Regional Water Quality Issues:
Algae and Associated Drinking Water Challenges

Workshop – August 2005

A Cooperative Research and Implementation Program
Arizona State University (Tempe, AZ)
Milton Sommerfeld, Paul Westerhoff, Qiang Hu, John Crittenden,
YoungIl Kim, Bo Song, Tom Dempster, Everett Shock, Panjai
Prapaipong, Larry Baker and Marisa Masles

Salt River Project
Central Arizona Project
City of Phoenix
City of Tempe
City of Peoria
City of Chandler
ASU NSF Water Quality Center

Agenda

Purpose: Provide a forum to review and discuss on-going regional water quality issues, in particular algae-associated issues.

- 8:30 Introductions
- 8:45 Overview of T&O issues for 2005
- 9:15 Trace metals in the water supplies
- 9:30 Fundamentals of GAC: T&O and DOC control
- 10:00 Break
- 10:15 Recent Progress on DNA-based probes for T&O and toxin producing algae
- 10: 40 Sonication for algae control
- 10:50 Future directions & discussion
- 11:00 Meeting adjournment
Overview of T&O issues for 2005

What is unique about 2005?

Workshop will present results as water moves down through the watershed
Salt River Above Roosevelt

Hydrology Affects Water Quality
(conductance can affect algal dominance)
Arsenic

Temperature (°C)

Depth from surface (m)

Potential for Mn Release

Winter Rains

MCL = 10 µg/L

Saguaro Lake

Weak Stratification
Summary of Annual August Temperatures

Dissolved Nitrogen Trends in Reservoirs
Total Phosphorous

Secchi Disk Depth Influenced by Inorganic Suspended Sediment and/or Organic Biomass
Up-stream reservoirs attenuate DOC

Specific UV Absorbance at 254 nm
DOC Removal by WTP

- Influent (2004)
- Influent (2005)
- Effluent (2005)

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<thead>
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</thead>
<tbody>
<tr>
<td>24th Street WTP</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>DV WTP</td>
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<tr>
<td>VV WTP</td>
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<tr>
<td>Green WTP</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>NP WTP</td>
<td></td>
<td></td>
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<tr>
<td>SPT WTP</td>
<td></td>
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<td></td>
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<tr>
<td>UH WTP</td>
<td></td>
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</tbody>
</table>
Predicting Expected FPA Intensity based upon GC/MS data

Earthly Musty FPA Value = 0.800*MI**0.396**Geo**-0.110**Cyclocitral**0.350**

$R^2 = 0.728$

FPA= 2 when MIB=5, Geosmin=3, Cyclocitral=3 ng/L
FPA= 3 when MIB=8, Geosmin=8, Cyclocitral=8 ng/L

Geosmin Data
MIB Data – Lake Pleasant

MIB is low in Lake Pleasant in 2005

MIB Data – Bartlett Lake

MIB is low in Bartlett Reservoir in 2005

MIB is low in Lake Pleasant in 2005

MIB is low in Bartlett Reservoir in 2005
MIB Data – Saguaro Lake

MIB is low in Saguaro Lake in 2005

Conductance in reservoirs has been a general indicator for T&O
Blue-green algae prefer higher TDS

Baker MIB Production/Loss
Mass Balance Model for Canals

MIB load leaving segment = MIB load entering segment + production within the segment – MIB lost via diversions

- For the simple case of one diversion, the model is:
  \[ [\text{MIB}]_u \cdot Q_u \cdot 10^{-6} = [\text{MIB}]_l \cdot Q_l \cdot 10^{-6} + k \cdot L - k \cdot L_d \cdot Q_{d, out} / Q_{d, AZ} \]

- Where
  - \([\text{MIB}]_u\) = MIB concentration at upper end of segment
  - \(Q_u\) = flow at upper end of segment, m3/day
  - \([\text{MIB}]_l\) = MIB concentration at lower end of segment, ng/L
  - \(Q_l\) = flow at lower end of segment
  - \(k\) = MIB production rate (0th order), g/mile
  - \(L\) = length of segment, miles
  - \(L_d\) = length of segment from upper end down to diversion within a segment
  - \(Q_{d, out}\) = flow from diversion, m3/day
  - \(Q_{d, AZ}\) = flow in the Arizona Canal at the point of diversion
### Predict “k” values along Arizona Canal for loss of MIB (g/mile-day)

<table>
<thead>
<tr>
<th>Canal Segment</th>
<th>8/4/03</th>
<th>8/25/03</th>
<th>10/23/03</th>
<th>7/6/04</th>
<th>9/28/04</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below X-connect to Pima Road</td>
<td>2</td>
<td>6.1</td>
<td>9.2</td>
<td>0.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Pima Road to 24th Street WTP</td>
<td>0.6</td>
<td>-1</td>
<td>1.7</td>
<td>3.7</td>
<td>1.7</td>
</tr>
<tr>
<td>24th Street WTP to Deer Valley WTP</td>
<td>3.4</td>
<td>2.5</td>
<td>1.5</td>
<td>1</td>
<td>0.33</td>
</tr>
<tr>
<td>Deer Valley WTP to Greenway WTP</td>
<td>-1.6</td>
<td>-5.5</td>
<td>-4.4</td>
<td>-0.1</td>
<td>-5.1</td>
</tr>
</tbody>
</table>

### Recent Trends of In-situ MIB Production (ΔMIB in ng/L) in Arizona Canal
(Geosmin and Cyclocitrall follow similar patterns)

<table>
<thead>
<tr>
<th>Canal Segment</th>
<th>6/28/05</th>
<th>7/12/05</th>
<th>7/26/05</th>
<th>8/16/05</th>
<th>8/25/05</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIB below X-connect</td>
<td>&lt;2 ng/L</td>
<td>&lt;2 ng/L</td>
<td>3.1 ng/L</td>
<td>4.8 ng/L</td>
<td></td>
</tr>
<tr>
<td>Below X-connect to Pima Road</td>
<td>2.5</td>
<td>1.0</td>
<td>7.0</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>Pima Road to 24th Street WTP</td>
<td>1.2</td>
<td>~0</td>
<td>~0</td>
<td>3.3</td>
<td>~0</td>
</tr>
<tr>
<td>24th Street WTP to Deer Valley WTP</td>
<td>-0.8</td>
<td>0.7</td>
<td>2.4</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Deer Valley WTP to Greenway WTP</td>
<td>--</td>
<td>1.5</td>
<td>-3.2</td>
<td>-4.1</td>
<td></td>
</tr>
</tbody>
</table>
SRP Change in River Release affected MIB Production in the canals – suggests conductance effect

Dalla Riegel/SRP - says plan is to keep Verde flow low (300cfs) now that Horseshoe has been lowered for bird habitat. They will use primarily Salt River water through December unless it rains.

MIB levels higher in AZ Canal system compared against South Canal system
Table 3 - Canal Sampling – August 30, 2005

<table>
<thead>
<tr>
<th>System</th>
<th>Sample Description</th>
<th>MIB (ng/L)</th>
<th>Geosmin (ng/L)</th>
<th>Cyclocitrinal (ng/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAP</td>
<td>Waddell Canal</td>
<td>&lt;2.0</td>
<td>&lt;2.0</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td></td>
<td>Waddell Canal - CAP</td>
<td>&lt;2.0</td>
<td>&lt;2.0</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td></td>
<td>Union Hills Inlet</td>
<td>&lt;2.0</td>
<td>2.5</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>CAP Canal at Cross-connect</td>
<td>2.0</td>
<td>3.9</td>
<td>3.5</td>
</tr>
<tr>
<td>AZ</td>
<td>Salt River @ Blue Pt Bridge</td>
<td>18.2</td>
<td>3.0</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Verde River @ Beeline</td>
<td>21.8</td>
<td>2.1</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>AZ Canal above CAP Cross-connect</td>
<td>14.8</td>
<td>2.4</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td></td>
<td>AZ Canal below CAP Cross-connect</td>
<td>13.4</td>
<td>2.7</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td></td>
<td>AZ Canal at Highway 87</td>
<td>14.3</td>
<td>3.8</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>AZ Canal at Pima Rd.</td>
<td>15.8</td>
<td>4.4</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>AZ Canal at 56th St.</td>
<td>13.2</td>
<td>3.9</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>AZ Canal - Inlet to 24th Street WTP</td>
<td>13.9</td>
<td>4.3</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>AZ Canal - Central Avenue</td>
<td>16.9</td>
<td>4.9</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>AZ Canal - Inlet to Deer Valley WTP</td>
<td>20.8</td>
<td>7.2</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>AZ Canal - Inlet to Greenway WTP</td>
<td>16.0</td>
<td>3.9</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td>South</td>
<td>South Canal below CAP Cross-connect</td>
<td>16.2</td>
<td>2.6</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td></td>
<td>South Canal at Val Vista WTP</td>
<td>17.4</td>
<td>3.0</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td>Tempe</td>
<td>Head of the Tempe Canal</td>
<td>15.2</td>
<td>2.6</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td>Canals</td>
<td>Tempe Canal - Inlet to Tempe's South Plant</td>
<td>8.8</td>
<td>&lt;2.0</td>
<td>&lt;2.0</td>
</tr>
<tr>
<td></td>
<td>Chandler WTP - Inlet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trace Metals: Cycles, Transport and Urban Signatures

Panjai Prapaipong*, Brandon McLean, Natalya Zolotova, Prof. Everett Shock

GEOPIG, Department of Geological Science
Department of Chemistry and Biochemistry
Arizona State University
panjai@asu.edu

GEOPIG Analytical Facility

High Resolution ICP-MS (minor & trace elements)

Ion Chromatography (major ions)

Others: MS for stable isotopes & isotope ratio, quadrupole MS, GC, GC-MS, microwave digestor

http://geopig.asu.edu
Projects: Environmental Biogeochemistry

- Human-induced biogeochemical cycles of metals
- Chemical footprint of cities, using the Phoenix metropolitan area as a guide
- Micronutrient transport in rivers in response to climate forcing

Sample Locations

Salt River, Feb 2005  Gila River, May 2005
Salt - Gila River

**Pb**
- April 2005
- May 2005
- June 2005

**As**
- April 2005
- May 2005
- June 2005

**ppb**

**Salt + Gila confluence (suburban + farm)**
- Hassayampa Inlet (farm)

**upstream**

**downstream**
Salt - Gila River

**Co**
- April 2005
- May 2005
- June 2005

**Se**
- April 2005
- May 2005
- June 2005

Locations:
- Lab blank
- Field blank
- Saguro
- Salt N. Bush
- Salt Granite
- Tempe Town
- 67th Ave
- 10th Ave
- 115th Ave
- 203rd Ave
- old US 80

**Salt + Gila confluence (suburban + farm)**

**Salt - Gila River**

**Hassayampa Inlet (farm)**

**Verde R. Inlet**

**Tempe**

**Phoenix**

**Upstream**

**Downstream**
Acknowledgements

- Nathan Schnebly
- Marisa Masles
- Young-II Kim

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Fundamentals of GAC

Including T&O and DOC control

John Crittenden
Activated Carbon Adsorption

Is a process whereby molecules are transferred from a fluid stream and concentrated on a solid surface by chemical (e.g., reaction, chemisorption) and physical forces (e.g. Van der Waals, physisorption).
Crushing and sizing raw materials.
Carbonization process removes volatile components from the raw materials and realigns the carbon pore structure.
Activation process selectively removes carbon and opens up the closed pores and increases the average size of micropores. Max. surface area per weight found at 40-50% burnoff.
Two Types of Activation:
Chemical Activation - combines carbonization and activation steps with dehydrating agents (e.g., Zinc chloride, Phosphoric acid) at 300-600°C to extract the cellulose.
Physical Activation - contacting carbonized char with gaseous agents (e.g., CO₂, air, steam) at 850-1100°C

Size and Pore Area as a Function of Mass Burnoff (AC become very friable with a large amount of burnoff and usually use <50%)
Activate Carbon is carbonaceous material manufactured by a process that develops adsorptive properties.

We can see micropores inside of macropores.

Base Material

- Coconut Shell
- Bituminous Coal
- Lignite
- Peat
- Wood
- Petroleum
- Bone Char
Pore Size Distribution Depends on Several Things Including Starting Material

![Pore Size Distribution Chart]

Activated Carbon Adsorption

There are two factors that affect the adsorbability of a compound: size and solubility. Adsorbability increases with increasing size and decreasing solubility.

The factors that affect a given adsorbent's capacity for a given compound is surface chemistry and pore size. As far as surface chemistry is concerned, low ash content and the lowest possible concentration of oxygen containing functional groups will improve adsorption. Starting material affects this. Obviously, the pore size have to be appropriate. TOC requires macropore and mesopores. Some compounds that have very poor adsorbability (e.g., MTBE) can be removed with AC that has more micropores.

Experiments and or models need to be used to determine the effectiveness of AC.
Type of Adsorption reactors

(1) GAC Gravity Feed Filters
(2) GAC Sand Replacement Filters
(3) GAC Pressure Filters
(4) Biologically Active GAC Adsorbers
(5) Powder activated carbon (PAC) contactors

**Activated Carbon Adsorption**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Granular activated carbon (GAC)</th>
<th>Powdered activated carbon (PAC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Principal uses</strong></td>
<td>Control of toxic organic compounds that are present in groundwater</td>
<td>Seasonal control of taste and odor compounds and strongly adsorbed pesticides and herbicides at low concentration (&lt;10 ug/L). Typical Dosages 3 – 15 mg/L. Size: 10 to 70 microns.</td>
</tr>
<tr>
<td></td>
<td>Barrier to occasional spikes of toxic organics in surface waters and control of taste and odor compounds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Control of disinfection by-product precursors or DOC. Typical Operating Conditions: 10 to 30 min of contact time, Size: .7 to 1.3 mm.</td>
<td></td>
</tr>
<tr>
<td><strong>Advantages</strong></td>
<td>Easily regenerated</td>
<td>Easily added to existing coagulation facilities for occasional control of organics</td>
</tr>
<tr>
<td></td>
<td>Lower carbon usage rate per volume of water treated as compared to PAC</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>Need contactors and yard piping to distribute flow and replace exhausted carbon</td>
<td>Hard to regenerate and impractical to recover from sludge from coagulation facilities</td>
</tr>
<tr>
<td></td>
<td>Previously adsorbed compounds can desorb and in some cases appear in the effluent at concentrations higher than present in the influent</td>
<td>Much higher carbon usage rate per volume of water treated as compared to GAC</td>
</tr>
</tbody>
</table>
Important Variables in Fixed Bed Adsorption

\[ M_{GAC} \]

\[ Q \]

\[ V = \frac{Q}{A_F} \]

\[ A_F = \text{X-sec Area} \]

\[ V_F = \frac{\text{Volume of Bed}}{A_F} = A_F L \]

\[ L \]

\[ \text{Empty Bed Contact Time} \]

\[ \text{EBCT} = \frac{V_F}{Q} = \frac{A_F L}{V A_F} = \frac{L}{V} \]

GAC Packed Bed Alternatives

GAC Sand Replacement Reactor: Replacement of sand in a filtration operation. This gives only 3-7 minutes of EBCT but the GAC seems to last for many years for Taste and Odor compounds probably because of biological degradation.

Removal of Hazardous Organic Compounds: Provide longer EBCT (10-20 minutes). The greatest amount of water treated/ mass of GAC is found for EBCTs around 10-20 minutes. Backwashing is to be avoided.

DOC/TOC removal for disinfection by product removal: The greatest amount of water treated/ mass of GAC is found for EBCT 15-45 minutes. Backwashing is to be does not seem to matter and is required.

In water treatment, often BioI is high therefore hydraulic loading does not matter for a given EBCT. (External mass transfer does not matter.) Typical hydraulic loading is Typical filter velocities range from 5 - 15 m/h (2 - 7 gpm/ft²).
A beds in-series operation will utilize more column capacity than a single bed operation especially for less stringent treatment objectives (e.g. $C/C_{TO} < 0.05$). Increase of 20 to 50% more water treated/mass GAC.
A beds in-parallel operation will utilize more column capacity than a single bed operation specially for less stringent treatment objectives (e.g. $C/C_{TO} > 0.3$). An increase of 50 to 150% more water treated/ mass GAC depending on Treatment Objective and increases as the number of contactors in parallel is increased.

### GAC Column Operation

**Methods for estimating full scale GAC performance**

<table>
<thead>
<tr>
<th>Method</th>
<th>Reliability</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot studies</td>
<td>Excellent</td>
<td>1. Can predict full scale GAC performance very accurately.</td>
<td>1. Can take a very long time to obtain results.</td>
</tr>
<tr>
<td>RSSCTs</td>
<td>Good</td>
<td>1. Can predict full scale GAC performance accurately.</td>
<td>2. Expensive and must be conducted onsite.</td>
</tr>
<tr>
<td>Models</td>
<td>Fair</td>
<td>1. Once calibrated, models can be used to predict impact of EBCT and changes in influent concentration.</td>
<td>1. Cannot predict TOC breakthrough and must be used in conjunction with pilot or RSSCT data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Can predict breakthrough of SOCs with 20 to 50 percent error.</td>
<td>2. Accurate prediction of SOC removal requires calibration with pilot or RSSCT data.</td>
</tr>
</tbody>
</table>
Consider the case study performed by Metropolitan Water District of Southern California to remove trihalomethane formation potential from their drinking water. In this case, the influent concentration is about 2.5 mg/L as TOC and the treatment objective is 1.0 mg/L as TOC which corresponds to 50 ug/L SDS THMFP.

Design Strategies for TOC Removal – Notice the Convex downward Breakthrough Curve
Fig. 9. Liters of water treated per gram of GAC for a DOC treatment objective of 1 mg/l as a function of EBCT for both the raw pilot data and PDM calculations.
Design Strategies for TOC Removal

Rapid Small Scale Column Tests (RSSCTs) can be used to assess GAC performance
Photograph of RSSCT setup with large 250-gallon feed tank behind columns

Rapid Small Scale Column Tests (RSSCTs) can be used to assess GAC performance

Figure 12. Comparison of TOC breakthrough profile from RSSCT with that from pilot GAC column (setup of RSSCT assumed intraparticle diffusivity to be a linear function of GAC particle size)
Rapid Small Scale Column Tests (RSSCTs) can be used to assess GAC performance.

**Figure 14.** TOC breakthrough profiles for RSSCT and pilot plant for Jefferson Parish (RSSCT EBCT—15 min; pilot EBCT—20 min; pilot run 3)

### City of Scottsdale Testing by ASU

<table>
<thead>
<tr>
<th>Design Parameters</th>
<th>Full-scale</th>
<th>RSSCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Radius (cm)</td>
<td>0.0513 (12 X 40)</td>
<td>0.0049 (140x170)</td>
</tr>
<tr>
<td>EBCT (minutes)</td>
<td>20</td>
<td>1.91</td>
</tr>
<tr>
<td>Loading Rate (gpm/ft²) [m/h]</td>
<td>4.3 (12)</td>
<td>3.0 (7.35)</td>
</tr>
<tr>
<td>GAC Contactor Length (ft)</td>
<td>25</td>
<td>1.1</td>
</tr>
<tr>
<td>Width (ft)</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Surface Area (ft²)</td>
<td>1250</td>
<td></td>
</tr>
<tr>
<td>RSSCT Column Diameter (cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bed Depth</td>
<td>10 ft (256 cm)</td>
<td>23.4 cm</td>
</tr>
</tbody>
</table>
TOC and UVA breakthrough curves from RSSCTs

![Graph showing TOC and UVA breakthrough curves from RSSCTs with different adsorbents.]

- TOC (mg/L) against BV Treated
- UVA254 (1/cm) against BV Treated
- Adsorbents: Calgon(F400), NORIT1240, NORIT40S, COL-GL, Aquasorb1500
Consider a pilot plant study performed by Hand et al. (1989). The following table summarizes the organic compounds to the column and their average influent concentrations from well no. 4 (Hand et al., 1989).

<table>
<thead>
<tr>
<th>Volatile Organic Compound</th>
<th>Number of Data</th>
<th>Average Influent Concentration (µg/L)</th>
<th>Standard Deviation (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl Chloride</td>
<td>41</td>
<td>8.2</td>
<td>2.4</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>44</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Cis-1,2-Dichloroethene</td>
<td>44</td>
<td>70.9</td>
<td>19.0</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>44</td>
<td>47.9</td>
<td>22.1</td>
</tr>
<tr>
<td>Tetrachloroethene</td>
<td>44</td>
<td>37.6</td>
<td>17.6</td>
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<tr>
<td>Toluene</td>
<td>36</td>
<td>19.3</td>
<td>11.7</td>
</tr>
<tr>
<td>Ethyl Benzene</td>
<td>35</td>
<td>4.5</td>
<td>.9</td>
</tr>
<tr>
<td>P-Xylene</td>
<td>37</td>
<td>5.2</td>
<td>1.7</td>
</tr>
<tr>
<td>O and P Xylene</td>
<td>38</td>
<td>9.3</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Consider the following effluent profiles for cis-1,2-dichloroethene (DCE) taken from a pilot plant study in Wausau, WI (Hand et al., 1989). Notice the shape to the Breakthrough Curve.
Design Strategies for a Single Compound

Consider the following effluent profiles for cis-1,2-dichloroethene (DCE) taken from a pilot plant study in Wausau, WI (Hand et al., 1989).

Impact of Backwashing for SOC Removal
**Model Predicted Removal**

<table>
<thead>
<tr>
<th></th>
<th>k</th>
<th>unit</th>
<th>n</th>
<th>Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIB</td>
<td>17.6</td>
<td>ng/mg(L/ug)1/n</td>
<td>0.34</td>
<td>184.2946</td>
</tr>
<tr>
<td>Geosmin</td>
<td>34.5</td>
<td>ng/mg(L/ug)1/n</td>
<td>0.35</td>
<td>387.0964</td>
</tr>
</tbody>
</table>


**EBCT = 7.5min**

Results for the PSDM (No Reactions Present)

<table>
<thead>
<tr>
<th></th>
<th>MIB</th>
<th>Length of the MTZ (cm)</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% of influent conc:</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>50% of influent conc:</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>95% of influent conc:</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Treatment Objective</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Grid Style: None

Excel... Save Curves Select Printer Print Print to File
GAC Caps for MIB Control

- GAC Filter caps
- Replace anthracite layer in dual media filters; sand layer remains
- Provides short-term adsorption for DOC (DBP precursors) and MIB / Geosmin
- Provides sustainable removal via biodegradation
- Would have to delay point of chlorination to have biologically active GAC
- MPI pilot study; Chandler WTP experience

Chandler WTP

- Full-Scale Filter Design:
  - Filter caps designed to act as a barrier against synthetic organic compounds and T&O compounds
  - 20 inches GAC (8x30 US mesh size, Elf Atochem)
  - 10 inches of sand support
  - 12 inches of graded gravel
  - GAC replaced every 3 years @ HLR = 4 gpm/sf Purpose of the study:
    - It was planned to increase the capacity the WTP by increasing the rate of filtration from 4 to 6 gpm/sf
    - Evaluate the effect of a higher filtration rate on the removal of T&O compounds
    - RSSCT Tests
    - Modeling and cost estimates
Rapid Small Scale Columns

Effect of EBCT and carbon "age"
100 ng/L Spike of Geosmin and MIB
Effect of EBCT and carbon “age”

100 ng/L Spike of Geosmin and MIB

Effect of EBCT and carbon “age”

100 ng/L Spike of Geosmin and MIB
MIB
• 40% sustainable removal
• 1000 bed volumes ~ 1 day

Geosmin
• 80% sustainable removal
Fraction MIB and geosmin remaining according to Powder Activated Carbon (PAC)

<table>
<thead>
<tr>
<th>NO</th>
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<tbody>
<tr>
<td>1</td>
<td>wood</td>
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<tr>
<td>2</td>
<td>wood</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Coal</td>
</tr>
<tr>
<td>5</td>
<td>Lignite</td>
</tr>
<tr>
<td>6</td>
<td>Bituminous</td>
</tr>
</tbody>
</table>

Fraction MIB remaining (C/Co)

- PAC Dose 15 mg/L
- PAC Dose 25 mg/L

Fraction geosmin remaining (C/Co)

- PAC Dose 15 mg/L
- PAC Dose 25 mg/L

NO | source  |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>wood</td>
</tr>
<tr>
<td>2</td>
<td>wood</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Coal</td>
</tr>
<tr>
<td>5</td>
<td>Lignite</td>
</tr>
<tr>
<td>6</td>
<td>Bituminous</td>
</tr>
</tbody>
</table>
Activated Carbon Summary

- There are two factors that affect the adsorbability of a compound: size and solubility. Adsorbability increases with increasing size and decreasing solubility.
- The factors that affect a given adsorbent's capacity for a given compound is surface chemistry and pore size. As far as surface chemistry is concerned, low ash content and the lowest possible concentration of oxygen containing functional groups will improve adsorption. Starting material affects this. Obviously, the pore size have to be appropriate. TOC requires macropore and mesopores. Some compounds that have very poor adsorbability (e.g., MTBE) can be removed with AC that has more micropores.
- GAC has a much lower carbon usage rate per volume of water treated as compared to PAC; however, contactors and yard piping is Needed to distribute flow and replace exhausted carbon
- PAC can easily be added to existing coagulation facilities for occasional control of organics such as MIB and Geosmin but very high dosages of PAC are required to control MIB.
Activated Carbon Summary

- GAC:
  - TOC and DBP precursors can only be controlled using GAC
  - In terms of reliability and time requirements to predict GAC effectiveness, this is the order: Pilot, RSSCTs, and mathematical models.
  - Beds in parallel can reduce the GAC usage rate for treatment objectives greater than ~30%
  - Beds in series can reduce the GAC usage rate for treatment objectives less than ~5%
  - Backwashing is detrimental to GAC treatment of hazardous organics and not important for DOC
  - GAC can be effective as a sand filter replacement for biological and long term removal of taste and odor compounds

Recent Advances For Early Warning Algae Systems
DNA-Based Sensor for T&O- and Toxin-Producing Algae

Qiang Hu¹, Milton Sommerfeld¹, and Paul Westerhoff²

¹School of Life Sciences
²Dept. of Civil and Environmental Engineering
Arizona State University

Project supported by:
Salt River Project
ASU Water Quality Center

September 2, 2005

Goal of Research

To develop a PCR-based DNA fingerprinting method for rapid, sensitive, and reliable detection of potential toxin-producing cyanobacteria, and integrate the method into current water quality monitoring and management practices.
Specific Objectives

- Design PCR primers specific for *Cylindrospermopsis* and other potential toxin-producing cyanobacterial species/strains
- Develop an optimized real-time PCR protocol for quantitative detection of *Cylindrospermopsis* and other toxin-producing cyanobacteria
- Use the Arizona Canal and Saguaro Lake as field experimental systems to validate the PCR and real-time PCR methods developed

Isolation of *Cylindrospermopsis* sp. from the Arizona Canal and Saguaro Lake

Light photomicrographs of *Cylindrospermopsis raciborskii* isolates
- A, B = trichomes (coiled form)
- C, D = trichomes (straight form)
- E, F = trichome cells (without gas vesicles)
### Cylindrospermopsis raciborskii Isolates

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Description</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ-82</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-83</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-84</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-85</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-86</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-87</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-88</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-89</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-91</td>
<td>Cylindrospermopsis raciborskii (straight)</td>
<td></td>
</tr>
<tr>
<td>AZ-14</td>
<td>Cylindrospermopsis raciborskii (straight, no gas vesicle)</td>
<td></td>
</tr>
</tbody>
</table>

### Alignment of 16S rRNA gene segments among Cylindrospermopsis and other cyanobacterial species

<table>
<thead>
<tr>
<th>Species</th>
<th>Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planktothrix</td>
<td>ATGCAAGTCGAACGGGAATCCTCGGATTTAATGCGGAACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Anabaena 7120</td>
<td>ATGCAAGTCGAACGGATCTCTTCGGAGATAGTGGCGGACGGGTGAGTAACGCGTGAGAA</td>
</tr>
<tr>
<td>Calothrix</td>
<td>ATGCAAGTCGAACGGGAATCTTCGGTATAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Microcystis</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Microcoleus</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Anabaenopsis</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Aph. gracile</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Aph. flos-aquae</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Nostoc sp.</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Anabaena bergii</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>Nodularia sp.</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>CR (Straight)</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>CR (coiled)</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
<tr>
<td>CR (Florida)</td>
<td>ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTAAGAA</td>
</tr>
</tbody>
</table>

**Cyl 16S-I**
PCR Detection of *Cylindrospermopsis* in Saguaro Lake Samples

1: *Anabaena* TAC426  
2: *Saguaro Lake sample*  
3: *Nodularia* strain 575  
4: *Cylindrospermopsis AWT205*  
5: *Plankothrix PCC7811*

6: *Microcystis LE-3*  
7: *Nostoc PCC73102*  
8: *Saguaro Lake sample*  
9: *Aphanizomenon strain Zayi*  
10: No DNA sample

LC/MS/MS Screening of Toxins from Isolated *Cylindrospermopsis* Strains

<table>
<thead>
<tr>
<th>ID #</th>
<th>AZ-6</th>
<th>AZ-14</th>
<th>AZ-19</th>
<th>AZ-30</th>
<th>AZ-33</th>
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<tbody>
<tr>
<td>Description</td>
<td>Cylindro</td>
<td>Cylindro</td>
<td>Cylindro</td>
<td>Cylindro</td>
<td>Cylindro</td>
</tr>
<tr>
<td>Analyte</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
</tr>
<tr>
<td>Cylindrospermisin</td>
<td>1.2</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>0.96</td>
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<tr>
<td>Anatoxin-a Isomer</td>
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<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Microcystin RR</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Microcystin LR</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
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<tr>
<td>Microcystin YR</td>
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<td>1.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Nodularin</td>
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<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
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</tbody>
</table>

<table>
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<th>AZ-22</th>
<th>AZ-60</th>
<th>AZ-70</th>
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<tr>
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<td>Cylindro</td>
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<td>Cylindro</td>
</tr>
<tr>
<td>Analyte</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
</tr>
<tr>
<td>Cylindrospermisin</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>~ 2.5</td>
<td>~50</td>
<td>&gt;0.5</td>
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<td>Anatoxin-a Isomer</td>
<td>&lt;0.5</td>
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<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Microcystin RR</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;2.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
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<tr>
<td>Microcystin LR</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;2.5</td>
<td>~50</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Microcystin YR</td>
<td>&lt;0.5</td>
<td>1.1</td>
<td>&lt;2.5</td>
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<td>&lt;0.5</td>
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<tr>
<td>Nodularin</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;2.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>
Isolation and identification of *Microcystis* sp. from Saguaro Lake

**Elisa analysis:** 1.21 mg *microcystin-LR* /g cell dry weight

Organization of the Gene Cluster for Microcystin Biosynthesis

- Regions homologous to nonribosomal peptide synthetases
- Regions homologous to polyketide synthetases
- ORFs of putative microcystin tailoring function
- Non-microcystin synthetase ORFs
PCR Detection of *Microcystis* sp. from Saguaro Lake Samples

Lanes 1, 4, & 7: Negative controls  
Lanes 2, 5, & 8: *Microcystis* sp. AZ-93 gene segments  
Lanes 3, 6, & 9: *Microcystis* positive controls

Planned Activities for Next Period

- Design PCR primers to specifically detect 16S rRNA of heterocystous cyanobacteria that are potential toxin-producers
- Continue efforts to screen for toxins from additional cyanobacteria obtained from Arizona Canal and Saguaro Lake
- Apply optimized PCR protocols to monitor potential toxin-producing cyanobacteria in the Arizona Canal and Saguaro Lake
Sonication for algae control

YoungIl Kim

✓ Ultrasonic algae control device is the state-of-the-art, gets rid of algae without harming other aquatic life
✓ Ultrasonic device is environmentally friendly, easy to use, cost-effective and uses no chemicals
Ultrasonic device generate ultrasonic waves that shock and kill the algae by ripping the vacuole of the algae cell.

![Day 0 and Day 14 images]

---

**Before**

**After**

![Diagram showing influent and effluent, test basin, control basin, presed. #1, presed. #2, presed. #3, sampling points, and dimension of presed. basin: 140 ft (W) x 140 ft (L) x 12 ft (H)]
Chl-a (mg/m²)

Wrapping Up

2-Methylisoborneol (MIB)

Geosmin
OTHER ACTIVITIES IN PAST YEAR

- Continued to publish/distribute water quality newsletter
- Collected extra samples for Phoenix and ASU from Roosevelt Lake to understand DOC runoff issues
- Cultured DOC-producing algae to learn more about their contributions to nitrogen containing DBPs
- Collaborated with S. Nevada Water Authority to screen isolated cyanobacteria for toxins and to improve analytical capability & understand reasons for fish kills in Saguaro Lake
- Completed evaluation of biocide coatings for canal linings
- Evaluate new technologies (sonic) and products (GAC) to improve water quality treatment

FUTURE DIRECTIONS/ACTIVITIES

- Arizona Virtual Water University
- AwwaRF Proposal
- Facility For Toxin Analysis
- Portable MIB sensor
- Other Ideas?
“In 2006, we will establish a virtual water university that unites the cutting edge work in each university is doing on water management into one supercenter of research, community assistance and economic development.”
Governor Napolitano, Arizona Town Hall at the Grand Canyon

MISSION:

Serve as hub of research and technology development to give Arizona the tools to assure clean and sustainable water resources for the next century;
Provide education, information, and analytical support to the public, government decision makers, water professionals, industry, and others about using, conserving, and managing water in arid environments;
Be a resource for new water management technologies that produce new products and services for Arizona companies to export worldwide, thus creating a major new economic driver for Arizona.
AwwaRF PROPOSAL

“STRATEGIES FOR CONTROLLING AND MITIGATING ALGAL GROWTH WITHIN WATER TREATMENT PLANTS”

In response to RFP 3111

Collaboration between Malcolm Pirnie, Inc., ASU and 14 Water Treatment Plants/Districts

PARTICIPATING WATER TREATMENT PLANTS

- Chandler  AZ
- Peoria  
- Phoenix  
- Alameda CWD  CA
- Contra Costa WD  
- Santa Clara  
- Denver Water  CO
- Tampa Bay W  FL
- Central Lake CJWA  IL
- Indianapolis W  IN
- Minneapolis WW  MN
- St. Paul RWS  
- Philadelphia WD  PA
- Greenville  SC
- Newport News WW  VA
OBJECTIVES

- Collect and analyze existing information on types of algae found in water treatment plants
- Document the dominant algal types found in water treatment plants
- Identify algal issues triggered by modifications of treatment trains
- Develop case studies of treatment plants that are controlling/mitigating algae using different strategies
- Develop recommendations and guidance for utilities on
  - sampling and analysis to address algal issues within the plant
  - optimal control strategies that work for other utilities
  - best practices for operation and maintenance to reduce algal problems in treatment plants

ADVANCED WATER QUALITY EVALUATION AND MANAGEMENT STRATEGY

GOAL:

TO RESPOND TO THE RECENT AND EMERGING CONCERNS ABOUT TOXIC ALGAE
RESOURCE FOR TOXIC ALGAE AND TOXIN ANALYSIS

Establish an ASU facility with the capabilities to:

- Develop PCR primers specific for potential toxin-producing algae
- Develop real-time PCR protocol for quantitative detection of specific potentially toxic algae
- Apply these methods to detect the occurrence of potentially toxic strains
- Isolate and characterize potential toxic strains
- Develop an optimized HPLC/MS protocol for rapid toxin analysis

Continue to Urge SRP & CAP to install remote monitoring systems
In-situ MIB Sensors

- Goal: use biomedical type sensors based upon surface plasma resonance technology to develop a field portable MIB sensor
- Initial work would start in 2006 and then external funding would be sought
- Inexpensive MIB sensor could be used to optimize WTP processes, find hot-spots of MIB production in canals, rivers, and lakes, and be used to assess customer complaints

Future directions & discussion

What do you see as the biggest challenge for the fall and into 2006?

What research would you like to see expanded?
Visit Our Websites
http://ceaspub.eas.asu.edu/pwest/tasteandodor.htm