# Water Treatment Pilot Studies at SCWA

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ENGINEERING

## Why Pilot?

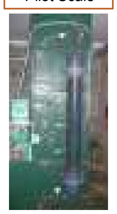
- Looking at something for the 1st time
- Develop operational understanding
- Generate Data
  - design purposes
  - regulatory approval
- Experimental Design of Pilot Study Critical

## Conducting Water Treatment Research

**Bench Scale**

- Timeframe – very short
- Low cost
- Good for testing new technologies
- Good screening tool
- Validity full-scale?

**Pilot Scale**



- Timeframe – shorter than full-scale
- Results valid full-scale
- Lower cost
- Good for testing new technologies
- Control of variables

**Full / Demonstration Scale**

- Timeframe long
- Results valid full-scale
- High cost
- Difficult to test new technologies
- Poor control of variables

## Granular Activated Carbon (GAC)

- Extremely large surface/pore space area, 1 gm of GAC has a surface area in excess of a tennis court.
- Contaminants adsorb into micropores within the GAC particles.

## World of Raw Materials for AC

Low Density, Soft, Weakly Adsorbing

**Vegetable Waste**
Rice Hulls Corn Cobs — Biomass — Fermentation Residues

**Wood Chips and Sawdust**
Pine — Oak — Walnut — Teak — Ebony

**Pits, Stones, and Kernels**
Cherry pits — Peach pits — Palm Kernels — Olive Stones

**Nut Shells**
Almond — Pecan — Walnut — Coconut — Babassu

**Coals – Coalification Series**
Peat — Lignite — Bituminous — Anthracite

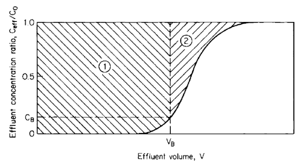
High Density, Hard, Strongly Adsorbing

Courtesy of Calgon Carbon Corp.

## GAC Use @ SCWA

- “Workhorse” treatment process
  - Removes many organic contaminants
  - Relatively low capital cost
  - Simple operation; no pretreatment
    - Inf/Eff sampling
  - Replace media upon contaminant “breakthrough”

## Breakthrough in GAC Filter




GAC Changeout @ SCWA

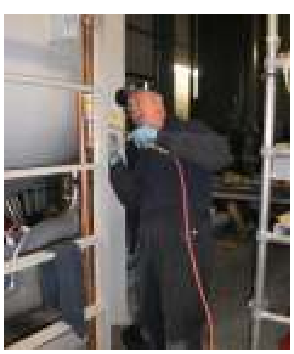
## GAC Use @ SCWA

- 2016 – 135 GAC adsorbers in service
- Contaminants include VOCs; pesticides; herbicides
- Annual GAC budget: $3.0 M
- 2 annual GAC contracts
- NYS – Only allow use of Virgin GAC

## GAC Pilot Studies @ Flower Hill PS
2011 - 2016

- Pilot Scale – Phase I/II/III
  - 8 pilot columns – 6” dia.
  - GAC bed depth: 8.5 ft (2.6 m)
  - GAC mesh size: 8 x 30 U.S.
  - WRF/EPA Project #4235
    “Evaluation of Available Scale- Up Approaches for the Design of GAC Contactors”
- Full Scale – Phase I/II
  - Reactivated GAC

## Constructing the GAC Pilot



## Constructing the GAC Pilot

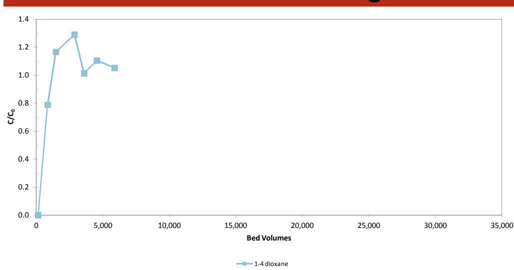
## GAC Pilot - Phase I/II (2011-13)

- SCWA Objectives
  - Compare VOC removal in:
    - direct activated vs. agglomerated bituminous
    - coconut GAC
    - virgin vs. reactivated GAC
  - Develop data for approval of reactivated GAC
  - Develop better performance predicting surrogates
    - TCN; I#; Dye; TAC TIC
  - Effect of BW; EBCT

## GAC Pilot Study
(Avg. Influent Concentrations)

- 1,4 – dioxane = 2.3 ug/L
- 1,1-dichloroethane (1,1-DCA) = 2.2 ug/L
- 1,2-dichloroethane (1,2-DCA) = 0.9 ug/L
- 1,1,2-trichlorotrifluoroethane (TCTFA; Freon 113) = 4.2 ug/L
- 1,1,1-trichloroethane (1,1,1-TCA) = 3.2 ug/L
- *cis*-1,2-dichloroethene (*cis*-1,2-DCE) = 1.2 ug/L
- 1,1-dichloroethene (1,1-DCE) = 2.1 ug/L
- Carbon tetrachloride (CT) = 0.9 ug/L
- 1,2,3-trichloropropane (1,2,3-TCP) = 0.8 ug/L
- Tetrachloroethene (PCE) = 3.2 ug/L
- Trichloroethene (TCE) = 3.7 ug/L

## GAC Pilot Phase I Results
## Contaminant Breakthrough Order

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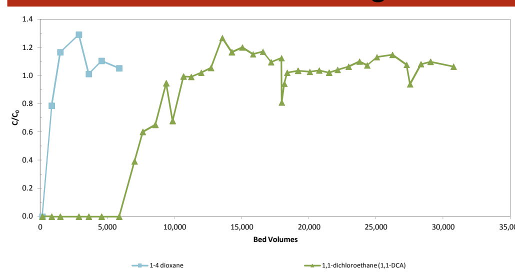


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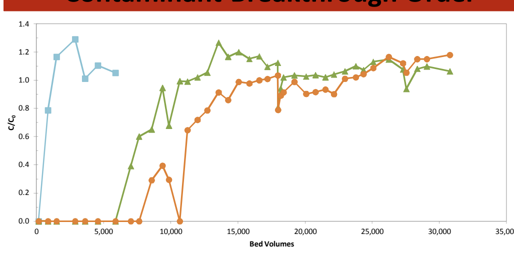


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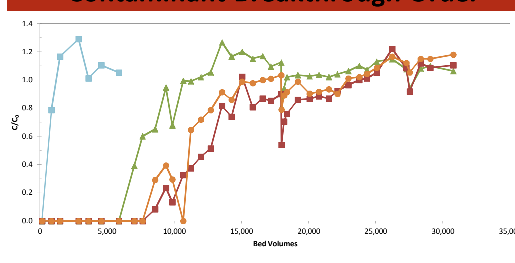

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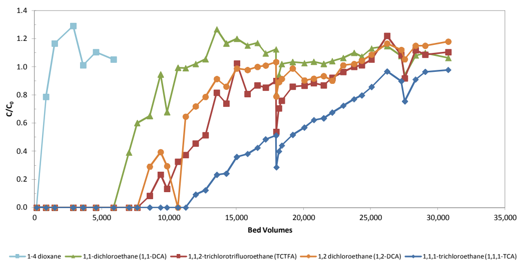


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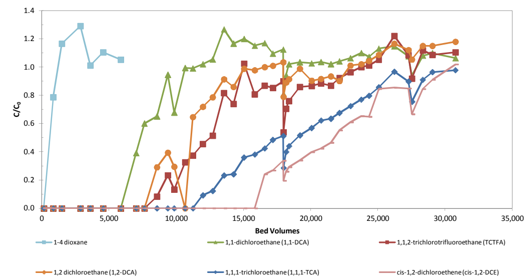


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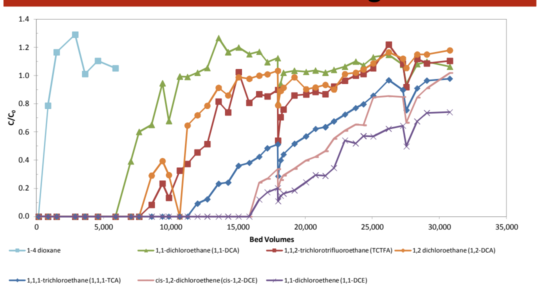


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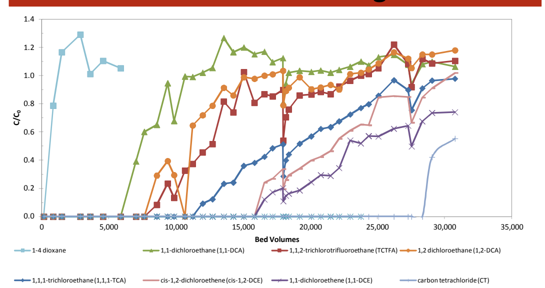
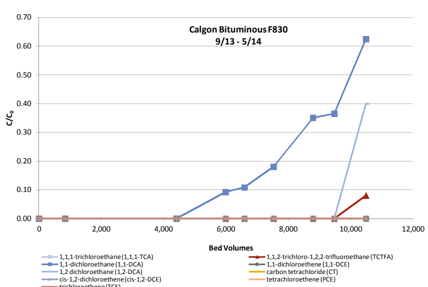


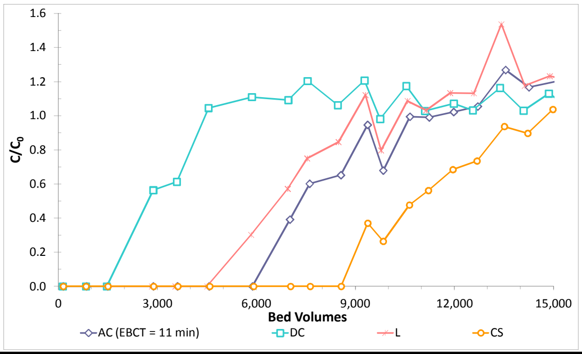

## Full-Scale GAC Filter Run




## Conclusions – GAC Pilot Phase I/II

- GAC ineffective for 1,4-dioxane removal.
- 1,1-DCA - least adsorbable of VOCs present.
- 1,2,3-TCP, TCE, and PCE - most adsorbable of VOCs present. No detectable breakthrough after 30,000 BV.
- GAC type important for VOC removal
  - Direct activated bituminous - least effective
  - Coconut-shell based - most effective
  - Bituminous - Agglomerated outperformed direct activated

## Not All GACs Created Equal
## 1,1-DCA Breakthrough vs. GAC Type




## GAC Adsorptive Tests

- Can predict GAC performance if chosen correctly
  - Need one that targets correct pore sizes
  - Iodine #
    - Industry standard
    - Not good for many SCWA contaminants
  - TCN
    - Targets smaller, high energy pores
  - Tannin #

## Phase II - GAC Performance

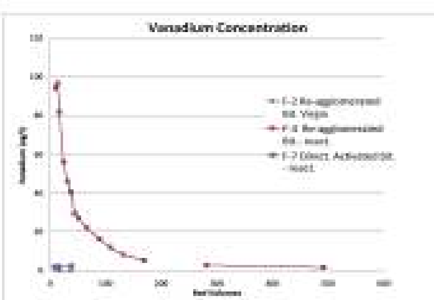
| | Coco-nut # 1 | Coco-nut # 2 | Coco-nut # 3 | RBA | Coco-nut # 4 | VBA | RBD | VBD |
|---|---|---|---|---|---|---|---|---|
| BV to 50% Breakthrough of 1,1-DCA | 12500 | 12000 | 11500 | 11400 | 10000 | 8200 | 4500 | 4500 |
| CUR (#GAC/MG) | 336 | 334 | 362 | 405 | 516 | 625 | 897 | 855 |
| I2 # | 1130 | 1190 | 1432 | 929 | 870 | 832 | 864 | 978 |
| TCN # | 14.5 | 15.4 | 14 | 12.7 | 14.9 | 12.6 | 6.8 | 6.7 |

R = reactivated; B = bituminous;
V = virgin; D = direct activated;
A = agglomerated

## Conclusions – GAC Pilot Phase I/II (cont'd.)

- Reactivated GAC
  - Acceptable removal of contaminants:
    - Agglomerated reactivated outperformed its virgin counterpart for all adsorbates except 1,1,2-TCTFA & 1,1,1-TCA.
    - Direct activated reactivated GAC outperformed its virgin counterpart for all adsorbates except 1,2-DCE & CT.
  - Metals leaching a potential problem

## Metal Leaching from Reactivated GAC Phase I GAC Pilot



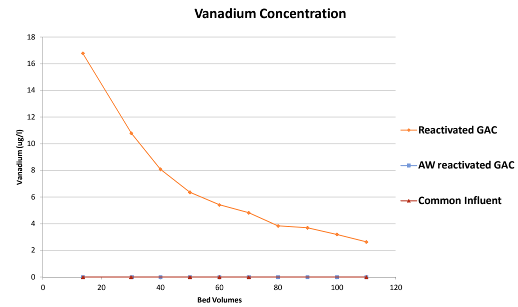

## Metal Leaching from Reactivated GAC Phase II GAC Pilot

| B.V. | Sb | As | Mo | Ni | Se | V |
|---|---|---|---|---|---|---|
| 14 | | 4.22 | 6.3 | | | 15.3 |
| 30 | | 2.56 | 3.56 | 1.51 | | 10.2 |
| 50 | | 1.28 | 1.79 | 2.3 | | 5.78 |
| 85 | | | | 2.91 | | 4.12 |
| 115 | | | | 3.19 | | 3.1 |
| 190 | | | | 2.9 | | 1.38 |

## GAC Pilot Study - Phase III (2015)

- Objective: Determine if vendors can provide reactivated GAC with no start-up metals problems
- Reactivated GAC (CMR) Only
  - CMR vs. acid wash CMR

## Phase III Metals Results




## Improvements to GAC Use @ SCWA

- 2014:
  - System-wide use of coconut GAC
  - GAC contracts changed to bituminous and coconut.
  - Removed geographic distinction from contracts
- 2015:
  - Include TCN # in bituminous GAC specs.
  - \$0.75M - \$1M savings in GAC expenditures – FY2015
  - SCDHS/NYSDOH approve reactivated GAC for SCWA
    - Limited full-scale piloting
    - Potential 30% cost savings over virgin GAC

## Improvements to GAC Use (cont'd.)

- 2016:
  - Reactivated GAC - Full-Scale Pilot
    - Completed Phase I/II – Reactivated Bituminous
    - SCDHS approval for full-scale pilot of reactivated coconut
    - SCDHS approval for continued full-scale reactivated bituminous
  - PFOS/PFOA
    - Full-scale pilot begins
    - RSSCT at NCSU – compare 3 types of GAC
- Future:
  - SCWA full DHS approval for virgin & reactivated GAC?
    - Bituminous and coconut

## Piloting an Advanced Oxidation Process (AOP) at SCWA

## Advanced Oxidation Process (AOP)

- UV light systems: commonly used for DW disinfection
- UV AOP:

  UV + oxidant → •OH

  highly reactive •OH radical formed.
- Common oxidants: $H_2O_2$; $O_3$; $Cl_2$
- Effective for oxidation of many emerging contaminants
- Most common AOP uses:
  - indirect potable reuse
  - GW remediation

## Oxidant Potentials – Common Oxidants

| Oxidant | Oxidation Potential (eV) |
|---|---|
| •OH | 2.80 |
| $O_3$ | 2.07 |
| $H_2O_2$ | 1.77 |
| Hydroperoxyl Radicals | 1.70 |
| Permanganate | 1.67 |
| Chlorine Dioxide | 1.50 |
| Chlorine | 1.36 |
| $O_2$ | 1.23 |

## Scavenging

•OH

- is highly reactive, non-specific oxidant
- reacts with many background (“scavenging”) compounds
  - Inhibits oxidation / destruction of target contaminants
  - scavengers include dissolved NOM, organic carbon (DOC), alkalinity, chloride, sulfate and nitrate.

## Quenching

- Conversion from oxidant → •OH << 100%
- Residual oxidant ($H_2O_2$; $Cl_2$; $O_3$) persists in AOP Effluent; requires “quenching”
  - UV/$H_2O_2$ AOP
    - 75-90% Carry-over of $H_2O_2$
    - Full-scale AOP - Quench excess $H_2O_2$ with $Cl_2$ or GAC
      - $Cl_2$ quenching - Requires 2.1:1 $Cl_2$ to $H_2O_2$ mass ratio
      - GAC quenching – Occurs quickly in GAC bed

## Use of AOP @ SCWA?

- Why investigate this treatment process?
  - Ability to remove “emerging” contaminants
    - 1,4-dioxane
    - VOCs
    - NDMA; PPCPs; MTBE
  - Get pilot experience before regulatory requirements effective
    - Design data; cost
    - Operational concerns
    - System integration to existing station layout, treatment train, and controls.

## Exploring the Use of AOP @ SCWA

- Phase I: Pilot scale testing
  - lower flows; treated water to waste
  - Short duration
  - Gain process experience; provide design data
- Phase II : Full-scale testing (pending)
  - Treat SCWA GW well; treated water to system
  - Provide full-scale data

## Commercial Blvd. AOP Pilot Study

## Phase I: AOP Pilot Test (2011)

Commercial Blvd #3

- 1,4-dioxane; 1,1-DCA; 1,1-DCE; TCE

- TrojanUVPhox™ 8AL30 system used
  8 low-pressure high-output amalgam lamps; 2 kW
- UV / peroxide AOP

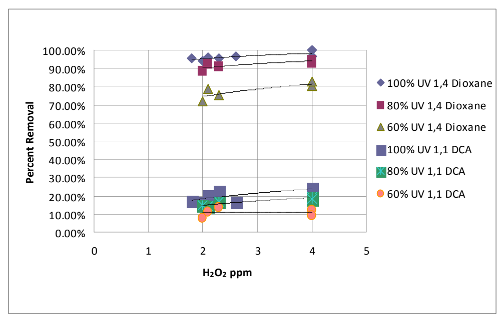
## AOP Pilot System

- Control Panel
- Adjustable UVI
- UV Transmissivity Monitor
- 35% $H_2O_2$
- FlexFlo variable peristaltic pump

# AOP Pilot Study - SCWA

- Trials:
  - Varied:
    - Flow rate: 20 – 200 GPM
    - UV Intensity: 0% (lamps off); 60% - 100% (lamps on)
    - Oxidant type: $H_2O_2$ and NaOCl
      - $H_2O_2$ Dose: 2 – 6 mg/L

# % Removal vs. Peroxide Dose - 150 gpm




# AOP Pilot Study - Conclusions

- Water quality @ SCWA favors effective AOP treatment
  - high UV transmissivity (>99%)
  - very low •OH scavenging
  - Excellent 1,4-dioxane destruction with comparatively low energy input; low peroxide doses
- Low operational costs
- Simple process

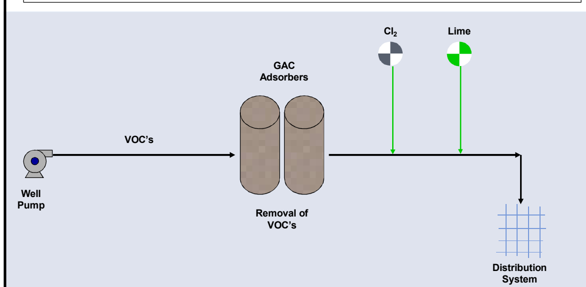
# AOP Phase II: Full-Scale AOP Pilot

- Commercial Blvd Well #3
- Pro-active step in meeting anticipated 1,4-dioxane regulations
- Gain experience @ full-scale
  - siting process
  - permitting / regulatory issues
  - Process/operational issues
  - determine actual costs

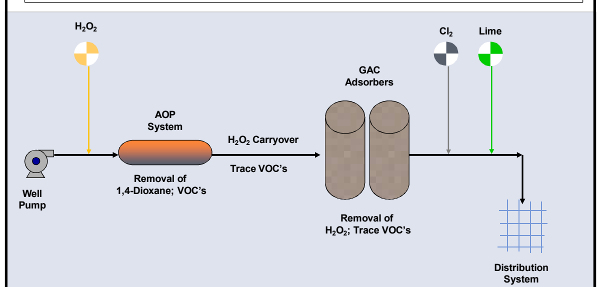
## Full Scale AOP at SCWA - Status

- Contract to construct awarded
- Will be 1st AOP system for drinking water in NY
- In Final Regulatory Review Phase
- Construction to begin Fall 2016
- When complete
  - Initial 30 day (?) BTW period.
  - In service
  - Possible side studies?


## Current Process Flow Diagram




## Proposed Process Flow Diagram




## Acknowledgements

- SCWA - Administration; Production Control; Lab; Engineering
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- Hazen & Sawyer – Ben Stanford; Erik Rosenfeldt; Paul Brandt

## Questions?