REGIONAL WATER QUALITY NEWSLETTER

DATE: Report for August 2009
Sampling conducted August 3 & 4, 2009
A Phoenix, Tempe, Glendale, Peoria, CAP, SRP – ASU Regional Water Quality Partnership

http://enpub.fulton.asu.edu/pwest/tasteandodor.htm

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SUMMARY: EVALUATION AND RECOMMENDATIONS

1. MIB plus geosmin levels above 10 ng/L in finished water lead to noticeable earthy-musty odors by customers. There are high levels of MIB (70 to 80 ng/L) near the surface of Saguaro Lake (17 ng/L deeper) and is the major source of MIB in the SRP canals right now (11 to 16 ng/L in canals upstream of groundwater well pumping sites). If these canal MIB levels exceed 25 to 30 ng/L, current powder activated carbon dosages will be insufficient to maintain MIB levels below 10 ng/L
2. **Hold the date for our Annual Regional Water Quality Workshop: Friday September 18 (8:30-11:30 am).**
3. A description of reservoir thermal profiles and how this affects MIB levels is presented.
4. Data for bank filtration and DOC reduction at GRUSP is presented.
5. A new project by SRP & ASU on water quality & reservoir release optimization is summarized.
6. A dialog on mussel controls during membrane treatment is initiated, and will be followed up on in the future.

Table 1a Summary of WTP Operations August 3, 2009

	Verde WTP	Union Hills	24th Street WTP	N.Tempe J.G. Martinez	Deer Valley	Glendale Cholla WTP [3]	Peoria Greenway WTP	Val Vista	South Tempe
	Verde River	CAP Canal	Arizona Canal					South Canal	
PAC Type and Dose		None	15 ppm Calgon WPH	15 ppm MWV Aqua Nuchar		None	Uses GAC	Target 15 ppm (actual 8 ppm)	15 ppm Aqua Nuchar
Copper Sulfate		None	0.5 ppm (0.3 ppm active coper)	None		None	None	0.25 ppm	None
PreOxidation		None	None	None		4.6 ppm Sunday-thursday	2.25 mg/L Ozone	None	None
Alum Dose Alkalinity pH		12.5 [1] 108 7.0	50 133/111 6.85	27 176 7.9		20 133 7.8	18 135/125 7.2	35 100 6.8	30 mg/lL 120 7.4
Finished water DOC DOC removal[2]									
Average turbidity over last 7 days		~0.5	4 to 9 ntu	16 ntu		8 ntu	4 to 6 ntu	5 ntu	3.3 NTU
Notes from operators		No plants reported T&O, however (see below) influent MIB levels are 10 to 20 ng/L at the SRP plants and should be noticeable in raw waters. Take a smell? Does it smell earthy-musty?							
Recommendations		Current PAC dosages max out at 15 ppm – this may not be suitable to control MIB to < 10 ng/L if levels of MIB continue to increase over coming weeks.							

[1] Ferric chloride instead of alum; plus ppm sulfuric acid
[2] Calculated based upon influent and filtered water DOC (note that DOC and not TOC is used in this calculation)
[3] Sample from finished water includes a blend of surface and ground water sources

Chandler WTP: No PAC (uses GAC capped filters), 60 ppm Alum at pH 7.3 for coagulation

Table 1
**SRP/CAP OPERATIONS - ** Values in cfs, for August 3, 2009

System	SRP Diversions	CAP
Arizona Canal	786	0
South Canal	804	0
Pumping	118	0
Total	1708	0

- **SRP is releasing water from both Verde and Salt River Systems**. Salt River release from Saguaro Lake: 1629 cfs; Verde River release from Bartlett Lake: 139 cfs.

- **What is going on in the Colorado River in terms of reservoir storage levels?** Lake Powell water elevation has been rising due to runoff from snowmelt and June rains in the Rocky Mountains. The levels below indicate that Lake Powell is 59 feet below full pool, which represents 66% of full pool capacity. Inflows so far this calendar year are 9.2 million acre-feet, which is just below the long term average for this time of year.

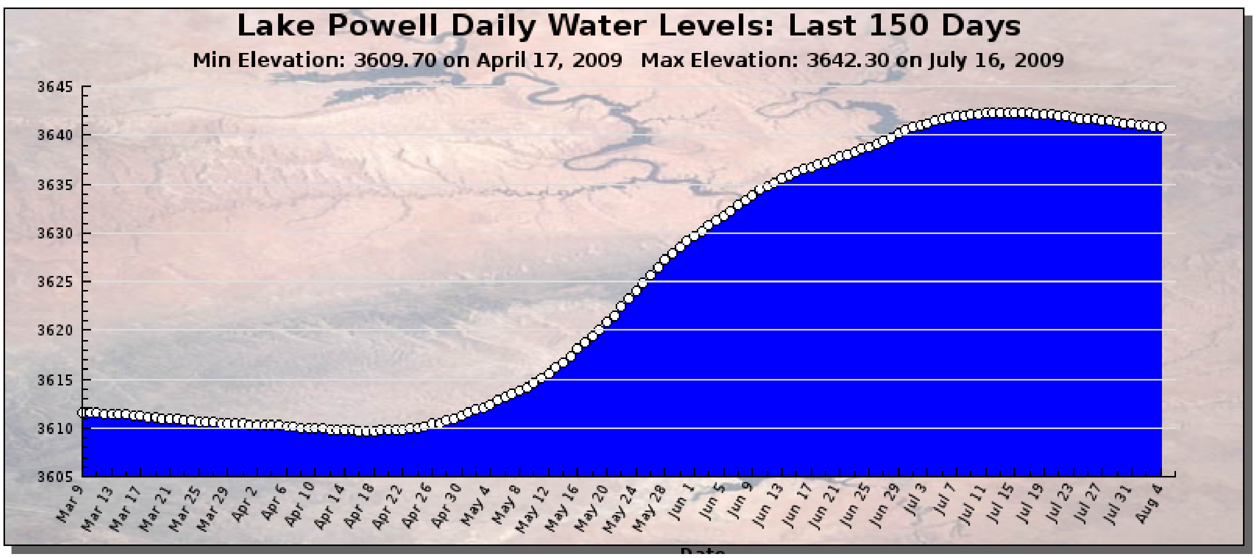


Table 2 - Water Treatment Plants – Aug 3, 2009

Sample Description	MIB (ng/L)	Geosmin (ng/L)	Cyclocitral (ng/L)
24th Street WTP Inlet	11.7	4.7	<2.0
24th Street WTP Treated	7.7	2.3	<2.0
Deer Valley Inlet	11.1	5.0	<2.0
Deer Valley WTP Treated	8.2	2.7	<2.0
Val Vista Inlet	12.7	2.8	<2.0
Val Vista WTP Treated –East	7.5	<2.0	<2.0
Val Vista WTP Treated -West	8.0	<2.0	<2.0
Union Hills Inlet	2.1	<2.0	<2.0
Union Hills Treated	2.0	<2.0	<2.0
Tempe North Inlet	15.6	4.7	<2.0
Tempe North Plant Treated	7.8	<2.0	<2.0
Tempe South WTP	5.5	<2.0	<2.0
Tempe South Plant Treated	6.4	<2.0	<2.0
Greenway WTP Inlet	2.3	<2.0	<2.0
Greenway WTP Treated	<2.0	<2.0	<2.0
Glendale WTP Inlet	12.5	5.6	<2.0
Glendale WTP Treated	<2.0	<2.0	<2.0
Glendale WTP Treated (Lab)			

MIB plus geosmin levels above 10 ng/L in finished water lead to noticeable earthy-musty odors by customers. Currently MIB+geosmin levels are near or slightly above 10 ng/L in several WTPs. However, treatment with PAC or GAC is bringing these levels down to less noticeable levels.

Glendale blends surface and groundwaters, and is not using PAC or GAC for control of T&O compounds. Union Hills WTP is on the CAP canal which has lower MIB and Geosmin levels than the SRP system.

Powder Activated Carbon (PAC) is being added at 4 WTPs. Three of these plants are achieving 25% to 50% MIB removal at PAC dosages of 8 to 15 ppm (Table 1). One plant is adding PAC but getting no removal, which suggests there could be in-plant formation sources of MIB (S. Tempe WTP) as we have observed in past years.

We used some of this data in a PAC model we developed (below). The model slightly overpredicts observed MIB removal. However, the model suggests that if MIB levels in the canals reach 30 ng/L, then the current PAC dosages will be inadequate to keep MIB in finished water below 10 ng/L.

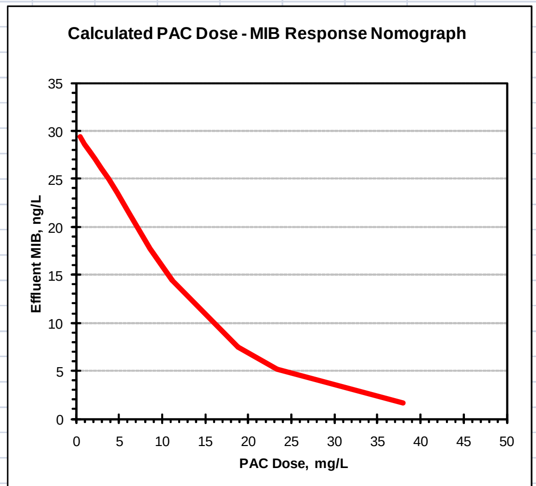
Arizona State University (Tempe, Arizona) June 2004

Estimation of PAC Doses to remove Taste and Odor Compounds

Directions: User should input values for each step. For step#2 enter <u>either</u> blends of water OR a fixed influent DOC.

Step #

Step					
1	Enter PAC Brand Number	2	1 = Norit 20 B		
			2 = Westvaco Aquanuchar		
			3 = Super PAC2(Norit Supplied Test Product)		
2	Enter % Each Water Type	0%	1 = CAP Water	2.8	mgDOC/L
	(Enter updated DOC values	0%	2 = Groundwater	1.5	mgDOC/L
	or use default DOC values)	92%	3 = Salt River Water	4.32	mgDOC/L
		8%	4 = Verde River Water	2.33	mgDOC/L
	Calculated DOC	4.2			
	OR Enter DOC	0	(Enter "0" if unknown & using blends from above)		
	Calculated DOC for PAC modeling	4.2	mg/L		
3	Initial MIB =	30	ng/L		
4	Flowrate =	50	Million of Gallons per Day, MGD		
5	PAC Equivalent Contact Basin Size:	2	Million of Gallons, MG		
	Calculated Basin Contact Time =	58	minutes		



HRT Range for calculations	(Only change if Calculated Basin Contact Time is > 8 hours)				
Minimum Contact Time	from	10	minutes	(Default = 10 minutes)	
Maximum contact time	to	8	hours (Value should be > Basin Contact Time)		
			(Default maximum time is 8 hours)		

6 Calculated PAC doses from model (do not change)

PAC Dose, mg/L	37.9	23.3	18.8	11.2	8.6	6.2	4.8	3.8	2.9	2.2	1.6	1.0	0.5
Effluent MIB, ng/L	2	5	8	14	18	21	24	25	26	27	28	29	29
% C/Co	6	17	25	48	59	72	79	83	87	90	93	95	98

ENTER Target Effluent MIB: 8 ng/L

Calculated Recommended PAC Dose 18.8 mg/L

Acknowledgement: This model was developed by Prof. Paul Westerhoff and Dr. Mario Esparza-Soto at Arizona State University (Tempe, A
The HSDM empirical equations and relationships were developed and provided by Prof. John Crittenden/ASU.

Disclaimer: Recommended PAC doses are predicted concentrations, and many factors (alum or chlorine addition, temperature, etc.) can also affect MIB removal peformance.

Table 3 - Canal Sampling – Aug 3, 2009				
System	**Sample Description**	**MIB (ng/L)**	**Geosmin (ng/L)**	**Cyclocitral (ng/L)**
CAP	Waddell Canal	**<2.0**	**<2.0**	**<2.0**
	Union Hills Inlet	**2.1**	**<2.0**	**<2.0**
	CAP Canal at Cross-connect			
	Salt River @ Blue Pt Bridge	**16.0**	**2.1**	**<2.0**
	Verde River @ Beeline	**4.2**	**2.5**	**<2.0**
AZ Canal	AZ Canal above CAP Cross-connect	**13.7**	**3.3**	**<2.0**
	AZ Canal below CAP Cross-connect	**15.4**	**3.2**	**<2.0**
	AZ Canal at Highway 87	**15.2**	**3.9**	**<2.0**
	AZ Canal at Pima Rd.	**11.8**	**3.4**	**<2.0**
	AZ Canal at 56th St.	**12.8**	**4.9**	**<2.0**
	AZ Canal - Inlet to 24th Street WTP	**11.7**	**4.7**	**<2.0**
	AZ Canal - Central Avenue	**11.2**	**5.9**	**<2.0**
	AZ Canal - Inlet to Deer Valley WTP	**11.1**	**5.0**	**<2.0**
	AZ Canal - Inlet to Glendale WTP	**12.5**	**5.6**	**<2.0**
South and Tempe Canals	South Canal below CAP Cross-connect	**14.8**	**3.8**	**<2.0**
	South Canal at Val Vista WTP	**12.7**	**2.8**	**<2.0**
	Head of the Tempe Canal	**13.1**	**3.0**	**<2.0**
	Tempe Canal - Inlet to Tempe's South Plant	**5.5**	**<2.0**	**<2.0**

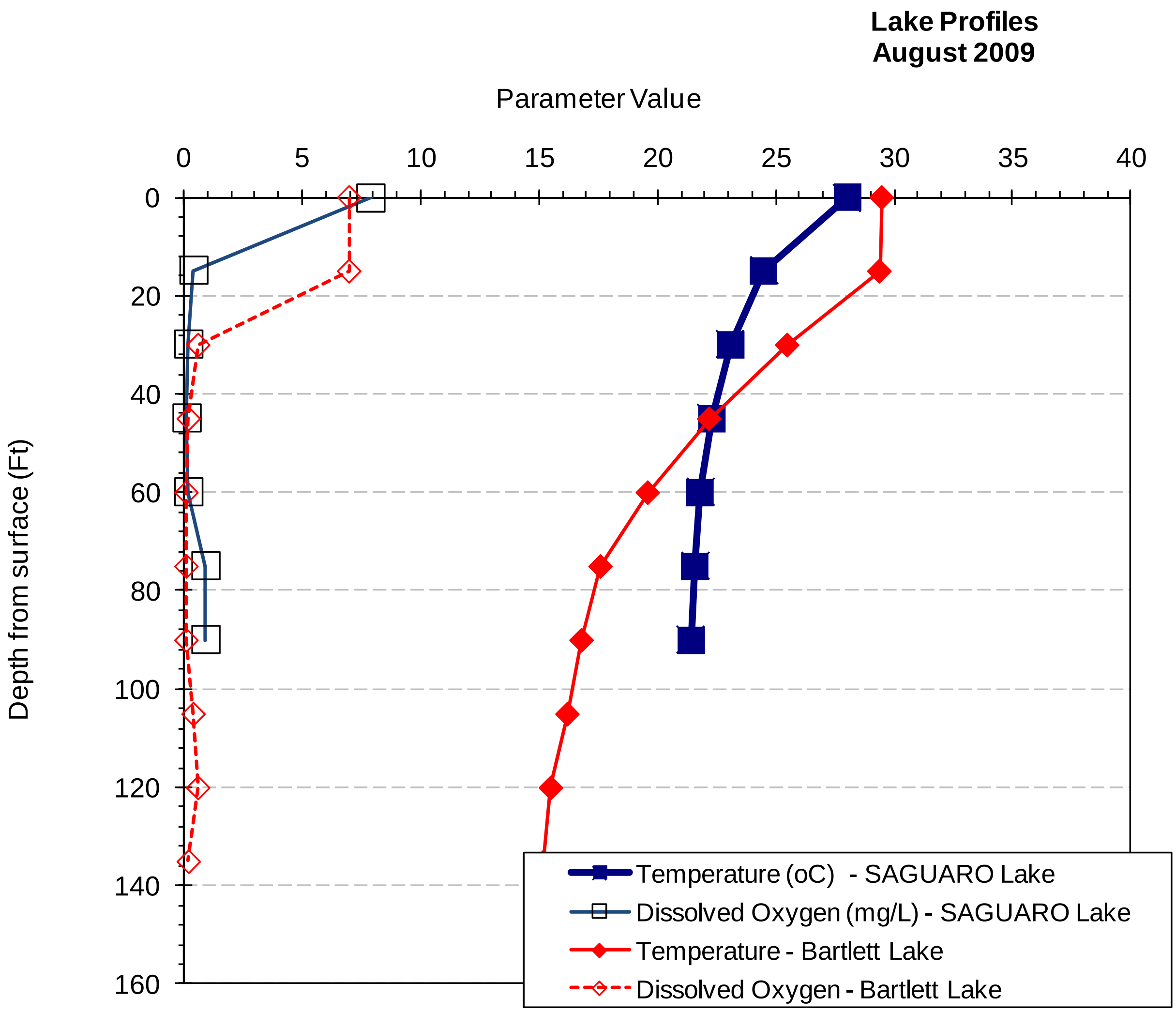
There is no apparent FORMATION of MIB in the canals – but perhaps a slight formation of geosmin because concentrations increase by nearly 40% along the length of the canal.

Table 4 - Reservoir Samples – Aug 4, 2009				
Sample Description	**Location**	**MIB (ng/L)**	**Geosmin (ng/L)**	**Cyclocitral (ng/L)**
Lake Pleasant (sampling later in August)	Eplimnion			
Lake Pleasant	Hypolimnion			
Verde River @ Beeline		**4.2**	**2.5**	**<2.0**
Bartlett Reservoir	Epilimnion	**4.4**	**<2.0**	**<2.0**
	Epi-near dock	**8.5**	**<2.0**	**<2.0**
	Hypolimnion	**<2.0**	**<2.0**	**<2.0**
Salt River @ BluePt Bridge		**16.0**	**2.1**	**<2.0**
Saguaro Lake	Epilimnion	**73.7**	**4.9**	**2.6**
	Epi - Duplicate	**77.3**	**4.5**	**<2.0**
	Epi-near dock	**80.0**	**7.3**	**<2.0**
	Hypolimnion	**17.7**	**<2.0**	**<2.0**
Verde River at Tangle Creek				

MIB and geosmin levels are now detectable in the reservoirs and rivers as the summer progresses. This is typical as the lake temperatures go above 20 ^{o}C and cyanobacteria that produce these compounds start to grow. We usually observe the highest concentrations in lakes between now and September. There is no evidence of MIB or geosmin production in the SRP canal system.

Very high MIB levels (70 to 80 ng/L) are present in the upper water column of Saguaro Lake. Saguaro lake becomes weakly thermally stratified as shown on next page. This means heavier, cold water sinks towards the bottom while warmer (less dense) and lighter water stays near the lakes surface where sunlight warms the water. When the reservoir is stratified – MIB in the upper 20 feet of the water (near the surface – aka *epilimnion*) does not mix well with water deeper (*hypolimnion*) in the lake. This is good news because MIB is highest near the surface of the lake. The outlet from Saguaro Lake is near the bottom (roughly 80 feet below the surface) – so the water SRP is releasing from Saguaro Lake has only 17 ng/L of MIB instead of near 80 ng/L like the upper parts of the lake. The bad news is that Saguaro Lake is weakly stratified because of upstream hydropower production. That means slow mixing is occurring in the lake. In contrast on the verde river, Bartlett Lake is not involved with hydropower generation and a *stronger* thermal temperature gradient sets up which prohibits much vertical mixing.

What we don't know is for how long MIB production in Saguaro Lake will continue. Last year we say it last for only 1 month in the epilimnion (that would be good news). If is lasts longer, we could have very high MIB levels over the coming weeks being released from Saguaro Lake on the Salt River, where SRP is getting ~ 90% of its water for the canals for currently.



Organic Matter Status In the Treatment Plants

Table 5 - Water Treatment Plants – August 03, 2009

Sample Description	DOC (mg/L)	UV254 (1/cm)	SUVA (L/mg-m)	TDN		DOC removal (%)
24th Street WTP Inlet	4.38	0.100	2.29	0.30		
24th Street WTP Treated	2.83	0.042	1.48	0.35		35
Deer Valley Inlet	4.22	0.096	2.28	0.58		
Deer Valley WTP Treated	2.83	0.046	1.62	0.46		33
Val Vista Inlet	4.38	0.100	2.27	0.28		
Val Vista WTP Treated –East	2.84	0.045	1.59	0.30		35
Val Vista WTP Treated -West	2.39	0.035	1.45	0.19		45
Union Hills Inlet	3.07	0.042	1.37	0.42		
Union Hills Treated	2.32	0.021	0.92	0.33		24
Tempe North Inlet	4.31	0.100	2.32	0.28		
Tempe North Plant Treated	3.27	0.057	1.74	0.24		24
Tempe South WTP	4.24	0.097	2.29	0.29		
Tempe South Plant Treated	3.31	0.059	1.79	0.22		22
Greenway WTP Inlet	3.49	0.078	2.23	1.83		
Greenway WTP Treated	2.47	0.026	1.06	0.83		29
Glendale WTP Inlet	4.23	0.094	2.21	0.74		
Glendale WTP Treated	2.95	0.037	1.25	0.38		30

DOC = Dissolved organic carbon
UV254 = ultraviolet absorbance at 254 nm (an indicator of aromatic carbon content)
SUVA = UV254/DOC
TDN = Total dissolved nitrogen (mgN/L)

Organic Matter Status In the Canals

Table 6 - Organics in Canals (August 3, 2009)

Sample Description	DOC (mg/L)	UV254 (1/cm)	SUVA (L/mg-m)	TDN
Waddell Canal	2.81	0.044	1.56	0.47
Union Hills Inlet	3.07	0.042	1.37	0.42
CAP Canal at Cross-connect				
Salt River @ Blue Pt Bridge	4.32	0.101	2.33	0.33
Verde River @ Beeline	2.33	0.059	2.51	0.22
AZ Canal above CAP Cross-connect	4.35	0.101	2.33	0.31
AZ Canal below CAP Cross-connect	4.37	0.100	2.30	0.30
AZ Canal at Highway 87	4.46	0.101	2.26	0.27
AZ Canal at Pima Rd.	4.47	0.099	2.21	0.26
AZ Canal at 56th St.	4.49	0.100	2.23	0.29
AZ Canal - Inlet to 24th Street WTP	4.38	0.100	2.29	0.30
AZ Canal - Central Avenue	4.39	0.100	2.27	0.28
AZ Canal - Inlet to Deer Valley WTP	4.22	0.096	2.28	0.58
AZ Canal - Inlet to Glendale WTP	4.23	0.094	2.21	0.74
AZ Canal - Inlet to Greenway WTP	3.49	0.078	2.23	1.83
South Canal below CAP Cross-connect	4.31	0.100	2.32	0.31
South Canal at Val Vista WTP	4.38	0.100	2.27	0.28
Head of the Tempe Canal	4.31	0.100	2.31	0.27
Tempe Canal - Inlet to Tempe's South Plant	4.24	0.097	2.29	0.29
Chandler WTP – Inlet				

Reservoirs

Table 7 - Reservoir Samples – August 03, 2009					
Sample Description	**Location**	**DOC (mg/L)**	**UV254 (1/cm)**	**SUVA (L/mg-m)**	**TDN**
Lake Pleasant (July 2009)	Eplimnion	**2.90**	**0.046**	**1.59**	**0.46**
Lake Pleasant	Hypolimnion	**3.62**	**0.044**	**1.22**	**0.24**
Verde River @ Beeline		**2.33**	**0.059**	**2.51**	**0.22**
Bartlett Reservoir	Epilimnion	**4.09**	**0.073**	**1.77**	**0.34**
Bartlett Reservoir	Epi-near dock				
Bartlett Reservoir	Hypolimnion	**3.46**	**0.094**	**2.73**	**0.28**
Salt River @ BluePt Bridge		**4.32**	**0.101**	**2.33**	**0.33**
Saguaro Lake	Epilimnion	**5.95**	**0.112**	**1.88**	**0.68**
Saguaro Lake	Epi - Duplicate	**5.51**	**0.108**	**1.97**	**0.49**
Saguaro Lake	Epi-near doc				
Saguaro Lake	Hypolimnion	**5.48**	**0.108**	**1.98**	**0.66**
Verde River at Tangle					
Havasu	Jul-09	**2.78**	**0.044**	**1.58**	**0.53**

SRP Funds New Project with ASU Team

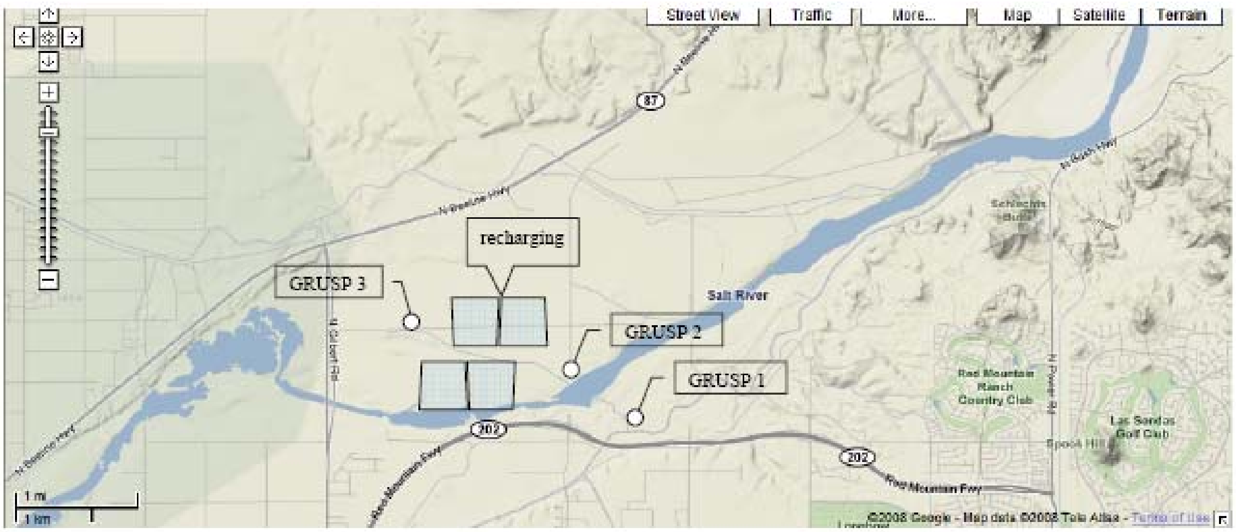
Title: **Predictive Models for Managing Water Sources for Municipal Disinfection By-Product Control**
PI: Paul Westerhoff
Dates: July 2009-June 2010

Several cities have asked SRP "What would it take for SRP to provide water from one source with lower DBP precursors instead of another source that is currently being used but contains higher DBP precursor levels?" The goal of this project will be to provide a series of models that assess the potential blends of water to specific municipal water intakes that would enable them to more readily meet DBP regulations. We would use existing water treatment models in conjunction with data from our routine reservoir sampling, and historic data, to predict chemical usage requirements for WTPs to meet DBP regulations. We would then work with SRP to develop models that represent "off-set" costs for not using a specific water source (e.g., decrease Salt River releases in favor of Verde River or groundwater). The central questions to answer will be

- At what point do the chemical (or future capital) treatment costs cease to achieve DBP regulatory levels or become greater than the offset costs of releasing water or pumping water from specific SRP (or other sources)?
- Using historical data, what modifications (i.e., how much water) would have had to been made to assist a specific municipality (Tempe South WTP, Phoenix 24th Street WTP) to achieve DBP regulations – and how does that compare with the chemical costs the cities actually used instead of the blended water option.

Organics at SRPs Granite Reef Underground Storage Project (GRUSP)

SRP operates GRUSP as a long-term surface water recharge facility. It is located along the Salt River near Gilbert Road and the Salt River. Surface water from the SRP canal (contains roughly 4 mg/L of DOC right now) is recharged through surface spreading basins into the groundwater. DOC undergoes biological and chemical removal during recharge, which we have reported on previously. We also showed data on EDC/PPCPs for this site in our March 2009 Newsletter. We have resampled for EDC/PPCPs (data in future newsletters) and here report data on DOC in the monitoring wells for July 2009 (see table below). The DOC levels are much lower than the surface water. In other work we confirmed these magnitudes of change. While there is some mixing with local groundwater (as evident by elevated total nitrogen (TN) levels from nitrate), well #2 is mostly recharged surface water. This data continues to build strong evidence for and support of the concept of **BANK FILTRATION** as a means of reducing DOC levels (these are disinfection by-product precursors) prior to use as raw water for water treatment plants.



Sampling date: 7/21/2009	pH	Conductivity (mS)	DO (mg/L)	DOC (mg-C/L)	TN (mg-N/L)	UV254
GRUSP Measuring Well #1	8.1	0.75	9.34	0.42	0.88	0.007
GRUSP Measuring Well #2	7.8	1.04	7.39	0.48	0.01	0.004
GRUSP Measuring Well #3	7.8	1.02	7.54	0.86	1.66	0.01

We are coordinating with CAP to sample 3 of their recharge sites (the Agua Fria, Hieroglyphic Mountains and Tonopah Desert Recharge Projects, - http://www.cap-az.com/operations/recharge/) that recharge CAP water.

How can we keep veligers and mussels from affecting our membrane treatment plants?

Comment/Question:

Although it seems that only our membrane treatment plant off the CAP has been affected so far, is there anyway we can discuss the quagga mussels again and preventative measures different types of Surface water treatment plants can implement?

We've tried KMnO4 and ended up with yellow water, but thought we'd achieved a good kill on the veligers and have been super-chlorinating basins to kill the adult attached mussels. Because of the yellow water, we've stopped the KMnO4 feed.

We've been asking around about the different levels of KMnO4 that would be effective on the veliger stage, to prevent them from settling in the raw water ponds and the membrane basins, but haven't found anyone who has used KMnO4 in a membrane plant that doesn't have the capacity to add other coagulants to remove excess Mn.

Thanks, Nina

Nina Miller
Environmental Compliance Manager
Arizona American Water
(623) 445-2406

Response:

Potassium permanganate ($KMnO_4$) after use can turn water yellow or brown in color. In addition, $KMnO_4$ can also oxidize reduced metals (iron, manganese), if present from Lake Pleasant, to form yellow-ish colloids too.

In a quick review of the literature, I did not find reports of >50% veliger removal by $KMnO_4$ at reasonable dosages (< 3 mg/L) or contact times (< 5 hours). Klerks, P.L. , P.C. Fraleigh and R.C. Stevenson. 1993. Controlling zebra mussel (*Dreissena polymorpha*) veligers with three oxidizing chemicals: chlorine, permanganate, and peroxide + iron. Pp. 621-641, In: Zebra Mussels: Biology, Impacts and Control. T.F. Nalepa and D.W. Schloesser (Eds.). Lewis Publishers, Boca Raton.

The effectiveness of chlorine is well known, but here is information on some other molluscicide chemicals. This is from a paper in 1994, so I am not sure how many are still commercially available or if they have NSF approval.

TABLE 2.

Toxicity of candidate molluscicides to zebra mussel life stages. Concentrations are based on percent active ingredient of formulation.

Life Stage	Calgon H-130		Clamtrol CT-1		Bayer 73	
	24 hour $LC_{50}^{a,b}$	95% CL	24 hour $LC_{50}^{a,b}$	95% CL	24 hour LC_{50}	95% CL
PreVeliger	39.0^{z}	30.0-50.0	48.0^{z}	38.0-61.0	25.0^{z}	21.0-30.0
D-Stage	89.0^{y}	85.0-95.0	95.0^{y}	79.0-114.0	24.0^{z}	22.0-26.0
Post-D Stage	175.0^{x}	170.0-185.0	179.0^{x}	165.0-195.0	28.0^{z}	27.0-29.0
Plant: grade	8.8^{W*}	8.3-9.2	8.8^{W*}	8.6-9.1	92.0^{x}	88.0-95.0
Adult, 5 to 8 mm	$>10^{V*}$		$>13^{V*}$		49.9^{Y}	46.1 -54.1
Adult, 20 to 25 mm	5.6*	2.6-12.1	$>13^{V*}$		55.6^{Y}	50.4-61.3

Life Stage	Rotenone		Sal I		TFM	
	24 hour LC_{w}^{a}	95% CL	24 hour LC_{w}^{a}	95% CL	24 hour $LCM^{a,b}$	95% CL
PreVeliger	232.0^{XY}	203.0 -266.0	1.7^{z}	1.6-1.8	$3 7^{ZY*}$	2.2-6.2
D-Stage	230.0^{Y}	221.0-40.0	1.3^{z}	1.1-1.7	2.3^{z*}	2.1-2.5
Post-D Stage	264.0^{WX}	256.0-272.0	3.2^{Y}	3.1-3.4	2.5^{z*}	2.4-2.6
Planti grade	275.0^{W}	270.0-280.0	13.5^{x}	11.4-16.0	4.3^{Y*}	4.2-4.5
Adult, 5 to 8 mm	161.0^{z}	137.0 -189.0	55.1^{W}	46.2-65.6	10.3^{X*}	7.9-13.5
Adult, 20 to 25 mm	155.0	139.0 -174.0	65.0^{W}	51.8-81.6	11.0^{X*}	7.5-16.2

CL, confidence limit.

[a] For a given compound, LC_{50} values followed by the same letter are not significantly different from each other

[b] LC_{50} values are reported in μg 1^{-1} except where an asterisk appears, in which case the units are mg 1.

TABLE 1.

Technical data for candidate molluscicides for zebra mussel control.

Compound (Trade Name)	Chemical Name	% Active Ingredient	Source
Bayer 73 (Bayluscide)	2',5-dichloro-4'-nitro-salicylanilide	70	Mobay Corp.
Calgon H-130	didecyl dimethyl ammonium chloride (polyquarternary ammonium)	50	Calgon Corp.
Clamtrol CT-1	n-alkyl dimethyl benzyl ammonium chloride and dodecylguanidine hydrochloride (Polyquarternary ammonium)	13	Betz Chem.
Rotenone (Noxfish)	1,2.12,12a-tetrahydro-2-iso-propenyl 8.9-dimethoxy-[1]benzopyrano-[3. 4] furo [2,3-b] [1] benzo pyran-6 (6aH) one	5	Penick Corp.
Salicylanilide I (Sal I)	2',5-dichloro-3- *tert* -butyl-6-methyl-4'-nitrosalicylanilide	100	Aldrich Chem. Co.
TFM	3-trifluoromethyl-4-nitrophenol	36	Hoescht

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SENSITIVITY OF ZEBRA MUSSEL *(DREISSENA POLYMORPHA)* LIFE STAGES TO CANDIDATE MOLLUSCICIDES

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