DBP Removal and Control in Distribution Systems

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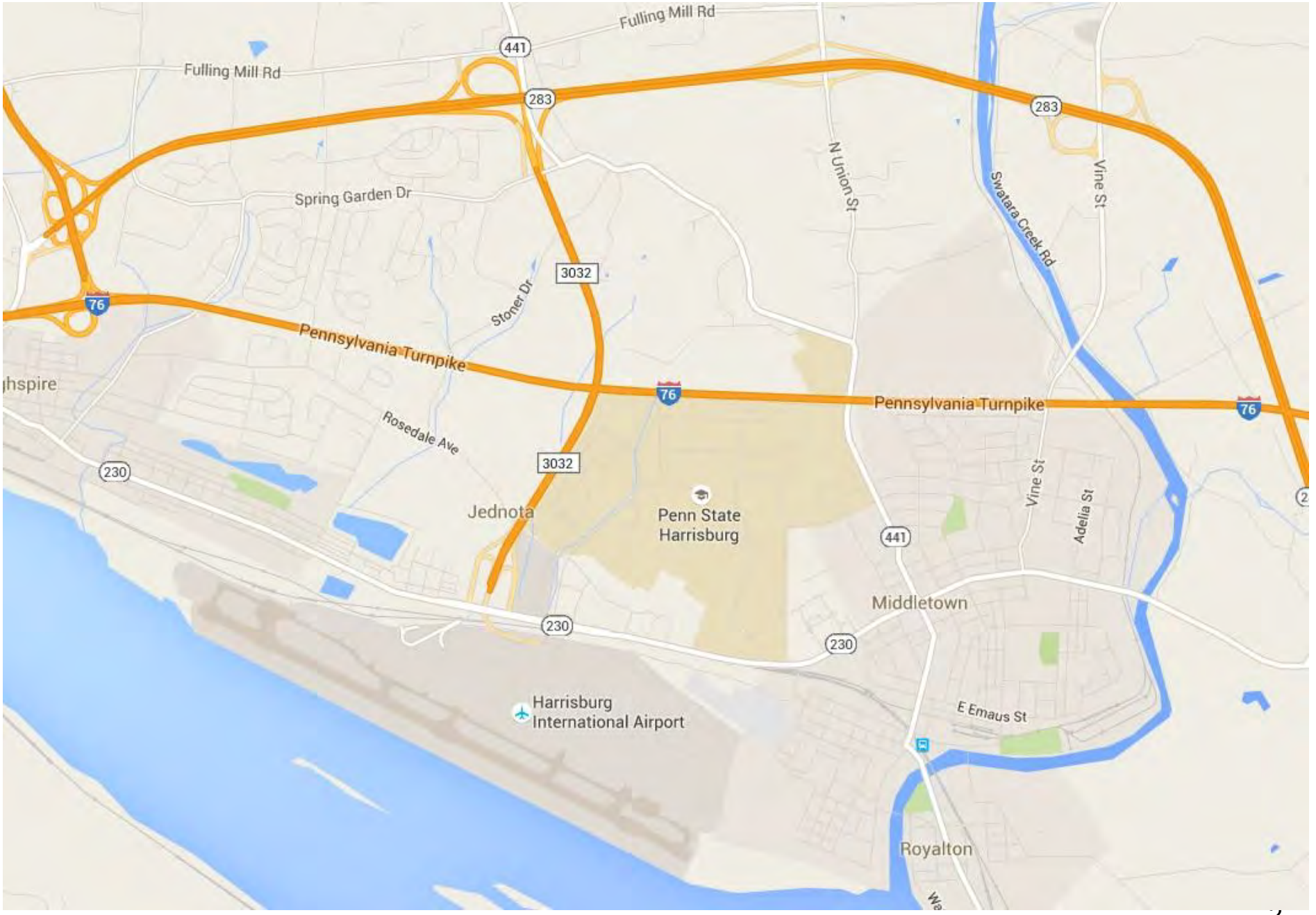
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Fulling Mill Rd
283
283
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N Union St
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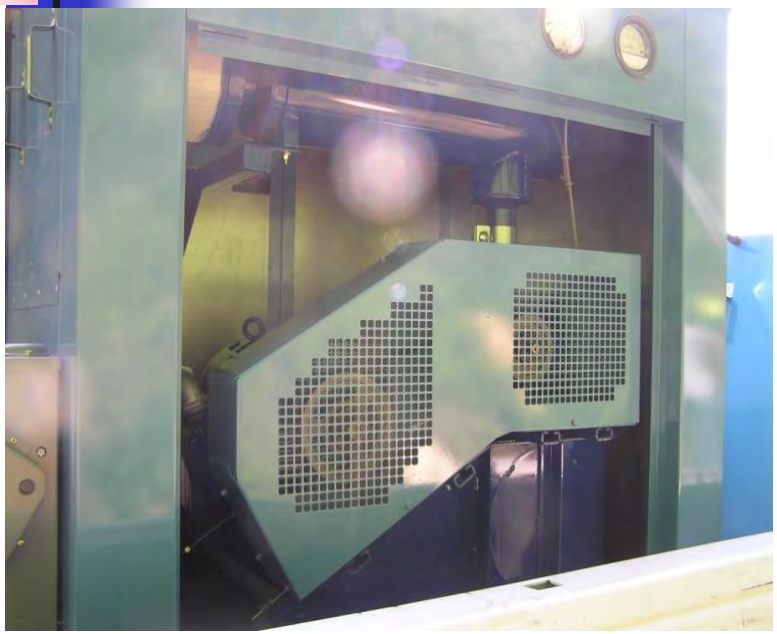
Vine St
3032
Stoner Dr
76
Pennsylvania Turnpike
Pennsylvania Turnpike
76
76
Rosedale Ave
3032
230
Jednota
Penn State
Harrisburg
Vine St
Adelia St
441
Middletown
230
230
Harrisburg
International Airport
E Emaus St
Royalton

My Car License Plate

DBP Control

- NOM + chlorine → DBPs
- Precursor removal and modification
- Alternative disinfectants
- DBP Removal after formation
  - Aeration
  - Carbon adsorption
  - Chemical/biological degradation
  - Nano filtration and reverse osmosis

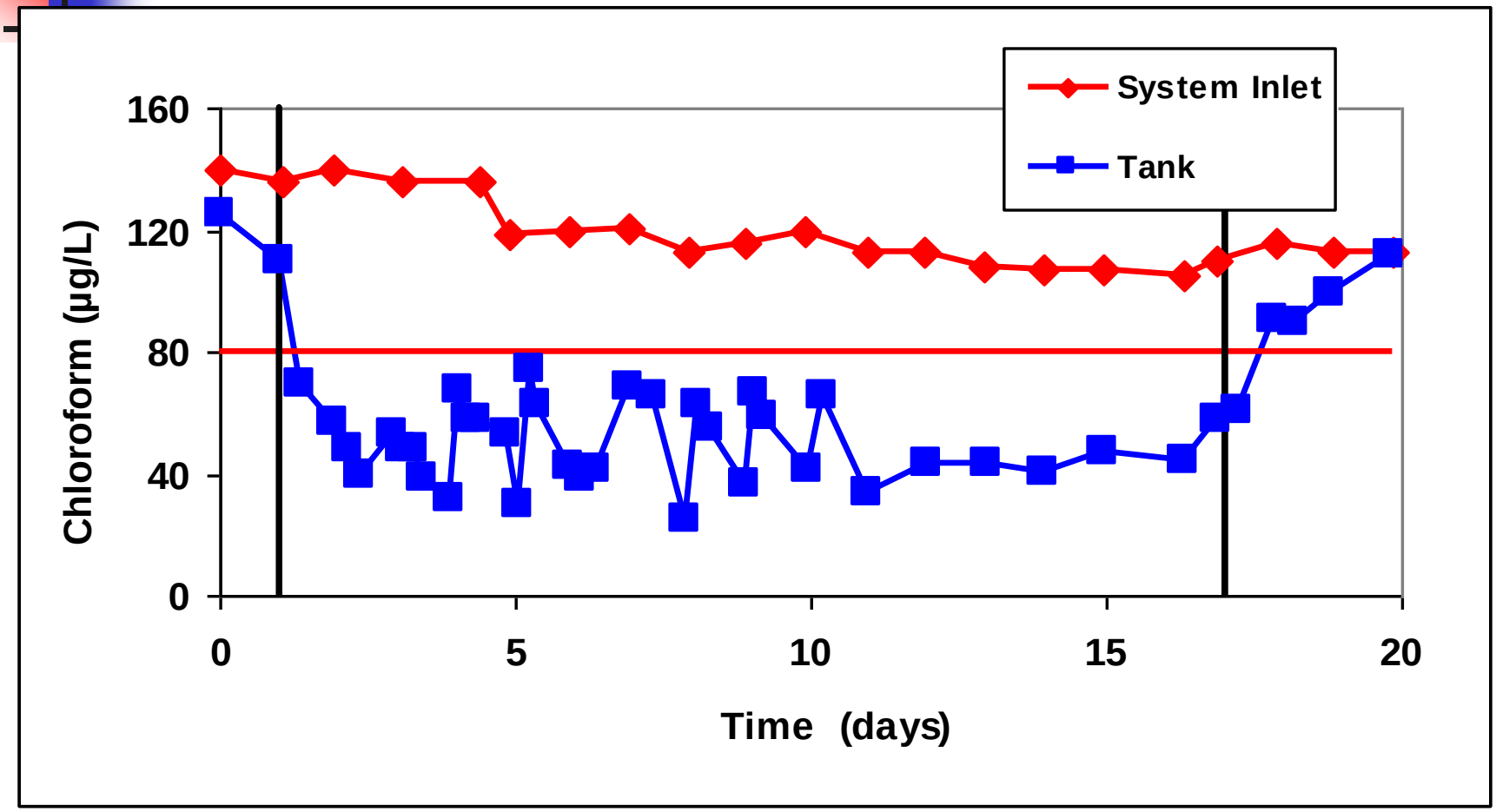
Field Trial, October 2007



- Twin Rocks Tank
- Black Lick, PA
- 20 days of operation

- Blower
  - 63 ft^3/min, 15-19° C

Results at the Tank



HAA Removal

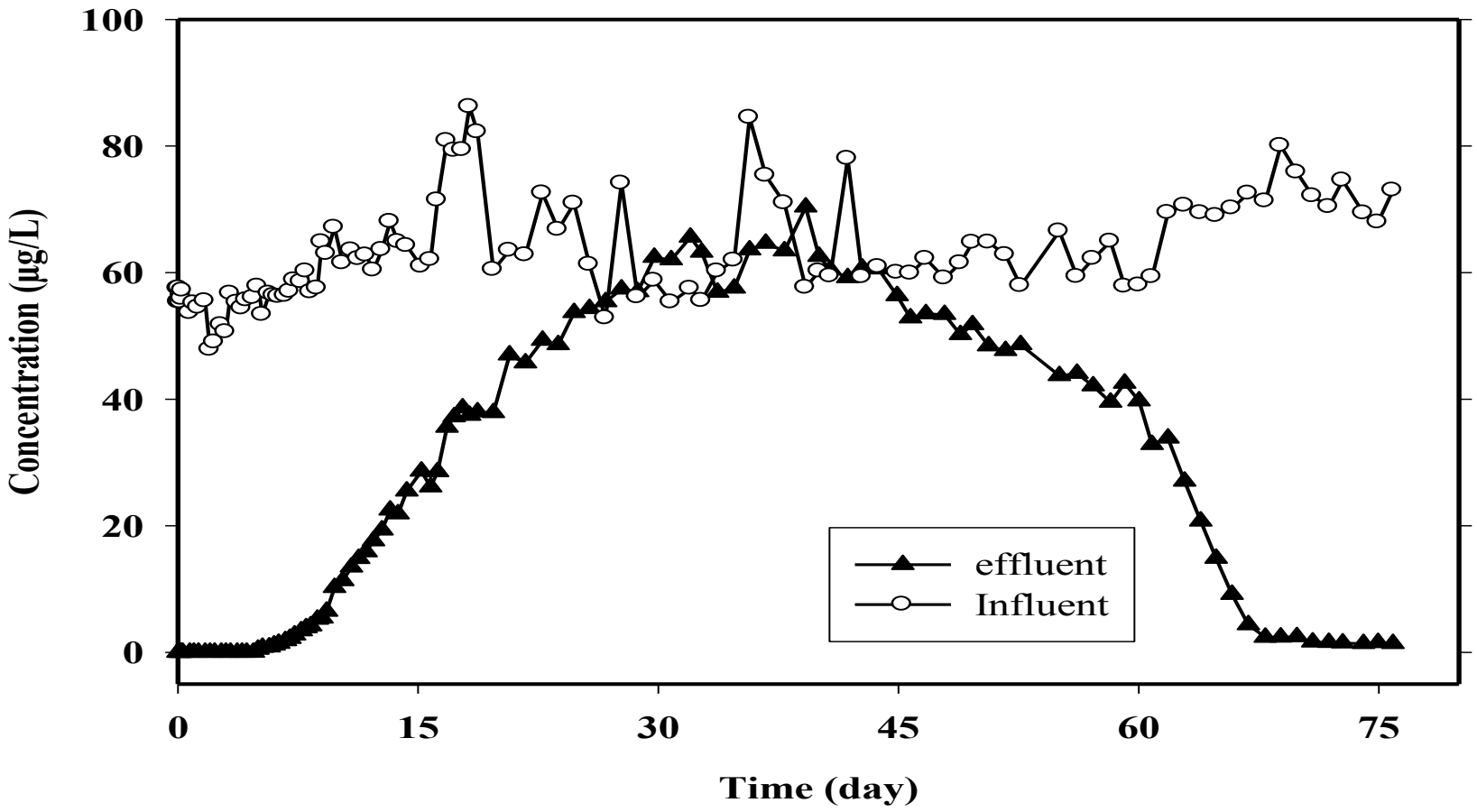
- Aeration X
- Carbon adsorption ?
- Chemical/biological degradation √
- Nano filtration and reverse osmosis √

Trichloroacetic Acid (TCAA) as a Chemical Peel

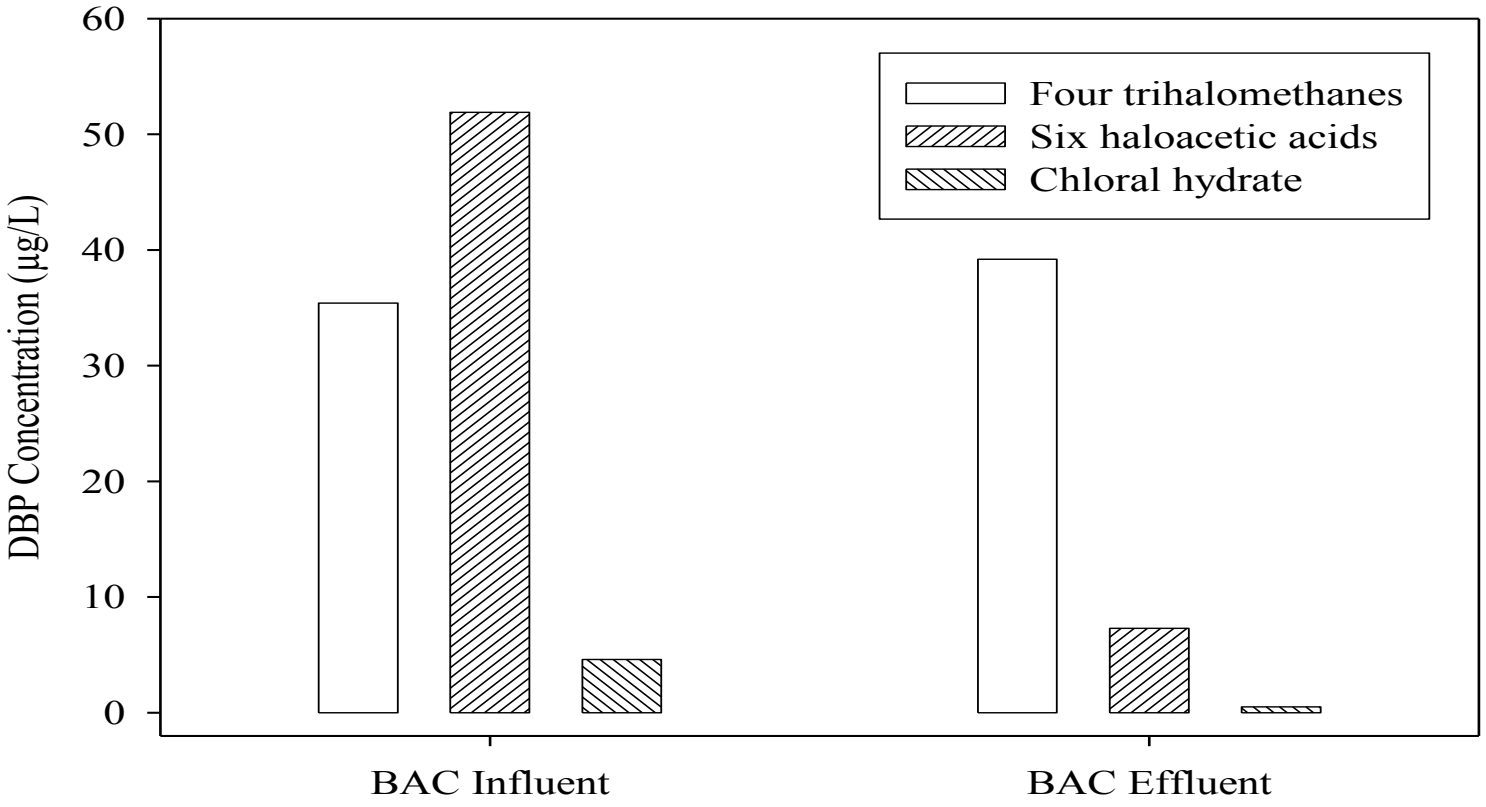
http://www.charmedmedispa.com/

25% =
250,000,000 µg/L
250,000,000 ppb

Dichloroacetic Acid Removal by GAC



BAC Filtration on DBPs



HAA Biodegradation in BAC Filters (10°C) (Pseudo-1st-order)

HAA	**k, min^{-1}**	**$t_{1/2}$, min**
ClAA	0.117	5.92
BrAA	0.102	6.80
Cl_2AA	0.085	8.15
BrClAA	0.094	7.37
Br_2AA	0.098	7.07
Cl_3AA	0.040	17.3

DBPs in Distribution Systems, THMs/HAA5

NonGAC systems	1	2	3
50% Distribution	28.2/41.2	37.3/65.6	40.0/78.6
Max Distribution	35.6/38.6	35.2/60.1	56.8/84.1
GAC systems	4	5	6
GAC Influent	11.7/26.0	24.8/37.0	70.5/93.3
50% Distribution	28.3/28	41.7/36.9	88.6/39.7
Max Distribution	29.4/28.0	88.4/54.8	88.4/54.8

HAA Removal in a Swimming Pool
Pool volume: 17000gal, BAC: 4 inx3 ft

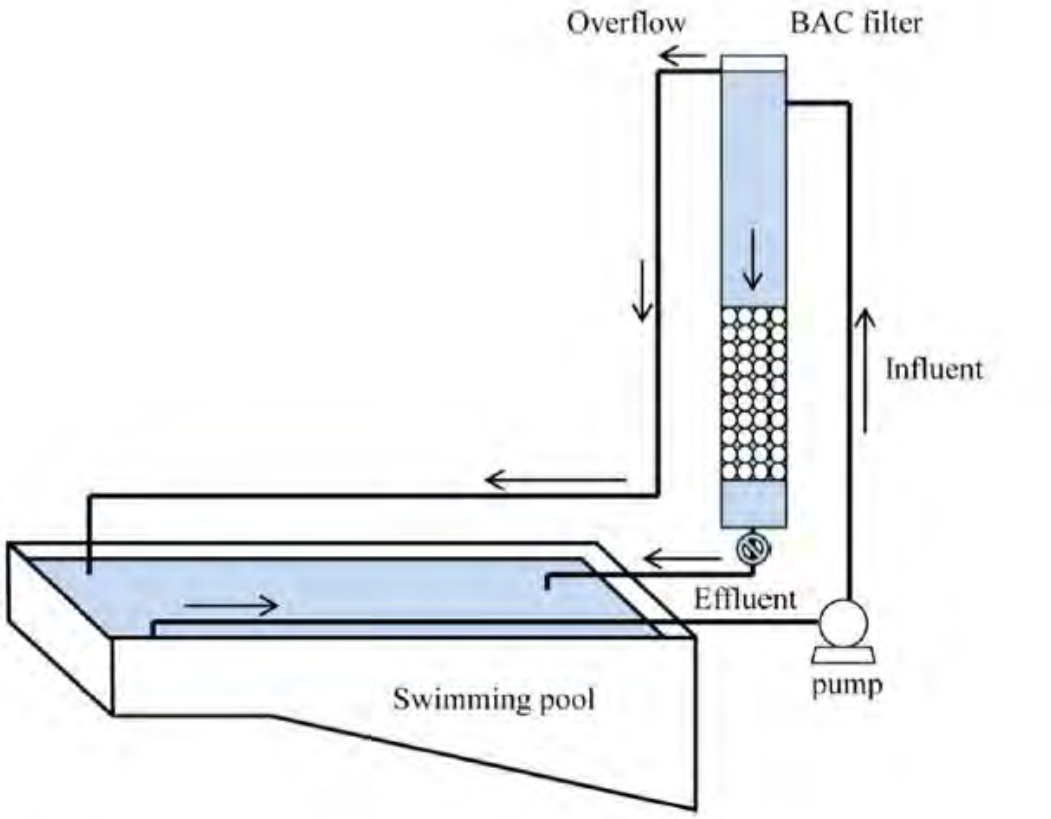
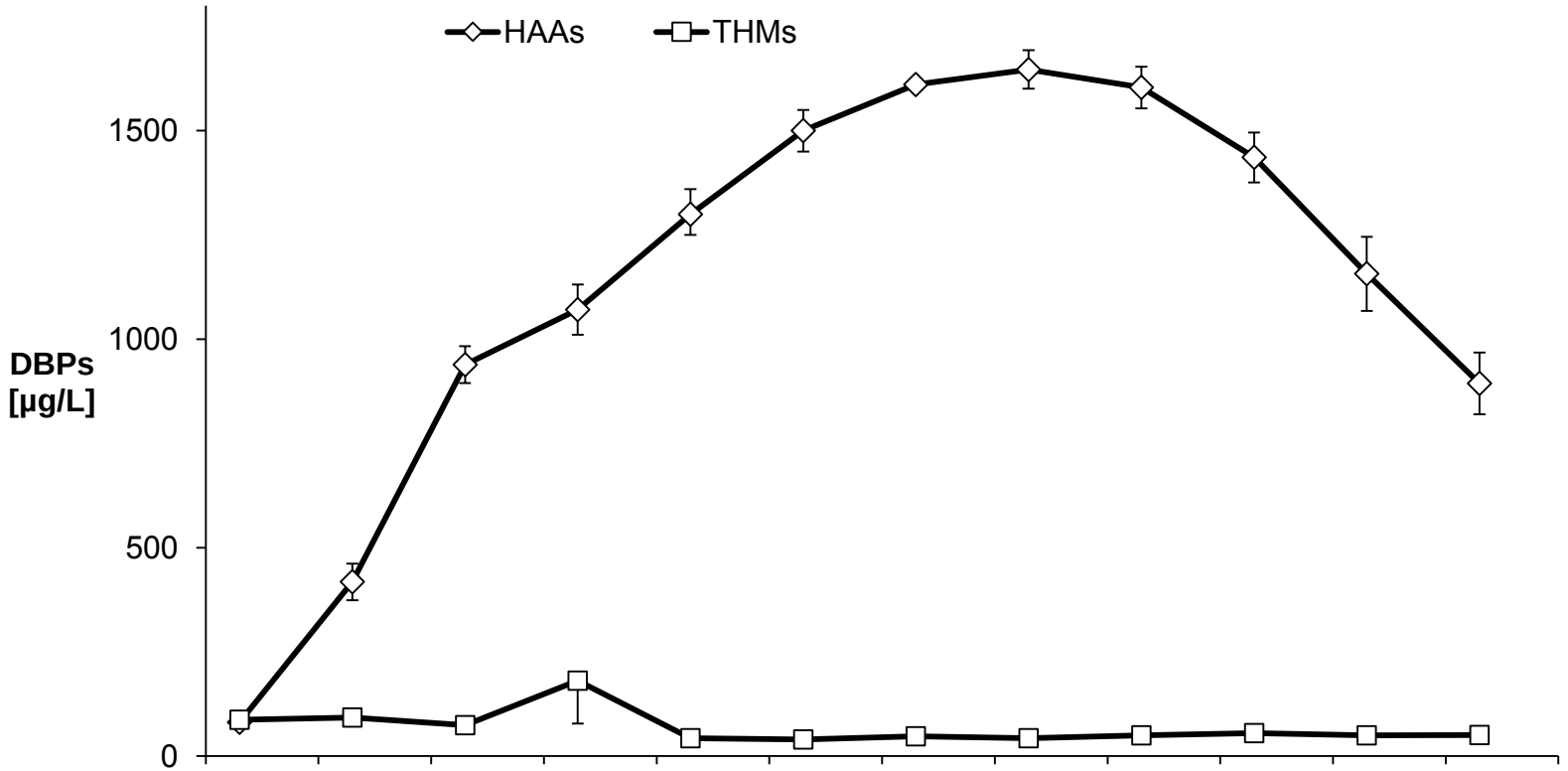


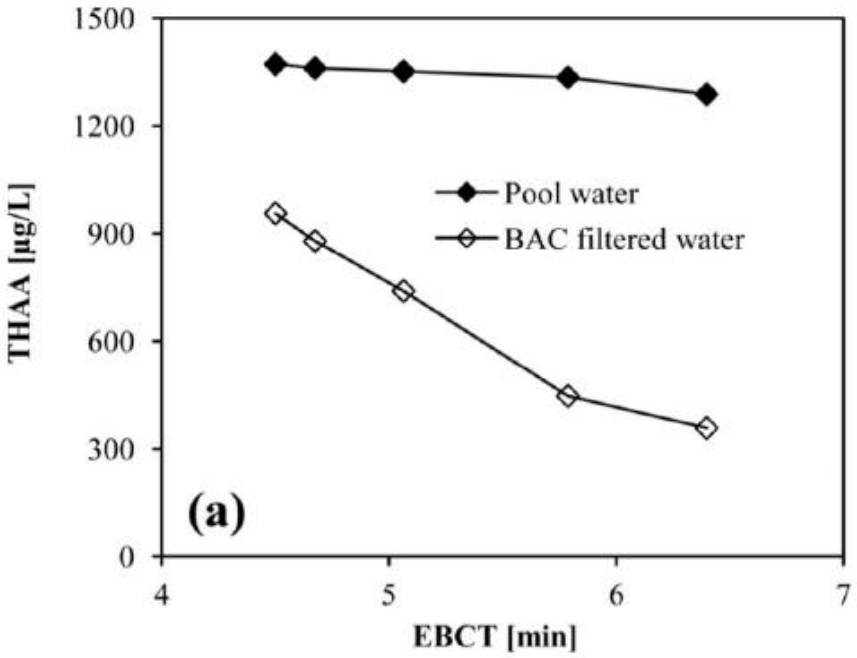
Fig. 1. Schematic diagram of the BAC filter setup at the pool (sizes are not to scale).

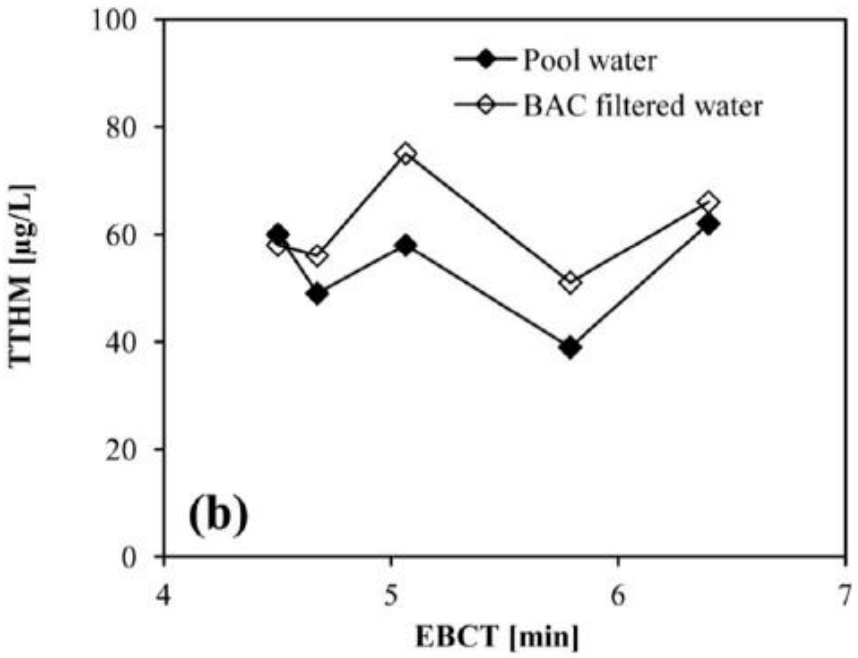
DBPs in a Swimming Pool

(a)

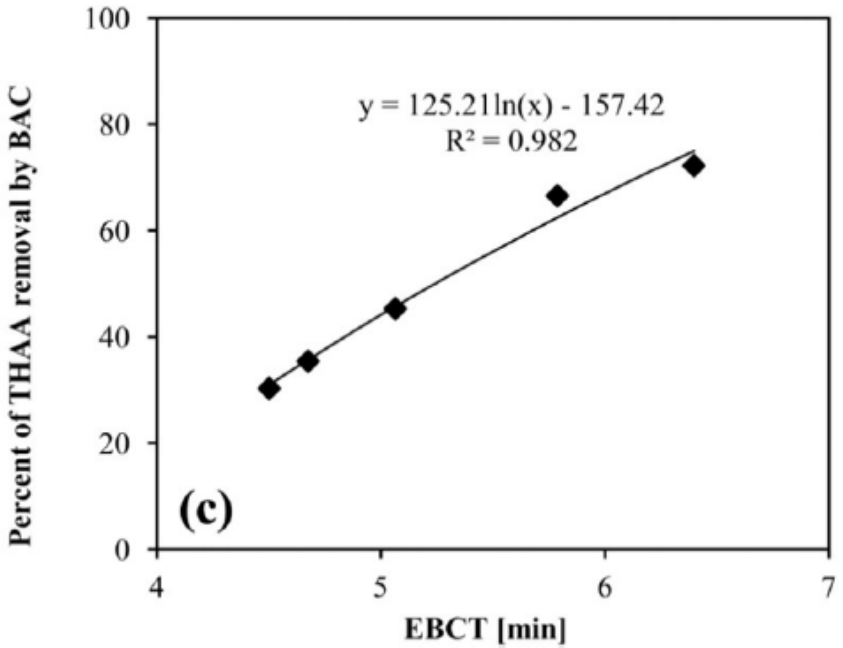


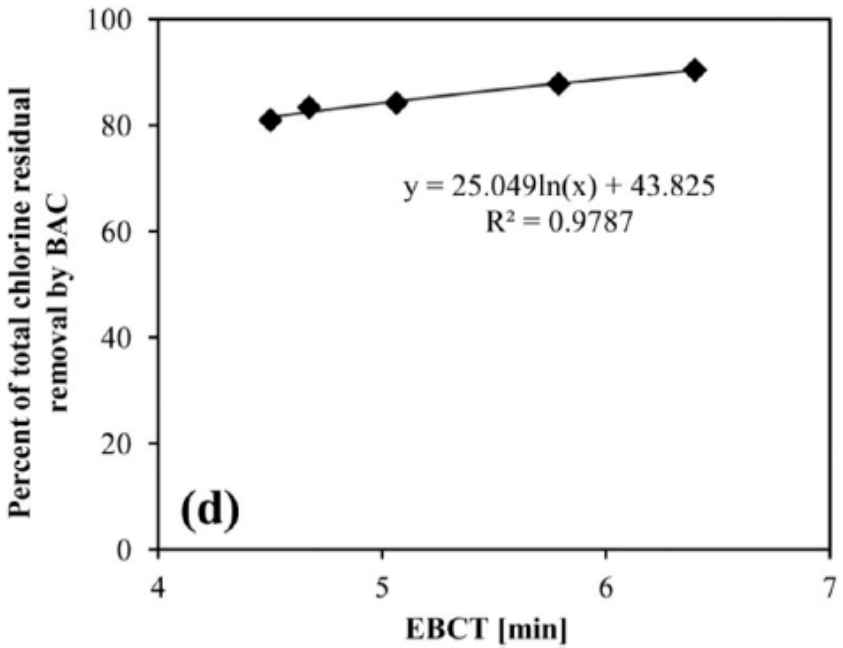
DBP Removal by BAC



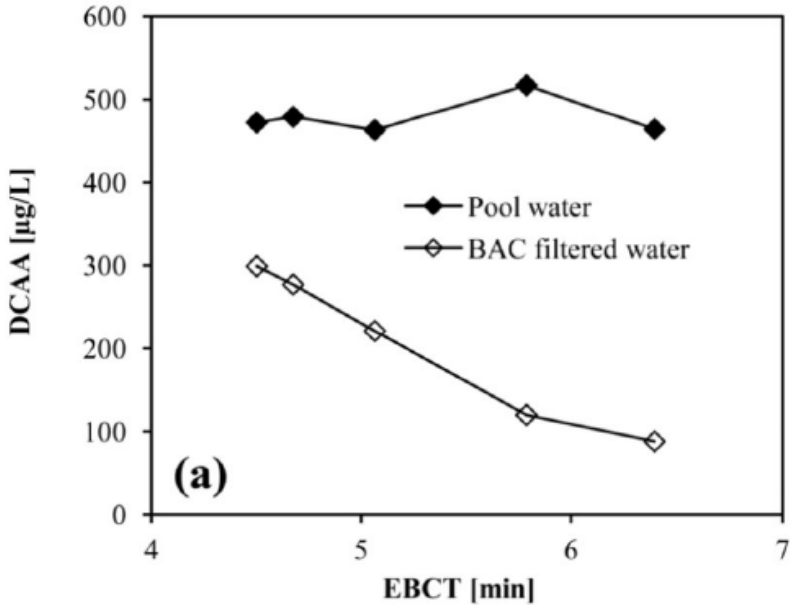


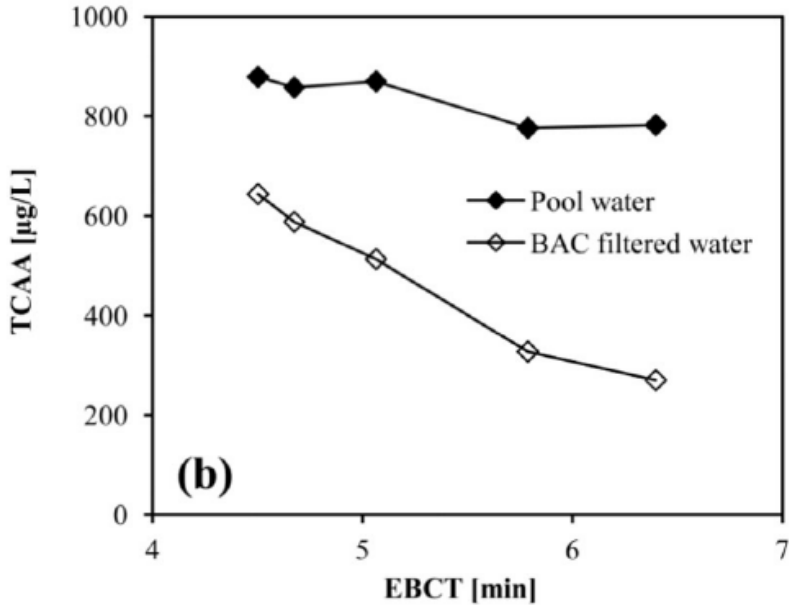
HAA Removal by BAC





HAA Removal by BAC





Effects of BAC on HAAs in the Swimming Pool

- Initial HAA concentration
  - 1400 µg/L
- After BAC filtration
  - 1030 µg/L
  - 26% removal
- Volume filtered
  - 58% of pool water
  - 5400 bed volume (4 in by 3 ft)

HAA Biodegradation in BAC Filters (10°C) (Pseudo-1st-order)

HAA	**k, min^{-1}**	**$t_{1/2}$, min**
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Br_2AA	0.098	7.07
Cl_3AA	0.040	17.3

Haloacetic Acid Removal

- Biological degradation
  - TCAA degradation: slow
  - MCAA and DCAA degradation: fast
- Fe^0 dehalogenation (Hozalski 2001)
  - MCAA degradation: slow
  - DCAA and TCAA degradation: fast

Haloacetic Acid Removal

- Zero Valence Iron dehalogenation
  - TCAA to DCAA, DCAA to MCAA
    - Fast
- Biological degradation
  - MCAA degradation, DCAA degradation
    - Fast

Fe^0 and BAC System

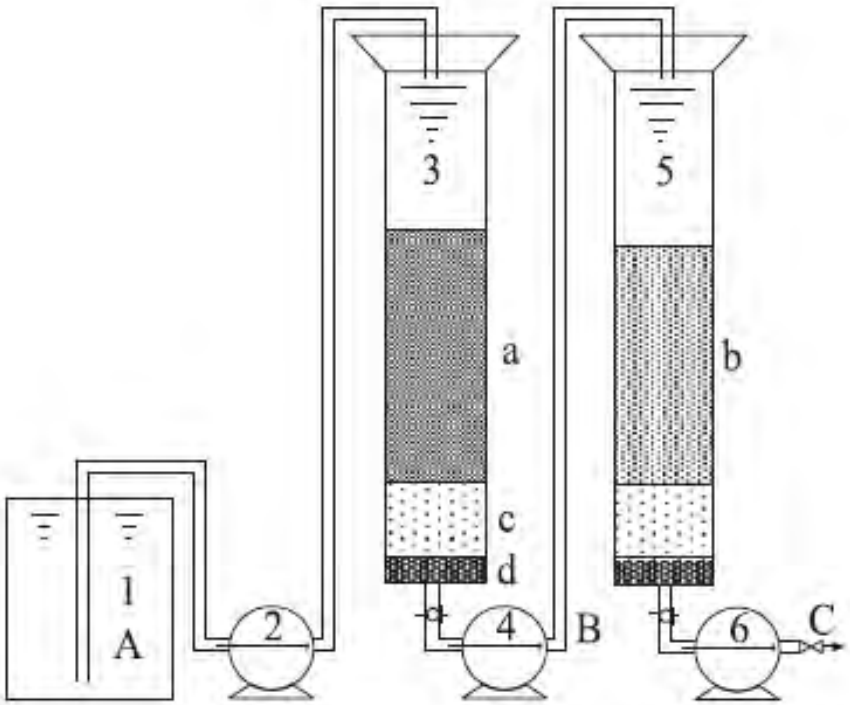
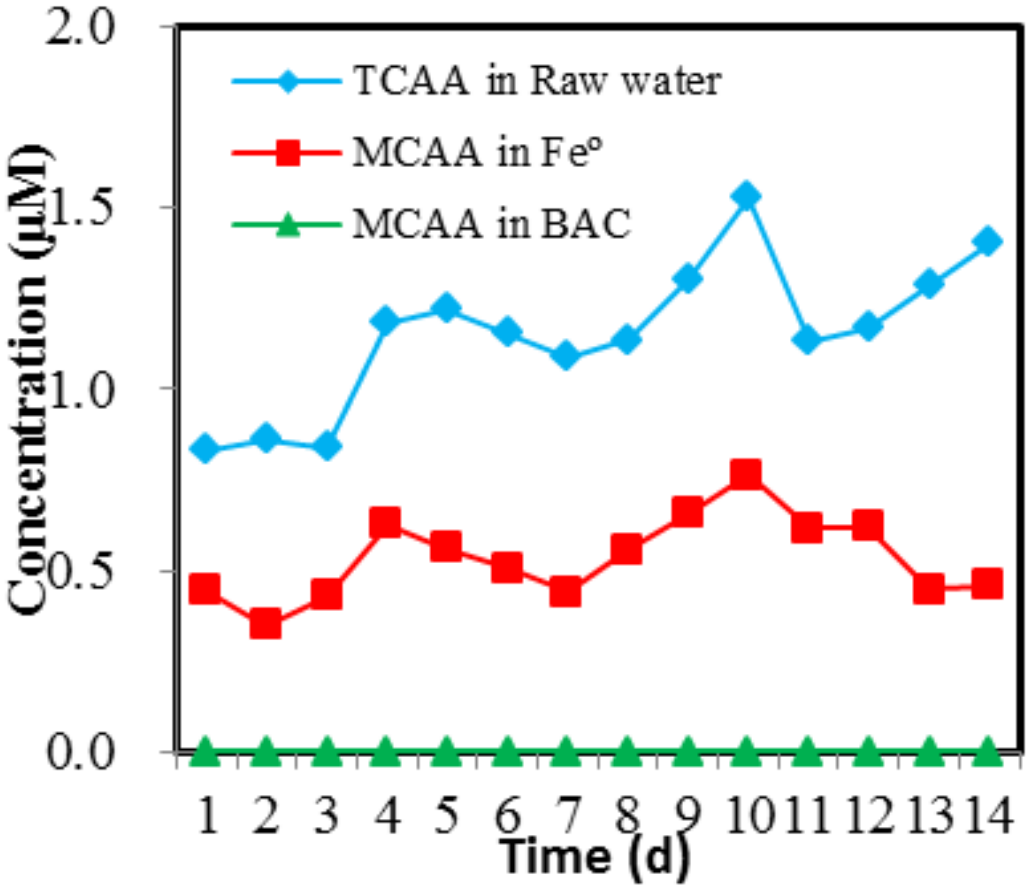
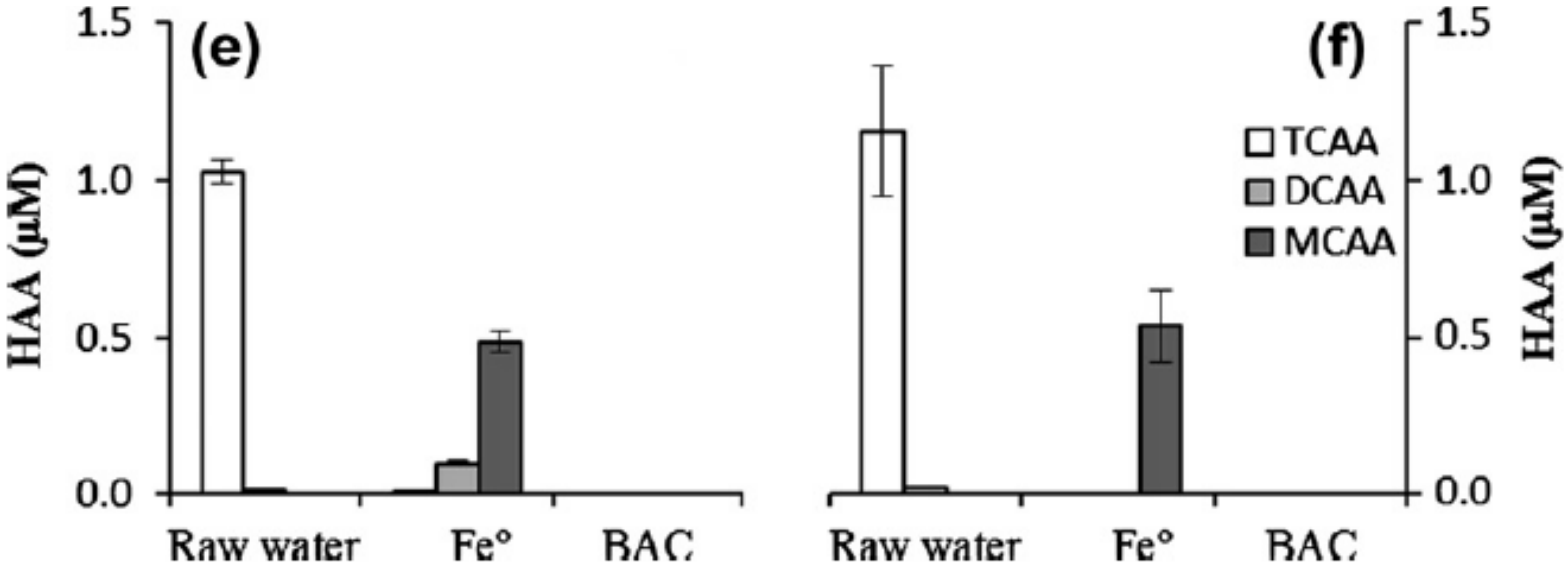


Fig. 1. Schematic diagram of the sequential Fe^0 and BAC system for HAA removal (1 – feed tank; 2, 4, 6 – peristaltic pumps; 3 – Fe^0 column; 5 – BAC column; A, B, C – sampling points; a – cast iron particles; b – BAC; c – silica sand; and d – glass fiber).

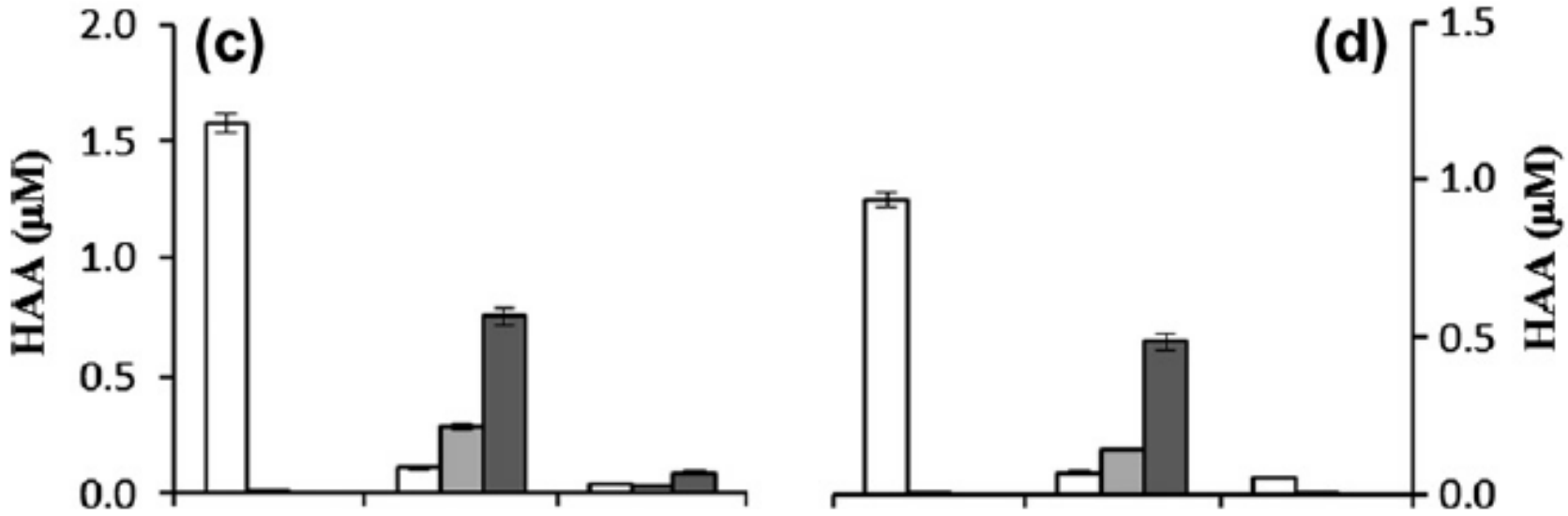
Trichloroacetic Acid Degradation Fe^0 (6 min) + BAC (6 min)



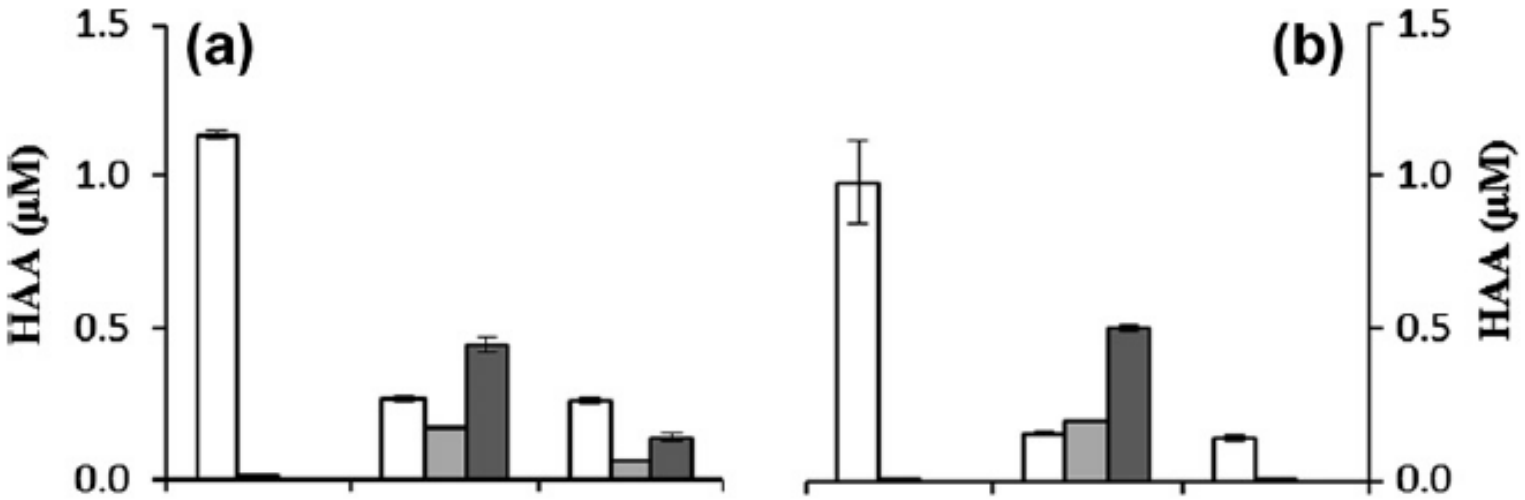
TCAA Removal
Fe^0 (10, 30min) + BAC (10, 30min)



TCAA Removal
Fe^0 (5, 6 min) + BAC (5, 6 min)



TCAA Removal
Fe^0 (2.5, 4 min) + BAC (2.5, 4 min)



Implications

- An off line treatment process
  - For storage tanks
  - As point-of-entry or point-of-use

- Potential issues
  - Potential impact on residual chlorine
  - Color issues associated with Fe^{3+} if Fe^{0}
  - Backwash

Conclusions

- Biological degradation is an effective way in removing HAAs
- BAC is an effective way to control HAA levels in distribution systems
- BAC can be used to control HAAs in swimming pools
- A combination of Fe^0 and BAC maybe an effective process in HAA removal.

Acknowledgements

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Additional Information

- Yuefeng Xie, Profh2o@psu.edu

- S. Sherant, H. Yeuell and Y.F. Xie, "A Simple Technology for THM Control in Consecutive Systems", Proceedings of the AWWA WQTC, Charlotte, NC, 2007
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- H. Wu and Y.F. Xie (2005) "Effects of EBCT and Water Temperature on HAA Removal using BAC" JAWWA, 97(11), 94-101.
- Shun Tang, Xiao-mao Wang, Hong-wei Yang, Yuefeng F. Xie (2013) Technical Note, Haloacetic acid removal by sequential zero-valent iron reduction and biologically active carbon degradation, Chemosphere 90, 1563–1567.
- Hao Tang and Yuefeng Xie (2015) Biologically active carbon filtration for haloacetic acid removal from swimming pool water, Sci Total Environ, 541:58-64.