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Calgon Carbon Corporation
Pittsburgh, PA

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Isotherm: Removal of TOC and PFCs from Drinking Water using F-400 GAC

Prepared For:

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INTRODUCTION

Calgon Carbon Corporation, hereinafter CCC, services were requested by Hoosick Falls to conduct an Isotherm. Hoosick Falls is considering using activated carbon to reduce the concentration of total organic carbon (TOC) and perfluorinated compounds (PFCs) in their potable water stream.

PFCs are used in many industrial and commercial applications including non-stick cookware, fire-fighting foam, and stain resistant fabrics. They are problematic because of their persistence in the environment and their long half-life in humans. In general, PFCs are separated into main categories: perfluoroalkyl sulfonates (PFAS) and long-chain (greater than 8 carbons) perfluroalkyl carboxylates (PFAC). The two major PFCs of interest are perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) due to their predominance in industrial applications.

SUMMARY and CONCLUSIONS

A ten-point isotherm test was performed by CCC using Filtrasorb 400 (F-400) activated carbon and the water sample supplied by Hoosick Falls. The water sample is considered representative of their potable water stream. This isotherm will define the feasibility of achieving the treatment objective and approximate the carbon use rate achievable in the proposed carbon system.

The isotherm test was conducted at ambient temperature (70º F), contacting a series of precise weights of activated carbon with known volumes of water, until equilibrium is achieved (approx 16 hours). After the carbon was removed by pressure filtration, the residual TOC and PFC concentrations were determined.

> Note: Carbon use rates derived from isotherm testing represent minimum carbon use rates achievable if operating in Lead/Lag configurations. Isotherm derived carbon use rates assume the activated carbon will be saturated with the contaminant at the time of replacement, and does not account for unused activated carbon if the bed is changed out at initial breakthrough.

The results of the isotherm test are presented in Tables 1 and 2 as well as in Figures 1 and 2. The following conclusions can be drawn from them:

- F-400 activated carbon was shown to be effective at reducing TOC (Figure 1).
    - For TOC removal, several carbon dosages were able to reduce TOC concentration to below the MDL (0.1 ppm). Results for TOC removal indicate a maximum loading of 4.2 g TOC/100 g of carbon, equivalent to a carbon use rate of 0.20 lbs. GAC/1000 gallons treated. The summary of the dosages and their loadings can be found in Table 1.
- F-400 activated carbon was also shown to be effective at reducing PFCs (Figure 2).

  - For PFC removal, several carbon dosages were able to reduce individual PFC concentrations below their MDLs. The summary of the dosages and their loadings can be found in Table 2. The composition of PFCs in each dosage can also be found in Table 2.

- This isotherm suggests that based on typical well-designed systems, for removal of total PFCs the carbon use rate (based on first dosage with non-detect values) should not exceed 0.1 lbs GAC / 1000 gallons treated.

EXPERIMENTAL

Feed Preparation

A 26-Liter water sample was received from Hoosick Falls on April 30, 2015. The sample was stored at 40ºF until testing began. The water was used as received. The "control" was stirred overnight with no carbon treatment alongside the carbon dosages and later filtered.

Carbon Preparation

A representative sample of F-400 granular activated carbon was obtained from CCC's sample stock for testing purposes. Carbon specifications for the carbon product are located in Appendix A of this report. The carbon was pulverized to 95% -325 mesh (US Sieve). The pulverized carbon was oven dried at 220º F (105°C) overnight, and then cooled in a dessicator before use.

Isotherms

Carbon dosages and liquid volumes used for the isotherm are summarized in Tables 1 and 2. Each isotherm dosage was stirred for at least 16 hours, at ambient temperature, to ensure that adsorption equilibrium was achieved. The carbon was then removed from solution via pressure filtration through Millipore HVLP (PVDF) 0.45µm filter pads. Samples were collected into pre-cleaned 1-liter amber bottles prior to dividing for TOC and PFCs analysis.

The isotherm test protocol is described in Appendix B of this report.

Analytical

All TOC samples (i.e. control and carbon dosages) were analyzed in CCC's analytical laboratory according to the described methods:

Standard Methods [SM 5310B] Total Organic Carbon, High Temperature Combustion Method

All PFC samples were sent to Eurofins Eaton Analytical for analysis according to the following method:

EEA 537 – Perfluorinated compounds

Table 1:

Hoosick Falls					
TOC Removal					
#	Dosage (g)	Volume of Sample (ml)	Dosage (wt%)	Residual TOC Concentration (mg/L)	TOC "Loading" (g/100 g GAC)
	control (0)			1.38	
1	0.0012	1000	0.0001%	1.06	26.67
2	0.0033	1000	0.0003%	1.25	3.94
3	0.0058	1000	0.0006%	1.15	3.97
4	0.0105	1000	0.0011%	0.97	3.90
5	0.0213	1000	0.0021%	0.83	2.58
6	0.0499	1000	0.0050%	0.47	1.82
7	0.1030	1000	0.0103%	0.18	1.17
8	0.4998	1000	0.0500%	0.23	0.23
9	1.0042	1000	0.1004%	0.37	0.10
10	2.0031	1000	0.2003%	0.29	0.05

Table 2:

Hoosick Falls												
PFC Removal												
#	Dosage (g)	Volume of Sample (ml)	Dosage (wt%)	Residual Total PFC Concentration (ng/L)	Total PFC "Loading" (µg/g GAC)	PFC Concentrations (ng/L)						
						Total	PFBS	PFHpA	PFHxS	PFNA	PFOS	PFOA
	control (0)			570.00		570.00	*<90*	20	*<30*	*<20*	*<40*	550
1	0.0012	1000	0.0001%	440.00	108.33	440.00	*<90*	10	*<30*	*<20*	*<40*	430
2	0.0033	1000	0.0003%	190.00	115.15	190.00	*<90*	*<10*	*<30*	*<20*	*<40*	190
3	0.0058	1000	0.0006%	50.00	89.66	50.00	*<90*	*<10*	*<30*	*<20*	*<40*	50
4	0.0105	1000	0.0011%	0.00	54.29	*0.00*	*<90*	*<10*	*<30*	*<20*	*<40*	*<20*
5	0.0213	1000	0.0021%	0.00	26.76	*0.00*	*<90*	*<10*	*<30*	*<20*	*<40*	*<20*
6	0.0499	1000	0.0050%	0.00	11.42	*0.00*	*<90*	*<10*	*<30*	*<20*	*<40*	*<20*
7	0.1030	1000	0.0103%	0.00	5.53	*0.00*	*<90*	*<10*	*<30*	*<20*	*<40*	*<20*
8	0.4998	1000	0.0500%	0.00	1.14	*0.00*	*<90*	*<10*	*<30*	*<20*	*<40*	*<20*
9	1.0042	1000	0.1004%	0.00	0.57	*0.00*	*<90*	*<10*	*<30*	*<20*	*<40*	*<20*
10	2.0031	1000	0.2003%	0.00	0.29	*0.00*	*<90*	*<10*	*<30*	*<20*	*<40*	*<20*

PFBS Perfluorobutanesulfonic acid
PFHpA Perfluoroheptanoic acid
PFHxS Perfluorohexanesulfonic acid
PFNA Perfluorononanoic acid
PFOS Perfluorooctane sulfonate
PFOA Perfluorooctanoic acid

Figure 1
TOC Removal - Hoosick Falls
F-400 Isotherm Plot

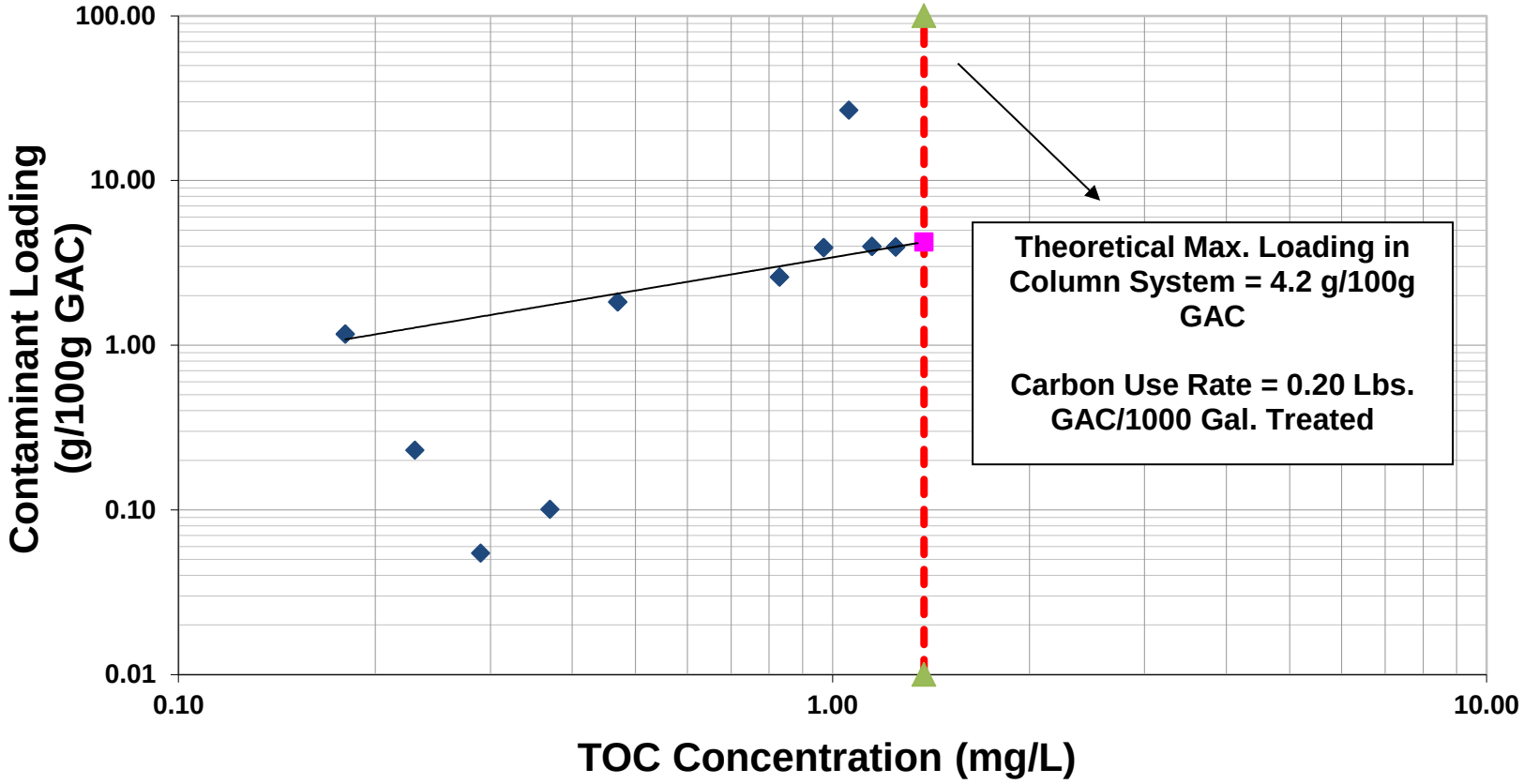
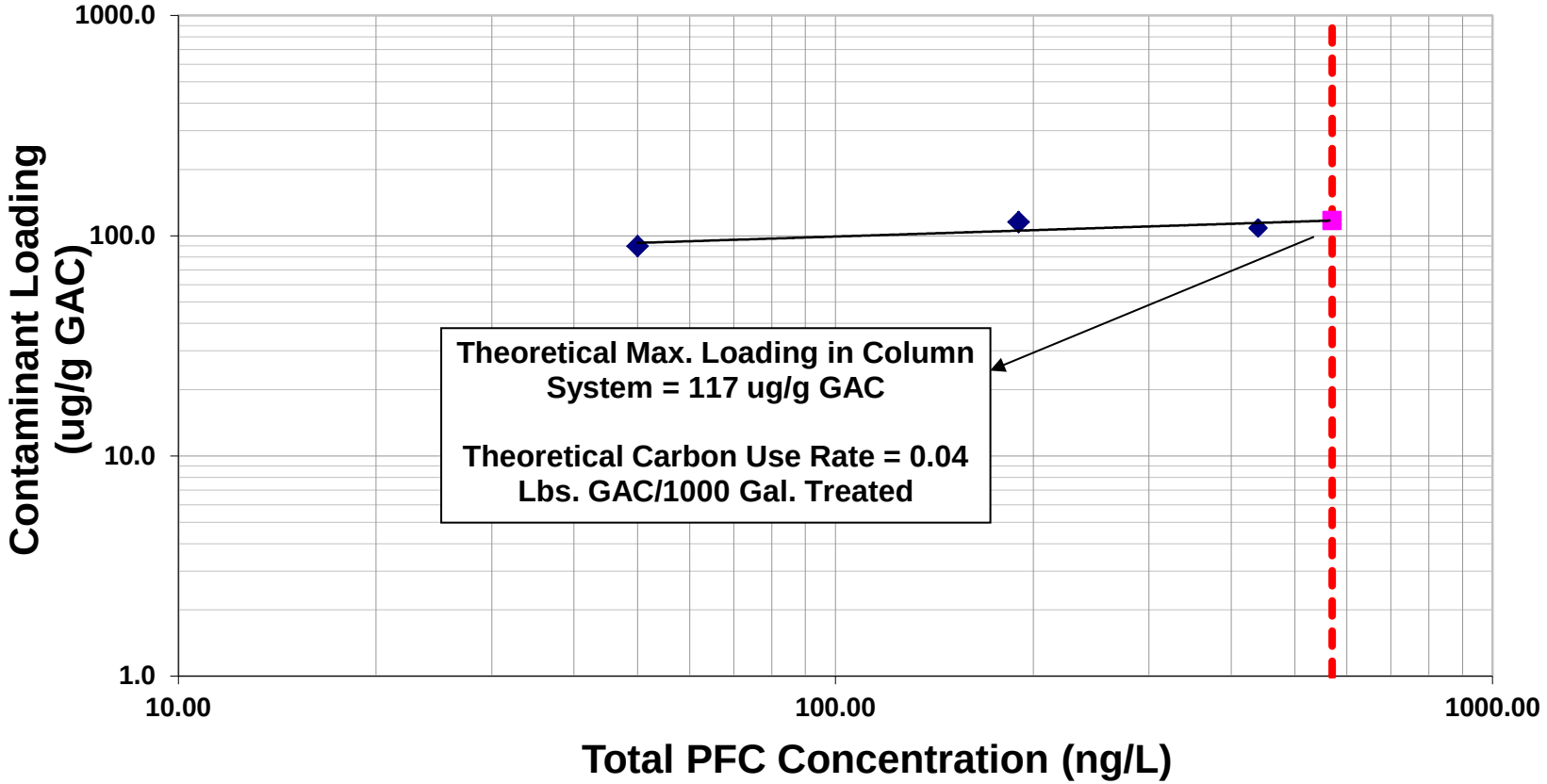


Figure 2
PFC Removal - Hoosick Falls
F-400 Isotherm Plot



Appendix A

Sales Specification Sheet for F-400

SALES SPECIFICATION SHEET

FILTRASORB 400

Granular Activated Carbon

Test	Specification		Calgon Carbon Test Method
	Min	Max	
IODINE NUMBER, mg/g	1000	-	TM-4,ASTM D4607
MOISTURE (AS PACKAGED), wt%	-	2	TM-1,ASTM D2867
ABRASION NUMBER	75	-	TM-9,AWWA B604
EFFECTIVE SIZE, mm	0.55	0.75	TM-47,ASTM D2862
UNIFORMITY COEFFICIENT	-	1.9	TM-47,ASTM D2862
12 US MESH [1.70 mm], wt%	-	5	TM-8,ASTM D2862
< 40 US MESH [0.425 mm] (PAN), wt%	-	4	TM-8,ASTM D2862

Typical Properties:

This product complies with ANSI/AWWA B604 (2005) – Granular Activated Carbon.

This product complies with the requirements for activated carbon as defined by the Food Chemicals Codex (FCC) (8th Edition) published by the U.S. Pharmacopeia.

This product is produced under supervision of the Islamic Food and Nutrition Council of America (IFANCA).

This product is prepared under the supervision of the Kashruth Division of the Orthodox Union and is Kosher.

Only products bearing the NSF Mark are Certified to NSF/ANSI 61 - Drinking Water System Components - Health Effects standard. Certified Products will bear the NSF Mark on packing or documentation shipped with the product.

Calgon Carbon Corporation's activated carbon products are continuously being improved and changes may have taken place since this publication went to press. (2030-08/29/2013)

Appendix B

ISOTHERM TEST PROTOCOL

An isotherm is a batch test designed to demonstrate the degree to which a particular dissolved organic compound (adsorbate) is adsorbed on activated carbon (adsorbent). The data generated shows the distribution of adsorbate between the adsorbent and solution phases at various adsorbate concentrations. From the data, a plot of the amount of impurity remaining in solution at constant temperature can be generated. For a single adsorbate, a straight-line plot can be obtained when using the empirical Freundlich equation:

$$X/M = kC \exp l/n \quad \text{or} \quad \log X/M = \log k + l/n \log C$$

where:

X = amount of contaminant adsorbed

M = weight of carbon

C = equilibrium concentration in solution after adsorption

k and n = constants

For mixtures of adsorbates, a series of straight lines can be obtained. The presence of a non-adsorbable component will result in a curvature of the line when in combination with an adsorbable component, and in a vertical line when alone.

Data for generating this type of isotherm are obtained by treating fixed volumes of the water sample with a series of known weights of carbon. The carbon-liquid mixture is agitated for a fixed time at a constant temperature. After the carbon has been removed by filtration, the residual adsorbate concentration is then determined. The amount of organic adsorbed by the carbon (X) is divided by the weight of carbon in the sample (M) to give one value of X/M for the isotherm.

The adsorption isotherm interpretation yields a theoretical equilibrium carbon dosage. In most cases, further testing in columns is required to obtain a carbon usage rate to be used for design purposes.