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

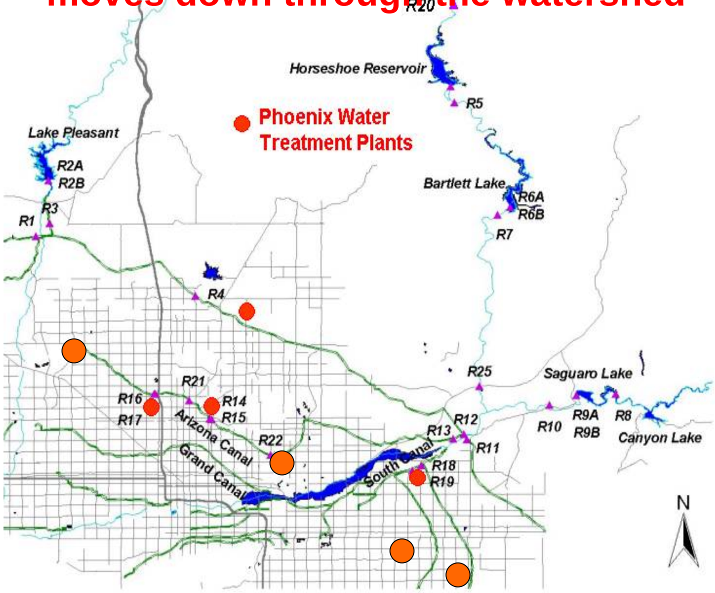
Purpose: Provide a forum to review and discuss on-going regional water quality issues, in particular algae-associated issues.

- **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

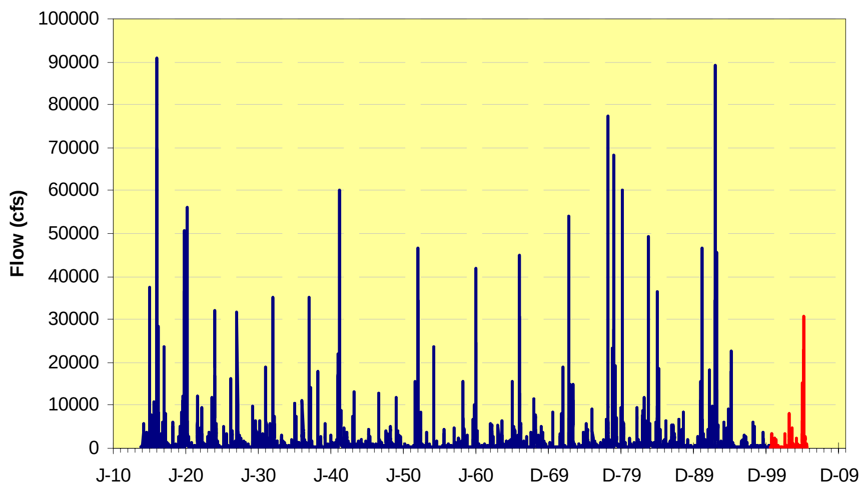
Overview of T&O issues for 2005

What is unique about 2005?

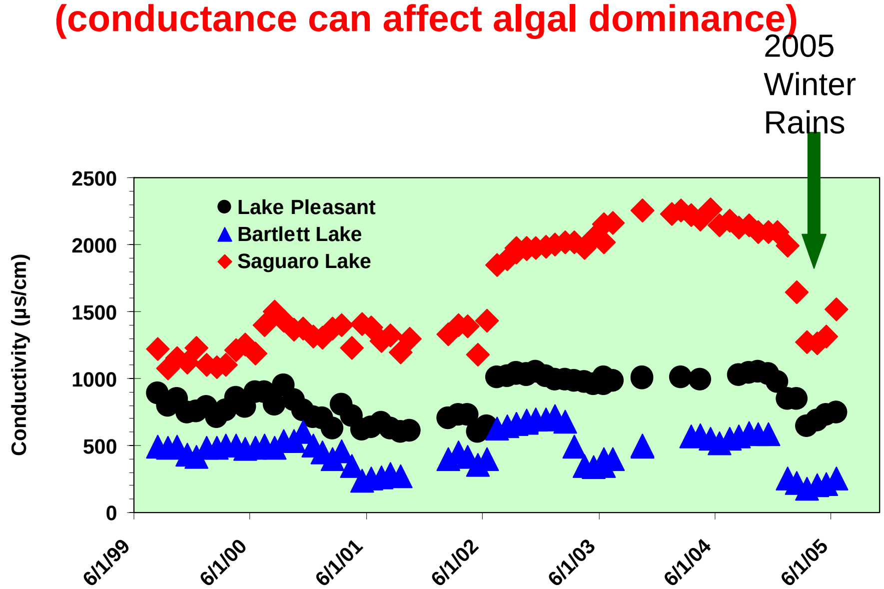
Workshop will present results as water moves down through the watershed



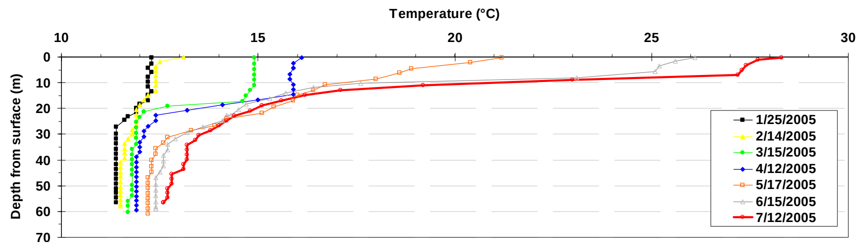
Salt River Above Roosevelt

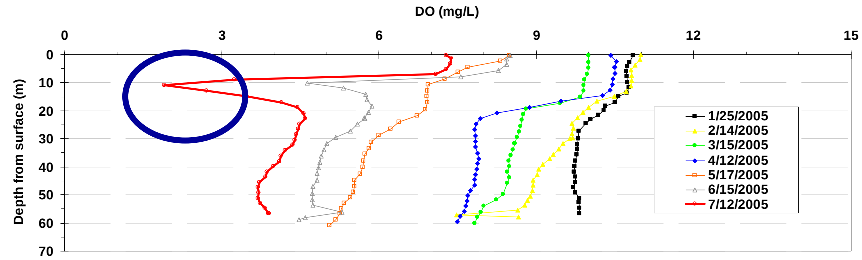


Hydrology Affects Water Quality (conductance can affect algal dominance)

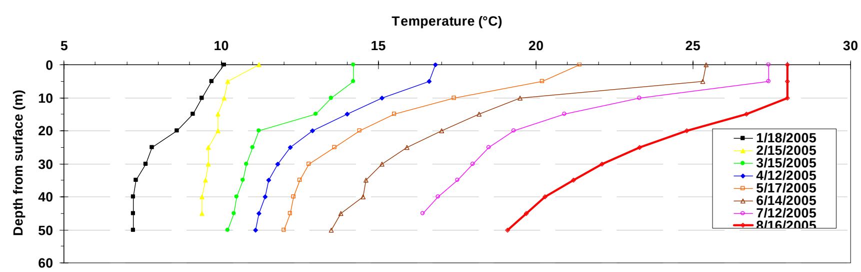


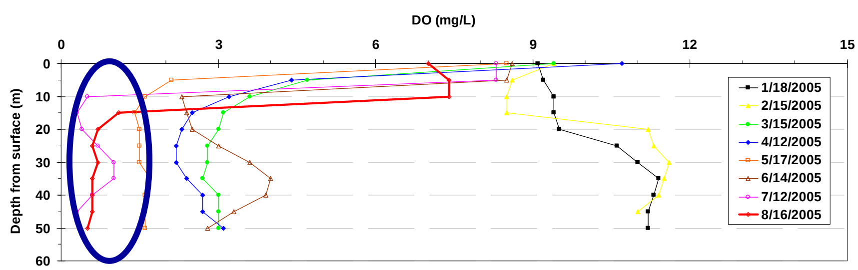
Lake Pleasant



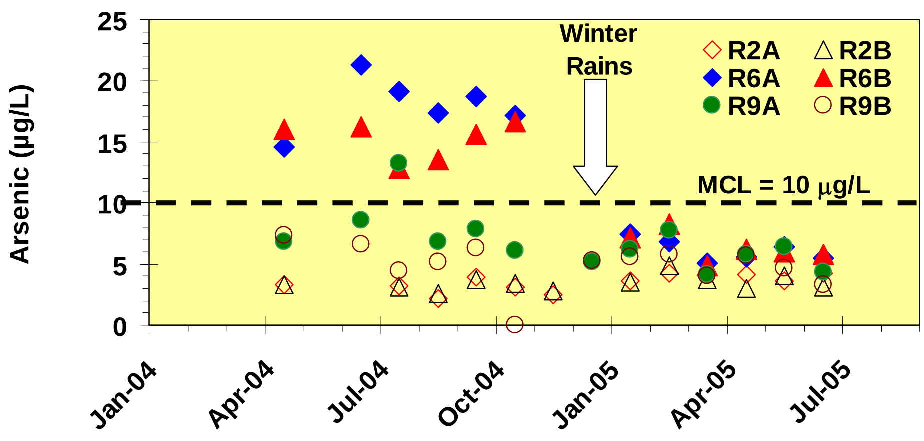


Bartlett Lake

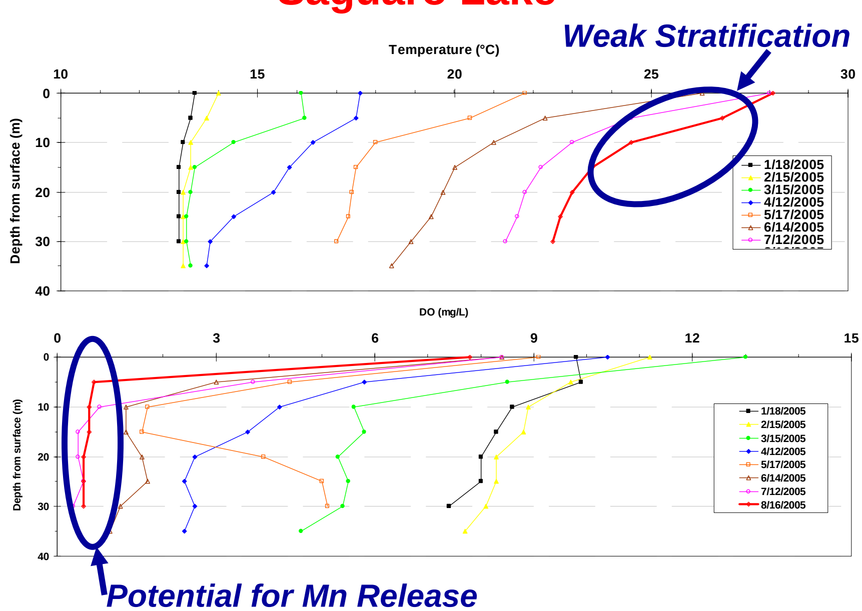


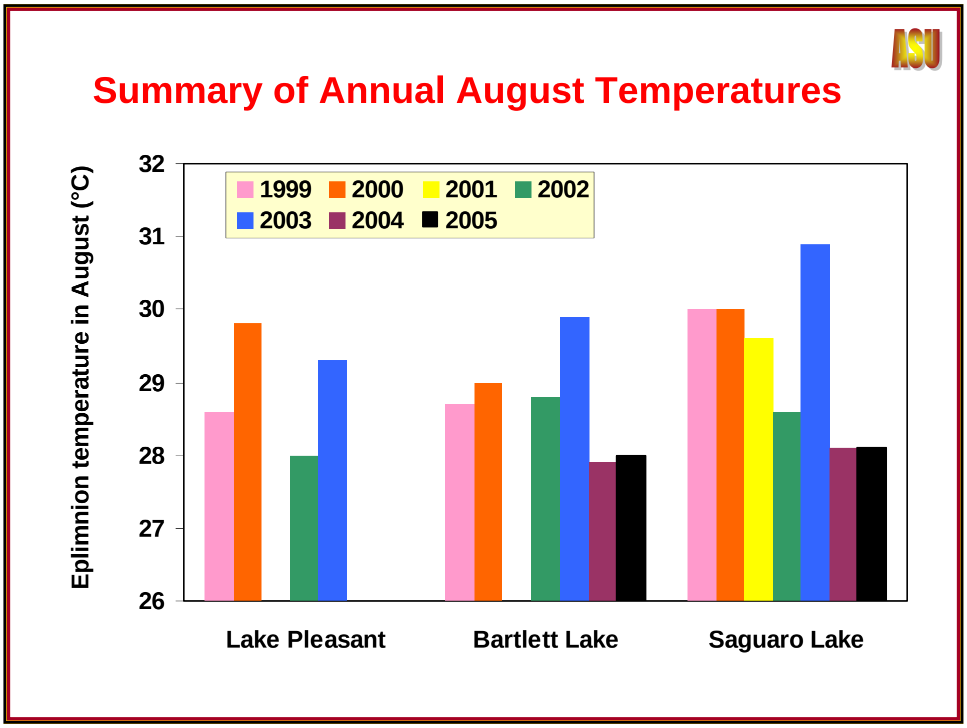


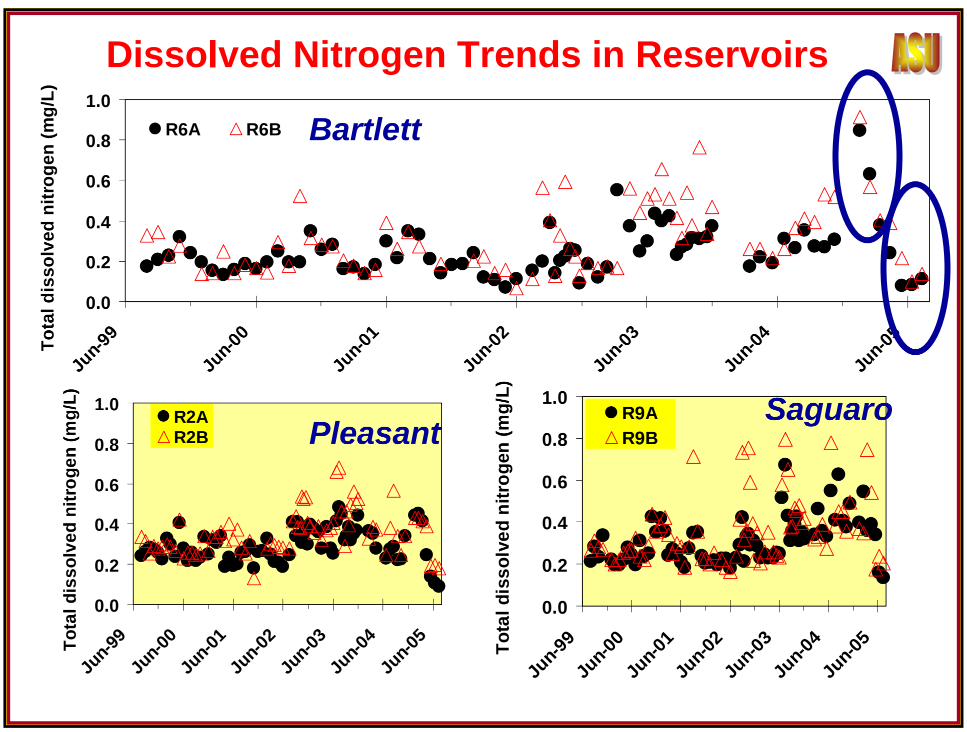
Arsenic



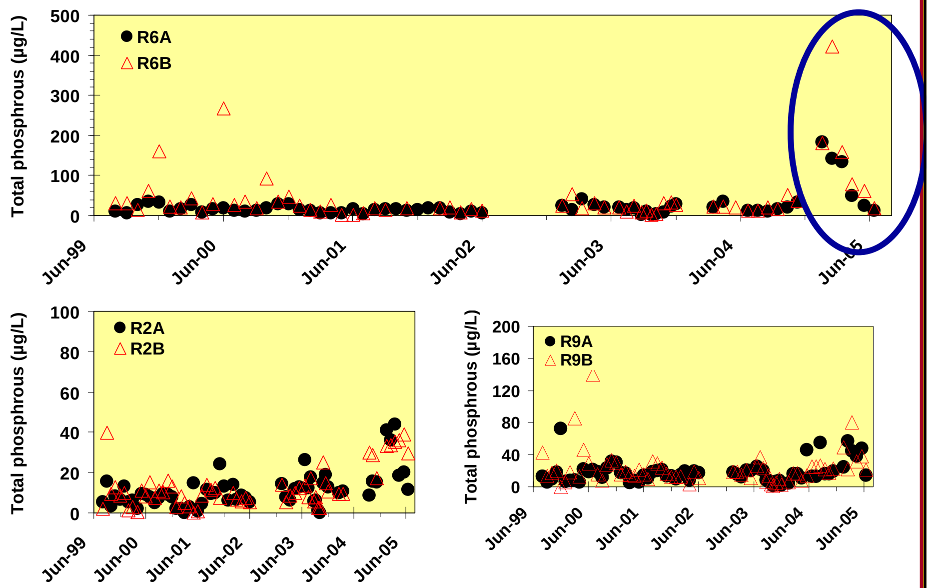
Saguaro Lake



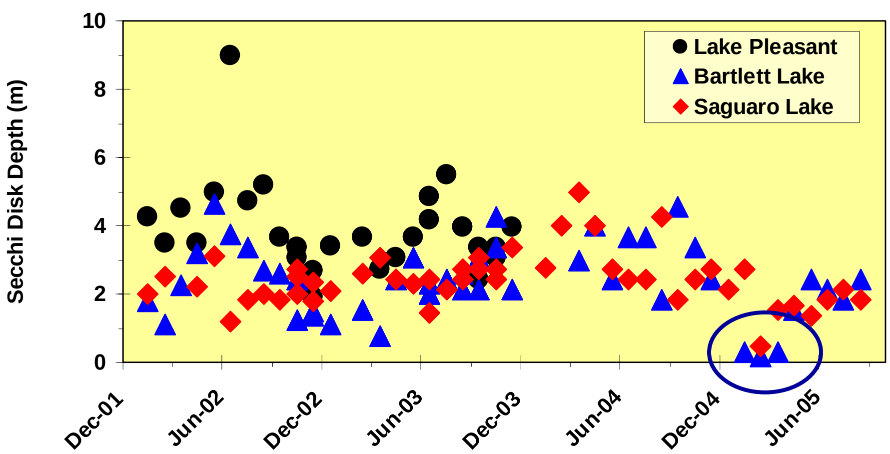

Summary of Annual August Temperatures
1999 2000 2001 2002
2003 2004 2005
Eplimnion temperature in August (°C)
32
31
30
29
28
27
26
Lake Pleasant
Bartlett Lake
Saguaro Lake


Dissolved Nitrogen Trends in Reservoirs
R6A
R6B
Bartlett
Total dissolved nitrogen (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
Jun-99
Jun-00
Jun-01
Jun-02
Jun-03
Jun-04
R2A
R2B
Pleasant
Jun-05
R9A
R9B
Saguaro

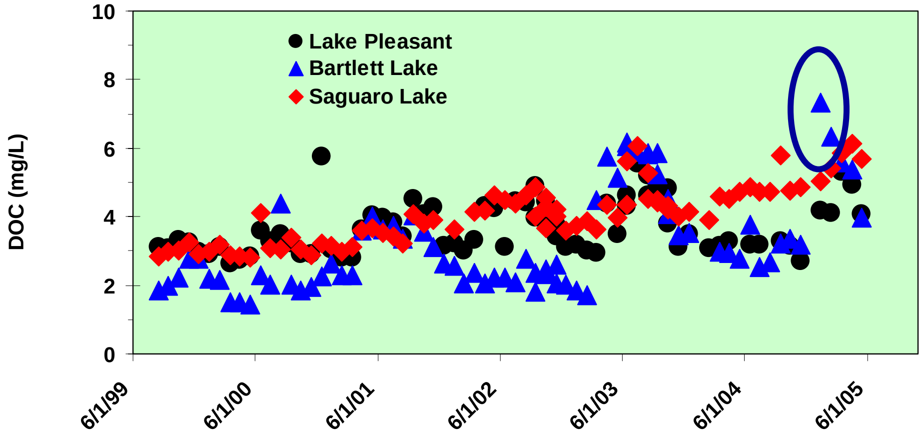
Total Phosphorous



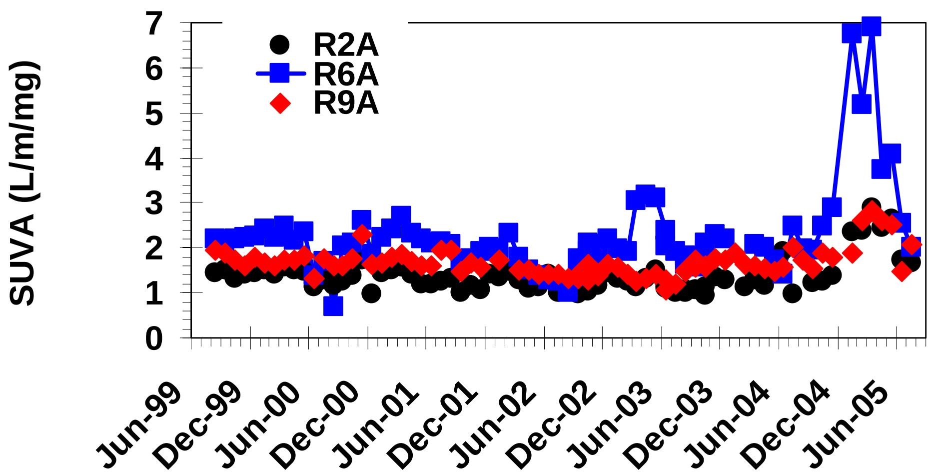
Secchi Disk Depth Influenced by Inorganic Suspended Sediment and/or Organic Biomass



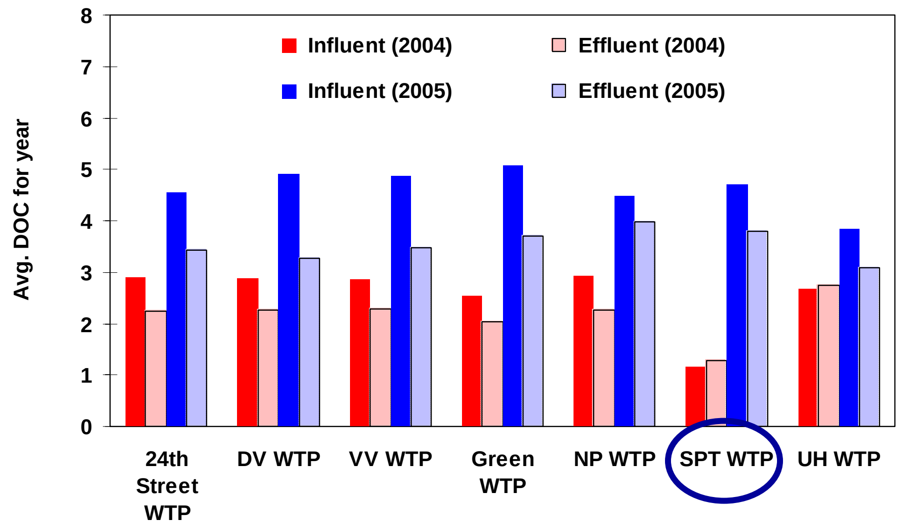
Up-stream reservoirs attenuate DOC

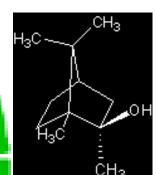


Specific UV Absorbance at 254 nm

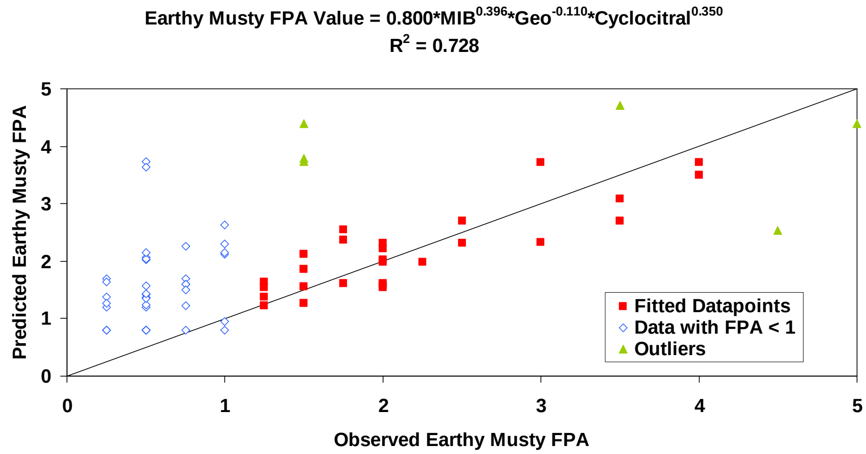


DOC Removal by WTP



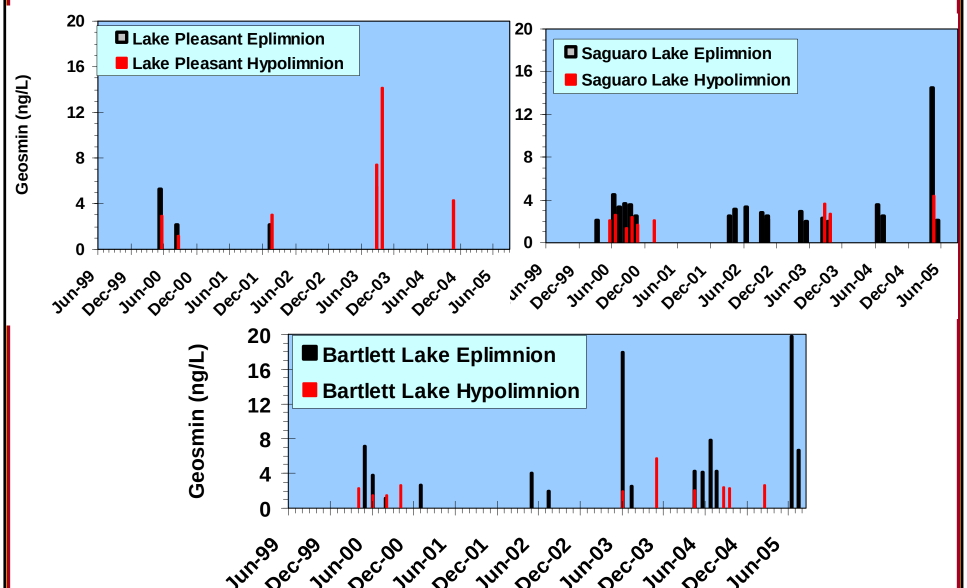


Predicting Expected FPA Intensity based upon GC/MS data

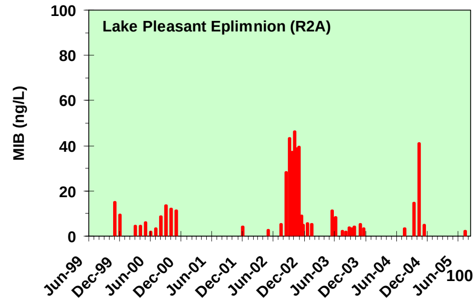


FPA= 2 when MIB=5, Geosmin=3, Cyclocitral=3 ng/L
FPA= 3 when MIB=8, Geosmin=8, Cyclocitral=8 ng/L

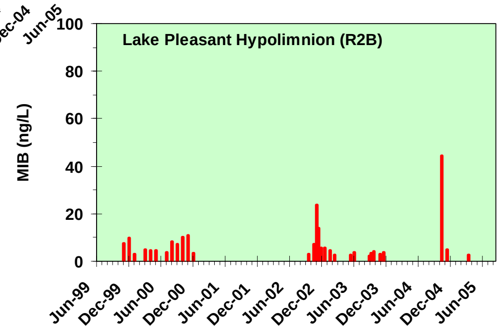
Geosmin Data



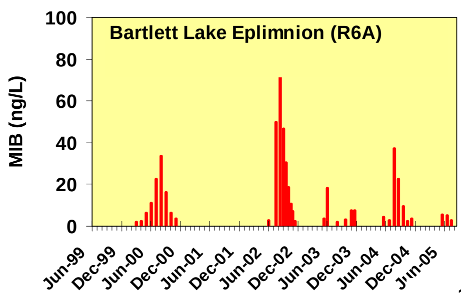
MIB Data – Lake Pleasant



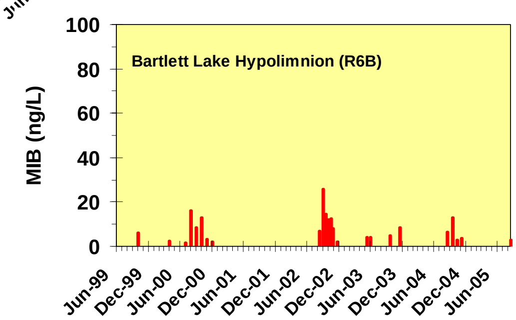
MIB is low in Lake Pleasant in 2005



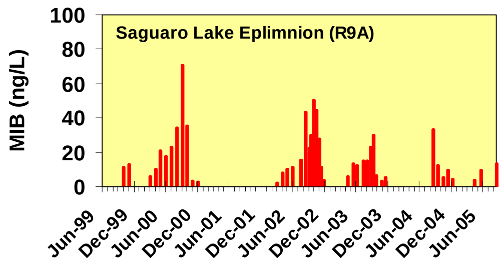
MIB Data – Bartlett Lake



MIB is low in Bartlett Reservoir in 2005



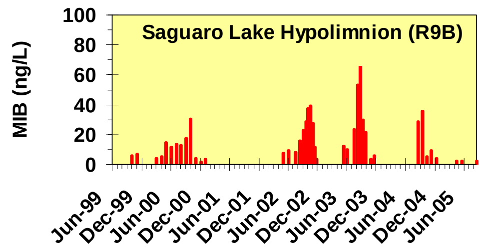
MIB Data – Saguaro Lake



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:**
  $[MIB]_l*Q_l*10^{-6} = [MIB]_u*Q_u*10^{-6} + k*L - k*L_d*Q_{d,out}/Q_{d,AZ}$
- **Where**
  - $[MIB]_u$ = MIB concentration at upper end of segment
  - Q_u = flow at upper end of segment, m3/day
  - $[MIB]_l$ = 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)

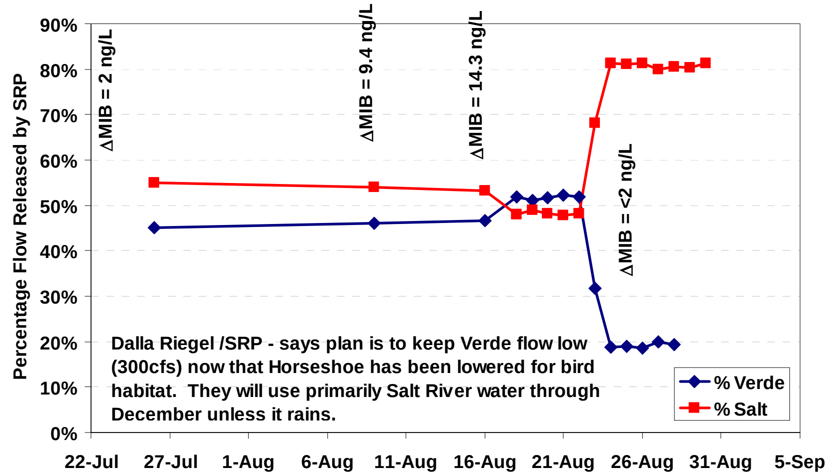
Canal Segment	8/4/03	8/25/03	10/23/03	7/6/04	9/28/04
Below X-connect to Pima Road	2	6.1	9.2	0.5	2.1
Pima Road to 24th Street WTP	0.6	-1	1.7	3.7	1.7
24th Street WTP to Deer Valley WTP	3.4	2.5	1.5	1	0.33
Deer Valley WTP to Greenway WTP	-1.6	-5.5	-4.4	-0.1	-5.1

MIB Production　MIB Loss

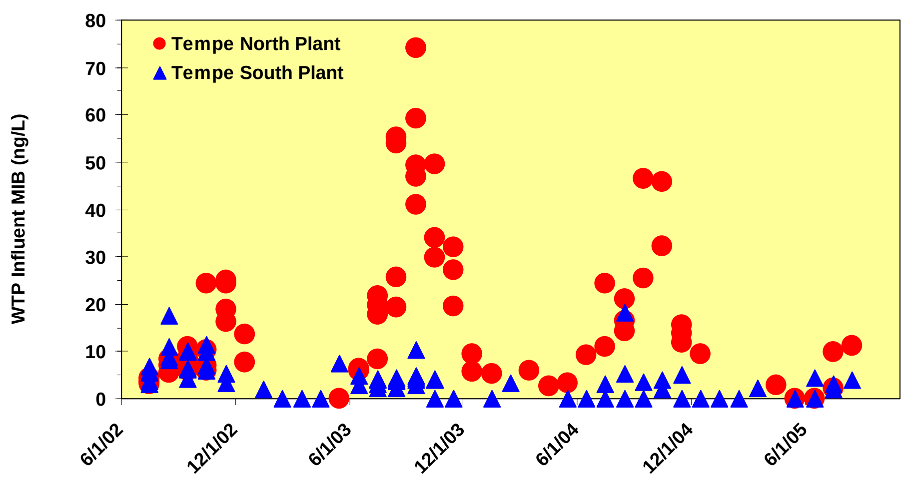
Recent Trends of In-situ MIB Production (ΔMIB in ng/L) in Arizona Canal (Geosmin and Cyclocitral follow similar patterns)

Canal Segment	6/28/05	7/12/05	7/26/05	8/16/05	8/25/05
MIB below X-connect	<2 ng/L	<2 ng/L	3.1 ng/L	4.8 ng/L	
Below X-connect to Pima Road	2.5	1.0	7.0	7.4	
Pima Road to 24th Street WTP	1.2	~0	~0	3.3	~0
24th Street WTP to Deer Valley WTP	-0.8	0.7	2.4	3.6	
Deer Valley WTP to Greenway WTP	--	1.5	-3.2	-4.1	

SRP Change in River Release affected MIB Production in the canals – suggests conductance effect



MIB levels higher in AZ Canal system compared against South Canal system



Geosmin is higher in Recent Years

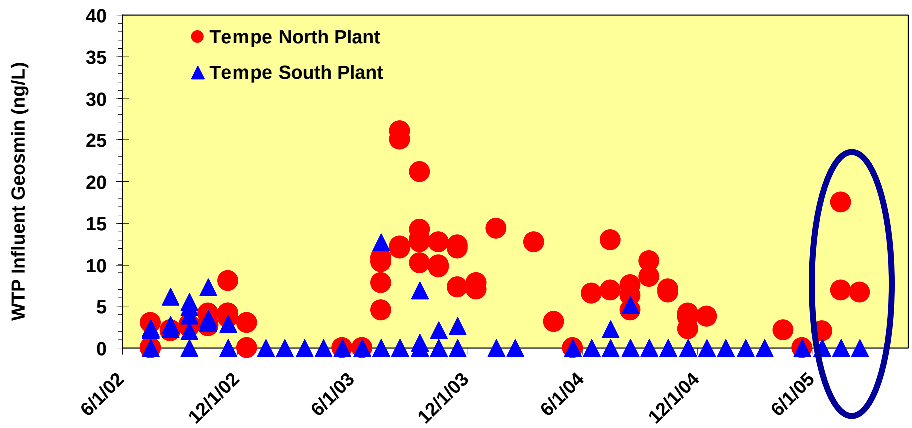


Table 3 - Canal Sampling – August 30, 2005

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

Trace Metals : Cycles, Transport and Urban Signatures

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

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Department of Chemistry and Biochemistry
Arizona State University
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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

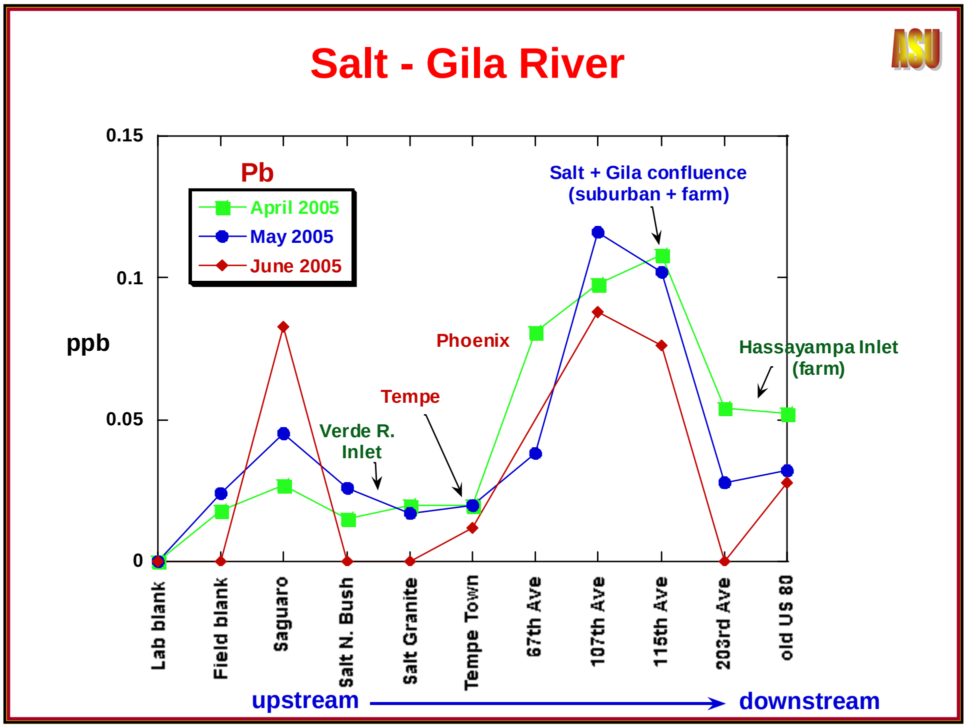
Projects: Environmental Biogeochemistry

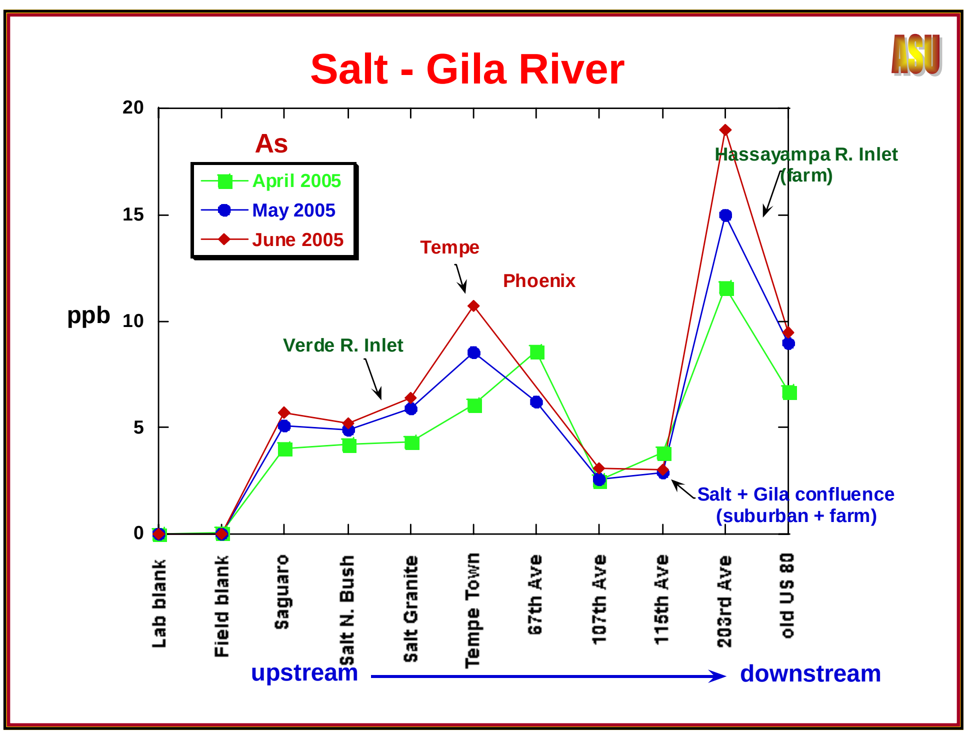
- Human-induced biogeochemical cycles of metals
- Chemical footprint of cities, using the Phoenix metropolitan area as a guide
- Micronutrient transport in rivers in response to climate forcing

Sample Locations

Salt River, Feb 2005

Gila River, May 2005


Salt - Gila River
Pb
April 2005
May 2005
June 2005
ppb
0.15
0.1
0.05
0
Salt + Gila confluence
(suburban + farm)
Phoenix
Hassayampa Inlet
(farm)
Tempe
Verde R.
Inlet
Lab blank
Field blank
Saguaro
Salt N. Bush
Salt Granite
Tempe Town
67th Ave
107th Ave
115th Ave
203rd Ave
old US 80
upstream
downstream


Salt - Gila River
As
April 2005
May 2005
June 2005
ppb
20
15
10
5
0
Hassayampa R. Inlet
(farm)
Tempe
Phoenix
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Salt + Gila confluence
(suburban + farm)
Lab blank
Field blank
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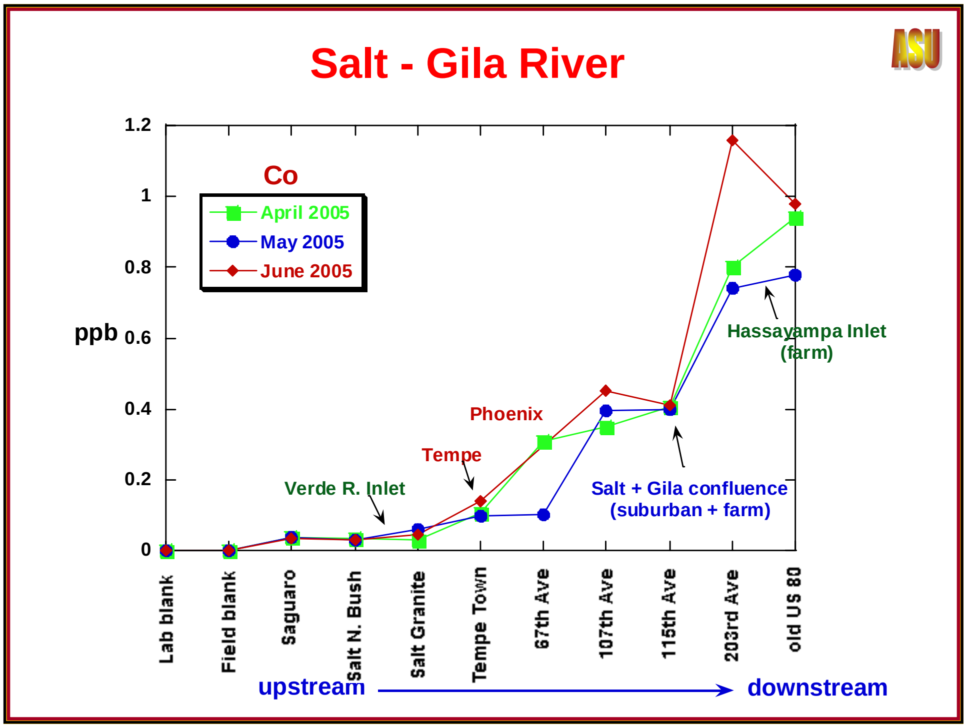
old US 80
upstream
downstream


Salt - Gila River
Co
April 2005
May 2005
June 2005
ppb
1.2
1
0.8
0.6
0.4
0.2
0
Hassayampa Inlet
(farm)
Phoenix
Tempe
Verde R. Inlet
Salt + Gila confluence
(suburban + farm)
Lab blank
Field blank
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Salt N. Bush
Salt Granite
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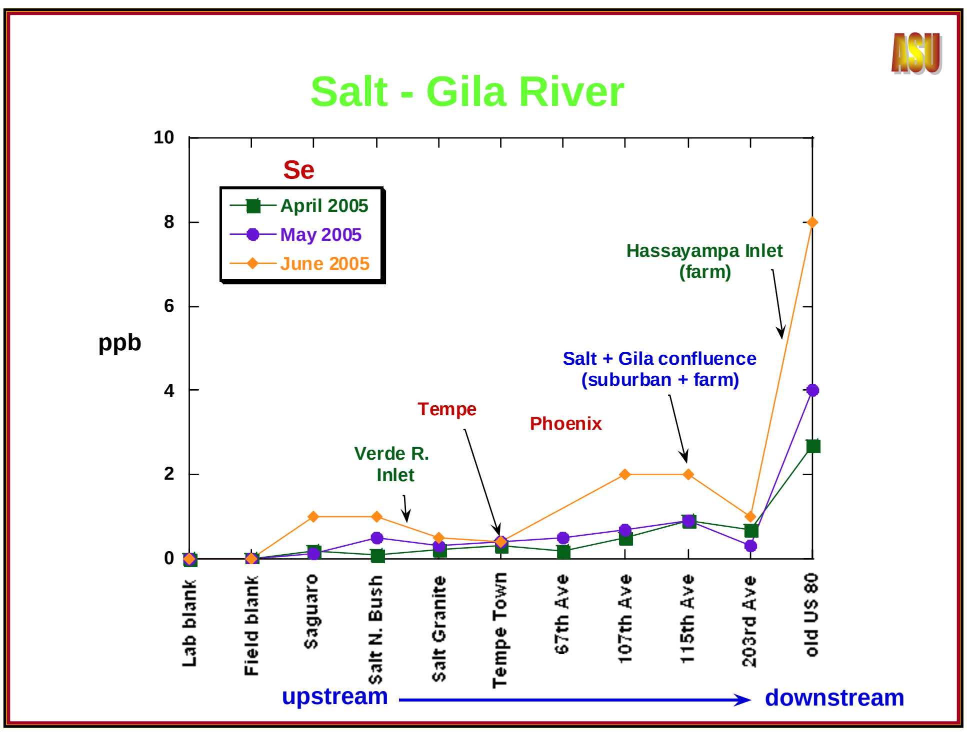
67th Ave
107th Ave
115th Ave
203rd Ave
old US 80
upstream
downstream


Salt - Gila River
Se
April 2005
May 2005
June 2005
ppb
10
8
6
4
2
0
Hassayampa Inlet
(farm)
Salt + Gila confluence
(suburban + farm)
Tempe
Phoenix
Verde R.
Inlet
Lab blank
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67th Ave
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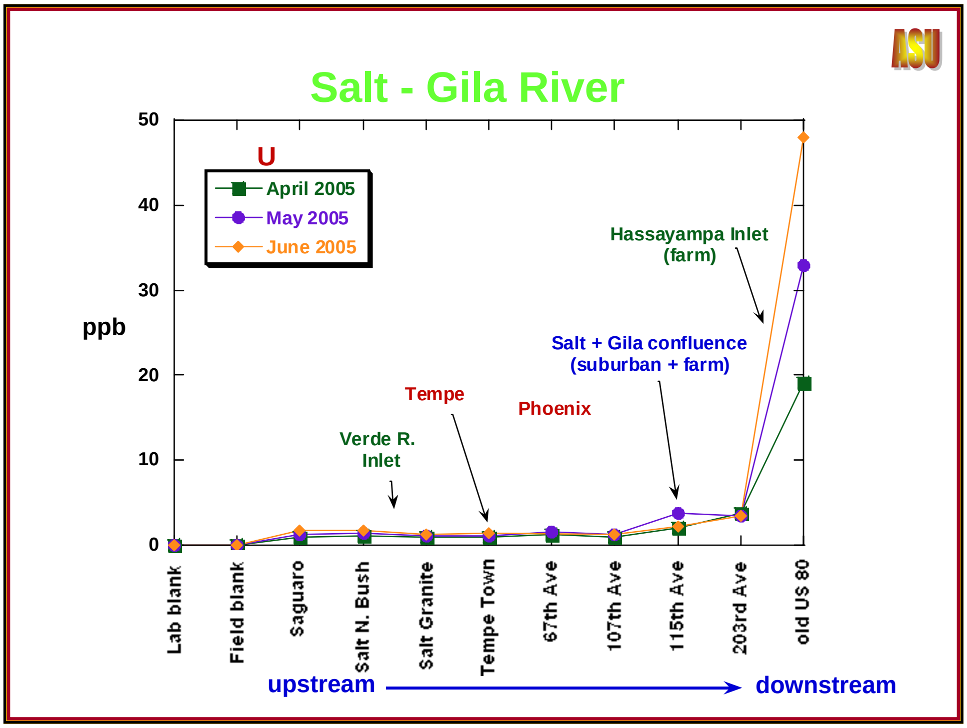
203rd Ave
old US 80
upstream
downstream


Salt - Gila River
U
April 2005
May 2005
June 2005
ppb
50
40
30
20
10
0
Hassayampa Inlet
(farm)
Salt + Gila confluence
(suburban + farm)
Tempe
Phoenix
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Inlet
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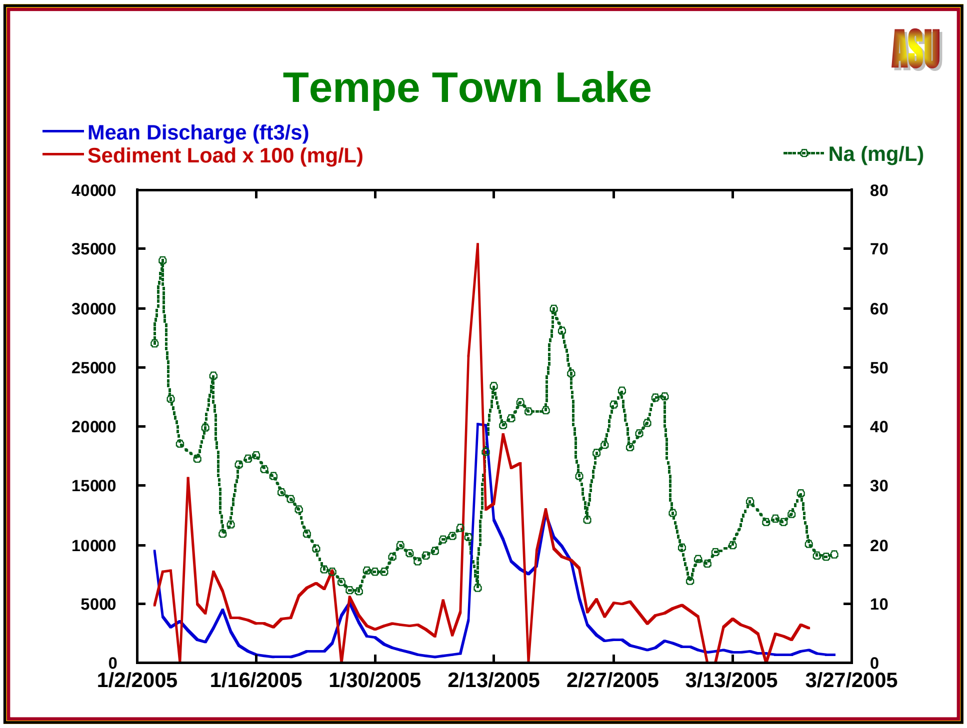
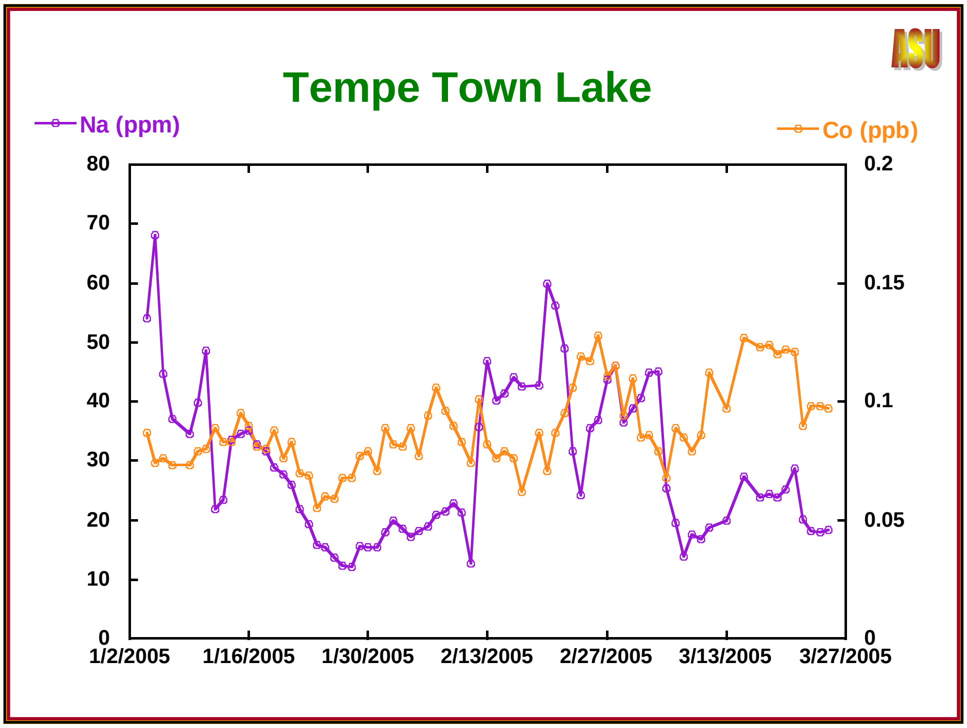
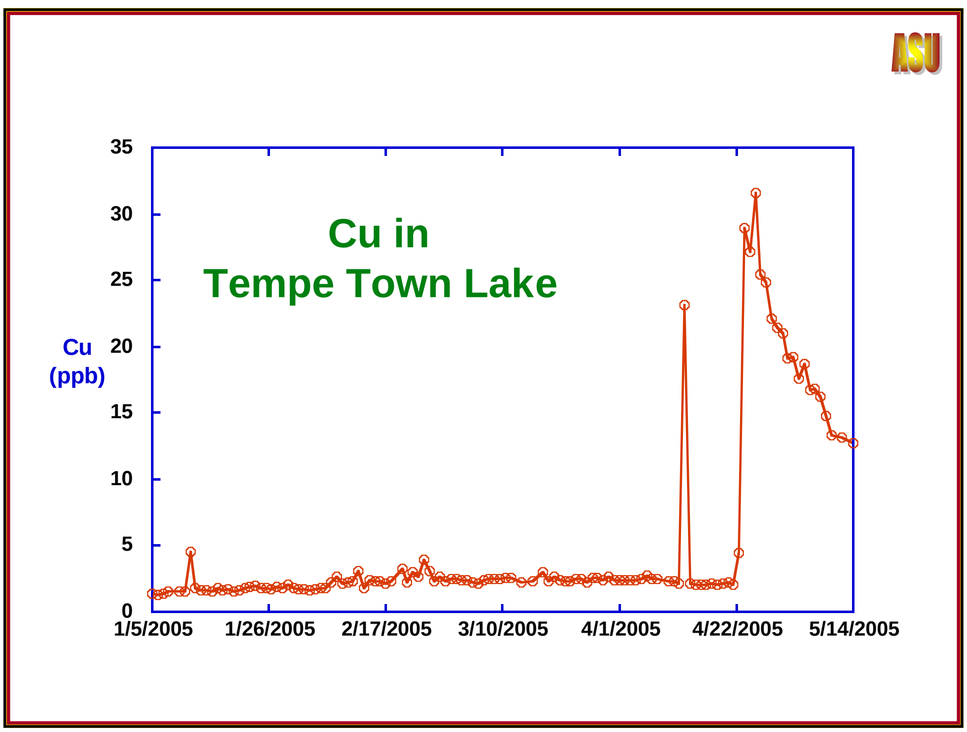

Tempe Town Lake
Mean Discharge (ft3/s)
Sediment Load x 100 (mg/L)
Na (mg/L)
40000
35000
30000
25000
20000
15000
10000
5000
0
80
70
60
50
40
30
20
10
0
1/2/2005
1/16/2005
1/30/2005
2/13/2005
2/27/2005
3/13/2005
3/27/2005



Tempe Town Lake
Na (ppm)
Co (ppb)
80
70
60
50
40
30
20
10
0
0.2
0.15
0.1
0.05
0
1/2/2005
1/16/2005
1/30/2005
2/13/2005
2/27/2005
3/13/2005
3/27/2005



Cu in
Tempe Town Lake
Cu
(ppb)
35
30
25
20
15
10
5
0
1/5/2005
1/26/2005
2/17/2005
3/10/2005
4/1/2005
4/22/2005
5/14/2005

Acknowledgements

- Nathan Schnebly
- Marisa Masles
- Young-Il Kim

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Central Arizona Project
City of Phoenix
City of Tempe
City of Peoria

Agenda

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

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- 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

Fundamentals of GAC

Including T&O and DOC control

John Crittenden

International Institute for Sustainability: Consortium Of Rapidly Developing Regions

Issues and Technologies Associated with Sustainable Water Supplies

John C. Crittenden, Ph.D., N.A.E., P.E.
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Department of Civil and Environmental Engineering

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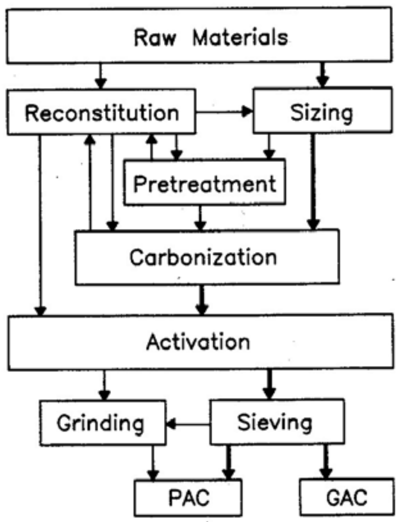
Activated Carbon Adsorption

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).

Flow scheme to produce activated carbon

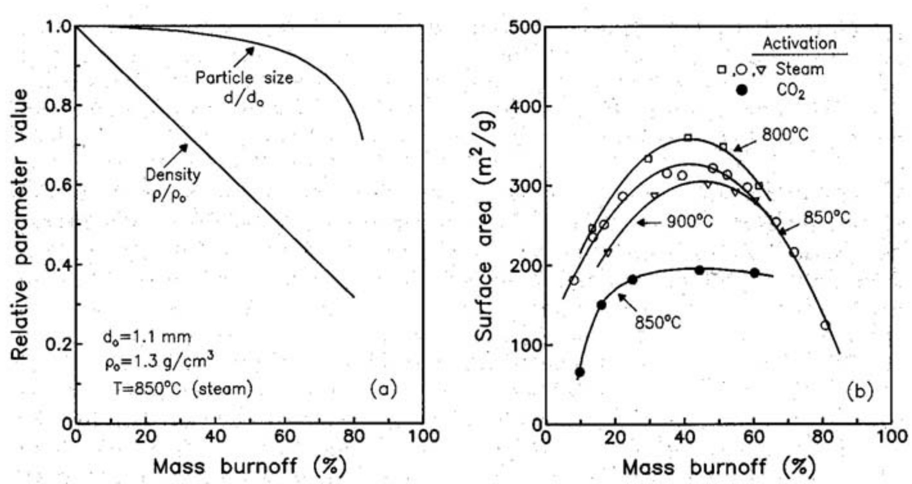
General Flow Scheme



Process Flow Description

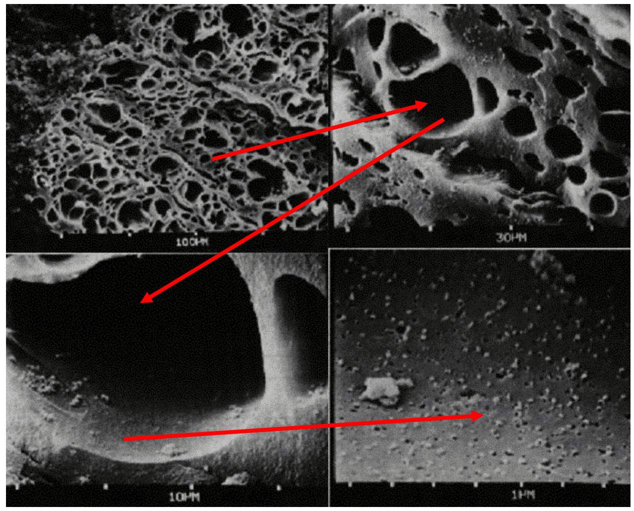
- Crushing and sizing raw materials.
- Carbonization process removes volatile components from the raw materials and realigns the carbon pore structure.
- Activation process selectively removes carbon and opens up the closed pores and increases the average size of micropores. Max. surface area per weight 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. CO_2, 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%)



Activated Carbon

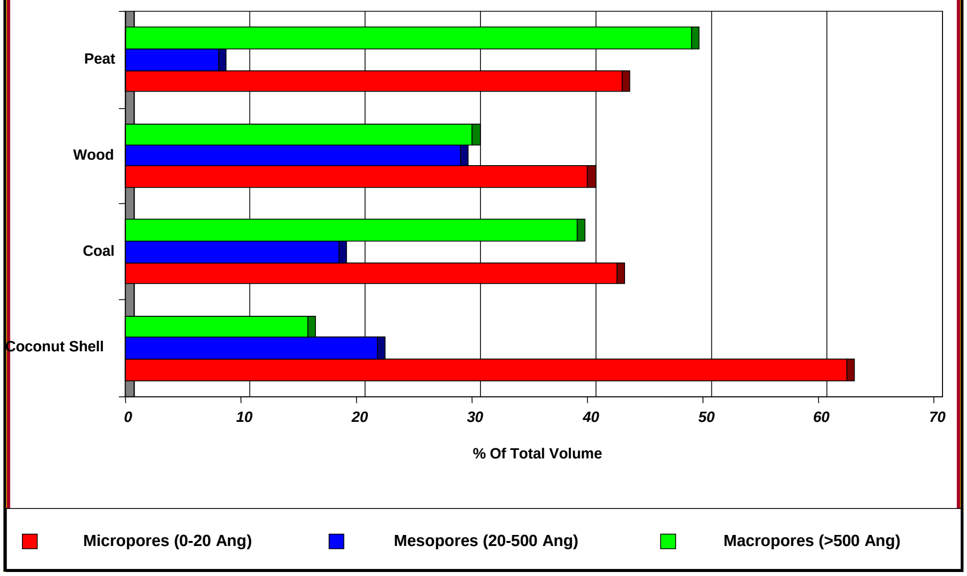
- Activate Carbon is carbonaceous material manufactured by a process that develops adsorptive properties.
- We can see micropores inside of macropores.



Base Material

- Coconut Shell
- Bituminous Coal
- Lignite
- Peat
- Wood
- Petroleum
- Bone Char

Pore Size Distribution Depends on Several Things Including Starting Material



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

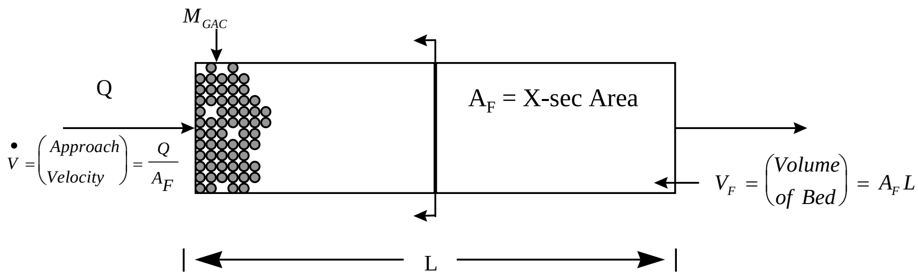
(4) Biologically Active GAC Adsorbers

(5) Powder activated carbon (PAC) contactors

Activated Carbon Adsorption

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

Important Variables in Fixed Bed Adsorption



$$\begin{pmatrix} \text{Empty Bed} \\ \text{Contact Time} \end{pmatrix} = EBCT = \frac{V_F}{Q} = \frac{A_F L}{\dot{V} A_F} = \frac{L}{\dot{V}} \qquad (6-1)$$

GAC Packed Bed Alternatives

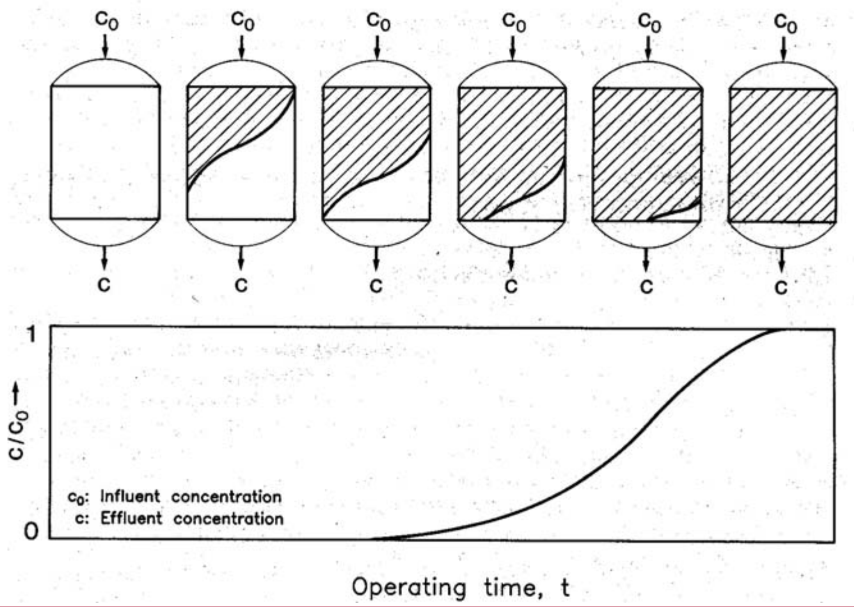
GAC Sand Replacement Reactor: Replacement of sand in a filtration operation. This gives only 3-7 minutes of EBCT but the GAC seems to last for many years for Taste and Odor compounds probably because of biological degradation.

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.

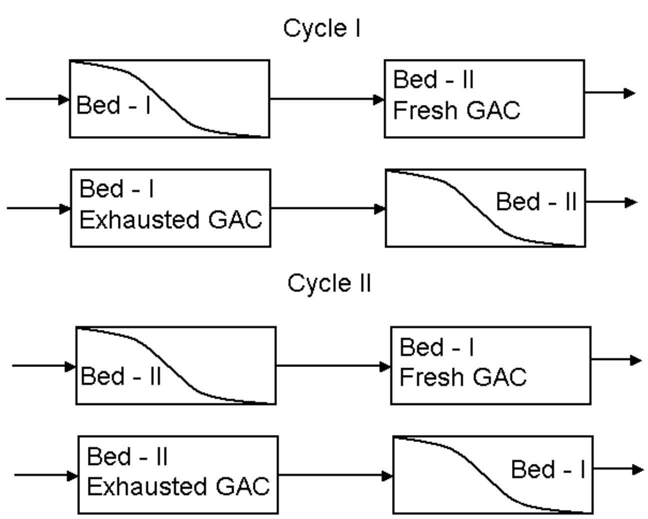
In water treatment, often Biot is high therefore hydraulic loading does not matter for a given EBCT. (External mass transfer does not matter.) **Typical hydraulic loading is Typical filter velocities range from 5 - 15 m/h (2 - 7 gpm/ft2).**

Breakthrough Characteristics of a Fixed Bed Adsorption (Vermeulen, 1958)



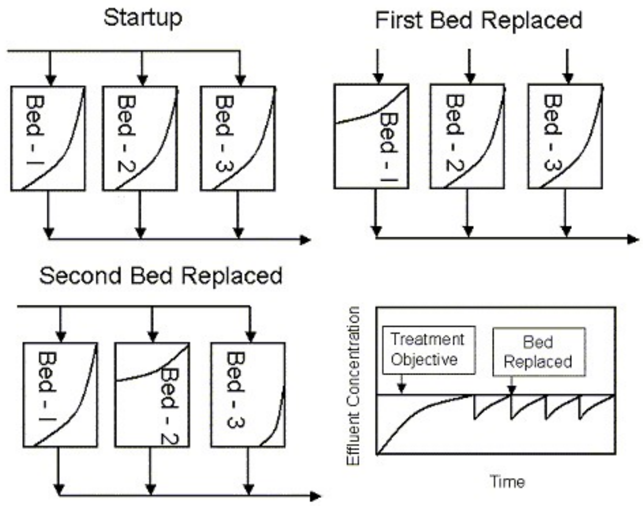
GAC Column Operation

A beds in-series operation will utilize more column capacity than a single bed operation specially for less stringent treatment objectives (e.g. $C/C_{TO} < 0.05$). Increase of 20 to 50% more water treated/mass GAC.



GAC Column Operation

A beds in-parallel operation will utilize more column capacity than a single bed operation specially for less stringent treatment objectives (e.g. $C/C_{TO} > 0.3$). 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.



Methods for estimating full scale GAC performance

Method	Reliability	Advantages	Disadvantages
Pilot studies	Excellent	1. Can predict full scale GAC performance very accurately.	1. Can take a very long time to obtain results. 2. Expensive and must be conducted onsite.
RSSCTs	Good	1. Can predicts full scale GAC performance accurately. 2. Small volume of water is required for the test, which can be transported to a central laboratory for evaluation. 3. Can be conducted in the fraction of the time and cost that is required to conduct pilot studies.	1. Cannot predict GAC performance for different concentrations. 2. Biological degradation that may prolong GAC bed life is not considered.
Models	Fair	1. Once calibrated, models can be used to predict impact of EBCT and changes in influent concentration. 2. Can predict breakthrough of SOCs with 20 to 50 percent error.	1. Cannot predict TOC breakthrough and must be used in conjuction with pilot or RSSCT data. 2. Accurate prediction of SOC removal requires calibration with pilot or RSSCT data.

Design Strategies for TOC Removal

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.

Six participating utilities: MWD, Cincinnati, Jefferson Parish, Philadelphia, Atlanta.

Design Strategies for TOC Removal

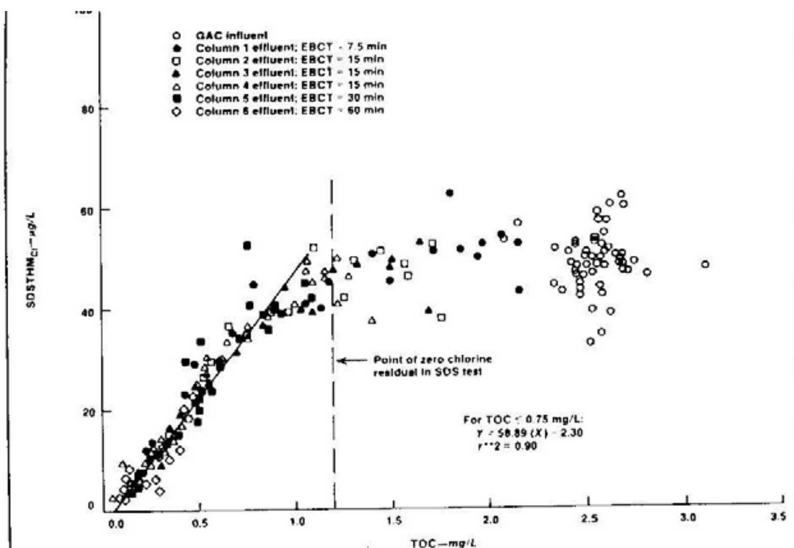
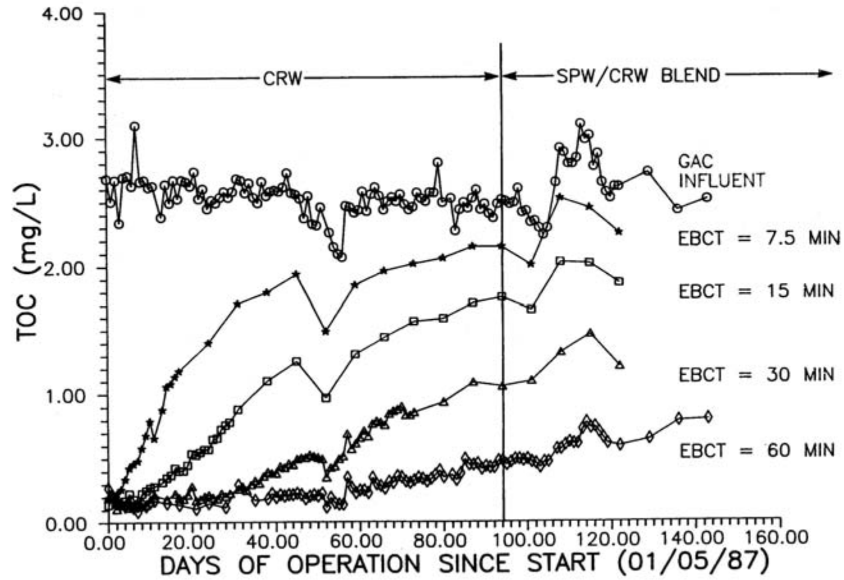
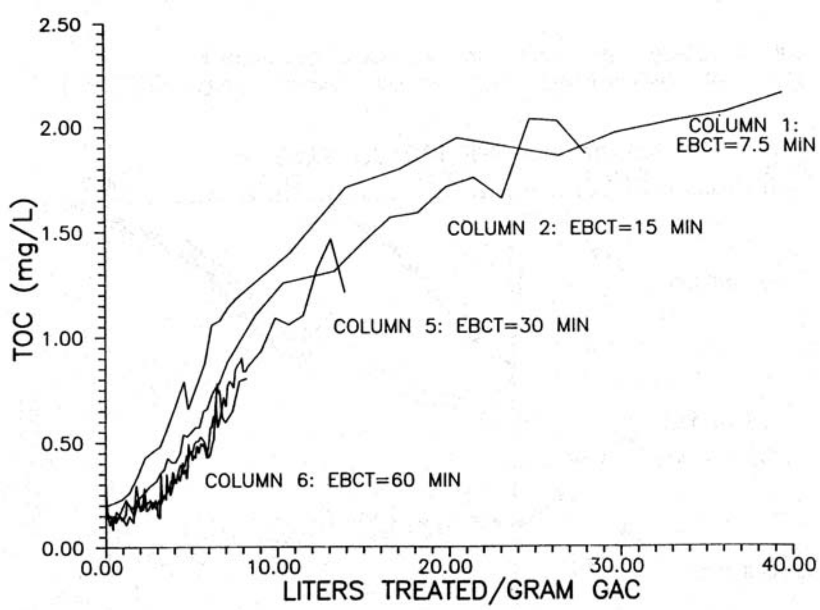


Figure 10. Linear relationship between $SDSTHM_{Cl}$ and TOC (*100 percent CRW*)

Design Strategies for TOC Removal – Notice the Convex downward Breakthrough Curve



Design Strategies for TOC Removal



Design Strategies for TOC Removal – Treatment Objective = 1 mg/L = 50 ug/L of THM

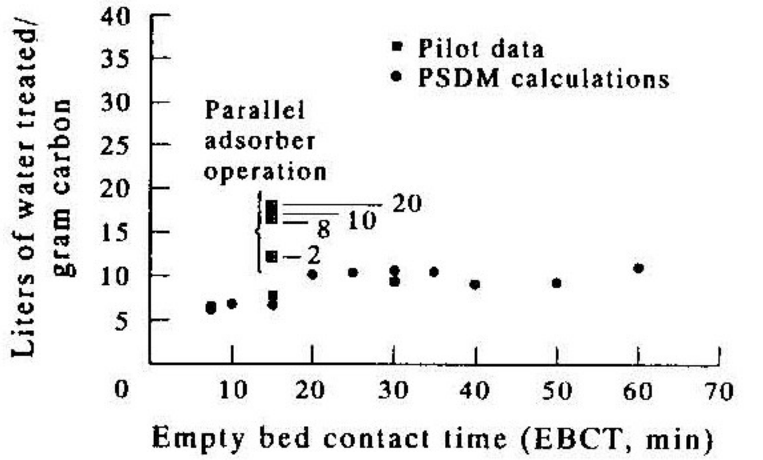
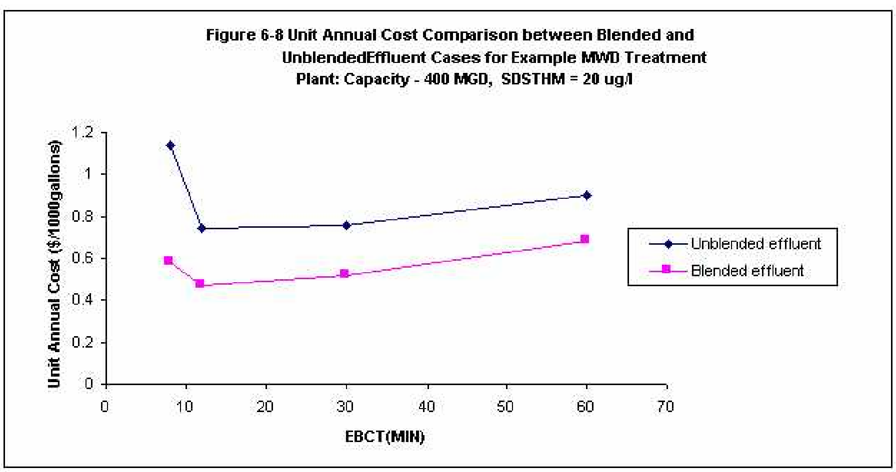


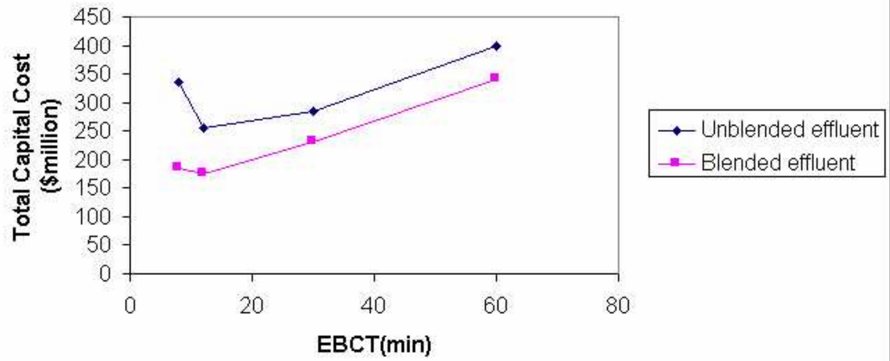
Fig. 9. Liters of water treated per gram of GAC for a DOC treatment objective of 1 mg/l as a function of EBCT for both the raw pilot data and PDM calculations.

Design Strategies for TOC Removal

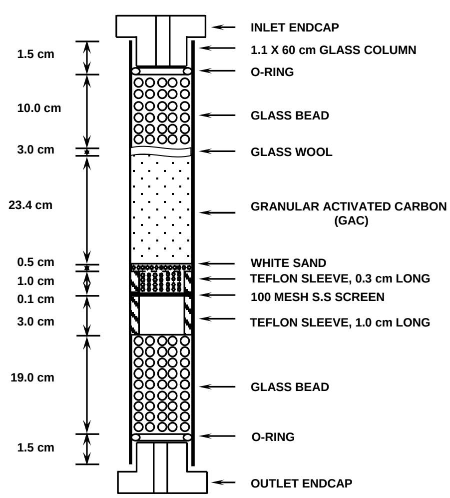


Design Strategies for TOC Removal

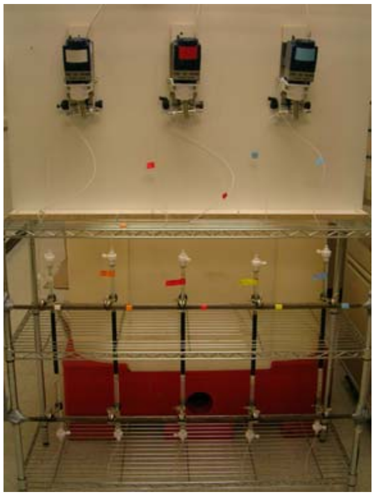
Figure 6-9 Total Capital Cost Comparison between Blended and Unblended Effluent Cases for Example MWD Treatment Plant: Capacity - 400 MGD, SDSTHM = 20 ug/l



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

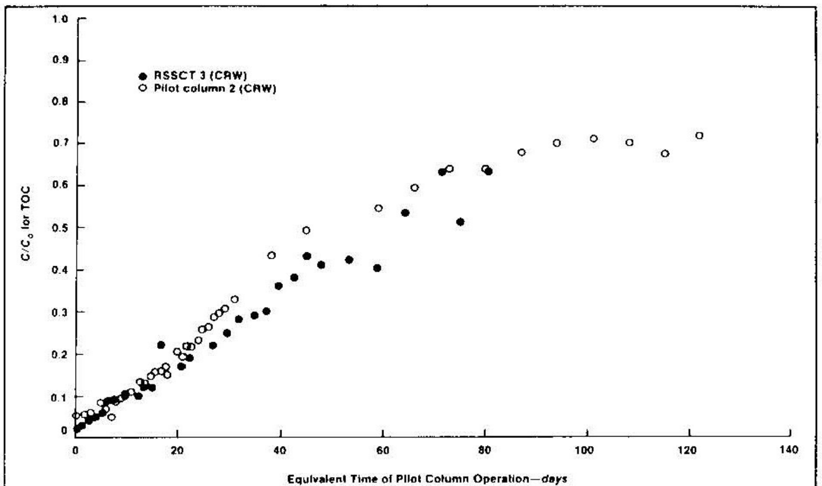


Figure 12. Comparison of TOC breakthrough profile from RSSCT with that from pilot GAC column (*setup of RSSCT assumed intraparticle diffusivity to be a linear function of GAC particle size*)

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

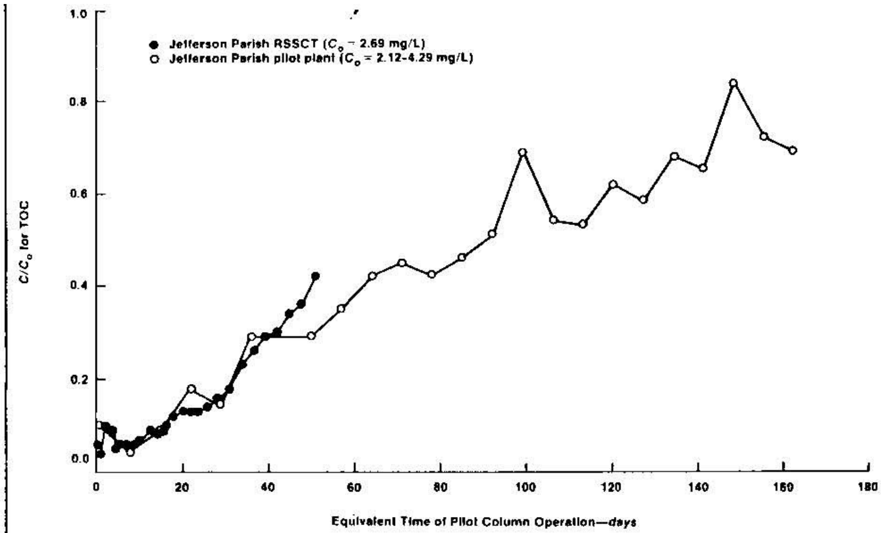


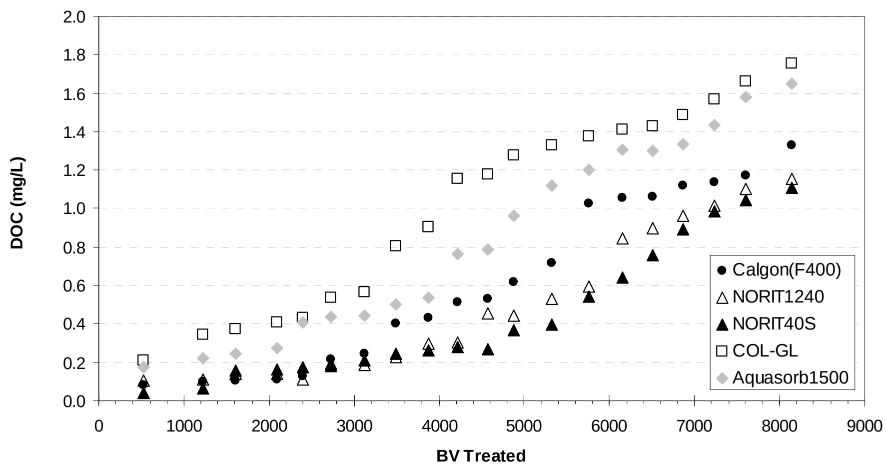
Figure 14. TOC breakthrough profiles for RSSCT and pilot plant for Jefferson Parish (*RSSCT EBCT—15 min; pilot EBCT—20 min; pilot run 3*)

City of Scottsdale Testing by ASU

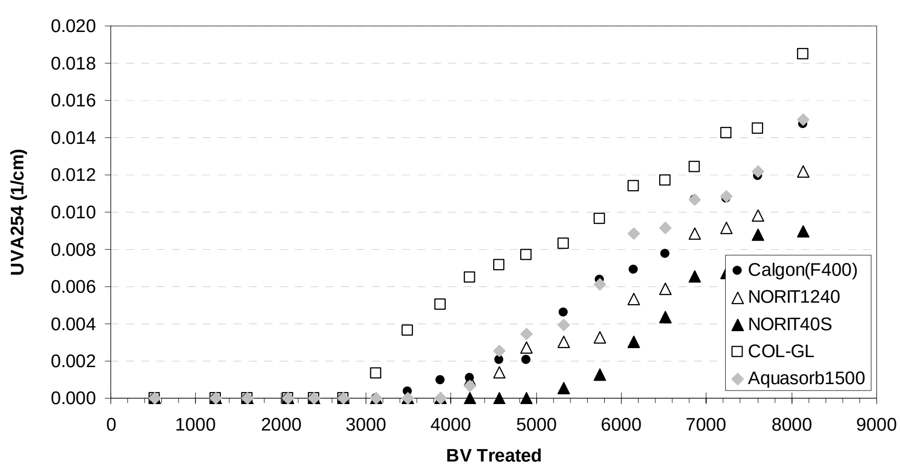
Design & operating parameters for full-scale contactor and RSSCT

Design Parameters	Full-scale	RSSCT
Particle Radius (cm)	**0.0513 (12 X 40)**	**0.0049 (140x170)**
EBCT (minutes)	**20**	**1.91**
Loading Rate (gpm/ft²) [m/h]	**4.3 (12)**	**3.0 (7.35)**
GAC Contactor **Length (ft)** **Width (ft)** **Surface Area (ft²)** **RSSCT** **Column Diameter (cm)**	**25** **50** **1250**	**1.1**
Bed Depth	**10 ft (256 cm)**	**23.4 cm**

TOC and UVA breakthrough curves from RSSCTs



TOC and UVA breakthrough curves from RSSCTs



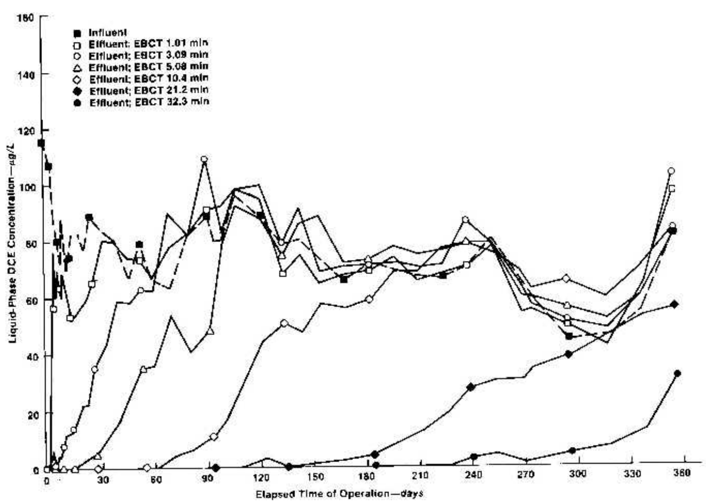
Design Strategies for a Single Compound

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).

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

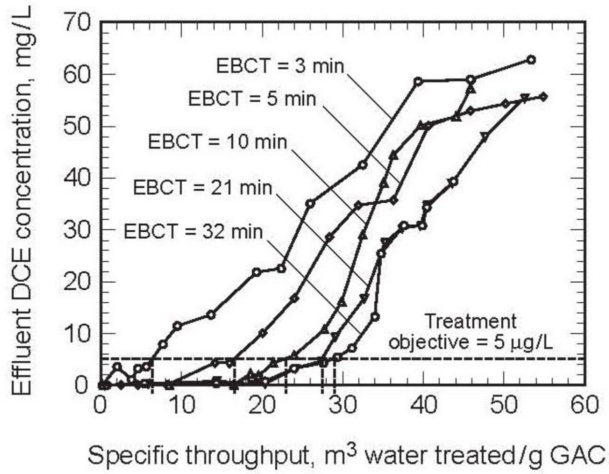
Design Strategies for a Single Compound

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

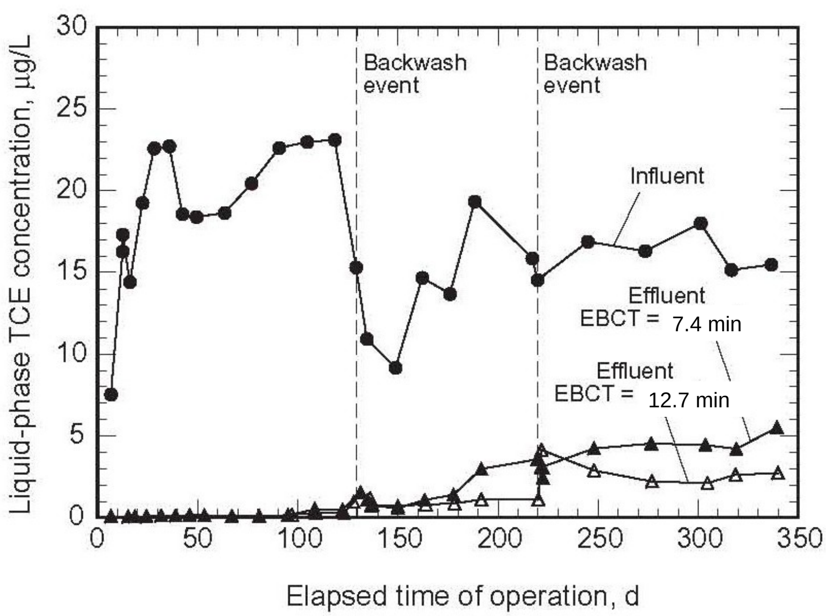


Design Strategies for a Single Compound

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



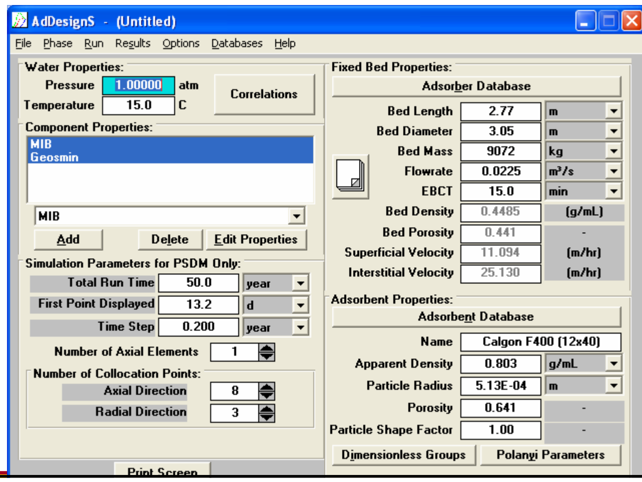
Impact of Backwashing for SOC Removal



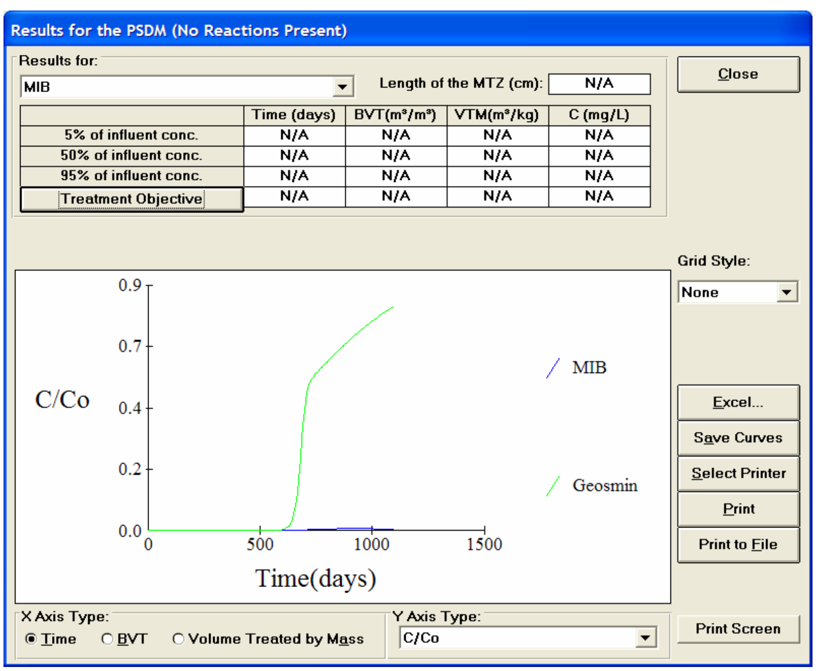
Model Predicted Removal

	k	unit	n		
MIB	17.6	ng/mg(L/ng)1/n	0.34	184.2946	ug/g(L/ug)1/n
Geosmin	34.5	ng/mg(L/ng)1/n	0.35	387.0964	ug/g(L/ug)1/n

Source: Graham, Wat. Res., vol 34, 8, pp2291-2300, 2000



EBCT = 7.5min

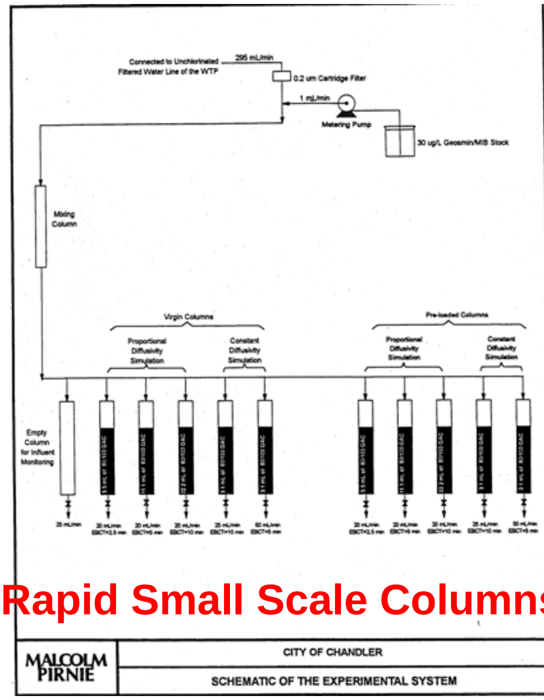


GAC Caps for MIB Control

- 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

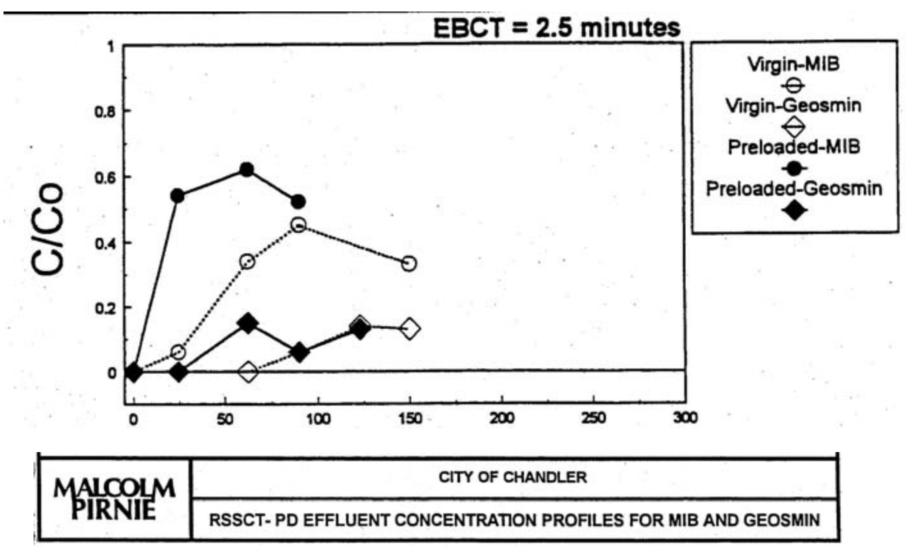
- Full-Scale Filter Design:
  - Filter caps designed to act as a barrier against synthetic organic compounds and T&O compounds
  - 20 inches GAC (8x30 US mesh size, Elf Atochem)
  - 10 inches of sand support
  - 12 inches of graded gravel
  - GAC replaced every 3 years @ HLR = 4 gpm/sf Purpose of the 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

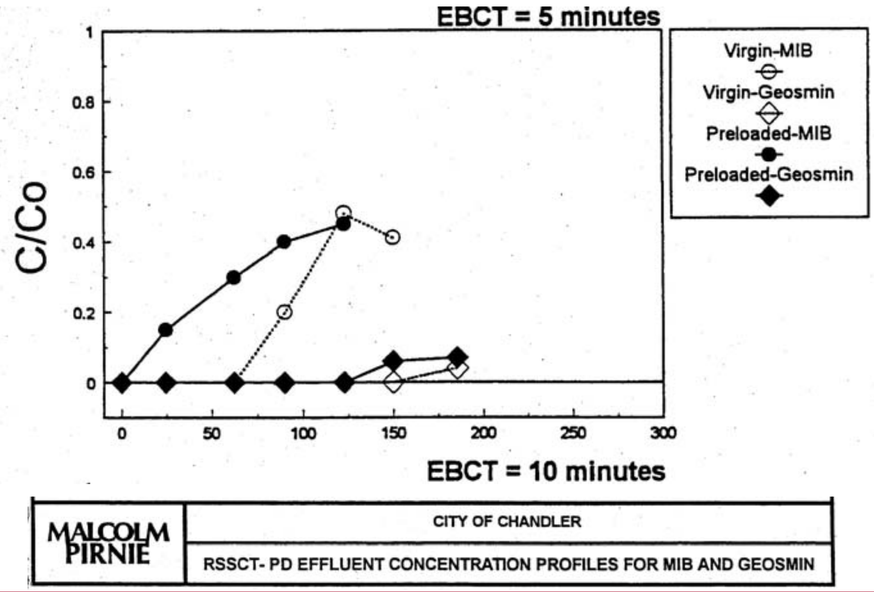
Effect of EBCT and carbon "age"

100 ng/L Spike of Geosmin and MIB



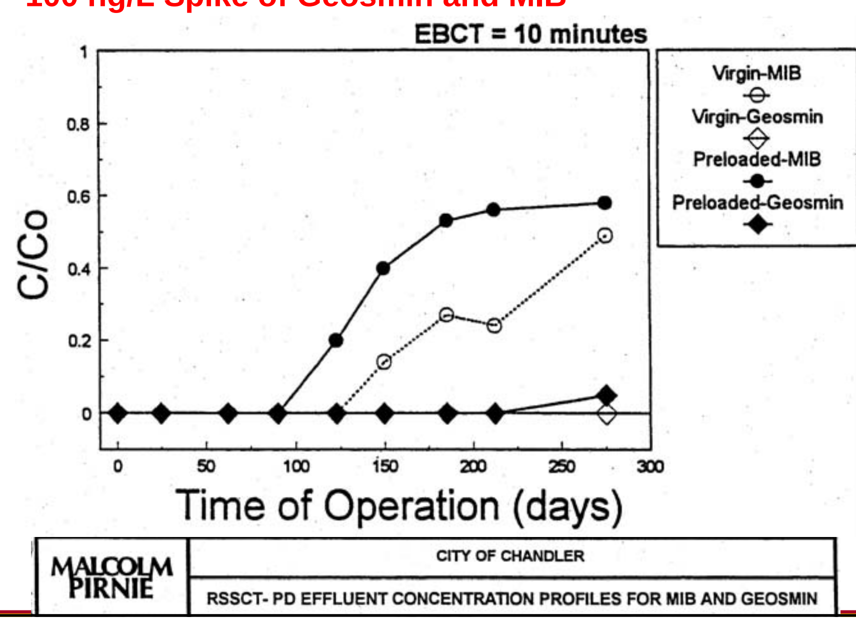
Effect of EBCT and carbon "age"

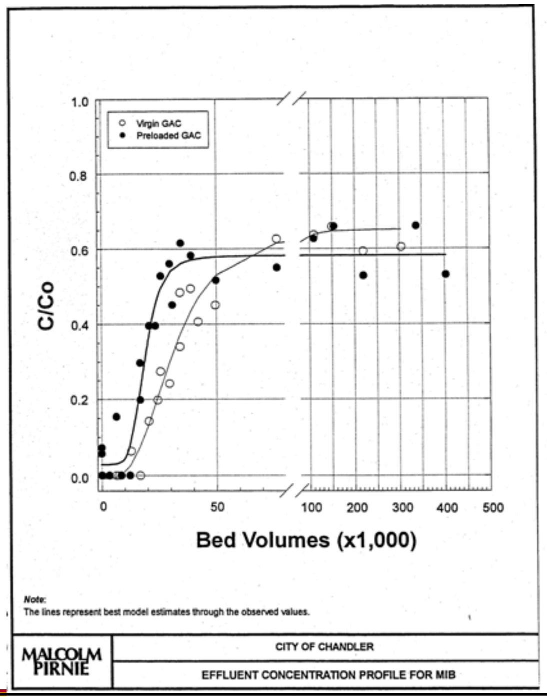
100 ng/L Spike of Geosmin and MIB



Effect of EBCT and carbon "age"

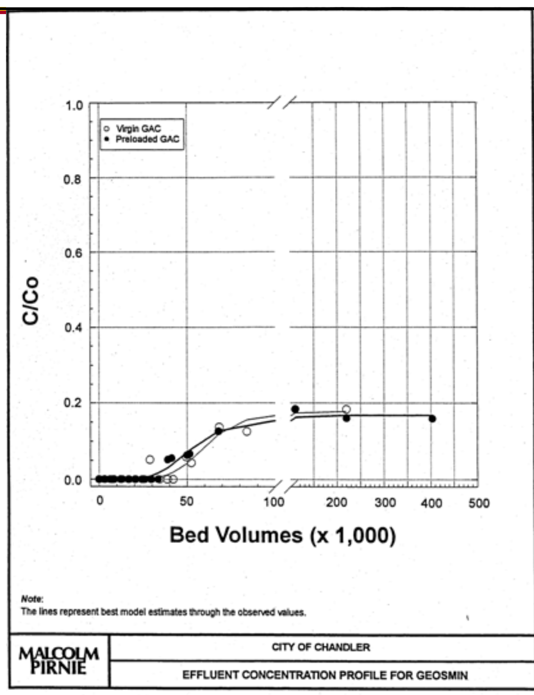
100 ng/L Spike of Geosmin and MIB





MIB

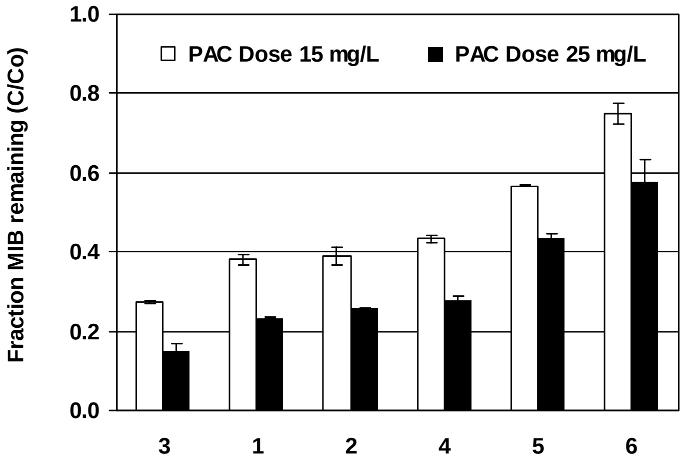
- 40% sustainable removal
- 1000 bed volumes ~ 1 day



Geosmin

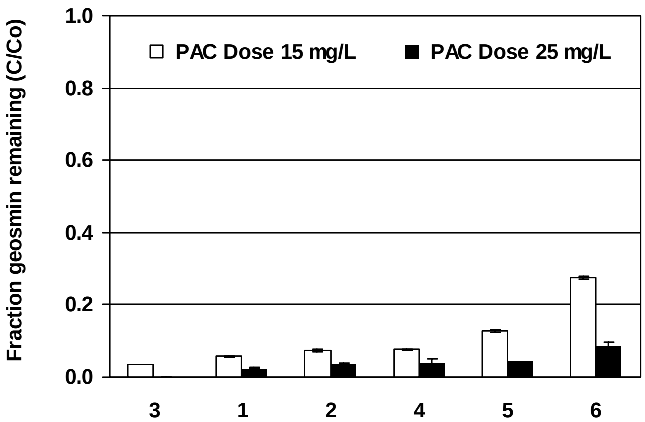
- 80% sustainable removal

Fraction MIB and geosmin remaining according to
Powder Activated Carbon (PAC)



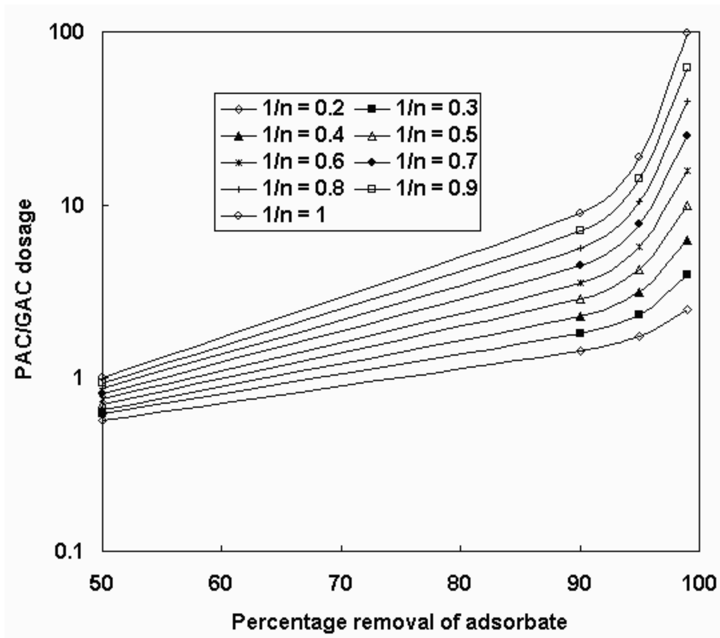
NO	source
1	wood
2	wood
3	-
4	Coal
5	Lignite
6	Bituminous

Fraction MIB and geosmin remaining according to
Powder Activated Carbon (PAC)

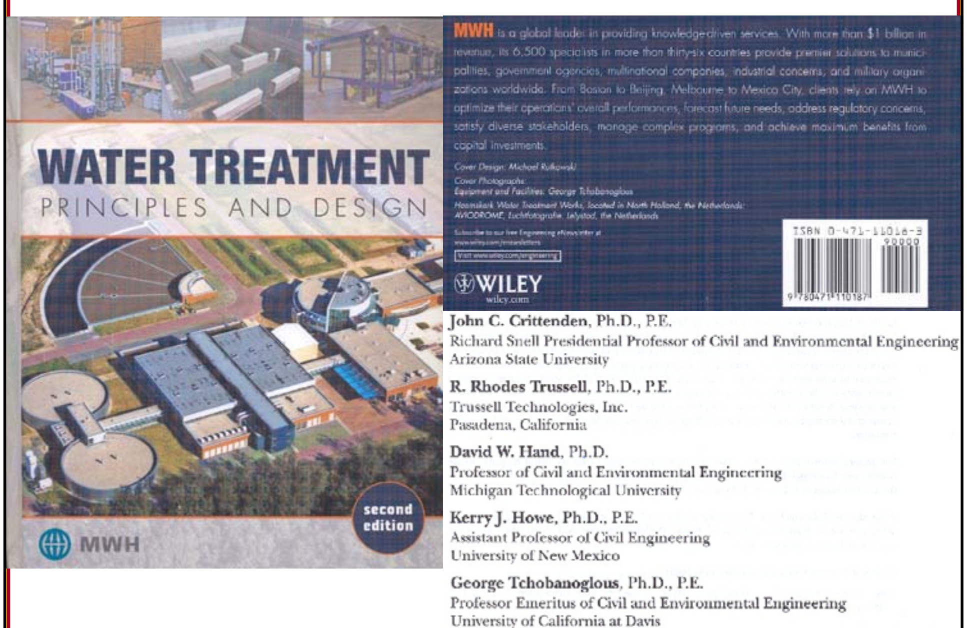


NO	source
1	wood
2	wood
3	-
4	Coal
5	Lignite
6	Bituminous

Usage Rates GAC versus PAC



Water Treatment Book -Theory Reduced to Practice
Montgomery-Watson-Harza invested $ 1 million, 1948 Pages



Water Treatment Book -Theory Reduced to Practice
Montgomery-Watson-Harza invested $ 1 million, 1948 Pages

Activated Carbon Summary

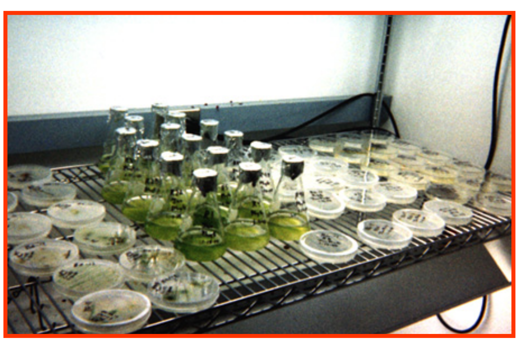
ASU

- 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 precusors 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 is 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 Hu[1], Milton Sommerfeld[1], and Paul Westerhoff[2]

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

Project supported by:
Salt River Project
ASU Water Quality Center

September 2, 2005

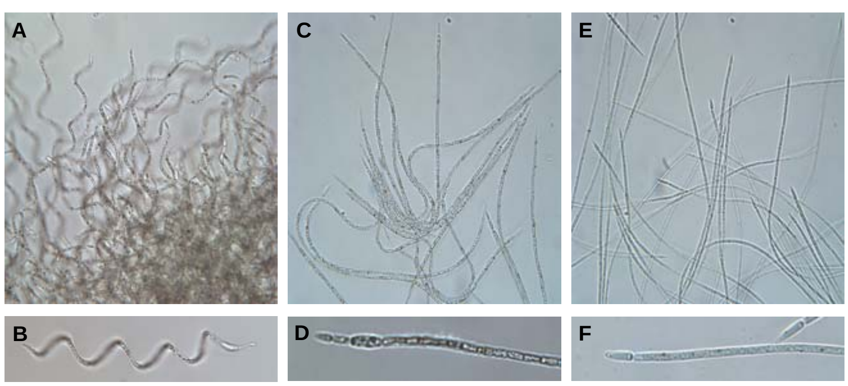
Goal of Research

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

AZ-82	*Cylindrospermopsis raciborskii* (straight)
AZ-83	*Cylindrospermopsis raciborskii* (straight)
AZ-84	*Cylindrospermopsis raciborskii* (straight)
AZ-85	*Cylindrospermopsis raciborskii* (straight)
AZ-86	*Cylindrospermopsis raciborskii* (straight)
AZ-87	*Cylindrospermopsis raciborskii* (straight)
AZ-88	*Cylindrospermopsis raciborskii* (straight)
AZ-89	*Cylindrospermopsis raciborskii* (straight)
AZ-11	*Cylindrospermopsis raciborskii* (straight)
AZ-33	*Cylindrospermopsis raciborskii* (straight)
AZ-60	*Cylindrospermopsis raciborskii* (straight)
AZ-14	*Cylindrospermopsis raciborskii* (straight, no gas vesicle)

AZ-5	*Cylindrospermopsis raciborskii* (curved)
AZ-19	*Cylindrospermopsis raciborskii* (curved)
AZ-30	*Cylindrospermopsis raciborskii* (curved)
AZ-50	*Cylindrospermopsis raciborskii* (curved)
AZ-51	*Cylindrospermopsis raciborskii* (curved)
AZ-52	*Cylindrospermopsis raciborskii* (curved)
AZ-53	*Cylindrospermopsis raciborskii* (curved)
AZ-54	*Cylindrospermopsis raciborskii* (curved)
AZ-76	*Cylindrospermopsis raciborskii* (curved)
AZ-80	*Cylindrospermopsis raciborskii* (curved)
AZ-81	*Cylindrospermopsis raciborskii* (curved)

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

```
Planktothrix       ATGCAAGTCGAACGGAATCCTTCGGGATTTAGTGGCGGACGGGTGAGTAACACGTAAGAA
Anabaena 7120      ATGCAAGTCGAACG--GTCTCTTCGGAGATAGTGGCGGACGGGTGAGTAACGCGTGAGAA
Calothrix          ATGCAAGTCGAACGG--TACCTTCGGGTATAGTGGCGGACGGGTGAGTAACGCGTGAGAA
Microcystis        ATGCAAGTCGAACGGGAATCTTCGGATTCCAGTGGCGGACGGGTGAGTAACGCGTAAGAA
Microcoleus        ATGCAAGTCGAACG-CAACCTTCGGGTTGAG-TGGCGGACGGGTGAGTAACGCGTGAGAA
Anabaenopsis       ATGCAAGTCGAACG--GTCTTTTCGGAGATAGTGGCGGACGGGTGAGTAACGCGTGAGAA
Aph. gracile       CATCAAGTCGAACGGTCTTTTCGG--AGATAGTGGCGGACGGGTGAGTAACGCGTAAGAA
Aph. flos-aquae    ATGCAAGTCGAACG--GTCTTTTAGGAGACAGTGGCGGACGGGTGAGTAACGCGTAAGAA
Nostoc sp.         ATGCAAGTCGAACG--GTGTCTTCGGACACAGTGGCGGACGGGTGAGTAACGCGTGAGAA
Anabaena bergii    ATGCAAGTCGAACGGTCTTTTCGG--AGATAGTGGCGGACGGGTGAGTAACGCGTGAGAA
Nodularia sp.      ATGCAAGTCGAACGGTCTCTTCGG--AGATAGTGGCGGACGGGTGAGTAACGCGTGAGAA
CR (Straight)      ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTGAGAA
CR (coiled)        ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTGAGAA
CR (Florida)       ATGCAAGTCGAACGGGATGCTTAGGCATCTAGTGGCGGACGGGTGAGTAACGCGTGAGAA
                   .:***********    :            . *******************.***.****
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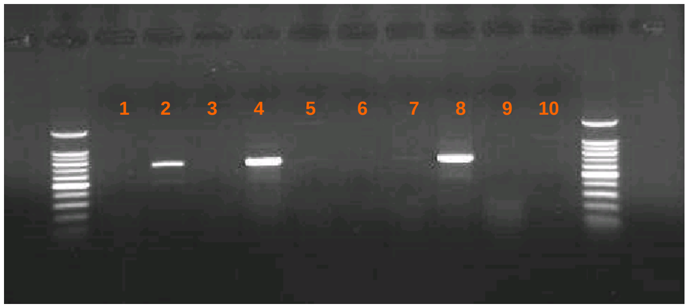
Cyl 16S-I

PCR Detection of *Cylindrospermopsis* in Saguaro Lake Samples



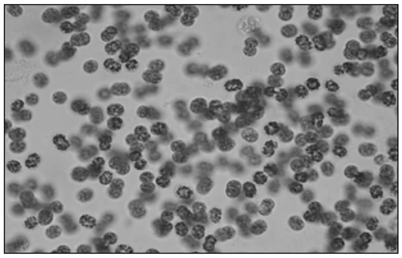
1: *Anabaena* TAC426
2: Saguaro Lake sample
3: *Nodularia* strain 575
4: *Cylindrospermopsis* AWT205
5: *Plankothrix* PCC7811
6: *Microcystis* LE-3
7: *Nostoc* PCC73102
8: Saguaro Lake sample
9: *Aphanizomenon* strain Zayi
10: No DNA sample

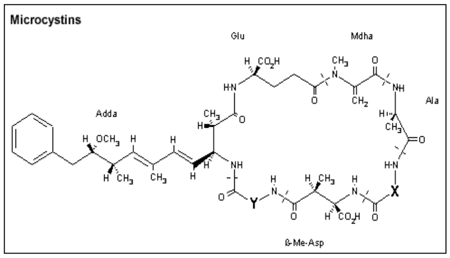
LC/MS/MS Screening of Toxins from Isolated *Cylindrospermopsis* Strains

ID #	**AZ-6**	**AZ-14**	**AZ-19**	**AZ-30**	**AZ-33**
Description	**Cylindro**	**Cylindro**	**Cylindro**	**Cylindro**	**Cylindro**
Analyte	**ppb**	**ppb**	**ppb**	**ppb**	**ppb**
Cylindrospermopsin	**1.2**	<0.5	<0.5	<0.5	**0.96**
Anatoxin-a Isomer	<0.5	<0.5	<0.5	<0.5	<0.5
Microcystin RR	<0.5	<0.5	<0.5	<0.5	<0.5
Microcystin LR	<0.5	<0.5	<0.5	<0.5	<0.5
Microcystin YR	<0.5	**1.5**	<0.5	<0.5	<0.5
Nodularin	<0.5	<0.5	<0.5	<0.5	<0.5

ID #	**A-12**	**AZ-16**	**AZ-22**	**AZ-60**	**AZ-70**
Description	**Cylindro**	**Cylindro**	**Cylindro**	**Cylindro**	**Cylindro**
Analyte	**ppb**	**ppb**	**ppb**	**ppb**	**ppb**
Cylindrospermopsin	<0.5	<0.5	**~ 2.5**	**<50**	<0.5
Anatoxin-a Isomer	<0.5	<0.5	**<0.5**	<0.5	<0.5
Microcystin RR	<0.5	<0.5	**<2.5**	<0.5	<0.5
Microcystin LR	<0.5	<0.5	**<2.5**	**~ 50**	<0.5
Microcystin YR	<0.5	**1.1**	**<2.5**	<0.5	<0.5
Nodularin	<0.5	<0.5	**<2.5**	<0.5	<0.5

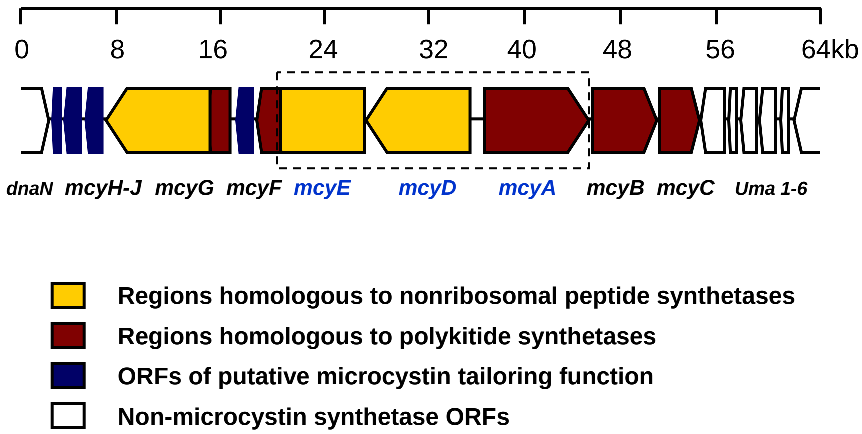
Isolation and identification of *Microcystis* sp. from Saguaro Lake



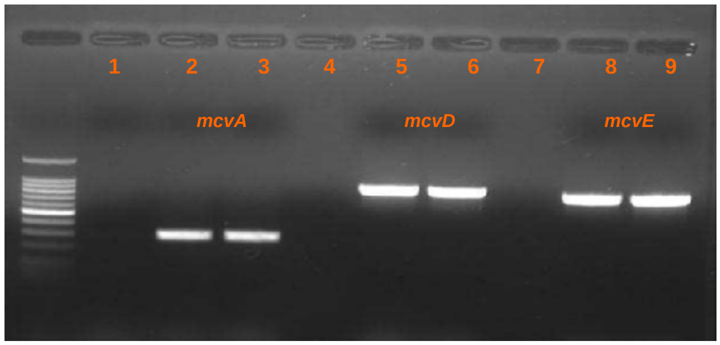


Elisa analysis: 1.21mg *microcystin-LR* /g cell dry weight

Organization of the Gene Cluster for Microcystin Biosynthesis



PCR Detection of *Microcystis* sp. from Saguaro Lake Samples



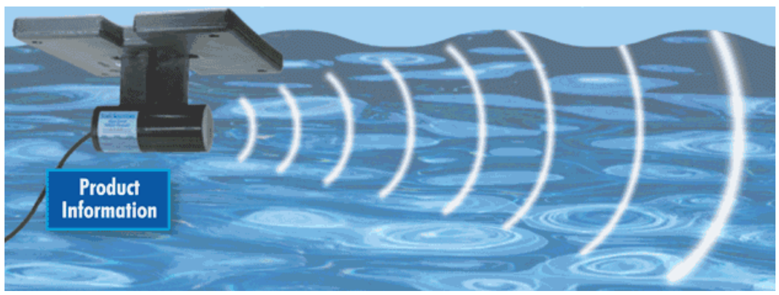
Lanes 1, 4, & 7: *N*egative controls
Lanes 2, 5, & 8: *Microcystis* sp. AZ-93 gene segments
Lanes 3, 6, & 9: *Microcystis* positive controls

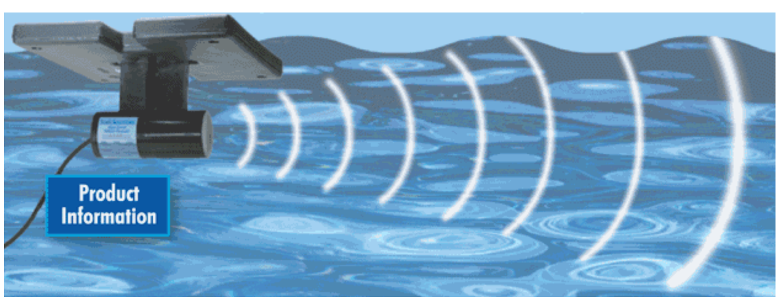
Planned Activities for Next Period

- 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

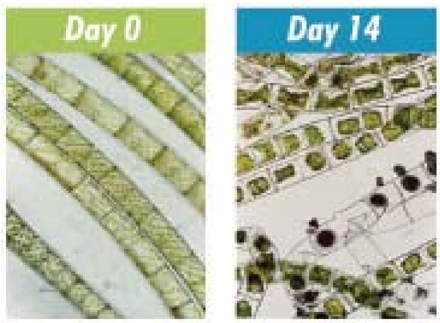
YoungIl Kim

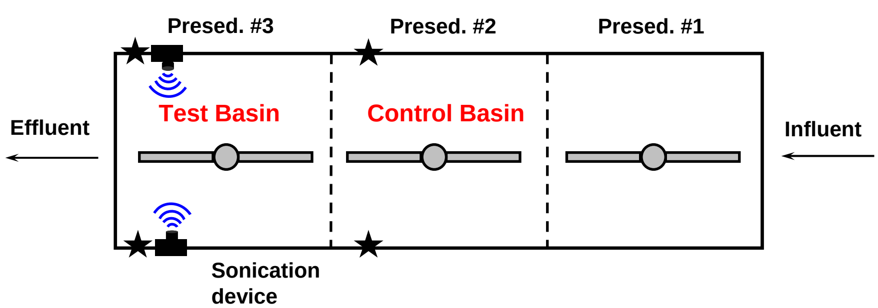




- ✓ Ultrasonic algae control device is the state-of-the-art, gets rid of algae without harming other aquatic life
- ✓ Ultrasonic device is environmentally friendly, easy to use, cost-effective and uses no chemicals

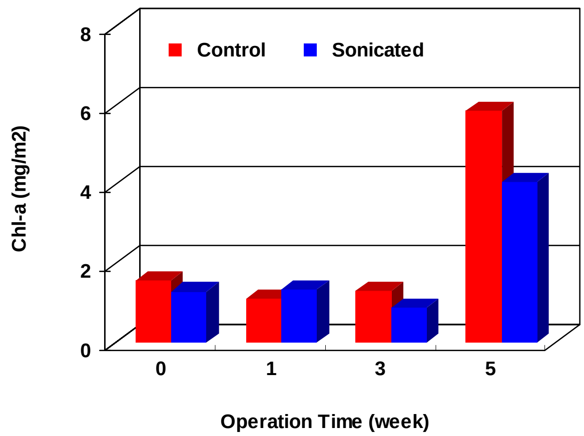
✓ **Ultrasonic device generate ultrasonic waves that shock and kill the algae by ripping the vacuole of the algae cell**



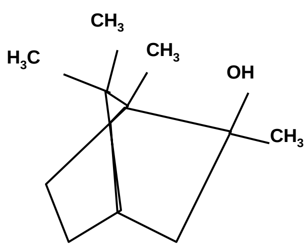


★ **Sampling Point**

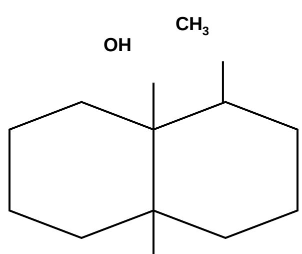
Dimension of Presed. Basin : 140 ft (W) x 140 ft (L) x 12 ft (H)



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?

ARIZONA VIRTUAL WATER UNIVERSITY

- **"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

ARIZONA VIRTUAL WATER UNIVERSITY

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:

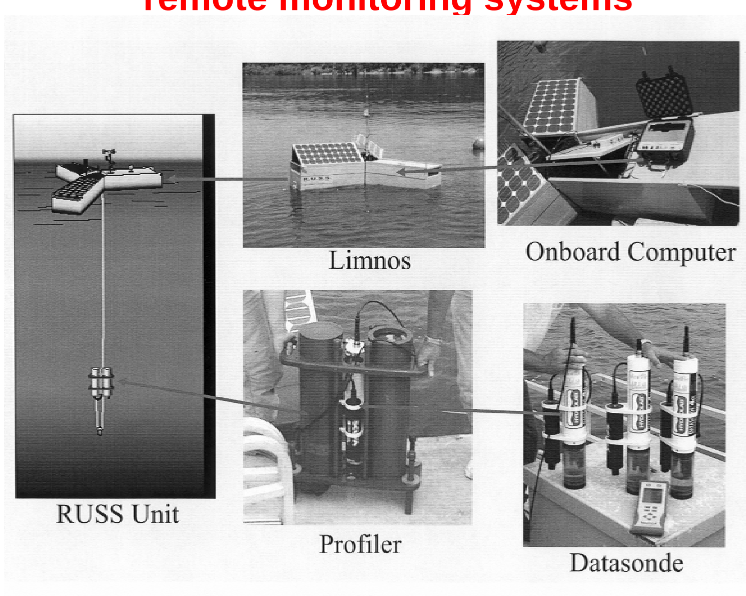
TO RESPOND TO THE RECENT AND EMERGING CONCERNS ABOUT TOXIC ALGAE

RESOURCE FOR TOXIC ALGAE AND TOXIN ANALYSIS

Establish an ASU facility with the capabilities to:

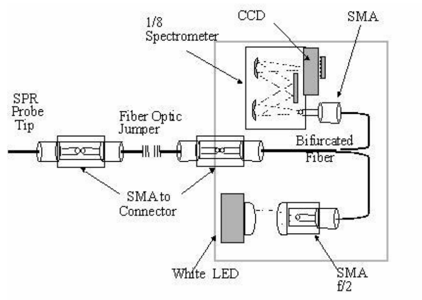
- Develop PCR primers specific for potential toxin-producing algae
- Develop real-time PCR protocol for quanitative detection of specific potentially toxic algae
- Apply these methods to detect the occurrence of potentially toxic strains
- Isolate and characterize potential toxic strains
- Develop an 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



Fiber-optic based SPR instrumentation

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

Arizona Canal – Water Temperatures