# Disinfection By-Products

## Meeting the Challenge of Compliance with USEPA DBPR Stage 2

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# Presentation Outline

- Background
- Investigation of Alternatives
- Pilot Testing Program
- Full Scale Implementation
- Operating Data
- Treatment Costs
- Current Status

Granular Activated Carbon

# Background

- The City of Celina, OH supplies drinking water to 11,647 residents
- Source water is *Grand Lake*, a 21 sq. mile water body
- *Grand Lake* contains high levels of total organic carbons (TOC) and supports a high concentration of Planktothrix algae

# Background

Celina, Ohio

Grand Lake

Grand Lake / St Marys Watershed

# Background

- Grand Lake watershed is primarily agricultural land
  - Lake itself is only 7’ deep

- TOC concentrations average 12.5 mg/l and peak at over 20 mg/l

- Turbidity ranges from 10 to 300 NTU

**Image of water samples showing 5, 50, and 500 NTU turbidity**

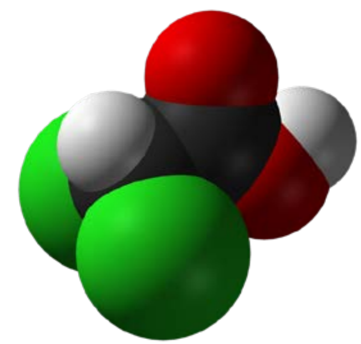
# Background

- Celina water treatment consisted of:
  - Lime slaking
  - Upflow clarification
  - Recarbonation
  - Sand Filtration
  - Ozonation
  - Chlorination for residual disinfection

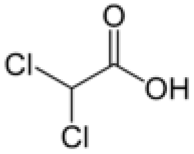
- In 1995, levels of disinfection by-products (DBPs) became an issue

# Currently Regulated Disinfection By-Products

| REGULATED CONTAMINANTS | Stage I MCL (mg/l) | Stage II MCL (mg/l) |
|---|---|---|
| **TOTAL TRIHALOMETHANES (TTHM)** | **0.080 RAA** | **0.080 LRAA** |
| Chloroform ($CHCl_3$) | | |
| Bromodichloromethane ($CHBrCl_2$) | | |
| Dibromochloromethane ($CHBr_2Cl$) | | |
| Bromoform ($CHBr_3$) | | |
| **FIVE HALOACETIC ACIDS (HAA5)** | **0.060 RAA** | **0.060 LLRA** |
| Monochloroacetic acid ($C_2H_3ClO_2$) | | |
| Dichloroacetic acid ($CHCl_2COOH$) | | |
| Trichloroacetic acid ($CCl_3COOH$) | | |
| Bromoacetic acid ($C_2H_3BrO_2$) | | |
| Dibromoacetic acid ($C_2H_2Br_2O_2$) | | |



Dichloroacetic Acid




Plus 1.0 mg/L for chlorite and 10 ug/L for bromate

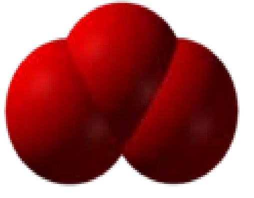
# Background

- Total trihalomethane (TTHM) four-quarter running average was found to be 221.5 *u*g/l
  - US and Ohio EPA limits are 80 *u*g/l

- May 31, 2003: Ohio EPA placed the city water facility under a Findings and Orders consent degree with a scheduled compliance date for TTHM of November 2007

# Investigation of Alternatives

- It was determined that none of the City's existing treatment processes were effective in reducing TTHMs
  - In fact, the ozonation was suspected of breaking down the TOC into compounds which would more easily react with chlorine to form TTHMs



Ozone

- The City began a program to investigate alternative solutions

# Investigation of Alternatives

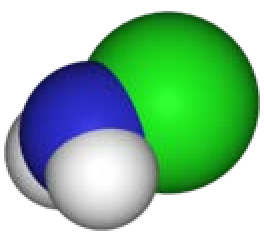
- Initial alternatives explored in 2003-2004
  - Switch to groundwater
    - Unrealistic – Great Lakes Water Compact prohibits withdrawal of water from GL watershed for expulsion into another basin – City discharges into Gulf of Mexico watershed
  - Sulfur modified iron (SMI)
    - No appreciable effect
  - Conventional water clarification system
    - Reduced TOC 69%, but TTHM remained at 170 *u*g/l
  - Magnetic ion exchange (MIEX)
    - 38%-48% DOC removal, but TTHM remained above 100 *u*g/l except when combined with chloramine as final disinfectant

# Investigation of Alternatives

- In September 2004, City Council authorized an RFQ for facility improvements
- Floyd Browne and Metcalf & Eddy/AECOM were selected to lead the project
- Short list of treatment technologies was developed:
  - Switching to monochloramine disinfection
  - Installation of a reverse osmosis (RO) system
  - Installation of a granular activated carbon (GAC) system

# Investigation of Alternatives

- Monochloramine addition was viewed as a potential short term solution
  - Technology was rejected due to:
    - concerns regarding formation of emerging DBPs (e.g. N-Nitrosodimethylamine, cyanogen chloride)
    - known effects of toxicity to marine life and potential nitrification in the distribution lines



**Chloramine**

# Investigation of Alternatives

- Reverse Osmosis (RO) to remove organic DBP precursors was considered
  - Problems arose in the piloting effort
  - Issues centered on pretreatment of water to protect the RO membranes from fouling
  - The pretreatment problem proved complicated and time consuming
  - Given the high degree of urgency to meet the consent decree and the complexity of the pretreatment issues, RO was eliminated as a viable solution

# Investigation of Alternatives

- Ultimately, granular activated carbon (GAC) technology was selected
  - Well known technology
  - Widely effective for a broad variety of drinking water sources
  - Piloting was simple and easily implemented

# Pilot Testing Program

- A 3-phase pilot study was begun on December 13, 2005
  - Phase I: evaluated different GAC products
  - Phase II: simulated a two-vessel series system containing the selected GAC
  - Phase III: studied the operation of two vessels in a lead/lag staged bed operation

- Water plant operation was expanded to 3 shifts

- Calgon Carbon Corporation provided pilot columns and various grades of GAC for testing

# Pilot Testing Program

- Individual pilot columns were filled to 4' depth with selected products
- These were run in various combinations to simulate beds with 8' media depths

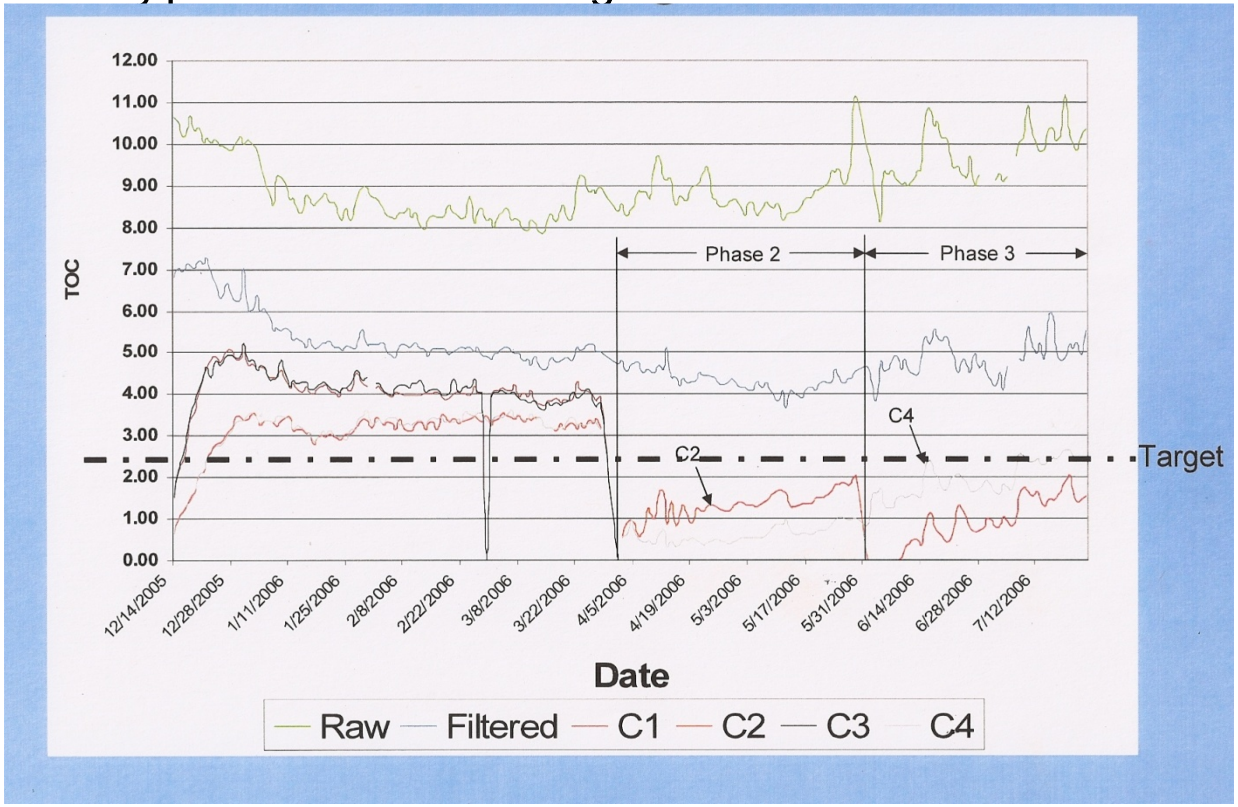
# Pilot Testing Program

# Pilot Testing Results

- Series operation with staged replacement provided significant reduction in carbon usage over single bed operation
  - Staged Operation: spent GAC in lead vessel is exchanged with fresh GAC and valved to operated second in the series
- GAC adsorption could easily and consistently achieve targeted TOC level of 2.5 mg/l
- Projected annual operating cost (using virgin GAC only) was $1.21/1,000 gal treated
  - Assumes influent TOC of 10 mg/l
  - This cost is higher than average municipal GAC systems, which typically range from $0.15/1,000 gal to $0.70/1,000 gal treated
    - Increase due to extraordinarily high influent TOC level present at Celina

# Pilot Testing Results

- Bituminous coal based, agglomerated GAC was found to provide the best performance
  - Specific type selected: Calgon Carbon FILTRASORB 300



# Full Scale Implementation

- Full scale system:
  - (8) x 40,000 lb. GAC pressure vessels
  - Operate in (4) parallel trains
  - Operate in staged sequence
  - Design flow rate: 520 gpm
    - Current actual flow rate: 240 gpm = 1.5 MGD for the entire system
    - At current flow, empty bed contact time (EBCT) = 78 minutes/vessel

# Full Scale Implementation

- Full scale system:
  - At current flow, empty bed contact time (EBCT) = 78 minutes/vessel
  - **8 vessels, each holding 40,000 lbs. of GAC.**
  - **Assumed BWD density of 32 pcf.**
  - **GAC volume is therefore 40000/32 = 1,250 cf**
  - **Vessels are arranged in (4) parallel trains.**
  - **Current flow rate is 240 gpm per train, per your note below.**
  - **(2) vessels in each train operate in parallel, so that the flow rate per vessel is 120 gpm**
  - **Therefore total system flow at this time equals 120 gpm x 8 = 960 gpm, which equals 1.38 MGD**
  - **EBCT = (V*C)/Q, where V = GAC volume in cubic feet, Q = flow rate in gpm, and C = conversion factor of 7.48 gallons/cf**
  - **EBCT = (1250*7.48)/120 = 77.92 minutes**

  - EBCT (at design flow) = (1250*7.48)/260 = 36 minutes

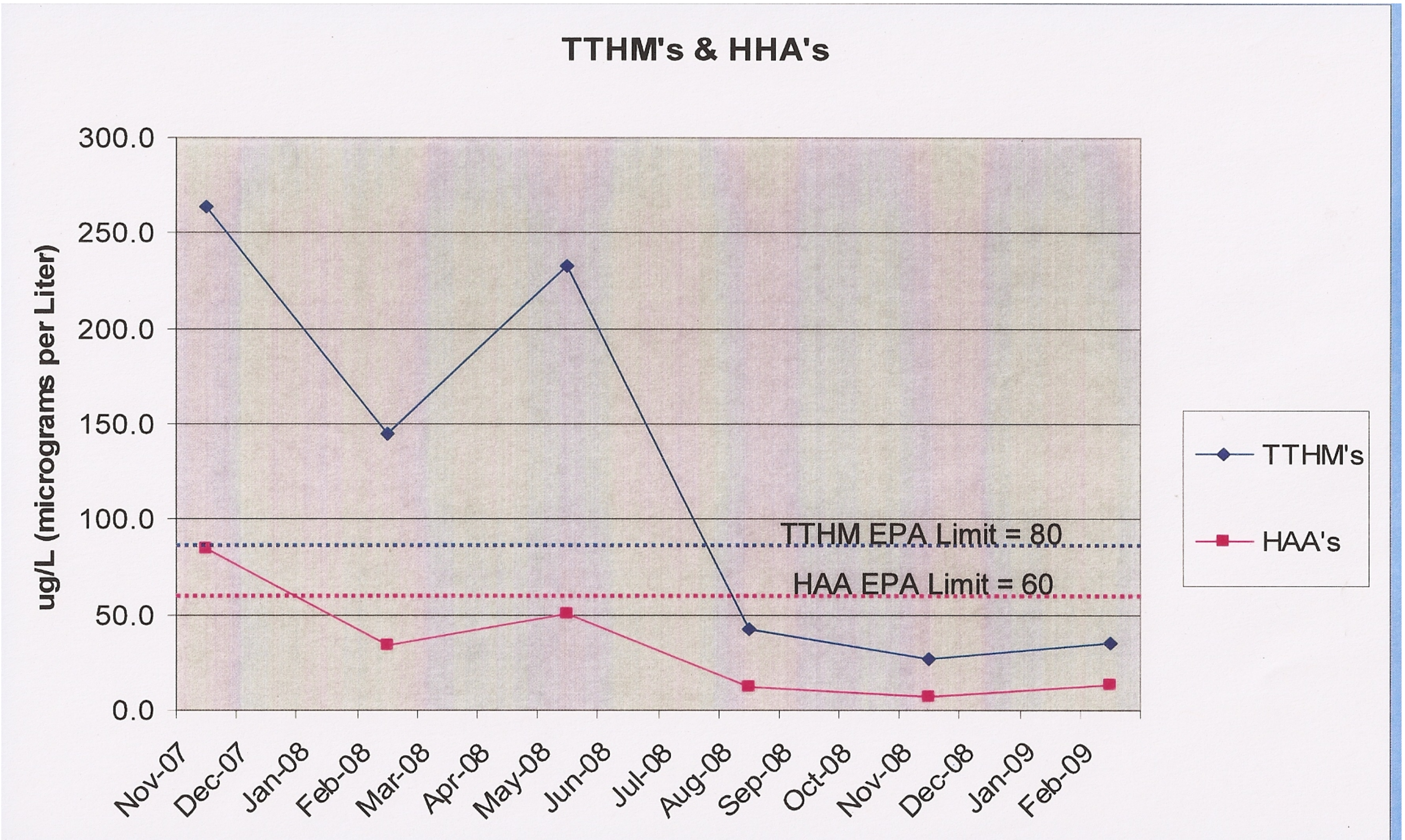
# Full Scale Implementation


**Full scale Celina systems – (8) x 12' diameter, 40,000 lb capacity vessels**

# Operating Data

- GAC system brought on-line July 2008
- System reduced finished water TOC to below 2.0 mg/l
- System reduced TTHM and HAA5 levels below the required levels of 80 *u*g/l and 60 *u*g/l, respectively

# Operating Data



# Treatment Costs

- Total capital cost for project: $7 million
  - Included: building, pumps, wet well, controls, lab, replacement intake structure, replacement sand filter valves, piloting, engineering, and the GAC system

- GAC system, including initial GAC fill, amounted to $1.73 million

# Treatment Costs

- Plant has switched to custom reactivated GAC (from virgin GAC)
  - Significant reduction in operating cost
  - No measurable reduction in performance

- Operating cost: $384,000/year
  - $0.35/1,000 gal treated based on installed capacity
  - Includes: reactivation of GAC, addition of make-up GAC, transportation, warehousing and services

- Estimated ten (10) year lifecycle cost
  - $0.51/1,000 gal treated
  - Accounts for initial capital expenditure plus ongoing operating costs

# Current Status

- Since start-up of the GAC systems, the expanded and improved WTP has produced an average of 1.5 MGD of drinking water, consistently measuring below the treatment goals for TTHMs and HAA5s

- As of Sept 30, 2009, the Findings and Orders decree has been lifted

# Current Status

- If necessary, space exists for an additional four (4) GAC adsorbers
- At this point, GAC addition appears to have completely solved the issues associated with DBP compliance, while also significantly improving the taste, odor, and appearance of the Grand Lake water
- They are currently using custom reactivation service for the spent carbon

# Thank You!

# Questions?