based on the linear slope model of the regression. The study notes strong correlation between PFOS and PFOA, making mutual adjustment in the regression difficult. However, in spite of this the BMDL developed does provide a strong epidemiologic basis to develop a MCL.

Based on the immunotoxic effects shown in this study we propose that a 0.33 ng/ml BMDL for PFOA be used as a target human serum level. Assuming a serum:water ratio of 100:1 and an uncertainty factor (UF) of 10 to account for human variation in susceptibility, we calculate a MCL as follows:

$$MCL = \frac{0.33\ ng/ml}{UF\ 10 \times 100\ serum:water\ ratio} = \frac{330\ ng/L}{1000} = 0.33\ ng/L\ (rounded\ to\ 0.5\ ng/L)$$

Alternatively, the NJDWQI methodology uses a clearance factor of 0.00014 L/kg/day to apply to the Target Human Serum Level. Using that methodology, a BMDL of 0.3 ng/ml as the POD (point of departure) for RfD determination, and a UF of 10 for human variation in susceptibility to determine the Target Human Serum Level, the RfD is:

$$RfD = \frac{330\ ng/L}{UF\ 10} \times .00014\ L/kg/day = 0.0046\ ng/kg/day$$

Using NJDWQI default adult exposure values of 70 kg body weight, 2 L/day water intake, and a relative source contribution of 0.2 the MCL is:

$$MCL = \frac{0.0046\ ng/kg/day \times 70\ kg \times 0.2}{2\ L/day} = 0.032\ ng/L$$

Based on the above we propose that the MCL for PFOA be 0.5 ng/L.

Calculation of MCL based on Delayed Mammary Gland Development (Animal Studies)

Delayed mammary gland development in mice resulting from developmental exposures to PFOA is a sensitive endpoint. This toxicity effect has been shown in nine different studies (NJDWQI report 2016). Delayed mammary gland development is especially concerning since adverse effects including histological changes related to delayed mammary gland development persist into adulthood and become permanent. Several researchers indicate that delayed mammary gland growth may result in greater susceptibility to cancer later in life (Fenton 2006; Rudel et al., 2011; Fenton et al., 2012; Osborne et al. 2015). Others note that developmental exposures in sensitive time periods can result in increased risk of later disease or dysfunction (Heindel and Vandenberg, 2015). Mode of action is explained by Osborne: "Anything that changes the timing of mammary development will affect the timing of the presence of TEBs (terminal end buds), and therefore the window of susceptibility to

carcinogens. Late initiation of mammary development causes decreased longitudinal growth of the epithelium and fewer TEBs, and decreased alveolar budding at weaning. As development progresses, these glands may have more TEBs at puberty, because the pace of development is slower. It is hypothesized that factors that lengthen the period when TEBs are present lengthen the period during which the MG is susceptible to carcinogens" (Osborne et al., 2015).

NJDWQI acknowledged these studies, which may result in increased susceptibility to cancer later in life. The NJDWQI states that "The Health Effects Subcommittee chose not to use this (delayed mammary gland development) RfD as the basis for a recommended Health-based MCL, not because of uncertainty about the scientific validity of doing so, but rather because of lack of precedent for use of this endpoint as the primary basis for health-based criteria for environmental contaminants. Instead the Subcommittee arbitrarily applied an additional 10 UF to an unrelated endpoint (increased liver weight that forms the basis for their MCL derivation) to compensate for the more sensitive endpoint (delayed mammary gland development). This is confusing. Why not use the more sensitive endpoint for which adequate toxicity data already exists, including a BMDL, even if that endpoint has not previously been used, versus adding an additional uncertainty factor to an alternate endpoint to compensate for an uncertainty that is, in fact, known?

We propose that the MCL be determined using the sensitive endpoint BMDL for delayed mammary gland development, clearance factor, and default adult exposure values per NJDWQI analyses, as follows:

Summary of variables used and values

BMDL	POD of 22.9 ng/ml (22,900 ng/L)
total UF	30 (10 human variation, 3 animal-to-human extrapolation)
RSC	0.20
clearance factor	0.00014 L/Kg/day
default adult body weight	70 kg per NJDWQI report
default adult intake	2.0 L per NJDWQI report

$$\text{RfD} = \frac{22{,}900 \text{ ng/L} \times 0.00014 \text{ L/kg/day}}{30 \text{ UF}} = 0.107 \text{ ng/kg/day}$$

$$\text{MCL} = \frac{0.107 \text{ ng/kg/day} \times 70 \text{ kg} \times 0.2}{2 \text{ L/day}} = 0.75 \text{ ng/L (rounded to 1 ng/L)}$$

Based on the above we propose that the MCL for PFOA be 1 ng/L.

Children, PFOA Exposure, and Use of Adult Default Exposure Values

There is evidence that young children are exposed to greater levels of PFOA than adults. This

may occur because of age-specific behaviors such as hand-to-mouth behaviors resulting in greater ingestion of house particulates, and more time spent on floors with treated carpets. Using NHANES data, Lorber and Egeghy found that incidental ingestion of dust is far less important among adults than among children (Lorber and Egeghy 2011). Children's dust intakes are highly variable due to the distribution of dust PFOA concentrations in homes. The 95th percentile intake from dust ingestion is about three times the intake from food ingestion (Lorber and Egeghy 2011).

Peak serum PFOA concentrations occur during the first year of life, in part due to "off-loading" from the mother at birth. As noted in NJDWQI report, levels remain elevated for at least several additional years. Blood serum levels have been found to be higher in children. Higher serum levels were observed in children ages 2-5 versus older children and adults in Little Hocking, Ohio residents who have been exposed to PFOA in drinking water (Emmet et al 2006). Toxicity effects to children during this developmental period may persist into adulthood and become permanent.

Children therefore represent a special case. They have greater drinking water and food consumption on a body weight basis. Using adult default exposure values is inappropriate since a priori use of adult default values for body weight and water intake omits protection to children, the population's most vulnerable exposure group. Calculation of a MCL using adult default values results in a RfD to children (age group 1-6) that significantly exceeds that deemed allowable by NJDWQI based on the increased liver weight toxicity endpoint.

Although the MCL should be based on human immunotoxicity and/or the delayed mammary gland development shown in test animals, as calculated above, we believe that at a minimum MCL calculations using increased liver weight as an endpoint should be based on children exposure values for body weight and drinking water intakes. Using children group ages 1-6 we determined the MCL as follows:

Summary of variables used and values

BMDL	POD of 4351 ng/ml (4,351,000 ng/L)
CUF	300 (10 human variation, 3 animal-to-human extrapolation, 10 for delayed mammary gland development
RSC	0.20
Children body weight[a]	16.8 kg
Children intake[b]	0.69 L/day mean, 1.19 L/day 90th percentile

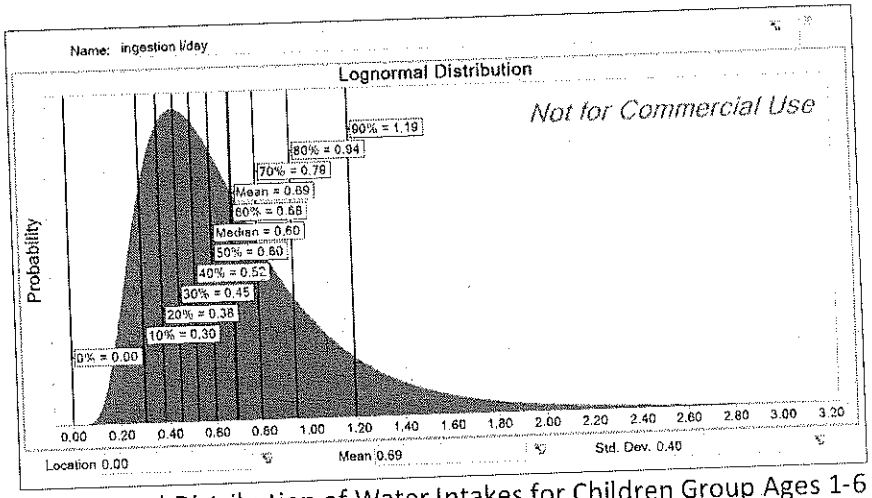
Children Group (age 1-6)

$$RfD = \frac{4{,}351{,}000\ ng/L \times 0.00014\ L/kg/day}{300\ UF} = 2.03\ ng/kg/day$$

$$MCL = \frac{2\ ng/kg/day \times 16.8\ kg \times 0.2}{1.19\ L/day} = 5.65\ ng/L \text{ (rounded to 6 ng/L)}$$

a. 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.)

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



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

Based on the above the MCL for PFOA should be 6 ng/L.

Conclusion

NJDWQI's Health Effects Subcommittee's work in developing a MCL for PFOA demonstrates a considerably sounder scientific basis than EPA's recent drinking water advisory for PFOA, where a 70 ng/L MCL is developed (USEPA 2016). However, NJDWQI's reliance upon Increased Relative Liver Weight in animal studies as an endpoint to develop a RfD disregards more sensitive toxicity endpoints. We believe that animal studies showing significant delayed mammary gland development are sufficient and appropriate to use in the MCL determination, irrespective of whether there is absence of precedence, where benchmark dose modeling allows calculation of an approximate MCL of 1 ng/L. Substantial epidemiological evidence showing a range of toxic effects should also be taken into account versus reliance solely upon animal studies. One such study, the Immunotoxicity study by Grandjean and Budtz-Jørgensen 2013 showing a significant association between PFOA and suppression of antibody responses in children, provides benchmark dose response data to calculate a MCL of ≤1 ng/L.

In addition, the proposed MCL of 14 ng/l calculated using adult default values for body weight results in a PFOA dose to children (ages 1-6) that is 50% higher at mean water intake levels, and 2½ times higher at 90th percentile water intake levels, than the reference dose (RfD) allowed to assure that serum levels remain below a protective maximum target level. Thus, the proposed

MCL of 14 ng/L using default adult exposure values is not protective of all age groups. This is concerning since, based on animal developmental studies that likely relate to humans, toxic effects from PFOA exposures in early childhood may persist into adulthood and could result in more profound disease in later life.

Absent lowering the proposed MCL to 1 ng/L, the MCL should be no higher than 6 ng/L.

** The views expressed in this report do not necessarily reflect those of the Harvard T.H. Chan School of Public Health, Harvard University, of which one of the authors is affiliated as a Research Fellow.*

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Loveren, I. S., Lovik, M., Nygaard , U. C. (2013). Pre-natal exposure to perfluoroalkyl substances may be associated with altered vaccine antibody levels and immune-related health outcomes in early childhood. J. Immunotoxicol. 10: 373-379.

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DELAWARE RIVERKEEPER NETWORK

January 31, 2018

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Trenton, New Jersey

Re: Health-Based Maximum Contaminant Level Support Document: Perfluorooctane Sulfonate (PFOS) 11 (CAS #: 1763-23-1; Chemical Formula: C8HF17O3S)

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 this organization and its membership regarding the Support Document and recommendation by the New Jersey Drinking Water Quality Institute (NJDWQI) for a **Health-Based Maximum Contaminant Level for Perfluorooctane Sulfonate (PFOS)**. Also attached are two PDFs 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 PFOS contamination and that New Jersey's drinking water be required to be treated to a safe level based on the best available scientific evidence.

We support all the recommendations and findings made by Dr. Oliaei and Don Kriens of Cambridge Environmental Consulting in this technical analysis. We advocate that an appropriately protective MCL be recommended to and acted upon by the New Jersey Department of Environmental Protection and agree with Cambridge Environmental Consulting's finding that that the NJDWQI's recommended drinking water MCL of 13 ng/L for PFOS is not adequately protective of all population segments. We support Cambridge Environmental Consulting's position that the standard should be calculated based on children's exposure values. We agree that it is of utmost importance to assure protection of children's health since the developing fetus, infants, and young children are particularly sensitive to PFOS exposure during early sensitive periods. As explained by Dr. Oliaei and Don Kriens, even at very low doses, early life exposure of children to PFOS may affect risk for disease later in life. **We support Cambridge Environmental Consulting's analysis and final conclusion that the recommended MCL should be lowered to 5 ng/L.**

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We also support Cambridge Environmental Consulting's conclusion that when found combined with PFOA in water, the combination of PFOS and PFOA concentrations in water supplies should be no higher than 13 ng/L.

Thank you for proposing a recommended MCL for PFOS, an action that is critically needed to remove this toxic compound from New Jersey's drinking water supplies.

Sincerely,

Maya K. van Rossum — Tracy Carluccio

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

Attached: **Technical Analysis of New Jersey's Proposed Health-Based Maximum Contaminant Level (MCL) for Perfluorooctane Sulfonate (PFOS)**, Fardin Oliaei, Ph.D. and Don L. Kriens, Sc.D., Cambridge Environmental Consulting, submitted January 2018.

Technical Analysis of New Jersey's Proposed Health-Based Maximum Contaminant Level (MCL) for Perfluorooctane Sulfonate (PFOS)

by

Fardin Oliaei, Ph.D. and Don L. Kriens, Sc.D.
Cambridge Environmental Consulting
submitted January 2018

Executive Summary

The RfD (reference dose) for PFOS (perfuorooctane sulfonate) derived by the NJDWQI (New Jersey Drinking Water Quality Institute) is the most stringent and protective in the U.S., based on a rigorous analysis of all available PFOS animal and epidemiologic toxicological studies. However, in its use of adult default exposure values to determine a maximum contaminant level (MCL), younger children would not be protected since younger children dose intakes would exceed the allowable RfD. This is disconcerting since existing PFOS serum levels in children in the normal population are already within or near the serum PFOS levels associated with immunotoxic effects found in epidemiologic studies. In addition, other toxic effects found associated with children and PFOS exposure may lead to increased potential for later disease manifestation. It is essential, therefore, that the NJDWQI depart from the typical use of adult default exposure values and use children's values. Using appropriate children exposure values, we recommend a ***MCL for PFOS of 5 ng/L***.

Alternatively, we recommend a MCL such that the combination of PFOS and PFOA concentrations in water supplies be no higher than 13 ng/L, ***MCL [PFOA + PFOS] ≤ 13 ng/l***.

Introduction

The presence of PFOS and PFOA (perfluoro-octanoic acid) in New Jersey is of public health concern because relatively high concentrations have been found in public water supplies (PWS), in some instances at levels greater than the existing 14 ng/l MCL for PFOA and the proposed 13 ng/l MCL for PFOS. Ten of 80 PWS tested by the New Jersey DEP (Department of Environmental Protection) had PFOS at levels ≥ 20 ng/l with 7 PWS containing PFOS at levels exceeding 40 ng/l (NJDEP 2017). Testing of 175 New Jersey PWS, including 165 large community systems and 10 small community systems completed under the UCMR3, found 6 PWS with PFOS levels exceeding 40 ng/L and 18 PWS with PFOA levels exceeding 20 ng/L (UCMR3 2017, NJDWQI 2017). Ingestion of any level of PFOS and PFOA contaminated water could further increase residents' PFOS blood serum levels beyond that already found in epidemiologic studies to be associated with adverse health effects (immunotoxicity) in the general U.S. population.

A large number of animal studies indicate a wide range of PFOS toxicity effects. These include decreased body weight, increased liver weight with microscopic lesions in monkeys and rats, increased incidence of hepatocellular adenomas in rats, developmental effects on rats and mice including neonatal mortality, decreased gestation length, lower birth weights, and developmental delays. For post-gestation and lactational exposure these include: developmental neurotoxicity, changes in thyroid and reproductive hormones, altered lipid and glucose metabolism, and decreased immune function (USEPA 2016b).

Among non-cancer endpoints the NJDWQI concludes that, for adult animals, the most sensitive endpoints (lowest LOAELs based on serum PFOS concentrations) are described in 9 studies and include: "endocrine/metabolic effects (e.g., decreases in thyroid hormone and increased incidence of thyroid follicular cell adenomas), changes in immune parameters (e.g., increased relative number of macrophages and decreased plaque forming cell response), and increased liver weight and liver histopathology" (NJDWQI 2017). For post-natal or gestational exposures, NJDWQI concludes the most sensitive non-cancer endpoints (lowest LOAELs based on serum PFOS concentrations) are described in 11 studies and include: "decreased body weight, changes in endocrine/metabolic parameters (i.e., fasting levels of serum glucose and insulin, markers of insulin resistance, and thyroid hormone levels), increased liver weight, changes in lung morphology, and increased mortality" (NJDWQI 2017).

NJDWQI examined these 20 toxic endpoints in terms of the timing of biological significance and suitability for dose-response analysis, and determined 4 endpoints suitable to calculate a (POD) point of departure. The immunotoxic effect shown in the Dong et al. (2009) study was chosen as the most sensitive POD (point of departure) at 674 ng/ml.

The immunotoxic endpoint chosen to develop an MCL based on decreased plaque forming cell response, a predictor of immunosuppression, in animal studies is supported by epidemiologic studies that found associations between PFOS and PFOA blood serum levels in humans and decreases in immune function.

A study by Grandjean and Budtz-Jørgensen (2013) found an association between increases in serum PFOS and PFOA levels and decreases in serum antibody concentrations against tetanus and diphtheria toxoids. In this study regression modeling of PFOA and PFOS concentrations as independent variables along with potential confounders of sex, age, and booster type at age 5 and 7, with antibody concentrations as outcome, allowed determination of benchmark response (BMR) and benchmark dose (BMD). The lower one-sided 95% confidence limit of the BMD, the BMDL (benchmark dose level), was determined in this study to be approximately 0.33 ng/ml for PFOA and 1.3 ng/ml for PFOS, based on the linear slope model of the regression. The study notes strong correlation between PFOS and PFOA, making mutual adjustment in the regression difficult. However, the BMDL developed provides a strong epidemiologic basis using an immunosuppression endpoint to develop a MCL.

A study in Norway evaluated the effect of prenatal exposure to PFAS (perfluoroalkyl substances) on responses to pediatric vaccines and immune-related health outcomes in

children up to 3 years of age (Granum et al. 2013). In this study blood samples were taken from the mothers at time of delivery and children at 3 years age. The study found an inverse association between the level of anti-rubella antibodies in the children's serum at age 3 years and the concentrations of four PFAS compounds (PFOS, PFOA, PFNA, and PFHxS). The strength of the association between rubella antibody-levels and PFAS concentrations were PFNA>PFOA>PFH_xS>PFOS.

A cross-sectional study of 1191 children 12-19 years old using NHANES data (1999-2000 and 2003-2004) found that increased exposure to several PFAS compounds was associated with lower levels of mumps and rubella antibody concentrations, especially among seropositive individuals (Stein et al. 2016). This study found that a doubling of PFOS serum concentration was associated with a 7.4% (95% CI: -12.8, -1.7) decrease in mumps antibodies. A doubling of PFOS serum concentration was also associated with a 13.3% decrease in rubella antibodies; this association occurred among seropositive individuals. Decreases in rubella antibodies were also found to be associated with PFOA and PFH_xS. The authors found that children with higher PFOS levels were less likely to be sensitized to allergens, but children with higher PFOS levels were more likely to be sensitized to mold (IQR OR 1.33, 95% CI: 1.06, 1.69).

A small study in Denmark evaluated reduced antibody responses to perfluorochemical exposures (Kielsen et al. 20016). Twelve adults were boosted with tetanus and diphtheria toxoids with antibody responses and followed in a subsequent one-month period. Participants had been vaccinated with diphtheria and tetanus toxoids in childhood, but no boosters had been received within the last 5 years. The study found that at a doubling of PFOS exposure, based on serum obtained from participants 10 days post-vaccination, the relative increase in the diphtheria antibody concentration decreased by an average of about 12%, $p = 0.044$. Significant diptheria antibody concentration reductions were also found for PFNA, PFDA, PFU_nDA, and PFD_oDA.

A study of 411 adults in the mid Ohio region of Ohio and West Virginia, where the drinking water supply had been contaminated with PFOA (Dupont plant), evaluated antibody response and PFOS and PFOA levels in blood serum following vaccination with influenza vaccine. The study found that elevated PFOA serum concentrations were "associated with reduced antibody titer rise, particularly to A/H3N2 influenza virus, and an increased risk of not attaining the antibody threshold considered to offer long-term protection" (Looker et al. 2014). However, in this study no association was found between PFOS serum levels and reductions in antibody rise.

The National Toxicology Program concluded that "exposure to PFOS is ***presumed to be an immune hazard to humans*** based on a high level of evidence that PFOS suppressed the antibody response from animal studies and a moderate level of evidence from studies in humans". NTP also concludes that "PFOS is suspected to suppress infectious disease resistance and NK cell activity in humans, and these conclusions are based on moderate level of evidence from animal studies and low or inadequate level of evidence from human studies" (NTP 2016).

Reference Dose and Uncertainty Factors - Immunotoxicity Endpoint

Human epidemiologic data have current limitations and are not used as a quantitative basis for a health-based RfD and MCL. However, a RfD based on quantitative epidemiologic data for an immunotoxic effect should be taken into account. In our review of the New Jersey 2016 proposed standard for PFOA we derived a MCL based on the Grandjean and Budtz-Jørgensen (2013) study where benchmark calculations based on regression modeling enabled a determination of a BMDL. Based on that study's BMDL we calculated a 0.03 MCL for PFOA (Oliaei and Kriens 2016). Using the same methodology, we derive a MCL for PFOS as follows:

The lower one-sided 95% confidence limit of the BMD, the BMDL (benchmark dose level) determined in the Grandjean and Budtz-Jørgensen (2013) study, is approximately 1.3 ng/ml for PFOS, based on the linear slope model of the regression. Based on the immunotoxic effects shown in this study we propose a 1.3 ng/ml BMDL for PFOS as the target human serum level. An uncertainty factor of 10 for human variation in susceptibility is applied. A clearance factor of 8.1×10^{-5} L/kg/day derived by USEPA for PFOS (USEPA 2016b) is applied to the target human serum Level to calculate an RfD.

$$\text{RfD} = \frac{1.3 \text{ ng/ml} \times 1000 \text{ ml/L}}{\text{UF } 10} \times 8.1 \times 10^{-5} \text{ L/kg/day} = 0.01 \text{ ng/kg/day}$$

Using NJDWQI default adult exposure values of 70 kg body weight, 2 L/day water intake, and a relative source contribution of 0.2, the MCL is:

$$\text{MCL} = \frac{0.01 \text{ ng/kg/day} \times 70 \text{ kg}}{2 \text{ L/day}} \times 0.2 \text{ RSC} = 0.07 \text{ ng/L (round to 0.1 ng/L)}$$

Absent application of epidemiologic data, NJWQI's rigorous methodology and criteria used to select a BMDL, or NOAEL if applicable, is scientifically sound and conservative. Of the 4 final studies chosen by NJWQI for dose-response modeling, the Dong et al 2009 study of decreased plaque forming cell response, predictive of immunotoxicity, resulted in the lowest (most sensitive) point of departure (POD). As discussed in the report, the NOAEL of the study was used as the POD, or 674 ng/L, since BMDS software modeling would not calculate a BMDL for this study's dose-response data (NJDWQI 2017). After application of uncertainty factors the target human serum level calculated was the lowest among the 4 final studies, and resulted in the lowest RfD of 1.8 ng/kg/day.

This RfD is considerably more protective than the USEPA RfD of 20 ng/kg/day based on animal developmental effects (e.g. decreased pup body weight) (USEPA 2016b). However, because of potential increased susceptibility during pregnancy and lactation EPA used drinking water intake and body weight exposure values at the 90% distribution for lactating women, moderating the calculation (versus use of adult default weight and intake) to 70 ng/l for a lifetime health advisory (HA) or "MCL" for this target population.

Although the RfD determined by NJDWQI is a significant departure from the much less

protective RfD of 20 ng/kg/day developed by USEPA, we disagree with the UF (uncertainty factor) used to determine the target human serum level. NJDWQI applied a UF of unity (1.0) for sub-chronic versus chronic testing used in Dong et al (2009) even though this study of 60 days is of sub-chronic duration. Sub-chronic duration is > 30 day to ≤ 90 days. A UF of 10 is normally applied when sub-chronic is used instead of chronic testing to estimate a NOAEL.

NJDWQI asserts that an uncertainty factor to extrapolate sub-chronic to chronic is not needed because the immunotoxicity studies of sub-chronic duration did not show a greater effect (response) at longer duration (but within the sub-chronic duration period) among the three studies reviewed. NJDWQI notes that for the same PFOS serum concentration of 1×10^5 ng/ml, plaque forming cell response decreased by the same 60% in two studies despite the difference in duration between these two studies, Zheng et al (2009) at 7 days duration and Dong et al (2009) at 60 days duration. NJDWQI asserts, therefore, that the decrease in plaque forming cell response does not progress at longer exposure duration. Although suggestive of a lack of progression over time, these tests are of very short duration (7-60 days) and would not fully explain whether this premise holds true at longer chronic durations of 6 months or more. Further, the mechanistic basis for the immunotoxic effect of PFOS is unknown, and whether further long-term exposures accelerate this effect.

Omission of a UF for sub-chronic-to-chronic in risk assessment should not be done on the basis of results taken solely from short term studies, especially without an understanding of the mechanism of toxicity. A UF should be applied. In lieu of some (limited) evidence of no increase in effect in dose-response between the 7-day and 60-day short-term sub-chronic studies applying a UF of 3 versus 10 is reasonable.

As indicated by NJDWQI, "serum PFOS levels in the general U.S. population are currently near or within the range of central tendency serum PFOS levels in the studies that found associations with decreased immune response (NJDWQI 2017). Median and 95% serum PFOS concentrations are 5.2 ng/ml and 19 ng/ml, respectively, in the general U.S. population (CDC-NHANES 2017). Decreases in vaccine response were found at serum levels 6 – 27 ng/ml (Grandjean et al. 2012; Granum et al. 2013; Kielsen et al. 2016; Stein et al., 2016), within the range of serum levels in the general population. Therefore, contribution of any additional PFOS from exposure to contaminated drinking water, irrespective of the MCL level chosen, may be inadequate to assure protection for these toxicity effects (immunotoxicity), especially in sensitive individuals and vulnerable segments like infants and children. This uncertainty is broadly reflected in applying UFs to calculate MCLs.

Derivation of RfD and MCL – Adding an Uncertainty Factor to Adjust Sub-chronic to Chronic

A UF of 3 should be applied to extrapolate from sub-chronic to chronic testing in the Dong et al. (2009) study, to calculate a RfD and MCL, as follows:

A UF_{human} of 10 was used to account for increased sensitivity in sensitive sub-populations versus the average human population, and for general physiological and metabolic variation within the human population. A UF of 3 was used to account for interspecies (rodent to human) toxicodynamic differences. No UF is needed for toxicokinetic differences since the POD (point of departure), in this case the NOAEL, is based on blood serum PFOS levels. A UF of 3 is applied to estimate the NOAEL for chronic testing from sub-chronic testing used. Since individual UFs are as log-units the product of 3 x 3 is taken as 10. Therefore, the total UF applied is 100.

$$\text{Target Human Serum Level} = \text{POD (NOAEL)} \ \frac{674 \text{ ng/ml}}{\text{UF } 100} = 6.74 \text{ ng/ml}$$

The RfD (reference dose) is calculated as: target human serum level x clearance factor, where the clearance factor is the constant 1.8×10^{-5} derived by USEPA (EPA 2016b).

Reference dose (RfD) = 6.74 ng/ml x 1000ml/L x .000081 L/kg/day = ***0.55 ng/kg/day***

Summary of variables

NOAEL (POD)	674 ng/ml
total UF	100 (10 UF_{human}, $3UF_{subcronic\text{-}chronic}$, $3UF_{interspecises\ toxicodynamic}$)
Target human serum level	6.74 ng/ml
RSC	0.20
clearance factor	0.000081 L/Kg/day
default adult body weight	70 kg per NJDWQI
default adult water intake	2.0 L/day per NJDWQI

To compare with NJDWQI in its derivation, the MCL is calculated using adult default exposure values of weight and intake:

$$\text{MCL} = \frac{0.55 \text{ ng/kg/day} \times 70 \text{ kg} \times 0.2}{2 \text{ L/day}} = \textbf{\textit{3.85 ng/L (rounded to 4 ng/L)}}$$

Adjusting the total UF to 100, the MCL calculated using NJDWQI variables should be 4 ng/L.

Children Exposure and Risk

There is evidence that young children are exposed to differential intakes of PFOS and PFOA because of age-specific behaviors, such as hand-to-mouth behavior, resulting in greater ingestion of house dust and dust on surfaces/products containing perfluorochemicals such as upholstered furniture, clothing, bedding, automobile fabrics, and carpets. These exposures are

generally in addition to normal PFOS exposures from food and water, packaging, and a range of consumer products.

Using NHANES data, Lorber and Egeghy found that incidental ingestion of dust is far less important among adults than children (Lorber and Egeghy 2011). Children dust intakes are highly variable due to the distribution of dust PFOA concentrations in homes; the 95th percentile intake from dust ingestion is about three times the intake from food ingestion (Lorber and Egeghy 2011). In another study by Egeghy and Lorber, the authors estimated that under typical exposure conditions, where exposure media concentrations are representative of background conditions, the median PFOS intake (sum of the median route-specific intakes) for 2-year-old children under typical exposure conditions was 50 ng/day (Egeghy and Lorber 2011). In the typical scenario for 2-year olds the contribution from ingested dust and ingested water were found to be nearly the same at 36% and 42%, respectively. Alternatively, for adults the contributions to PFOS daily intakes were much different, 6% for dust ingestion and 72% for food.

Under a typical scenario Egeghy and Lorber estimated a median total PFOS intake at 160 ng/day for adults. Under a contaminated environment scenario (contaminated water supply) they estimate median total PFOS intakes of 640 ng/day in 2-year olds and 2200 ng/day in adults. In either the typical scenario or a contaminated water scenario the authors estimated that the contribution of water to total PFOS intake is about the same in adults as in 2-year olds, about 20%. Using the authors median PFOS intake data and median weight for 2-year olds of about 13 kg (Table 8-12, Exposure Factors Handbook 2011), we calculate the median PFOS daily dose to 2-year olds at 3.85 ng/kg/day, and the median daily PFOS dose to adults (using a default 70 kg adult weight) at 2.29 ng/kg/day under the typical scenario. The 2-year old children PFOS daily exposure dose is therefore about 70% higher than adults. ***Both adults and children (2-year olds) median daily dose under the typical exposure scenario would exceed the allowable reference dose (RfD) of 1.8 ng/kg/day proposed by NJDWQI for PFOS, double the proposed RfD in 2-year olds.***

In addition to greater environmental exposures than adults, children are burdened with PFOS at birth. "Evidence shows that PFOS is distributed within the body and can be transferred from pregnant women to their unborn children and offspring" (USEPA 2016b). PFOS has been quantified in umbilical cord blood, suggesting maternal transfer (Apelberg et al. 2007; Cariou et al. 2015; Tao et al. 2008; Völkel et al. 2008; Von Ehrenstein et al. 2009; USEPA 2016b). One study found PFOS at a mean of 1.28 ng/ml in 99 of 100 samples of cord blood (Cariou et al. 2015).

PFOS is also transferred to children via breast milk. Cariou et al. 2015 found PFOS in 82% of breast milk samples at a mean concentration of 0.04 ng/ml. In a study of 70 human breast milk samples in patients from Germany and Hungary PFOS concentrations ranged from 0.028 to .309 ng/ml (Völkel et al. 2008; USEPA 2016b). PFOS transfer to infants during breast feeding lowers the mother's PFOS blood serum levels. In a study by Mondal et al. (2014) of 633 women and 49 infants each month of breast feeding was found to lower maternal serum PFOS levels by 3%

and increase infant serum levels by 4%. Using the Cariou et al. (2015) mean breast milk PFOS concentration of 0.04 ng/ml and an upper percentile daily milk intake of 951 ml/day (table 15-3, USEPA 2008), we calculated daily PFOS intake from breast milk to breast fed infants 0 < 1 years at about 38 ng/day. Based on a 90th percentile body weight of 10.8 kg for infants 6 < 12 months age (table 8-3 USEPA 2008), ***the daily dose intake for this infant group of 0 < 1 years from breast milk is estimated at 3.5 ng/kg/day***.

In summary, age-specific behaviors (e.g. hand-to-mouth) and exposures from placental transfer and breastfeeding, in addition to normal exposures from ingested water and food, increase the PFOS body burdens in young children.

Children Toxicity Studies

Epidemiologic studies have shown many associations between PFOS and PFOA exposure and health effects in children. A systematic review by Rappazzo et al. (2017) summarized the epidemiologic evidence (literature) for relationship between prenatal/childhood perfluorochemical exposure and health outcomes in children. They conclude: "there is evidence for positive associations between PFAS (perfluoroalkyl substances) and dyslipidemia, immunity (including vaccine response and asthma), renal function, and age at menarche", as described below (Rappazzo et al. 2017).

A study by Geiger et al. (2014) in adolescents from NHANES data, found increases in PFOA, PFOS, or total PFAS serum concentrations positively associated with high total cholesterol (>170 mg/dL) and high LDL-C. Results in a study of 12,476 children and adolescents found that PFOA was significantly associated with increased total cholesterol and LDL-C, and PFOS was significantly associated with increased total cholesterol, HDL-C, and LDL-C (Frisbee et al. 2010). Several other studies support dyslipidemia effects from exposure to PFCs in children (Rappazzo et al. 2017).

Delayed onset of puberty has been associated with altered risk of adult disease: diabetes mellitus, heart disease, bone disease, substance abuse, and asthma" (Rappazzo et al 2017). A C8 cross-sectional analysis of 3076 boys and 2931 girls found later age of puberty in both boys and girls associated with serum PFOS and PFOA levels (Lopez-Espinosa et al. 2011). For boys in that study "there was a relationship of reduced odds of reached puberty (raised testosterone) with increasing PFOS (delay of 190 days between the highest and lowest quartile)". In girls, "higher concentrations of PFOA or PFOS were associated with reduced odds of postmenarche (130 and 138 days of delay, respectively)". Delayed onset of puberty associated with PFOS and PFOA levels in epidemiologic studies is supported by animal studies. For example, PFOA was found to cause delayed mammary gland development in female mice offspring (White et al. 2011).

A limited number of studies have shown associations between renal function and serum PFC levels. Decrements in estimated glomerular filtration rate (eGFR) were found to be associated with increases in PFOA and PFOS concentrations in a large community study of 9660 children

age 1<18 years (Watkins et al. 2013). The study population was children and adolescents highly exposed to PFOA from contaminated water supplies, but exposed to levels typical of PFOS, PFNA, and PFHxS in the normal population. Another cross-sectional analyses of NHANES 2003-2010 data of 1960 adolescents aged 12-19 years found PFOS and PFOA associated with a reduction in kidney function and increased uric acid levels (Kataria et al. 2015). The authors found that adolescents in the highest PFOA and PFOS quartile had a lower eGFR (estimated glomerular filtration), 6.84 mL/min/1.73 m^2 (95 % CI: 2.19 to 11.48) and 9.69 mL/min/1.73 m^2 (95 % CI: -4.59 to 14.78), respectively, compared to the lowest quartile. However, the authors note that reverse causality and residual confounding could explain their findings.

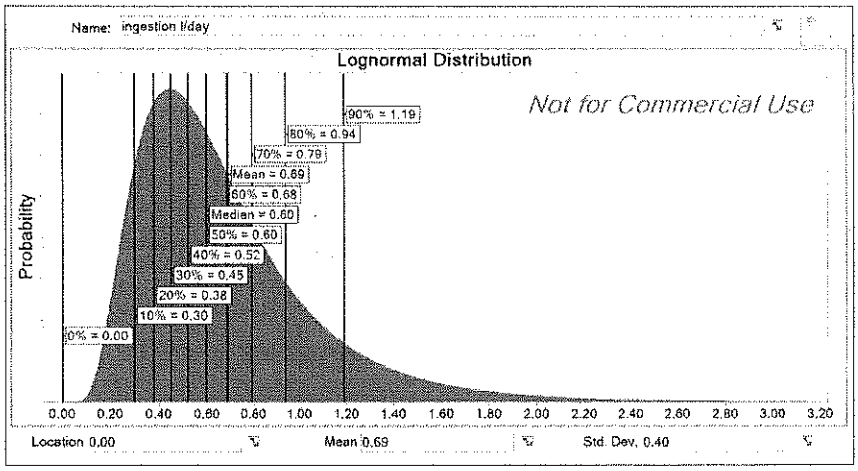
As described in the Introduction, three epidemiologic studies found suppression of vaccine-mediated antibody response to be associated with PFOS and PFOA exposure in children. The study by Grandjean and Budtz-Jørgensen (2013) found an association between increases in serum PFOS and PFOA levels and decreases in serum antibody concentrations against tetanus and diphtheria toxoids in young children (follow-up of a Faroese birth cohort). A study in Norway of 99 participants found an inverse association between the level of anti-rubella antibodies in children's serum at age 3 years and the concentrations of PFOS, PFOA, PFNA, and PFHxS (Granum et al. 2013). A recent large cross-sectional study by Stein et al (2016) of 1191 children 12-19 years old using NHANES data (1999-2000 and 2003-2004) found that a doubling of PFOS serum concentration was associated with a 7.4% (95% CI: -12.8, -1.7) decrease in mumps antibodies. A doubling of PFOS serum concentration was also associated with a 13.3% decrease in rubella antibodies; this association occurred among seropositive individuals (Stein et al. 2016).

PFOS serum levels in children associated with these immunosuppressive effects, found in these studies, are within or close to the PFOS serum levels found in the normal population.

Calculation of MCL Based on Children-Specific Exposure Variables

Some of the PFOS toxic endpoints to children have lasting effects and may subject children to later disease development. Deriving a MCL based on adult weights and water intakes results in a RfD imposed on children in excess of the maximum allowable 1.8 ng/kg/day. The uncertainty factor for sensitivity in the human population applied in the derivation accounts only for human variability in sensitivity to effect. To assure protection of children it is important that children-specific weight and water intake exposure values be used in the MCL calculation.

Body weight and water intakes of children ages 1-6 are used herein to determine a MCL. We use a mean body weight for this group of 16.8 kg and water intakes of 0.69 L/day mean, 1.19 L/day 90^{th} percentile. Mean weight for the group 1-6 were determined using EPA 2011 Exposure Factor Handbook data for these ages, 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. We determined a 1.19 L/day composite water intake rate for children 1-6 at the 90^{th} percentile, based on the lognormal distribution of water intakes for this combined age group, shown in the graph below.



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

To compare the difference in MCLs derived by NJDWQI with that derived herein using children weight and water intakes, we use the same RfD of 1.8 ng/kg/day derived by NJDWQI (which excludes applying the uncertainty factor of 3 we used to estimate NOAEL chronic from sub-chronic testing).

Summary of variables used and values

RfD	1.8 ng/kg/day
RSC	0.20
children body weight	16.8 kg
children intake	1.19 L/day 90th percentile

Children Group (age 1-6)

$$MCL = \frac{1.8\ ng/kg/day \times 16.8\ kg}{1.19\ L/day} \times 0.2\ RSC = \mathbf{5.08\ ng/L\ (round\ to\ 5\ ng/L)}$$

(Using a mean water intake of 0.69 L/day results in a MCL of 8.8 ng/L)

The MCL for PFOS should be 5 ng/l.

If a UF of 3 to estimate chronic NOAEL from sub-chronic is included the MCL becomes:

$$MCL = \frac{0.55\ ng/kg/day \times 16.8\ kg}{1.19\ L/day} \times 0.2\ RSC = 1.55\ ng/L\ (round\ to\ 2\ ng/L)$$

Other states have recognized children and infants as a more vulnerable population segment. Vermont used a 95th percentile body weight-adjusted water intake rate of 0.175 L/kg/day for the first year of life in its MCL calculation to determine a MCL of 20 ng/l. The MCL is applied as a

sum combination, [PFOS + PFOA] ≤ 20 ng/l (Vermont 2016). In 2017 the Minnesota Department of Health (MDH) updated its earlier Health Risk Limit (HRL) for PFOS in drinking water. MDH used the USEPA RfD of 20 ng/kg/day based on animal developmental effects but incorporated a database uncertainty factor of 3 in recognition of immunotoxicity shown in animal studies. This resulted in a RfD of 5.1 ng/kg/day. MDH modeled two scenarios and found a breast-fed infant exposure scenario as most limiting, and determined a PFOS limit of 27 ng/L (MDH 2017).

Conclusion

NJDWQI's evaluation of animal and epidemiologic PFOS toxicity studies was comprehensive and rigorous. The New Jersey Department of Environmental Protection has been progressive in efforts to protect public health from PFOS, PFOA, and other perfluorochemical exposures. We concur with the process used to derive a PFOS reference dose, concluding with the Dong et al (2009) study showing an immunotoxic effect in test animals.

However, all population segments must be protected. Our analysis finds that at the proposed 13 ng/l MCL, PFOS daily intakes by body weight posed to young children 1-6 would be more than double the PFOS dose of 1.8 ng/kg/day deemed allowable by NJDWQI. This is disconcerting since existing serum PFOS levels in children in the population are already within or near serum PFOS levels associated with immunotoxic effects found in epidemiologic studies. The developing fetus, infants, and young children are particularly sensitive to PFOS and PFOA exposures during early sensitive periods. Early PFOS exposures in children, even at low doses of 1.8 ng/kg/day, may affect risk for later disease manifestation. To assure protection of children's health NJDWQI should depart from using adult default exposure values and use children-specific exposure values in its MCL derivation, as described in this review.

We recommend an MCL of 5 ng/L, as calculated above based on children exposure values.

Alternatively, due to PFOS and PFOA co-occurrence in water supplies and additivity concerns, we recommend that the combination of PFOS and PFOA concentrations in water supplies be no higher than 13 ng/L. ***[PFOA + PFOS] ≤ 13 ng/L***

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exposure. In addition, perfluorinated compounds do not cross the dermal barrier. However, further testing is needed to assure that POU GAC/RO systems remove PFOS, PFOA, and PFNA to low ppt levels. Use of POU GAC/RO systems is somewhat complicated by the requirement of homeowner management of carbon change-out and proper operation.

Conclusion

The proposed New Jersey MCL of 13 ng/L, our recommended MCL in this review of 5 ng/L, the Minnesota limit (HRL) of 27 ng/L, and the Vermont drinking water advisory of 20 ng/L (combined) for PFOS are within the same very small "ballpark". Changing an uncertainty factor or exposure value used in these derivations obscures the difference in values. Accordingly, further emphasis should be placed on treatment and removal.

In addition to shorter chain perfluorinated compounds such as PFBS and PFBA, PFOA usually co-exists with PFOS in water supplies. Although the shorter chain perfluorinated compounds (e.g. PFBA, PFBS) are less toxic and excreted faster than longer chain perfluorinated compounds (e.g. PFOS, PFOA), they remain persistent, as demonstrated in the Oakdale, MN drinking water supply. The toxicity of shorter chain perfluorinated compounds is not fully understood, although toxicity of PFBA has been shown in animal testing and, in the case of Minnesota, a health risk limit (limitation) has been derived. There are differential removal efficiencies among perfluorinated compounds in GAC systems. PFOA is often poorly removed by GAC alone, as described in the full-scale GAC operating systems and research discussed above. Short chain perfluorinated carboxylic acids (e.g. PFBA) generally remain unchanged (not removed) through GAC systems.

The treatment system chosen for removal of perfluorinated compounds must be capable of removing both PFOA and PFOS, as well as providing best treatment technology available to remove other perfluorinated compounds, such as PFBA, that pose some toxicity. Removal of shorter chain perfluorinated compounds requires reverse osmosis in addition to GAC. Granular activated carbon (GAC) followed by reverse osmosis, or nanofiltration if pilot-scale studies demonstrate efficiency, is needed as a combined option to adequately remove both PFOS and PFOA, as well as other perfluorinated compounds that may be present.

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DELAWARE RIVERKEEPER NETWORK

January 31, 2018

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

Re: Comment on the DWQI Draft Second Addendum to Appendix C: Recommendation on Perfluorinated Compound Treatment Options for Drinking Water (PFOS), November 2017

Please find enclosed a technical analysis prepared by Don Kriens, Sc.D., P.E. of Cambridge Environmental Consulting commissioned by Delaware Riverkeeper Network and submitted on behalf of this organization and its membership on the Drinking Water Quality Institute's document **Draft Second Addendum to Appendix C: Recommendation on Perfluorinated Compound Treatment Options for Drinking Water (PFOS), November 2017.**

Also enclosed is a copy of the Curriculum Vitae for Don Kriens, Sc.D., P.E.

Delaware Riverkeeper Network submits these comments advocating that the public be protected from PFOS 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 the most effective treatment technologies.

We support the recommendations and findings made by Don Kriens of Cambridge Environmental Consulting in this technical analysis regarding the Draft Second Addendum to the Treatment Options Report by the DWQI. We support the utilization of the most effective methods of removing perfluorinated compounds (PFCs), including PFOS, considering the highly toxic properties of these compounds.

Cambridge Environmental Consulting **recommends granular activated carbon (GAC) combined with reverse osmosis technology (RO)** to completely remove all PFCs from drinking water to the proposed safe drinking water standards. Dr. Oliaei and Don Kriens recommend further research on nanofiltration, which may demonstrate adequacy to remove PFOA, PFOS and lower carbon number PFCs as a substitute for RO. Delaware Riverkeeper Network supports these findings and advocates for the use of the best available technology that will be capable of removing both PFOS and PFOA as well as other PFCs such as shorter chain PFCs with a goal of providing safe drinking water to the public.

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Thank you for the opportunity to comment on the Treatment Options to remove PFCs, including PFOS.

Sincerely,

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

Attachments: **Review of New Jersey Draft Second Addendum to Appendix C: Recommendation on Perfluorinated Compound Treatment Options**, Don L. Kriens Sc.D., P.E., Cambridge Environmental Consulting, January 2018.

Review of New Jersey
Second Addendum to Appendix C: Recommendation on Perfluorinated Compound Treatment Options

prepared by
Don L. Kriens Sc.D., P.E.
Cambridge Environmental Consulting
January 2018

Executive Summary

The treatment system must be capable of removing both PFOA and PFOS, as well as providing best treatment technology available to remove other perfluorinated compounds, such as PFBA, that pose some toxicity. GAC alone does not remove low carbon number perfluorinated carboxylic acids (e.g. PFBA) and, at times, low carbon number perfluorinated sulfonic acids (e.g. PFBS). There are differential removal efficiencies among perfluorinated compounds through GAC systems. As described in the full-scale GAC operating systems and research discussed herein, PFOA is often marginally removed by GAC alone. Granular activated carbon (GAC) followed by reverse osmosis technology is needed at public water treatment systems to assure removal of all perfluorinated compounds. Further testing of nanofiltration, as discussed in the Subcommittee's Recommendation on Perfluorinated Compound Treatment Options (2015), may demonstrate adequacy to remove PFOA and low carbon number perfluorinated compounds, as a substitute for reverse osmosis.

Prevalence of PFCs in New Jersey Drinking Water

PFOS and PFOA are found in New Jersey water supplies at relatively high concentrations, in some instances at levels greater than the existing 14 ng/l MCL for PFOA and the proposed 13 ng/l MCL for PFOS. We expect that in excess of one million people are ingesting PFOS and PFOA at these levels. PFOS levels in some New Jersey PWS (public water supplies) are such that ingestion of this contaminated water further increases residents' PFOS blood serum levels beyond those already found in epidemiologic studies in the U.S. population to be associated with adverse health effects (immunotoxicity).

Following discovery of PFOA levels in PWS (public water systems) at levels up to 190 ng/l in groundwater and 64 ng/l in tap or finished drinking water, New Jersey Department of Environmental Protection completed two studies, in 2006 and 2009-2010, to test for PFOS, PFOA, and other perfluorinated compounds in 53 PWS (NJDWQI 2017).

PFOS was found in the 2006 study in 30% of 23 PWS tested at or above the minimum reporting limit (MRL) of 4 ng/L (NJDWQI 2017), with the highest PFOS level at 19 ng/L (NJDWQI 2017). In the 2009-2010 study raw water was tested in 30 PWS in 19 of New Jersey's 21 counties. PFOS was found in 8 of 29 PWS sampled at levels up to 12 ng/L in 5 PWS using groundwater, and up

to 43 ng/L in 3 PWS using surface water (NJDWQI 2017). Finished drinking water in these PWS would be expected to contain the same concentrations, since minimal to no removals of perfluorinated compounds are achieved through conventional water treatment technologies.

Testing of 175 New Jersey PWS, including 165 large community systems and 10 small community systems, completed under the UCMR3 (Third Unregulated Contaminant Monitoring Rule) found 6 PWS with PFOS levels exceeding 40 ng/L, and 18 PWS with PFOA levels exceeding 20 ng/L (UCMR3 2017, NJDWQI 2017). Based on the New Jersey DEP database we note that 10 of 76 PWS tested were found to contain PFOS ≥ 20 ng/l, with 7 PWS containing PFOS at levels exceeding 40 ng/L.

The 80 PWS tested represent about 14% of the total community water supplies in New Jersey. In 2016 New Jersey had 581 community water systems (NJ DEP Division of Water Supply and Geoscience 2017), serving about 91% of the total population, of which 42% were medium to large systems, and 58% were small systems.

State-wide studies of PFOA and PFOS in private wells have not been conducted in New Jersey. About 12% of New Jersey's population obtains drinking water from private wells (NJDEP Division of Water Supply and Geoscience 2017). Although it is likely the majority of these wells are not contaminated, groundwater at locations proximate to industrial activities using perfluorinated compounds or where AFFF (aqueous fire fighting foam) has been used may exhibit levels of PFOS and PFOA. PFOA has been found at levels exceeding 40 ng/L (maximum >400 ng/L), in 59 private wells within 2 miles of a New Jersey industrial source (NJDWQI 2016 Report, DuPont, 2009). PFOS was found in private wells at levels above the USEPA advisory of 70 ng/L (PFOS + PFOA) and the proposed MCL of 13 ng/L near sites contaminated with fire fighting foam (NJDWQI 2017).

Treatment Technologies and Capabilities, Chemistry of PFSAs versus PFCAs

The NJDWQI Treatment Subcommittee states in its 2015 report, Appendix C: Recommendation on Perfluorinated Compound Treatment Options for Drinking Water: "the treatment options are not expected to differ from compound to compound due to their similar properties (e.g. persistence, water solubility, similar structure, strong carbon-fluorine bonds, and high polarity)". The NJDWQI subcommittee does not diverge from this position in the Appendices to the 2015 Report. We disagree with this position. Peer-reviewed studies show that treatment options differ in removal capability among perfluorinated compounds.

Although perfluorinated compounds have somewhat similar structure, polarity, and solubility, there are differences in structural chemistry that affect removal among treatment options. Specifically, the charged functional group, carboxylic or sulfonic acid, affects the adsorption capability of activated carbon. PFSAs (perfluoroalkyl sulfonic acids, e.g. PFOS) are stronger acids and more hydrophobic compared to PFCAs (pefluoroalkyl carboxylic acids, e.g. PFOA, PFBA). Therefore, their tendency to adsorb onto activated carbon is greater.
In a review of adsorption behavior of perfluorinated compounds (mostly PFOS and PFOA) by Du

et al. (2014) sorption capacities of PFSAs (e.g. PFOS) onto activated carbon or other adsorbents were observed to be higher than PFCAs (PFOA) with the same carbon numbers due to greater hydrophobicity of PFSAs versus PFCAs (Du et al. 2014).

Activated column experiments by Ostlund (2015) found higher removal efficiency of PFSAs than PFCAs, comparing the same number of carbons in the perfluorocarbon chain length, indicating that that functional group affects removal efficiencies of PFASs; "sulfonic group resulted in higher removal efficiency compared to carboxylic group" (Ostlund 2015). This study also found that branched isomers (for PFOS) were less efficiently removed by GAC (granular activated carbon) compared to linear PFOS isomers. We note this finding could, in part, account for differences in PFOS removal among locations using GAC.

The Water Research Foundation study of 15 full-scale water treatment systems in the U.S., including two potable reuse treatment systems, found that full-scale anion exchange and GAC column treatments were more effective at removing long-chain perfluorinated compounds and PFSAs (e.g. PFOS) versus PFCAs (e.g PFOA, PFBA) (Water Research Foundation 2016). Full-scale reverse osmosis systems demonstrated significant removal for all perfluorinated compounds, including the smallest, perfluorobutanoic acid (PFBA).

The WRF (2016) study further evaluated nanofiltration (NF) for removal of a suite of PFCAs and PFSAs and notes that NF "has been deemed potentially effective (> 95%) in bench-scale experiments using NF270 membranes" (WRF 2016; Steinle-Darling and Reinhard 2008). WRF (2016) indicated that NF may be as capable of rejecting (treating) perfluorinated compounds as reverse osmosis at lower cost.

A study of sorption onto GAC, zeolite, and sludge found that PFOS is strongly adsorbed by GAC; PFOA and PFBS were also removed by GAC but to a lesser extent. The authors noted "that the length of the fluorocarbon chain and the nature of the functional group influenced sorption of the anionic surfactants" (Ochoa-Herrera and Reyes-Sierra 2008).

Perfluorinated compound removal was studied at two water reclamation plants (treating domestic effluents as influent) in Southeast Queensland, Australia. In the treatment plant using reverse osmosis, PFOA was removed to less than reporting level to 1.4 ng/L, from influent levels ranging from 15 to 27 ng/L, and PFOS was removed to less than reporting with influent PFOS levels ranging from 23 to 39 ng/L. In the treatment plant using biologically activated carbon, PFOA and PFOS were ineffectively removed, although lack of removal may have been due to the age of the carbon or short contact times (Thompson et al., 2011).

In a study at a water treatment plant in Amsterdam using GAC, PFOA was not effectively removed, with a final (treated) mean PFOA concentration of 5.3 ng/L (range 0.8 ng/L - 9.4 ng/L) versus a mean influent (raw) PFOA concentration of 4.4 ng/L (range 3.8 ng/L - 5.2 ng/L). The authors found greater removals of PFOS and PFNA with a mean final (treated) water level of <0.23 ng/L and <0.24 ng/L, respectively, versus influent (raw) levels of 6.7 to 10 ng/L for PFOS and 0.5 to 0.8 ng/L for PFNA (Eschauzier et al. 2012). This study also found that PFBA, PFPeA,

PFHxA, PFOA, and PFBS were not well removed by the (operating) GAC filtration. In general, the authors found that PFOA decreased by only 50% using GAC.

A study in Spain suggests that although GAC alone was reasonably effective to remove PFOS, reverse osmosis was needed to achieve efficient PFOA removal. In this study 2 separate stages following conventional water treatment (GAC, or Ultrafiltration followed by Reverse Osmosis) were evaluated. The system treats 100 million gallons per day of surface river water to supply over 1 million inhabitants. The authors found that ultrafiltration/reverse osmosis removed PFOS and PFOA by ≥ 99%, but GAC alone removed PFOS and PFOA by only 64 ± 11% and 45 ± 19%, respectively (Flores et al. 2013).

In a study monitoring drinking water treatment facilities across the U.S., a utility that used microfiltration and reverse osmosis for indirect potable reuse in wastewater treatment reduced total perfluorinated compound influent levels of 80 ng/L and influent PFOS of 41 ± 18 ng/L to no reportable levels. Minimum reporting levels were 1.0 ng/L for all perfluorinated compounds monitored except PFOA, where the minimum reporting level was 5 ng/L (Quinones and Snyder 2009).

Granular Activated Carbon Treatment Systems – Removal Efficiency

NJDWQI subcommittee describes 2 facilities in New Jersey, one in Pennsylvania, and one in Minnesota where GAC is used to treat perfluorinated compounds in public water supplies.

In the New Jersey Penns Grove GAC treatment system PFOS was reported at levels lower than the reporting limit of 5 ng/l in finished water, although the highest PFOS level in the raw water was 13 ng/L. At the New Jersey Logan System Birch Creek GAC system PFOS was reported at levels lower than the reporting limit of 5 ng/l in finished water, although the average PFOS raw water concentration was only slightly above the reporting limit, at 7 ng/L. We believe that PFOS and PFOA removal performance may be much different at other locations, where PFOS and PFOA are present in raw water at higher levels and/or where source water contains greater natural organic matter.

The Subcommittee notes the Horsham Water and Sewer Authority (HWSA) in Horsham, Pennsylvania, where GAC was recently installed to treat well water contaminated with perfluorinated compounds. Wells are believed contaminated from fire fighting foam used at the nearby Naval Air Station Joint Reserve Base - Willow Grove. NJDWQI subcommittee states that HSWA raw (well) water samples collected between January and March 2017 "show a range of PFOS concentrations from 230 - 1297 ng/L and an average of 629.3 ng/L", and indicates PFOS was not detected in finished water. We characterize HSWA well data differently, based on our review of HWSA active well data (HWSA, PFOS PFOA Active Source Monitoring Results with Charts, 2017), as summarized in Table 1 below.

We observed that, during limited periods, post-GAC treatment in 4 HSWA contaminated wells

did not remove PFOS or PFOA to levels below the reporting limit of 5 ng/L. This appeared to occur just prior to carbon change-out, as shown in the HSWA data. However, it should be noted that GAC treated water is also blended with other HSWA wells and water sources, as shown in HSWA system schematics (HSWA June 2016), to assure that levels are below applicable standards and protective. As of December 2017 the HSWA indicates "the combined concentration of PFOS/PFOA from all sources currently supplying the public system is approximately 4 ppt (ng/l)" (HSWA Dec 2017 Update). This is below the USEPA health advisory level applied of 70 ppt (ng/l) for combined concentration (PFOA + PFOS).

Based on HSWA data as of December 19, 2017, the following table summarizes results for active HSWA wells (HWSA, PFOS PFOA Active Source Monitoring Results with Charts, 2017).

HSWA well number	Period	PFOS lowest	PFOS highest	PFOA lowest	PFOA highest
7	May 5, 2016 - Dec 19, 2017	ND	11	3.1	11
10*	Jan 19, 2016 - April 5, 2017	16	76	12	48
17**	Jan 19, 2016 - Dec 22, 2016	50	110	20	37
21***	Jan 2016 - Jan 11, 2017	5.1	14	8.4	13
26****	Jan 25, 2016 - March 8, 2017	340	1297	640	1765
40*****	Jan 11, 2017 - March 24, 2017	230	1203	33	88

Table 1. Summary Table of HSWA Raw Water PFOS and PFOA Concentrations (ng/L)

ND – non detect at reporting limit 5 ng/L

*After April 5, well 10 was treated through GAC system with N.D results.

** After December 22, 2016 well 17 was treated with GAC. Results post GAC treatment in 2017 mostly ND (reporting levels 5 ng/L), except for 6 positive PFOS values ranging from 3.1 to 159 ng/L, and 5 positive PFOA values ranging from 13 ng/L to 29 ng/L.

*** After January 2017 well 21 was treated with GAC. Results post GAC treatment ND (reporting levels 5 ng/L), except one PFOS value of 4.2 ng/L, and 5 PFOA values ranging from 3.3 to 7.8 ng/L.

**** After March 8, 2017 well #26 was treated with GAC. Results post GAC treatment ND, except for one PFOS value of 5 ng/l and one value of 5 ng/L for PFOA

***** After March 24, 2017 well #40 treated with GAC. Results post GAC treatment ND, except 4 PFOS

values ranging from 2.5 ng/L – 131 ng/L and 3 PFOA values ranging from 3.1 ng/L to 5.3 ng/L

The Second Addendum discusses the city of Oakdale, Minnesota GAC system used to remove perfluorinated compounds, including PFOS, from well (drinking) water. NJDWQI subcommittee notes that the Oakdale PFOS method detection limit is 0.5 ng/L and the Minimum Reporting Limit (MRL) is 5 ng/L. However, these limits were only recently put into effect by the Minnesota Department of Health (Rinker communication, Jan 5, 2018). (A MRL for PFOA of 5 ng/L was also recently put into effect.) Prior RLs (reporting limits) for PFOS and PFOA at Oakdale were 25 ng/L and 35 ng/L, respectively. The Subcommittee states that "samples taken after GAC treatment show no detection of PFOS". However, these non-detects are based on the prior RLs (25 ng/L and 35 ng/L), not 5 ng/L. It is yet unknown whether the Oakdale GAC system will remove PFOS or PFOA to ≤ 5 ng/L.

Based on Oakdale's perfluorinated compound data (Bachmeier 2017), PFOS was non-detect in finished drinking water for the period November 2015 through November 2017, at a RL of 50 ng/L for the period November 2015 through July 2016, and a RL of 25 ng/L for the period August 2016 to present. PFOA was non-detect for all samples at a RL of 50 ng/L for the period November 2015 through July 2016, and a RL of 35 ng/L for the period August 2016 to present. We observed that PFBA (perfluorobutanoic acid) remains at relatively high levels in Oakdale's drinking water, typically at around 1400 ng/L, consistent with other installations and research showing poor or no removal by GAC of low carbon number PFCAs. Generally PFBA passes through unchanged in concentration through the Oakdale GAC system. However, PFBA levels in Oakdale's finished water are well below the Minnesota Department of Health HRL (health risk limit) for PFBA of 7000 ng/L.

The 3M Cottage Grove manufacturing plant in Cottage Grove, Minnesota operates a GAC system to treat wastewater discharged to the Mississippi River, installed in 2004 pursuant to requirement by the NPDES (National Pollutant Discharge Elimination System) permit. 3M was the primary global producer of PFOS-related perfluorinated compounds, and PFOA, and manufactured these chemicals at its two U.S. plants in Decatur, Alabama and Cottage Grove, Minnesota, and in Europe at its plant in Antwerp, Belgium. 3M perfluorochemical production began at the Minnesota plant around 1950 (Oliaei et al. 2006).

Based on one sampling event in 2006 by Minnesota Pollution Control Agency staff, the 3M GAC treatment facility removed PFOS by 95% and PFOA by 79%. The GAC treatment plant was less effective at removal of carboxylic perfluorinated compounds (PFCAs). In the 2006 sampling of post-GAC treated wastewater perfluorinated compound concentrations were very high: PFOA 1670 ng/L, PFOS 1330 ng/L, PFBS 169,000 ng/L, and PFBA 58,100 ng/L (Oliaei et al. 2006).

Since 2006 levels of perfluorinated compounds in the 3M discharge (post-GAC treated wastewater) are considerably lower, but remain elevated, as summarized in the following table for the period October 2015 through November 2017 (NPDES 3M data provided by Marco Graziani, Minnesota Pollution Control Agency, January 2018).

Period	PFOA ng/L	PFBA ng/L	PFNA ng/L	PFOS ng/L	PFBS ng/L
Oct-15	126	13100	<25	<46.4	94.7
Nov-15	<48	102000	<25	<23.2	1170
Dec-15	61.9	8470	<25	<23.2	1410
Jan-16	38.2	36500	<25	<46.4	1660
Feb-16	166	27500	<25	<23.2	210
Mar-16	329	15400	<25	27.8	217
Apr-16	584	55700	<25	58.1	434
May-16	<24	28100	<25	<23.2	353
Jun-16	75.9	6040	<25	<23.2	120
Jul-16	193	83700	<25	<23.3	817
Aug-16	116	380000	<25	<46.4	644
Sep-16	81.6	21200	<25	<23.2	1240
Oct-16	90.3	13400	<25	<23.3	469
Nov-16	194	18200	<25	43.3	848
Dec-16	370	19200	<25	69.3	286
Jan-17	77.2	7470	<25	25.4	195
Feb-17	108	6870	<25	26.6	201
Mar-17	157	12800	<25	37.5	6240
Apr-17	265	10700	<25	44.9	676
May-17	165	11000	<25	38.6	465
Jun-17	113	14100	<25	71.4	1340
Jul-17	170	21700	<25	28.7	3740
Aug-17	328	13900	<25	60.3	2580
Sep-17	50.6	4090	<25	<23.2	1780
Oct-17	129	11600	<25	29.4	18700
Nov-17	133	7680	<25	<46.4	6920
~ mean	**172**	**36555**	**<25**	**43**	**2031**

Table 2. 3M Perfluorinated Compound Discharge (SD001) Post-GAC Treatment ng/L

Mean concentrations in Table 2 are means of positive values, excluding non-detects. The post-GAC discharge perfluorinated compound discharge concentrations for October 2015 to present remain high: mean PFOA 172 ng/L, mean PFBA 36,555 ng/L, mean PFOS 43 ng/L, and mean PFBS 2031 ng/L. However, these concentrations are much lower than those discharged during the period January 2007 though July 2010: mean PFOA 2989 ng/L, mean PFBA 54,098 ng/L, mean PFOS 595 ng/L, and mean PFBS 18,673 ng/L. The 3M data indicate that low carbon perfluoroalkyl compounds (such as PFBS and PFBA) and PFCAs (e.g. PFBA, PFOA) are not removed by this GAC system to low levels.

Recommended Treatment - GAC Followed by Reverse Osmosis

GAC alone has not been shown in most cases to consistently remove PFOA to low ng/L levels. Therefore, GAC followed by reverse osmosis (RO) is required to remove PFOA and, in some cases PFOS, to assure consistent removal. GAC followed by RO will also enable removal of low carbon number perfluorinated compounds such PFBA. PFBA has been shown in animal studies to cause toxicity. The Minnesota Department of Health identified critical toxic effects of "liver weight changes, morphological changes in liver and thyroid gland, decreased TT4, decreased red blood cells, decreased hematocrit and hemoglobin, and subcritical toxic effects of increased relative thyroid weight, decreased serum TT4 and dFT4, decreased cholesterol, and delayed eye opening (rat)", in PFBA animal studies as the basis to derive a HRL (health risk limit) for PFBA (MDH 2017 Perfluorobutyrate).

A consideration using GAC/RO in large municipal treatment systems is disposal of the RO reject. Technologies to treat RO reject are generally limited to evaporative technologies applied to high salt concentrating RO systems, to eliminate the reject discharge. Evaporative systems require excessive energy input and are often prohibitively expensive. RO reject evaporative systems may be relatively cost effective, however, in arid climate locations to allow lined evaporation ponds, or where untreated reject water does not pose a concern or environmental impact (such as RO systems used for drinking water treatment in coastal areas, where the salt RO reject is discharged to the ocean). Such is not the case for the temperate geographic region under consideration in New Jersey. Thus, RO rejects at large GAC/RO plants would likely require direct discharge to a receiving water.

The GAC system, however, will enable removal of a significant mass of PFOS, and to a lesser extent, PFOA. A primary concern with waters receiving perfluorinated compounds is uptake of PFOS in fish, which bioaccumulates, and subsequent consumption of PFOS-contaminated recreationally caught fish. PFOA does not bioaccumulate. In any case, the mass of perfluorinated compounds, including PFOS and PFOA, discharged to a receiving water in a GAC followed by reverse osmosis system (reject) would not be greater than the mass discharged by a GAC system alone.

NJDWQI briefly discusses Point of Use (POU) drinking water systems, for use in individual homeowners on private wells, and certification by NSF (National Sanitation Foundation). NSF developed protocol NSF P473 to evaluate drinking water treatment device capability to reduce PFOA and PFOS in drinking water. The NSF certified a number of systems using GAC or GAC/RO that meet the EPA "standard" (combined PFOS and PFOA) of 70 ng/L. The NSF protocol included "challenge" of influent level of 1500 ng/L [5 parts PFOA and 10 parts PFOS by weight] to the GAC and GAC/RO systems. Studies by NSF showed good removal performance by GAC with highest performance in POU systems using GAC followed by reverse osmosis (NSF personal communication, E. Valentine, Jan 4, 2018)

We concur that GAC/RO POU systems offer a treatment solution to homeowners on private wells. Perfluorinated compounds do not volatize and therefore inhalation via showering and bathing do not pose an exposure pathway, versus other compounds such as DBPs (disinfection byproducts) where inhalation in showering may comprise a significant portion of total

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DELAWARE RIVERKEEPER NETWORK

January 31, 2018

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New Jersey Department of Environmental Protection
Trenton, New Jersey

Re: Report on the Development of a Practical Quantitation Level for Perfluorooctanesulfonic Acid (PFOS) in Drinking Water, NJ Drinking Water Quality Institute Testing Subcommittee

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 this organization and its membership on the Drinking Water Quality Institute's document **Report on the Development of a Practical Quantitation Level for Perfluorooctanesulfonic Acid (PFOS) in Drinking Water.**

Also attached are copies of 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 PFOS contamination and that New Jersey's drinking water be required to be treated to a safe level based on the best available scientific evidence.

We support the recommendations and findings made by Dr. Oliaei and Cambridge Environmental Consulting in this technical analysis regarding a Practical Quantitation Level (PQL) for PFOA. We support Cambridge Environmental Consulting's concurrence with the DWQI Testing Subcommittee's analysis that determined a PQL on the basis of multiplication of the method detection limit by a factor of 5, resulting in a PQL of 4.2 ng/L for PFOS. The PQL of 4.2 ng/L is below the MCL of 5 ng/L that Cambridge Environmental Consultants recommends as more protective. Thank you for the opportunity to comment on the PQL for PFOS.

Sincerely,

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

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Attachments:

Review of NJDWQI Report on the Development of a Practical Quantitation Level for PFOS in Drinking Water, Fardin Oliaei Ph.D. and Don L. Kriens Sc.D., Cambridge Environmental Consulting, January 2018

Curriculum Vitae for Fardin Oliaei, MPA, PhD

Curriculum Vitae for Don Kriens, Sc.D., P.E.

Review of NJDWQI Report on the Development of a Practical Quantitation Level for PFOS in Drinking Water

prepared by
Fardin Oliaei Ph.D. and Don L. Kriens Sc.D.
Cambridge Environmental Consulting
January 2018

The NJDWQI Testing Subcommittee determined that use of low calibration standards for PFOS among laboratories was the most appropriate performance standard to base a practical quantitation limit (PQL). Using low calibration standards of 19 laboratories that used either EPA Method 537, modified EPA Method 537, or a proprietary method, the Subcommittee applied bootstrap analysis (bootstrap estimate of a confidence interval of the mean) to determine an upper confidence limit of 95% for PFOS at 4.2 ng/L. (One laboratory with a low calibration standard above the upper confidence level (95%) was excluded.) The same methodology was applied to 12 laboratories using EPA Method 537 to determine an upper confidence limit (95%) of 3.8 ng/l. (Two laboratories were excluded from that analysis since their low calibration standards were outside the 95% confidence interval.)

The Subcommittee's methodology appropriately diverts from the prior or traditional use of developing a PQL on the basis of multiplication of the MDL (method detection limit) by a factor of 5, consistent with USEPA "trend" not to use MDLs to develop a PQL.

We concur with the Subcommittee's analysis that determined a PQL of 4.2 ng/l for PFOS. This PQL concentration is below the proposed MCL of 13 ng/l, and below the 5 ng/l that we assert is more protective.

Fardin Zoe Oliaei
fardin_oliaei@hks09.harvard.edu
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 2010 - 2012
Auditing several courses: Air Pollution; Water Pollution; and Risk Assessment

Harvard University John F. Kennedy School of Government, Cambridge, MA
Master in Public Administration 2009
- Concentration: Leadership and International Environmental Health Policy and Management

Bush Foundation Leadership Fellow (MN) to pursue studies at Harvard University 2008 - 2010

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 in Chemistry Minor in Biology

PROFESSIONAL EXPERIENCE

DST Health Solutions, LLC, Home Office East 2014 - Present
Sr. Project Management Specialist
- Evaluating the global pattern of disease and morbidity in growing population and identifying social determinants of population health as a tool for managing healthier population and creating effective health care systems.

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

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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.

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Oakdale, MN 55128
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dlk810@mail.harvard.edu

Curriculum Vitae

AREAS OF EXPERTISE

- Professional engineer - civil and environmental engineering design.
- Modeling exposure/risk of environmental contaminants, including disinfection byproducts and contaminants in drinking water supplies.
- Global water scarcity, climate change impacts on water supplies
- Toxic contaminant cleanup.
- Design of water/wastewater treatment systems, remediation, stormwater.
- Industrial processes, pollution prevention, industrial process chemistry.
- Emerging treatment technologies.
- Engineering economic analysis.
- Regulatory enforcement, civil and criminal.
- Environmental policy and justice

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

Research Fellow, Harvard T.H. Chan School of Public Health, Harvard University

Principal Engineer: 1978-2008 Minnesota Pollution Control Agency
- Lead Agency technical expert for water projects. Mentor engineers and technical staff.
- Research projects - ecological and health impacts of contaminants. Evaluate emerging technologies.
- Conducted major civil and criminal investigations with MN Attorney General staff, U.S. Attorney's Office, USEPA Region V. Expert witness.
- Developed major industrial permits, technologies to comply. Economic impact.
- Technical expert for water/wastewater treatment, remediation and water supplies.
- Technical expert for emergency response regarding toxics and resolution.

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

Engineer: Castek Consulting Engineering Services
• Operation, design, process chemistry of wastewater plants; indoor air quality studies.

Research Scientist and Environmental Engineering Laboratory Supervisor, University of Iowa
Department of Civil and Environmental Engineering

- Supervised laboratory conducting biological and chemical analyses, including GC and GC/MS. Conducted field studies. Occasional teaching assistant for graduate courses.

TEACHING EXPERIENCE

Harvard University
• Teaching Assistant in water pollution and risk assessment. Lecture in "Farm to Fork" course at Harvard Extension School.

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

LICENSES AND PROFESSIONAL AFFLILIATIONS

- Registered Professional Engineer
- Individual Sewage Treatment System Designer (Minnesota)
- Certification Air Quality Inspections (California Air Resources Board)
- Certification Stormwater Treatment and Erosion Design
- Member, Minnesota Government Engineers Council

PUBLICATIONS

Oliaei F, Kriens D, Kessler K. Investigation of Perfluorochemical Contamination (PFC) in Minnesota, MN Senate Report. Feb 2006.

Discovery of PFOS Contamination in Fish Near a PFC Manufacturing Plant in Minnesota, presentation at EPA Conference on PFCs and Perfluorocarbons, Research Triangle Park, North Carolina, June, 2010

Environmental Releases of Perfluoroalkyl Compounds from Two Landfill Sites in Minnesota, presentation at EPA Conference on PFCs and Perfluorocarbons, EPA Research Triangle Park, North Carolina, June, 2010

Discovery and Investigation of PFOS/PFCs Contamination from a PFC Manufacturing Facility in Minnesota, Kriens D, Oliaei F, The International Symposium on Halogenated Persistent Organic Pollutants – Dioxin 2010, San Antonio, Texas, August 2010

Estimating the Fraction of Methyl Mercury Exposures from Locally Caught Fish: A Case Study of U.S. Gulf Coast Residents", International Conference on Mercury, Halifax, Nova Scotia, July, 2011.

Contamination of Drinking Water and the Environment by Production and Industrial Use of Perfluoralkyl Compounds (PFCs) ", Oliaei F, Weber R, Kriens D, Watson A, The 31st International Symposium on Halogenated Persistent Organic Pollutants – Dioxin 2011, August 2011, Brussels, Belgium.

Contamination of Drinking Water and the Environment by Production and Industrial Use of Perfluoralkyl Compounds (PFCs), Oliaei F, Weber R, Kriens D, Watson A, presentation at 11th International HCH and Pesticides Conference, Gabala, Azerbaijan, September, 2011

Sunderland E, von Stackelberg K, Kriens D. Pilot Analysis of Gulf of Mexico State Residents' Methylmercury Exposure to Commercial and Locally Caught Fish. Harvard Center for Risk Analysis. March 2012.

PFOS and PFC releases and associated pollution from a PFC production plant in Minnesota (USA). Environ Science Pollution Research Journal, Oliaei F, Weber R, Kriens D, Watson A, November 2012.

Challenge and response in the Indus Basin, Condon M, Kriens D, Lohani A, Sattar E, Water Policy. Vol 16, no. S1, pp 58-86. 2014.

Buonocore J, Kriens D, Cahalan S, Michanowicz D, Gast A, Konschnik K. California's Unconventional Energy-Water Nexus. Running Dry. Harvard College Review of The Environment and Society, May 2016

DELAWARE
RIVERKEEPER
NETWORK

November 19, 2016

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

Re: Report on the Proposed DWQI Development of a Practical Quantitation Level for Perfluorooctanoic Acid (PFOA) in 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 **Development of a Practical Quantitation Level for Perfluorooctanoic Acid (PFOA).**

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 PFOA contamination and that New Jersey's drinking water be required to be treated to a safe level based on the best available scientific evidence.

We support the recommendations and findings made by Dr. Oliaei and Cambridge Environmental Consulting in this technical analysis regarding a Practical Quantitation Level (PQL) for PFOA. We support the utilization of the most accurate measurements of PFOA in water that can be achieved at the lowest reporting limits. Since the MCL recommended by Dr. Oliaei and Don Kriens is 1 ng/L, Delaware Riverkeeper Network supports using the most sensitive measurement method.

There are two methods recommended as alternatives to the EPA technique "Bootstrap Estimate of a Confidence Interval of a Mean". Using the method detection limit (MDL) approach, Dr. Oliaei's and Don Krien's calculations yielded a PQL of 3.0 ng/L. To use the minimum reporting level (MRL) approach to determine a PQL for PFOA, Dr. Oliaei and Don Kriens propose a MRL of 2 ng/L.

Thank you for the opportunity to comment on the PQL for PFOA.

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Sincerely,

Maya van Rossum
the Delaware Riverkeeper

Tracy Carluccio
Deputy Director

Attachments: Technical Analysis of Proposed DWQI Development of a Practical Quantitation Level for Perfluorooctanoic Acid (PFOA) in Drinking Water, Fardin Z. Oliaei, Don Kriens, Cambridge Environmental Consulting, Nov. 18, 2016

Technical Analyses of New Jersey Drinking Water Quality Institute

Development of a Practical Quantitation Level for Perfluorooctanoic Acid (PFOA) in Drinking Water

prepared by

Fardin Z. Oliaei MPA, Ph.D.
Don L. Kriens* Sc.D., P.E.

Cambridge Environmental Consulting

November 18, 2016

PREFACE

The opinions in this report are stated to a reasonable degree of scientific probability. The methods and principals 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.

** The views expressed in this report do not necessarily reflect those of the Harvard T.H. Chan School of Public Health, Harvard University, of which the author is affiliated as a Research Fellow.*

Technical Analysis of Proposed NJDWQI Development of a Practical Quantitation Level for Perfluorooctanoic Acid

by

Cambridge Environmental Consulting

Introduction

Different laboratories, programs and methods have different terminology for similar concepts. In general, the Method Detection Limit (MDL) and derivative Practical Quantitative Level (PQL) are used to estimate the limits of performance of analytical methods for measuring contaminants. The MDL is the minimum detection capability of a particular method reported by each laboratory and defined as the concentration of a contaminant (with true value greater than zero) that can be measured and reported with 99% confidence. The PQL is the lowest concentration for which the contaminant can be reliably quantified within specified limits of precision, accuracy and acceptable limits of uncertainty. There are also method specific Minimum Reporting Levels (MRL) which are similar in concept to a PQL. Analytical methods are changing and improving over time, thus, lowering the values of MDL, MRL, and PQL.

To develop an appropriate PQL requires evaluation of analytical methods with adequate sensitivity to detect PFOA at or below a proposed health based Maximum Contaminant Level (MCL).

The PQL for PFOA has been determined as a result of performance data compiled from three selected data sources by the testing committee. The Testing Subcommittee considered the RLs, lowest calibration standards and MDLs from laboratories that meet at least one of the criteria below:

1. The laboratories that analyzed water samples for PFOA during the NJDEP 2006 and 2009 studies;
2. The laboratories must use PFOA methods that have been vetted by the NJDEP OQA, NELAP or EPA; and
3. The laboratories must be EPA UCMR3 approved and demonstrated capability of reporting PFOA lower than the UCMR3 MRL of 20 mg/L using EPA 537 or modifications of EPA 537.

The Testing Subcommittee evaluated the following three methods for deriving the PQL for PFOA:

A. Determination of the PQL using MDLs

According to Testing Subcommittee report, the determination of the PQL using MDLs requires a sample size of at least five MDLs from which to obtain an inter-laboratory MDL value. The

individual MDL value from each laboratory for a given method is used to obtain a median MDL value as a representative inter-laboratory MDL. According to Eaton, et. al. (1993), this inter-laboratory MDL can be multiplied by a factor of 4, 5, or 6 in order to yield a supportable PQL value. Although the Testing Subcommittee chose to use a multiplier of five to determine the PQLs, considering uncertainties around the PQL calculation and lower MCL value proposed for PFOA (1ng/l), we recommend using the lower factor of 4 instead.

Researchers from Harvard University who are investigating PFAS contamination in drinking waters reported a MDL of 0.2 ng/L for PFOA in their recent studies (Zhang et al, 2015).

In order to obtain more representative inter-laboratory MDL value we propose to remove the two unusually highest MDLs (SGS Accutest-Orlando with reported MDL of 8ng/L and Test America-Denver with reported MDL of 9.79 ng/L). The median for the remaining eleven MDLs (0.748 ng/L) multiplied by factor of 4 (0.748 ng/L X 4 = 2.992), results in a PQL of 3.0.

B. Determination of PQL Using Reporting Limits or Lowest Calibration Standards

The Minimum Reporting Level (MRL) is defined as the minimum concentration by which PFOA is reliably quantitated by the individual laboratory. The Testing Subcommittee also assessed PQL value using the MRLs that account for both accuracy and precision as opposed to MDLs that are mainly a measure of precision.

According to the Testing Subcommittee report, since 2007, laboratories have demonstrated that lower reporting limits are achievable. In fact, NYDEC contracted the services of a laboratory capable of providing a PFOA reporting limit of 2 ng/L. Studies in Southeast Queensland, Australia, reported the Minimum Reporting Levels (MRLs) for PFCs, including PFOA, ranged from 0.4 to 1.5 ng/l (Thompson et al, 2011).

In order to determine a PQL for PFOA based on minimum reporting levels we propose a MRL of 2 ng/L. This is a value that most credible laboratories are currently capable to achieve.

C. Bootstrap Estimate of a Confidence Interval of a Mean

The Testing committee also used an EPA technique called "Bootstrap Estimate of a Confidence Interval of the Mean." This method was applied to generate a normal distribution and associated 95 % upper and lower confidence intervals from the inter-laboratory MDL values and the RLs or the lowest calibration standard. The PQL value of 6.5 ng/L derived from bootstrap analysis of the MDLs multiplied by 5, and the PQL value of 6.0 ng/L derived from the bootstrap analysis of the RLs are both higher the MCL proposed by the authors.

The testing Subcommittee recommended a PQL of 6 ng/L for PFOA to the Drinking Water Quality Institute. This is considerably higher than our proposed MCL of 1 ng/L.

Considering serious adverse health impacts of PFOA, uncertainty inherent in toxicological

studies to develop a protective MCL, and challenges in developing appropriate PQL, the best available control technology for removal of PFOA should be applied in order to protect public health.

References:

1. Eaton, Andrew, Principal Investigator, Evaluation of PQL Determination Methodologies, Division of Science and Research Final Report Contract P33501, 1993.

2. http://www.caslab.com/EPA-Methods/PDF/EPA-Method-537.pdf

3. Thompson J, Eaglesham G , Reungoat J, Poussade Y, Bartkow M, Lawrence M, Mueller J. Removal of PFOS, PFOA and other perfluoroalkyl acids at water reclamation plants in South East Queensland Australia. Chemosphere 82 (2011) 9–17

5. Xianming Zhang, et. al. Source Attribution of Poly- and Perfluoroalkyl Substances (PFASs) in Surface Waters from Rhode Island and the New York Metropolitan Area. Environ. Sci. Technol. Lett., 2016, 3 (9), pp 316–321

6. Xindi C. Hu et. al. Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants. Environ. Sci. Technol. Lett., 2016, 3 (10), pp 344–350

7. Zhang X, Weber A, Hu C Zhao W, Cai M, August P, Lohmann R, Vecitis C, Sunderland E. Application of offline/online SPE and LC5MS/MS in analysis of perfluoroalkyl substances in river water. SciX 2015, Providence R.I. http://docplayer.net/10952478-Applica-on-of-offline-online-spe-and-lc-ms-ms-in-analysis-of-perfluoroalkyl-substances-in-river-water.html 09/29/2011.

Appendix C: Written Commenter #14: Perkasie Regional Water Authority. Four attachments to the August 31, 2018 e-mail

Cherry, Timothy

From: Nicholas Fretz <nick.fretz@perkasieauthority.org>
Sent: Friday, August 31, 2018 3:37 PM
To: Patel, Ragesh; Wade, Colin
Cc: Greg Lippincott; Marianne K. Morano; dwatt@mckeegroup.net; Pete Andersen (petea@Andersenengineering.com); Tom Horn
Subject: Cost Estimates for Ridge Run PFC Contamination
Attachments: Option #1 Cost Estimate.pdf; Option #1 Map.pdf; Option #2 Cost Estimate.pdf; Option # 2 Map.pdf

Importance: High

Follow Up Flag: Follow up
Flag Status: Flagged

Good Afternoon All,

I wanted to get everyone some final estimates and options along with a brief explanation of each, since today is the last day for comments.

Option #1:
This option is an all-encompassing option that includes over 11,700 linear feet of water main. In order for PRA to provide service to this entire area, a booster pump station would need to be installed at the Authority water tank. Although that cost of roughly $1.3m is included in this estimate, that Authority Board would contribute this cost towards the project to install the pumps and generator.

Option #2:
This option is a slightly slimmed-down project with over 7,100 linear feet of water main. Since there are financial concerns with providing service, this option is a viable option because it is under the $2m threshold that DEP is legally allowed to spend on the contamination clean-up and this will serve all of the customers with private wells above the 70 PPT HAL. In addition, since the water mains in this option do not extend as far north on Old Bethlehem Pike compared to Option #1, a booster pump is not needed to provide service.

If anyone has any questions or would like a more detailed explanation, please don't hesitate to call or contact me.

Thanks and I hope everyone has a great holiday weekend.

Nick

Nicholas Fretz
Manager

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Sellersville, PA 18960

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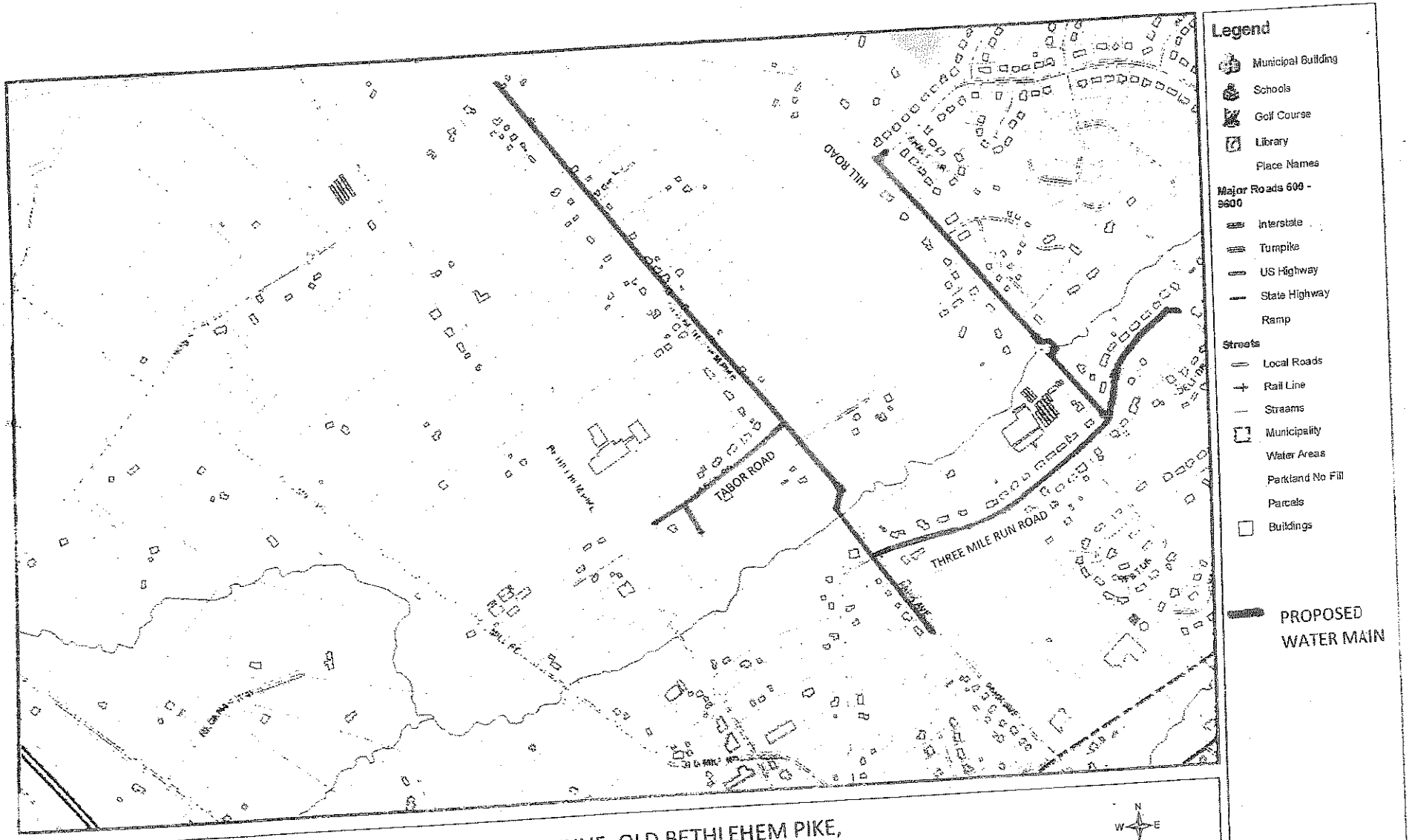
fax: 215-257-5590

RIDGE RUN PFAS HSCA
TAKEOFF AND BUDGET ESTIMATE III
8/30/2018

ITEM NO.	CONSTRUCTION ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST
	PARK AVENUE, OLD BETHLEHEM PIKE, & TABOR ROAD WATER MAIN				
1	Tie Into Existing Main	LS	1	$ 1,291.50	$ 1,291.50
2	8" Water Main, Off Road	LF	4786	$ 61.50	$ 294,339.00
3	8" Water Main, In Paved Road	LF	157	$ 125.46	$ 19,697.22
4	8" Water Main, In Stone Road (Tabor)	LF	1353	$ 73.80	$ 99,899.00
5	8" Water Main, Crossing Stream	LF	190	$ 98.40	$ 18,696.00
6	Fire Hydrant Assembly, 6" DIP, 6" MJ GV	EA	13	$ 6,150.00	$ 79,950.00
7	6x8 Hydrant Tee	EA	13	$ 645.75	$ 8,394.75
8	8" MJ Gate Valve	EA	19	$ 1,943.40	$ 36,924.60
9	8" MJ Tees, MJ Reducers, MJ Sleeves & MJ Bends	EA	14	$ 492.00	$ 6,888.00
10	8" MJ Plug	EA	5	$ 430.50	$ 2,152.50
11	Water Service - Near Side	EA	37	$ 1,476.00	$ 54,612.00
12	Water Service - Far Side	EA	22	$ 1,722.00	$ 37,884.00
13	Water Service Connection to Home	EA	59	$ 3,690.00	$ 216,630.00
14	Existing Well Seal	EA	59	$ 2,000.00	$ 118,000.00
15	8" EBAA Restraint Harness	EA	1	$ 338.25	$ 338.25
16	Disinfection and Testing	LF	6480	$ 2.78	$ 18,035.34
17	Thrust Blocks	EA	44	$ 246.00	$ 10,086.00
18	Stream Crossing	EA	1	$ 40,000.00	$ 40,000.00
19	Traffic Control	LS	1	$ 7,350.00	$ 7,350.00
20	Road Crossings - Mill and Overlay	SY	381	$ 20.98	$ 7,985.50
21	Tapping Fee Distribution	LS	1	$ 94,400.00	$ 94,400.00
	PARK AVE, OLD BETHLEHEM PIKE, & TABOR ROAD TOTAL				$ 1,173,553.66
	THREE MILE RUN ROAD				
1	Tie Into Existing Main	LS	1	$ 1,291.50	$ 1,291.50
2	8" Water Main, Off Road	LF	0	$ 61.50	$ -
3	8" Water Main, In Paved Road	LF	2737	$ 125.46	$ 343,384.02
4	8" Water Main, In Stone Road (Tabor)	LF	0	$ 73.80	$ -
5	8" Water Main, Crossing Stream	LF	0	$ 98.40	$ -
6	Fire Hydrant Assembly, 6" DIP, 6" MJ GV	EA	6	$ 6,150.00	$ 36,900.00
7	6x8 Hydrant Tee	EA	6	$ 645.75	$ 3,874.50
8	8" MJ Gate Valve	EA	4	$ 1,943.40	$ 7,773.60
9	8" MJ Tees, MJ Reducers, MJ Sleeves & MJ Bends	LF	8	$ 492.00	$ 3,936.00
10	8" MJ Plug	EA	0	$ 430.50	$ -
11	Water Service - Near Side	EA	22	$ 1,476.00	$ 32,472.00
12	Water Service - Far Side	EA	16	$ 1,722.00	$ 27,552.00
13	Water Service Connection to Home	EA	38	$ 3,690.00	$ 139,460.00
14	Existing Well Seal	EA	38	$ 2,000.00	$ 76,000.00
15	8" EBAA Restraint Harness	EA	0	$ 338.25	$ -
16	Disinfection and Testing	LF	2737	$ 2.78	$ 7,608.31
17	Thrust Blocks	EA	20	$ 246.00	$ 4,920.00
18	Stream Crossing	EA	0	$ 40,000.00	$ -
19	Traffic Control	LS	1	$ 5,000.00	$ 5,000.00
20	1/2 Width - Mill and Overlay	SY	3897	$ 20.98	$ 81,778.53
21	Tapping Fee Distribution	LS	1	$ 60,800.00	$ 60,800.00
	THREE MILE RUN ROAD TOTAL				$ 832,750.46
	HILL ROAD WATER MAIN				
1	Tie Into Existing Main	LS	1	$ 1,291.50	$ 1,291.50
2	8" Water Main, Off Road	LF	0	$ 61.50	$ -
3	8" Water Main, In Paved Road	LF	2337	$ 125.46	$ 293,200.02
4	8" Water Main, In Stone Road (Tabor)	LF	0	$ 73.80	$ -
5	8" Water Main, Crossing Stream	LF	190	$ 98.40	$ 18,696.00
6	Fire Hydrant Assembly, 6" DIP, 6" MJ GV	EA	5	$ 6,150.00	$ 30,750.00
7	6x8 Hydrant Tee	EA	5	$ 645.75	$ 3,228.75
8	8" MJ Gate Valve	EA	6	$ 1,943.40	$ 11,660.40
9	8" MJ Tees, MJ Reducers, MJ Sleeves & MJ Bends	LF	8	$ 492.00	$ 3,936.00
10	8" MJ Plug	EA	2	$ 430.50	$ 861.00
11	Water Service - Near Side	EA	11	$ 1,476.00	$ 16,236.00
12	Water Service - Far Side	EA	17	$ 1,722.00	$ 29,274.00
13	Water Service Connection to Home	EA	28	$ 3,690.00	$ 103,360.00
14	Existing Well Seal	EA	28	$ 2,000.00	$ 56,000.00
15	8" EBAA Restraint Harness	EA	0	$ 338.25	$ -
16	Disinfection and Testing	LF	2527	$ 2.78	$ 7,024.55
17	Thrust Blocks	EA	18	$ 246.00	$ 4,428.00
18	Stream Crossing	EA	1	$ 40,000.00	$ 40,000.00
19	Traffic Control	LS	1	$ 2,585.00	$ 2,585.00
20	1/2 Width - Mill and Overlay	SY	3394	$ 20.98	$ 71,214.35
21	Tapping Fee Distribution	LS	1	$ 44,800.00	$ 44,800.00
	HILL ROAD TOTAL				$ 737,945.58
	HIHG SERVICE AREA BOOSTER STATION				
1	Booster Station, Generator, Transfer Switch, SCADA	LS	1	$ 1,279,300.00	$ 1,279,300.00
	SUBTOTAL CONSTRUCTION				$ 4,023,549.71
	10% CONTINGENCY				$ 402,354.97
	TOTAL				$ 4,425,904.68

A) ENGINEERING DESIGN (8% OF CONSTRUCTION)		$ 321,883.98
B) INSPECTION (8% OF CONSTRUCTION)		$ 321,883.98
C) LEGAL (1% OF CONSTRUCTION)		$ 40,235.50
D) AUTHORITY ADMINISTRATION (10% OF A, B, AND C)		$ 68,400.35
TOTAL ENGINEERING DESIGN, INSPECTION AND LEGAL FUND		$ 752,403.80

SUM OF CONSTRUCTION, CONTINGENCY, DESIGN, INSPECTION, LEGAL, AND PRA ADMINISTRATION	$ 5,178,308.47



PARK AVENUE, OLD BETHLEHEM PIKE,
THREE MILE RUN ROAD, AND HILL ROAD
RIDGE RUN PFAS HSCA SITE

Date: 7/31/2018

Bucks County Pennsylvania GIS

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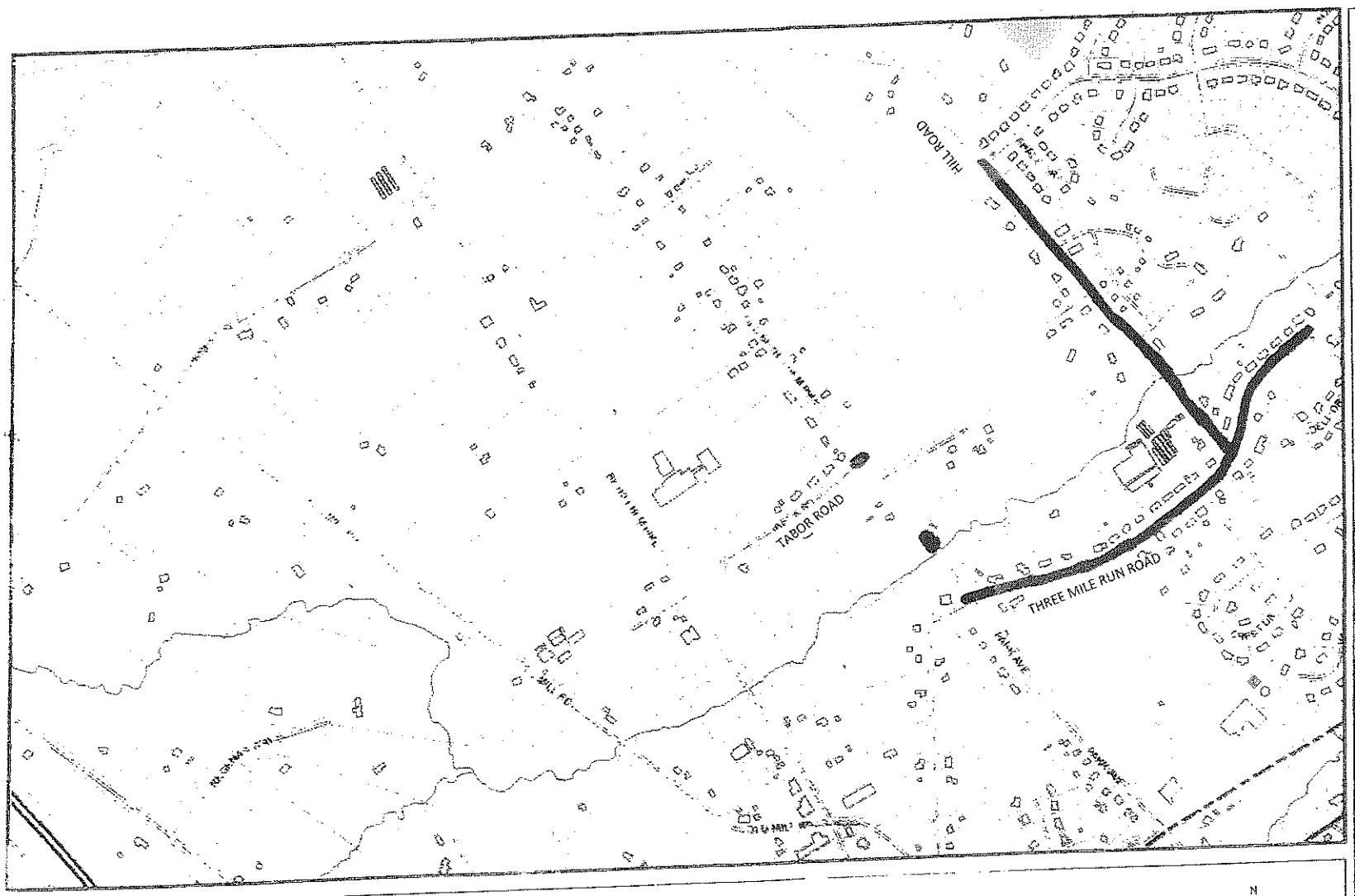

Legend

- Municipal Building
- Schools
- Golf Course
- Library
- Place Names

Major Roads 600 - 9600

- Interstate
- Turnpike
- US Highway
- State Highway
- Ramp

Streets

- Local Roads
- Rail Line
- Streams
- Municipality
- Water Areas
- Parkland No Fill
- Parcels
- Buildings

PROPOSED 1/2 WIDTH MILL AND OVERLAY

Bucks County Pennsylvania GIS

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PARK AVENUE, OLD BETHLEHEM PIKE, THREE MILE RUN ROAD, AND HILL ROAD RIDGE RUN PFAS HSCA SITE

N W E S

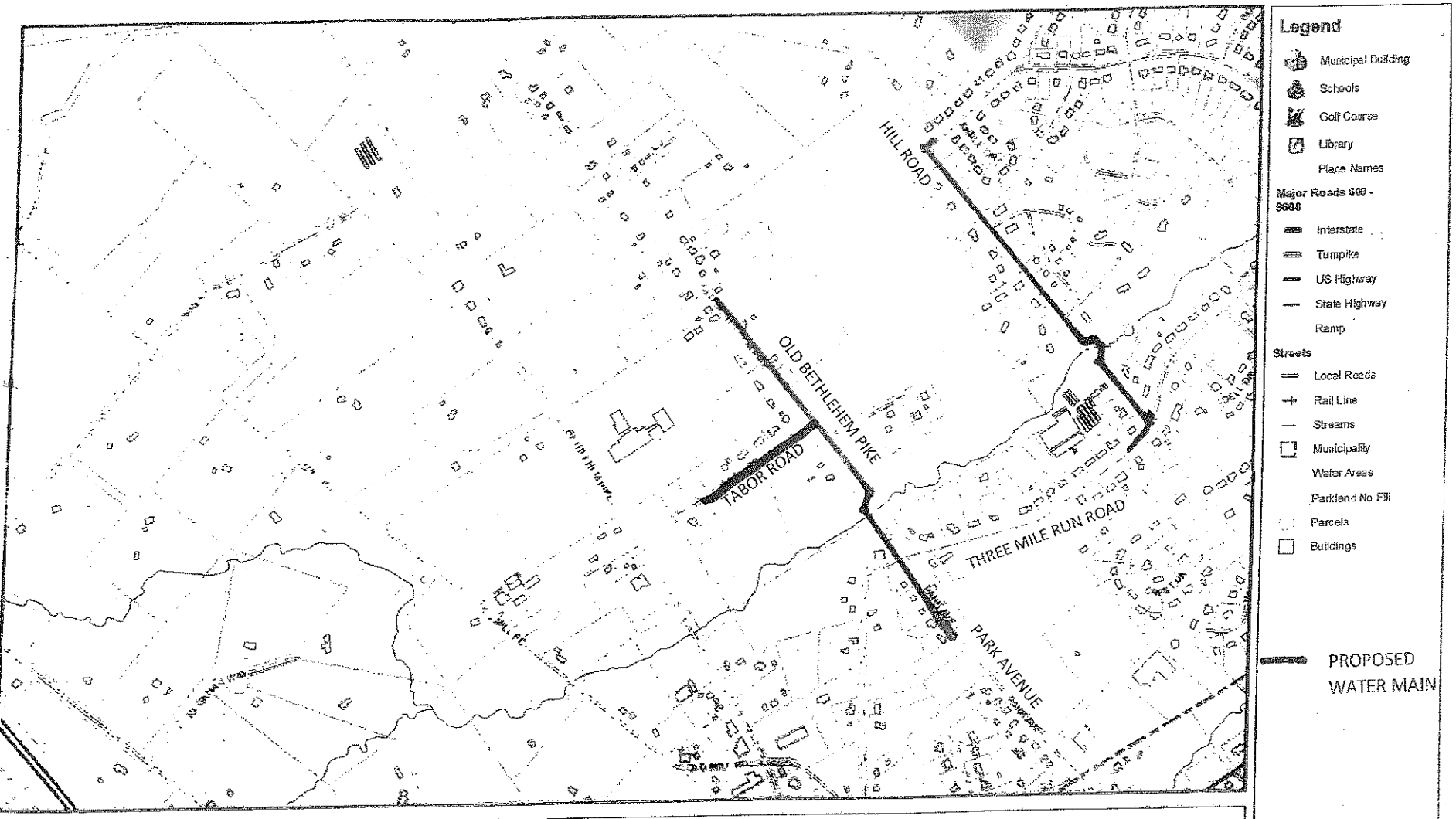
Date: 7/31/2018

RIDGE RUN PFAS HSCA
TAKEOFF AND BUDGET ESTIMATE V
8/31/2018

ITEM NO.	CONSTRUCTION ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST
	PARK AVENUE, OLD BETHLEHEM PIKE, & TABOR ROAD WATER MAIN				
1	Tie Into Existing Main	LS	1	$ 1,291.50	$ 1,291.50
2	8" Water Main, Off Road	LF	2644	$ 61.50	$ 162,606.00
3	8" Water Main, In Paved Road	LF	157	$ 125.46	$ 19,697.22
4	8" Water Main, In Stone Road (Tabor)	LF	1355	$ 73.80	$ 99,999.00
5	8" Water Main, Crossing Stream	LF	190	$ 98.40	$ 18,696.00
6	Fire Hydrant Assembly, 6" DIP, 6" MJ GV	EA	8	$ 6,150.00	$ 49,200.00
7	6x8 Hydrant Tee	EA	8	$ 645.75	$ 5,166.00
8	8" MJ Gate Valve	EA	16	$ 1,943.40	$ 31,094.40
9	8" MJ Tees, MJ Reducers, MJ Sleeves & MJ Bends	EA	14	$ 492.00	$ 6,888.00
10	8" MJ Plug	EA	5	$ 430.50	$ 2,152.50
11	Water Service - Near Side	EA	24	$ 1,476.00	$ 35,424.00
12	Water Service - Far Side	EA	9	$ 1,722.00	$ 15,498.00
13	Water Service Connection to Home	EA	33	$ 3,670.00	$ 121,110.00
14	Existing Well Seal	EA	33	$ 2,000.00	$ 66,000.00
15	8" EBAA Restraint Harness	EA	1	$ 338.25	$ 338.25
16	Disinfection and Testing	LF	4846	$ 2.78	$ 13,481.01
17	Thrust Blocks	EA	31	$ 246.00	$ 7,626.00
18	Stream Crossing	EA	1	$ 40,000.00	$ 40,000.00
19	Traffic Control	LS	1	$ 5,000.00	$ 5,000.00
20	Road Crossings - Mill and Overlay	SY	381	$ 20.98	$ 7,985.50
21	Tapping Fee Distribution	LS	1	$ 53,000.00	$ 53,000.00
	PARK AVE, OLD BETHLEHEM PIKE, & TABOR ROAD TOTAL				$ 760,853.38
	THREE MILE RUN ROAD				
1	Tie Into Existing Main	LS	1	$ 1,291.50	$ 1,291.50
2	8" Water Main, Off Road	LF	0	$ 61.50	$ -
3	8" Water Main, In Paved Road	LF	242	$ 125.46	$ 30,361.32
4	8" Water Main, In Stone Road (Tabor)	LF	0	$ 73.80	$ -
5	8" Water Main, Crossing Stream	LF	0	$ 98.40	$ -
6	Fire Hydrant Assembly, 6" DIP, 6" MJ GV	EA	1	$ 6,150.00	$ 6,150.00
7	6x8 Hydrant Tee	EA	1	$ 645.75	$ 645.75
8	8" MJ Gate Valve	EA	2	$ 1,943.40	$ 3,886.80
9	8" MJ Tees, MJ Reducers, MJ Sleeves & MJ Bends	LF	1	$ 492.00	$ 492.00
10	8" MJ Plug	EA	1	$ 430.50	$ 430.50
11	Water Service - Near Side	EA	2	$ 1,476.00	$ 2,952.00
12	Water Service - Far Side	EA	3	$ 1,722.00	$ 5,166.00
13	Water Service Connection to Home	EA	5	$ 3,670.00	$ 18,350.00
14	Existing Well Seal	EA	5	$ 2,000.00	$ 10,000.00
15	8" EBAA Restraint Harness	EA	0	$ 338.25	$ -
16	Disinfection and Testing	LF	242	$ 2.78	$ 672.71
17	Thrust Blocks	EA	4	$ 246.00	$ 984.00
18	Stream Crossing	EA	0	$ 40,000.00	$ -
19	Traffic Control	LS	1	$ 500.00	$ 500.00
20	1/2 Width - Mill and Overlay	SY	399	$ 20.98	$ 8,364.38
21	Tapping Fee Distribution	LS	1	$ 8,030.30	$ 8,030.30
	THREE MILE RUN ROAD TOTAL				$ 98,277.26
	HILL ROAD WATER MAIN				
1	Tie Into Existing Main	LS	1	$ 1,291.50	$ 1,291.50
2	8" Water Main, Off Road	LF	0	$ 61.50	$ -
3	8" Water Main, In Paved Road	LF	2337	$ 125.46	$ 293,209.02
4	8" Water Main, In Stone Road (Tabor)	LF	0	$ 73.80	$ -
5	8" Water Main, Crossing Stream	LF	190	$ 98.40	$ 18,696.00
6	Fire Hydrant Assembly, 6" DIP, 6" MJ GV	EA	5	$ 6,150.00	$ 30,750.00
7	6x8 Hydrant Tee	EA	5	$ 645.75	$ 3,228.75
8	8" MJ Gate Valve	EA	6	$ 1,943.40	$ 11,660.40
9	8" MJ Tees, MJ Reducers, MJ Sleeves & MJ Bends	LF	8	$ 492.00	$ 3,936.00
10	8" MJ Plug	EA	2	$ 430.50	$ 861.00
11	Water Service - Near Side	EA	11	$ 1,476.00	$ 16,236.00
12	Water Service - Far Side	EA	17	$ 1,722.00	$ 29,274.00
13	Water Service Connection to Home	EA	28	$ 3,670.00	$ 102,760.00
14	Existing Well Seal	EA	28	$ 2,000.00	$ 56,000.00
15	8" EBAA Restraint Harness	EA	0	$ 338.25	$ -
16	Disinfection and Testing	LF	2527	$ 2.78	$ 7,024.55
17	Thrust Blocks	EA	18	$ 246.00	$ 4,428.00
18	Stream Crossing	EA	1	$ 40,000.00	$ 40,000.00
19	Traffic Control	LS	1	$ 2,585.00	$ 2,585.00
20	1/2 Width - Mill and Overlay	SY	0	$ 20.98	$ -
21	Tapping Fee Distribution	LS	1	$ 44,969.70	$ 44,969.70
	HILL ROAD TOTAL				$ 666,900.92
	SUBTOTAL CONSTRUCTION				$ 1,526,031.56
	10% CONTINGENCY				$ 152,603.16
	TOTAL				$ 1,678,634.72

A) ENGINEERING DESIGN (8% OF CONSTRUCTION)		$ 122,082.53
B) INSPECTION (8% OF CONSTRUCTION)		$ 122,082.53
C) LEGAL (1% OF CONSTRUCTION)		$ 15,260.32
TOTAL ENGINEERING DESIGN, INSPECTION AND LEGAL FUND		$ 259,425.37

SUM OF CONSTRUCTION, CONTINGENCY, DESIGN, INSPECTION, AND LEGAL	$ 1,938,060.09



Legend

- Municipal Building
- Schools
- Golf Course
- Library
- Place Names

Major Roads 600 - 9600

- Interstate
- Turnpike
- US Highway
- State Highway
- Ramp

Streets

- Local Roads
- Rail Line
- Streams
- Municipality
- Water Areas
- Parkland No Fill
- Parcels
- Buildings

PROPOSED WATER MAIN

PARK AVENUE, OLD BETHLEHEM PIKE, THREE MILE RUN ROAD, AND HILL ROAD RIDGE RUN PFAS HSCA SITE

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W E
S

Bucks County Pennsylvania GIS

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Date: 7/31/2018