

DECLARATION OF DR. JOHN BERGENDAHL

U.S. Patent No. 12,478,948

Issue Date: November 25, 2025

Title: PERFLUOROALKYL AND POLYFLUOROALKYL SORBENT
MATERIALS AND METHODS OF USE

Post Grant Review No.: PGR2026-00071

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37 C.F.R. § 42.8(b)(4)

37 C.F.R. §§ 42.200

37 C.F.R. § 42.208

37 C.F.R. § 42.22

37 C.F.R. § 42.204(a)

Petition for PGR of U.S. Patent No. 12,478,948

I. INTRODUCTION

1. I am over the age of eighteen (18) and otherwise competent to make this declaration.

2. I have been retained by Norit Americas, Inc. (“Norit”) as an independent expert consultant. Although I am being compensated at my rate of \$200 per hour for the time I spend on this matter, no part of my compensation depends on the outcome of this proceeding, and I have no other interest in this proceeding. To the best of my knowledge, I have no financial interest in Norit.

3. This Declaration involves U.S. Patent No. 12,478,948 (the “’948 Patent”) (*EX-1001*), titled “PERFLUOROALKYL AND POLYFLUOROALKYL SORBENT MATERIALS AND METHODS OF USE” and listing Rebecca L. Distefano and Richard A. Mimna as the inventors.

4. For the purposes of this declaration, as discussed later, I have been instructed to assume that the effective filing date of the claims of the ’948 Patent is no earlier than April 3, 2019, the filing date of provisional application 62/828,790.

5. I understand that according to USPTO records, the ’948 Patent is currently assigned to Calgon Carbon Corporation (“Calgon” or “Patent Owner”).

6. The ’948 Patent describes well-known sorbent compositions for use in removal for perfluoroalkyl and polyfluoroalkyl substances (PFAS) and perfluorooctanoic acid (PFOA), and well-known methods for using such sorbents

in water to remove PFAS and PFOA. *EX-1001*, Abstract. I am familiar with the technology described in the '948 Patent as of the earliest possible priority date of April 3, 2019.

7. In preparing this Declaration, I have reviewed the '948 Patent (*EX-1001*), the file history of the '948 Patent (*EX-1002*), and each of the documents cited herein, and I have considered these documents in light of the general knowledge in the art as of April 3, 2019. For convenience, the materials I considered in forming my opinion are listed in Appendix A. In formulating my opinions, I have relied upon my experience in the relevant art. I have also considered the viewpoint of a person of ordinary skill in the art ("POSA") in the relevant field, as of April 3, 2019, who I describe below (§V.E).

8. The opinions and comments formulated during this assessment are based on observations and information available at the time of the investigation. The findings presented herein are made to a reasonable degree of scientific certainty. I have made every effort to accurately and completely investigate all areas of concern identified during my investigation.

9. I have been asked to provide my technical expertise, analysis, insights, and opinions regarding the '948 Patent and relevant references that form the basis of the arguments set forth by Norit, with respect to the validity of the '948

Patent. As I describe in detail below, I offer the following opinions in this

Declaration:

- A POSA would have found Claims 1-5 of the '948 Patent anticipated by Kempisty.
- A POSA would have found Claims 1-5 of the '948 Patent obvious over McNamara, alone or in view of Cannon.
- A POSA would have found Claims 1-5 of the '948 Patent obvious over Mueller in view of McDougall and Cannon.
- A POSA would have found Claims 1-5 of the '948 Patent obvious over Mimna in view of Reactivation Services and Cannon.
- A POSA would have found Claim 5 fails to meet the written description requirement under 112(a).

II. MY BACKGROUND AND QUALIFICATIONS

10. My expertise qualifies me to do the type of analysis required in this case for the field of contaminated water treatment. Of particular relevance, I am an associate professor in the Department of Civil and Environmental Engineering at Worcester Polytechnic Institute, and I was the Director of the Environmental Engineering Program from 2015 to 2026. At Worcester Polytechnic Institute, I have developed and teach courses related to treatment of contamination including: CE3060 Water Treatment, CE3061 Wastewater Treatment, CE4600 Hazardous

and Industrial Waste Management, CE4620 Environmental Engineering Lab II, ES2800 Environmental Impacts of Engineering Decisions, CE561 Advanced Principles of Wastewater Treatment, CE563 Industrial Waste Treatment, CE569 Environmental Treatability Laboratory, and CE572 Physical and Chemical Treatment Processes.

11. Throughout the remainder of this Declaration, I will refer to the field of water purification and sorbents, as the “relevant field” or the “relevant art.” In formulating my opinions, I have relied upon my training, knowledge, and experience in the relevant art. A copy of my current curriculum vitae is provided in Appendix B, and it provides a comprehensive description of my academic and employment history, including a list of relevant art publications for at least the last 30 years.

12. I started in the relevant art as a student at the University of Connecticut (“UCONN”) where I earned a B.S. in Mechanical Engineering in 1985, and M.S. in Environmental Engineering in 1996, and a Ph.D. in Chemical Engineering in 1999. Relevant coursework that I took during my studies included: Environmental Engineering Chemistry, Environmental Organic Chemistry, Bioprocesses, Contaminant Source Remediation, Contaminant Transport, Chemical Engineering Thermodynamics, Transport Phenomena, and Reaction Kinetics.

13. In 1985, I began my career in engineering when I joined General Dynamics, Electric Boat Division, Groton, CT as an Associate Engineer (“EB”). Between 1985 and 1992, I continued my career at EB serving as an Associate Engineer, Engineer, and Senior Engineer. After leaving EB, I had the privilege of serving during an internship in the Technical Assistance Program at the Connecticut Hazardous Waste Management Service in Hartford, CT.

14. Throughout my doctoral program I served as a Teaching Assistant and a Research Associate. Following completion of my Ph.D., I served as a Postdoctoral Research Fellow with the Environmental and Water Resources Engineering Program for the Department of Civil Engineering, at the University of Texas, Austin. In January 2000 I joined the faculty at Worcester Polytechnic Institute (“WPI”) in Worcester, MA as an Assistant Professor. I am currently a tenured member of the faculty at WPI as an Associate Professor, serving in that role since July 2006.

15. During my tenure with the faculty at WPI, I have instructed undergraduate and graduate level courses in Physical and Chemical Treatment Processes, Advanced Principles of Wastewater Treatment, Civil Engineering and Computer Fundamentals, Environmental Treatability Laboratory, Wastewater Treatment, Hazardous and Industrial Waste Management, Treatment System Hydraulics, and Industrial Waste Treatment.

16. Throughout a career spanning over three decades, including twenty-five years in research and teaching at WPI, I have published numerous articles and contributed to scholarly works devoted to environmental remediation, including, for example, peer-reviewed publications such as “Identification and Quantification of Wide Variety of Inorganic Nanoparticles in Municipal Wastewater,” by Chen and Bergendahl, published in 2021 in *Journal of Hazardous, Toxic, and Radioactive Waste*, **25** (4), “Effect of pH, Temperature, and Use of Synergistic Oxidative Agents on the Ultrasonic Degradation of Tris-2 Chloroethyl Phosphate, Gemfibrozil, and 17b Estradiol in Water,” by Alvarez Corena and Bergendahl, published in 2021 in *Journal of Environmental Chemical Engineering*, **9**, “Transdisciplinarity and the Food Energy and Water Nexus: Ecological Modernization and Supply Chain Sustainability Perspectives,” by Bergendahl, Sarkis, and Timko, published in 2018 in *Resources, Conservation, and Recycling*, **133**, 309-319, “Advanced Oxidation of Five Contaminants in Water by UV/TiO₂: Reaction Kinetics and Byproduct Identification,” by Alvarez Corena, Bergendahl, and Hart, published in 2016 in *Journal of Environmental Management*, **181**, 544-551, “Photocatalytic Oxidation of Five Contaminants of Emerging Concern by UV/TiO₂: Identification of Intermediates and Degradation Pathways,” by Alvarez Corena, Bergendahl, and Hart, published in 2016 in *Environmental Engineering Science*, **33**, 140-147, “Biodegradability of Fluorinated Fire-Fighting Foams in

Water,” by Bourgeois, Bergendahl, and Rangwala, published in 2015 in *Chemosphere*, **131**, 104-109, “An Equilibrium Study on Trichloroethylene Adsorption and Desorption from ZSM-5 in Water,” by Hawley, Bergendahl, and Thompson, published in 2013 in *Energy and Environmental Engineering*, **1**, 5-8, “A Kinetic Model for the Aqueous Degradation of MTBE by $\text{Fe}^0/\text{H}_2\text{O}_2$ ” by Al Ananzeh, Bergendahl, and Thompson, published in 2007 in *Progress in Reaction Kinetics and Mechanism*, **32**, 131-151, “Kinetic Model for the Degradation of MTBE by Fenton’s Oxidation” by Al Ananzeh, Bergendahl, and Thompson published in 2006 in *Environmental Chemistry*, **3**, 40-47, “Fenton’s Oxidation of MTBE with Zero-Valent Iron” by Thies and Bergendahl published in 2004 in *Water Research*, **38**, 327-334, and “Pilot-Scale Fenton’s Oxidation of Organic Contaminants in Groundwater Using Autochthonous Iron” by Hubbard, Bergendahl, and Grasso published in 2003 in *Journal of Hazardous Materials*, **99**, 43-56, 2003.

17. I authored a book chapter “Environmental Issues of Gasoline Additives – Aqueous Solubility and Spills” in *Solubility, Thermodynamics and Environmental Issues*, edited by T. Letcher, published by Elsevier in 2007. I also authored a textbook *Treatment System Hydraulics*, published by American Society of Civil Engineers in 2007.

18. I am currently a member of the American Institute of Chemical Engineers and American Society of Civil Engineers. I have been on the Editorial Board of *Soil and Sediment Contamination, An International Journal*, since 2003, and have reviewed manuscripts for many professional journals (including *Environmental Science and Technology*, *Environmental Engineering Science*, etc.), and have served on proposal review panels for organizations such as the *Environmental Protection Agency*, the *Transportation Research Board*, ACS's *Petroleum Research Fund*, and the *National Science Foundation*. I am a licensed Professional Engineer in Connecticut.

III. RELEVANT LEGAL STANDARDS

19. I am not a lawyer and do not provide any legal opinions in this Declaration. Although I am not a lawyer, I have been informed by counsel and understand that certain legal standards are to be applied by technical experts in forming opinions regarding the meaning and validity of patent claims. I have been asked to provide my opinions regarding whether the claims of the '948 Patent would have been obvious to a POSA at the time of the alleged invention, in light of the prior art.

20. I have been informed that, to anticipate a claim under 35 U.S.C. § 102, a reference must teach or disclose every element of the claim either expressly or inherently to a person having ordinary skill in the relevant art. I have also been

informed that, to be an inherent disclosure, the prior art reference must necessarily disclose the limitation, and the fact that the reference might possibly practice or contain a claimed limitation is insufficient to establish that the reference inherently teaches the limitation.

21. I have been informed by counsel and understand that a patent claim is not patentable under 35 U.S.C. § 103 if the differences between the patent claim and the prior art are such that the claimed subject matter as a whole would have been obvious at the time the claimed invention was made to a POSA.

Obviousness, as I have been informed by counsel and understand, is based on the scope and content of the prior art, the differences between the prior art and the claim, the level of ordinary skill in the art, and, to the extent that they exist, certain objective indicia of non-obviousness.

22. I have been informed by counsel and understand that objective indicia can be important evidence regarding whether a patent is obvious or nonobvious, if it has an appropriate nexus to the claimed invention, i.e., is a result of the merits of a claimed invention (rather than the result of design needs or market-pressure advertising or similar activities). Such indicia include: commercial success of products covered by the patent claims; a long-felt need for the invention; failed attempts by others to make the invention; copying of the invention by others in the field; unexpected results achieved by the invention as compared to the closest prior

art; praise of the invention by the infringer or others in the field; the taking of licenses under the patent by others; expressions of surprise by experts and those skilled in the art at the making of the invention; and the patentee proceeded contrary to the accepted wisdom of the prior art.

23. I have been informed by counsel and understand that whether there are any relevant differences between the prior art and the claimed invention is to be analyzed from the view of a POSA at the time of the invention. As such, my opinions below as to a POSA are as of the time of the invention, even if not expressly stated as such; for example, even if stated in the present tense. In this case, as I discuss in section V.C below, I have been instructed to assume that “the time of the invention” for the claims of the ’948 Patent is April 3, 2019.

24. In analyzing the relevance of the differences between the claimed invention and the prior art, I have been informed by counsel and understand that I must consider the impact, if any, of such differences on the obviousness or non-obviousness of the invention as a whole, not merely some portion of it. The person of ordinary skill in the art faced with a problem is able to apply his or her experience and ability to solve the problem and also look to any available prior art to help solve the problem.

25. I have been informed by counsel and understand that a precise teaching in the prior art directed to the subject matter of the claimed invention is

not needed. I have been informed by counsel and understand that one may take into account the inferences and creative steps that a POSA would have employed in reviewing the prior art at the time of the invention. For example, if the claimed invention combined elements known in the prior art and the combination yielded results that were predictable to a POSA at the time of the invention, then this evidence would make it more likely that the claim was obvious. On the other hand, if the combination of known elements yielded unexpected or unpredictable results, or if the prior art teaches away from combining the known elements, then this evidence would make it more likely that the claim that successfully combined those elements was not obvious.

26. I have been informed by counsel and understand that there are recognized, exemplary, rationales for combining or modifying references to show obviousness of claimed subject matter. Some of the rationales include the following: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to yield predictable results; use of a known technique to improve a similar device (method or product) in the same way; applying a known technique to a known device (method or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; known work in one field of endeavor may prompt

variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations are predictable to a POSA; and some teaching, suggestion, or motivation in the prior art that would have led a POSA to modify the prior art reference or to combine prior art teachings to arrive at the claimed invention.

27. I have been informed by counsel and understand that 35 U.S.C. § 112(a) requires, among other things, that the specification contain a written description of the invention sufficient to demonstrate to a person of ordinary skill in the art that the inventor had possession of the claimed invention as of the filing date. I have been informed by counsel and understand that, to satisfy the written description requirement, the specification must describe the claimed invention in sufficient detail such that a POSA can reasonably conclude that the inventor had possession of the full scope of the claimed invention, and that the written description requirement is not satisfied merely by disclosing a desired result or function without adequately describing how the result or function is achieved.

28. I have been informed by counsel and understand that whether the written description requirement is met is assessed from the perspective of a POSA reading the specification as of the filing date, and that the specification need not describe every embodiment of a claimed genus, but it must convey enough information — through representative species, structural features, or other

identifying characteristics — to demonstrate that the inventor possessed the full scope of the claimed invention. I have also been informed by counsel and understand that, when a claim is drawn broadly to encompass a genus, the specification must disclose a representative number of species falling within the scope of the genus, or structural features common to the members of the genus, so that a POSA can visualize or recognize what is claimed, and that the disclosure of a single species or a narrow subset does not necessarily provide adequate written description support for a broad genus claim unless the POSA would understand from the disclosure that the inventor possessed the full breadth of what is claimed.

IV. OVERVIEW

29. The Challenged Claims are generally directed to using reactivated carbon to remove per- and polyfluoroalkyl substances (PFAS), commonly known as man-made “forever chemicals”, from a fluid, and specify a reactivation temperature range and the source of the reactivated carbon, namely spent activated carbon that was previously used for water filtration. In particular, the ’948 Patent claims that an activated carbon sorbent, which was previously used for water filtration until it became “spent”, is reactivated at a temperature within a specified range (500-1100°C) to form a successor sorbent of reactivated carbon, and then this successor sorbent is used to remove PFAS from a fluid. However, these limitations were well known in the art as described in the State of the Art (V.G)

and disclosed by the prior art references Kempisty, McNamara, Cannon, Mueller, McDougall, Mimna and Reactivation Services as I discuss below in section VII.

V. BACKGROUND

A. Summary of the '948 Patent

30. The '948 Patent is titled “PERFLUOROALKYL AND POLYFLUOROALKYL SORBENT MATERIALS AND METHODS OF USE” and describes “sorbents that have improved performance in removing per- and polyfluoroalkyl substances, including but not limited to PFOA, PFOS, and similar compounds from liquids and gases.” *EX-1001*, 1:44-47.

31. The '948 Patent acknowledges that several technologies, including granular activated carbon (GAC), were conventionally known and employed to remove PFAS substances from the environment, and specifically from drinking water, and identifies that “GAC has emerged as a leading solution.” The '948 patent explains there is “a continued need for performance improvements so that the GAC is even more effective at removing PFAS compounds from the environment and from drinking water.” *EX-1001*, 1:33-40.

32. In the context of improving the effectiveness of GAC at removing PFAS compounds, the Patent states that sorbents which include “inorganic materials” (also called “inorganic minerals”) as part of the sorbent composition – specifically ions, salts, oxides, hydroxides, or carbonates of calcium (Ca),

magnesium (Mg), strontium (Sr), barium (Ba), sodium (Na), potassium (K), or zinc (Zn) – are more effective at removing PFAS compounds compared to sorbents that do not include such inorganic materials/minerals. *EX-1001*, Abstract, 6:11-67, 7:40-8:19.

33. The Patent notes that, although it primarily discloses the mineral-containing sorbent materials as improving PFAS removal from water (compared to sorbents that do not include such inorganic minerals), these same mineral-containing sorbent materials are also suitable for removing any compounds and/or byproducts that cause taste and odor problems in water, *e.g.*, Geosmin, MIB, IBMP, MTBE, chlorine, chloramine, hydrocarbons, volatile organic compounds (VOCs), etc. *EX-1001*, 8:34-50; 6:22-25.

34. The '948 Patent does **not** disclose *how* nor *why* the presence of inorganic minerals (*e.g.*, Ca, Mg, Sr, Ba, Na, K, Zn) improves the effectiveness of GAC at removing PFAS compounds (or at removing taste and odor compounds) from water; rather, it simply discloses that they do. *EX-1001*, Abstract, 6:11-67, 7:40-8:19. And, the Patent does **not** disclose whether any inorganic mineral type (*e.g.*, Ca) results in more improvement, or less improvement, at PFAS compound (or taste and odor compound) removal over another inorganic mineral type (*e.g.*, Na). *Id.* And, as discussed below, the results of experimental examples depicted in Figures 4-7 demonstrate that the presence of inorganic minerals on GAC does

not always improve the GAC's effectiveness at removing PFAS compounds, but the '948 Patent lacks **any** explanation as to these different performance results.

EX-1001, 11:25-12:52, Figures 4-7.

35. The Patent describes that mineral-containing sorbent materials may be achieved by either (1) adding inorganic minerals to the sorbent composition during the process of forming the sorbent (*EX-1001*, 6:26-48, 7:30-52), or (2) reactivating spent activated carbon, that was previously used for water filtration (where inorganic minerals are naturally present), in a process that does not include a separate treatment step to remove inorganic minerals retained on the spent activated carbon as a result of the previous water filtration (*EX-1001*, 6:11-25, 6:48-63, 7:53-8:19).

36. Related to the second technique, the Patent explains that, if a precursor to a sorbent material is activated carbon that was previously used for water filtration¹ until it became "spent" (when its sorbent capacity is exhausted),

¹ The '948 Patent distinguishes "water filtration" uses of activated carbon – which "frequently" result in an inorganic-mineral-containing spent activated carbon – from "other applications" of activated carbon – which do not – including "food processing, beverage processing, sugar refining, wastewater treatment, waste gas

then the spent activated carbon will be impregnated with inorganic minerals that are naturally present in the ground water that was being filtered, including ions, oxides, and carbonates of calcium, magnesium, sodium, potassium and zinc. *EX-1001*, 6:48-63, 7:53-60, 7:67-8:4, 6:11-15, 5:55-58. During the subsequent reactivation of the mineral-containing spent activated carbon, the Patent describes that the inorganic minerals are retained to thereby form a sorbent material, *e.g.*, the spent activated carbon is not treated by acid washing to remove the inorganic minerals impregnated thereon. Accordingly, the resulting reactivated sorbent carries that mineral content forward into reuse. *EX-1001*, 8:5-19, 2:35-44.

37. The Patent describes that reactivated carbon is manufactured by heating spent activated carbon in furnaces that are devoid of oxygen and using steam as a selective oxidant, whereby the heating may take place above 700°C, and the resulting reactivated carbon may thereafter be reused for various purposes including water treatment. *EX-1001*, 5:62-6:4. The '948 Patent also describes that the temperature of heating during reactivation may be “about² 500°C, about 550°C,

treatment, tank cleaning, tank degassing, and combinations of the above.” *EX-1001*, 7:53-67, 6:11-15.

² The '948 Patent defines “about” as “plus or minus 10% of the numerical value of the number with which it is being used.” *EX-1001*, 3:28-31.

about 600°C, about 650°C, about 700°C, about 750°C, about 800°C, about 900°C, about 950°C, about 1000°C, about 1050°C, about 1100°C, or any range that is made of any two or more points in the above list.” *EX-1001*, 6:4-10; *see also id.*, 9:44-47 (“[t]he exhausted F400 is reactivated under elevated temperatures...”). Thus, the Patent presents the range of about 500°C to about 1100°C as the thermal environment for producing the reactivated sorbent. *Id.* The Patent does **not** identify any benefits or tradeoffs associated with heating spent activated carbon at one stated temperature (*e.g.* 500°C), versus a different stated temperature (*e.g.*, 1100°C), within this thermal environment temperature range. By not disclosing such details, the Applicant acknowledged that selecting a reactivation heating temperature was a known design choice to a POSA, and the benefits and tradeoffs associated with such selection were well-within the knowledge of a POSA. *Id.*

38. The Patent presents several experimental examples with several exemplary sorbents in Figures 1-7. *EX-1001*, 9:32-12:52, 2:52-3:9. For example, with respect to Fig. 1, the breakthrough curves of an experiment with F400 and F400 CMR sorbents³, “the virgin F400 carbon began to show elevated

³ The now-reactivated F400 is designated as F400 CMR (Custom Municipal React). The reactivated F400 CMR is similar to virgin F400 material, but because the reactivated F400 CMR was previously used to treat groundwater with elevated

concentrations at about 10,000 bed volumes” whereas the F400 CMR (reactivated) containing residual inorganic material “resisted breakthrough of PFOA until at least about 20,000 bed volumes.” *EX-1001*, 10:1-12.

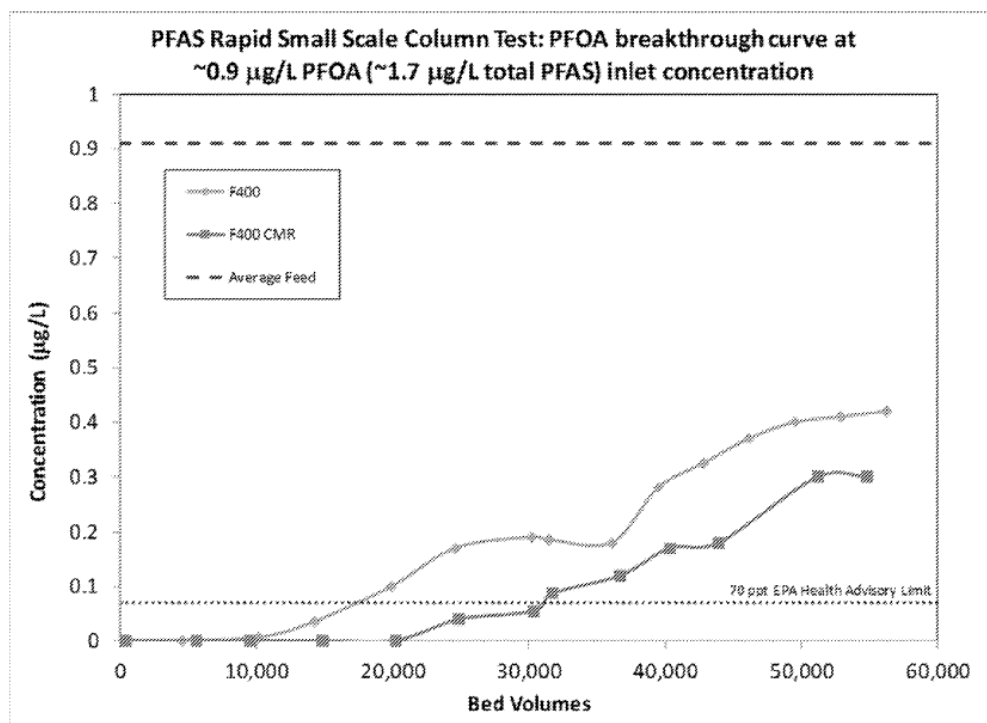


FIG. 1

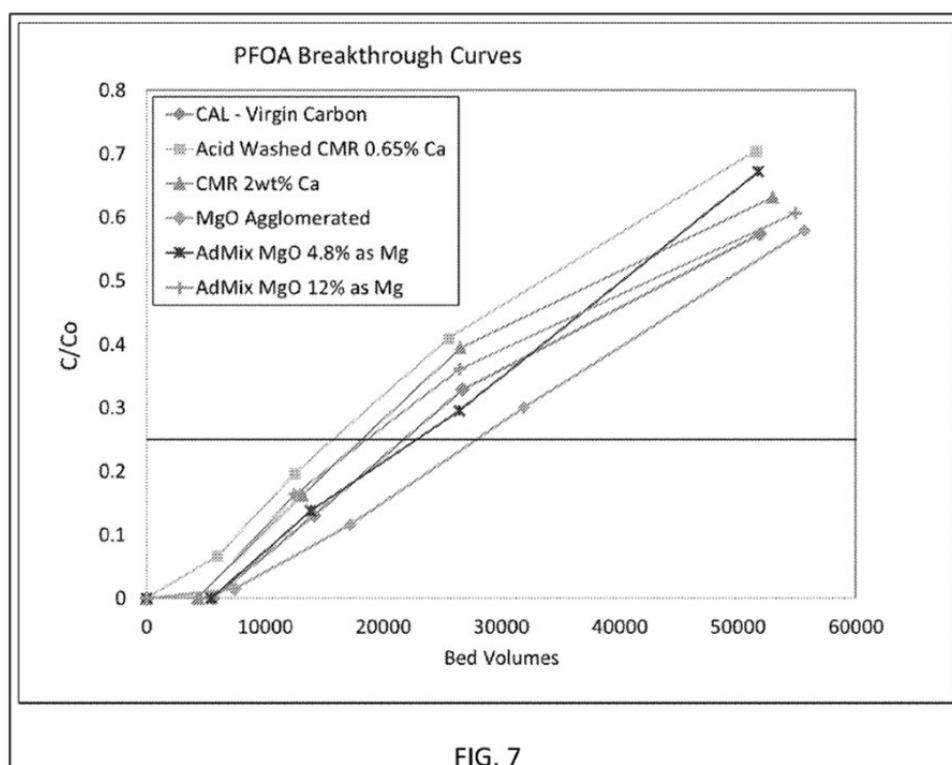
EX-1001, Fig. 1.

39. The depicted results in other experimental examples demonstrate that the Patent’s statement that mineral-containing sorbent materials have improved calcium levels, the reactivated F400 CMR has a higher calcium content than virgin F400 activated carbon. In Example 1, the F400 CMR had a calcium content of about 0.36 wt. % versus 0.05 wt. % for virgin F400. *EX-1001*, 9:48-55.

PFAS removal performance (compared to sorbents that do not include such inorganic minerals) may be PFAS-compound dependent, GAC-type dependent, and/or inorganic-mineral-amount dependent; however, the Patent lacks **any** explanation as to *how* or *why* these dependencies, and differing performance results, exist.

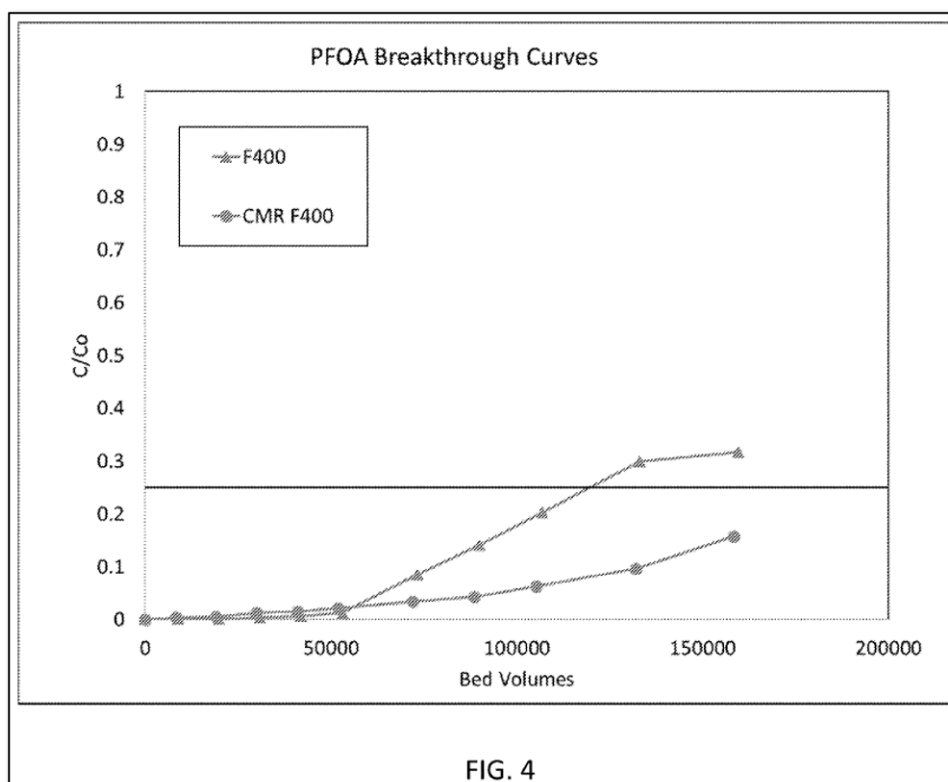
40. For example, the results shown and described for the Figure 7 experimental example show that CAL-Virgin Carbon (a virgin sorbent that is **not** treated to include inorganic minerals)⁴ had better PFOA removal performance than three inorganic-mineral-containing sorbents: (i) AdMix MgO 12% as Mg, (ii) CMR 2 wt% Ca; and (iii) Acid Washed CMR 0.65% Ca. *EX-1001*, Fig. 7, 11:53-12:52, Table 3. And, these same experimental results show that, with magnesium (Mg) as the inorganic mineral contained in the sorbent, PFOA removal performance declined with increasing wt% of Mg (4 wt% to 4.8 wt% to 12 wt%). *Id.*

⁴ Table 3 identifies CAL-Virgin Carbon as having 0.05 wt % of an unidentified divalent cation.



41. For the respective experiments of Figures 4 to 6, in which the same two GACs – reactivated CMR F400 (0.36 wt% Ca) and virgin F400 (0.05 wt% Ca) – were respectively used to treat water contaminated with different PFAS compounds, the performance results demonstrate that the presence of inorganic minerals on GAC does **not** improve the GAC’s effectiveness at removing **every** PFAS compound. Indeed, while the Figure 4 experimental example showed that reactivated CMR F400 (0.36 wt% Ca) had **better PFOA** removal performance than virgin F400 (0.05 wt% Ca)⁵,

⁵ For the RSSCT experiment with a 0.153 µg/L PFOA inlet concentration in water, the virgin F400 (0.05 wt% Ca) and F400 CMR (0.36 wt% Ca) showed similar

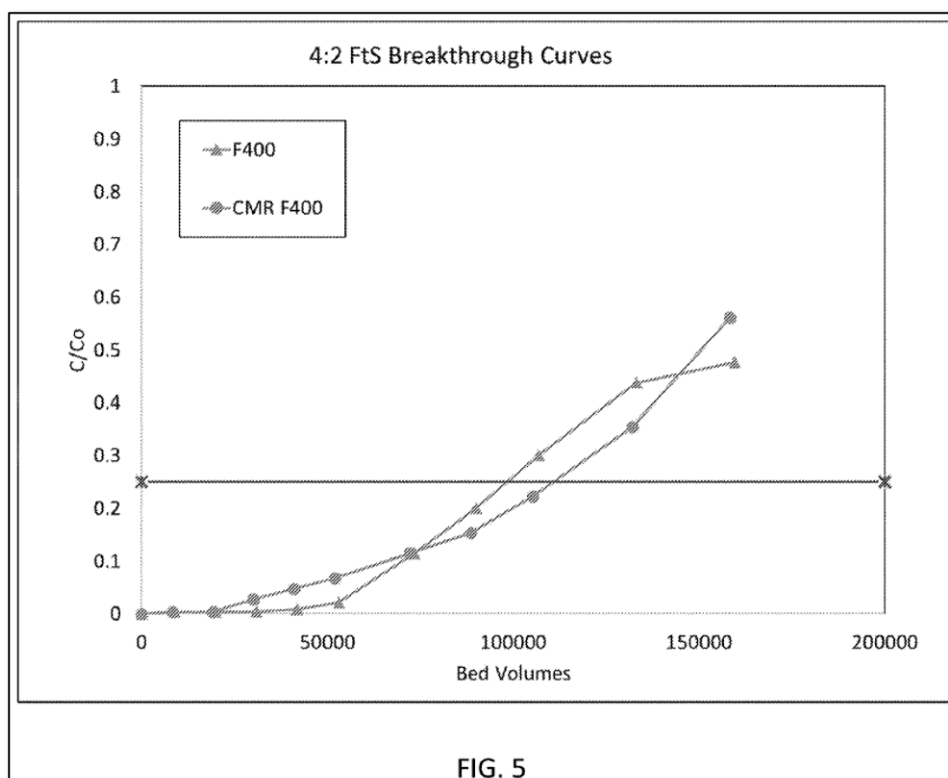


the Figure 5 experimental example showed that reactivated CMR F400 (0.36 wt% Ca) had **worse 4:2 FtS** removal performance in the initial experimental run

resistance to elevated PFOA concentrations until about 50,000 bed volumes, when the virgin F400 began to show increasing PFOA concentrations until reaching a 25% effluent-to-original-inlet breakthrough concentration ($0.03825 \mu\text{g/L}$ PFOA) around 125,000 bed volumes, while the F400 CMR's resistance was still well below this 25% breakthrough concentration at 150,000 bed volumes. *EX-1001*, 11:30-36, Figure 4.

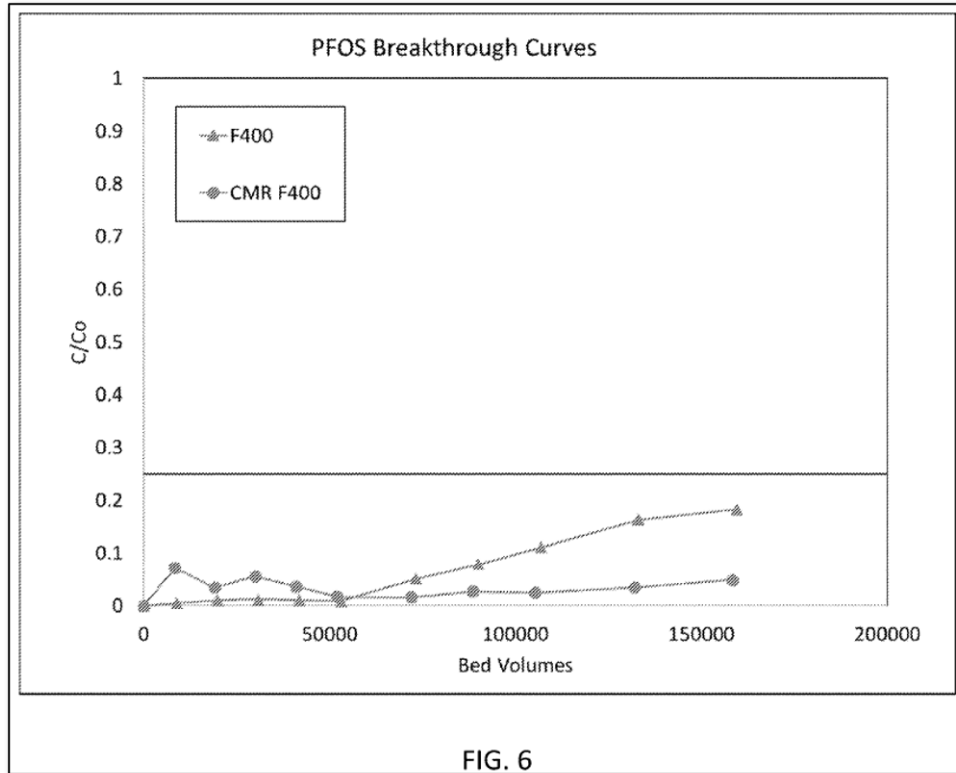
(<75,000 bed volumes) and at the end of the experimental run (>150,000) than virgin F400 (0.05 wt% Ca)⁶,

⁶ Figure 5 shows that, for the RSSCT experiment with a 0.130 µg/L 4:2 FtS inlet concentration in water, the F400 CMR began to show elevated 4:2 FtS concentrations at about 25,000 bed volumes while the virgin F400 resisted elevated 4:2 FtS concentrations until about 50,000 bed volumes, and with the virgin F400 reaching a 25% effluent-to-original-inlet breakthrough concentration (0.0325 µg/L 4:2 FtS) slightly faster than the F400 CMR (about 100,000 bed volumes for virgin F400 compared to 110,000 bed volumes for F400 CMR). *EX-1001*, 11:37-43, Figure 5. Additionally, as shown in the Figure 5 example, the F400 CMR reached the EPA Health Advisory Limit of 0.07 µg/L (equivalent to 0.538 C/C_o on the Y-axis in Figure 5) around 150,000 bed volumes, while the virgin F400 does not appear to reach the EPA limit. *Id.* (with the inlet concentration of 0.130 µg/L 4:2 FtS, C (0.07) divided by C_o (0.130) = 0.538).



and the Figure 6 experimental example showed that reactivated CMR F400 (0.36 wt% Ca) had **mixed (worse initial) PFOS** removal performance than virgin F400 (0.05 wt% Ca)⁷.

⁷ The PFOS breakthrough curves in Figure 6 show that, from the start of the RSSCT experiment with a 0.177 µg/L PFOS inlet concentration in water and until about 50,000 bed volumes, the F400 CMR had low, but more elevated, PFOS concentrations than the virgin F400, with the reverse occurring thereafter (after about 50,000 bed volumes the virgin F400 showed increasing PFOS concentrations higher than those for the F400 CMR), and with neither reaching a 25% effluent-to-



EX-1001, Figs. 4-6, 11:25-49. Again, the '948 Patent lacks **any** explanation as to **how** or **why** these differing performance results exist for the same two GACs but different PFAS compounds. *Id.*

original-inlet breakthrough concentration (0.04425 $\mu\text{g/L}$ PFOS) as of 150,000 bed volumes. *EX-1001*, 11:44-49, Figure 6.

B. Summary of the Challenged Claims

42. The Challenged Claims (Claims 1-5) include one independent method claim, Claim 1. Claim 1 (and dependent Claims 2-5) are each directed to the following method:

1. A method of removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid or gas, the method comprising:

providing a sorbent material comprising reactivated carbon, wherein the reactivated carbon is formed from a spent activated carbon, wherein the spent activated carbon was previously used for water filtration; and

contacting the sorbent material with a liquid or gas containing the PFAS wherein the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C.

EX-1001, Claim 1.

C. Claim Construction

43. I have been informed by counsel and I understand that in order to properly evaluate the Challenged Claims of the '948 Patent, the terms of the claims must first be interpreted. I have been informed by counsel and I understand that, for the purposes of this Declaration, the claims are to be construed under the so-called *Phillips* standard, under which each claim term in the Challenged Claims be

given its plain and ordinary meaning in this proceeding as would be understood by a person of ordinary skill in the art (“POSA”, defined below in Section V.E) as of the Priority Date (*see* Section V.C above) in light of the specification and prosecution history, unless the inventor has set forth a special meaning for a term. That is the meaning that I have applied in my analysis.

44. I have been informed by counsel that no court or administrative board has construed any of the claims of the ’948 Patent. If a board or court construes any term of the ’948 Patent, I reserve the right to supplement my opinions in view of such construction. I have also been informed by counsel that the Board does not construe claims terms unless the terms are in controversy, and then only to the extent necessary to resolve the controversy.

1. “about”

45. Claims 1 and 2 recite “a temperature of about 500°C to about 1100°C”, and “a temperature of about 700°C”, respectively. While the plain and ordinary meaning of the claim term “about” as an adverb is understood as approximate or around, the specification has provided a quantification of the term. The ’948 Patent explicitly states:

As used herein, the term ‘about’ means plus or minus 10% of the numerical value of the number with which it is being used. Therefore, about 50% means in the range of 45%-55%,”

EX-1001, 3:28-31.

2. “[T]he spent activated carbon is not treated to remove any inorganic materials that are present in ground water”

46. Claim 5 recites this phrase. A POSA would understand that the plain and ordinary meaning of this negative limitation, in view of the claim language and intrinsic evidence as a whole, is that the reactivated carbon, formed from the spent activated carbon, includes some amount of inorganic materials that the spent activated carbon adsorbed while it was being previously used for water filtration of ground water.

47. The specification uses similar negative language in the same context as claim 5, and identifies that a POSA should interpret this language as simply meaning that a successor sorbent material, formed from a spent activated carbon precursor, includes some amount of inorganic materials that the spent activated carbon adsorbed while it was being previously used for water filtration of ground water:

In some embodiments, the sorbent material is formed from a precursor that is **a** spent activated carbon that was previously used for water filtration and which is reactivated... In some embodiments, **the** spent activated carbon that was previously used for water filtration contains one or more inorganic materials that are present in ground water including ions, oxides and carbonates of calcium, magnesium, sodium, potassium, and zinc. In

some embodiments, **the sorbent material** formed from a precursor that is a spent activated carbon **is not treated to remove any of the inorganic materials that are present in ground water**. **This means that** the sorbent material will include ions, oxides, and carbonates of calcium, magnesium, sodium, potassium, and zinc. In still further embodiments, the sorbent material formed from a precursor that is a spent activated carbon is not treated by acid washing to remove any of the inorganic materials that are present in ground water. In such embodiments, the one or more ions, salts, oxides, hydroxides, or carbonates that are present in ground water have been slowly impregnated onto the surface of the spent activated carbon, and are retained during reactivation to thereby form a sorbent material.

EX-1001, 7:53-55, 7:67-8:19. Acid washing of the successor sorbent material (reactivated carbon) is the only disclosed example of “treatment to remove any inorganic materials present in ground water” that is forbidden by this negative language in the specification and in claim 5. *EX-1001*, 8:10-19 (reproduced above), 2:35-44, 11:53-60 (and 10:39-45). Consistent with the specification of the ’948 Patent, a POSA would understand claim 5 to recite: (i) an inherent characteristic of activated carbon becoming “spent” while filtering groundwater – the spent activated carbon adsorbed some amount of inorganic materials that were naturally present in the groundwater that it previously filtered – and (ii) not taking

a treatment action intended to remove these adsorbed inorganic materials from the spent activated carbon (*e.g.*, acid washing the spent activated carbon, acid washing the reactivated carbon, etc.). *Id.*; *EX-1001*, 6:48-54, 7:53-60, 7:67-8:4, 6:11-15, 5:55-58; State of the Art §V.G.5. Accordingly, and for example, a POSA understood that the plain and ordinary meaning of the negative limitation recited in claim 5, in view of the intrinsic evidence, is met by the disclosure of a reactivated carbon, formed by reactivating spent activated carbon that was previously used for filtration of groundwater, that has a higher ash content than the original activated carbon (before it was used for filtration of groundwater until it became “spent”). *EX-1001*, 7:53-55, 7:67-8:19; *see* State of the Art §V.G.5.

48. There is no disclosure in the '948 Patent specification of **any** activated carbon that would adsorb **all** inorganic materials (regardless of type or amount) from **all** ground waters (which may differ in inorganic composition and respective amounts), nor of **how** to form an activated carbon with such surface area and pore structure to adsorb **all** inorganic materials that may be present in **any** given ground water. *See* §VII.E (below).

49. Thus, a POSA would understand that the plain and ordinary meaning of the negative limitation of claim 5 is that the reactivated carbon, formed from the spent activated carbon, includes some amount of inorganic materials that the spent

activated carbon adsorbed while it was being previously used for water filtration of ground water.

50. It is noted that these interpretations are only applicable to this declaration and should not be construed as constituting, in whole or in part, Norit's own interpretation of any claims for any other purposes. It is my opinion that no other specific construction of any claim term is required because the relied-upon prior art meets each of the claims terms under any proper construction.

D. Priority Date of the Challenged Claims

51. For the purposes of this Declaration, I have been instructed by counsel to assume that the effective filing date of the '948 Patent is no earlier than April 3, 2019. For purposes of this Petition, Petitioner does not challenge the April 3, 2019 priority claim for the Challenged Claims. In this Declaration, when I use the shorthand "Priority Date", I am referring to April 3, 2019.

E. Person of Ordinary Skill in the Art

52. I have been informed by counsel and I understand that a person of ordinary skill in the art ("POSA") is a hypothetical person who is presumed to be aware of all pertinent prior art, thinks along conventional wisdom in the art, and is a person of ordinary creativity. I have also been informed by counsel and understand that there are multiple factors relevant to determining the level of ordinary skill in the pertinent art, including (1) the levels of education and

experience of persons working in the field at the time of the invention; (2) the sophistication of the technology; (3) the types of problems encountered in the field; and (4) the prior art solutions to those problems.

53. In my opinion, with respect to the '948 Patent, a person of ordinary skill in the art (POSA) in April 2019 would have a working knowledge of the principles of water filtration and sorbents. A POSA would have gained knowledge of these materials and processes through a mixture of education and work experience, such as by (i) having a Bachelor's degree in environmental engineering, civil engineering, mechanical engineering, chemical engineering, or equivalent degree, coupled with at least three years of experience; (ii) by obtaining a Master's degree or Doctorate in environmental engineering, civil engineering, mechanical engineering, chemical engineering, or equivalent degree, but having less experience; or (iii) by having no formal degree, but having experience in the relevant field of at least six years.

54. The knowledge and skill of a POSA is further reflected in the prior art references themselves, as well as in the State of the Art, which I discuss in section V.F below.

55. For purposes of this Declaration, in general, and unless otherwise noted, my statements and opinions, such as those regarding my experience and the understanding of a POSA generally (and specifically related to the references I

consulted herein), reflect the knowledge that existed in the field as of the Priority Date of the '948 Patent. Unless otherwise stated, when I provide my understanding and analysis below, it is consistent with the level of a POSA as of the Priority Date of the '948 Patent.

F. State of the Art

56. The following section describes the state of the art for activated carbon sorbents and methods of using such sorbents as of April 2019. The prior art references, and the discussions of what was known to a POSA, provide the factual support for the general description of the state of the art at the time of the invention, provide additional motivation to modify or combine the references. Accordingly, the Board should consider each of these references.

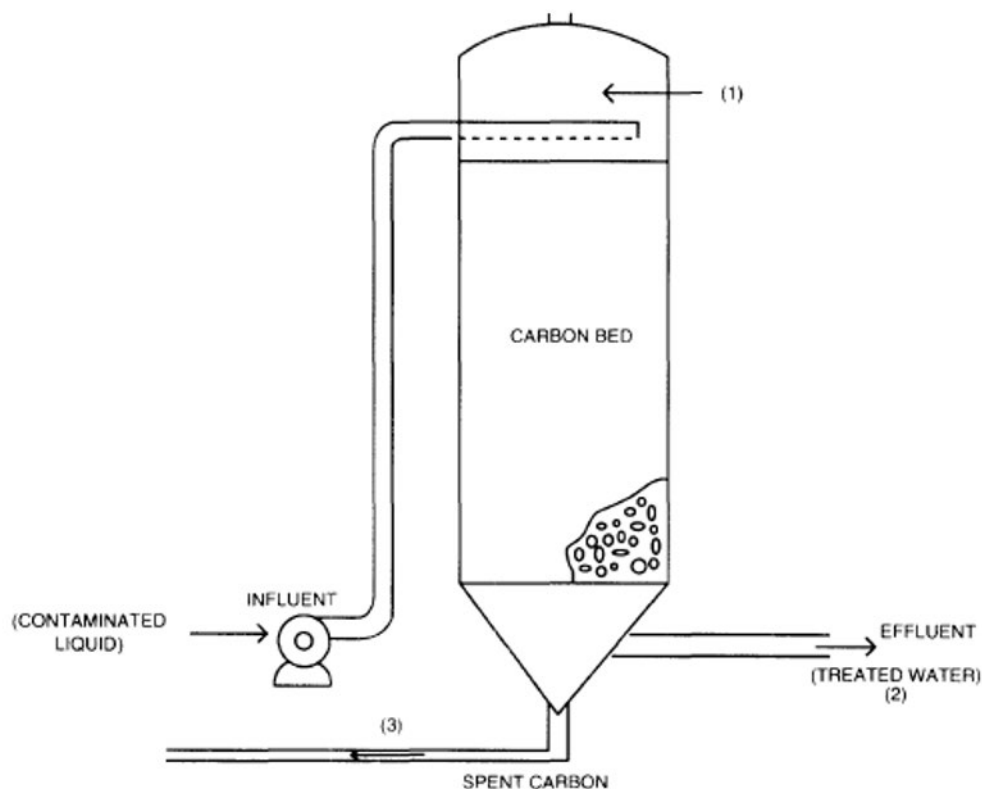
1. Activated Carbon

57. Activated carbon is a well-established sorbent material that has been used for purification purposes since Roman times. *EX-1015*, p. 1. Activated carbon treatment is based on the naturally occurring phenomenon of adsorption, in which molecules of a liquid or gas are trapped by the external or internal surfaces of a solid. *EX-1015*, p. 1; *EX-1038*, p. 2. The raw materials and production processes used to manufacture activated carbons give rise to the different physical properties and pore size distributions found in commercial grades of carbon. *EX-1015*, pp. 1-2; *EX-1038*, pp. 1-2. Regular carbon is activated by gaseous oxidation

or chemical activation. In gaseous oxidation, carbonization of the material occurs by destructive distillation, and heating to a temperature above 400°C and preferably from about 600° to about 800°C in an atmosphere of steam, carbon dioxide, or flue gas. This leaves a structure of relatively pure carbon. *EX-1010* 5:49-57. The activation process produces an extensive network of internal pores, and the process of adsorption takes place in three steps: first, the contaminant moves to the external surface of the activated carbon granules; it then moves deeper into the pore structure; and finally, a physical or chemical bond forms between the contaminant and the internal carbon surface. *EX-1016*, p. 2.

58. In the below-reproduced figure from a 1991 EPA publication, a simplified schematic of an example of a single-stage, fixed-bed granular activated carbon (“GAC”) system for use on a liquid stream (*e.g.*, contaminated groundwater) is shown:

Figure 1. Schematic Diagram of Fixed-Bed GAC System



EX-

1022, p. 3 (Figure 1).

59. Referring to the 1991 schematic of an exemplary fixed-bed GAC system shown in Figure 1 (reproduced above), the contaminated liquid (*e.g.*, contaminated groundwater) enters the top of the column (1). As the contaminated liquid flows through the column, the contaminants are adsorbed by the GAC in the carbon bed. The treated liquid (effluent) exits out of the bottom (2) of the column. During the carbon adsorption process, the available surface and pores of the GAC begin to fill up with the contaminants. At some point, the GAC becomes so saturated with the contaminants that they can no longer be effectively adsorbed

such that the effluent no longer meets the treatment objective / required performance criteria (*e.g.*, $C_{\text{effluent}} \approx C_{\text{influent}}$), and the carbon is said to be “spent” (3). The spent GAC (3) must be either disposed of and replaced, or recycled for reuse by reactivation (as discussed in more detail in §V.F.2 below), so that the treatment of the contaminated liquid may continue through the carbon adsorption process. *EX-1022*, pp. 2-3; *EX-1038*, pp. 3-4.

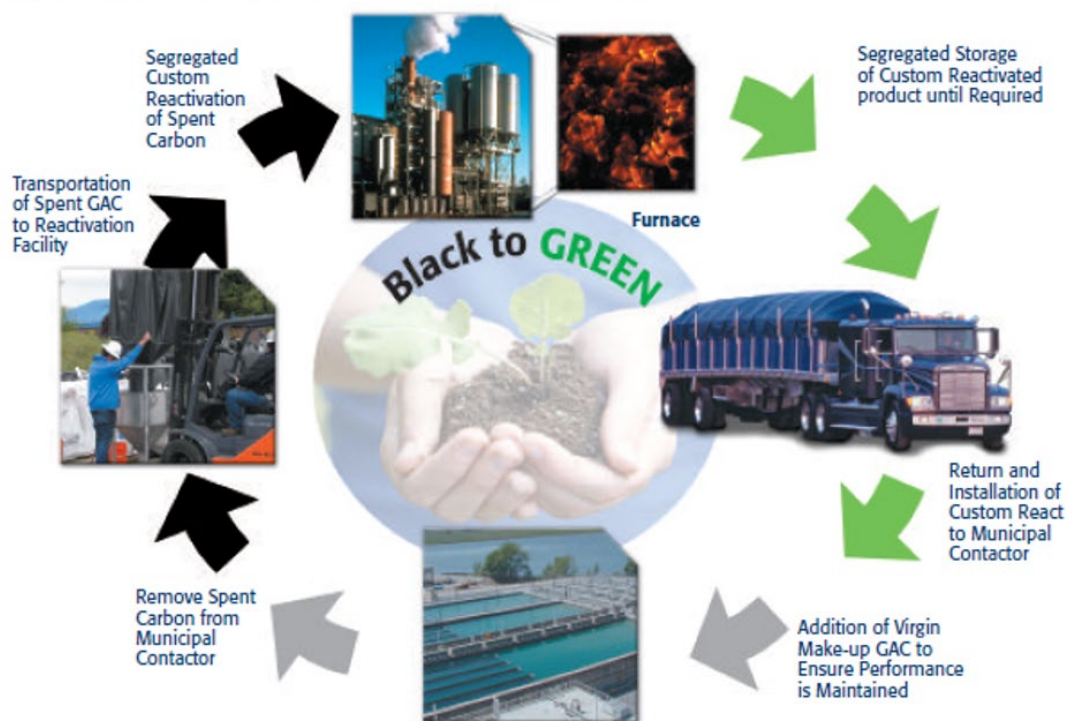
60. Adsorption by activated carbon has a long history of use as a treatment for municipal, industrial, and hazardous wastes. *EX-1016*, pp. 1-2. In particular, adsorption with GAC was widely accepted as a treatment technology for removing organic contaminants, including volatile organic compounds (“VOCs”), from groundwater, in part based on its long history of effectively removing organic contaminants from water and wastewater. *EX-1017*, p. 1; *EX-1038*, p. 1. GAC was established as a “Best Available Technology” under the Safe Drinking Water Act for the removal of regulated contaminants from drinking water by 1989. *EX-1017*, p. 1. Beyond conventional organic contaminants, and as discussed in more detail in State of the Art §V.G.4 (below), GAC emerged as a leading solution for the removal of per- and polyfluoroalkyl substances (“PFAS”) from drinking water and the environment.

2. Thermal Regeneration/Reactivation⁸ of GAC

61. Reactivation of spent granular activated carbon (GAC) is a well-established, high-temperature process, known and practiced for decades, by which the adsorptive properties of exhausted GAC are restored in a process that substantially parallels the activation process. *See EX-1010*. Reactivation allows the GAC to be recycled and reused. An example of the recycling and reuse of spent GAC provided by reactivation is depicted at a high level in the figure reproduced below from Patent Owner's 2009 whitepaper:

⁸ A POSA understood that the terms Regeneration and Reactivation, in the context of activated carbon and process temperatures greater than about 400°C, are generally used synonymously in the art as a whole.

Calgon Carbon's Cycle of Custom Reactivation



EX-1039, pp. 2-3; EX-1038, pp. 3-4.

62. As early as 1969, the Federal Water Pollution Control Administration published a comprehensive study on the thermal regeneration of spent GAC, establishing the reactivation process as a three-step procedure consisting of (1) drying, in which the wet carbon is dewatered at carbon temperatures in the range of 60°F to 212°F; (2) baking or pyrolysis, in which the adsorbed organic compounds are carbonized and volatilized in the temperature range of 212°F to 1500°F; and (3) activation, in which the remaining carbon residue is oxidized by steam and CO₂ at elevated temperatures to restore the original pore structure (the latter two steps paralleling the activation process). EX-1010 5:49-57; EX-1018, pp. iv, 3-4. By the late 1960s, multiple facilities were already performing thermal reactivation of

spent GAC in direct-fired multiple hearth furnaces. *EX-1018*, p. 2. In the activation step, spent carbon was heated at activating gas temperatures of approximately 1700°F, with carbon temperatures in the range of 1500°F to 1650°F (approximately 815°C to 900°C), utilizing steam as a selective oxidant. *EX-1018*, pp. iv, 7; *EX-1027*, p. 1.

63. It was also known that spent carbon could be thermally regenerated to its original virgin carbon properties or close to it, including bulk density, particle density, pore volume, and iodine number, with a carbon loss of only about 2%. *EX-1018*, pp. 5, 47; *EX-1008*, p. 1; *EX-1027*, p. 1; *EX-1037*, pp. ix, 3. As early as 1977, regeneration of spent activated carbon at a regeneration temperature in excess of 400°C and preferably about 600°C, and as high as 800°C or even 1,000°C, using steam, with complete regeneration achieved at 600°C was known. *EX-1010*, 7: 5-15, Table II; *see also EX-1008*, p. 1 (describing Reactivation Services of Cabot Corporation and stating “During thermal reactivation the exhausted GAC is heated to temperatures over 900°C. Adsorbed organics are thermally destroyed...”); *EX-1027*, p. 1 (describing Reactivation Services of Patent Owner and stating “Spent carbon is reactivated in the same manner that it is manufactured. In multiple hearth furnaces or rotary kilns, the spent carbon is heated to temperatures above 1,700°F utilizing steam as a selective oxidant. Adsorbed organics are either volatilized or pyrolysed to a carbon char.”); *EX-1011*,

pp. 76-77. As another example, related to per- and polyfluoroalkyl substances (“PFAS”) discussed in more detail in State of the Art §§V.G.3-V.G.4 below, studies showing testing of GAC, previously used to treat PFAS-contaminated water, and during thermal regeneration of the GAC, found no residual PFAS on the GAC when heated to 700°C in nitrogen, while noting that “short-chained PFASs were slightly detected in the aqueous trapping of off-gas at 800°C to 900°C conditions” and that “[d]estruction in gaseous phase can be completed at 1000°C.” *EX-1012*, pp. 625-626, 629, FIGS. 1-4; *EX-1013*, E4 (*citing same*).

64. Thus, thermal reactivation of spent GAC at temperatures of about 700°C and above was not only well-known but had been practiced and documented in the art for over fifty years before the priority date of the ’948 Patent.

65. The economics and performance of thermal reactivation further support its widespread adoption as a standard practice for GAC management. Reactivation of GAC was well-known to be significantly less expensive than purchasing replacement virgin GAC, and, as just one example, at the Cincinnati Water Works, reactivation represented roughly one-third the cost of replacement with new carbon. *EX-1019*, p. 790; *EX-1027*, p. 1; *EX-1008*, p. 1; *EX-1038*, pp. 3-4. Moreover, the overall CO₂ emission of reactivation is only 20 percent of the benchmark for producing virgin GAC, underscoring the environmental and economic advantages of the process. *EX-1008*, p. 1; *EX-1038*, p. 4. Furthermore,

data from the Cincinnati Water Works (recognized, in 2001, as the world's largest municipal GAC potable water treatment system) confirmed that reactivated carbon performs comparably to, and in some cases better than, its virgin counterpart. *EX-1019*, p. 795. Studies further corroborate that successful thermal regeneration, in which the physical properties of the spent carbon were restored to those of the virgin Filtrasorb 400, was achieved with only minimal volume loss per cycle. *EX-1018*, pp. 47, 79–81.

66. Thus, thermal reactivation of GAC at temperatures of between 500°C and 1000°C was a well-understood, economically advantageous, and technically proven process for restoring spent GAC for continued use in drinking water treatment applications, and had been so for decades before the filing of the '948 Patent.

3. Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)

67. PFAS are well-known, man-made chemical compounds that were developed in the 1930s and commonly manufactured for industrial and commercial applications in the 1950s. *EX-1023*, p. 1; *EX-1009*, p. 247. PFAS are “known to be resistant to heat, water, and oils, and, as a result, are frequently incorporated into a variety of industrial and commercial products such as nonstick cookware, stain-resistant clothing, food packaging, and firefighting foams.” *EX-1024*, p. 19; *see also EX-1009*, p. 247. PFAS contains fluorine atoms bonded to a carbon atom

chain where the “carbon-fluorine bond is the shortest and strongest covalent chemical bond found in nature and is the basis for the unique and beneficial chemical properties of PFAS.” *EX-1024*, p. 19. PFAS are typically characterized as being short-chain or long-chain compounds for which, following their long-standing and widespread use, there was increasing (and somewhat established) knowledge of their harmful toxicological effects. *EX-1024*, p. 19.

68. Detection of PFAS in humans was documented as early as the 1970s with wider documentation and testing for PFAS beginning in the 2000s. *EX-1023*, p. 2. The Environmental Protection Agency (EPA), in coordination with worldwide partners and companies, began raising awareness of the harmful effects of PFAS and initiated phaseouts of PFAS manufacturing and use in commercial and industrial applications. *EX-1023*, p. 2-3. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), which are examples of “perfluorinated compounds (PFCs)” that are a subset of PFAS, garnered the most attention due to their persistence in nature and exposure increasing the risks of cancer, birth defects, and hormone disruption, among other health related issues. *EX-1024*, p. 20; *EX-1030*, p. 1; *EX-1033*, p. 1. In May 2016, the EPA revised the lifetime health advisory limit for PFOA and PFOS from 400 nanograms per liter (ng/L) and 200 ng/L, respectively, to 70 ng/L, individually or in combination. *EX-1024*, p. 19; *EX-1031*, p. 462.

4. Remediation of PFAS

69. Removal of PFAS, among many other contaminants, in liquids is generally accomplished with sorbent materials, such as activated carbon. *EX-1005*, pp. 5-6; *EX-1030*, p. 2; *EX-1033*, p. 2. The most commonly used media for removal of PFAS in liquids is granular activated carbon (GAC), with studies on the use of GAC for PFAS removal dating at least back to 2013. *EX-1005*, p. 6; *EX-1030*, p. 2; *EX-1033*, p. 2; *EX-1026*, pp. 741 (§2.1, Table 1), 742-743 (§2.3), 744-745 (§3.2); *EX-1009*, pp. 251-253 (§3.2.5); *EX-1031*, pp. 462-463. However, as discussed in more detail in State of the Art §§ V.G.1-V.G.2 (above), activated carbon had been used to remove contaminants from liquids for many years, with the first powdered commercial carbon produced in 1909. *EX-1025* p. 6; *see* §§ V.G.1-V.G.2 (above). GAC is effective due to its high porosity and large surface area that come in contact with various contaminants, making it ideal for treating groundwater, drinking water, industrial wastewater, and other water sources that may be contaminated. *EX-1005*, pp. 5-6; *EX-1038*, pp. 2-3. GAC with larger pores (more mesopores, macropores) was known to be effective for PFAS, and it was well-known to use activated carbon to treat water contaminated with PFAS. *EX-1026*, pp. 741 (§2.1, Table 1), 742-743 (§2.3), 744-745 (§3.2); *EX-1009*, pp. 251-253 (§3.2.5); *EX-1031*, pp. 462-463; *EX-1030*, p. 2; *EX-1033*, p. 2.

70. Beyond conventional organic contaminants, GAC emerged as a leading solution for the removal of PFAS from drinking water and the environment. The '948 Patent itself acknowledges that several technologies, including GAC, were conventionally known and employed to remove PFAS from the environment, and specifically from drinking water, and identifies that “GAC has emerged as a leading solution.” *EX-1001*, 1:33–40. Kempisty (discussed below) noted GAC is “**commonly** used to remove” PFAS and other organic species from a variety of water sources, including groundwater, surface water, and wastewater. *EX-1004*, pp. 303–305. Similarly, McNamara (also addressed in detail below) describes GAC as the “currently... most researched and installed technology for PFC removal,” confirming that GAC “has been shown to be effective at removing compounds such as PFOA and PFOS” from water. *EX-1013*, pp. E2–E4. Likewise, for example, Mimna identifies GAC as a “**leading** technology for removal of PFCs from drinking water and groundwater.” *EX-1007*, pp. 4, 9, 16, 27.

71. Moreover, reactivated GAC was a known solution, and was successfully used, for the removal of PFAS from drinking water and the environment. For example, Mimna (addressed in detail below) identifies that, as of January 2017, the Patent Owner itself “ha[d] **over 10 years** of experience reactivating carbons with [Perfluorinated Compounds]”, *i.e.*, PFAS compounds

like PFOA and PFOS, whereby the reactivated carbon “is then reusable” to treat water contaminated with PFAS because “[r]eactivation of spent [Granular Activated Carbon] destroys adsorbed contaminants including [Perfluorinated Compounds].” *EX-1007*, pp. 9, 30-32. Similarly, Patent Owner’s 2017 and 2018 PFAS web pages stated:

Incineration of any concentrated PFC waste is required for complete destruction of PFOS and PFOA. Spent activated carbon containing adsorbed species can be thermally reactivated, destroying the adsorbed contaminants and allowing the activated carbon to be recycled and reused.

* * * * *

WHAT CAN CALGON CARBON DO FOR YOU?

* * * * *

... CCC has carbon reactivation sites globally that will thermally destroy the PFCs and enable the reuse of the activated carbon.

EX-1030, 2; *EX-1033*, 2.

72. By way of another example, at a conference in September 2017 (and in the associated conference proceedings), Patent Owner published results showing that its Custom Municipal Reactivated (CMR) Filtrasorb GAC had similar, if not slightly better, PFOA removal performance compared to its virgin Filtrasorb GAC (as shown in the annotated FIG. 1 below):

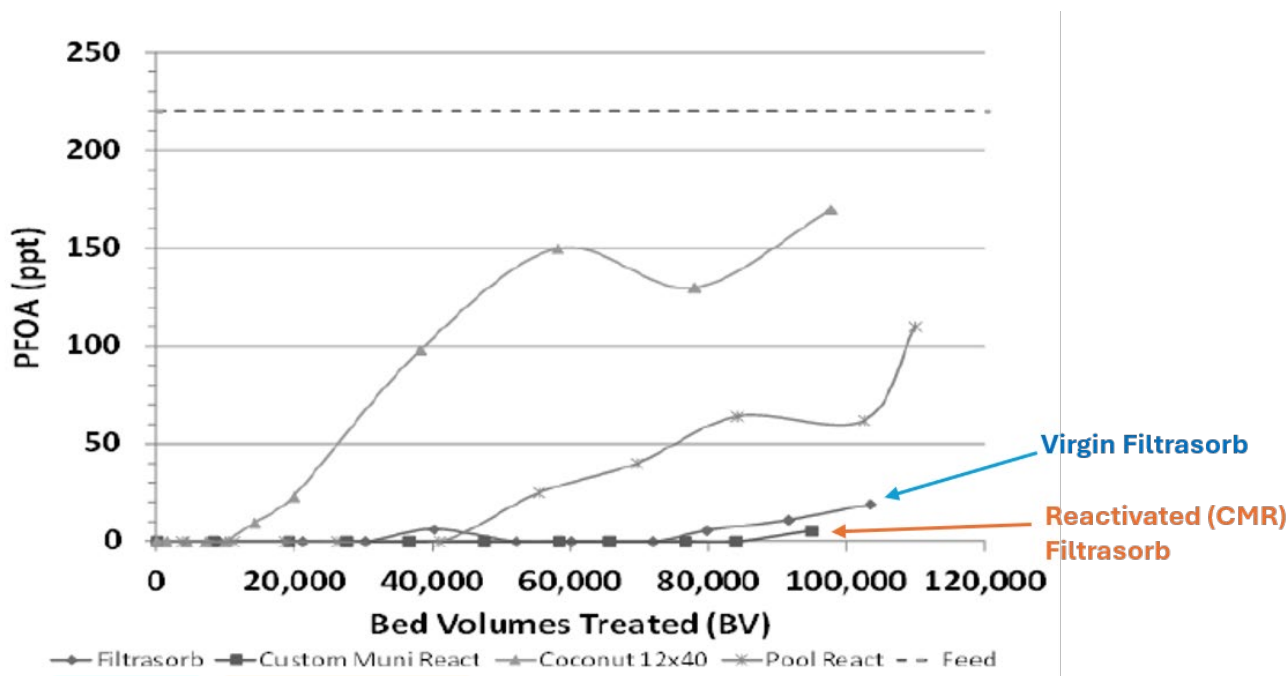


Fig. 1. Efficacy for Removing PFOA

EX-1031, pp. 462-463, Fig. 1 (annotated above).

73. On its 2017 website, Patent Owner explained that its Custom Municipal Reactivated (CMR) GAC was formed by thermally reactivating spent GAC from drinking water applications at “a dedicated potable reactivation facility” and using procedures that “adhere to AWWA B605” so that the spent GAC can be “recycled for reuse” in these same drinking water applications. EX-1034, pp. 1-2 (PO 2017 CMR webpage); see EX-1037 (AWWA B605-18).

5. Inorganic Materials

74. Naturally, as the '948 Patent readily acknowledges, ground water contains dissolved, inorganic mineral ions including, (i) as major constituents (1.0-

1,000 mg/L), calcium, sodium, and magnesium cations, and bicarbonate, sulfate, chloride and silica anions; (ii) as secondary constituents (0.01-10 mg/L), potassium, iron and strontium cations, and carbonate, nitrate, fluoride and boron anions; as well as other trace constituents. *EX-1035*, pp. 1-2; *EX-1020*, pp. 73-74; *EX-1001*, 6:50-63, 7:67-8:4. During water treatment service, GAC accumulates inorganic compounds, most notably calcium, but also iron, aluminum, manganese, and magnesium, through several well-understood mechanisms. *EX-1020*, pp. 73-74, Table 1; *EX-1011*, pp. 76-77, 87. Determining the ash content of GAC used for water treatment (*e.g.*, of spent GAC), and comparing it to the ash content of the GAC before the water treatment (*e.g.*, of virgin GAC), used standardized methods and was a common way of demonstrating the well-known accumulation of inorganic compounds on GAC used for water treatment service. *EX-1020*, pp. 73-74 (Tables 1, 2), 76; *EX-1011*, pp. 79-80, Tables 2, 3; *EX-1035*, pp. 1-2.

75. The accumulation of calcium is especially pronounced in drinking water treatment plants, where calcium is ubiquitous in natural waters, readily forms complexes with natural organic matter (NOM), and is often added in the form of lime during treatment. *EX-1020*, p. 73. Data from field-spent GACs confirm that calcium concentrations commonly range from 0.4 to 7 percent within spent GACs used in water treatment plants. *EX-1021*, pp. 1285-1286. In one example, spent GAC which had been in service for approximately four years, contained 1.8%

calcium and 9.9% ash. *EX-1021*, p. 1290. Similarly, field data from other locations showed calcium contents of 1.0% and 1.4%, respectively, along with significant concentrations of aluminum, iron, magnesium, and manganese. *EX-1020*, p. 76, Table 6.

76. It was known that the presence of internally loaded calcium may be beneficial with respect to thermal regeneration of GAC. As a catalyst, calcium was known to accelerate the oxidation reactions during thermal regeneration by increasing the number of active sites on the carbon surface through an oxygen-transfer mechanism involving a CaCO_3/CaO catalytic cycle. *EX-1021*, pp. 1286–1287; *EX-1020*, p. 74. This catalytic acceleration means that spent GAC loaded with calcium can be regenerated at lower temperatures or shorter times, potentially translating into significant energy savings. For example, the regeneration of GAC at 750°C in the presence of calcium proceeded at the same rate as regeneration at 850°C in its absence. *EX-1020*, p. 80. At higher temperatures (above 800°C), pore development was characterized by more uniform widening dispersed throughout all pore size ranges, better preserving the micropore structure important for water treatment. *EX-1021*, pp. 1299-1300. It was understood that, “with proper precautions, the presence of calcium need not be adverse” and that “the calcium can be employed advantageously,” allowing the oxidation step of thermal regeneration (reactivation) to proceed an order of magnitude more rapidly and

achieving a target apparent density with far less time, steam, and energy. *EX-1021*, p. 1300. Importantly, it was thus understood that, with proper precautions, calcium-loaded GACs could be thermally regenerated (reactivated) to yield a product with the properties of the virgin GAC by reducing the regeneration time or temperature, and that acid-washing to remove calcium would not be recommended. *EX-1021*, p. 1300; *EX-1020*, p. 73, 80.

77. It was understood that the predominate calcium species is a function of “both the temperature and by the steam or CO₂ partial pressures it experiences.” *EX-1021* p. 1288, Fig. 1. In a CO₂ environment, CaCO₃ would predominate below 775°C. *EX-1021* p. 1288, Fig. 1; *EX-1020*, pp. 73-75. The calcium in GAC was known to precipitate as CaCO₃ and would have a chemical composition similar to limestone (CaCO₃). *EX-1021*, p. 1289.

VI. IDENTIFICATION OF PRIOR ART CHALLENGES

A. Identification of Challenges

78. Based on my understanding of the law of anticipation and obviousness discussed in Section III above, Claims 1-5 of the '948 Patent are unpatentable as set forth in the grounds below.:

Grounds	Claims	Basis	Reference(s)
1	1-5	§102	Kempisty
2	1-5	§103	McNamara alone, or in view of Cannon

Grounds	Claims	Basis	Reference(s)
3	1-5	§103	Mueller in view of McDougall and Cannon
4	1-5	§103	Mimna in view of Reactivation Services and Cannon
5	5	§112	Fails written description requirement under 112(a)

B. The Prior Art

1. Kempisty (*EX-1004*)

79. I have been informed by counsel that Environmental and Occupational Health Series book titled “Perfluoroalkyl Substances in the Environment: Theory, Practice, and Innovation” (“Kempisty”) qualifies as prior art under at least § 102(a)(1).

2. McNamara (*EX-1013*)

80. I have been informed by counsel that American Water Works Association Journal article titled “Comparison of Activated Carbons for Removal of Perfluorinated Compounds from Drinking Water” (“McNamara”) qualifies as prior art under at least 102(a)(1).

3. Cannon (*EX-1011*)

81. I have been informed by counsel that Carbon journal article titled “Reaction Mechanism of Calcium-Catalyzed Thermal Regeneration of Spent

Granular Activated Carbon” (“Cannon”) qualifies as prior art under at least § 102(a)(1).

4. Mueller (*EX-1005*)

82. I have been informed by counsel that Interstate Technology Regulatory Council fact sheet titled “Remediation Technologies and Methods for Per- and Polyfluoroalkyl Substances (PFAS)” (“Mueller”) qualifies as prior art under at least § 102(a)(1).

5. McDougall (*EX-1006*)

83. I have been informed by counsel that Journal of the South African Institute of Mining and Metallurgy titled “The Physical Nature and Manufacture of Activated Carbon” (“McDougall”) qualifies as prior art under at least § 102(a)(1).

6. Mimna (*EX-1007*)

84. I have been informed by counsel that Calgon Carbon Corporation’s presentation titled “Granular Activated Carbon: A Proven Solution for PFC Removal” (“Mimna”) qualifies as prior art under at least § 102(a)(1).

**7. Reactivation Services Frequently Asked Questions
 (“Reactivation Services”) (*EX-1014*)**

85. I have been informed by counsel that Calgon Carbon Corporation’s FAQ document titled “Reactivation Services Frequently Asked Questions” (“Reactivation Services”) qualifies as prior art under at least § 102(a)(1).

VII. IDENTIFICATION OF HOW THE CHALLENGED CLAIMS ARE UNPATENTABLE

A. Ground 1: Claims 1-5 are anticipated by Kempisty

1. The Kempisty reference

86. Kempisty discloses that reactivation of activated carbon is a commonly used method for thermal destruction of adsorbed chemicals, including spent carbons containing PFAS, allowing for the reactivated carbon to be reused. *EX-1004*, 303-304. Kempisty discloses the options for handling spent activated carbon such as disposal, incineration, and reactivation. *EX-1004*, 304. Kempisty details common reactivation processes to remove adsorbates from spent carbon at temperatures up to approximately 1,800°F (982°C). *EX-1004*, 304-306. Additionally, Kempisty discloses common regeneration processes, such as low-temperature thermal regeneration, chemical extraction, or solvent stripping, to restore adsorptive capacity. *EX-1004*, 304. Kempisty also discloses the physical effects of the reactivation process on spent activated carbon over multiple reactivation cycles with adsorbed inorganic materials, including calcium carbonate, metals, oil, and grease. *EX-1004*, 321-322.

2. Detailed Application of Kempisty to Claims 1-5

Claim 1

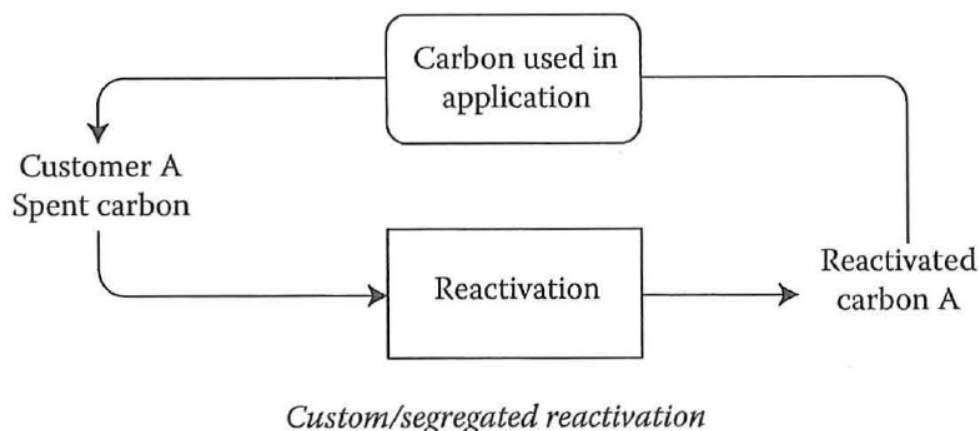
- i. A method of removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid or gas, the method comprising:*

87. To the extent the preamble is limiting, Kempisty discloses removing PFAS from liquid, particularly water. The chapter entitled “Reactivation of Spent Activated Carbon Used for PFAS Adsorption” explains that granular activated carbon (“GAC”) is “commonly used to remove” PFAS and other organic species from a variety of water sources [*method of removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid or gas*], including groundwater, surface water, and wastewater. *EX-1004*, 303-304.

ii. providing a sorbent material comprising reactivated carbon, wherein the reactivated carbon is formed from a spent activated carbon, wherein the spent activated carbon was previously used for water filtration; and

88. Kempisty describes reuse, as a sorbent, of reactivated carbon [*a sorbent material comprising reactivated carbon*], reactivation of spent activated carbon for reuse [*the reactivated carbon is formed from a spent activated carbon*] and that the spent carbon was used for PFAS adsorption in water treatment [*wherein the spent activated carbon was previously used for water filtration*]. Specifically, Kempisty states that granular activated carbon (“GAC”) is “commonly used to remove organic species... and PFAS from a variety of water sources (groundwater, surface water, and wastewater),” and explains that once the carbon’s capacity is exhausted, the spent carbon may undergo “reactivation of the spent carbon for reuse.” *EX-1004*, 303-304.

89. Figure 13.9 of Kempisty illustrates spent carbon from Customer A is reactivated and reused in the same application.



EX-1004, 13.9.

90. Kempisty further defines reactivation as a “well-established, high-temperature process” after which “the reactivated carbon can be reused,” and notes that reactivation of spent carbon containing PFOS, PFOA, and other PFAS has been commercially practiced for more than 10 years. EX-1004, 303-305.

iii. contacting the sorbent material with a liquid or gas containing the PFAS,

91. Kempisty discloses that spent activated carbon used for PFAS adsorption in water-treatment service is thermally reactivated and then returned to be reused as a sorbent for PFAS adsorption [*contacting the sorbent material with a liquid or gas containing the PFAS*]. EX-1004, 303-305, 323.

92. Specifically, Kempisty explains that granular activated carbon (“GAC”) is “commonly used to remove” PFAS from water sources, including

groundwater, surface water, and wastewater, and further states that, after reactivation, “the reactivated carbon can be reused.” Kempisty also describes reactivation of spent carbon containing PFOS, PFOA, and other PFAS, thereby linking the reused, reactivated carbon to the same PFAS-removal context. *EX-1004*, 303-305.

iv. wherein the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C.

93. Kempisty specifically discloses reactivation as a “well-established, high-temperature process” in which the spent activated carbon enters a furnace or kiln where temperatures are increased to approximately 1800°F (approximately 982°C) [*the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C*]. *EX-1004*, 304.

94. Kempisty further breaks the reactivation process into temperature stages, including calcination/pyrolyzation at 1000°F–1450°F (537.8°C to 787.8°C) and activation process/steam gasification at 1450°F–1800°F (787.8°C to 982.2°C) [*the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C*]. *EX-1004*, 306-307, Fig. 13.2.

95. The four general steps in carbon reactivation (figure 13.2) are

1. Low-temperature pretreatment: Drying of carbon to remove the water remaining in the carbon pores (212°F)

2. Physical processes and reactions: Thermal devolatilization and desorption of weakly held adsorbates (212°F-1000°F)
3. High-temperature carbon condensation reactions: High-temperature pyrolysis or calcination, in which adsorbates that are not removed in step 2 (thermal devolatilization and desorption) are converted to char (1000°F-1450°F)
4. High-temperature carbon gas or solid reactions: Chemical reactions for carbon gasification with water vapor, carbon dioxide, or oxygen to gasify (partially remove) char formed in the step 3 and regain some adsorptive capacity (1450°F-1800°F)

EX-1004, 306.

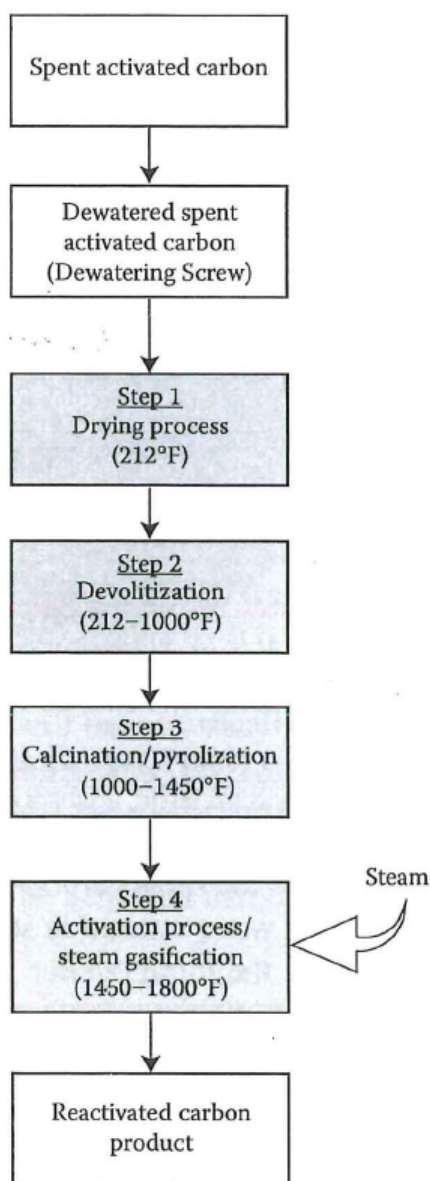


FIGURE 13.2 Steps of reactivating a spent carbon. The gray boxes indicate the steps taking place inside of a furnace.

EX-1004, Fig. 13.2.

96. Because Kempisty's disclosed reactivation stages span temperatures well within the claimed range, Kempisty teaches reactivation of the spent carbon by heat at temperatures falling within about 500°C to about 1100°C. *EX-1004*,

304, 306-307; *see also* Claim Construction § V.C.1 (identifying Patent’s quantification of “about” as plus or minus 10% of, here, the range of “about 500°C to about 1100°C”, *i.e.*, 450°C to 1210°C).

Claim 2

The method of claim 1, wherein the reactivated carbon was reactivated by heat at a temperature of about 700°C.

97. Kempisty expressly discloses thermal reactivation of spent activated carbon at temperatures that encompass about 700°C. Specifically, Kempisty describes reactivation as a “well-established, high-temperature process” and explains that the reactivation process includes a calcination/pyrolyzation stage at 1000°F–1450°F (approximately 538°C–788°C) and an activation process/steam gasification stage at 1450°F–1800°F (about 788°C–982°C). Kempisty also states more generally that reactivation commonly refers to a high-temperature thermal treatment process at approximately 1800°F (about 982°C). The claimed reactivation temperature of about 700°C falls squarely within Kempisty’s disclosed reactivation temperature range of 1000°F–1450°F (approximately 538°C–788°C). *EX-1004*, 304, 306-307.

Claim 3

The method of claim 1, wherein the reactivated carbon is formed from spent sorbent material feedstock comprising calcium carbonate.

98. Kempisty discloses that “poor-quality reactivated carbon”
[reactivated carbon] may be produced [formed] from spent activated carbon that
CaCO₃ has agglomerated onto [material feedstock comprising calcium carbonate].

Hardness as **CaCO₃ can agglomerate** and harden the carbon, cause
processing or mechanical problems in a furnace or kiln, and **produce**
a poor-quality reactivated carbon.

EX-1004, 322.

Claim 4

*The method of claim 1, wherein the reactivated carbon
comprises one or more of granular activated carbon
and powdered activated carbon.*

99. Kempisty expressly identifies the reactivated sorbent as granular
activated carbon (“GAC”). Kempisty explains that granular activated carbon
(GAC) is commonly used to remove PFAS from water sources, and that, after
high-temperature reactivation, “the reactivated carbon can be reused.” EX-1004,
303–305.

Claim 5

*The method of claim 1, wherein the spent activated
carbon is not treated to remove any inorganic materials
that are present in ground water.*

100. As discussed above for claim 3, Kempisty’s disclosure of “poor-
quality reactivated carbon”, that is produced from spent activated carbon onto

which CaCO_3 has “agglomerate[d]”, discloses that such *spent activated carbon* is *not treated to remove any inorganic materials (e.g., CaCO_3) that are present in ground water.* *EX-1004*, 322.

B. Ground 2: Claims 1-5 are unpatentable over McNamara alone, or in view of Cannon

1. The McNamara Reference

101. McNamara discloses using granular activated carbon (“GAC”) for the treatment of drinking water, contaminated with perfluorinated compounds (“PFC”), including perfluorooctanoic acid (“PFOA”) and perfluorooctane sulfonate (“PFOS”). *EX-1013*, E2-E3. McNamara studies the removal of PFCs from a Pennsylvania municipality’s groundwater source with different types of GACs and measures the effectiveness of removal with rapid small-scale column testing. *EX-1013*, E6-E8. McNamara uses a reactivated bituminous coal carbon, designated as custom municipal reactivated (CMR) GAC, that was used to treat drinking water and had undergone three reactivation cycles at temperatures of approximately 800°C. *EX-1013*, E4-E5. Further, the municipal groundwater source included calcium carbonate, such that reactivated carbon included calcium carbonate. *EX-1013*, E9 (Table 5). Additionally, McNamara discloses the effects of reactivation on GAC physical characteristics, such as improved transport pore structure for removal of PFCs, identifying reactivated coal-based GAC outperformed virgin coal-based GAC. *EX-1013*, E10-E11.

2. The Cannon Reference

102. Cannon proposes that retaining calcium, that accumulated on spent activated carbon during filtration of drinking water, through the reactivation process can yield a commercially useful, virgin-like regenerated sorbent, while beneficially affecting the generation of meso- and macro- pore structures developed during regeneration. *EX-1011*, 76-77.

103. Cannon describes that field-spent GAC had been used in a drinking-water treatment plant for “nearly four years” and “contained 2 percent calcium” and that, when reactivated, the retained calcium “always caused micropores to be converted to small mesopores during thermal oxidation.” *EX-1011*, 76.

104. Cannon teaches that the retained calcium improves regeneration performance in an operational sense because it greatly enhances oxidation efficiency. Cannon discloses that “the calcium catalyst would allow a higher GAC throughput through a regeneration furnace,” and further explains that “the calcium dramatically improved oxidation efficiency,” versus acid-washed carbon. *EX-1011*, 84.

105. Cannon recognizes retained calcium on spent activated carbon is beneficial to the reactivation process itself, in that more meso- and macro- pores are generated, and specifically that retained calcium “primarily widened pores of

the <5-nm range, forming pores in the 5-10-nm range.” *EX-1011*, 77, 87.

Specifically, Cannon discloses:

When calcium appeared inside the spent GAC, it always caused micropores to be converted to small mesopores during thermal oxidation. In contrast, if the calcium was leached out of the spent GAC with acid, thermal oxidation increased only the micropore volume.

EX-1011, 76.

106. Cannon’s Table 2 (reproduced below) compares spent, pyrolyzed, mildly oxidized, and acid-washed/oxidized products and shows that the calcium-bearing carbon may be regenerated to a product approaching virgin pore structure:

TABLE 2 <i>Comparison of regeneration products for Hays Mine GAC</i>						
Parameter	Spent, Hays Mine	Spent, Pyrolyzed	Spent, Pyrolyzed, Mildly Oxidized	Acid- Washed, Pyrolyzed, Oxidized	Type A	Type B*
Regeneration conditions						
Temperature—°C		850	850	850		
Oxidation time—min	0	0	3	35		
Mass loss—percent	0	13.7	18.6	24.5		
Volume loss—percent	0	3.8	3.4	6.8		
Oxidant employed— g H ₂ O/g GAC	0	0	0.4	4.7†		
Product characterization						
Apparent density—g/mL	0.548	0.494	0.466	0.428	0.437	0.497
Ash-free apparent density—g-C/mL	0.492	0.440	0.414	0.406	0.410	0.473
Micropore volume—mL/mL	0.100	0.134	0.124	0.134	0.130	0.142
Mesopore volume—mL/mL	0.049	0.065	0.097	0.107	0.094	0.057
(Volumetric) surface area—m ² /mL	300	410	420	460	430	410
(Gravimetric) surface area—m ² /g-GAC	540	820	900	1,080	990	820
Ash content—percent	9.9	10.8	11.1	5.1	6.22	4.92

*This virgin GAC type B sample was not from the same batch that became spent at Hays Mine, Pa.
†Plus 6.5 g CO₂/g GAC

EX-1011 Table 2.

107. Cannon, at Figures 3–6, illustrates that calcium retained in spent activated carbon shifts pore development from micropore gain toward conversion of micropores to small mesopores during oxidation. *EX-1011*, 79-83.

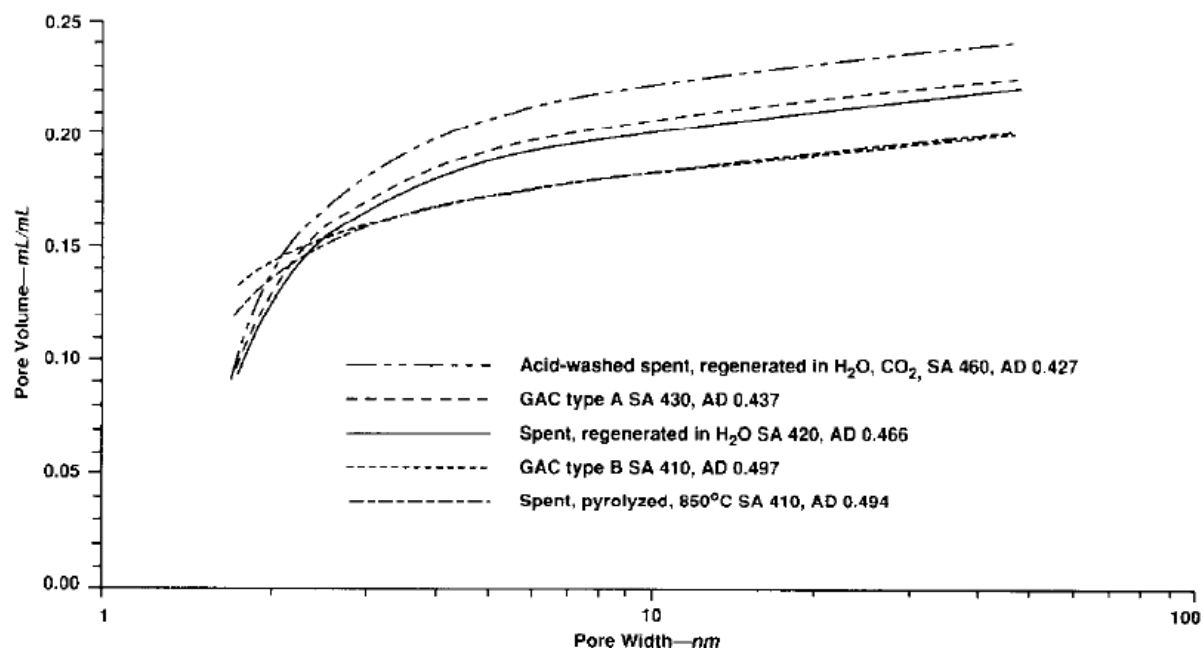


Figure 3. Cumulative pore volume distribution and surface area (m²/mL) for spent Hays Mine GAC pyrolyzed and regenerated at 850°C to the apparent density shown (compared with virgin GAC types A and B)

EX-1011, Fig. 3; see also *id*, Figures 4-6.

108. Cannon, from its data, concludes that calcium need not be removed for successful reuse of the activated carbon (*e.g.*, reuse for filtering contaminants from drinking water), because “proper regeneration restored the spent GAC to the same pore structure and surface area that was exhibited by several virgin GACs.”

EX-1011, 76.

3. Detailed Application of McNamara in view of Cannon

Claim 1

- i. A method of removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid or gas, the method comprising:*

109. To the extent the preamble is limiting, McNamara discloses removing PFAS from liquid, particularly drinking water and other water sources. Specifically, McNamara explains that granular activated carbon (“GAC”) is the “currently... most researched and installed technology for PFC removal,” and states that GAC “has been shown to be effective at removing compounds such as PFOA and PFOS” from water at favorable loading capacities [*A method of removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid or gas*]. McNamara further describes contaminated drinking water, groundwater, surface water, and wastewater, and reports both laboratory and full-scale GAC treatment of those PFAS-containing waters, including removal of PFOA and PFOS to nondetectable or below-reporting levels. *EX-1013*, E2-E4, E10-E11.

- ii. providing a sorbent material comprising reactivated carbon, wherein the reactivated carbon is formed from a spent activated carbon, wherein the spent activated carbon was previously used for water filtration; and*

110. McNamara discloses using reactivated granular activated carbon (“GAC”) in water-treatment service and explains that the reactivated carbon is

produced from spent activated carbon previously used for municipal water filtration. Specifically, McNamara states that a key feature of GAC use is the “thermal reactivation of the spent product” by which it is “remanufactured for reuse in the application,” and notes that this reactivation process “has been widely used at several municipal treatment plants and commercial facilities.” *EX-1013*, E4.

Reactivation of GAC. A key feature in GAC use is the thermal reactivation of the spent product by which it is essentially remanufactured for reuse in the application. Not only does the use of reactivation greatly improve the economics of applying GAC, but it also eliminates the need to dispose of spent carbon and its contaminant loadings, removing any future liabilities associated with those wastes. This process has been widely used at several municipal treatment plants and commercial facilities across the United States.

EX-1013, E4.

111. McNamara further describes one of the tested carbons as a “custom municipal reactivated (CMR) GAC” that, before use, had been the same product as the virgin GAC tested, and explains that this CMR carbon had previously been “in service for 12 to 18 months at an unnamed drinking water treatment facility, removing surface water NOM and total organic carbon (TOC)” before undergoing reactivation cycles. *EX-1013*, E4-E5. Thus, McNamara teaches *providing a*

sorbent material comprising reactivated carbon formed from spent activated carbon that had previously been used for water filtration.

iii. contacting the sorbent material with a liquid or gas containing the PFAS

112. As also identified for limitation [1.ii] above, McNamara discloses that reactivated granular activated carbon (“GAC”) is used for “PFC removal” from drinking water and other water sources, and further describes laboratory and full-scale treatment of PFAS-contaminated groundwater, surface water, and wastewater using GAC. McNamara also reports that reactivated GAC (CMR) “has been shown to be effective at removing compounds such as PFOA and PFOS,” including full-scale systems in which contaminated drinking water or groundwater was passed through GAC vessels, including those containing reactivated GAC (CMR), and the PFAS concentrations were reduced to nondetectable or below-reporting levels [*contacting the sorbent material with a liquid or gas containing the PFAS*]. *EX-1013*, E2-E4, E7-E8; *see* limitation [1.ii] above. Thus, McNamara teaches contacting the sorbent material with a liquid containing PFAS.

iv. wherein the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C.

113. McNamara expressly discloses thermal reactivation of spent activated carbon at temperatures within the claimed range. Specifically, McNamara explains that, in the reactivation process, “the activated carbon is heated to temperatures of

at least 800°C using steam as a selective oxidant,” and further notes that custom reactivation is conducted with steam at “approximately 800°C” [*wherein the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C*]. McNamara also cites testing showing no residual perfluoroalkyl substances on activated carbon when heated to 700°C in nitrogen. *EX-1013*, E4. Thus, McNamara teaches that the reactivated carbon was reactivated by heat at temperatures falling squarely within the about 500°C to about 1100°C range, including expressly disclosed temperatures of about 700°C and at least/about 800°C. *EX-1013*, E4-E5.

114. Because McNamara’s disclosed reactivation stages span temperatures well within the claimed range, McNamara teaches reactivation of the spent carbon by heat at temperatures falling within about 500°C to about 1100°C. *EX-1013*, E4-E5.

Claim 2

The method of claim 1, wherein the reactivated carbon was reactivated by heat at a temperature of about 700°C.

115. As also identified for limitation [1.iv] above, McNamara discloses a reactivation process including heating activated carbon [*reactivated carbon*] to 700°C to remove residual perfluoroalkyl substances [*reactivated by heat at a temperature of about 700°C*]. McNamara further explains that, during the

reactivation process, the activated carbon is heated to temperatures of at least 800°C using steam as a selective oxidant, with custom reactivation conducted at approximately 800°C. *EX-1013*, E4.

In the reactivation process, the **activated carbon is heated to temperatures of at least 800°C** using steam as a selective oxidant. It should be noted that in testing of activated carbons containing PFCs, Watanabe et al. (2016) found **no residual perfluoroalkyl substances on activated carbon when heated to 700°C in nitrogen**.

EX-1013, E4 (emphasis added).

116. Thus, McNamara teaches reactivated carbon that was reactivated by heat at about 700°C, both through its express disclosure of heating activated carbon to 700°C and through its broader description of reactivation at comparable and higher temperatures. *EX-1013*, E4-E5; *see also* Claim Construction §V.C.1 (identifying Patent’s quantification of “about” as plus or minus 10% of, here, “about 700°C”, *i.e.*, 630°C to 770°C).

Claim 3

The method of claim 1, wherein the reactivated carbon is formed from spent sorbent material feedstock comprising calcium carbonate.

117. McNamara discloses calcium carbonate is in the treated water, and that the reactivated GAC has a higher ash % (9.9) than the virgin GAC’s ash % (8); however, McNamara does not explicitly disclose that the calcium is deposited or

otherwise contained in the sorbent [*spent sorbent material feedstock*] prior to reactivation. *EX-1013*, E9 (Table 5, showing 300 mg/L as CaCO₃), E5 (Table 3). However, a POSA understood that inorganic substances, specifically dissolved salts (*e.g.*, calcium carbonate) in the filtered liquid are routinely deposited on the spent carbon (“While the GAC is in service,” the GAC “can also accumulate metals”) and thus would be contained in the spent carbon feedstock, unless specifically removed. *EX-1011*, 76.

118. Moreover, Cannon explicitly discloses inorganic materials, *e.g.*, calcium carbonate, contained within the spent carbon. *EX-1011*, 77.

In spent GACs, calcium contents were the highest (0.4-7 percent), followed by aluminum (0.3-3.7 percent), iron (nonpyritic-0.1-0.5 percent), manganese (0.02-0.6 percent), and magnesium (0.06-0.3 percent).

EX-1011, 77.

119. Cannon notes the presence of calcium and other inorganic materials present during reactivation may increase the mesopore volume and thus improve the adsorption of contaminants. *EX-1011*, 77, 87.

120. A POSA understood that the calcium present in the GAC would partially exist in ionic Ca⁺² form, with a significant portion expected to react with carbonate to form calcium carbonate which deposits on the GAC in the form of calcium carbonate. Carbon dioxide ubiquitous in the atmosphere dissolves into

GAC-associated water resulting in aqueous carbonate as a reactant in excess which produces calcium carbonate after reaction with ionic calcium. *See* State of the Art §V.G.5;

121. Thus, a POSA would understand that, given the teachings and disclosure of Cannon, that spent activated carbon recovered from water treatment plants [*water-filtering*] would “contain high concentrations of calcium (0.4-7 percent)” at least a significant portion being calcium carbonate. Therefore, it is implicit that some of the spent activated carbon disclosed in McNamara comprises calcium carbonate, and renders the limitation of Claim 3 obvious. *EX-1011*, 87.

Claim 4

The method of claim 1, wherein the reactivated carbon comprises one or more of granular activated carbon and powdered activated carbon.

122. McNamara expressly identifies the reactivated carbon as **granular activated carbon (“GAC”)**. Specifically, McNamara describes “**custom municipal reactivated (CMR) GAC**” as one of the activated carbons tested and explains that this reactivated product had previously been used in a drinking-water treatment facility before undergoing multiple reactivation cycles. McNamara further states that the CMR bituminous coal-based re-agglomerated **GAC** remained very effective at removing PFOA and PFOS after repeated cycles of high-temperature reactivation. *EX-1013*, E4-E5, E10-E12.

Claim 5

The method of claim 1, wherein the spent activated carbon is not treated to remove any inorganic materials that are present in ground water.

123. McNamara discloses that the reactivated GAC has a higher ash % (9.9) than the virgin GAC's ash % (8), and discloses several inorganic materials as being present in the treated water. *EX-1013*, E5 (Table 3, Table 2), E6 (identifying that "standard... ash (ASTM International 2011)" carbon test "[r]esults are shown in Table 3."), E9 (Table 5). McNamara does not explicitly disclose a treatment to remove inorganic materials, nor however does McNamara prohibit such a treatment to remove inorganic materials deposited on the spent activated carbon. However, Cannon discloses the benefits of not acid washing [*not treated to remove any inorganic materials*] the spent carbon. *EX-1011*, 84.

This difference highlighted how calcium dramatically improved oxidation efficiency, a factor that could offer advantages during full-scale, carefully controlled regenerations."

EX-1011, 84.

Indeed, the calcium catalyst would allow a higher GAC throughput through a regeneration furnace, which probably would offset the potential need for more frequent regeneration cycles.

EX-1011, 84.

primarily widened pores of the <5-nm range, forming pores in the 5-10-nm range.

EX-1011, 84.

These oxidations caused lower total surface areas, higher mesopore surface area, lower micropore volumes, higher 2-10-nm pore volumes, and a linear pore size distribution between 2 and 10 nm.

EX-1011, 88.

regeneration option for this calcium loaded GAC provided potential as a viable alternative to discarding or incinerating spent GAC and replacing it with virgin GAC.

EX-1011, 88.

The authors recommend that the slight improvement would not justify the added nuisance and expense incurred by employing an acid-washing step before regenerating coal-based GACs that contain ~2 percent calcium.

EX-1011, 88.

124. Therefore, to the extent that McNamara would treat the spent activated carbon to remove inorganic materials accumulated thereon during municipal water filtration, it would have been obvious to a POSA to preserve the inorganic materials deposited from the ground water, rather than treat the spent carbon to remove those inorganic materials. A POSA would have been motivated

to modify McNamara to preserve the inorganic materials for both economic and performance reasons because, as taught by Cannon:

- 1) The presence of calcium (an inorganic material) improves the efficiency of the oxidation during regeneration/reactivation of the spent activated carbon. *EX-1011*, 84.
- 2) The presence of calcium created more pores in the 5-10 nm range, which a POSA understood would improve filtering of some PFAS molecules. *EX-1011*, 77, 87.
- 3) Regeneration/reactivation of calcium-loaded-GAC is a viable alternative with respect to performance and cost to discarding or incinerating spent GAC and replacing it with virgin GAC. *EX-1011*, 88.
- 4) To achieve a higher GAC throughput through a regeneration furnace. *EX-1011*, 84; and
- 5) Avoids the cost and efforts of treating the spent carbon. *EX-1011*, 88.

125. In addition such a modification would be merely:

- 6) using a known technique to improve a similar device or method in the same way. McNamara already teaches thermal reactivation and reuse of spent municipal-water-filtered-GAC, applying Cannon's known no-acid-wash approach to McNamara's reactivation process to improve efficiency and cost in the same kind of water-treatment carbon-regeneration setting.

7) design choice / optimization of a known process parameter. Cannon expressly treats calcium loading and acid washing as process variables affecting oxidation efficiency, throughput, pore development, and cost. *EX-1011*, 84, 88.

126. A POSA would have had a reasonable expectation of success of applying the teachings of Cannon to regenerate/reactivate the spent activated carbon of McNamara. Given Cannon's teaching of refraining from an acid washing step in the regeneration/reactivating process, the process employed by McNamara would not be materially changed.

127. Claim 5 is thus rendered unpatentable over McNamara in view of Cannon.

C. Ground 3: Claims 1- 5 are unpatentable over Mueller in view of McDougall and further in view of Cannon

1. The Mueller Reference

128. Mueller discloses multiple remediation technologies for removing PFAS from liquids, including GAC and PAC. Mueller describes that GAC is a demonstrated technology and is typically made from organic material GAC, such as coal and coconut, and the physical characteristics of GAC that allow for effective adsorption of PFAS. Additionally, Mueller discloses that GAC may be reused following reactivation, to reduce costs and provide a more sustainable option than disposing of virgin GAC. *EX-1005*, 1, 5-6.

2. The McDougall Reference

129. McDougall discloses the physical characteristics and adsorptive properties of activated carbon, including the raw materials and manufacturing processes used in activated carbon. *EX-1006*, pp. 109-113. Further, McDougall discloses reactivation of granular activated carbon between 700 to 950°C. *EX-1006*, p. 112. Additionally, McDougall differentiates between chemical and physical manufacturing processes, such as chemical activation of wood into activated carbon and the thermal activation of a source material into activated carbon. *EX-1006*, pp. 113-114. McDougall discusses the physical differences of coal-based and coconut-based activated carbon and their applications in various remediation and/or treatment of liquid and gases. *EX-1006*, pp. 117-119.

3. Detailed Application of Mueller and McDougall

Claim 1

- i. A method of removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid or gas, the method comprising:*

130. To the extent the preamble is limiting, Mueller discloses PFAS remediation for liquids [*removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid*].

131. Specifically, Mueller explains that “[s]everal technologies are currently available for remediating PFAS in liquids,” including applications to

“drinking water supplies, groundwater, industrial wastewater, surface water, and other miscellaneous applications.” Mueller identifies multiple liquid-phase PFAS removal technologies, including sorption onto carbon media. For example, Mueller discloses that GAC treatment removes PFAS from treated water by adsorption. *EX-1005*, 1.

- ii. providing a sorbent material comprising reactivated carbon, wherein the reactivated carbon is formed from a spent activated carbon, wherein the spent activated carbon was previously used for water filtration; and***

132. Mueller discloses providing reactivated carbon [*a sorbent material comprising reactivated carbon*] for PFAS treatment in water. Specifically, Mueller identifies granular activated carbon (“GAC”) as a treatment technology for PFAS in liquids, including drinking water, groundwater, industrial wastewater, surface water, and leachate, thereby placing the carbon in a water-treatment/water-filtration context [*previously used for water filtration*]. *EX-1005*, 1.

133. Mueller further states that, for GAC treatment of PFAS-contaminated water, “either virgin or reactivated GAC can be used” and explains that the spent media may be regenerated/reactivated for reuse, by commercial thermal reactivation facilities available for spent GAC media. *EX-1005*, 5–6. Thus, Mueller teaches providing a sorbent material comprising reactivated carbon formed from spent activated carbon that had previously been used in treating water.

iii. *contacting the sorbent material with a liquid or gas containing the PFAS*

134. Mueller discloses contacting the reactivated carbon [*sorbent material*] with a liquid containing PFAS. Specifically, Mueller addresses treatment of PFAS in “liquids (for instance, groundwater, leachate, or surface water)” and states that “[s]everal technologies are currently available for remediating PFAS in liquids,” including sorption technologies such as granular activated carbon (“GAC”), and that “either virgin or reactivated GAC can be used” to treat PFAS-contaminated water. *EX-1005*, 1, 5-6. Mueller also identifies that “[c]olumn studies show that... thermally reactivated GAC ha[s] similar [PFAS] removal rates and breakthrough times” as “virgin GAC.” *EX-1005*, 6-7. Mueller further explains that, in GAC treatment (including with “reactivated GAC”), PFAS-containing water is passed through the carbon because “GAC treatment removes PFAS from treated water by adsorption,” which maps to contacting the sorbent material with a liquid containing PFAS. *EX-1005*, 1, 5-6.

iv. *wherein the reactivated carbon was reactivated by heat at a temperature of about 500° C to about 1100° C.*

135. Mueller in view of McDougall discloses this limitation.

136. Mueller, while disclosing reactivated carbon may be used as a sorbent for removing PFAS (*see* §§VII.C.3. i-iii, above), and that the spent carbon is

thermally reactivated at high temperatures, it does not disclose the specifics of how the spent carbon was reactivated, however McDougall does. *EX-1005*, 1, 5-7.

137. McDougall expressly discloses regeneration of granular activated carbon [*reactivated carbon*] by heat within the claimed temperature range. Specifically, McDougall states that, for spent carbon bearing substances that “pyrolyse on heating,” “thermal reactivation at 700 to 950°C is employed,” [*the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C*] with steam usually injected into the kiln, and explains that this treatment “cleans the pyrolysed contaminant carbon from the walls of the pores, and returns the carbon to its original activity”:

The regeneration of granular activated carbon is generally accomplished using steam, hot solvents, or thermal routes.

Regeneration by extraction with steam can be applied if the carbon contains substances that volatilize at temperatures below 150°C. For substances of higher boiling points that pyrolyse on heating, thermal reactivation at 700 to 950° C is employed.

EX-1006, 113.

This treatment cleans the pyrolysed contaminant carbon from the walls of the pores, and returns the carbon to its original activity. It should be noted that the pyrolysed residue is indistinguishable from the original carbon,

EX-1006, 113.

138. A POSA understood that PFAS materials pyrolyse within the range of 700°C to 950°C. *EX-1005*, 6-7; *EX-1006*, 113; *See also* State of the Art §V.G.2.

139. McDougall also teaches “Because granular activated carbons are expensive, their application is usually economically viable only if the carbon can be regenerated and therefore recycled in the process.” *EX-1006*, 113.

140. It would have been obvious to a POSA to use the reactivated carbon formed by thermal reactivation [*the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C.*] as taught by McDougall as the thermally reactivated carbon [*sorbent material*] used in Mueller.

141. A POSA would have been motivated to use the thermally reactivated carbon taught by McDougall as the “thermally reactivated GAC” used in Mueller because Mueller expressly teaches PFAS removal from water using GAC, states that “either virgin or reactivated GAC can be used,” and further explains that spent GAC media may be “regenerated/reactivated for reuse” using commercial thermal reactivation facilities, with studies showing virgin and thermally reactivated GAC had similar PFAS removal rates and breakthrough behavior. *See EX-1005*, 5-6. McDougall, in turn, provides the known technique a POSA would have used to implement that very thermal reactivation, teaching that because GAC is expensive it is economically desirable to regenerate and recycle it, and that regeneration is commonly accomplished by thermal routes, including thermal reactivation at 700–

950°C, which cleans contaminant carbon from the pore walls and returns the carbon to its original activity. *See EX-1006*, 113–115. Thus, combining these teachings of Mueller and McDougall would have amounted to nothing more than the predictable use of a known thermal reactivation method to supply the reactivated carbon that Mueller expressly calls for in PFAS water treatment, with a reasonable expectation of success. *EX-1005*, 5-6; *EX-1006*, 113-115.

142. This combination is also supported by multiple obviousness rationales, including: (1) express teaching, suggestion, or motivation, because Mueller directly suggests use of thermally reactivated GAC and thermal reactivation facilities; (2) substitution of one known technique for another known and equivalent technique, because McDougall discloses a standard thermal reactivation method for restoring spent GAC to activity; and (3) application of a known technique to a known device ready for improvement, because a POSA seeking the thermally reactivated GAC contemplated by Mueller would naturally have looked to established activated-carbon-thermal-regeneration methods such as McDougall’s thermal reactivation process.

143. A POSA would have had a reasonable expectation of success in using McDougall’s thermally reactivated carbon as the sorbent in Mueller because Mueller expressly teaches that, for PFAS treatment of water, “either virgin or reactivated GAC can be used”, and that virgin and thermally reactivated GAC

showed similar removal rates and breakthrough times (*EX-1005*, 5-6), while McDougall teaches that thermal reactivation at 700–950°C cleans contaminant carbon from the pore walls and “returns the carbon to its original activity” (*EX-1006*, 113-114).

144. Thus, Mueller in view of McDougall meets this limitation.

Claim 2

The method of claim 1, wherein the reactivated carbon was reactivated by heat at a temperature of about 700°C.

145. McDougall expressly discloses thermal reactivation of spent activated carbon by heat at 700°C. Specifically, McDougall states that, for substances of higher boiling point that pyrolyze on heating, “thermal reactivation at 700 to 950°C is employed.” *EX-1006*, 113. Accordingly, and for the reasons stated above for limitation [1.iv], Mueller in view of McDougall meets this limitation, and a POSA would have been motivated to use the thermally reactivated carbon taught by McDougall as the “thermally reactivated GAC” used in Mueller. *See* § VII.C.3 ([1.iv]) above.

Claim 3

The method of claim 1, wherein the reactivated carbon is formed from spent sorbent material feedstock comprising calcium carbonate.

146. Mueller does not explicitly disclose that calcium carbonate is deposited or otherwise contained in the spent GAC sorbent [*spent sorbent material feedstock*] prior to thermal reactivation. *EX-1005*, 5-6. However, a POSA understood that inorganic substances, specifically dissolved salts (*e.g.*, calcium carbonate) in the filtered liquid (routinely found in ground water) are routinely deposited on the spent carbon and thus would be contained in the spent carbon feedstock, unless specifically removed. *See State of the Art §V.G.5.*

147. Moreover, Cannon explicitly discloses inorganic materials, species of Ca (*e.g.*, CaCO_3 , Ca(OH)_2), contained within the spent carbon. Cannon notes the presence of calcium carbonate and other inorganic materials present during reactivation may increase the mesopore volume and as understood by a POSA thus improve the adsorption capacity of the sorbent, especially with respect to PFAS. *EX-1011*, 77, 78.

Thermal regenerations were conducted on a spent granular activated carbon (GAC) that had served in a water treatment plant for about four years, and contained 1.8% calcium.

EX-1011, Abstract.

148. A POSA understood that the calcium present in the GAC would partially exist in ionic Ca^{+2} form, with a significant portion expected to react with carbonate to form calcium carbonate which deposits on the GAC in the form of calcium carbonate. Carbon dioxide ubiquitous in the atmosphere dissolves into

GAC-associated water resulting in aqueous carbonate as a reactant in excess which produces calcium carbonate after reaction with ionic calcium. *See* State of the Art §V.G.5.

149. Thus, a POSA would understand, given the teachings and disclosure of Cannon, that spent activated carbon recovered from water treatment plants [water-filtering] would “contain high concentrations of calcium (0.4-7 percent)” at least a significant portion being calcium carbonate. Therefore, it is implicit that some of the spent activated carbon disclosed in Mueller comprises calcium carbonate, and renders the limitation of Claim 3 obvious. *EX-1011*, 87.

Claim 4

The method of claim 1, wherein the reactivated carbon comprises one or more of granular activated carbon and powdered activated carbon.

150. Mueller expressly identifies granular activated carbon (“GAC”) as a PFAS sorbent used in liquid treatment and further states that “either virgin or reactivated GAC can be used,” thereby mapping directly to a reactivated carbon that comprises granular activated carbon.⁹ *EX-1005*, 5-6.

⁹ Mueller also discusses powdered activated carbon (“PAC”) as an activated-carbon sorbent in PFAS remediation. *EX-1005*, 6. However, only one is required to meet the one or more limitation.

Claim 5

The method of claim 1, wherein the spent activated carbon is not treated to remove any inorganic materials that are present in ground water.

151. Mueller and McDougall do not explicitly disclose a treatment to remove inorganic materials, nor however does Mueller or McDougall prohibit such a treatment to remove inorganic materials deposited on the spent activated carbon. However, Cannon discloses the benefits of not acid washing [*not treated to remove any inorganic materials*] the spent activated carbon. *EX-1011*, 84.

This difference highlighted how calcium dramatically improved oxidation efficiency, a factor that could offer advantages during full-scale, carefully controlled regenerations.”

EX-1011, 84.

Indeed, the calcium catalyst would allow a higher GAC throughput through a regeneration furnace, which probably would offset the potential need for more frequent regeneration cycles.

EX-1011, 84.

primarily widened pores of the <5-nm range, forming pores in the 5-10-nm range.

EX-1011, 88.

These oxidations caused lower total surface areas, higher mesopore surface area, lower micropore volumes, higher 2-10-nm pore volumes, and a linear pore size distribution between 2 and 10 nm.

EX-1011, 88.

regeneration option for this calcium loaded GAC provided potential as a viable alternative to discarding or incinerating spent GAC and replacing it with virgin GAC.

EX-1011, 88.

The authors recommend that the slight improvement would not justify the added nuisance and expense incurred by employing an acid-washing step before regenerating coal-based GACs that contain ~2 percent calcium.

EX-1011, 88.

152. Therefore, to the extent that Mueller and McDougall would treat the spent activated carbon to remove inorganic materials accumulated thereon during water filtration (*e.g.*, ground water where inorganics are routinely found), it would have been obvious to a POSA to preserve the inorganic materials deposited from the ground water, rather than treating the spent carbon to remove those inorganic materials. *EX-1005*, 5-6. A POSA would have been motivated to modify Mueller and McDougall to preserve the inorganic materials for both economic and performance reasons because, as taught by Cannon:

- 1) The presence of calcium (an inorganic material) improves the efficiency of the oxidation during regeneration/reactivation of the spent activated carbon. *EX-1011*, 84.
- 2) The presence of calcium created more pores in the 5-10 nm range, which a POSA understood would improve filtering of some PFAS molecules. *EX-1011*, 77, 87.
- 3) Regeneration/reactivation of calcium loaded GAC is a viable alternative with respect to performance and cost to discarding or incinerating spent GAC and replacing it with virgin GAC. *EX-1011*, 88.
- 4) To achieve a higher GAC throughput through a regeneration furnace. *EX-1011*, 84; and
- 5) Avoids the cost and efforts of treating the spent carbon. *EX-1011*, 88.

153. In addition such a modification would be merely:

- 6) using a known technique to improve a similar device or method in the same way. Mueller and McDougall already teach thermal reactivation and reuse of spent municipal-water-filtered-GAC, applying Cannon's known no-acid-wash approach to Mueller and McDougall's reactivation process to improve efficiency and cost in the same kind of water-treatment carbon-regeneration setting.

7) design choice / optimization of a known process parameter. Cannon expressly treats calcium loading and acid washing as process variables affecting oxidation efficiency, throughput, pore development, and cost. *EX-1011*, 84, 88.

154. A POSA would have had a reasonable expectation of success of applying the teachings of Cannon to regenerate/reactivate the spent activated carbon of Mueller and McDougall. Given Cannon's teaching of refraining from an acid washing step in the regeneration/reactivating process, the process employed by Mueller and McDougall would not be materially changed.

155. Claim 5 is thus rendered unpatentable over Mueller and McDougall in view of Cannon.

D. Ground 4: Claims 1-5 are Unpatentable Over Mimna in view of Reactivation Services and Cannon

1. The Mimna Reference

156. Mimna discloses that GAC is an effective material for removing perfluorinated compounds (PFC), a subset of PFAS, in water. Specifically, Mimna details that GAC is a proven technology for removal of PFCs in drinking water and groundwater, and provides studies of Calgon Carbon Filtrasorb® products removal of PFC. Additionally, Mimna explains the reactivation process of GAC and details Calgon Carbon services offered to reactivate spent carbon. *EX-1007*, 4, 9, 16, 27, 30-32.

2. The Reactivation Services Reference

157. Reactivation Services discloses the thermal reactivation process for spent granular activated carbon, including the specific temperatures used and the restoration of adsorptive properties. Specifically, Reactivation Services teaches that “[s]pent carbon is reactivated in the same manner that it is manufactured. In multiple hearth furnaces or rotary kilns, the spent carbon is heated to temperatures above 1,700°F utilizing steam as a selective oxidant.” Reactivation Services further explains that “[a]dsorbed organics are either volatilized or pyrolysed to a carbon char” and that “[t]he high-temperature steam reaction serves to develop the pore volume of the activated carbon and restore its adsorptive capacity.” *EX-1014*, 1.

158. Reactivation Services also discloses that the reactivation process restores the performance characteristics of spent carbon to near-virgin quality. Reactivation Services states that “[i]n most applications, reactivated carbon will perform nearly as well as virgin carbon” and explains that “[t]he adsorptive capacity of the spent carbon can be restored at a lower cost than the manufacture of activated carbon from raw material.” Reactivation Services further teaches that “[s]pent carbons from drinking water and other food grade applications can be reactivated for reuse in their prior applications if these carbons are segregated for custom reactivation at a food grade facility.” Thus, Reactivation Services teaches

a thermal reactivation process at temperatures above 1,700°F (approximately 927°C) that restores the adsorptive capacity and performance of spent activated carbon, including carbon previously used for drinking water treatment. *EX-1014*, 1.

3. Detailed Application of Mimna in view of Reactivation Services and Cannon

Claim 1

- i. A method of removing perfluoroalkyl and polyfluoroalkyl substances (PFAS) from liquid or gas, the method comprising:*

159. To the extent that the preamble is limiting, Mimna discloses removing PFAS from liquid. Specifically, Mimna identifies perfluorinated compounds (“PFCs”) including PFOA and PFOS [*perfluoroalkyl and polyfluoroalkyl substances (PFAS)*] as contaminants in drinking water and explains that granular activated carbon (“GAC”) is a “leading technology for removal of PFCs from drinking water and groundwater.” Mimna further states that “PFCs/PFASs are found in trace amounts in water,” recommends testing with customer raw water samples, and concludes from a case study that “FILTRASORB® can remove PFCs to non-detectable levels.” *EX-1007*, 4, 9, 16, 27.

160. A POSA understood generally, and from Mimna specifically, that PFCs are a subset of PFAS, and include well-known PFAS such as PFOA and PFOS. *Id.* Thus, Mimna discloses a *method of removing perfluoroalkyl and*

polyfluoroalkyl substances (PFAS) from liquid, namely from PFC-contaminated water such as drinking water and groundwater. EX-1007, 4, 9, 16, 27.

- ii. providing a sorbent material comprising reactivated carbon, wherein the reactivated carbon is formed from a spent activated carbon, wherein the spent activated carbon was previously used for water filtration; and*

161. Mimna expressly discloses reactivation of spent GAC used in water treatment and reuse of that carbon as a sorbent material [*a sorbent material comprising reactivated carbon... previously used for water filtration*]. Specifically, Mimna states that GAC is the “leading technology for removal of PFCs from drinking water and groundwater,” thereby placing the activated carbon in a water-filtration context, and further explains that “[r]eactivation of spent GAC thermally destroys adsorbed contaminants including PFC’s.” *EX-1007, 9, 32.* Mimna also states, under a “Reactivation of GAC” heading, that “[c]arbon reactivation is a thermal treatment process in which adsorbed chemical constituents are removed from spent activated carbon,” that the desorbed constituents are “thermally destroyed in the reactivation process”, and that the “[c]arbon is then **reusable**.” *EX-1007, 30, 32.* Thus, Mimna teaches providing a sorbent material comprising **reactivated carbon** formed from **spent activated carbon** that had previously been used for **water filtration**, including drinking water and groundwater treatment. *EX-1007, 9, 16, 30, 32.*

iii. *contacting the sorbent material with a liquid or gas containing the PFAS*

162. Mimna expressly discloses that granular activated carbon (“GAC”), including is the “[l]eading technology for removal of PFCs from **drinking water** and **groundwater**,” further explains that “PFCs/PFASs are found in trace amounts in water”, that Patent Owner “has over 10 years of experience reactivating carbons with PFCs”, whereby the reactivated carbon “is then **reusable**” to treat PFAS-contaminated “drinking water” or “groundwater” because “[r]eactivation of spent GAC thermally destroys adsorbed contaminants including PFCs.” *EX-1007*, 9, 16, 30, 32. Mimna also describes isotherm testing in which a water sample is placed “in contact with increasing amount of carbon” [*contacting the sorbent material with a liquid or gas containing the PFAS*], followed by filtration and analysis of residual concentration, and describes column testing that simulates full-scale performance for PFAS removal from water. *EX-1007*, 9, 16, 17, 19. Thus, Mimna teaches contacting the sorbent material comprising reactivated carbon with a **liquid** containing PFAS, namely contaminated water such as drinking water or groundwater, so that the PFAS is adsorbed onto the reactivated carbon. *EX-1007*, 9, 16, 17, 19, 30, 32.

iv. **wherein the reactivated carbon was reactivated by heat at a temperature of about 500° C to about 1100° C.**

163. Mimna does not disclose the specifics of how the reactivated carbon was formed from the spent activated carbon, however Reactivation Services does.

164. Reactivation Services expressly discloses thermal reactivation of spent granular activated carbon by heating it to temperatures within the claimed range. Specifically, Reactivation Services states that “[s]pent carbon is reactivated in the same manner that it is manufactured. In multiple hearth furnaces or rotary kilns, the spent carbon is heated to temperatures above 1,700°F utilizing steam as a selective oxidant.” *EX-1014*, 1. Because 1,700°F (approximately 927°C) falls squarely within the claimed range of about 500°C to about 1100°C, Mimna in view of Reactivation Services teaches that the reactivated carbon, that “is... reusable” to treat PFAS-contaminated “drinking water” or “groundwater”, was reactivated by heat at a temperature within the claimed range. *EX-1014*, 1; *EX-1007*, 9, 16, 17, 19, 30, 32.

165. It would have been obvious to a POSA to use the reactivated carbon formed by thermal reactivation within the claimed temperature range [*the reactivated carbon was reactivated by heat at a temperature of about 500°C to about 1100°C*] as taught by Reactivation Services as the “reusable” reactivated carbon [*sorbent material*] used in Mimna.

166. A POSA would have been motivated to use the thermally reactivated carbon taught by Reactivation Services as the “reusable” reactivated carbon used in

Mimna because Mimna expressly teaches PFAS removal from drinking water and groundwater using GAC, states that “[r]eactivation of spent GAC thermally destroys adsorbed contaminants including PFC’s”, and further explains that “[c]arbon reactivation is a thermal treatment process in which adsorbed constituents are removed from spent activated carbon” whereby the “[c]arbon is then reusable.” *EX-1007*, 9, 30, 32.

167. Reactivation Services provides the known implementation details for that very reactivation step, for which the publisher of both Mimna and Reactivation Services (*i.e.*, Patent Owner) used in its “over 10 years of experience reactivating carbons with PFCs” by January 2017, teaching that spent carbon is reactivated by heating to temperatures above 1,700°F (approximately 927°C) utilizing steam as a selective oxidant, that adsorbed organics are destroyed and the activated carbon’s adsorptive capacity is restored, and that, in most applications, reactivated carbon will perform nearly as well as virgin carbon. *EX-1007*, 9, 30-32; *EX-1014*, 1. Reactivation Services further teaches that spent carbons from drinking water applications can be reactivated for reuse in their prior applications. *EX-1014*, 1. Thus, a POSA would have understood that combining Mimna and Reactivation Services would have been no more than the predictable use of a known thermal reactivation technique to produce the reusable reactivated GAC that Mimna expressly contemplates for PFAS-contaminated water treatment, with the expected

benefit of lowering cost, restoring adsorption capacity, and thermally destroying adsorbed contaminants.

168. This combination is supported by multiple obviousness rationales, including express teaching, suggestion, or motivation (Mimna's express endorsement of reactivation for PFAS-laden GAC), application of a known technique to a known device ready for improvement (using Reactivation Services' established thermal reactivation process for the spent GAC used in Mimna's PFAS-removal systems), and predictable use of prior-art elements according to their established functions (spent potable-water GAC is thermally reactivated and reused as adsorbent).

169. A POSA would have had a reasonable expectation of success in using the thermally reactivated carbon taught by Reactivation Services as the "reusable" reactivated carbon sorbent used in Mimna because Mimna teaches that spent GAC used for PFAS removal is thermally reactivated and then reusable (*EX-1007*, 9, 30-32), while Reactivation Services teaches that reactivated carbon will perform nearly as well as virgin carbon and that spent carbons from drinking water applications can be reactivated for reuse in their prior applications (*EX-1014*, 1).

Claim 2

The method of claim 1, wherein the reactivated carbon was reactivated by heat at a temperature of about 700°C.

170. Reactivation Services teaches this limitation because it expressly discloses thermal reactivation of spent granular activated carbon by heating it to temperatures that encompass about 700°C. Specifically, Reactivation Services states that spent carbon is heated to temperatures above 1,700°F (approximately 927°C) utilizing steam as a selective oxidant, and further explains that adsorbed organics are destroyed and the activated carbon’s adsorptive capacity is restored. Because a process conducted at temperatures above 927°C necessarily includes operation at and through temperatures around 700°C during heat-up and within the broader thermal reactivation regime, Reactivation Services teaches reactivation at about 700°C to a POSA. *EX-1014*, 1. Accordingly, and for the reasons stated above for limitation [1.iv], Mimna in view of Reactivation Services meets this limitation, and a POSA would have been motivated to use the thermally reactivated carbon taught by Reactivation Services as the “reusable” reactivated carbon used in Mimna. *See* § VII.D.3 ([1.iv]) above.

Claim 3

The method of claim 1, wherein the reactivated carbon is formed from spent sorbent material feedstock comprising calcium carbonate.

171. Mimna does not explicitly disclose that calcium carbonate is deposited or otherwise contained in the spent GAC sorbent [*spent sorbent material feedstock*] prior to thermal reactivation. *EX-1007*, 9, 30-32. However, a POSA

understood that inorganic substances, specifically dissolved salts (e.g. calcium carbonate) in the filtered liquid (routinely found in ground water) are routinely deposited on the spent carbon and thus would be contained in the spent carbon feedstock, unless specifically removed.

172. Moreover, Cannon explicitly discloses inorganic materials, species of Ca (e.g. CaCO_3 , Ca(OH)_2), contained within the spent carbon. Cannon notes the presence of calcium carbonate and other inorganic materials present during reactivation may increase the mesopore volume and, as understood by a POSA, thus improve the adsorption capacity of the sorbent, especially with respect to PFAS. *EX-1011*, 77, 78.

Thermal regenerations were conducted on a spent granular activated carbon (GAC) that had served in a water treatment plant for about four years, and contained 1.8% calcium.

EX-1011, Abstract.

173. A POSA understood that the calcium present in the GAC would partially exist in ionic Ca^{+2} form, with a significant portion expected to react with carbonate to form calcium carbonate which deposits on the GAC in the form of calcium carbonate. Carbon dioxide ubiquitous in the atmosphere dissolves into GAC-associated water resulting in aqueous carbonate as a reactant in excess which

produces calcium carbonate after reaction with ionic calcium. *See* State of the Art §V.G.5;

174. Thus, a POSA would understand, given the teachings and disclosure of Cannon, that spent activated carbon recovered from water treatment plants [*water-filtering*] would “contain high concentrations of calcium (0.4-7 percent)” at least a significant portion being calcium carbonate. Therefore, it is implicit that some of the spent activated carbon disclosed in Mimna comprises calcium carbonate, and renders the limitation of Claim 3 obvious. *EX-1011*, 87.

Claim 4

The method of claim 1, wherein the reactivated carbon comprises one or more of granular activated carbon and powdered activated carbon.

175. Mimna repeatedly identifies the relevant sorbent as granular activated carbon (“GAC”) and further discusses reactivation of spent GAC. Specifically, Mimna states that GAC is the “leading technology for removal of PFCs from drinking water and groundwater,” describes comparative testing and case studies using FILTRASORB® GAC, and explains that “[r]eactivation of spent GAC thermally destroys adsorbed contaminants including PFC’s,” after which the reactivated carbon is “reusable.” *EX-1007*, 9, 16, 27, 30, 32.

Claim 5

The method of claim 1, wherein the spent activated carbon is not treated to remove any inorganic materials that are present in ground water.

176. Mimna does not explicitly disclose a treatment to remove inorganic materials, nor however does Mimna prohibit such a treatment to remove inorganic materials deposited on the spent activated carbon. However, Cannon discloses the benefits of not acid washing [*not treated to remove any inorganic materials*] the spent activated carbon. *EX-1011*, 84.

This difference highlighted how calcium dramatically improved oxidation efficiency, a factor that could offer advantages during full-scale, carefully controlled regenerations.”

EX-1011, 84.

Indeed, the calcium catalyst would allow a higher GAC throughput through a regeneration furnace, which probably would offset the potential need for more frequent regeneration cycles.

EX-1011, 84.

primarily widened pores of the <5-nm range, forming pores in the 5-10-nm range.

EX-1011, 87.

These oxidations caused even lower total surface areas, higher mesopore surface area, lower micropore volumes, higher 2-10-nm

pore volumes, ...and a linear pore size distribution between 2 and 10 nm.

EX-1011, 87.

regeneration option for this calcium loaded GAC provided potential as a viable alternative to discarding or incinerating spent GAC and replacing it with virgin GAC.

EX-1011, 88.

The authors recommend that the slight improvement would not justify the added nuisance and expense incurred by employing an acid-washing step before regenerating coal-based GACs that contain ~2 percent calcium.

EX-1011, 88.

177. Therefore, to the extent that Mimna and Reactivation Services would treat the spent activated carbon to remove inorganics, it would have been obvious to a POSA to preserve the inorganic materials accumulated thereon during water filtration (*e.g.*, from the treated “groundwater” where inorganics are routinely found), rather than treat the spent activated carbon to remove those inorganic materials. *EX-1007*, 9, 30-32. A POSA would have been motivated to modify Mimna and Reactivation Services to preserve the inorganic materials for both economic and performance reasons because, as taught by Cannon:

- 1) The presence of calcium (an inorganic material) improves the efficiency of the oxidation during regeneration/reactivation of the spent activated carbon. *EX-1011*, 84.
 - 2) The presence of calcium created more pores in the 5-10 nm range, which a POSA understood would improve filtering of some PFAS molecules. *EX-1011*, 77, 87.
 - 3) Regeneration/reactivation of calcium loaded GAC is a viable alternative with respect to performance and cost to discarding or incinerating spent GAC and replacing it with virgin GAC. *EX-1011*, 88.
 - 4) To yield a higher GAC throughput through a regeneration furnace. *EX-1011*, 84; and
 - 5) Avoids the cost and efforts of treating the spent activated carbon. *EX-1011*, 88.
178. In addition such a modification would be merely:
- 6) using a known technique to improve a similar device or method in the same way. Mimna already teaches thermal reactivation and reuse of spent drinking-water-filtered-GAC (and spent groundwater-filtered-GAC), applying Cannon's known no-acid-wash approach to Mimna's reactivation process to improve efficiency and cost in the same kind of water-treatment carbon-regeneration setting. *EX-1007*, 9, 30-32.

7) design choice / optimization of a known process parameter. Cannon expressly treats calcium loading and acid washing as process variables affecting oxidation efficiency, throughput, pore development, and cost. *EX-1011*, 84, 88.

179. A POSA would have had a reasonable expectation of success of applying the teachings of Cannon to regenerate/reactivate the spent carbon of Mimna and Reactivation Services. Given Cannon's teaching of refraining from an acid washing step in the regeneration/reactivating process, the process employed by Mimna and Reactivation Services would not be materially changed.

180. Claim 5 is thus rendered unpatentable over Mimna and Reactivation Services in view of Cannon.

E. Ground 5: Claim 5 Fails to Meet the Written Description Requirement Under 112(a)

181. As discussed in Claim Construction §V.C.2 (above), a POSA would understand that the plain and ordinary meaning of the negative limitation recited in claim 5 – “the spent activated carbon is not treated to remove any inorganic materials that are present in ground water” –, in view of the claim language and intrinsic evidence, is that the reactivated carbon, formed from the spent activated carbon, includes some amount of inorganic materials that the spent activated carbon adsorbed while it was being previously used for water filtration of ground water. §V.C.2 (*above*).

182. The '948 Patent specification does disclose outer limits of a broad genus of “reactivated carbon [that] has not undergone any process to remove or reduce the amount of the ions, oxides, or carbonates of calcium, magnesium, sodium, potassium and zinc” that such “reactivated carbon compris[es].” *EX-1001*, 2:35-44. However, there is no disclosure in the '948 Patent specification of, for example, **any** activated carbon that would adsorb **all** inorganic materials (regardless of type or amount) from **all** ground waters (which may differ in inorganic composition and amounts), nor of **how** to form an activated carbon with such surface area and pore structure to adsorb **all** inorganic materials that may be present in **any** given ground water. *See EX-1001 generally.*

183. Moreover, there is no disclosure in the specification for **how** an activated carbon used in filtering groundwater until spent, and then processed, transported, stored, reactivated, and returned for reuse, would not lose **any** amount of inorganic materials that **could** have been impregnated on it and retained, with the sole exception being the specification's teaching of don't acid wash the reactivated carbon. Indeed, the only disclosed example of “treatment” forbidden by the negative language “not treated to remove any inorganic materials that are present in ground water” in the specification, which parallels the negative limitation of claim 5, is acid washing of the successor sorbent material (reactivated carbon). *EX-1001*, 8:10-19, 2:35-44, 11:53-60 (and 10:39-45).

184. For example, the '948 Patent contains **no** disclosure of any actions, or processes, that could reduce the amount of inorganic materials that are naturally present in groundwater **before** the groundwater is filtered by activated carbon (*e.g.*, pre-treatment of the ground water by physically filtering the ground water to remove larger sediment and suspended solid particles before the ground water is fed into an activated carbon bed). *See EX-1001 generally.* Additionally, for example, the '948 Patent contains **no** disclosure of any actions, or processes, that could, **while** the groundwater **is being** filtered by activated carbon (and before it becomes "spent"), keep the activated carbon from having adsorbed **all** (*i.e.*, **the highest possible** amount) of inorganic material present in the filtered groundwater (*e.g.*, backwashing the activated carbon bed to flush out the larger sediment and suspended solid particles that are blocking the flow of groundwater through the bed). *See EX-1001 generally.* Further, for example, the '948 Patent contains **no** disclosure of any other post-groundwater-filtering actions or processes – besides acid washing – that could reduce the amount of inorganic materials that are present on the spent activated carbon prior to (or during) its reactivation such as, for example, (i) during processing and unloading the spent activated carbon from a water treatment vessel (*e.g.*, backwashing, draining, educting, dewatering); (ii) during loading, unloading and transport for reactivation at an off-site reactivation facility (*e.g.*, physical movement causing some spent activated carbon particles to

be broken down by movement against one another and against other surfaces (causing a loss of some weakly, physically-connected inorganic materials), cleaning of transport trucks/railcars/storage vessels (as required by AWWA B605)); **nor** (iii) during testing (*e.g.*, for spent carbon acceptance for reactivation to comply with AWWA B605). *See EX-1001 generally.*

VIII. CONCLUSION

185. For all the reasons set forth within my Declaration, it is my opinion that: a POSA would have found Claims 1-5 of the '948 Patent anticipated by Kempisty; a POSA would have found Claims 1-5 of the '948 Patent obvious over McNamara, alone or in view of Cannon; a POSA would have found Claims 1-5 of the '948 Patent obvious over Mueller in view of McDougall and Cannon; a POSA would have found Claims 1-5 of the '948 Patent obvious over Mimna in view of Reactivation Services and Cannon; and Claim 5 is unpatentable for failing to meet the written description requirement.

CONCLUSION AND DECLARATION

The findings and opinions set forth in this declaration are based on my research and analysis to date. I may continue my examinations in view of additional documents or other factual evidence over the course of this proceeding that may necessitate supplementing and/or refining my opinions. I reserve the right to add to, alter, or delete my opinions and my Declaration upon discovery of additional information. I reserve the right to make such changes as necessary.

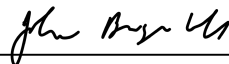
In signing this declaration, I understand that the declaration may be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

I declare that all statements made herein on my own knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

[SIGNATURE ON FOLLOWING PAGE]

Petition for PGR of U.S. Patent No. 12,478,948

Dated: 8/20/2026

By: 

John Bergendahl, Ph.D.

Appendix A-MATERIALS CONSIDERED

<i>NORIT</i> <i>Exhibit #</i>	<i>Description</i>
1001	U.S. Patent No. 12,478,948
1002	File History for U.S. Patent No. 12,478,948
1004	Kempisty, D.M., et al. “Perfluoroalkyl Substances in the Environment: Theory, Practice, and Innovation,” Boca Raton: CRC Press, Taylor & Francis Group, <i>Environmental and occupational health series</i> , 2018 (“Kempisty”)
1005	Mueller, R., et al. “Remediation Technologies and Methods for Per- and Polyfluoroalkyl Substances (PFAS)”, Interstate Technology Regulatory Council (ITRC), March 15, 2018, archived by the Internet Archive’s Wayback Machine on December 18, 2018 at https://web.archive.org/web/20181218193617/https://pfas-1.itrcweb.org/wp-content/uploads/2018/03/pfas_fact_sheet_remediation_3_15_18.pdf (“Mueller”), which was (and is) accessible from a link entitled “Remediation Technologies and Methods (published 3-15-18)” on the ITRC PFAS Fact Sheets web page, which was archived by the Internet Archive’s Wayback Machine on August 19, 2018 at https://web.archive.org/web/20180819033439/https://pfas-1.itrcweb.org/fact-sheets/ .
1006	McDougall, G.J. “The Physical Nature and Manufacture of Activated Carbon,” Journal of the South African Institute of Mining and Metallurgy, Vol. 91, No. 4, pp. 109-120, April 1991 (“McDougall”)

<i>NORIT</i> <i>Exhibit #</i>	<i>Description</i>
1007	Mimna, Richard, “Granular Activated Carbon: A Proven Solution for PFC Removal,” Calgon Carbon Corporation Presentation, 30 January 2017, https://www.calgoncarbon.com/app/uploads/PFC-Webinar-Presentation-1-30-17.pdf , archived by the Internet Archive’s Wayback Machine on September 18, 2017 at https://web.archive.org/web/20170918144158/http://www.calgoncarbon.com:80/wp-content/uploads/2016/02/PFC-Webinar-Presentation-1-30-17.pdf (“Mimna”), which was (and is) accessible from a link entitled “Webinar: Granular Activated Carbon – A Proven Solution for PFC Removal” on the Calgon Carbon Corporation PFAS webpage, which was archived by the Internet Archive’s Wayback Machine on February 22, 2017 at https://web.archive.org/web/20170222172255/http://www.calgoncarbon.com/PFOA/ (EX-1030), and was archived by the Internet Archive’s Wayback Machine on February 10, 2018 at https://web.archive.org/web/20180210015520/https://www.calgoncarbon.com/municipal-drinking-water/perfluorinated-compounds-pfcs-perfluorooctane-sulfonate-pfos-and-perfluorooctanoic-acid-pfoa/ (EX-1033).
1008	“Infosheet-Reactivation Services”, 2016, Cabot Corporation, archived by the Internet Archive’s Wayback Machine on May 3, 2017 at https://web.archive.org/web/20170503071928/http://www.cabotcorp.com/~media/files/infosheets/activated-carbon/infosheet-reactivation-services.pdf (“Cabot”).
1009	Appleman, T. D., et al. “Treatment of poly- and perfluoroalkyl substances in U.S. full-scale water treatment systems,” Journal of Water Research, 51, 246-255 (2014), available online November 7, 2013, (“Appleman”).
1010	U.S. Patent No. 4,038,301 (“Otto”).
1011	Cannon, F.S., et al. “Effect of Calcium in Field-Spent GACs on Pore Development During Regeneration”, Journal-American Water Works Association (AWWA), Vol. 85, Issue 3, pp. 76-89, March 1993 (“Cannon”).

<i>NORIT Exhibit #</i>	<i>Description</i>
1012	Watanabe, N., et al. “Residual organic fluorinated compounds from thermal treatment of PFOA, PFHxA and PFOS adsorbed onto granular activated carbon (GAC),” Journal of Material Cycles and Waste Management, January 2016, 18:625-630 (“Watanabe”)
1013	McNamara, J. D., et al. “Comparison of Activated Carbons for Removal of Perfluorinated Compounds From Drinking Water,” Journal American Water Works Association, January 2018 (“McNamara”).
1014	Reactivation Services FAQ, Calgon Carbon Corporation, archived by the Internet Archive’s Wayback Machine on April 19, 2016 at https://web.archive.org/web/20160419140003/http://www.calgoncarbon.com/wp-content/uploads/2015/02/Reactivation_Services_FAQ.pdf .
1015	“Activated Carbon Principles”, Calgon Carbon Corporation, 2007, archived by the Internet Archive’s Wayback Machine on January 10, 2011 at https://web.archive.org/web/20110110024153/http://www.calgoncarbon.com/documents/ACPrinciples.pdf .
1016	U.S. Environmental Protection Agency (EPA), “EPA Facts About Activated Carbon Treatment”, Pub. No. 6847, June 1992.
1017	Calgon Carbon Corporation, “Use of Carbon Adsorption in Groundwater Treatment”, Application Bulletin, AB-1042-12/99, states “Reprinted from ENVIRONMENTAL PROGRESS, November 1989”, archived by the Internet Archive’s Wayback Machine on January 10, 2011 at https://web.archive.org/web/20110110015337/http://www.calgoncarbon.com/documents/UseofCarbonAdsorptioninGroundwaterTrmnt.pdf .
1018	U.S. Federal Water Pollution Control Administration (FWPCA), “Regeneration of Spent Granular Activated Carbon”, Report No. TWRC-7, February 1969.
1019	B.C. Moore, F. S. Cannon, et al., “Changes in GAC Pore Structure During Full-Scale Water Treatment at Cincinnati: A Comparison Between Virgin and Thermally Reactivated GAC,” Carbon, Vol. 39, Issue 6, pp. 789-807 (May 2001).
1020	Knappe et al., “Effect of Calcium on Thermal Regeneration of GAC,” Journal American Water Works Association (AWWA), Vol. 84, Issue 8, pp. 73-80, August 1, 1992.

<i>NORIT</i> <i>Exhibit #</i>	<i>Description</i>
1021	F.S. Cannon et al. “Reaction Mechanism Of Calcium-Catalyzed Thermal Regeneration Of Spent Granular Activated Carbon”, Carbon, Vol. 32, No. 7, pp. 1285-1301, 1994 (“Cannon 94”).
1022	U.S. Environmental Protection Agency (EPA), “Granular Activated Carbon Treatment”, Engineering Bulletin, EPA/540/2-91/024, Office of Emergency and Remedial Response, Washington, DC (Oct. 1991).
1023	Mueller, R., et al. “History and Use of Per- and Polyfluoroalkyl Substances (PFAS) found in the Environment,” Interstate Technology Regulatory Council (ITRC), August 2020 (“Mueller-PFAS History”).
1024	Westreich, P., et al., “The removal of short-chain and long-chain perfluoroalkyl acids and sulfonates via granular activated carbons: A comparative column study”, Remediation, 2018:29:19-26, December 4, 2018 (“Westreich”).
1025	Hassler, J. W., “Activated Carbon,” Chemical Publishing Company Inc. (1963) (“Hassler”).
1026	Appleman, T. D., et al. “Nanofiltration and granular activated carbon treatment of perfluoroalkyl acids,” Journal of Hazardous Materials, 260, 740-746 (2013) (“Appleman 2013”).
1027	Reactivation Services FAQ (2008), Calgon Carbon Corporation, archived by the Internet Archive’s Wayback Machine on October 10, 2008 at https://web.archive.org/web/20081010042904/http://www.calgoncarbon.com/carbon_reactivation/faq.html (“Reactivation Services 2008”).
1028	“Industry Affiliates Program”, Interstate Technology Regulatory Council (ITRC), archived by the Internet Archive’s Wayback Machine on December 18, 2017 at https://web.archive.org/web/20171218120219/http://itrcweb.org/IAP/IAP (identifying Calgon Carbon as a member) (“ITRC IAP”).
1029	“PFAS - Per- and Polyfluoroalkyl Substances: References”, Interstate Technology Regulatory Council (ITRC), archived by the Internet Archive’s Wayback Machine on January 26, 2019 at https://web.archive.org/web/20190126023953/https://pfas-1.itrcweb.org/references/ (“ITRC References”).

NORIT Exhibit #	Description
1030	“PERFLUORINATED COMPOUNDS (PFCS), PERFLUOROOCTANE SULFONATE (PFOS) AND PERFLUOROOCTANOIC ACID (PFOA)”, Calgon Carbon Corporation PFAS web page, 2017, archived at the Internet Archive’s Wayback Machine on February 22, 2017 at https://web.archive.org/web/20170222172255/http://www.calgoncarbon.com/PFOA/, which includes broken links to Calgon prior art documents entitled (i) “Reactivation of Spent Carbon Containing PFCs” (https://web.archive.org/web/20170222172255/http://www.calgoncarbon.com/wp-content/uploads/2016/02/Calgon_Carbon_PFCs-and-Reactivation-Fact-Sheet.pdf (not working)), and (ii) “Case Study: GAC Removes PFOA from Drinking Water” (https://web.archive.org/web/20170222172255/http://www.calgoncarbon.com/case-study/upstate-new-york-granular-activated-carbon-removes-pfoa-drinking-water/ (not working)) (“Calgon PFAS Page 2017”).
1031	J. Brewer, J. McNamara, P. Westreich, “Granular activated carbon: a proven solution of PFAS treatment”, presented September 13, 2017 at the 7th International Contaminated Site Remediation Conference incorporating the 1st International PFAS Conference in Melbourne, Australia (September 10-14, 2017), published in the Proceedings of the 7th International Contaminated Site Remediation Conference, CRC CARE Pty Ltd., No. INIS-AU--0099, pp. 462-463, September 2017 (“Brewer”).
1032	“PFAS TREATMENT: PROTECTING WHAT MATTERS”, Calgon Carbon Corporation PFAS web page, 2026, accessed on July 28, 2026 at https://www.calgoncarbon.com/pfas/, where link entitled “Case Study: GAC Removes PFAS from Drinking Water” links to a 2023 document (rather than a 2017 document per EX-1030, 2), contains no link to a 2016 document entitled “Reactivation of Spent Carbon Containing PFCs” (<i>cf.</i> EX-1030, 2; EX-1033, 2), and contains no link to a 2017 document entitled “Calgon Carbon Memo on Reactivation – June 2017” (<i>cf.</i> EX-1033, 2) (“Calgon PFAS Page 2026”).

NORIT Exhibit #	Description
1033	“PERFLUORINATED COMPOUNDS (PFCS), PERFLUOROOCTANE SULFONATE (PFOS) AND PERFLUOROOCTANOIC ACID (PFOA)”, Calgon Carbon Corporation PFAS web page, 2018, archived at the Internet Archive’s Wayback Machine on February 10, 2018 at https://web.archive.org/web/20180210015520/https://www.calgoncarbon.com/municipal-drinking-water/perfluorinated-compounds-pfcs-perfluorooctane-sulfonate-pfos-and-perfluorooctanoic-acid-pfoa/, which includes broken links to Calgon prior art documents entitled (i) “Calgon Carbon Memo on Reactivation – June 2017” (https://web.archive.org/web/20180210015520/https://www.calgoncarbon.com/app/uploads/CCC-Memo-on-Reactivation-6-17.pdf (not working)), (ii) “Reactivation of Spent Carbon Containing PFCs” (https://web.archive.org/web/20170222172255/http://www.calgoncarbon.com/wp-content/uploads/2016/02/Calgon_Carbon_PFCs-and-Reactivation-Fact-Sheet.pdf (not working)), and (iii) “Case Study: GAC Removes PFOA from Drinking Water” (https://web.archive.org/web/20170222172255/http://www.calgoncarbon.com/case-study/upstate-new-york-granular-activated-carbon-removes-pfoa-drinking-water/ (not working)) (“Calgon PFAS Page 2018”).
1034	“CUSTOM MUNICIPAL REACTIVATED CARBON”, Calgon Carbon Corporation CMR web page, 2017, archived at the Internet Archive’s Wayback Machine on September 19, 2017 at https://web.archive.org/web/20170919034011/http://www.calgoncarbon.com/products/cmr/ (“Calgon CMR”).
1035	ASTM International, “Standard Test Method for Total Ash Content of Activated Carbon”, D2866-11 (2011).
1036	Harter, T., “Groundwater Quality and Groundwater Pollution”, Publication 8084, Farm Water Quality Planning (FWQP) Reference Sheet 11.2, Regents of the University of California, Division of Agriculture and Natural Resources, 2003.
1037	ANSI/American Water Works Association (AWWA) Standard, “Reactivation of Granular Activated Carbon”, ANSI/AWWA B605-18, 2018.

<i>NORIT</i> <i>Exhibit #</i>	<i>Description</i>
1038	R. Deithorn, “Carbon Adsorption & Reactivation”, Calgon Carbon Corporation, White Paper, 2012, archived at the Internet Archive’s Wayback Machine on April 20, 2016 at https://web.archive.org/web/20160420235152/http://www.calgoncarbon.com/wp-content/uploads/case-studies/WP-AdsorpReactIndust15-ZOLT-E1.pdf .
1039	Calgon Carbon Corporation, “Go Green – Custom Reactivation of Activated Carbon for Drinking Water Treatment”, White Paper, 2009, archived at the Internet Archive’s Wayback Machine on August 6, 2010 at https://web.archive.org/web/20100806211221/http://www.calgoncarbon.com/carbon_reactivation/documents/CustomReactBrochurev9-23-09.pdf .
1041	U.S. Pat. No. 11,911,743 (the “Parent ’743 Patent”).
1042	File history of the parent application to the ’948 Patent, U.S. Pat. Appl. Ser. No. 16/839,862, which issued as the Parent ’743 Patent.
1043	Ronald L. Droste, “Theory and Practice of Water and Wastewater Treatment,” John Wiley & Sons, Inc., 1997 (ISBN 0-471-12444-3).

Appendix B CV

John Bergendahl, Ph.D., P.E.

Director, Environmental Engineering Program
Associate Professor, Department of Civil and Environmental Engineering
Worcester Polytechnic Institute, Worcester, MA
email: jberg@wpi.edu; phone: 508-831-5772

Education

- *Doctor of Philosophy in Chemical Engineering*, February 1999; Univ. of Connecticut
- *Master of Science in Environmental Engineering*, August 1996; Univ. of Connecticut
- *Bachelor of Science in Mechanical Engineering*, December 1985; Univ. of Connecticut

Professional Experience

- *Associate Professor*, July 2006 – present; Department of Civil and Environmental Engineering (collaborative appointment in Chemical Engineering), Worcester Polytechnic Institute, Worcester, MA
- *Director, Environmental Engineering Program*; July 2015 – July 2026; Worcester Polytechnic Institute, Worcester, MA
- *Assistant Professor*, January 2000 – June 2006; Department of Civil and Environmental Engineering, Worcester Polytechnic Institute, Worcester, MA
- *Postdoctoral Research Fellow*, March 1999 – December 1999; Environmental and Water Resources Engineering Program, Department of Civil Engineering, University of Texas, Austin, TX
- *Research Associate*, 1995 – February 1999; University of Connecticut, Storrs, CT
- *Teaching Fellow*, 1993 – February 1999; University of Connecticut
- *Intern*, September 1994 – May 1995; Connecticut Hazardous Waste Management Service, Technical Assistance Program, Hartford, CT
- *Senior Engineer, Engineer, Associate Engineer*, 1985 – 1992; General Dynamics, Electric Boat Div., Groton, CT

Courses Taught

Undergraduate courses:

CE1030	<i>Civil Engineering and Computer Fundamentals</i>
CE3060	<i>Water Treatment</i>
CE3061	<i>Sustainable Wastewater Engineering: Treatment and Reuse</i>
CE4600	<i>Hazardous and Industrial Waste Management</i>
CE4620	<i>Environmental Engineering Laboratory II</i>
ES2800	<i>Environmental Impacts of Engineering Decisions</i>
FY160X, ES200X	<i>Humanitarian Engineering (co-taught)</i>

Graduate courses:

CE561	<i>Advanced Principles of Wastewater Treatment</i>
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CE563	<i>Industrial Waste Treatment</i>
CE569	<i>Environmental Treatability Laboratory (co-taught)</i>
CE572	<i>Physical and Chemical Treatment Processes</i>
CE573	<i>Treatment System Hydraulics</i>

Student Work Advised (reports available at www.wpi.edu/library)

M.S. Theses

- *Pyrolytic Transformations of PFAS Precursors in AFFF when Applied for Fire Suppression*, Drew Grenier, May 2023, advisor: Bergendahl, co-advisor: A. Rangwala
- *Polycyclic Aromatic Hydrocarbon Release from Pavement Rejuvenators Due to Rolling Wheel Contact: An Investigation Using a Model Mobile Load Simulator*, Joshua Anderson, April 2019, advisor: Bergendahl
- *Enhancement of Municipal Wastewater Biosolids Drying Through Interfacial Energy Modifying Amendments to Promote Uniform Aggregation: Bench Scale Testing*, Sarah Stine, January 2019, advisor: Bergendahl, co-advisor: Plummer
- *Enhancement of Municipal Wastewater Biosolids Drying Through Interfacial Energy Modifying Amendments to Promote Uniform Aggregation*, Helin Zhang, August 2018, advisor: Bergendahl, co-advisor: Plummer
- *Sonochemical Defluorination of Perfluorinated Compounds by Activated Persulfate Ions*, Kevin Gray, July 2018, advisor: Bergendahl, committee members: Mathisen, Alvarez-Corena
- *Radioisotopes in Domestic Wastewater and Their Fate in Wastewater Treatment*, Xiaodi Pan, September 2016, advisor: Bergendahl, co-advisors: Medich, Mathisen
- *Biodegradability of Fluorinated Fire Fighting Foams*, Amy Bourgeois, May 2014, advisor: Bergendahl, co-advisors: Rangwala, Mathisen
- *Permethrin for Mosquito Control: Drinking Water Impacts and Treatment*, Lesley Eckert, December 2013, advisor: Plummer, co-advisor: Bergendahl
- *Ozonation of Tris-2-Chloroethyl Phosphate (TCEP) in Water*, Michael Votruba, May 2013, major advisor: Bergendahl, co-advisor: Mathisen
- *Advanced Oxidation Treatment for Ibuprofen, Ketoprofen, and Naproxen in Water and Method for Determining Ibuprofen, Ketoprofen, and Naproxen Concentration Using Liquid-Liquid Extraction – Gas Chromatography-Flame Ionization Detection*, Marc Weller, January 2013, major advisor: Bergendahl, co-advisor: Mathisen
- *Advanced Oxidation of Tris-2-Chloroethyl Phosphate (TCEP) in Water*, Huong Nguyen, May 2011, major advisor: Bergendahl, co-advisor: O'Shaughnessy.
- *Microanalysis of Heterogeneous Radiation in Particulate Matter as an Aid to Nuclear Source Identification*, Marco Kaltfen, August 2009, major advisor: Bergendahl, co-advisor: O'Shaughnessy.
- *Novel Simultaneous Reduction/Oxidation Process for Destroying Organic Solvents*, Anita Padmanabhan, April 2008, major advisor: Bergendahl, co-advisor: O'Shaughnessy.

- *Modified UNIFAC-LLE Group-Interaction Parameters for the Prediction of Gasoline-Ethanol-Water Equilibria*, Jason Lewandowski, April 2008, major advisor: Bergendahl, co-advisor: O'Shaughnessy.
- *Slurry Test Evaluation for In-Situ Remediation of TCE-Contaminated Aquifers*, Sachin Sharma, August 2006, major advisor: Bergendahl, co-advisor: O'Shaughnessy.
- *Sorption/Oxidation of Estrogens*, Huajing Wen, May 2006, major advisor: Bergendahl, co-advisors: Thompson, O'Shaughnessy.
- *The Role of Roughness on Particle Detachment in Porous Media*, Ryan Neyland, May 2005; major advisor: Bergendahl, co-advisor: Camesano.
- *TCE Removal Utilizing Coupled Zeolite Sorption and Advanced Oxidation*, Harmonie Hawley, 2003; major advisor: Bergendahl, co-advisor: Thompson.
- *Advanced Oxidation of MTBE in the Presence of Zero-Valent Iron*, Timothy Thies, 2002.
- *Evaluation of Batch Leaching Tests for Soils Contaminated with Hydrophobic Organics*, Brian Morgan, 2001.
- *Wastewater Disinfection: Chlorine Residual versus Oxidation Reduction Potential*, Laurie Vinagro, 2001.
- *Pilot-Scale Study of Fenton's Reagent for the Oxidation of Organic Contaminants in Groundwater*, Stephanie Hubbard, 2001.

Ph.D. Dissertations

- *Emerging Contaminants from Tire Wear Particles*, Terrence McFarland, expected 2027.
- *Anthropogenic Nanoparticulate Material in Wastewater: Occurrence, Measurement, and Treatment*, Yinduo Chen, 2022.
- *Opportunities and Challenges of Low-Carbon Hydrogen via Metallic Membrane Reactors*, Kourosh Kian, May 2020, major advisor: Wilcox, committee members: Bergendahl, Liguori, Kazantzis, Timko, Rashidi.
- *Removal of Sulfamethoxazole by Adsorption and Biodegradation in the Subsurface: Batch and Column Experiments with Soil and Biochar Amendments*, Wenwen Yao, January 2018, major advisor: Mathisen, committee members: Bergendahl, Tao, Reckow.
- *Heterogeneous Photocatalysis for the Treatment of Contaminants of Emerging Concern in Water*, Jose Alvarez Corena, July 2015, major advisor: Bergendahl, committee members: Hart, Mathisen, Plummer, and Thompson.
- *Minimizing Water Requirements for Electricity Generation in Water Scarce Areas*, Erica Stults, May 2015, major advisor: Bar-on, committee members: Bergendahl, Trapp, Sisson, Savilonis, Liu.
- *Assessing Human Exposure to Contaminants in House Dust*, Marco Kaltofen, Civil Engineering, March 2015; major advisor: Bergendahl, committee members: Mathisen, Iannacchione, and Medich
- *Removal of Chloroform and MTBE from Water by Adsorption onto Granular Zeolites: Equilibrium, Kinetic, and Mathematical Modeling Study*, L. Abu-Lail, Civil Engineering, 2011; major advisor: Bergendahl, co-advisor: Thompson, committee member: O'Shaughnessy.

- *Oxidation Processes: Experimental Study and Theoretical Investigations*, N. Al Ananzeh, Chemical Engineering, 2004; major advisor: Thompson, co-advisors: Ribero & Bergendahl.
- *The Effect of Biopolymer Properties on Bacterial Adhesion: An Atomic Force Microscopy (AFM) Study*, N. Abu-Lail, Chemical Engineering, 2003; major advisor: Camesano, Ph.D. committee members: Thompson, Clark & Bergendahl.

Undergraduate Major Qualifying Projects, MQPs: The MQP is a project in the student's area of study, and is usually completed in the senior year. It is considered the equivalent of 3 courses.

2026	<i>Identifying Short Chain PFAS Treatment Techniques</i> , B. Belanger, O. Diorio, advisors: Bergendahl and Kmiatek
2026	<i>PFAS Treatment System Batch Testing</i> , C. Bhanot, N. Cura, S. D'Annunzio, A. Pagan, advisors: Bergendahl & Kmiatek. With RI DEP
2026	<i>Exploration of Laccase- and Fenton Like-Functionalized Hydrogel–Biochar Systems for Water Remediation</i> , G. Page Violette, C. Walworth, N. Kessler, advisors: Bergendahl, Mishra, Eggleston
2026	<i>Elevating Soil Reuse by a Lightly Contaminated Soil Management System Design in Massachusetts, USA</i> , C. Johnson, advisors: Bergendahl and Elgert
2025	<i>Quantifying Residential Sources of PFAS</i> , M. Manning, A. McDonough, S. Tomaselli, advisors: Bergendahl and Kmiatek.
2025	<i>Extent of PFAS Contamination of Drinking Water Sources in Rhode Island</i> , R. Schultz, advisor: Bergendahl
2025	<i>Investigating Soil Amendments for Mycoremediation of Heavy Metals</i> , V. Corrente, M. Darrow, P. Agostini, advisors: Kmiatek and Bergendahl
2025	<i>Design of a 3-D Printable Biochar-PET Composite for Remediation of Water Contamination</i> , A. Gilbert, N. Pallius, advisors: Bergendahl, Mishra, Eggleston.
2024	<i>Potable Water Reuse in Massachusetts</i> , C. Burns, advisor: Bergendahl
2024	<i>Analyzing PFAS Concentrations Along the Blackstone River Watershed</i> , A. Parish, N. Noons, advisors: Bergendahl and Kmiatek
2024	<i>Simultaneous Degradation of PFAS and Ammonia in Landfill Leachate</i> , L. Thomson, I. Clowes, R. Bhargavi, advisors: Bergendahl and Kmiatek.
2024	<i>Evaluating PFAS Treatment Processes</i> , P. McKenna, M. Goggin, N. Raymond, M. Elwell, advisors: Bergendahl and Kmiatek.
2023	<i>Residential Per- and Poly-Fluoroalkyl Substances (PFAS) Sources</i> , L. Rodgers, S. Phan, C. Harvill, D. Evans, advisors: Bergendahl and Kmiatek
2023	<i>PFAS Contamination: Evaluation and Remediation</i> , S. Henderson, R. Widman, R. Trongone, advisors: Bergendahl and Kmiatek.
2023	<i>Degradation of Per- and Poly-Fluoroalkyl Substances via Advanced Oxidation Processes</i> , A. Clark, advisors: Bergendahl and Kmiatek

- 2023 *Air Emissions Control from Cannabis Processing*, B. Nieto, A. Lee, R. Singh, A. Cummings, advisors: Kmiotek and Bergendahl.
- 2023 *Water Contamination from Fire Events*, D. Tang, L. Marcoux, E. Mullin, advisors: Bergendahl, Rangwala, Jayachandran, Ranellone
- 2023 *Degradation of Per- and Poly-Fluoroalkyl Substances via Advanced Oxidation Processes*, K. Lacroix, S. Nguyen, advisors: Bergendahl and Kmiotek.
- 2022 *Contaminant Formation and Mobilization in Water Due to Fire Events*, L. Cristiano, N. Patel, R. Harter, A. Scariati, A. Vreeland, M. Penkala, D. Grenier, I. Rhodes, L. O'Donnell, advisors: Bergendahl, Rangwala, Jayachandran, Dittami.
- 2022 *Developing an Analytical Technique to Detect PFAS on Paper Food Packaging using SLE and NMR*, T. Dziechciarz, C. Wandell, J. Shimansky, S. Chase, advisors: Bergendahl, Kmiotek
- 2021 *Acid Leachate Active Treatment Pilot System for Cooledge Brook, MA*, Emma Burleson, Lauren Mitchell, Annemarie Eastwood, and Molly Youngs, advisors: Bergendahl, Eggleston
- 2021 *Analysis of the Effects of PFAS and Metallic Co-Pollutants on Bacterial Respiration*, Shelvey Swett, Olivia Madamba, Deanna Kay, Jennifer Condon, advisors: Bergendahl, Kmiotek
- 2021 *Developing an Analytical Technique for GenX in Water using Ion Exchange Resin and ICP-MS*, Gabriela Doskos, advisors: Bergendahl, Kmiotek
- 2021 *Treatment of Cannabinoids in Wastewater*, Elisabeth Christ, Adrian Reddick, Madeline Barnard, advisors: Bergendahl, Kmiotek
- 2020 *Comparative Analysis of Treatment Technologies for Per- and Polyfluorinated Substances in Water*, Michelle Amber Foote, advisors: Bergendahl, Kmiotek
- 2020 *An Environmental Analysis of Recreational Cannabis Cultivation and Processing*, Stephanie Salerno and Jacquelyn Valsamis, advisors: Bergendahl, Kmiotek
- 2020 *Developing an Analytical Technique for PFAS in Water using SPE and NMR*, Jonathan Cain, Zachary Powers, advisors: Bergendahl, Kmiotek
- 2020 *Evaluation of Corrosion Indices for Predicting Lead Leaching in Water Distribution Systems*, Kristen Chan, Christopher Brainard, major advisor: Dudle, co-advisor: Bergendahl
- 2019 *Designing a Total Organic Fluorine Test: PFAS Characterization & Quantitation Utilizing NMR Analysis*, Zachary Weiland, Dylan Muise, Ashley Choi, advisors: Bergendahl, Kmiotek, Kazantzis
- 2019 *Acid Rock Drainage/Metal Leaching at Cooledge Brook, MA: Feasibility of Alternative Remedial and Treatment Approaches*, Rachel Stickles, Jessica Locke, advisor: Bergendahl, sponsor: MA DEP
- 2019 *Improving Biosolids Drying with Ultrasonic Technology*, Remi Gaetjens, Carley Dykstra, advisor: Bergendahl

- 2018 *Environmental Impacts of Pavement Rejuvenators*, Jacqueline Barr, Daniel Cammarata, Rachel Rivera, Christian Walck, Justin Waters, advisor: Bergendahl
- 2017 *Environmental Effects of Coal-Tar Based Pavement Rejuvenators*, Seth MacDonald, Caroline Meyer, advisor: J. Bergendahl
- 2017 *Exploring the Potential for Reclaimed Wastewater Applications*, Jenna O'Connell, Mary Prescott, Meghan Trahan, advisors: J. Bergendahl, S. Kmiotek, W Bates (CEE Advisory Board Award)
- 2017 *Measuring Carbon Dioxide Flux in Highway Buffer Zones*, Annie McDonald-Schwartz, Matthew Michaels, Nicholas Santangelo, Alexis Sturgis, advisors: J. Bergendahl and R. Mallick
- 2017 *Salinity Impacts on Coastal Wastewater Treatment Facilities*, Amy Krayner, Matthew Michaels, Talia Solomon, advisor: J. Bergendahl
- 2016 *A Method for Coating Glass Beads with TiO₂ and Comparison of Photocatalytic Effectiveness for Contaminant Degradation*, Isaac Vrooman, advisors: Bergendahl & DiBiasio
- 2016 *Alternative Carbon Sources for Denitrification of Wastewater*, D. Clark, M. Filippone, K. Ouellette, H. Reinertson, advisors: J. Bergendahl, S. Kmiotek, W. Bates (CEE Advisory Board Award)
- 2016 *Design Improvements for the Activated Sludge Wastewater Treatment System at the American Farm School in Thessaloniki Greece*, C. Cerruti, N. Kalaitzidis, H. Morgan, M. Pereira, advisors: J. Bergendahl, B. Addison
- 2016 *Improving the Removal of Emulsified Oil from Wastewater using Powdered Activated Carbon with a Membrane Bioreactor*, C. Costa, T. Hctor, T. De Bacellar, C. Rota, advisors: J. Bergendahl, S. Kmiotek, R. Thompson, L. Elgert
- 2016 *Removal of 1,4-Dioxane from Water by UV/TiO₂ Advanced Oxidation*, J. Caccioppoli, D. Manhardt, advisor: J. Bergendahl
- 2015 *Sustainable Alternative Wastewater Treatment for Beneficial Reuse of Industrial Wastewater*, J. Hartzell, S. Mavilia, K. Ross, T. Wilson, advisors: J. Bergendahl, R. Thompson
- 2015 *Removal of Diazinon from Water by Potassium Ferrate (VI) Oxidation*, Y. Won, Y. Yang, advisor: J. Bergendahl
- 2014 *Photocatalytic Oxidation for the Removal of Chlorpyrifos From Aqueous Solution*, D. Throop, I. Schulman, advisors: J. Bergendahl, F. Hart
- 2014 *Photocatalytic Oxidation for the Removal of Chlorpyrifos From Aqueous Solution*, J. Ringenbach, B. Matheny, advisors: J. Bergendahl, F. Hart
- 2014 *Treatability of 1,4-Dioxane Using UV/Hydrogen Peroxide Oxidation*, H. Wyman, J. Teixeira, A. Meunier, advisors: J. Bergendahl, B. Faber
- 2014 *Photocatalytic Wastewater Treatment with Titania Bound to Glass*, C. Brooks, advisors: J. Bergendahl, F. Hart
- 2014 *Removal of 1,4-Dioxane from Water by Adsorption to Resins*, C. Martineau, H. Prasad, P. Roll, advisors: J. Bergendahl, I. Bar-On

- 2014 *Adsorption of 1,4-Dioxane on Activated Carbon with Regeneration by Titanium Dioxide/Ultraviolet*, E. Rooney, C. Eigenbrodt
- 2013 *Photocatalytic Oxidation of Ciprofloxacin Under UV-LED Light*, C. Fogarty, advisors: J. Bergendahl and R. Thompson
- 2013 *Removal of Sulfamethoxazole from Water by Ion-Exchange*, K. Conoby, E. Anness
- 2013 *Ferrate Oxidation of Pharmaceuticals in Water*, D. Allen, J. Bellini, J. Hyde
- 2013 *Utilizing GAC and MIEX to Improve TOC Removal from Wastewater*, A. Davis, E. Fournier, R. Shooshan, L. Waring, advisors: J. Plummer and J. Bergendahl
- 2013 *Removal of Ciprofloxacin from Water Using Zeolites and Ozone*, K. Ruggles, K. Tolbert, R. Valdes, advisors: J. Bergendahl and R. Thompson
- 2013 *Titania for Treating Storm Runoff Water*, Galligan, L. Grasis, D. Patrick, advisors: J. Bergendahl and R. Mallick
- 2013 *Treatment of Ibuprofen in Water with Adsorption*, S. Connors, R. Lanza, A. Sirocki
- 2012 *Pesticide Removal from Water*, J. Price, E. Klinkhamer, A. Bourgeois
- 2012 *Removal of PFOA from Water Using UV Treatment, Chemical Oxidation, and Adsorption by Activated Carbon and Zeolites*, S. Kurrumchand, A. Bhakhi, Z. Wang, J. Bliss, K. Roberts, T. Finelli, Advisors: J. Bergendahl & N. Kazantis
- 2012 *Chlorination System for the Scum Manhole at the Sturbridge Wastewater Treatment Plant*, K. Woodward, E. Dudley, N. D'Angelo, advisors: J. Plummer and J. Bergendahl
- 2012 *Removal of Ciprofloxacin from Water with Chemical Oxidation*, H. Taylor, O. Shepherd, K. Powers, L. Hannmann, advisors: J. Bergendahl and R. Thompson
- 2011 *Removal of Ciprofloxacin from Water Using Adsorption, UV Photolysis and UV/H₂O₂ Degradation*, M. Roma, M. Weller, S. Wentzell, advisors: J. Bergendahl & R. Thompson.
- 2011 *Dispersants for Crude Oil Spills: Dispersant Behavior Studies*, R. Diemand, K. Francis, Advisors: J. Bergendahl & N. Kazantis
- 2011 *Treatment of Petroleum Contaminated Water Using Peat*, L. Alebeleye, C. Biltucci, J. Ferro
- 2010 *Incorporating Adsorbents into Porous Asphalt Design*, S. Brewster, B. Cassie, T. O'Connell, co-advised by M. Tao and R. Mallick.
- 2009 *Improving the Accessibility and Sustainability of the La Marta Wildlife Refuge*, B. Bigda, R. Eley, A. Gilday, R. Sottolano, co-advised by H. Ault (Mechanical Engineering) and T. El-Korchi (Civil and Environmental Engineering).
- 2009 *Adsorption of Methyl Tertiary Butyl Ether Using Granular ZSM-5*, A. Begin (Chemical Engineering), S. Shin.

- 2009 *Feasibility of Alternate Energies in Municipal Buildings*, M. Boudreau, C. Mehr.
- 2008 *Removal of Lead from Water Using Ionic Liquid*, A. Dungca, A. Hevey, and R. Patenaude.
- 2008 *Optimizing Sequestration of Manganese with Sodium Triphosphate*, J. Coelho, K. Kucher, and A. Ting.
- 2008 *Automated Bench-Scale Bioreactor Design*, N. Erickson, J. Kanis, J. Mello, and N. Wilbur
- 2007 *Treatment of Manganese in West Boylston Drinking Water*, R. Sullivan (Chemical Engineering).
- 2006 *Organic Contaminant Destruction in Ionic Liquids*, J. Appiah (Biology) & K. Fay (Chemical Engineering)
- 2006 *Filter Use and Regeneration*, P. Restrepo (Chemical Engineering), L. Reni (Chemical Engineering); major advisor: Thompson, co-advisor: Bergendahl.
- 2005 *Design and Development of a Biodiesel Manufacturing Plant*, O. Pinago (Mechanical Engineering), S. Scheriff (Mechanical Engineering); co-advised with Sisson & O'Shaughnessy.
- 2005 *Bioreactor Landfills*, M. Elbag & S. Neithercut
- 2005 *Treatment Options for Perchlorate Remediation*, C. Corbitt (Chemical Engineering)
- 2005 *Sludge Treatment with Advanced Oxidation*, N. Chin
- 2004 *Indoor Constructed Wetlands Wastewater Treatment*, A. Lee & C. Reynolds; co-advised with Fitzpatrick.
- 2004 *MTBE Removal from Water with Zerovalent Iron and Hydrogen Peroxide*, C. Hart
- 2004 *Drinking Water Disinfection with Fenton's Oxidation*, S. Armistead (Chemical Engineering)
- 2004 *Design of a Perchlorate Treatment System*, J. Spitzinger
- 2004 *Membrane Separated Chemical Oxidation*, M. Slack; major advisor: Bergendahl, co-advisor: Thompson.
- 2003 *Fenton's Oxidation of Cholesterol Lowering Drug Clofibric Acid in Water*, Malia Aull, Rachel Copeland, & Emily Dodd (Biochemistry); major advisor: Bergendahl, co-advisor: Wobbe.
- 2002 *Fenton's Oxidation of TCE Contaminated Water*, D. O'Brien & B. Tremblay (received Provost Award for best project in CEE department)
- 2002 *Optimizing Fenton's Oxidation for the Remediation of MTBE*, K. Caudill (Chemical Engineering)
- 2001 *Optimizing Fenton's Oxidation for MTBE Remediation*, Carrie Morse (Chemical Engineering); major advisor: Bergendahl, co-advisor: Camesano.
- 2001 *Fenton's Oxidation of Contaminated Groundwater*, Courtney Estaphan

Undergraduate Interactive Qualifying Projects, IQPs: The IQP is a project addressing the relationship of science and technology to society. Like the MQP, the IQP is considered the equivalent of 3 courses, and is usually undertaken in the junior year.

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| 2013 | <i>Hydraulic Fracturing: A Report as to the Implications Regarding Natural Gas</i> , E. Rooney, J. Morales, W. De Christofaro, C. Adams |
| 2013 | <i>Integrated Pest Management for Mosquito Control in Massachusetts</i> , V. Thai, A. Johns, S. Gile, advisors: J. Bergendahl, J. Plummer |
| 2011 | <i>Volatility of Tetrachloroethylene on Cape Cod</i> , J. Bliss, N. Bean, J. Ames, J. Stewart, advisors: P. Mathisen, J. Bergendahl |
| 2011 | <i>Pharmaceuticals in Water</i> , A. Miggels, C. Garceau, C. Beckel |
| 2011 | <i>Moon Water</i> , D. Velez, K. Sellahennedige, J. McKniff, advisors: J. Bergendahl and M. Tao |
| 2008 | <i>Neurotoxic Chemicals in the Environment</i> , K. Bedrosian, J. Charest, V. DeVault, and E. Lumley. |
| 2008 | <i>Land Use Among Rare Species</i> , J. Mello, J. Kanis, M. Desjardin, advisors: J. Bergendahl and C. Ryan. |
| 2007 | <i>Through Whose Looking Glass?</i> , M. Bellack |
| 2006 | <i>Issues in Water Reuse</i> , N. Beatty, D. Cozzens, L. Larson; advisor: Bergendahl, co-advisor: S. Vernon-Gerstenfeld |
| 2005 | <i>Social & Economic Impacts of Biodiesel</i> , T. Patierno (Mechanical Engineering), S. Scheriff (Mechanical Engineering) |
| 2005 | <i>Issues in Wastewater Reuse</i> , J. McLean & K. Bryant |
| 2005 | <i>Drinking Water Problems in Egypt and Sudan</i> , S. Basha & J. Fragachan |
| 2004 | <i>Lead Contamination of Soil on Shooting Ranges</i> , J. Kropp |
| 2003 | <i>Lead Contamination of Soil on Gun Ranges</i> , T. Li & A. Berezin |
| 2003 | <i>AOP Disinfection for Developing Countries</i> , S. Armistead & A. Freeman |
| 2003 | <i>Analysis of Water Contamination and Its Impact on Society</i> , J. Brown & S. Longley-Martines |
| 2002 | <i>Biodiesel and Alternative Fueling</i> , E. Bouvier |

Independent Studies and Projects Advised at WPI

- *A Deeper Look into PFAS*, Graduate Independent Study, L. Cristiano, 2022
- *PFAS: Physicochemical Properties, Occurrence, and Treatment*, April Locke, 2018
- *Impact of Dispersant Use on Polynuclear Aromatic Hydrocarbon Partitioning in Seawater*, Marco Kaltofen, 2010.
- Advanced Masters project: Managing WEEE (Waste from Electric and Electronic Equipment) in the US, Elizabeth DeCola, 2005.
- *Environmental Aspects of Alternative Energy*, N. Seifert, 2004
- *Recycling and Composting at WPI: An Analysis and Discussion of Financial and Environmental Issues*, N. Seifert, 2003

Publications

Books & Chapters

- *Environmental Impacts of Engineering Decisions*, by J. Bergendahl and J. O'Shaughnessy, to be published by Wiley-Blackwell, to be completed.
- *Treatment System Hydraulics*, by John Bergendahl, American Society of Civil Engineers, 2008.
- Chapter 13: "Environmental Issues of Gasoline Additives – Aqueous Solubility and Spills" by John Bergendahl, in *Solubility, Thermodynamics and Environmental Issues*, organized by the Physical Division (Thermodynamics Committee), the Solubility Commission and the Environmental Division of IUPAC; published by Elsevier, editor: Trevor Letcher, 2007.

Journal Articles (peer reviewed)

1. "Identification and Quantification of Wide Variety of Inorganic Nanoparticles in Municipal Wastewater", *J. of Hazardous, Toxic, and Radioactive Waste*, Y. Chen and J. Bergendahl, **25** (4), 04021030, 2021.
2. "Effect of pH, Temperature, and Use of Synergistic Oxidative Agents on the Ultrasonic Degradation of Tris-2-Chloroethyl Phosphate, Gemfibrozil, and 17 β Estradiol in Water", *J. of Environmental Chemical Engineering*, J.R. Alvarez Corena and J. Bergendahl, **9**, 105005, 2021.
3. "Transdisciplinarity and the Food Energy and Water Nexus: Ecological Modernization and Supply Chain Sustainability Perspectives", *Resources, Conservation, and Recycling*, J. Bergendahl, J. Sarkis, and M. Timko, **133**, 309-319, 2018.
4. "Advanced Oxidation of Five Contaminants in Water by UV/TiO₂: Reaction Kinetics and Byproduct Identification", *Journal of Environmental Management*, J. R. Alvarez Corena, J. Bergendahl, and F. Hart, **181**, 544-551, 2016.
5. "Photocatalytic Oxidation of Five Contaminants of Emerging Concern by UV/TiO₂: Identification of Intermediates and Degradation Pathways", *Environmental Engineering Science*, J. R. Alvarez Corena, J. Bergendahl, and F. Hart, **33**, 140-147, 2016.
6. "Biodegradability of Fluorinated Fire-Fighting Foams in Water", in *Chemosphere*, A. Bourgeois, J. Bergendahl, and A. Rangwala, **131**, 104-109, 2015.
7. "Internet-Enabled Experiment for Demonstrating Contaminant Adsorption to Activated Carbon", in *Journal of Professional Issues in Engineering Education and Practice*, J. Bergendahl, accepted 2014.
8. "An Equilibrium Study on Trichloroethylene Adsorption and Desorption from ZSM-5 in Water", in *Energy and Environmental Engineering*, H. Hawley, J. Bergendahl, and R. Thompson, **1** (1), 5-9, 2013.
9. "Mathematical Modeling of Chloroform Adsorption onto Fixed-Bed Columns of Highly Siliceous Granular Zeolites," in *Environmental Progress & Sustainable Energy*, L. Abu-Lail, J. Bergendahl, and R. Thompson, **31** (4), 591-596, 2012.

10. "Adsorption of Methyl Tertiary Butyl Ether on Granular Zeolites: Batch and Column Studies," in *Journal of Hazardous Materials*, L. Abu-Lail, J. Bergendahl, and R. Thompson, **178**, 363-369, 2010.
11. "Microanalysis of Workplace Dusts from the Mixed Waste Tank Farm of the Hanford Nuclear Reservation," in *Environmental Engineering Science*, M. Kaltofen and J. Bergendahl, **27**, 181-185, 2010.
12. "A Laboratory Study on CO₂ Emission from Asphalt Binder and its Reduction with the Use of Warm Mix Asphalt," in *International Journal of Sustainable Engineering*, R. Mallick and J. Bergendahl, **2** (4), 275-283, 2009.
13. "Removal of Estrone from Water by Adsorption on Zeolites with Regeneration by Direct UV Photolysis," in *Environmental Engineering Science*, H. Wen, J. Bergendahl, and R. Thompson, **26**, 319-326, 2009.
14. "Adsorption of Disinfection Byproducts on Hydrophobic Zeolites with Regeneration by Advanced Oxidation," *Microporous and Mesoporous Materials*, N. Koryabkina, J. Bergendahl, R. Thompson, and A. Giaya, **104**, 77-82, 2007.
15. "A Kinetic Model for the Aqueous Degradation of MTBE by Fe⁰/ H₂O₂," N. Al Ananzeh, J. Bergendahl and R. Thompson, *Progress in Reaction Kinetics and Mechanism*, **32**, 131-151, 2007.
16. "Kinetic Model for the Degradation of MTBE by Fenton's Oxidation," *Environmental Chemistry*, N. Al Ananzeh, J. Bergendahl, and R. Thompson, **3**, 40-47, 2006.
17. "Batch Leaching Tests: Colloid Release and PAH Leachability," *Soil and Sediment Contamination: An International Journal*, **14** (6), 527-543, 2005.
18. "Oxidation Reduction Potential as a Measure of Disinfection Effectiveness for Chlorination of Wastewater," *Environmental Progress*, with L. Vinagro Stevens, **24** (2), 214-222, 2005.
19. "Toward a Broader Technical Education for Engineers," *Journal of Professional Issues in Engineering Education and Practice*, ASCE, **131** (4), 257-262, 2005.
20. "Advanced Oxidation Processes for Wastewater Treatment," *Journal of the New England Water Environment Association*, with J. O'Shaughnessy, **38** (2), 179-189, November 2004.
21. "Observations on Solid Phase Micro-Extraction for MTBE Analysis," *Chemosphere*, with A. Erdem-Şenatalar and R.W. Thompson, **57** (6), 523-527, 2004.
22. "Adsorption of Methyl Tertiary Butyl Ether on Hydrophobic Molecular Sieves," *Environmental Engineering Science*, with A. Erdem-Şenatalar, A. Giaya and R.W. Thompson, **21** (6), 722-729, 2004.
23. "Fenton's Oxidation of MTBE with Zero-Valent Iron," *Water Research*, with T. Thies, **38** (2), 327-334, 2004.
24. "Mechanistic Basis for Particle Detachment from Granular Media," *Environmental Science and Technology*, with D. Grasso, **37** (10), 2317-2322, 2003.
25. "Pilot-Scale Fenton's Oxidation of Organic Contaminants in Groundwater Using Autochthonous Iron," *Journal of Hazardous Materials*, with S. Hubbard and D. Grasso, **99** (1), 43-56, April 4, 2003.

26. "A Review of Non-DLVO Interactions in Environmental Colloidal Systems," *Reviews in Environmental Science and Biotechnology*, with D. Grasso, K. Strevett, M. Butkus, and K. Subramanian, **1** (1), 17-38, 2002.
27. "Prediction of Colloid Detachment in a Model Porous Media: Hydrodynamics," *Chemical Engineering Science*, with D. Grasso, **55**, 1523-1532, 2000.
28. "Prediction of Colloid Detachment in a Model Porous Media: Thermodynamics," *American Institute of Chemical Engineers Journal*, with D. Grasso, **45**, 475-484, 1999.
29. "Colloid Generation During Batch Leaching Tests: Mechanics of Disaggregation," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, with D. Grasso, **135**, 193-206, 1998.

Journal Articles (non-peer reviewed)

1. "COVID-19 – Implications for the Water and Wastewater Industry," *NEWEA Journal*, J. Bergendahl, M. Fernandes, and W. Bates, Summer 2020.
2. Discussion Article: "Role of Short-Range Forces in Particle Detachment During Filter Backwashing," *Journal of Environmental Engineering*, with M. Butkus & D. Grasso, **123**, 726-728, 1997.
3. "Case Study: A Cardboard Box Manufacturer," *Pollution Prevention Review*, **5**, 15-19, 1995.

Conference Proceedings

1. *Knowing and Caring About Sanitation*, by L. Dodson and J. Bergendahl, with C. Abel, K. Boudreau, D. DiBiasio, G. Gaudette, J. Sullivan, and P. Quinn, American Society for Engineering Education Annual Conference, June 25th – 28th 2017, Columbus OH.
2. *How Role Playing Builds Empathy and Concern for Social Justice*, by L. Dodson, D. DiBiasio and P. Quinn, with J. Bergendahl, K. Boudreau, G. Gaudette, J. Sullivan, and C. Abel, American Society for Engineering Education Annual Conference, June 25th – 28th 2017, Columbus OH.
3. *The Theater of Humanitarian Engineering*, by K. Boudreau, D. DiBiasio and L. Dodson, with J. Bergendahl, L. Robinson, J. Sullivan, and P. Quinn, American Society for Engineering Education Annual Conference, June 25th – 28th 2017, Columbus OH. Selected as ASEE "Liberal Education/Engineering and Society (LEES) Division Best Paper" for 2017.
4. *Advising a Costa Rican Capstone Design Project by Distance*, J. Bergendahl and T. El Korch, Capstone Design Conference 2010, Boulder, CO, June 7-9, 2010.
5. *Bringing Graphics and Design to First Year Engineering Students*, ASEE 63rd Annual Midyear Meeting, January 4-7, 2009, C.E. Conron and J.A. Bergendahl.
6. *Development and Implementation of an Internet-Enabled Environmental Engineering Experiment*, 2006 ASEE Annual Conference and Exposition, Chicago, IL, June 20, 2006, by J. Bergendahl.

7. *Particle Mobilization in the Environment: Causes and Consequences*, 7th International Symposium on Environmental Geotechnology and Global Sustainable Development, Helsinki and Espoo, Finland, June 8-10, 2004, by J. Bergendahl.
8. *Fundamentally-Based Dimensionless Numbers For Predicting Particle Detachment From Porous Media*, 226th ACS National Meeting, New York, NY, September 10, 2003, with D. Grasso.
9. *Advanced Oxidation of MTBE with Zero-valent Iron and Hydrogen Peroxide*, 3rd International Conference on Oxidation Technologies for Water and Wastewater Treatment, Goslar, Germany, May 18-22, 2003, with T. Thies.
10. *Advanced Oxidation Treatment of High Organic Strength Industrial Wastewaters*, 3rd International Conference on Oxidation Technologies for Water and Wastewater Treatment, Goslar, Germany, May 18-22, 2003, with J. O'Shaughnessy and D. Sykes.
11. *Advanced Oxidation of MTBE with Zero-Valent Iron and Hydrogen Peroxide*, 34th Mid-Atlantic Industrial & Hazardous Waste Conference, Rutgers University, N.J., September 20-21, 2002, with T. Thies.
12. *Heat Liberation During Advanced Oxidation of High-Strength Wastewater*, 34th Mid-Atlantic Industrial & Hazardous Waste Conference, Rutgers University, N.J., September 20-21, 2002, with J. O'Shaughnessy.

Professional Presentations

1. Poster Presentation: *Pyrolytic Transformation of PFAS Precursors in AFFF when Applied for Fire Suppression*, by D. Grenier, J. Bergendahl, and A. Rangwala, AEEHS 39th Annual International Conference on Soils, Sediments, Water, and Energy, October 18, 2023, Amherst MA.
2. Panel Discussion: *What the Eyes Don't See* (book by Dr. Mona Hanna-Attisha), UMass Chan Medical School, December 15, 2021.
3. Panel Discussion: *Emerging Contaminants and Water Technologies*, Center for Global Public Safety Annual Symposium, November 9, 2021.
4. *Identification and Quantification of Inorganic Nanoparticles in Wastewater*, by Yinduo Chen and J. Bergendahl, American Water Resources Association, Virtual Annual Water Resources Conference, November 9-12, 2020.
5. Poster Presentation: *Environmental Impacts of Pavement Rejuvenators*, by Joshua Anderson, Jacqueline Barr, Daniel Cammarata, Rachel Rivera, Christian Walck, Justin Waters and J. Bergendahl, AIChE Annual Meeting, October 31, 2018, Pittsburgh, PA.
6. Poster Presentation: *Enhancement of Municipal Wastewater Biosolids Drying Through Interfacial Energy Modifying Amendments to Promote Uniform Aggregation*, S. Stine, H. Zhang, and J. Bergendahl, Sept. 10th – 12th, 2018, 9th Canadian Biosolids & Residuals Conference, Halifax, NS.
7. Poster Presentation: *PAH Mobilization from Coal-Tar Based Asphalt Rejuvenators*, by C. Meyer, S. MacDonald, and J. Bergendahl, 33rd Annual International Conference on Soils, Sediments, Water and Energy, October 16-19, 2017, Univ. of Mass, Amherst MA.
8. *Knowing and Caring About Sanitation*, by L. Dodson and J. Bergendahl, with C. Abel, K. Boudreau, D. DiBiasio, G. Gaudette, J. Sullivan, and P. Quinn, American

- Society for Engineering Education Annual Conference, June 25th – 28th 2017, Columbus OH.
9. *How Role Playing Builds Empathy and Concern for Social Justice*, by L. Dodson, D. DiBiasio and P. Quinn, with J. Bergendahl, K. Boudreau, G. Gaudette, J. Sullivan, and C. Abel, American Society for Engineering Education Annual Conference, June 25th – 28th 2017, Columbus OH.
 10. *The Theater of Humanitarian Engineering*, by K. Boudreau, D. DiBiasio and L. Dodson, with J. Bergendahl, L. Robinson, J. Sullivan, and P. Quinn, American Society for Engineering Education Annual Conference, June 25th – 28th 2017, Columbus OH. Selected as ASEE “Liberal Education/Engineering and Society (LEES) Division Best Paper” for 2017.
 11. *Photo-Assisted Heterogeneous Catalysis and Ultrasonic Cavitation for the Degradation of Emerging Contaminants*, by J. Alvarez Corena, with J. Bergendahl, and F. Hart, American Water Works Association Annual Conference, Chicago, June 21, 2016.
 12. *Humanitarian Engineering: Past & Present*, by D. DiBiasio and C. Abel, with K. Boudreau, L. Dodson, P. Kirby, J. Cullon, J. Sullivan, J. Bergendahl, G. Gaudette, and L. Robinson, at the Ninth Symposium on Engineering and Liberal Education, Union College, Schenectady, NY, June 3, 2016.
 13. Invited member to panel discussion on *Water Reuse*, Spring Workshop of the Connecticut Association of Water Pollution Control Authorities, Cromwell, CT, May 8, 2015.
 14. *Ozonation of Tris-2-Chloroethyl Phosphate (TCEP) in Water*, by M. Votruba, with J. Bergendahl, NEWEA Annual Conference, Boston, MA, January 26, 2015.
 15. *Heterogeneous Photocatalysis for the Degradation of Contaminants of Emerging Concern in Water*, by J. Alvarez Corena, with J. Bergendahl, F. Hart, and R. Emerick, NEWEA Annual Conference, Boston, MA, January 26, 2015.
 16. Panel Discussion: *Finding Solutions – Massachusetts Water Cluster*, at NEWIN (New England Water Innovation Network) 2014 Water Leadership Conference, Worcester, MA, November 19, 2014.
 17. Poster presentation: *Heterogeneous Photocatalysis for the Treatment of Contaminants of Emerging Concern in Water*, by J. Alvarez Corena, with J. Bergendahl, and F. Hart, NEWIN 2014 Water Leadership Conference, Worcester, MA, November 19, 2014.
 18. *Minimizing Water Requirements for Electricity Generation in Water Scarce Areas*, by E. Stults, with I. Bar-on, A. Trapp, and J. Bergendahl, Informs Annual Meeting, San Francisco, November 9 – 12, 2014.
 19. *Permethrin for Mosquito Control: Drinking Water Impacts and Treatment*, by Lesley Eckert, with J. Plummer and J. Bergendahl, AWWA ACE14 Annual Conference, Boston, June 11, 2014.
 20. *Sustainable Treatment Processes for 1,4-Dioxane in Water*, by J. Bliss, with J. Bergendahl, American Institute of Chemical Engineers Spring National Meeting, New Orleans, LA, March 30 – April 3, 2014.

21. *Analysis of the Effect of Technology Distribution on the Water Requirements for Energy Generation*, by E. Stults, with I. Bar-on, A. Trapp, and J. Bergendahl, Informs Annual Meeting, Minneapolis, October 6-9, 2013.
22. *Removal of Ciprofloxacin from Water Using Adsorption, UV Photolysis, and UV/H₂O₂ Degradation*, by M. Weller, with M. Roma, S. Wentzell, J. Bergendahl and R. Thompson, NEWEA Annual Conference, Boston, MA, January 25, 2012.
23. Poster Presentation: *Zeolite Sorbents for Treatment of Water for Reuse*, L. Abu-Lail, J. Bergendahl and W. Collentro, Water/Energy Sustainability Symposium at the 2010 GWPC Annual Forum, Pittsburgh, PA, September 26-29, 2010.
24. *Advising a Costa Rican Capstone Design Project by Distance*, J. Bergendahl and T. El Korchi, Capstone Design Conference 2010, Boulder, CO, June 7-9, 2010.
25. Poster Presentation: *Removal of Chloroform and MTBE from Water by Adsorption onto Granular Zeolites*, ACS 238th National Meeting, Washington D.C., August 19, 2009, by L. Abu-Lail, with J. Bergendahl and R. Thompson.
26. *Incorporating Innovation, Sustainability, Global Awareness and Ethics into the Curriculum*, Symposium XX: Novel, Green, and Strategic Processing and Manufacturing Technologies, PACRIM 8, Vancouver, Canada, May 31 – June 5, 2009, by R.D. Sisson, with J. O'Shaughnessy, K. Rong, J. Bergendahl, and D. Apelian.
27. *Teaching and Learning the Design, Development and Evaluation of Sustainable Materials Selection and Processes*, 33rd International Conference and Exposition on Advanced Ceramics and Composites; Symposium 8: 3rd International Symposium on Advanced Processing and Manufacturing Technologies (APMT) for Structural and Multifunctional Materials and Systems, Daytona Beach, FL, January 20th, 2009, by R.D. Sisson, with J. O'Shaughnessy, K. Rong, J. Bergendahl, and D. Apelian.
28. Poster Presentation: *Laboratory Study on CO₂ Emission Reductions through Use of Warm-Mix Asphalt*, Transportation Research Board Annual Meeting, Washington D.C., January 13, 2009, by R. Mallick, with J. Bergendahl and M. Pakula.
29. *Bringing Graphics and Design to First Year Engineering Students*, ASEE 63rd Annual Midyear Meeting, January 4-7, 2009, by C.E. Conron, with J. Bergendahl.
30. *Destruction of Trichloroethylene with Zerovalent Iron/Persulfate*, AIChE Annual meeting, Philadelphia, PA, November 18, 2008, by L. Abu-Lail, with A. Padmanabhan, and J. Bergendahl.
31. *Adsorption of Chloroform and MTBE on Granular Zeolites; Batch and Column Adsorption Studies*, AIChE Annual Meeting, Philadelphia, PA, November 18, 2008, by L. Abu-Lail, with J. Bergendahl, R. Thompson, and A. Giaya.
32. *Teaching and Learning Green Engineering and Environmental Sustainability*, MS&T 08, David L. Lawrence Convention Center, Pittsburgh, PA, October 9, 2008, by R. Sisson, with J. O'Shaughnessy, and J. Bergendahl.
33. *Fe⁰-Activated Persulfate Oxidation of TCE*, at the 2007 AWWA Water Quality Technology Conference, Charlotte, NC, November 4, 2007, by J. Bergendahl, with A. Padmanabhan.
34. *Sustainable Product Design: P2, P3 and Consumption*, at Sustainable Practices in the MedTech Industry: From Building Design to Manufacturing, Waltham, MA, September 27, 2006, with J. O'Shaughnessy.

35. *Removal of Estrone from Water with Adsorption on Zeolites Followed by UV Photolysis*, AIChE Annual Meeting, San Francisco, CA, November 17, 2006, by H. Wen, with R. Thompson.
36. *Development and Implementation of an Internet-Enabled Environmental Engineering Experiment*, 2006 ASEE Annual Conference and Exposition, Chicago, IL, June 20, 2006.
37. *Good to the Last Drop? Are We Really Treating our Water Sufficiently?* The Third US-Africa Business Conference, Building Partnerships for Economic Opportunities in Africa: The Way Forward, May 23, 2006.
38. Poster Presentation: *Broadening Engineering Education through Project-Based Curriculum – The WPI Experience*, 2005 AEESP Research and Education Conference, Clarkson University, NY, July 24-27, 2005.
39. Poster Presentation: *Teaching Environmental Impacts of Engineering Actions to a Multidisciplinary Audience*, 2005 AEESP Research and Education Conference, Clarkson University, NY, July 24-27, 2005, with J. O'Shaughnessy.
40. Poster Presentation: *Recent Findings in Advanced Oxidation Treatment and Remediation Processes*, Research Symposium on Environmental Issues Affecting Worcester County, Worcester MA, April 20, 2005, with R. Thompson, J. O'Shaughnessy, N. Koryabkina, & D. Grasso.
41. Poster Presentation: *Removal of Hazardous Organics from Water: Theoretical Basis for Understanding Interactions of Organics with Microporous Solids and Predictions for New Systems*, Research Symposium on Environmental Issues Affecting Worcester County, Worcester MA, April 20, 2005, with J. Wilcox & R. Thompson.
42. *The Effect of Hydrophobic Molecular Sieve Pore Properties on MTBE Adsorption*, 78th Colloid and Surface Science Symposium, American Chemical Society, Yale University, June 23-26, 2004, with N. Koryabkina, A. Erdem-Şenatalar, R.W. Thompson and A. Giaya.
43. *Application of Advanced Oxidation for Wastewater Treatment*, International Business and Education Conference, A Focus on Water Management, Worcester Polytechnic Institute, June 16, 2004, with J. O'Shaughnessy.
44. *Particle Mobilization in the Environment: Causes and Consequences*, 7th International Symposium on Environmental Geotechnology and Global Sustainable Development, Helsinki and Espoo, Finland, June 8-10, 2004.
45. *Fenton's Oxidation of Methyl Tertiary Butyl Ether Adsorbed on Silicalite*, The 1st European Conference on Oxidation and Reduction Technologies for *Ex-Situ* and *In-Situ* Treatment of Water, Air, and Soil (ECOR-1), Sartorius College, Göttingen, Germany, April 25-28, 2004, by H. Selcuk, with I.A. Alaton, A. Erdem-Şenatalar, and R.W. Thompson.
46. *Advanced Oxidation Applications for Wastewater Treatment*, New England Water Environment Association Annual Conference, Boston Marriott Copley Place, Boston, MA, January 26, 2004, with J. O'Shaughnessy.
47. *Fundamentally-Based Dimensionless Numbers for Predicting Particle Detachment from Porous Media*, 226th ACS National Meeting, New York, NY, September 10, 2003, with D. Grasso.

48. *Advanced Oxidation of MTBE with Zero-valent Iron and Hydrogen Peroxide*, 3rd International Conference on Oxidation Technologies for Water and Wastewater Treatment, Goslar, Germany, May 18-22, 2003, with T. Thies.
49. *Advanced Oxidation Treatment of High Organic Strength Industrial Wastewaters*, 3rd International Conference on Oxidation Technologies for Water and Wastewater Treatment, Goslar, Germany, May 18-22, 2003, with J. O'Shaughnessy and D. Sykes.
50. *TCE Removal from Water Utilizing Coupled Zeolite Sorption and Fenton's Oxidation*, New England Water Environment Association Annual Conference, Boston Marriott Copley Place, Boston, MA, January 28, 2003, with H. Hawley and R. Thompson.
51. *Advanced Oxidation of MTBE with Zero-Valent Iron and Hydrogen Peroxide*, 34th Mid-Atlantic Industrial & Hazardous Waste Conference, Rutgers University, N.J., September 20-21, 2002, with T. Thies.
52. *Heat Liberation During Advanced Oxidation of High-Strength Wastewater*, 34th Mid-Atlantic Industrial & Hazardous Waste Conference, Rutgers University, N.J., September 20-21, 2002, with J. O'Shaughnessy and D. Sykes.
53. Poster Presentation: *Engineering Design in the Junior Year*, AEESP/AAEE Conference, University of Toronto, Toronto, Canada, August 10 - 14, 2002, with J. O'Shaughnessy.
54. Poster Presentation: *Using Senior Projects for Fun and Profit*, AEESP/AAEE Conference, University of Toronto, Toronto, Canada, August 10 - 14, 2002, with J. O'Shaughnessy.
55. Poster Presentation: *Dimensional Analysis of Particle Detachment from Granular Media*, 76th ACS Colloid and Surface Science Symposium, University of Michigan, Ann Arbor, MI, June 23 - 26, 2002, with D. Grasso.
56. *Remediation of MTBE Contamination via Iron Catalyzed Advanced Oxidation*, The New England Water Environment Association Annual Conference, Boston, MA, January 29, 2002, with T. Thies, and C. Morse.
57. Poster Presentation: *Pilot-Scale Study of Fenton's Oxidation of Organic Contaminants in Water*, 33rd Mid-Atlantic Industrial & Hazardous Waste Conference, Manhattan College, Riverdale NY, June 19, 2001, with S. Hubbard, and D. Grasso.
58. *Thermodynamics and Hydrodynamics of Colloid Detachment in a Model Porous Media*, American Institute of Chemical Engineers Annual Meeting, Interfacial Aspects of Remediation Technology, Dallas, TX, November 5, 1999, with D. Grasso.
59. Poster Presentation: *Plutonium Colloid Mobility and Stability*, Environmental Solutions Program, University of Texas, Austin, TX, November 4, 1999, with S. Aghara, L. Katz, D. Lawler, and S. Landsberger.
60. *Colloid Detachment in Porous Media*, Advancing Filtration and Separation Solutions for the Millennium, The American Filtration and Separations Society, Boston, MA, April 6 - 9, 1999, with D. Grasso.
61. *Mechanisms of Colloid Detachment in Porous Media*, Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI, November 23, 1998.

62. *Implications of Colloid Generation for Coal-Tar Contaminated Soil Leach Testing*, 30th Mid-Atlantic Industrial and Hazardous Waste Conference, July 12 - 15, 1998, Villanova University, Villanova, PA, with D. Grasso.
63. Poster Presentation: *Mechanisms of Colloid Detachment in Environmental Systems*, 72nd ACS Colloid and Surface Science Symposium, Pennsylvania State University, University Park, PA, July 21 - 24, 1998, with D. Grasso.
64. Poster Presentation *Colloid Detachment in Porous Media*, University Consortium Solvents-in-Groundwater Research Program, Spring 1998 Meeting, Farmington, CT, May 5 - 7, 1998.
65. *Mechanisms of Colloid Detachment in Environmental Systems*, Northeast Regional Student Environmental Conference, University of Massachusetts, April 18, 1998.
66. *Mechanisms of Colloid Detachment in Porous Media*, 71st ACS Colloid and Surface Science Symposium, University of Delaware, Newark, DE, July 1, 1997, with D. Grasso.
67. *Quantification of PAH Concentrations During the Toxicity Characteristic Leaching Procedure*, Department of Civil and Environmental Engineering, University of Connecticut, Storrs, CT, November 1, 1996.

Grants and Fellowships Received

1. *Enhancement of Municipal Wastewater Biosolids Drying through Interfacial Energy Modifying Amendments to Promote Uniform Aggregation – Phase II*, \$45,000, PI: J. Bergendahl, funded by: Center for Advanced Research in Drying, 1/1/2018-12/31/2018
2. *Enhancement of Municipal Wastewater Biosolids Drying through Interfacial Energy Modifying Amendments to Promote Uniform Aggregation*, \$50,000, PI: J. Bergendahl, funded by: Center for Advanced Research in Drying (NSF-funded center with industry funding), 1/1/2017-12/31/2017
3. *DOE/Sandia National Laboratory RDD Environmental Resuspension Program*, \$229,464, PI: D. Medich, co-PI: J. Bergendahl, funded by: Sandia National Laboratories, 5/16/2016 – 5/30/2018
4. *Advanced Oxidation via ACT Hydrocavitation Technology*, \$99,420, PI: R. Thompson, co-PI: Bergendahl, funded by Triton Systems Inc., 1/2015-11/2015.
5. *Treatment of Today's Waters and Wastewaters Using a Photocatalysis Process Using TiO₂ with Natural and Artificial Sunlight*, \$85,000, PI: F. Hart, co-PI: Bergendahl, funded by Stantec, 2013-2014.
6. *Novel Adsorbents for the Removal of Disinfection Byproducts from Water - Phase II*, Triton Systems/National Institutes of Health, \$135,200, PI: Thompson, co-PI: Bergendahl, 2006.
7. *Development and Implementation of an Internet-Enabled Experiment*, Teaching Technology Fellowship, \$4,500, PI: Bergendahl, 2004 – 2006.
8. *Haestad Methods Software Grant*, from Haestad Methods, PI: Bergendahl, 2004.
9. *Novel Adsorbents for the Removal of Disinfection Byproducts from Water*, Triton Systems/National Institutes of Health, \$30,000, PI: Bergendahl, co-PI: R. Thompson, 2004.

10. *Evaluation of Rutting and Shoving Potential and Chloride Diffusion through Hot Mix Asphalt*, Royston Laboratories, \$16,962, PI: R. Mallick, co-PI: Bergendahl, 2003.
11. *Novel Adsorbents for the Removal of Disinfection By-Products from Drinking Water*, Triton Systems, Inc., \$5,000, PI: R. Thompson, co-PI: Bergendahl, 2003.
12. *Oxidation Reduction Potential versus Residual Control of Chlorine*, Damon S. Williams Associates / Water Environment Research Foundation, \$29,279, PI: Bergendahl, 2000.
13. *Field Testing Fenton's Oxidation at SRSNE*, de maximis, inc., \$59,007, PI: Bergendahl, co-PI: D. Grasso, Smith College, 2000.
14. *Ultrafiltration Pilot-Scale System*, Gift from the Butcher Company, Marlborough MA, \$10,000, PI: Bergendahl, 2002.
15. *Oxidation Reduction Potential versus Residual Control of Chlorine*, WPI's Research Development Council, \$5,900, PI: Bergendahl, 2000.
16. University of Connecticut, U.S. Department of Defense Fellowship, 1997 - 1998, Environmental Fellowship Program
17. University of Connecticut, Summer 1996 Fellowship for Advanced Graduate Students
18. University of Connecticut, Pollution Prevention Research and Development Center Fellowship, 1993 - 1994

Patents

- Provisional patent filed on 11/8/2005: *Synergistic Sorption of Organics on Molecular Sieves & Regeneration Using Advanced Oxidation*, with Koryabkina & Thompson.
- Patent application filed in April 2008: *Simultaneous Reduction/Oxidation Process for Destroying An Organic Solvent*, with A. Padmanabhan and S. Sharma.

Professional Society Memberships

- American Institute of Chemical Engineers
- American Society of Civil Engineers
- Water Environment Federation
- New England Water Environment Association

Editorial and Referee Activities

- Editorial Board, *Soil and Sediment Contamination, An International Journal*, 2003 – present
- Proposal review, National Science Foundation, Geobiology and Low-Temperature Geochemistry Program, Fall 2020.
- Review panel member, SERDP, May 2020, Improved Understanding of Thermal Destruction Technologies for Materials Laden with PFAS
- Review panel member, EPA SBIR Phase II Panel, August 2019, Removal of PFOA/PFAS from Drinking Water

- Manuscript Reviews:
 - Prentice Hall, College Division (Textbook)
 - Environmental Toxicology and Chemistry*
 - Water Research*
 - Environmental Engineering Science*
 - Environmental Progress*
 - Environmental Science and Technology*
 - Journal of Environmental Engineering*
 - Journal of Environmental Management*
 - Journal of Hazardous Materials*
 - Journal of Soil and Sediment Contamination*
 - Langmuir*
 - Microporous and Mesoporous Materials*
 - Encyclopedia of Surface and Colloid Science*
 - 19th Biennial International Conference, International Association of Water Quality, Paper Referee
 - 1st World Congress of the International Water Association (IWA): Paris 2000, Paper Referee
- Proposal Reviews:
 - Transportation Research Board
 - Environmental Protection Agency
 - Petroleum Research Fund, ACS
 - CICEET, the Cooperative Institute for Coastal and Estuarine Environmental Technology
 - National Science Foundation

Honors, Awards, and other Recognition

- Provost Award for MQP: *Exploration of Laccase- and Fenton Like-Functionalized Hydrogel–Biochar Systems for Water Remediation*, G. Page Violette, C. Walworth, N. Kessler, advisors: Bergendahl, Mishra, Eggleston, 2026
- Provost Award for MQP: *Acid Leachate Active Treatment Pilot System for Cooledge Brook, MA*, Emma Burleson, Lauren Mitchell, Annemarie Eastwood, and Molly Youngs, advisors: Bergendahl, Eggleston, 2021
- Provost Award for MQP: *An Environmental Analysis of Recreational Cannabis Cultivation and Processing*, Stephanie Salerno and Jacquelyn Valsamis, advisors: Bergendahl, Kmiotek, 2020
- ASEE “Liberal Education/Engineering and Society (LEES) Division Best Paper” for 2017: *The Theater of Humanitarian Engineering*, by K. Boudreau, D. DiBiasio and L. Dodson, with J. Bergendahl, L. Robinson, J. Sullivan, and P. Quinn, American Society for Engineering Education Annual Conference, June 25th – 28th 2017, Columbus OH.

- Advisory Board MQP Award: *Exploring the Potential for Reclaimed Wastewater Applications*, Jenna O’Connell, Mary Prescott, Meghan Trahan, advisors: J. Bergendahl, S. Kmiolek, W. Bates, 2017
- Advisory Board MQP Award: *Alternative Carbon Sources for Denitrification of Wastewater*, D. Clark, M. Filippone, K. Ouellette, H. Reinertson, advisors: J. Bergendahl, S. Kmiolek, W. Bates, 2016
- Provost Award for MQP: *Adsorption of 1,4-Dioxane on Activated Carbon with Regeneration by Titanium Dioxide/Ultraviolet*, E. Rooney, C. Eigenbrodt, 2014
- Advisory Board MQP Award: *Utilizing GAC and MIEX to Improve TOC Removal from Wastewater*, A. Davis, E. Fournier, R. Shooshan, L. Waring, advisors: J. Plummer and J. Bergendahl, 2013
- Meritorious Achievement MQP Award: *Dispersants for Crude Oil Spills: Dispersant Behavior Studies*, R. Diemand and K. Francis, 2011
- Honorable Mention for Provost MQP Award: *Sustainable Trail Design*, R. Eley and A. Gilday, 2009
- Provost Award for MQP: *Oxidation of TCE Contamination*, B. Tremblay and D. O’Brien, 2002
- Faculty Appreciation Award, Sigma Phi Epsilon, April 24, 2002
- Voted (one of two) “Favorite Professor,” in Readers’ Poll Results, WPI’s *Tech News*, April 23, 2002
- Inducted member *Chi Epsilon*, National Civil Engineering Honor Society
- Inducted member of the Honor Society of *Phi Kappa Phi*

Service

- Member WPI’s Committee on Academic Operations, July 2025 – present. Chair A/B 2026.
- Member WPI’s Faculty Review Committee, 2020 – 2023.
- Member, WPI’s Undergraduate Outcomes Assessment Committee, 2019 – 2022.
- Co-Moderator, “Contaminants of Emerging Concern” session, NEWEA 2021 Annual Conference, January 26, 2021 (virtual).
- Chair, WPI’s Committee on Academic Tenure and Freedom, 2018 – 2019.
- Member, WPI’s Committee on Academic Tenure and Freedom, 2016 – 2019.
- Editorial Board, *Soil and Sediment Contamination, An International Journal*, January 2003 – present.
- Member, WPI’s Educational Development Council, 2016 – 2017.
- Appointed Member of Evaluation Committee for Applicant’s Qualifications, School of Environmental Sciences, University of Nova Gorica, Slovenia, 2013.
- External Examiner for Ph.D. Dissertation, “Iron Nanoparticles for In-Situ Chemical Oxidation”, University of Waterloo, 2013.
- Member, WPI’s Committee on Graduate Studies and Research, 2007 – 2010.
- American Institute of Chemical Engineers, Environmental Division Programming Board, Technical Section Chair, Water, 2006-2008.

- *Insight Advisor* at WPI, 2005, 2006. The Insight program is an intensive mentoring and advising program for 1st year students at WPI.
- Member of Screening Panel for WPI President's *Interactive Qualifying Project* Awards, 2004, 2005.
- Committee to evaluate and select WPI's web conferencing software, 2003.
- University of Connecticut Resident Assistant Advisory Committee, 1998
- Resident Assistant for Graduate Residences; January 1997 - January 1999, University of Connecticut
- UCONN CONNECTS Facilitator; 1997 - 1999, Mentor for academic intervention program at the University of Connecticut for students on probation

Professional Licensure

Professional Engineer, State of Connecticut

Revised 8/19/2026