Date: November 14, 2023
Subject: Arcadis Foam Fractionation Qualifications

Arcadis of Michigan, LLC (Arcadis) is pleased to provide this qualifications package for experience related to PFAS treatment with foam fractionation.

Global Foam Fractionation experience with landfill leachate with confidence. Arcadis has almost 20 years of experience in PFAS systems with over 1,000 different types of PFAS projects in 17 countries since 2004. In 2019, Arcadis entered into a licensing agreement with Evocra for the rights to their patented technology which uses FF with ozone to separate and concentrate PFAS from impacted media. Currently, Arcadis is leading the design and implementation of PFAS treatment technologies for landfill-derived leachate for multiple sites in the U.S. and Australia. Arcadis is also working on cutting edge research with nine universities globally to develop treatment technologies such as residual management including destruction.

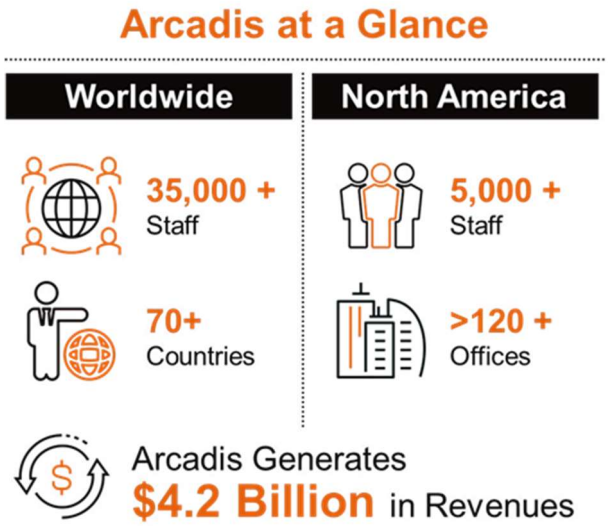
Streamlined delivery of project with one team – technology and design by one firm. Arcadis Design & Engineering delivery team can leverage our Foam Fractionation product line and provide clients with a single-team approach with better communication, faster delivery, and cost efficiency. Clients are able to interact directly with team members who are united with the goal of providing quality work products. Additionally, our team can adjust to evolving project needs by reaching into our organization to provide local and national technical experts in areas such as treatability studies, permitting, and construction.

Team members who have demonstrated success as a leader in Arcadis' global PFAS treatment practice. Corey Theriault, P.E. from our Portland, Maine office will serve as the Technical Expert. He brings more than 20 years of experience in design and has been at the forefront of the Foam Fractionation technology for over 4 years. He will be supported by a strong delivery team including Baxter Miatke and Bryan Bailey.

Qualifications and Experience

Introduction

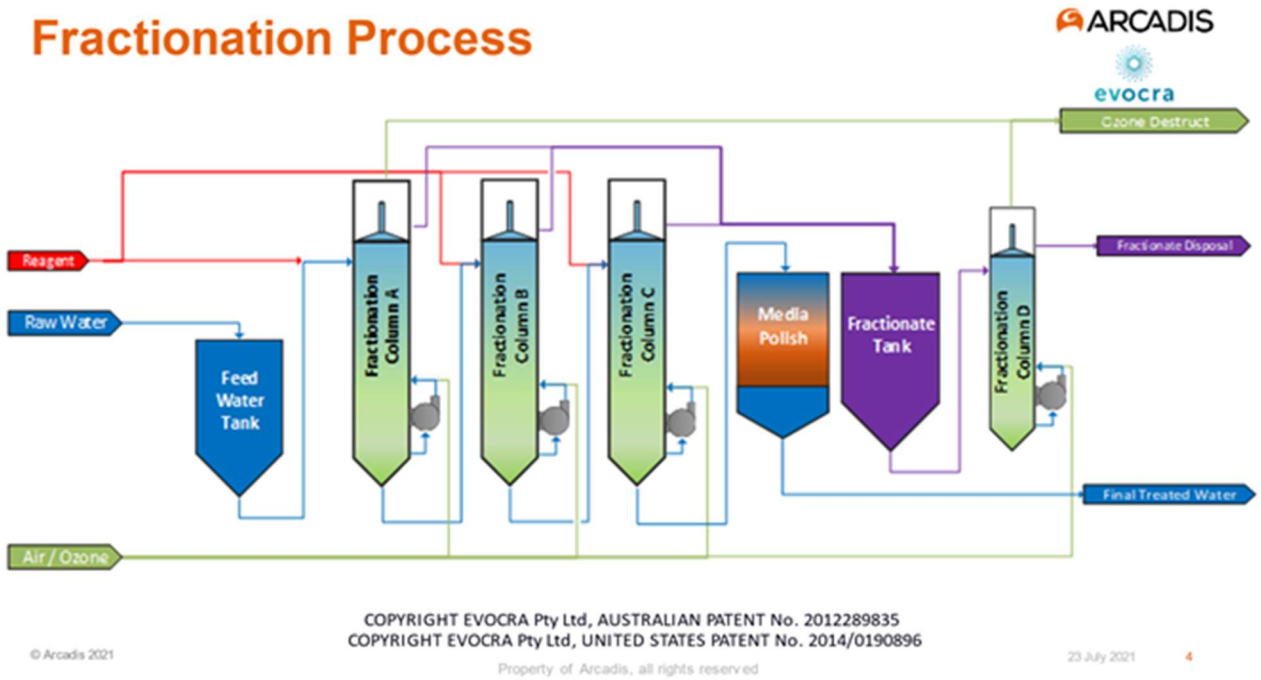
Arcadis U.S., Inc. is a nationally recognized consulting, design, engineering, and management services firm. With more than 120 offices nationwide, our company has over 5,000 employees in the U.S. Worldwide, Arcadis employs more than 35,000 people and is one of the world's largest engineering firms active in the fields of water, infrastructure, environment, and buildings. We deliver innovative, cost-effective engineering solutions to our clients to achieve operational, safety, and environmental objectives. We look beyond the immediate challenge to develop solutions that serve our clients throughout the lifecycle of a project. We combine our local expertise with our global network of technical experts to provide our clients with industry-leading solutions and a high level of responsiveness. We have an extensive network that is supported by strong local market positions so that we can confidently meet client needs across the U.S.



Foam Fractionation - Technology Qualifications

Foam fractionation is a separation technology that uses micron-sized gas (air or ozone) bubbles to remove emerging contaminants, such as PFAS from water. PFAS molecules have properties attracting them to the gas-liquid interfaces present in fractionation as the injected gas bubbles move through water. Fractionation exploits the tendency of PFAS to partition to the gas-liquid interface, concentrating them in a resultant foam. The concentrated foam is physically separated from the treated water, achieving a reduction in the contaminated volume.

Fractionation can be performed using air or ozone, or combinations of the two. Fractionation with ozone gas specifically is a patented process available commercially as ozofractionative catalyzed reagent addition (OCRA) from Evocra (www.evocra.com) through an exclusive license to Arcadis. Evocra's patented OCRA process utilizes micro-bubbles of ozone in a multiphase process that provides versatility for the removal of contaminants. OCRA's gas-liquid interface elevates oxidation-reduction potential (ORP) conditions of the OCRA chambers, degrading organic co-contaminants including petroleum hydrocarbons, and persistent contaminants as well as transforming metal ions into stable compounds and facilitating bubble adhesion for PFAS compounds. In a third-party comparative study, ozonated air fractionation showed better PFAS removal efficiency as a result of the enriched OH radicals in the gas bubbles (Dai et. al 2019). Utilizing both air and ozone in series in different reactors, foam fractionation can be optimized for site specific characteristics.

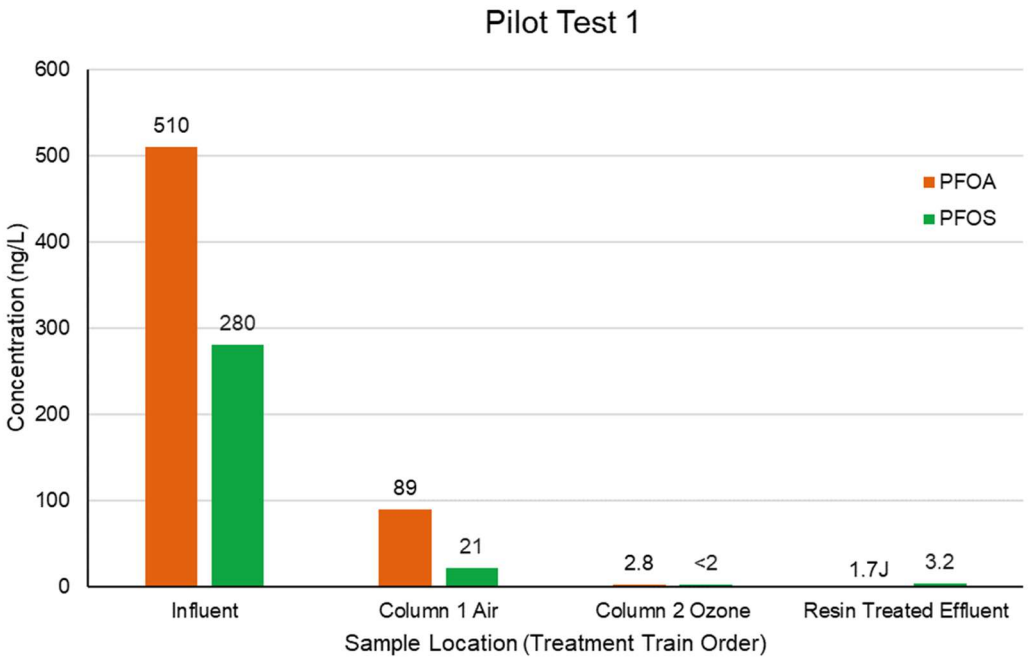


In 2019, Arcadis entered into a licensing agreement with Evocra for the rights to their patented technology which uses foam fractionation with ozone to separate and concentrate PFAS from impacted media. This technology has been deployed in Australia and in the U.S. at multiple sites with successful results. Within the United States, Arcadis' full-service Treatability Laboratory in Durham, North Carolina (Treatability Lab), has been performing fractionation bench-scale studies since 2019, providing proof of concept and pre-pilot design optimization across various waste streams. Furthermore, working in partnership with technology vendors, Arcadis has made foam fractionation technology for PFAS treatment available in North America in 2021 with its portable fractionation pilot system, the "PFAS0250". This technology is housed in a 53-foot shipping container with three foam fractionation reactors that can be shipped to a site for pilot testing. This system can evaluate the ability of air, ozone, and other gases to fractionate/concentrate PFAS from a leachate stream. There is an added benefit utilizing ozone specifically in the presence of leachate for TOC management that would otherwise impact traditional treatment methods like GAC media.

Foam Fractionation - Landfill Leachate Experience

Landfill leachate contaminated with PFAS is a challenging matrix for conventional treatment technologies due to the complicating presence of multiple co-contaminants in the waste stream. Multiple studies have investigated the applicability of OCRA for the removal of PFAS from landfill leachate with promising results; and Arcadis has performed multiple bench-scale studies evaluating the use of OCRA specifically for landfill leachate:

1. Arcadis was initially retained by Michigan Department of Environment, Great Lakes, and Energy (EGLE) to perform a Feasibility Study (FS) to evaluate technologies to treat PFAS in leachate at the Detroit Steel Corp McLouth Steel Gibraltar Superfund Site, Gibraltar, Michigan. Based on the findings of the FS, Arcadis performed bench-scale scale testing with the landfill leachate using several technologies including foam fractionation with both air and ozone. Based on the bench-scale scale testing, foam fractionation with air and ozone paired with (AIX) resin polish was selected for pilot testing. Arcadis proceeded with foam fractionation pilot testing at the Site with successful results used for full-scale design. The full-scale design is currently in progress for a 20 gpm OCRA system. As depicted in the figure below, the results of pilot test 1 demonstrate the effectiveness of the sequential treatments.



2. Arcadis worked with a solid waste company on a foam fractionation bench-scale test in 2021 for their landfill site in New Hampshire. PFAS constituents of interest for this bench-scale study included PFOS, PFOA, PFNA, and PFHxS because these constituents have drinking water maximum contaminant levels regulated in New Hampshire. Arcadis performed foam fractionation bench-scale testing at Arcadis' Treatability Laboratory in North Carolina and prepared a bench-scale testing summary report which showed that PFAS removal from the landfill leachate was within the expected operating envelope of the bench-scale-scale fractionation system, providing positive proof of concept. A copy of the results table from this bench-scale test summary report is provided for reference below showing the ozone test provided better or equal removal rates as air-only test for various PFAS.

While both tests showed some similar removal efficiencies, the test with ozone showed a higher removal of PFOS when compared with air. The concentrations in Test 1 (ozone) foam confirmed highly concentrated waste of up to 1,420 ng/L of PFOS and 32,800 ng/L of PFOA. **Ozone was successful reducing the volume of PFAS-impacted liquid in a single pass to approximately 5% of the influent volume while air only reduced the volume to approximately 8% of the influent volume in the same run time.** In this study, a small subset of samples were analyzed using the Total Oxidizable Precursor Assay (TOP). Results below in the table show results before and after TOP on the baseline influent concentrations and percent removal calculated from post-TOP values.

Sample	Unit	PFOA	PFHxS	PFOS	PFNA
Field Baseline	ng/L	430	99	66	34
Lab Baseline Influent[1]	ng/L	2,280	480	220	152
Lab Baseline Influent[2]	ng/L	2,290	618	246	164
Reactor Blank	ng/L	5.2	2.4	15	0.75
Test 1 Ozone Treated[2]	ng/L	10.5	15.5	19.5	<12.3
Test 1 Ozone Removal Percentage[3]	**%**	**99.5%**	**97.5%**	**92.1%**	**92.5%**
Test 1 Ozone Foam[2]	ng/L	32,800	8,080	1,420	1,150
Test 2 Air Treated[2]	ng/L	10.5	19.8	42.3	<12.3
Test 2 Air Removal Percentage[3]	**%**	**99.5%**	**96.8%**	**82.8%**	**92.5%**

Notes:

1- Results are before TOP to compare baselines from field and laboratory.
2- Results are after TOP used as influent concentrations for test.
3- Removal percentage calculated from laboratory baseline influent after TOP.
4- Test 2 air foam sample was not collected due to the change in operational scope.

Representative Experience Table

Relevant foam fractionation, leachate, and design projects completed by Arcadis are summarized below.

Project Name	Matrix	Client and Location	Year	Type
County Wide Landfill (CWLF) Leachate PFAS Treatment Evaluation, Testing and Design	Superfund Landfill Leachate	Michigan EGLE Gibraltar, Michigan	2020	Bench-scale Study
			2023	Full Scale Design
Landfill Leachate Foam Fractionation Testing	Commercial Landfill Leachate	Confidential Solid Waste Company, New Hampshire	2021	Bench-Scale
Landfill Leachate Collection Facility Foam Fractionation Testing	Commercial Landfill Leachate	Confidential Solid Waste Company, Michigan	2023	Bench-scale Study
			In Progress	Pilot Study
Industrial Landfill Leachate Characterization and Foam Fractionation Bench-scale Testing	Industrial Private Landfill Leachate	Industrial Confidential Client, Alabama	2021	Bench-scale Study
Industrial Wastewater with AFFF Foam Fractionation Testing	Industrial Wastewater/ AFFF	Industrial Confidential Client, Wisconsin	2019	Bench-scale Study
			2020	Pilot Study
Industrial Wastewater RO Reject Foam Fractionation Testing	Industrial Wastewater RO Reject	Industrial Confidential Client, Illinois	2020	Bench-scale Study
ESTCP Fire Decontamination Cleaning Agent Foam Fractionation Testing	PFAS Cleaning Agent	ESTCP Pennsylvania	2022	Bench-scale Study
Groundwater with AFFF Foam Fractionation Testing	Groundwater	Navy BAA Pennsylvania	2023	Bench-scale Study
			In Progress	Pilot Study
Arcadis Australia				
New Chum Landfill Leachate Trial	Landfill Leachate	Cleanaway Queensland, AU	2021	Pilot Study
			2022	Full Scale
Qantas Wastewater Treatment	Industrial Wastewater	Brisbane Airport Queensland, AU	2018	Full Scale
Fire Training Area Runoff Treatment	AFFF/ Sewer/ Combined Waste	Hobart Airport Tasmania, AU	2020	Full Scale
Campbellfield Industrial Wastewater Treatment	Industrial Wastewater	Cleanaway Victoria, AU	2021	Bench-scale Study
			In Progress	Full Scale
Rutherford Sour Water Treatment Trial	Industrial Wastewater	Cleanaway New South Wales, AU	2021	Bench-scale Study

Key Personnel

 Corey Theriault, PE Portland, ME	Mr. Theriault is a professional engineer registered in Maine with more than 20 years of professional experience in the areas of water and wastewater design, environmental management, and facilities and maintenance management. He has led engineering design teams on water and wastewater projects throughout the U.S and globally. Mr. Theriault has led the design, construction and operation of PFAS systems at Department of Defence (DoD) installations and commercial and industrial installations across the U.S. He serves as an Arcadis AIX resin expert and has led large-scale treatment installation and commissioning efforts at multiple facilities.
 Baxter Miatke, PE Portland, ME	Mr. Miatke is a professional engineer registered in Maine with 7 years of consulting experience in the areas of remedial design, operations, optimization, construction oversight; water and wastewater distribution and treatment design; environmental site assessments; and environmental sampling. His focus at Arcadis has been on PFAS specific treatment technology evaluation and design. He has experience with the design and operation of Arcadis' foam fractionation pilot system and is the lead process engineer on the current foam fractionation full-scale design project for Michigan EGLE.
 Bryan Bailey, PE Cincinnati, OH	Mr. Bailey is a professional engineer with over 26 years of experience in the water treatment industry and has worked on over 50 PFAS treatment projects since 2016 in the US, Australia, and Europe. Mr. Bailey was often responsible for the design and management of delivering these systems. Mr. Bailey is skilled at delivering integrated projects with multidisciplinary engineering teams, equipment providers and construction firms. Mr. Bailey developed his leadership skills while at firms such as Veolia and ECT2 in which he served in various director level roles leading engineering, project management and sales activities for these OEMs.

Arcadis Relevant Publications

Lang, J.R., McDonough, J., Guillette, T.C., Storch, P., Anderson, J., Liles, D., Prigge, R., Miles, J.A.L., Divine, C., 2022. Characterization of per- and polyfluoroalkyl substances on fire suppression system piping and optimization of removal methods. Chemosphere 308, 136254.

McDonough, J.T., Anderson, R.H., Lang, J.R., Liles, D., Matteson, K., Olechiw, T., 2021. Field-Scale Demonstration of PFAS Leachability Following In Situ Soil Stabilization. ACS Omega.10.1021/acsomega.1c04789

Solo-Gabriele, H. M. J., A.S.; Lindstrom, A.B.; Lang, J. (2020). Waste type, incineration, and aeration are associated with per- and polyfuoroalkyl levels in landfll leachates. Waste Management, 107, 191-200. doi:10.1016/j.wasman.2020.03.034

Ridel, T., Lang, J., Strynar, M., Lindstrom, A., and Ofenberg, J. Gas-Phase Detection of Fluorotelomer Alcohols and Other Oxygenated PFAS by Chemical Ionization Mass Spectrometry. ES&T Letters. 2019.

Schaider, L.A., Balan, S.A., Blum, A., Andrews, D.Q., Strynar, M.J., Dickinson, M.E., Lunderberg, D.M., Lang, J.R., and Peaslee, G.F. Fluorinated Compounds in U.S. Fast Food Packaging, ES&T Letters, 2017

Lang, J.R., Allred, B.M., Levis, J., Field, J.A., and Barlaz, M.A. National Inventory of Per- and Polyfluoroalkyl Substances (PFASs) in U.S. Municipal Landfill Leachate, ES&T, 2017

Lang et al. Physical and biological release of poly- and perfuoroalkyl substances (PFASs) in laboratory-scale anaerobic bioreactors flled with carpet and clothing, ES&T, 2016

Allred et al. Physical and biological release of poly- and perfuoroalkyl substances (PFASs) from municipal solid waste in anaerobic model landfll reactors, ES&T, 2015

Orthogonal zirconium diol/C18 liquid chromatography-tandem mass spectrometry analysis of poly and perfuoroalkyl substances in landfll leachate, Journal of Chromatography A, 2014

Miatke, Baxter et. al June 2021, 'Bench-Scale Optimization of Fractionation Technology to Treat PFAS Impacted Industrial Wastewater in the U.S", Michigan Water Environment Association (MWEA) Annual Conference- PFAS Session

Miatke, Baxter et. al May 2022, "Comparative Evaluation of Fractionation Treatment Technology for PFAS Impacted Landfill Leachate at Bench and Pilot Scale", Battelle 2022 Chlorinated Conference, Palm Springs, CA

Miatke, Baxter et al. 2023 "What a Waste! The Role of Innovative PFAS Treatment Technologies for Managing PFAS Waste from Water Treatment Systems" , Waste Management Conference 23, Phoenix, AZ.

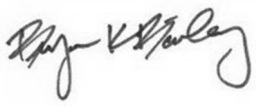
McDonough, J., Kirby, J, Quinnan, J, et. al, "Validation of supercritical ware oxidation to destroy perfluoroalkyl acids" September 2021.

Closing

Sincerely,
Arcadis of Michigan, LLC

Corey Theriault, PE
Principal Water Engineer

Email: corey.theriault@arcadis.com
Direct Line: 207.613.8527



Bryan Bailey, PE
Principal Engineer

bryan.bailey@arcadis.com
937.623.4232

Corporate Headquarters (U.S.)

✉ 630 Plaza Drive, Suite 10
Highlands Ranch, CO 80129
☎ 720.344.3500

Treatability Lab

✉ 4915 Prospectus Drive,
Suite G, Durham, NC, 27713
☎ 919 328 5574

Primary Contact

Corey Theriault, PE
Principal Engineer
☎ 207.210.0191
corey.theriault@arcadis.com