# Powdered and Granular Activated Carbon Treatment for TOC Reduction and Stage 2 D/DBPR Compliance

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# Learning Objectives and Outline

- Total Organic Carbon (TOC) Basics
- Activated Carbon Basics
- Testing Methods to Evaluate TOC Removal
- TOC Removal Performance with Activated Carbon
- Types of Delivery Systems
- Summary and Conclusions

# Natural Organic Matter

**NOM** = Decomposed organic matter from plants and animals

**Chemical Classes of NOM*:**

| | |
|---|---|
| Humic Species | 80 – 90 % of chlorinated DBPs |
| Carbohydrates | < 5 % |
| Amino Acids | 5 – 10 % |
| Proteins | 5 – 10 % |
| Carboxylic Acids | 5 – 10 % |
| Other | |

* Croue et al; AWWARF 2000

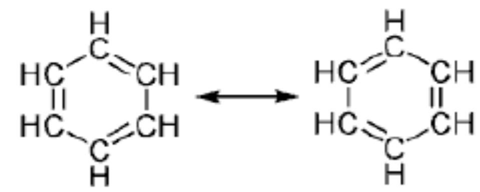
# Natural Organic Matter

## Characterization of NOM in Water Sources

Hydrophobic – doesn't like water (ie,humic acids)

Hydrophilic – does like water (dissovles with $H_20$)

Aromatic Compounds




Typical configuration for humic acids

**Chlorine consumption and DBP formation is proportional to aromatic carbon content of NOM**

**Reckhow, et al, 1990**

# Why Are We Concerned About NOM/TOC?

- Organic Compounds Represent Sources of Tastes, Odors and Color
- Precursor for Disinfection By-Products
- Potential Health Concerns
- Many Organics are EDCs, PPCPs and CECs and may be Subject to Future Regulation
- Potential Source for Biological Regrowth in Distribution Systems
- Regulatory Compliance
  - *Stage 1 and 2 D/DBPR*

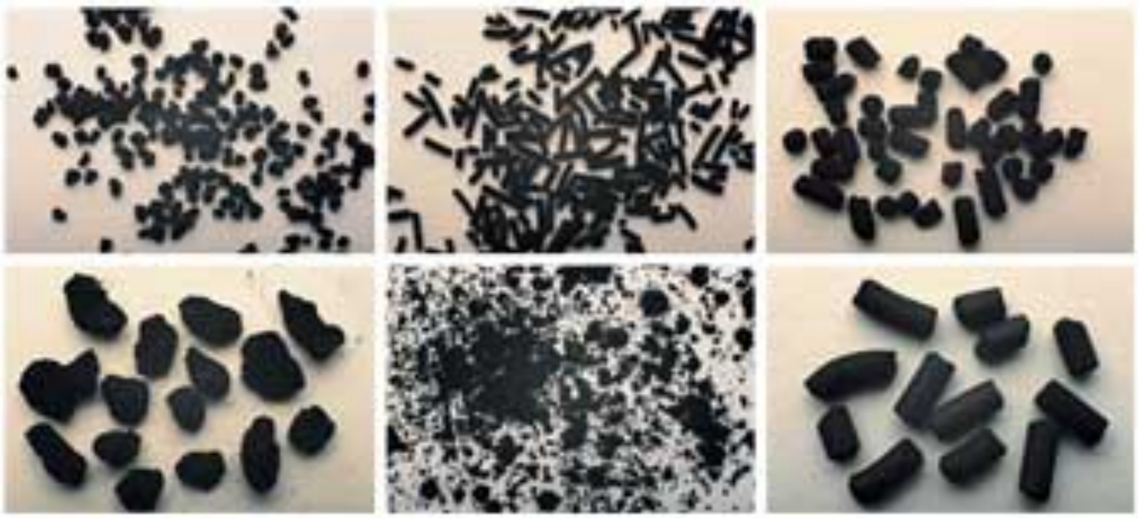
# DBP Control = Controlling this Equation

**Chemical Disinfectant** + **Precursor** = **DBPs**

| Chemical Disinfectant | | Precursor | | DBPs |
|---|---|---|---|---|
| Chlorine<br>Monochloramine<br>Ozone<br>Chlorine Dioxide | + | Natural Organic Matter<br>Bromide | = | Trihalomethanes<br>Haloacetic Acids<br>Haloacetonitriles<br>Haloketones<br>Aldehydes<br>Bromate<br>and many more |

# What is Activated Carbon?

- A highly porous charcoal that effectively removes organic compounds from air and water
- Available as a powdered (PAC) or granular (GAC) material



# GAC vs. PAC

## Granular Activated Carbon (GAC)

- *Particle size: larger than 0.1 mm*
- *Typical range – 0.4 to 2.5 mm*
- *Bulk dry (apparent) density – 0.22 to 0.5 kg/L*
- *Used in adsorption columns/filters*

## Powdered Activated Carbon (PAC)

- *Particle size: < 200 mesh (74 $\mu$m)*
- *Typical range – 10-50 $\mu$m*
- *Bulk dry (apparent) density – 0.34 to 0.74 kg/L*
- *Used by direct addition*

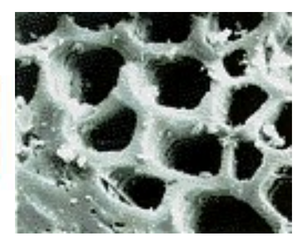
# Where Does it Come From?

- **Produced from a variety of source materials…**
  - *Coal*
  - *Wood*
  - *Coconut shells*


- **Raw materials are heated (in two stages) to form activated carbon**

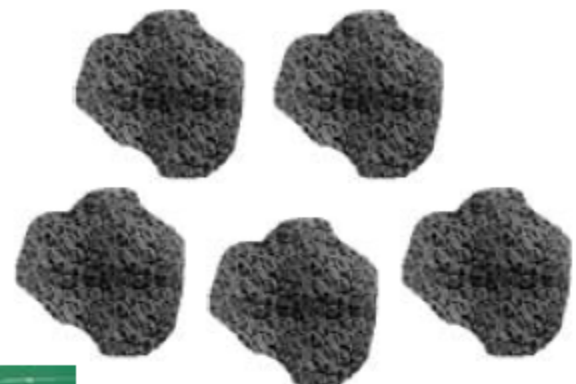
# Activated Carbon Manufacturing

High Grade Metallurgical Bitum. Coal → Pulverize → Reagglomerate → Crush → Size → Bake → Activate



Courtesy of Calgon Carbon Corporation

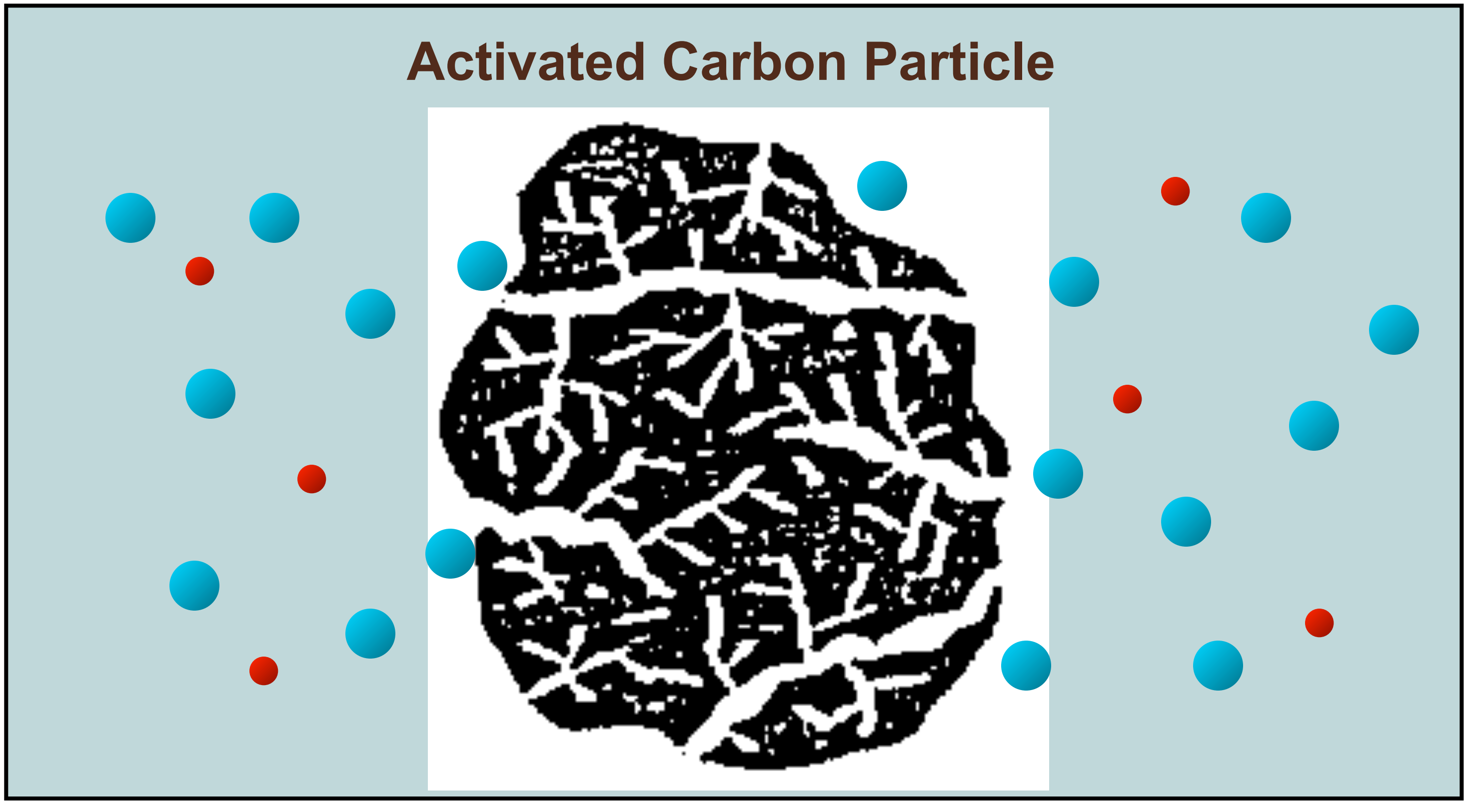
# Internal Surface Area



**5 grams of carbon has an internal surface area equivalent to the surface of a professional football field - including the end zones!**

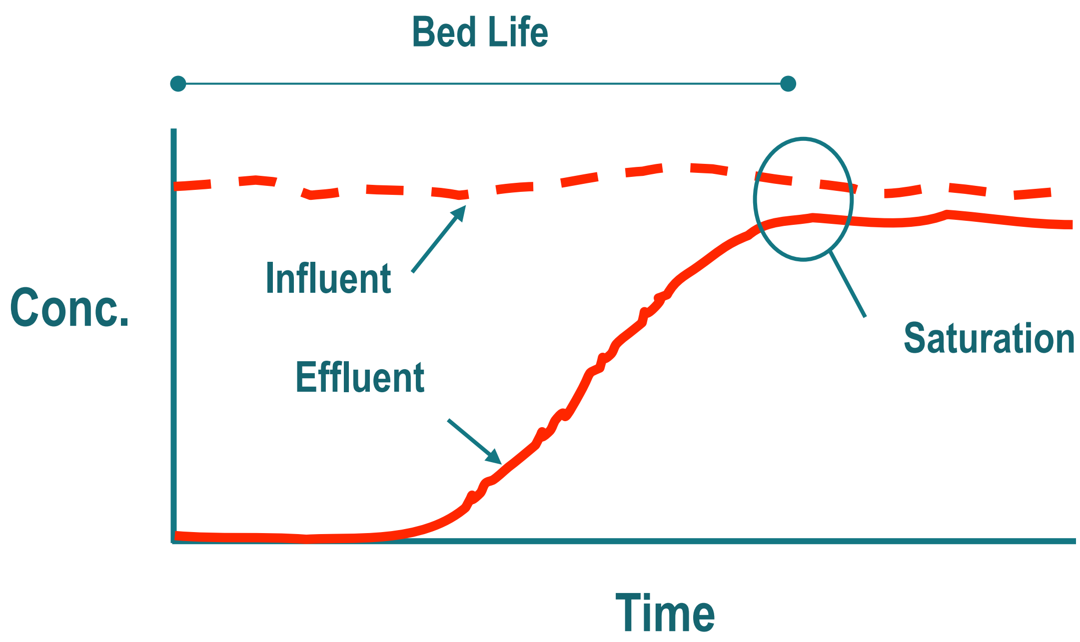
Courtesy of Calgon Carbon Corporation

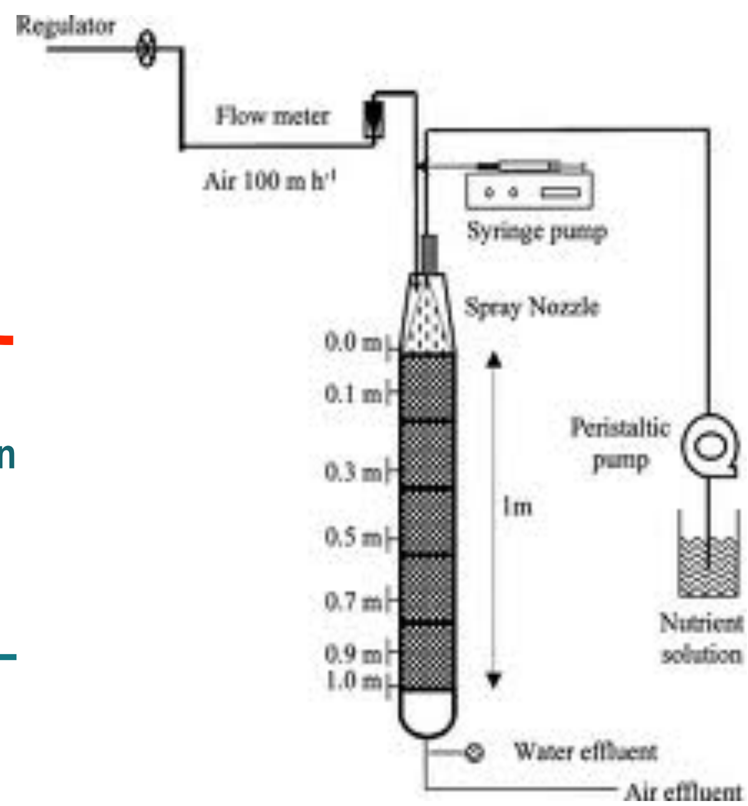
# Diffusion in Activated Carbon



TOC Basics → **Activated Carbon Basics** → TOC Removal Testing Methods → Activated Carbon Performance → Activated Carbon Delivery Systems → Cost Data

# Breakthrough Performance




Finished water TOC goal will determine what breakthrough percent is allowed and when carbon change-out will occur.

# Testing Methods for Assessing TOC Removal with Activated Carbon

- Isotherm Testing - GAC
- Jar Testing - PAC
- Rapid Small Scale Column Testing - GAC
- Pilot Column Testing - GAC

# GAC Adsorption Isotherm

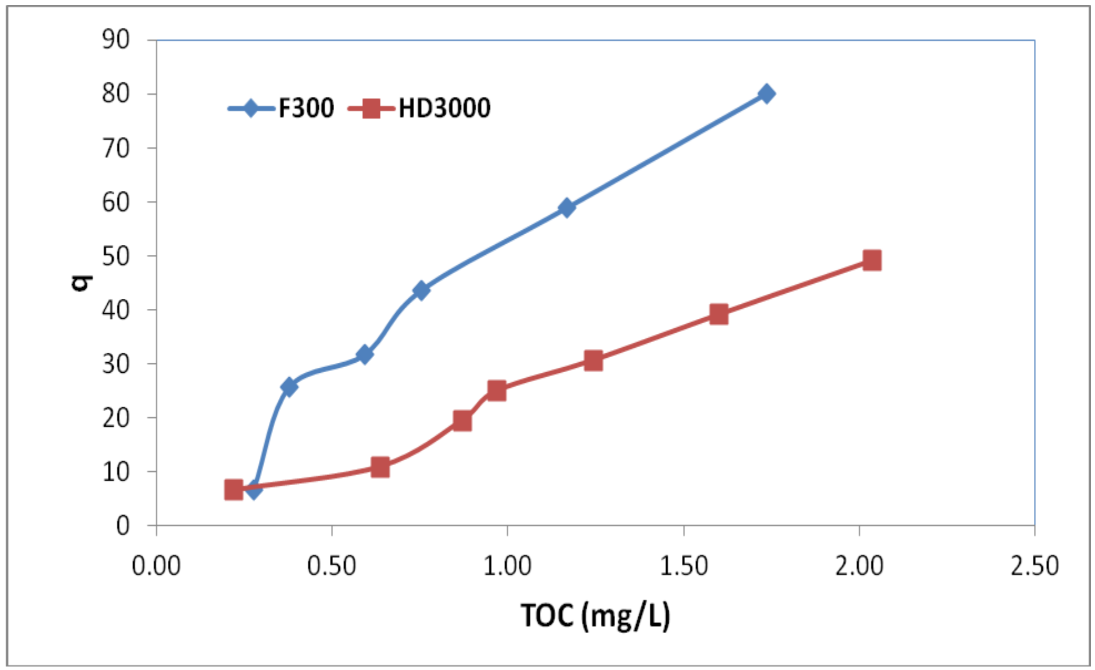
The adsorption equilibrium relates *q* to *C*. The equilibrium is a function of the temperature. Therefore, the adsorption equilibrium relationship at a given temperature is typically referred to as *adsorption isotherm*, i.e.:

$$q = f(C)$$

where:

***q* =** mass of species adsorbed/mass of adsorbent (i.e., equilibrium concentration of adsorbable species in solid adsorbent)

***C* =** equilibrium concentration of adsorbable species in solution




**Where q = ($TOC_{initial}$ – $TOC_{final}$)/Carbon Dose (g/L)**

Norit HD3000 and Calgon Filtersorb 300

TOC Basics → Activated Carbon Basics → **TOC Removal Testing Methods** → Activated Carbon Performance → Activated Carbon Delivery Systems → Cost Data

# PAC Jar Testing

- *Evaluate the performance of different PACs*
- *Determine optimum dose*
- *Evaluate mixing energy and time*
- *Evaluate impact on coagulation chemistry*

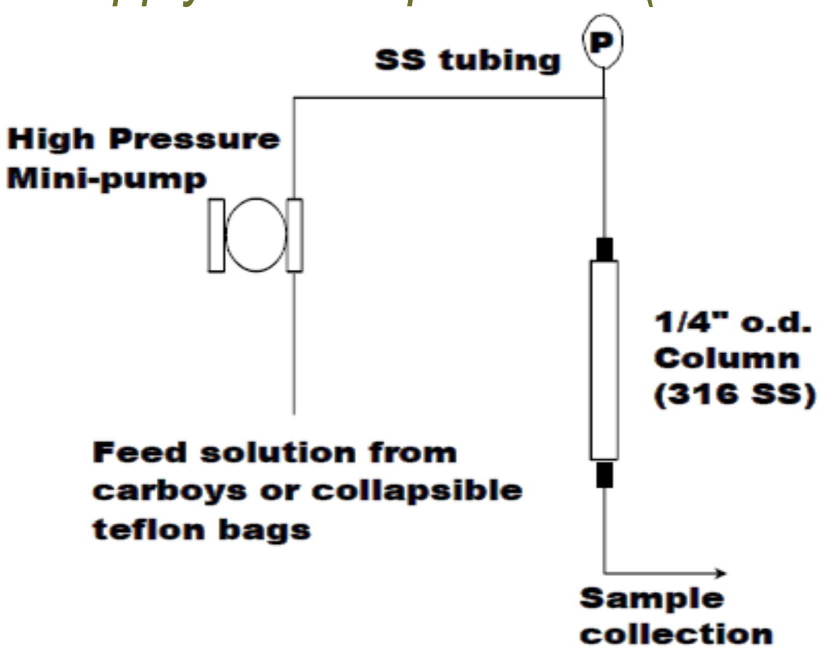

Obtain Raw Water for Testing → Conduct Jar Testing with Plant Specific Conditions → Analyze for TOC at Different Carbon Doses → Calculate Performance and Select PAC Type/ Dose

# Pilot Column

- Advantages:
  - Incorporates fluctuations in influent quality and flow rate
  - Large enough to backwash and consider physical throughput
- Disadvantages
  - Time consuming
  - Expensive

# Mini-column Testing

- *Accelerated Column Testing (ACT) (Calgon)*
- *Rapid Scale Small Column Test (RSSCT) (Michigan State)*
- *Pulverize to reduce particle size and increase rate*
- *Apply "scale up" factors (for reduced particle size and accelerated flow)*

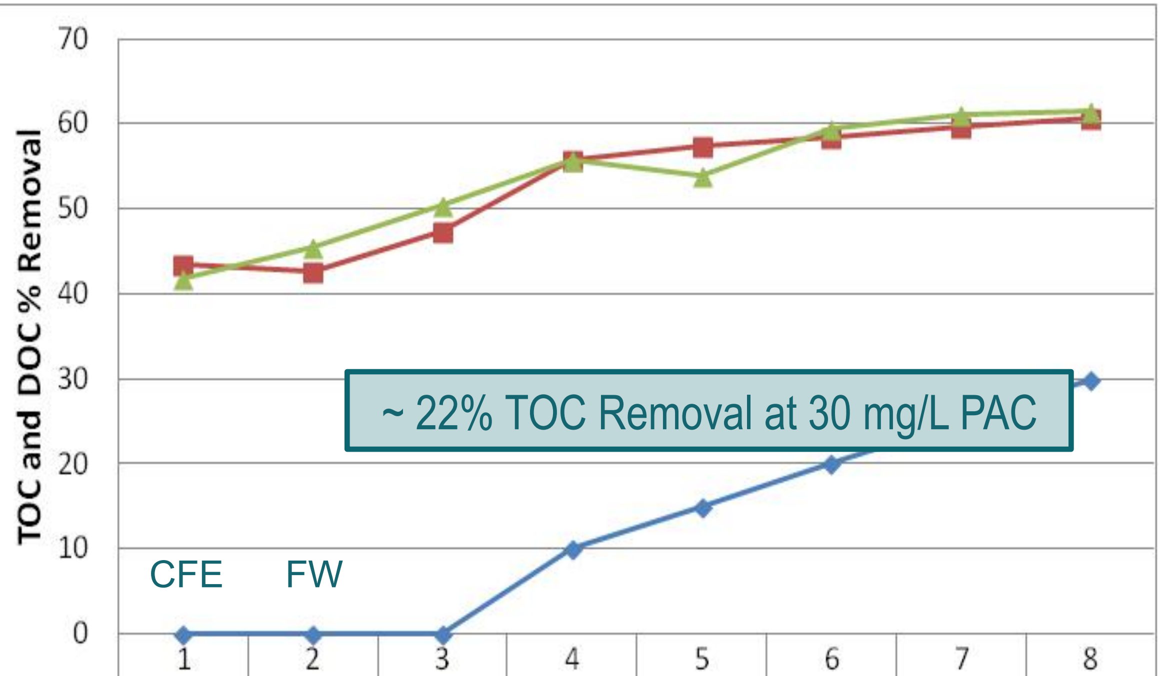



# TOC Removal and DBP Reduction with Activated Carbon

| Strategy/Technology | TOC/DBP Reduction Potential |
|---|---|
| Enhanced Coagulation/Alternate Coagulants | 0 to 10% |
| Chlorine Dioxide Pre-treatment | 0% TOC, 10 to 50% DBPs |
| PAC Pretreatment | 5 to 25% |
| MIEX ® | 50 to 70% |
| Ozone / Biological Active Filtration | 0 to 20% |
| Post Filtration GAC Contactors | 25 to 75% |

# Powdered Activated Carbon – Townsend WTP

| Raw Water TOC/DOC | 3.81 mg/L/3.75 mg/L |
|---|---|
| Ferric Dose | 40 mg/L |
| Caustic Dose | 4 mg/L |
| Raw Water Temperature | 25°C |
| Raw Water pH | 7.1 |

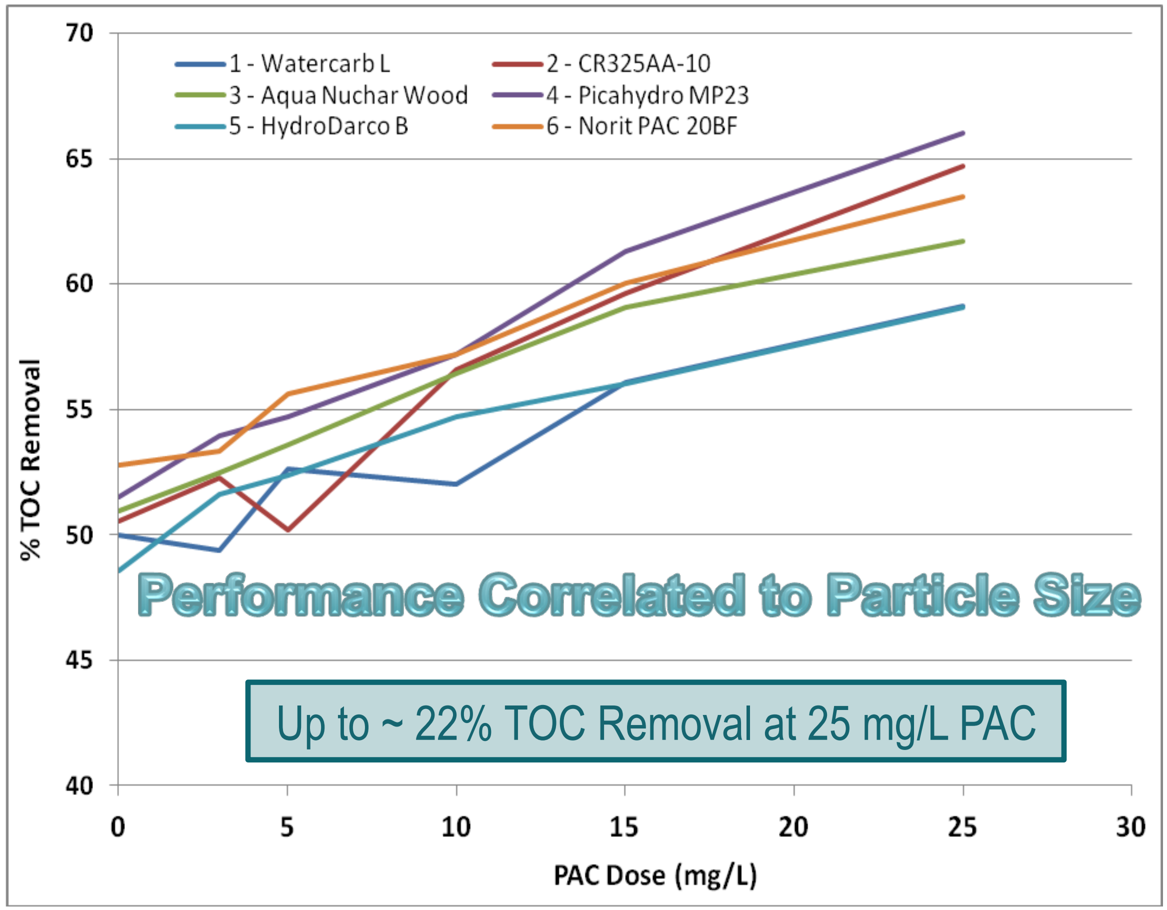



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Carbon PPM | 0 | 0 | 0 | 10 | 15 | 20 | 25 | 30 |
| TOC Removal % | 43.55 | 42.65 | 47.30 | 55.72 | 57.45 | 58.39 | 59.60 | 60.64 |
| DOC Removal % | 41.83 | 45.52 | 50.37 | 55.74 | 53.98 | 59.53 | 61.00 | 61.59 |

# PAC Addition – Concord, NC

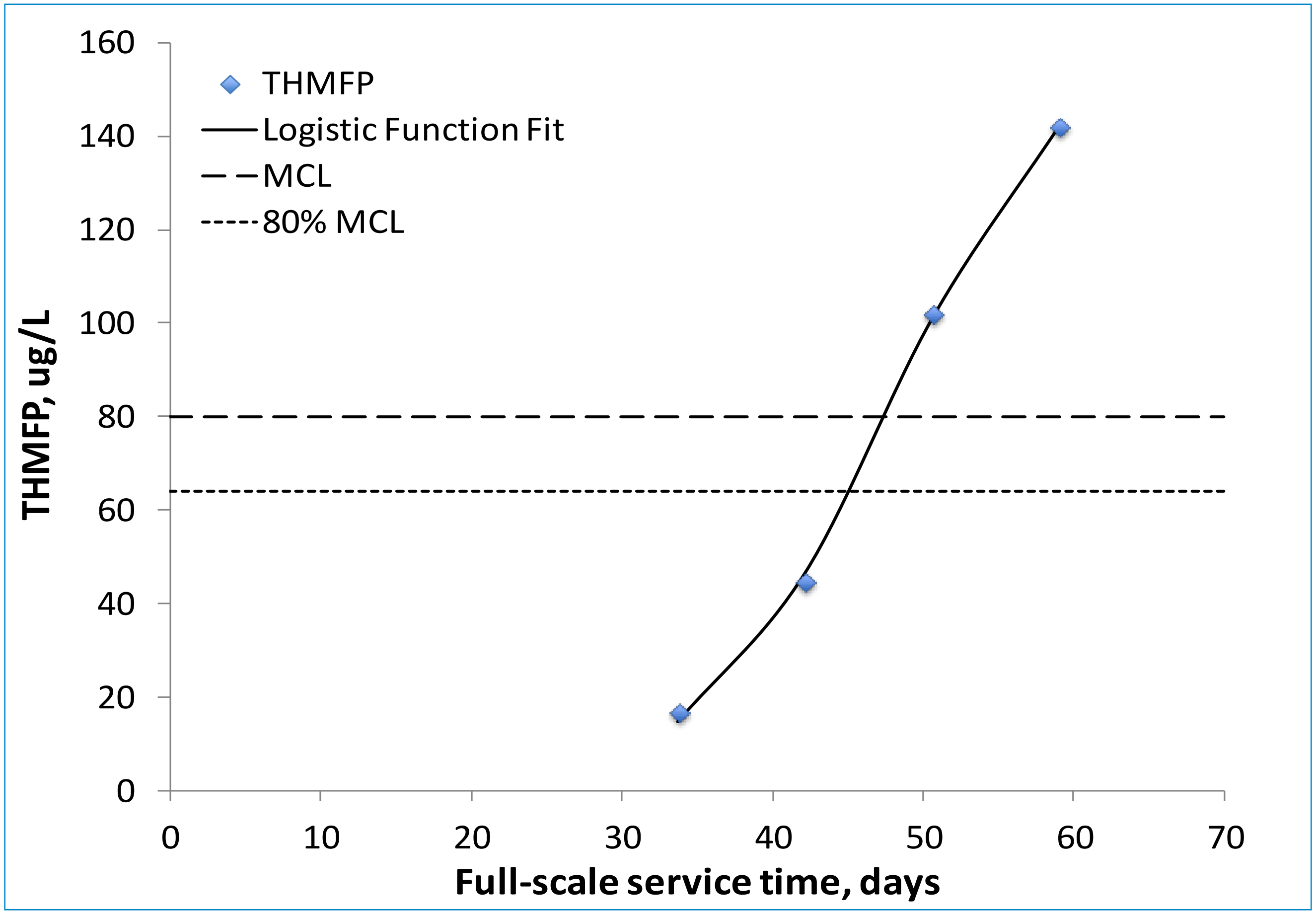
## Hillgrove WTP

- 7-Day TTHM Formation Potential – 67 mg/L per mg/L TOC
- 7-Day HAA5 Formation Potential – 45 mg/L per mg/L TOC
- ~ 14% DBP Reduction @ 15 mg/L PAC

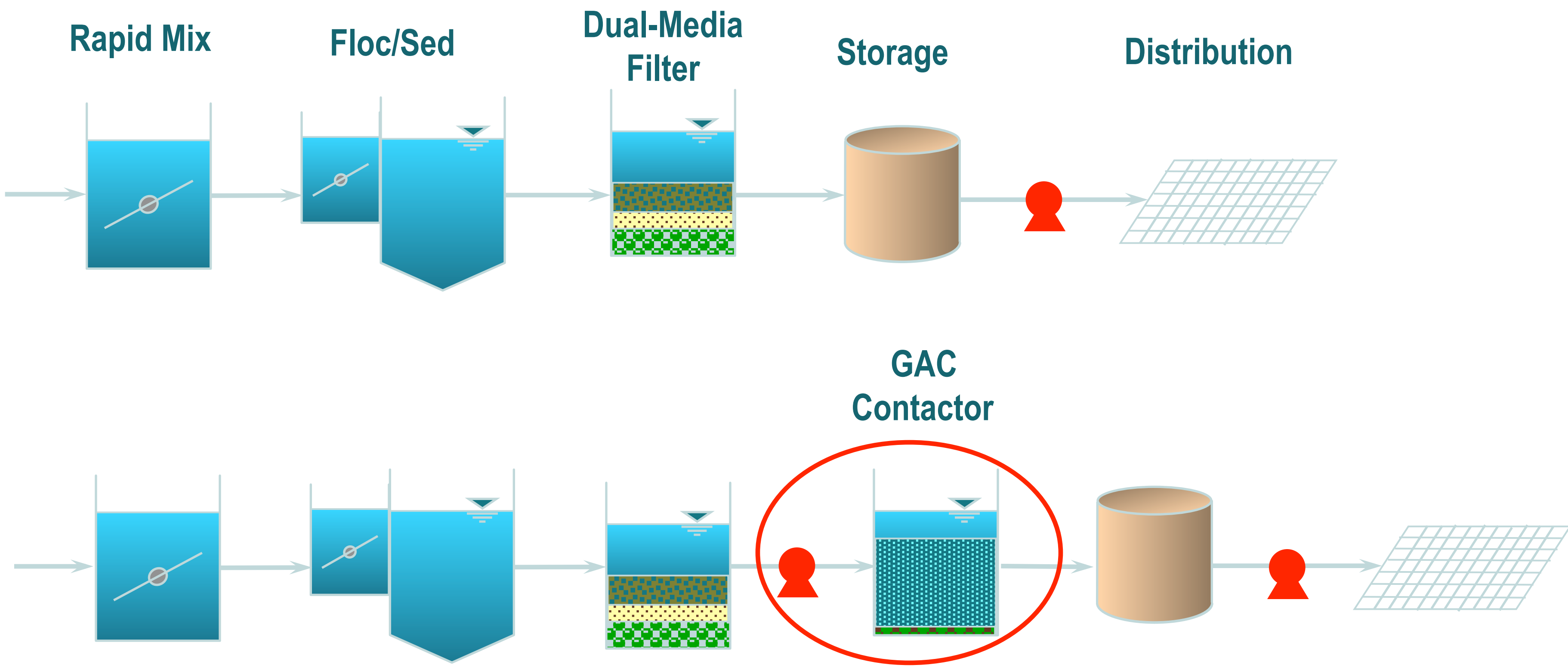


# RSSCT Results - GUC

- Filtersorb 300
- 100 x 200 mesh fraction
- EBCT – 1.26/15 minutes
- Temperature - 22-23.5°C
- pH – 6.3
- Initial TOC – 4 mg/L
- UV254 – 0.044 $cm^{-1}$
- Flow 2 ml/min



# Post-Filter GAC Contactors



# Typical GAC Arrangement

**Post-Filter Contactor**

- 2–8 gpm/sf
- EBCT of 7-25 minutes per vessel
- Typically 10' to 12' in diameter; 18' to 22' tall
- Typical carbon loading - 4 to 8 feet, 20,000 lbs


**Granular Media Filter Adsorber**

- 2–6 gpm/sf
- EBCT of 5-20 minutes
- Typical media depth – 3 to 6 feet

# Dry PAC Delivery Options

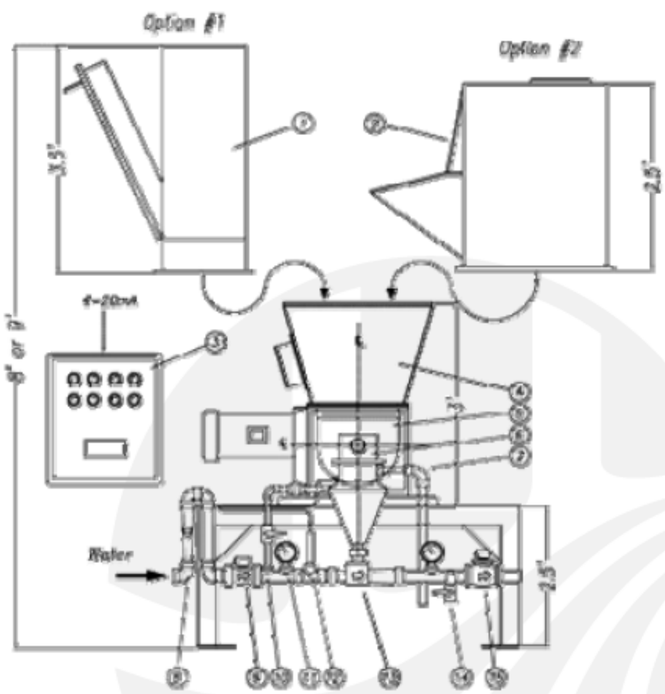
30,000 to 32,000 lb load

40 to 45 lbs/33 bags/pallet

750 lb bulk bags

# PAC Feeders

1. Bag Loading Hopper (Option 1)
2. Dust Collector (Option 2)
3. SCR Control Panel
4. Transition Hopper
5. Volumetric Feeder
6. Wetting Cone
7. 1" Overflow Piping
8. Flowmeter
9. Solenoid Valve
10. Water Inlet with Control Valve
11. Pressure Gauge
12. Presure Switch
13. Slurry Eductor
14. ½" Drain Valve
15. Pheumatic Operated Pinch Valve (Water Outlet)



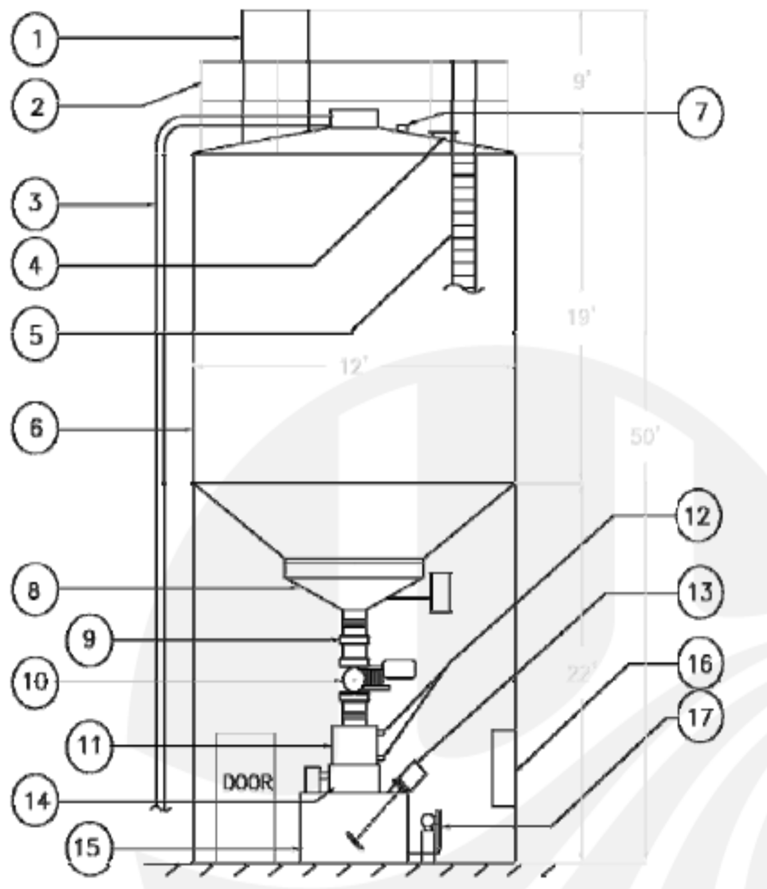

**Bag Loading**

Typical Bulk Bag System Configuration

**Bulk Bag**

# PAC Bulk Silo Feed

1. Bag type Dust Collector
2. Safety Railing
3. 4” Fill Line with Camlock Adaptor
4. Access Hatch
5. Access Ladder
6. Storage Hopper
7. Ultrasonic Flowmeter
8. Bin Activator
9. Knife Gate
10. Rotary Air Lock Valve
11. Extension Hopper
12. Hi & Lo Level Switches
13. Mixer
14. Volumetric Feeder
15. Slurry Tank
16. Control Panel
17. Slurry Metering Pump




# PAC Slurry System

Slurry (1- 2lbs/gal)

Mixer

Feed Pump

# Typical Cost Data - PAC

- **PAC - $0.50 to $1.00 per pound**

| Dose (mg/L) | 1 MGD | 5 MGD | 10 MGD | 20 MGD |
|---|---|---|---|---|
| 5 | $10,654 | $53,272 | $106,544 | $213,087 |
| 10 | $21,309 | $106,544 | $213,087 | $426,174 |
| 15 | $31,963 | $159,815 | $319,631 | $639,261 |
| 20 | $42,617 | $213,087 | $426,174 | $852,348 |

Based on $0.70/lb

- **Equipment Cost - $200K to $500K**

# Typical Cost Data - GAC

- **Capital Cost - $0.25 to $0.50 per gallon**
- **GAC Media - $1.50 per pound regenerated**
- **10 MGD WTP ~ $230,000 per change out**
  - *4 gpm/sf*
  - *1,750 SF filter area, 3 foot GAC depth*
  - *GAC density - 30,000 lbs/CF*

# Summary and Conclusions

- PAC and GAC are effective technologies for reducing TOC concentrations, minimizing DBPs and can remove selected contaminants of concern
- Both technologies are costly to operate
- Before considering the use of PAC, bench scale testing should be conducted to determine effectiveness and cost
- Bench and/or pilot scale testing are required for GAC including monitoring TOC removal and DBP formation potential

# Activated Carbon Specificity

## Relative Adsorption Strengths