TECHNICAL MEMORANDUM
AMEOX™ PROCESSING OF GAC from an
AFFF RELEASE SITE WATER TREATMENT SYSTEM

RE: AMEOX™ Treatment Viability Data for AFFF-Sourced PFAS Destruction in Spent GAC

DATE: December 15, 2020

In June 2020 Yost Brothers, LLC (YB) obtained a sample bucket of granular activated carbon (GAC) spent with PFAS from a confidential AFFF water remediation site in the Midwest. The purpose of the sample was to conduct viability processing studies on the material using the AMEOX™ treatment technology for the destruction of PFAS. At the time of sample transfer, the material was immediately sampled in duplicate and samples were sent to ALS Environmental in Holland, MI for characterization analyses of total PFAS (Michigan list of "28" telomeres). The remaining sample was used in the AMEOX™ viability treatment studies at Blue Q Labs, LLC in Lebanon, OR.

At Blue Q, the remaining GAC in the sample bucket (~32 lbs.) was examined and prepared for treatment. Water with an evident sheen was present in the carbon at the bottom of the bucket. After thorough mixing of the GAC and water in the bucket, another characterization sample was collected and sent to ALS for characterization analyses.

Based on the amount of GAC available for the viability treatment work, it was decided to perform three (3) viability treatment runs which coincided with the low end required mass (8-10 lbs.) for treatment processing using the bench-scale AMEOX treatment GAC reactor. Discrete AMEOX treatments were performed sequentially after receipt of preliminary analytical data from ALS of post-treated material.

Referring to the tables (attached), trials AMEOX-1 and -2 were processed using the two (2) regime processing variations of the AMEOX technology. AMEOX-3 was planned to enhance the treatment of either AMEOX-1 or AMEOX-2 pending on the results. Based on the results, the AMEOX-2 treatment regime was selected for enhanced processing in AMEOX-3 and future optimization efforts. The data from AMEOX-3, however, suggests that PFAS destruction was over 85-90%, indicating that further optimization may not be necessary depending on treated GAC use.

During the treatments, YB noted that the GAC released fines entrained within the spent carbon media granules. YB learned that the spend GAC had not been backflushed prior to its initial use onsite to treat PFAS impacted water. In treatment AMEOX-2, a 0.5um filter trap was installed in-line with the AMEOX fluid that recirculates between the GAC reactor and the AMEOX processing equipment. A limited mass of GAC fines was released (~100-150g) and captured. This material was then sampled for total PFAS by ALS. Unfortunately, the mass of GAC fines obtained was too little to apply the AMEOX technology, therefore, YB applied the MBT™ chemical treatment technology to the fines to mitigate any leachable PFAS from the material as determined by USEPA Method 1311 (TCLP) extraction. MBT™ reagents were applied using a generic formulation and dose based on total PFAS with the objective of reducing TCLP leachable PFAS from the fines to below the USEPA advisory PFAS level for water of <70 ppt. This would allow for potential disposal of the treated fines in a RCRA licensed non-hazardous subtitle D landfill. The MBT treatment data indicates that this treatment objective was achieved. The AMEOX process was slightly modified during the AMEOX-3 treatment run to prevent the release of GAC fines.

The AMEOX fluid used in this study had been prepared in the early months of 2020 and had been used repeatedly for various bench and engineering scale viability studies. To evaluate PFAS concentrations changes in the fluid, YB collected and analyzed AMEOX fluid before and after treatment of the carbon treated in this study. AMEOX fluid is recirculated/reused from treatment to treatment, and material to material without the need of discharge.

All laboratory reports available upon request.

Confidential Midwest Site Water Remediation

Water Treatment Plant - Carbon

TABLE 1

Untreated Characterization and AMEOX™ Viability Treatment Data for Spent Granular Activated Carbon (GAC)

Analytes: **PFAS - Totals**
Method: **D7968-17a**
Matrix: **PFAS Spent Activated Coal Carbon**
Lab: **ALS Environmental - Holland, MI**

		Sample:	UNTREATED PFAS GAC			AMEOX™ Treated GAC		
		AMEOX™ Treatability Phase:	Characterization			Viability (3 runs)		
		Date:	**6/12/2020**	**6/12/2020**	**6/26/2020**	**6/26/2020**	**7/23/2020**	**8/4/2020**
		Sample ID:	**Untreated**	**Untreated - DUP**	**Untreated**	**AMEOX-1**	**AMEOX-2**	**AMEOX-3**
		Units:	(ng/Kg)	(ng/Kg)	(ng/Kg)	(ng/Kg)	(ng/Kg)	(ng/Kg)
Telomere	Chemical Name	C Atoms	Result	Result	Result	Result	Result	Result
PFBA	Perfluorobutanoic Acid	C4	9,200	13,000	11,000	17,000	11,000	2,600
PFPeA	Perfluoropentanoic Acid	C5	33,000	42,000	32,000	56,000	32,000	5,100
PFHxA	Perfluorohexanoic Acid	C6	42,000	59,000	43,000	77,000	42,000	7,100
PFHpA	Perfluoroheptanoic Acid	C7	14,000	23,000	17,000	30,000	14,000	2,700
PFOA	**Perfluorooctanoic Acid**	**C8**	**160,000**	**310,000**	**250,000**	**470,000 ?**	**190,000**	**38,000**
PFNA	Perfluorononanoic Acid	C9	2,600	6,900	5,500	12,000	3,600	930
PFDA	Perfluorodecanoic Acid	C10	<230	<500	<610	<620	<25	<130
PFUnA	Perfluoroundecanoic Acid	C11	<230	<500	<610	<620	<120	<130
PFDoA	Perfluorododenoic Acid	C12	<230	<500	<610	<620	<120	<130
PFTriA	Perfluorortridecanoic Acid	C13	<230	<500	<610	<620	<120	<130
PFTeA	Perfluortetradecanoic Acid	C14	<230	<500	<610	<620	<120	<130
PFBS	Perfluorobutanesulfonic Acid	C4	360	580	310	940	470	60
PFPeS	Perfluoropentanesulfonic Acid	C5	270	420	420	1,000	210	26
PFHxS	Perfluorohexanesulfonic Acid	C6	1,900	4,300	3,500	7,400	2,400	350
PFHpS	Perfluoroheptanesulfonic Acid	C7	<230	<500	<610	<620	<120	<130
PFOS	**Perfluorooctanesulfonic Acid**	**C8**	**1,200**	**3,200**	**3,400**	**8,200**	**2,000**	**600**
PFNS	Perfluorononanesulfonic Acid	C9	<230	<500	<610	<610	<120	<130
PFDS	Perfluorodecanesulfonic Acid	C10	<46	<100	<120	<120	<25	<26
FtSA 4:2	Fluorotelomer Sulfonic Acid 4:2	C6	3,000	5,300	3,200	6,700	3,000	620
FtSA 6:2	Fluorotelomer Sulfonic Acid 6:2	C8	85,000	190,000	150,000	280,000 ?	120,000	25,000
FtSA 8:2	Fluorotelomer Sulfonic Acid 8:2	C10	1,300	3,400	4,600	10,000	2,300	670
PFOSA	Perfluorooctanesulfonaminde	C8	76	200	210	550	160	<26
EtFOSSA	N-Ethylperfluorooctanesulfon amidoacetic Acid	C12	<230	<500	<610	<620	<120	<130
MeFOSAA	N-Methylperfluorooctanesulfon amidoacetic Acid	C11	<230	<500	<610	<620	<120	<130
F-53BMin	11Cl-Pf3OUds	C10	<46	<100	<120	<120	<25	<26
ADONA	4,8-Doxa-3H-perfluorononanoic Acid	C8	<46	<100	<120	<120	<25	<26
F-53BMaj	9Cl-PF3ONS	C8	<46	<100	<120	<120	<25	<26
---	Hexafluoropropylene	C3	<230	<500	<610	<620	<120	<130
		Summation of PFOA and PFOS:	**161,200**	**313,200**	**253,400**	**478,200**	**192,000**	**38,600**
		Summation of PFAS Telomere Totals:	353,906	661,300	524,140	696,790	423,140	83,756
				PFOA + PFOS	**% Reduction:**		-24.2%	**-84.8%**
				Total PFAS (MI "28")	**% Reduction:**		-19.3%	**-84.0%**

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Water Treatment Plant - Carbon

TABLE 2

MBT™ Viability Treatment Data for Spent Granular Activated Carbon (GAC) Fines and AMEOX Fluid (Pre/Post Treatment)

Analytes: **PFAS - Totals in Solids and Water (TCLP Extract and AMEOX™ Treatment Fluids)**
Methods: **D7968-17a (Solids), EPA Method 1311 (TCLP), and D7979-17 (Fluids)**
Matrix A: **GAC Fines Removed from AMEOX System During GAC Processing**
Matrix B: **AMEOX Fluids (Pre- and Post-AMEOX Processing of Midwest Site Water GAC)**
Lab: **ALS Environmental - Holland, MI**

			Matrix A		Matrix B	
		Sample:	GAC Fines	GAC Fines	AMEOX™ Fluid	AMEOX™ Fluid
		AMEOX™ Treatability Phase:	Characterization	MBT™ Treated	Pre-Treatment	Post-Treatment
		Units:	(ng/Kg)	TCLP (ng/L)	(ng/L)	(ng/L)
Telomere	**Chemical Name**	**C Atoms**	**Result**	**Result**	**Result**	**Result**
PFBA	Perfluorobutanoic Acid	C4	12,000	94	52	49
PFPeA	Perfluoropentanoic Acid	C5	39,000	<49	<50	<49
PFHxA	Perfluorohexanoic Acid	C6	65,000	<49	<50	<49
PFHpA	Perfluoroheptanoic Acid	C7	24,000	<9.8	<9.9	<9.8
PFOA	**Perfluorooctanoic Acid**	**C8**	**190,000**	**<9.7**	**24**	**22**
PFNA	Perfluorononanoic Acid	C9	2,400	<9.7	<9.9	<9.8
PFDA	Perfluorodecanoic Acid	C10	<120	<49	<50	<49
PFUnA	Perfluoroundecanoic Acid	C11	<120	<49	<50	<49
PFDoA	Perfluorododenoic Acid	C12	<120	<49	<50	<49
PFTriA	Perfluorortridecanoic Acid	C13	<120	<49	<50	<49
PFTeA	Perfluortetradecanoic Acid	C14	<120	<49	<50	<49
PFBS	Perfluorobutanesulfonic Acid	C4	3,100	<9.7	<9.9	<9.8
PFPeS	Perfluoropentanesulfonic Acid	C5	840	<9.7	<9.9	<9.8
PFHxS	Perfluorohexanesulfonic Acid	C6	4,700	<49	<50	<49
PFHpS	Perfluoroheptanesulfonic Acid	C7	950	<49	<50	<49
PFOS	**Perfluorooctanesulfonic Acid**	**C8**	**170,000**	**<9.7**	**660**	**600**
PFNS	Perfluorononanesulfonic Acid	C9	<120	<50	<50	<50
PFDS	Perfluorodecanesulfonic Acid	C10	<25	<9.7	<9.9	<9.8
FtSA 4:2	Fluorotelomer Sulfonic Acid 4:2	C6	3,700	<49	<50	<49
FtSA 6:2	Fluorotelomer Sulfonic Acid 6:2	C8	100,000	<49	<50	<49
FtSA 8:2	Fluorotelomer Sulfonic Acid 8:2	C10	1,000	<49	<50	<49
PFOSA	Perfluorooctanesulfonaminde	C8	70	<9.7	<9.9	<9.8
EtFOSSA	N-Ethylperfluorooctanesulfon amidoacetic Acid	C12	<120	<49	<50	<49
MeFOSAA	N-Methylperfluorooctanesulfon amidoacetic Acid	C11	<120	<49	<50	<49
F-53BMin	11Cl-Pf3OUds	C10	<25	<9.7	<9.9	<9.8
ADONA	4,8-Doxa-3H-perfluorononanoic Acid (?	C8	<25	<9.7	<9.9	<9.8
F-53BMaj	9Cl-PF3ONS	C8	<25	<9.7	<9.9	<9.8
---	Hexafluoropropylene	C3	<120	<49	<50	<49
pH (S.U.)	pH (S.U.)	--				
		Summation of PFOA and PFOS:	360,000	ND	**684**	**622**
		Summation of PFAS Telomere Totals:	616,760	94	736	671