GAC for PFC Removal

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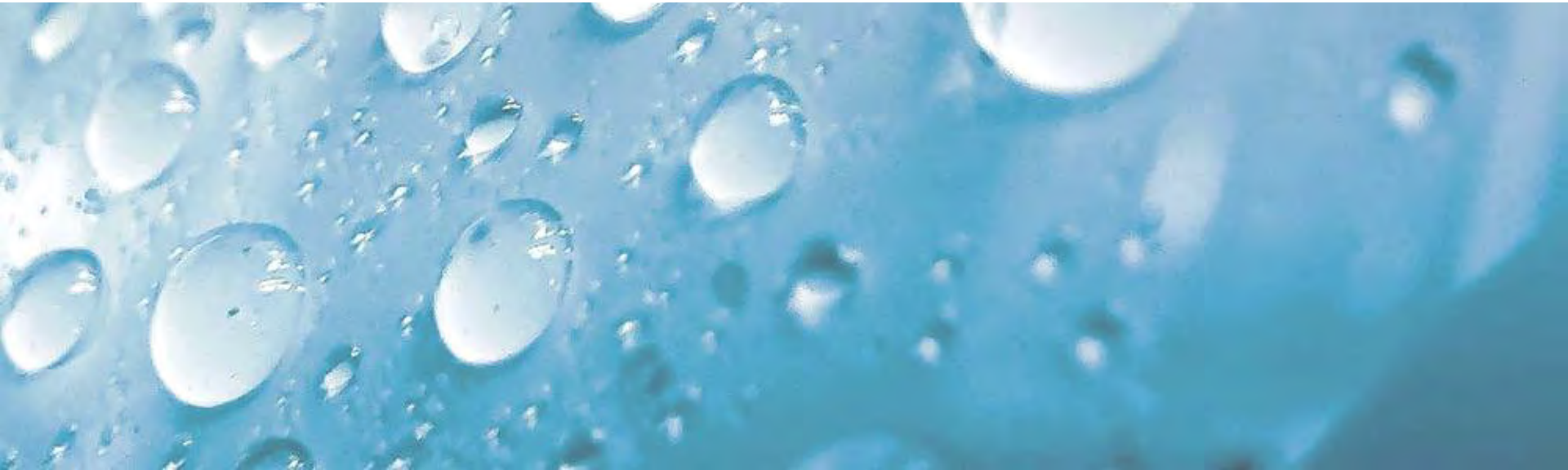
Agenda

- Perfluorinated Compounds
  - What are they?
  - Where are they?
  - Why are they harmful?

- Treating PFCs with Granular Activated Carbon
  - PFC removal data
    - Static vs. column tests
    - Comparing different GACs
    - Short chain PFCs
    - Lab vs. full scale performance

Perfluorinated Compounds



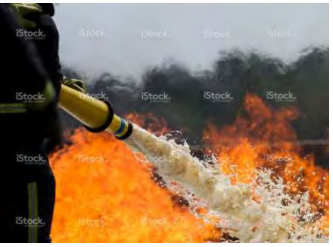
What Are PFCs?

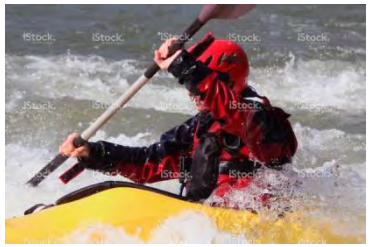
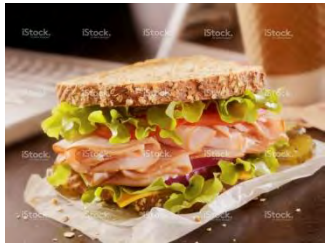
PFCs are manmade fully fluorinated organic compounds that are not naturally found in the environment

- PFOS: Perfluorooctane sulfonate
- PFOA: Perfluorooctanoic acid

PFCs are found in a number of products, although use of PFOA in manufacturing has been phased out

- Fire-fighting foams
- Non-stick cookware
- Water-proof/repellant outdoor gear
- Food paper wrappings
- Carpeting/upholstery



Why PFCs Are a Problem

Contaminate drinking water and food

- PFCs are highly mobile and infiltrate rapidly into groundwater
- PFC plumes travel quickly and travel long distances

Highly persistent and resistant to degradation

- Strong C-F bond allows PFC concentration in plumes to be stable over time
- PFCs pose a human health risk at minuscule concentrations

Accumulate in the body

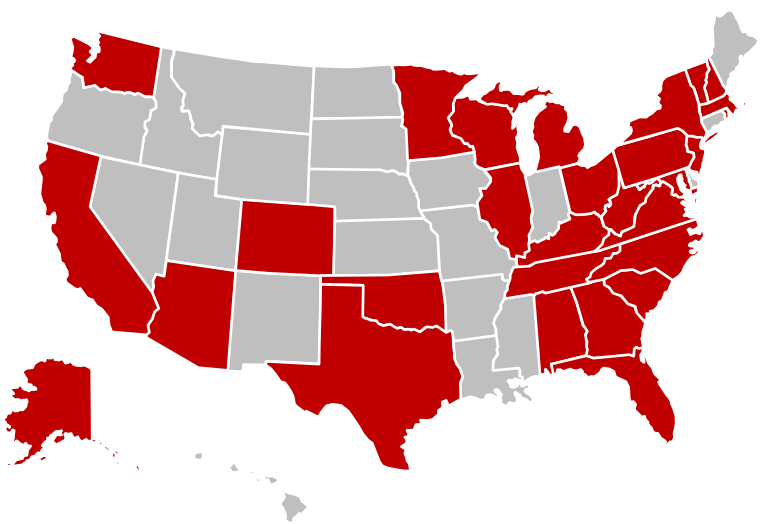
- PFCs have a long biological half-life – it takes bodies more than four years to flush out half of the PFCs residing in tissues
- PFCs are found in the liver, pancreatic, testicular, and mammary gland tumors in lab animals

Where Are PFCs?

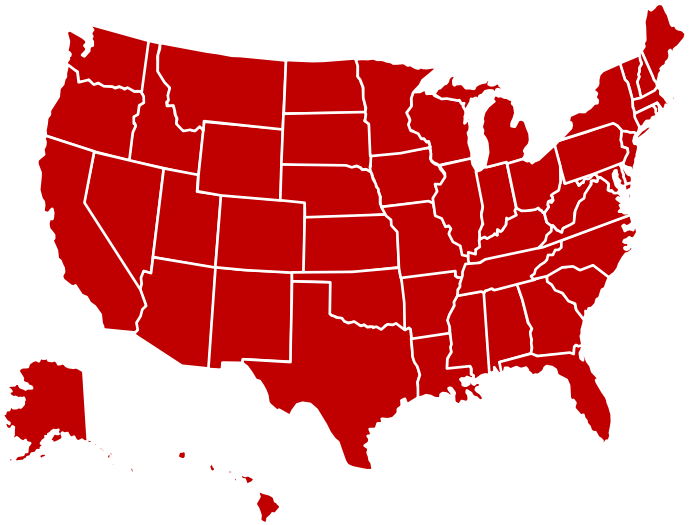
PFCs have been detected in drinking water sources throughout the United States

- Concentrations in the Northeast, Southeast, Southwest
- The Environmental Working Group (EWG) published a report of USEPA occurrence data showing 94 water utilities with detectable levels of PFCs
- The DOD has reported 664 occurrences at more than 100 military bases

*source http://news10.com/2016/06/02/pfoa-by-the-numbers-a-widespread-contamination-and-how-it-affects-your-health/



Drinking Water Utilities



DOD Facilities

EPA-Recognized Contaminant

In May 2016 the EPA established a Health Advisory Exposure limit for PFOA and PFOS at 70 ng/L (combined limit)

Granular Activated Carbon

GAC is a Proven Technology

GAC is the leading technology for removal of PFCs from groundwater

- Effective for PFC removal in drinking water and remediation applications
- Chosen since 2001 for PFC removal
- >20 large equipment installations
- >1,000 POE systems

Spent GAC containing adsorbed PFCs can be reactivated, destroying the adsorbed contaminants

- Eliminates future liability for the contaminant
- Safe, sustainable, environmentally responsible
- GAC is recycled and reused

Testing is Critical

Why

- Many factors influence the effective service life of GAC
  - Temperature
  - pH
  - EBCT
  - Concentration
  - Competitive Adsorption
- Extremely difficult to quantify without testing

Application Research

- Comparison of various types of activated carbon for removal of target contaminants
- Comparison of adsorbability of different PFC compounds on GAC
- Impact of background contaminants on adsorbability of PFCs
- Effectiveness of GAC treatment vs. other non-carbon treatment options

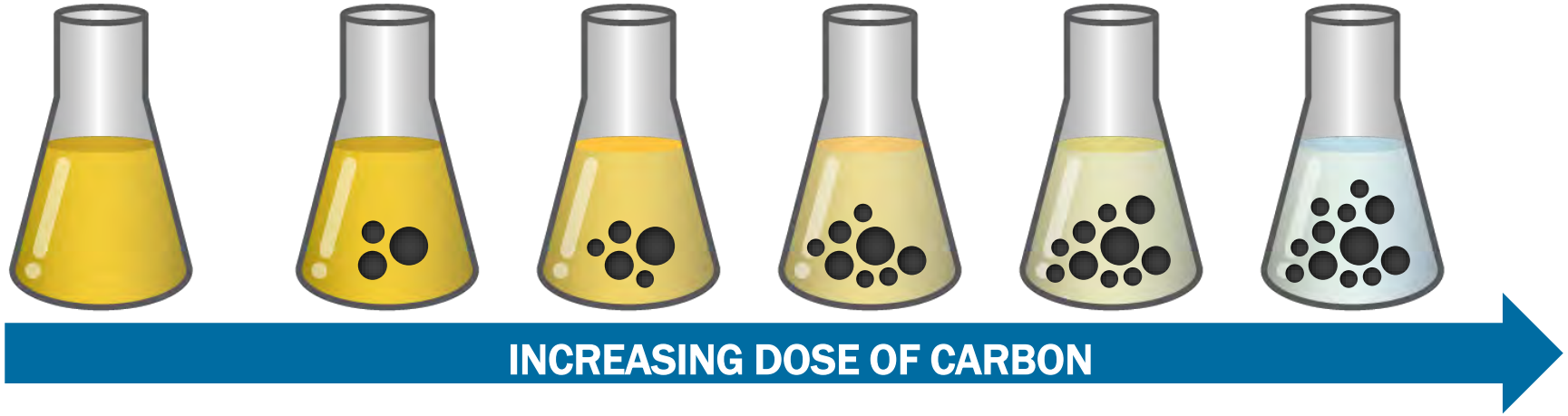
Specific Water/Customer

- **Isotherm Testing**
  - Feasibility adsorption of the target contaminants
  - Quick comparison of performance of various carbon types
  - Impacts of changeable operating parameters on the adsorbability of target contaminants
- **Column Testing (ACT or RSSCT)**
  - Define the kinetics of adsorption or minimum contact time required
  - Define accurate carbon use rates impacted by competitive adsorbing compounds

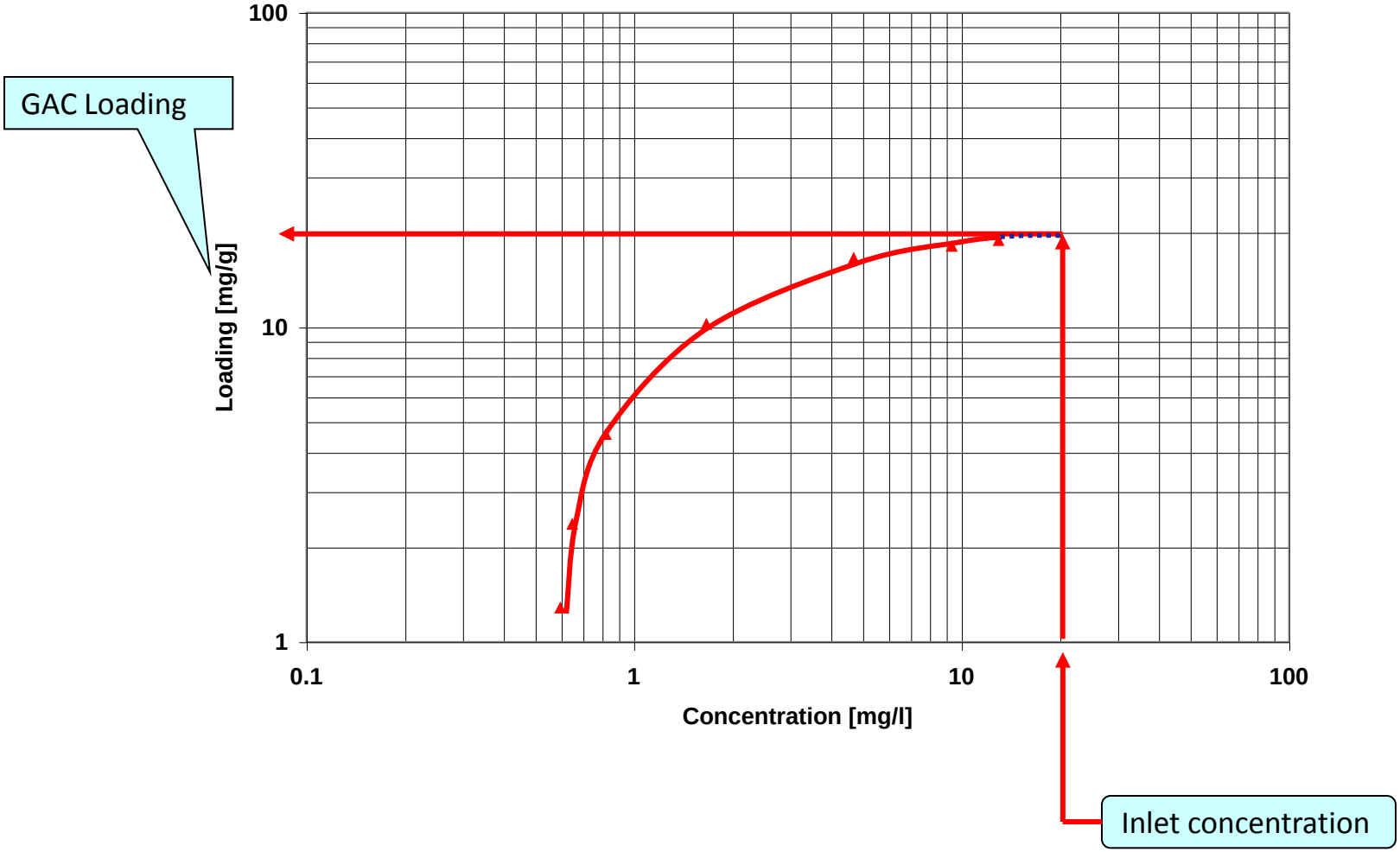
Isotherm

Equilibrium batch carbon adsorption tests

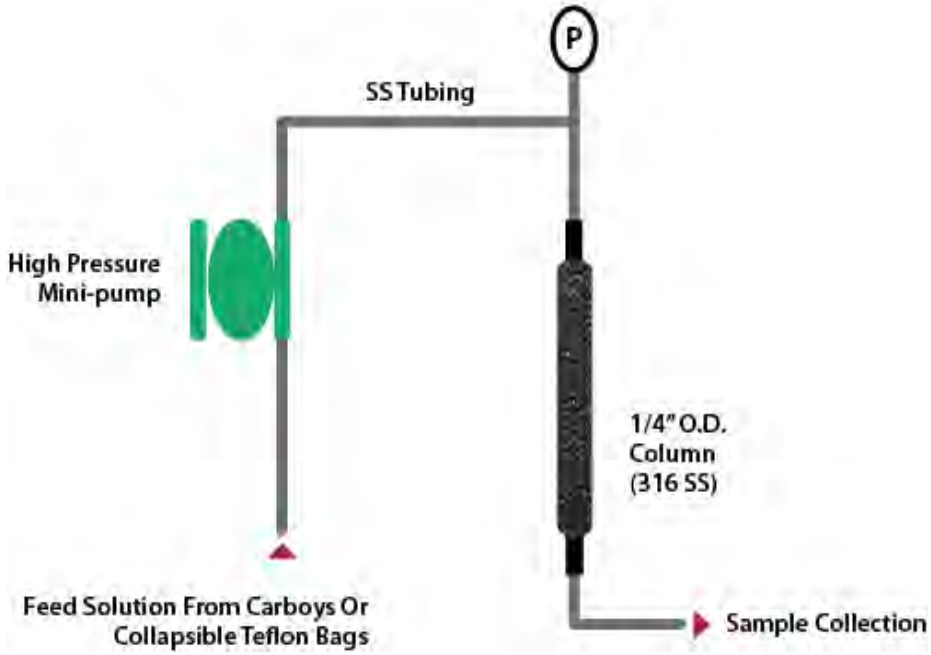
–Series of carbon dosages allowed to equilibrate

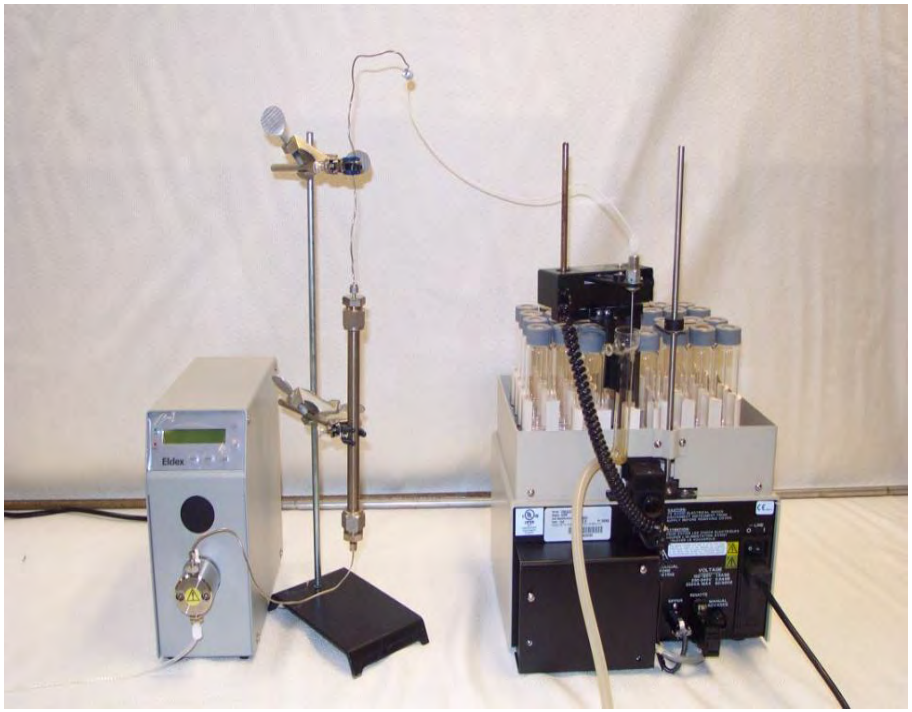


Isotherm


GAC Loading
100
10
1
Loading [mg/g]
0.1
1
10
100
Concentration [mg/l]
Inlet concentration

Column Test (ACT or RSSCT)





Performance Data

Research RSSCT Study:

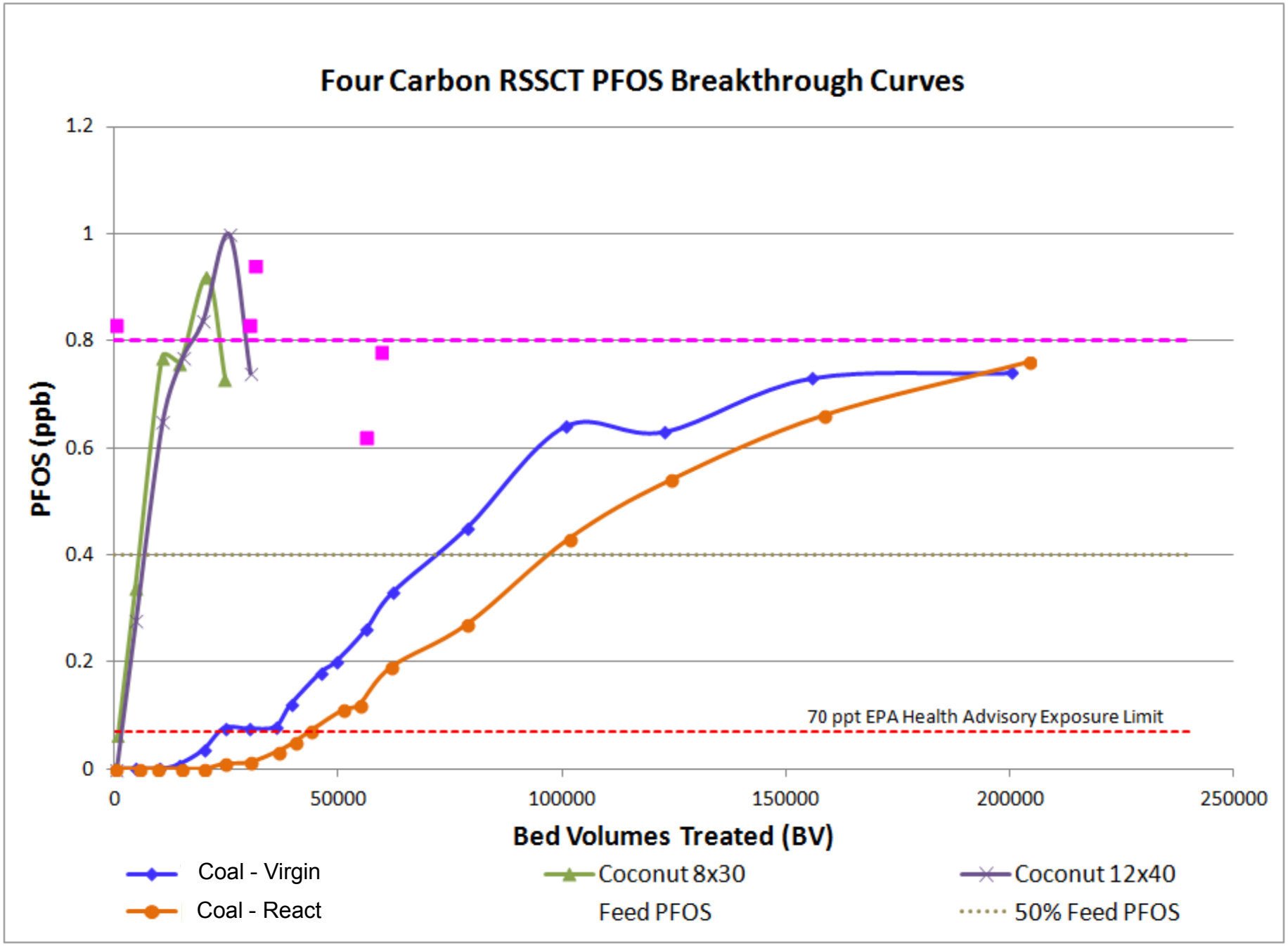
Comparison of Various GAC for PFOA and PFOS Removal

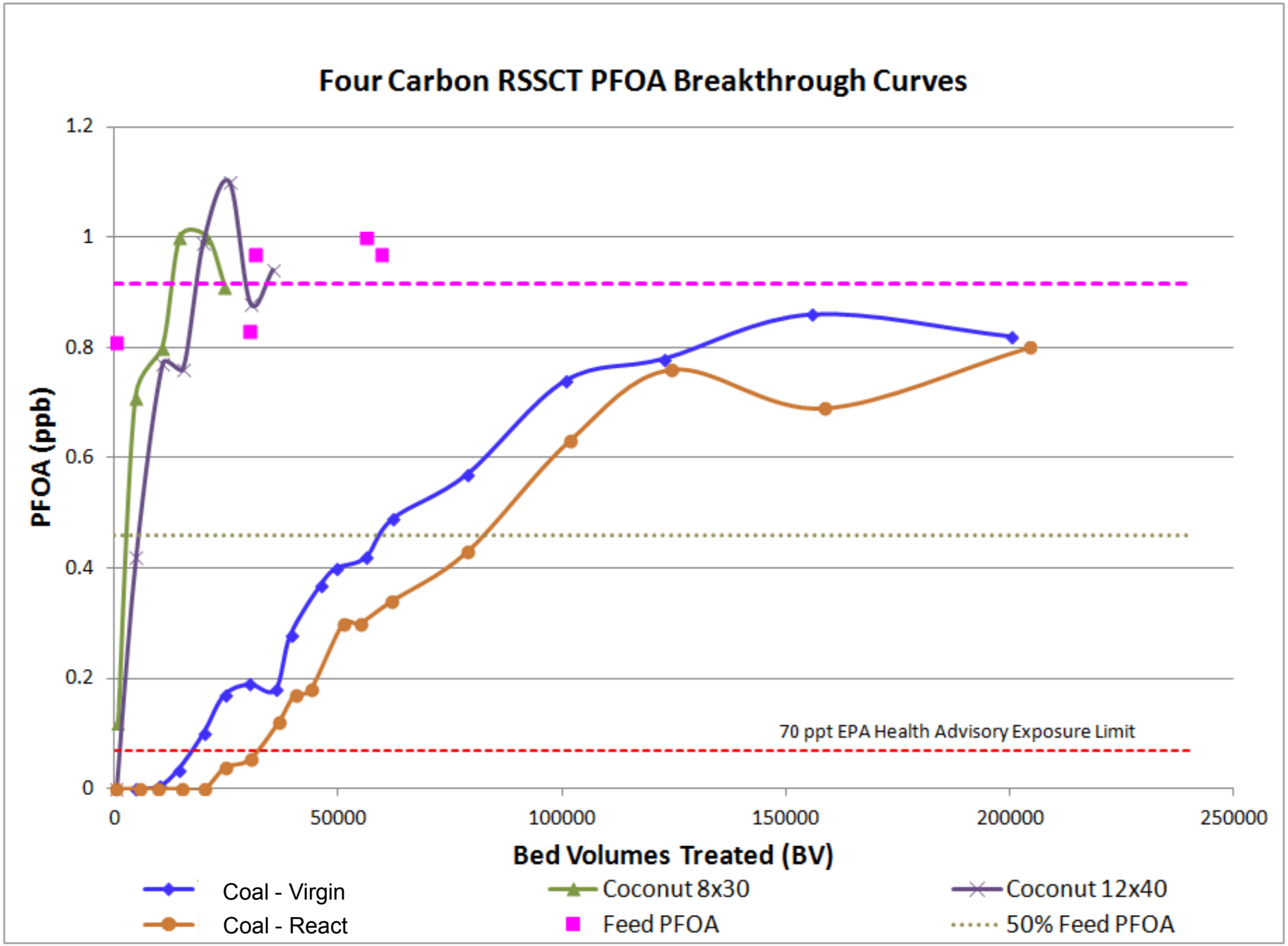
- Four GAC products evaluated under identical operating conditions and influent water quality

Carbon	Description
Coal – Virgin	Bituminous Reagglomerated Coal 12x40 mesh
Coconut 8x30	Direct activated Coconut 8x30 mesh
Coconut 12x40	Direct activated Coconut 12x40 mesh
Coal – React	Reactivated Bituminous Reagglomerated Coal 12x40 mesh

GAC Comparison Test Conditions

- Operating Parameters:
  - 10 minutes empty bed contact time (EBCT)
  - Source groundwater:
    - Center Township, PA drinking water
    - **<u>Water did not have PFCs as received</u>**
    - Water was spiked to contain:
      - 920 ppt of PFOA (target 1,000 ppt)
      - 800 ppt of PFOS (target 1,000 ppt)
    - 1.42 ppm background TOC


Four Carbon RSSCT PFOS Breakthrough Curves
PFOS (ppb)
1.2
1
0.8
0.6
0.4
0.2
0
0
50000
100000
150000
200000
250000
Bed Volumes Treated (BV)
70 ppt EPA Health Advisory Exposure Limit
Coal - Virgin
Coal - React
Coconut 8x30
Feed PFOS
Coconut 12x40
50% Feed PFOS


Four Carbon RSSCT PFOA Breakthrough Curves
PFOA (ppb)
1.2
1
0.8
0.6
0.4
0.2
0
0
50000
100000
150000
200000
250000
Bed Volumes Treated (BV)
70 ppt EPA Health Advisory Exposure Limit
Coal - Virgin
Coconut 8x30
Coconut 12x40
Coal - React
Feed PFOA
50% Feed PFOA

Carbon Use Rate Comparison

Single Vessel Design

Carbon	Bed Vol. Treated	Simulated Days	Gallons Treated	Carbon Use Rate (Lbs./1000 gals.)
Coconut 8x30	300	2	1,590,000	14.84
Coconut 12x40	500	3	2,650,000	9.01
Coal - Virgin	17,200	119	91,160,000	0.26
Coal - React	31,000	215	164,300,000	0.14

Lead/Lag Dual Vessel Design

Carbon	Bed Vol. Treated	Simulated Days	Gallons Treated	Carbon Use Rate (Lbs./1000 gals.)
Coconut 8x30	3,000	21	15,900,000	1.48
Coconut 12x40	5,400	38	28,620,000	0.83
Coal - Virgin	59,200	411	313,800,000	0.075
Coal - React	82,000	569	434,650,000	0.054

Conclusions:

- Coal based reagglomerated carbons greatly outperformed direct activated coconut carbons for removal of PFOA and PFOS

- PFCs tend to be removed well by higher activity carbons

- RANK
  - Coal – React > Coal – Virgin > Coconut 12x40 > Coconut 8x30
  - This is a single study

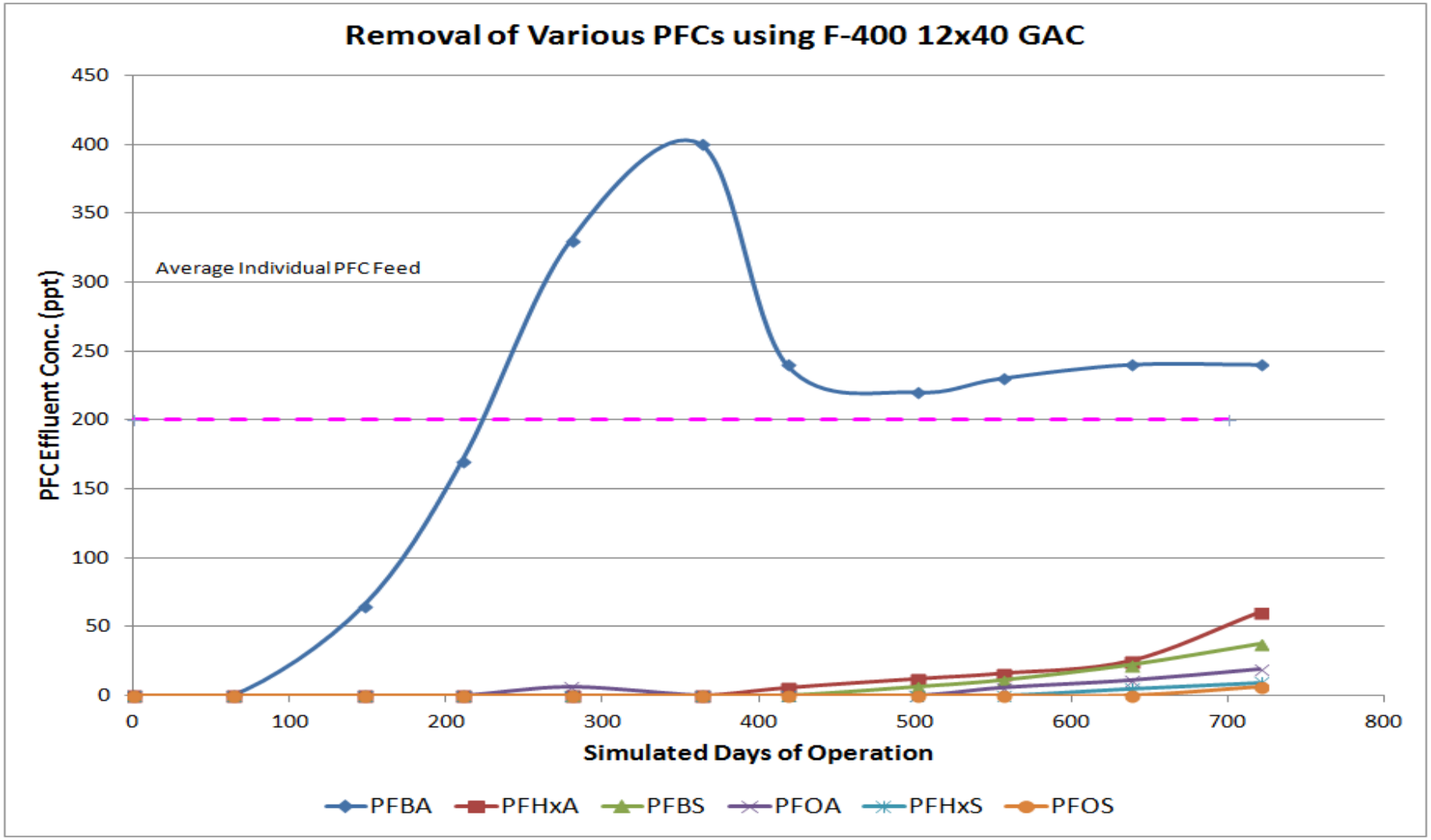
Research RSSCT Study:

Comparison of Various GAC for Short Chain PFC Removal

- Multiple PFCs, variety of chain lengths
  - PFBA/PFBS – C4
  - PFHxA/PFHxS – C6
  - PFOA/PFOS – C8
  - Each compounds spiked to approximately 200 ppt
- Bituminous coal GAC
  - Reagglomerated
  - 12x40 mesh
- Background TOC – 0.18 ppm
- Simulated EBCT – 10 minutes

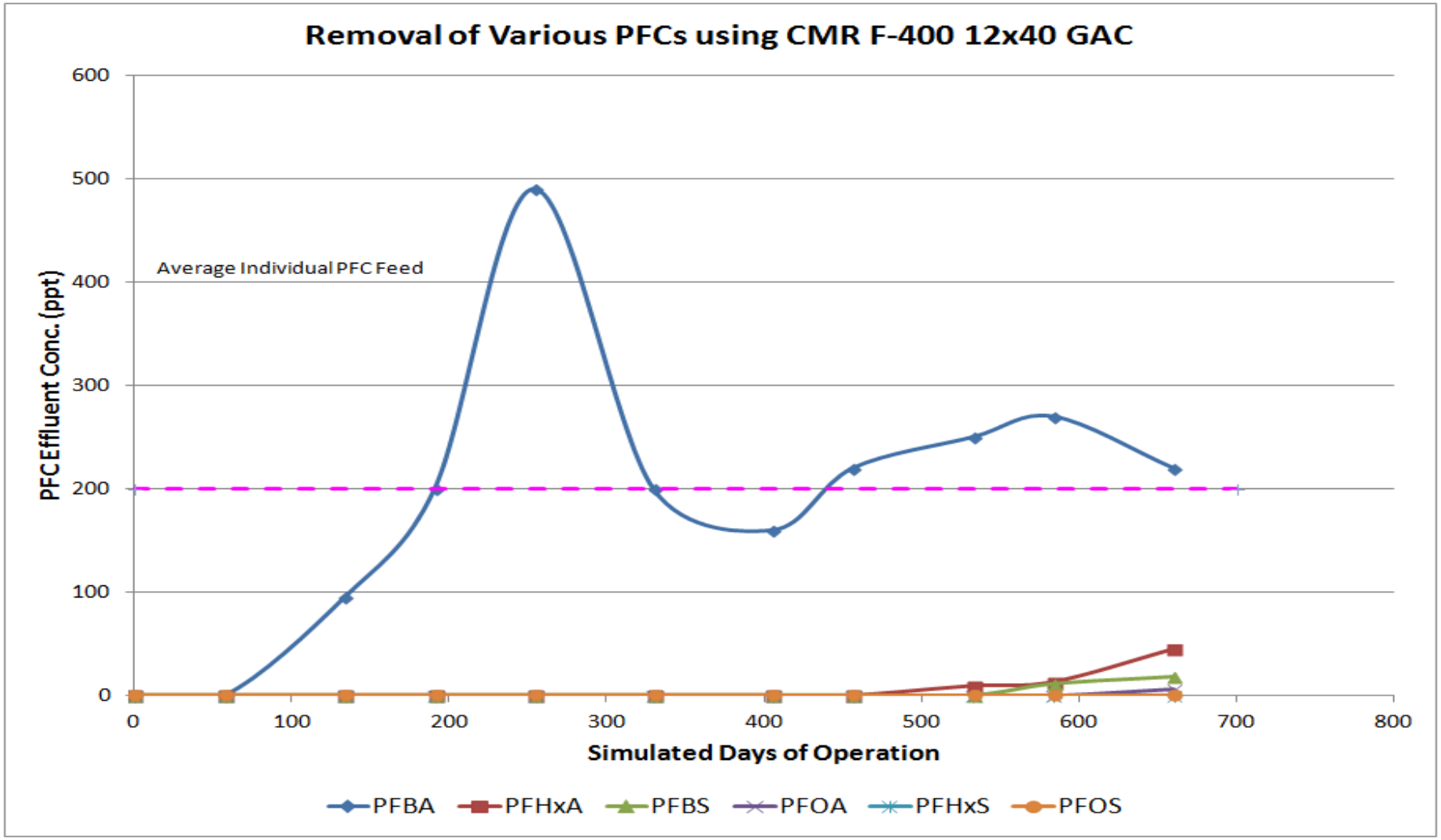
RSSCT Test Data:

Virgin Reagglomerated Coal



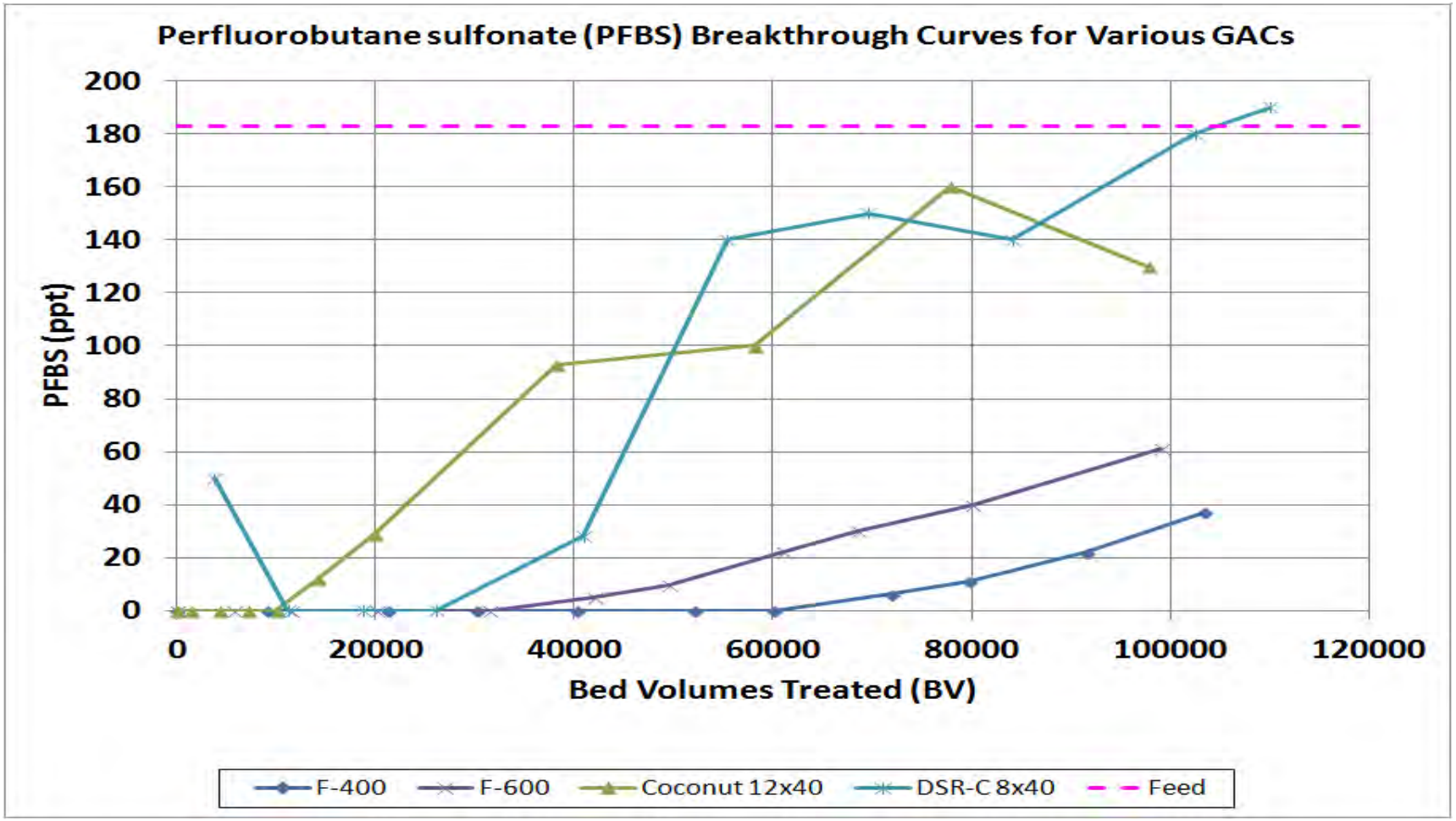
RSSCT Test Data:

Custom Reactivated Reagglomerated Coal



RSSCT Test Data:

Various GACs



Conclusions:

- All PFCs are removed by GAC treatment
- Lower molecular weight PFCs exhibit lower loadings and earlier breakthrough times
- Reagglomerated bituminous coal GAC outperformed coconut based GAC for PFC removal
- Reactivated GAC can be a viable treatment option

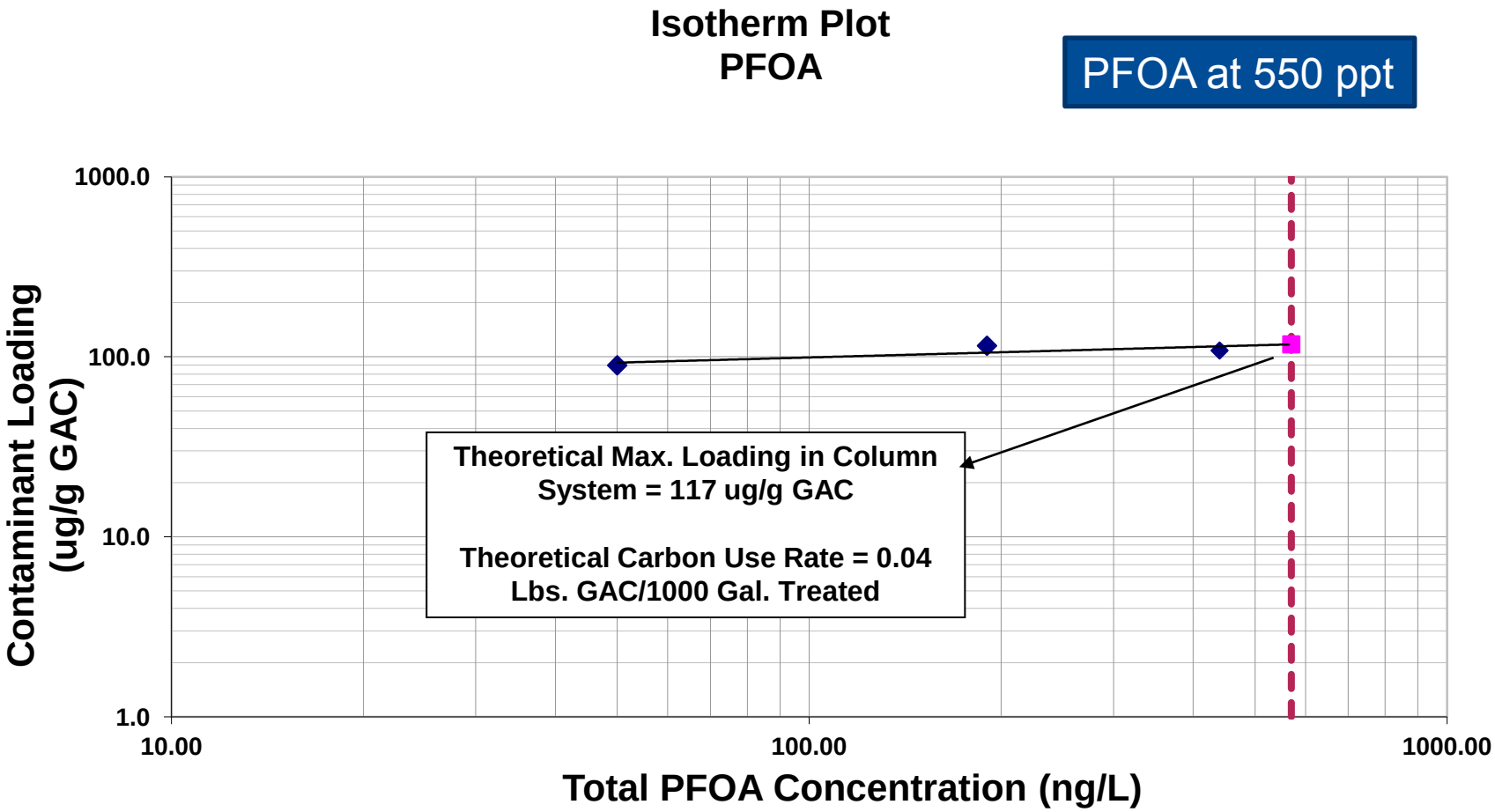
Municipal Case Study

- NY municipality encounters PFCs in drinking water

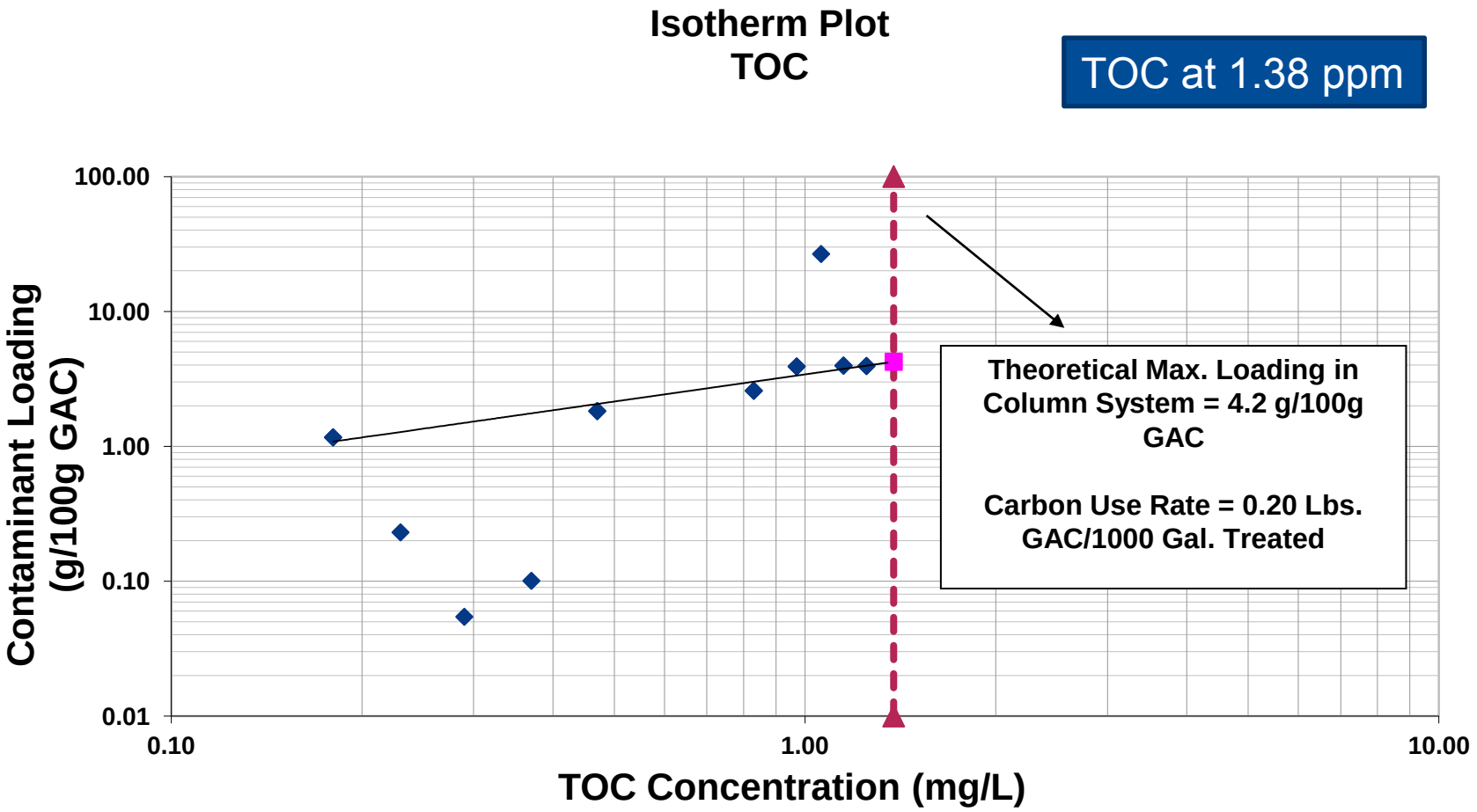
- Isotherm Testing
  - Measured adsorption of PFOA
  - Measured adsorption of background TOC
  - Ambient Temperature
  - Bituminous coal GAC
    - Reagglomerated

- Column Testing (ACT)
  - Determine efficacy of proposed treatment system
    - 2 vessels, lead-lag operation
    - 40,000 lbs GAC per vessel
    - 13.2 minutes EBCT

PFC Isotherm- NY Water Source



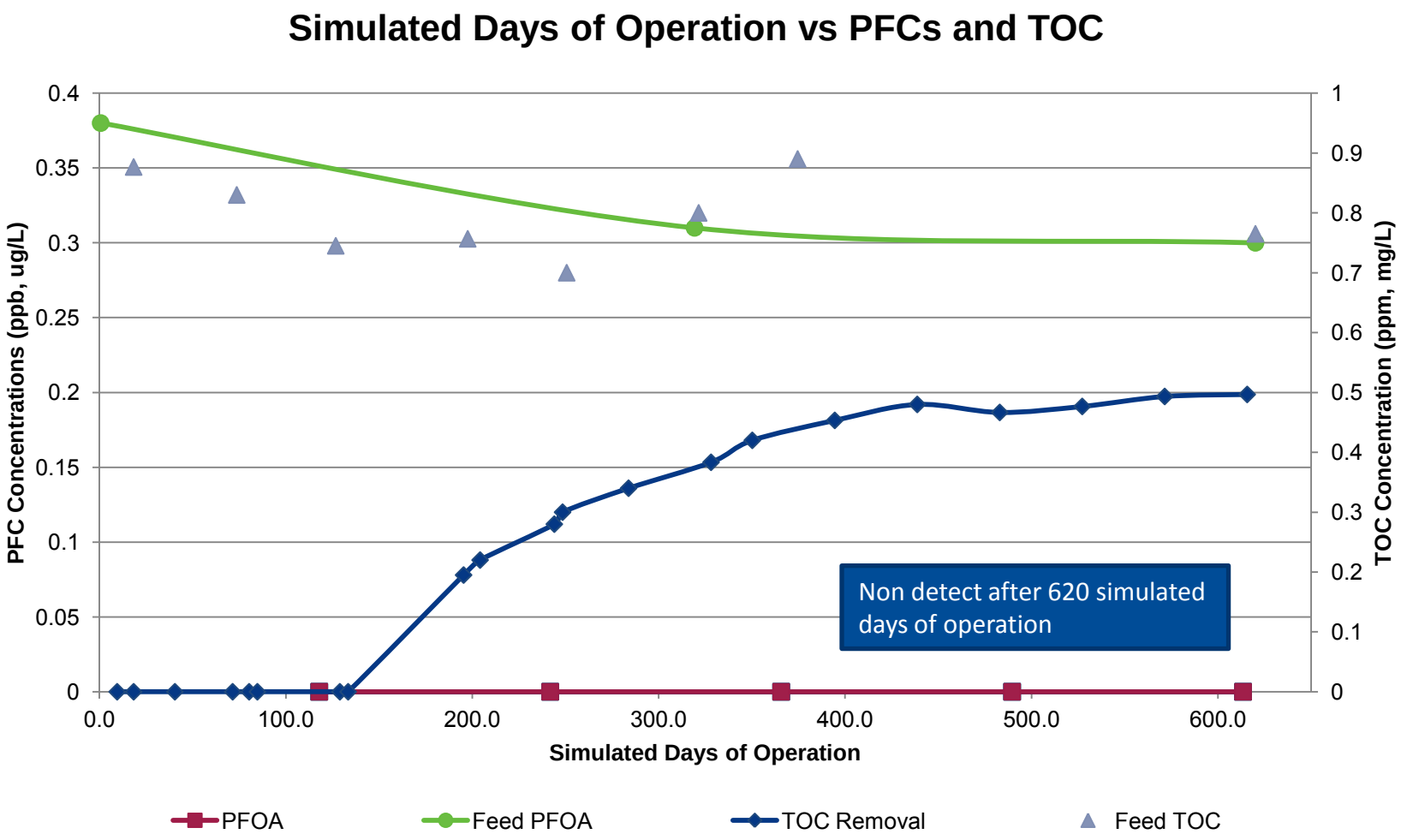
TOC Isotherm- Same NY Water Source



Preliminary Conclusions

- All PFCs were removed by GAC
  - Estimated carbon use rate = 0.04 Lbs/1000 gallons treated
- TOC content appears to be adsorbable
  - Estimated carbon use rate = 0.2 Lbs/1000 gals. treated
- Competition of TOC vs. PFCs not significant in this case

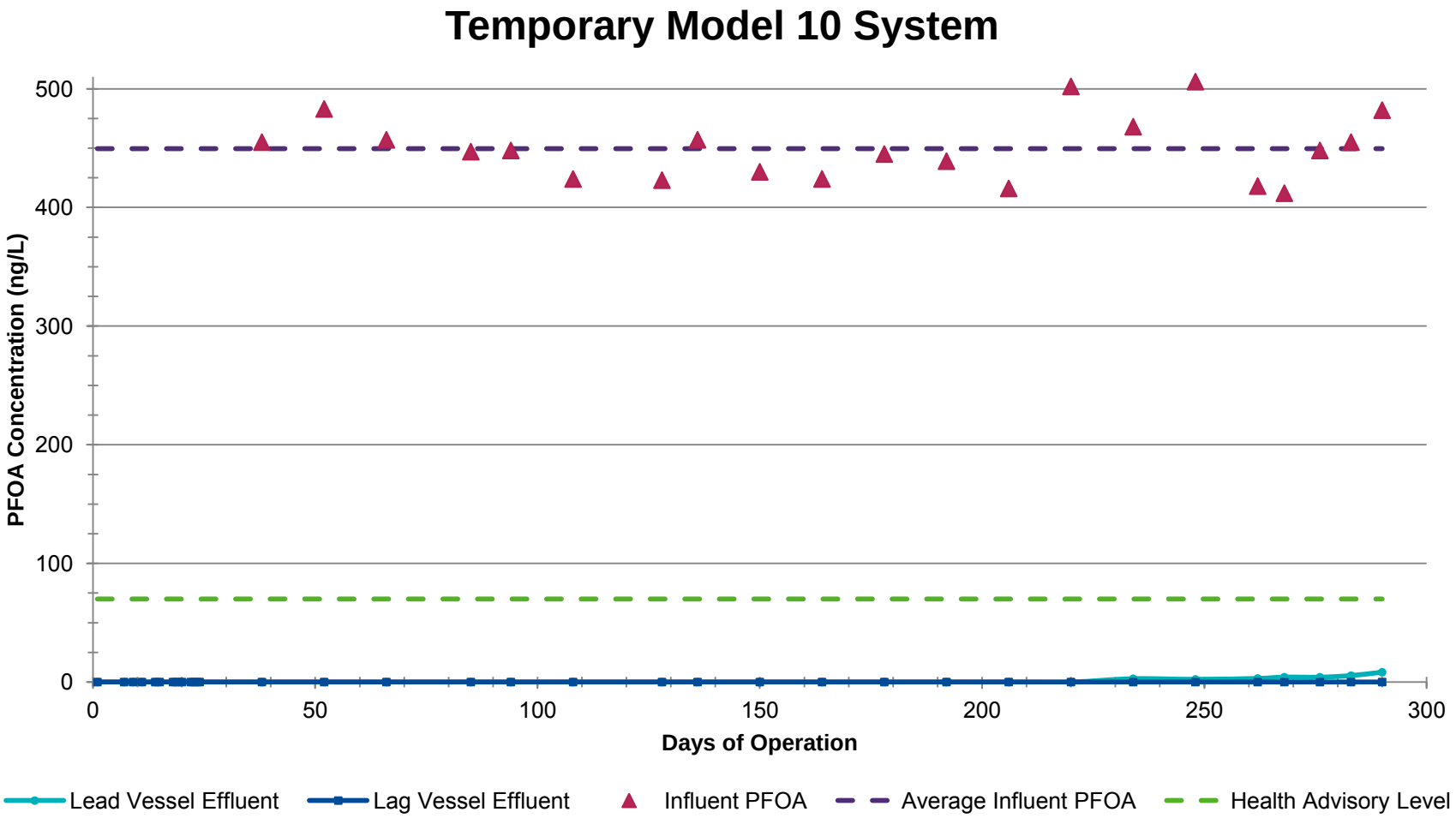
ACT Data


Simulated Days of Operation vs PFCs and TOC
PFC Concentrations (ppb, ug/L)
TOC Concentration (ppm, mg/L)
Simulated Days of Operation
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
Non detect after 620 simulated days of operation
PFOA
Feed PFOA
TOC Removal
Feed TOC

Conclusions

- Proposed lead-lag GAC system will remove PFCs for minimum of 620 days of operation
  - Equivalent carbon use rate of 0.064 lbs/1000 gallons treated
- The competition of the background TOC, present at about 0.9 ppm, is not significant in this case
- Temporary System: 2 x 10’ diameter vessels, 20,000 lbs GAC each
- Permanent System: 2 x 12’ diameter vessels, 40,000 lbs GAC each

Customer Field Data



Summary

Final Takeaways

- EPA Health Advisory Limit = 70 ppt PFOA + PFOS

- GAC is effective and proven for removal of PFCs
  - Long and short chain
  - Virgin and reactivated

- Testing is needed to accurately predict service life
  - Column > Isotherm
  - Longer than other GAC applications (TOC, DBPs, VOCs)
  - Generally 1-3 year bed life expected

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