Performance of GAC Filter-Adsorbers for Herbicide and DBP Control at Higginsville, MO

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Background

- Atrazine can be detected in most drinking water supplies throughout the northern agricultural region of Missouri and the Midwest.

- Drinking water MCL = 3 µg/L.

- Since 1994, herbicide-impacted water plants have controlled atrazine levels by treatment with powdered activated carbon (PAC) or sought alternative water sources.

- Some plants in Illinois and Iowa have used granular activated carbon (GAC) for atrazine control. No plants in Missouri were using GAC prior to August, 1996, when Higginsville installed GAC into two of its four filters.
Atrazine

- Atrazine enters the water supply via agricultural runoff. Excessive runoff levels (10 to 500 µg/L) occur when atrazine is over-applied, used on highly erodible land, or when an untimely, intense rain follows application.

- Additionally, the runoff may carry other herbicides (cyanazine, metolachlor) and atrazine breakdown products.

- In lakes, the degradation of atrazine is slow. Thus, high levels may persist over time unless the lake is “flushed” with inflow not containing atrazine.
Herbicide Levels in Missouri Surface Water Systems

Herbicide Occurrence (% Detects of Individual Species)

- atrazine
- cyanazine
- metolachlor
- others

Concentration Range (µg/L)

<1 1-3 3-5 5-10 >10
Overview

Higginsville Water Treatment Plant
- Surface water system, agricultural drainage
- 50-year old lake, 12-year old treatment facility
- ~1 MGD production, 10 to 12 hr/d production

Historical Atrazine and T&O Problems
- Notice of violation for atrazine MCL, 1994
- Feed PAC from 1995 to 1996, 10 to 30 mg/L
- Convert Filters 3&4 to GAC caps (24”) in Aug, 96
- Convert Filters 1&2 to GAC caps in March, 99

In-plant Operational Studies
- Particle counting study (1997)
- Monitoring of UV$_{254}$ absorbance
- Monitoring of total triazines
- Investigations of ammonia and T&O episodes
Higginsville Treatment Process

Higginsville Lake -> ClO₂, Alum, PAC (opt.) -> Floc. A -> Sed. A.

Sed. B -> Floc. B. -> Lime
Polymer
Fluoride
Cl₂

Cl₂

GAC-capped filters

Clearwell
# Higginsville Lake Water Quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Range</th>
<th>Mean</th>
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<tbody>
<tr>
<td>Production</td>
<td>Mgd</td>
<td>0.72 – 1.07</td>
<td>0.85</td>
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<tr>
<td>Temperature</td>
<td>°F</td>
<td>45 - 79</td>
<td>63</td>
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<tr>
<td>pH</td>
<td>pH units</td>
<td>7.19 – 9.27</td>
<td>8.14</td>
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<tr>
<td>Total Alkalinity</td>
<td>mg-CaCO\textsubscript{3}/L</td>
<td>56 - 116</td>
<td>89</td>
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<tr>
<td>Hardness</td>
<td>mg-CaCO\textsubscript{3}/L</td>
<td>84 - 189</td>
<td>129</td>
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<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>0.17 - 0.54</td>
<td>0.32</td>
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<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>2.4 - 96</td>
<td>18</td>
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<tr>
<td>Ammonia</td>
<td>mg/L</td>
<td>0.01-0.79</td>
<td>0.13</td>
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<tr>
<td>TOC</td>
<td>mg/L</td>
<td>4 - 17</td>
<td>6</td>
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<tr>
<td>UV\textsubscript{254}</td>
<td>cm\textsuperscript{-1}</td>
<td>0.08 - 0.3</td>
<td>0.11</td>
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</table>
PAC Application Considerations

- PAC feeding is a messy operation and requires operator labor. Potentially hazardous (respiratory, explosive).
- Storage and feeding equipment is required.
- Slurry introduction, contacting, and suspension time affect the performance (relatively inefficient). Complete removal of herbicides will not be attained.
- The PAC feed rate may be adjusted according to water quality; thus, PAC usage and costs can be minimized.
- A large amount of black sludge must be disposed of.
PAC Usage for Atrazine Removal at Higginsville

- Raw Water
- Finished Water

MCL = 3 µg/L

- Month/Year: 10/94, 1/95, 4/95, 7/95, 10/95, 1/96, 4/96, 7/96
- PAC Feed Rate (mg/L)
- Atrazine Concentration (µg/L)
Sludge Dewatering Basin with PAC
GAC Application Considerations

- Useful for T&O control, SOC (herbicides) removal, and partial removal of natural organic matter (THM precursors).
- GAC will scavenge free and combined chlorine. Thus, minimal chlorine should be applied ahead of the GAC.
- Backwash rates may need to be adjusted.
- Biological growth in bed will occur:
  - Beneficial contribution to removal of N & C.
  - May shed bacteria, but not known to grow pathogens.
- Exhausted GAC must be removed for regeneration and replaced. Off-site regeneration is the norm for all but the largest systems.
**AS Filter**

- **Anthracite**: 17 in
- **Fine Sand**: 12 in
- **Torpedo Sand**: 4 in
- **Coarse Sand**: 6 in
- **Graded Gravel**: 6 in
- **Under Drains**:

**Backwash Troughs**: 33.5 in

**Surface Wash Arms**: 2 in

**GS Filter**

- **GAC**:

- **Dimensions**:
  - Height: 21 in
  - Total Height: 26.5 in
  - Under Drains: 2 in
GAC Bulk Packs Awaiting Installation
One-step Anthracite Transfer and Dewatering Equipment
Slurrying the GAC into the Filter Well
Comparison of Anthracite and GAC Cap

Graph showing the comparison of turbidity (NTU) over time from Jan-97 to Jan-2K. The graph includes lines for Filter Influent, FA 3&4, FA 1,2,3&4, and AF 1&2. The x-axis represents the date, and the y-axis represents turbidity in NTU.
Comparison of Particle Counts

NP > 2 µm/mL

Time Elapsed Since Backwash of Filters, (hours)

AS Filtered Water
GS Filtered Water
Turbidity Reduction and Return

- **Turbidity (NTU)**:
  - 0.02
  - 0.03
  - 0.05
  - 0.07
  - 0.2
  - 0.3
  - 0.5
  - 0.7
  - 2
  - 3
  - 5
  - 7
  - 20
  - 30
  - 50
  - 70
  - 10.00
  - 1.00
  - 10.00

- **Dates**:
  - Jan-97
  - Apr-97
  - July-97
  - Oct-97
  - Jan-98
  - Apr-98
  - July-98
  - Oct-98
  - Jan-99
  - Apr-99
  - July-99
  - Oct-99
  - Jan-2K

- **Water Types**:
  - Raw Water
  - Clear Well
  - Filtered Water

- **MCL**

- **Filtering**
  - FA 3&4
  - FA 1,2,3&4

- **Legend**

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**Graph Description**

- The graph shows the turbidity levels of raw water, clear well, and filtered water over different periods from Jan-97 to Jan-2K.
- The raw water turbidity fluctuates significantly, while the turbidity levels in clear well and filtered water are much lower and more stable, generally below 0.3 NTU.
- The dotted line represents the maximum concentration level (MCL) for turbidity, which is typically set by regulatory bodies to ensure water quality.
Correlation of Clearwell Turbidity, Raw Water Ammonia, and Overall Chlorine Demand
Total Triazine Concentrations at Higginsville, MO WTP

Days in Service

0 90 180 270 360 450 540 630 720

EIA Total Triazine Concentration (µg/L)

0 1 2 3 4 5 6

Raw Water
Finished Water
GAC Filters

Atrazine Runoff Event
USEPA MCL
High Runoff Period Extensive Flushing
Triazine Removal at Higginsville, MO WTP

% Total Triazine Removal

Days in Service

GAC Filters

Anthracite Filters

PAC Feeding Periods
Days in Service (since inst. new GAC)

Total Triazine Concentration (µg/L)

- Raw water
- FA-3&4, inst. Aug., 96 (old)
- Finished water
- FA-1&2, inst. March, 99 (new)

USEPA MCL
NOM is produced from decaying vegetation and leaching of soil humins, and is typically composed of humic substances, fulvic acids, and humic acids.

NOM is often measured as TOC or DOC and \( \text{UV}_{254} \) is also a useful measure.

TOC concentrations in Midwest surface waters typically range from 3 to 10 mg/L.
Formation of DBP’s During Chlorination

\[ \text{Cl}_2 + \text{H}_2\text{O} \rightleftharpoons \text{HOCl} + \text{HCl} \]

\[ \text{HOCl} + \text{Br}^- \rightleftharpoons \text{HOBr} + \text{Cl}^- \]

\[ \text{HOCl} + \text{HOBr} + \text{NOM} \Rightarrow \text{THM} + \text{HHA} + \text{RX}??? \]

(toxins and carcinogens)
Removal of NOM by GAC Filter-Adsorbers

Days Since New GAC Installation

UV254 Removal (%)

- GAC-FA 1&2 (new)
- GAC-FA 3&4 (old)
Overall Removal of NOM by Coagulation and GAC

![Graph showing UV absorbance over time for different water types and coagulant doses.](image)

- Raw Water
- Treated Water (alum)
- Finished Water (GAC)

**1999**

- UV254 Absorbance (cm⁻¹)
- Coagulant Dose (mg/L)

- Alum
- Raw water
- Treated water
- Finished water

Switch to PACl
THHA_5 Running Annual Averages at Higginsville

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<tr>
<td>Total Haloacetic Acid (5) Concentration (µg/L)</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td></td>
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- Stage 1 MCL (2001)
- Stage 2 MCL (future)
- Post-FA 1&2
- Post-FA 3&4
Characterization of GAC Physical Deterioration

![Graph showing the change in Apparent Density (g/cc) and Iodine Number (mg/g) over Days in Service. The graph indicates a decrease in Apparent Density and an increase in Iodine Number over time.](image)
Conclusions

1. Atrazine removal is acceptable with high removal in the first year of service declining to minimal removal after 4 years of service.

2. GAC buffers against sudden increases in atrazine.

3. Operational adjustments must be made with backwashing and chlorination practice.

4. High, short-term removal of NOM is obtained for three months followed by long-term biological removal of 20%.

5. Particle removal is comparable to anthracite.

6. Reduction of HAA₅ is apparent with use of ClO₂ as preoxidant and good coagulation (alum).

7. Staggered replacement offers operational flexibility and reduces costs.