Regional Water Quality NEWSLETTER

DATE: Report for November 16, 2006
Samples Collected on November 14, 2006
From the Phoenix, Tempe, 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. SRP is releasing nearly 100% Verde River water into the SRP canals.
2. This is good for WTPs in the SRP system because this water has lower DOC than the Salt River or CAP systems.
3. MIB is low at the WTPs, and the T&O season has come and gone with only minor issues this year. We believe a real key reason for this is the apparent correlation between drought conditions, and associated water management strategies, and increased occurrence of taste and odors.
4. Canal Dry-up season is coming: SRP will be working on portions of the Southside canals from Nov. 17 to Dec. 17 and CANAL WORK STARTS IN NOVEMBER portions of Northside canals from Jan. 5 to Feb. 4. Southside and Northside canals refer to major SRP canals south and north of the Salt River, respectively.
5. This newsletter includes results from jar tests and DBP formation with water from Bartlett Lake, Saguaro Lake, and Lake Pleasant. THM formation after coagulation is related to UV absorbance at 254 nm and chlorine consumption.
6. The journal "*Southwest Hydrology*" has a Nov/Dec issue on DBPs in the southwest. Included is one article written by the ASU team, and links to other articles in the issue. If you have difficulty getting any of these articles let me know and I can assist you.
7. DOC data is NOW included – fortunately SRP is releasing Verde River water which has less DOC than the Salt River

Table 1 Summary of WTP Operations

	Union Hills	24th Street WTP	N.Tempe J.G. Martinez	Deer Valley	Greenway WTP	Val Vista	South Tempe	Chandler WTP
Location	**CAP**	**Arizona Canal System**				**South Canal System**		
PAC Type and Dose	None	Norit 20B at 7 ppm until Monday, 11/13 at 7:20 AM; PAC feed is currently OFF.			None			
Copper Sulfate	None	None			None			
PreOxidation	None	None			1.4 mg/L ozone			
Alum Dose Alkalinity pH	10[1] 105 7.1	45 222 7.1			14 232 7.8			

[1] Ferric chloride instead of alum
[2] Calculated based upon influent and filtered water DOC
[3] also adding 3 ppm floc aid

These tables include the DOC data

Table 2 - Water Treatment Plants – November 14, 2006

Sample Description	DOC (mg/L)	UV254 (1/cm)	SUVA
24th Street WTP Inlet	**2.72**	**0.072**	**2.7**
24th Street WTP Treated	**1.96**	**0.035**	**1.8**
Deer Valley Inlet	**2.53**	**0.068**	**2.7**
Deer Valley WTP Treated	**1.95**	**0.037**	**1.9**
Val Vista Inlet	**2.31**	**0.068**	**2.9**
Val Vista WTP Treated –East	**1.73**	**0.033**	**1.9**
Val Vista WTP Treated -West			
Union Hills Inlet	**2.79**	**0.040**	**1.6**
Union Hills Treated	**2.05**	**0.022**	**1.1**
Tempe North Inlet	**2.43**	**0.063**	**2.6**
Tempe North Plant Treated	**1.85**	**0.037**	**2**
Tempe South WTP			
Tempe South Plant Treated			
Chandler WTP Inlet			
Chandler WTP Treated			
Greenway WTP Inlet	**2.60**	**0.0670**	**2.6**
Greenway WTP Treated	**1.95**	**0.0240**	**1.3**

Table 3 - Canal Sampling – November 14, 2006

System	Sample Description	DOC (mg/L)	UV254 (1/cm)	SUVA
CAP	Waddell Canal	**3.39**	**0.053**	**1.6**
	Union Hills Inlet	**2.79**	**0.040**	**1.4**
	CAP Canal at Cross-connect	**3.39**	**0.043**	**1.3**
AZ Canal	Salt River @ Blue Pt Bridge	**4.51**	**0.096**	**2.1**
	Verde River @ Beeline	**2.52**	**0.065**	**2.6**
	AZ Canal above CAP Cross-connect	**2.57**	**0.050**	**1.9**
	AZ Canal below CAP Cross-connect	**2.65**	**0.066**	**2.5**
	AZ Canal at Highway 87	**2.30**	**0.061**	**2.7**
	AZ Canal at Pima Rd.	**2.45**	**0.064**	**2.6**
	AZ Canal at 56th St.	**2.42**	**0.063**	**2.6**
	AZ Canal - Inlet to 24th Street WTP	**2.72**	**0.072**	**2.7**
	AZ Canal - Central Avenue	**2.56**	**0.068**	**2.6**
	AZ Canal - Inlet to Deer Valley WTP	**2.53**	**0.068**	**2.7**
	AZ Canal - Inlet to Greenway WTP	**2.60**	**0.067**	**2.6**
South and Tempe Canals	South Canal below CAP Cross-connect	**2.24**	**0.067**	**3.0**
	South Canal at Val Vista WTP	**2.31**	**0.068**	**2.9**
	Head of the Tempe Canal	**2.24**	**0.068**	**3.0**
	Tempe Canal - Inlet to Tempe's South Plant			
	Chandler WTP – Inlet			

Table 4 - Reservoir Samples – November 14, 2006

Sample Description	Location	DOC (mg/L)	UV254 (1/cm)	SUVA
Lake Pleasant	Eplimnion	**3.33**	**0.056**	**1.70**
Lake Pleasant	Hypolimnion	**3.45**	**0.050**	**1.50**
Verde River @ Beeline		**2.52**	**0.065**	**2.60**
Bartlett Reservoir	Epilimnion	**2.59**	**0.063**	**2.4**
Bartlett Reservoir	Epi-near dock			
Bartlett Reservoir	Hypolimnion	**2.61**	**0.064**	**2.40**
Salt River @ BluePt Bridge		**4.51**	**0.096**	**2.10**
Saguaro Lake	Epilimnion	**4.69**	**0.107**	**2.30**
Saguaro Lake	Epi - Duplicate	**5.54**	**0.109**	**2.00**
Saguaro Lake	Epi-near doc			
Saguaro Lake	Hypolimnion	**4.97**	**0.108**	**2.20**
Verde River at Tangle		**1.15**	**0.036**	**3.10**
Havasu		**2.61**	**0.037**	**1.40**

Table 2 - Water Treatment Plants – November 14, 2006

Sample Description	MIB (ng/L)	Geosmin (ng/L)	Cyclocitral (ng/L)
24th Street WTP Inlet	**<2.0**	**<2.0**	**<2.0**
24th Street WTP Treated	**<2.0**	**<2.0**	**<2.0**
Deer Valley Inlet	**<2.0**	**2.9**	**<2.0**
Deer Valley WTP Treated	**3.3**	**3.3**	**<2.0**
Val Vista Inlet	**<2.0**	**<2.0**	**<2.0**
Val Vista WTP Treated –East	**<2.0**	**<2.0**	**<2.0**
Val Vista WTP Treated -West			
Union Hills Inlet	**<2.0**	**2.9**	**<2.0**
Union Hills Treated	**<2.0**	**4.0**	**<2.0**
Tempe North Inlet	**<2.0**	**<2.0**	**<2.0**
Tempe North Plant Treated	**<2.0**	**<2.0**	**<2.0**
Tempe South WTP			
Tempe South Plant Treated			
Tempe South Plant Treated (Lab)			
Chandler WTP Inlet			
Chandler WTP Treated			
Greenway WTP Inlet	**<2.0**	**<2.0**	**<2.0**
Greenway WTP Treated	**<2.0**	**<2.0**	**<2.0**

Table 3 - Canal Sampling – November 14, 2006

System	Sample Description	MIB (ng/L)	Geosmin (ng/L)	Cyclocitral (ng/L)
CAP	Waddell Canal	**2.7**	**<2.0**	**<2.0**
	Union Hills Inlet	**2.9**	**4.0**	**<2.0**
	CAP Canal at Cross-connect	**<2.0**	**2.7**	**<2.0**
AZ Canal	Salt River @ Blue Pt Bridge	**2.0**	**2.8**	**<2.0**
	Verde River @ Beeline	**<2.0**	**<2.0**	**<2.0**
	AZ Canal above CAP Cross-connect	**<2.0**	**<2.0**	**<2.0**
	AZ Canal below CAP Cross-connect	**<2.0**	**<2.0**	**<2.0**
	AZ Canal at Highway 87	**<2.0**	**2.7**	**<2.0**
	AZ Canal at Pima Rd.	**<2.0**	**<2.0**	**<2.0**
	AZ Canal at 56th St.	**<2.0**	**<2.0**	**<2.0**
	AZ Canal - Inlet to 24th Street WTP	**<2.0**	**<2.0**	**<2.0**
	AZ Canal - Central Avenue	**<2.0**	**2.6**	**<2.0**
	AZ Canal - Inlet to Deer Valley WTP	**<2.0**	**2.9**	**<2.0**
	AZ Canal - Inlet to Greenway WTP	**<2.0**	**<2.0**	**<2.0**
South and Tempe Canals	South Canal below CAP Cross-connect	**<2.0**	**3.6**	**<2.0**
	South Canal at Val Vista WTP	**<2.0**	**<2.0**	**<2.0**
	Head of the Tempe Canal	**<2.0**	**2.3**	**<2.0**
	Tempe Canal - Inlet to Tempe's South Plant			
	Chandler WTP – Inlet			

Table 4 - Reservoir Samples – November 14, 2006

Sample Description	Location	MIB (ng/L)	Geosmin (ng/L)	Cyclocitral (ng/L)
Lake Pleasant	Eplimnion	3.4	<2.0	<2.0
Lake Pleasant	Hypolimnion	3.3	<2.0	<2.0
Verde River @ Beeline		<2.0	<2.0	<2.0
Bartlett Reservoir	Epilimnion	<2.0	2.0	<2.0
Bartlett Reservoir	Epi-near dock	<2.0	<2.0	<2.0
Bartlett Reservoir	Hypolimnion	<2.0	<2.0	<2.0
Salt River @ BluePt Bridge		2.0	2.8	<2.0
Saguaro Lake	Epilimnion	38.1	2.1	<2.0
Saguaro Lake	Epi - Duplicate	39.2	2.5	<2.0
Saguaro Lake	Epi-near doc	51.5	5.8	<2.0
Saguaro Lake	Hypolimnion	46.2	2.7	<2.0
Verde River at Tangle		<2.0	<2.0	<2.0
Havasu		<2.0	<2.0	<2.0

Organic carbon Data is still being processed. Data below is from October sampling of the reservoirs. Updated DOC data will be sent out next week.

Table 5 - Reservoir Samples – October 11, 2006

CAP is sampling Lake Pleasant on slightly different days than the other reservoirs.

Sample Description	Location	DOC (mg/L)	UV254 (1/cm)	SUVA
Lake Pleasant (September 13, 2006)	Eplimnion	3.58	0.600	1.70
Lake Pleasant (9/13/06)	Hypolimnion	4.00	0.055	1.40
Bartlett Reservoir	Epilimnion	2.92	0.057	1.9
Bartlett Reservoir	Hypolimnion	3.24	0.057	1.70
Salt River @ BluePt Bridge		5.40	0.108	2.00
Saguaro Lake	Epilimnion	5.78	0.106	1.80
Saguaro Lake	Epi - Duplicate	5.96	0.107	1.80
Saguaro Lake	Hypolimnion	5.83	0.108	1.80
Verde River at Tangle		1.28	0.038	2.97
Havasu (9/13/06)		2.87	0.036	1.30

Table 6 - SRP/CAP OPERATIONS
Values in cfs, for November 13, 2006

System	SRP Diversions	CAP
Arizona Canal	440	42
South Canal	429	0
Pumping	110	0
Total	979	42

SRP is releasing water from both Verde and Salt River Systems. Salt River release from Saguaro Lake: 8 cfs; Verde River release from Bartlett Lake: 975 cfs.

SRP is drawing down Apache Lake – and will continue to use Salt River water released from Saguaro Lake in order to achieve this. Dam repairs/construction will be taking place in Apache Lake.

Canal Dry-up season is coming:
We will be working on portions of the Southside canals from Nov. 17 to Dec. 17 and CANAL WORK STARTS IN NOVEMBER portions of Northside canals from Jan. 5 to Feb. 4. Southside and Northside canals refer to major SRP canals south and north of the Salt River, respectively.

From the SRP Waterways Newsletter
(http://www.srpnet.com/water/pdfx/WATERWAYS1006.pdf) :

Central Arizona Project

Operations and Maintenance Update

11/13/2006

WADDELL RELEASE SCHEDULE

		% Flow	Date	Time
Current Waddell Releases	880 cfs	100%	11/13/06	12:00
Current Pass-Thru Flow	0 cfs	0%	11/13/06	12:00
New Waddell Releases	1030 cfs	100%	11/14/06	06:00
New Pass-Thru Flow	0 cfs	0%	11/14/06	06:00
New Waddell Releases				
New Pass-Thru Flow				
New Waddell Releases				
New Pass-Thru Flow				

SPECIAL NOTES / AQUEDUCT ACTIVITIES

West Plant Outage

11/13/2006, 06:00 West pumping will be stopped and releases from Waddell will start and continue until 16:00 on 11/22/2006. The outage is for dewater and inspection/repair of the Centennial Wash siphon. This outage will also include installation of an acoustic monitoring system in the siphon.

Jar Test Data (October 2006)

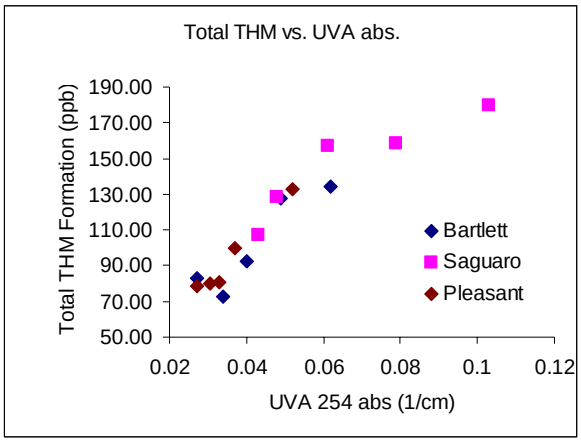
As part of a new SRP/ASU project we are conducting jar tests and THM studies on water from the three terminal reservoirs. As utilities strive to reduce the amount of DBP's formed in their finished waters a greater understanding into the formation of these chemicals is necessary. ASU has begun a study to monitor the formation of the 4 regulated Trihalomethanes (THM's) from 3 of the Phoenix area's reservoirs, Bartlett, Saguaro, and Lake Pleasant.

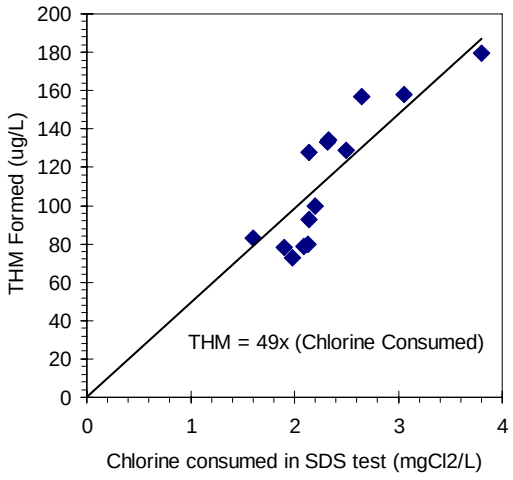
Samples were taken from each lake and a jar test was conducted on the waters with varying alum doses. DOC, UV 254, pH, alkalinity and Br^- were measured for each sample. Each sample was then dosed with Chlorine such that after 24 hours the free chlorine residual was 1 ± 0.1 mg/L. The four regulated THM's were then measured from each sample and can now be compared to the various parameters that were measured prior to chlorination.

Tabular data is presented on the next page. A series of figures are then included with brief key statements about each graph.

As this project moves forward we will continue to be collecting this an related data to develop two types of models: 1) simple and easy to use models that predict coagulation "ability" and THM formation, and 2) models based upon WTP.exe which are more inclusive of other water treatment plant processes and design goals.

Among the most significant findings are the following two plots, which relate THM formation (under simulated distribution system (SDS) conditions of 1 mg/L chlorine residual after 24 hours) to UV absorbance at 254 nm prior to chlorine, and to the amount of chlorine consumed. Statistically robust relationships are being developed.





Bartlett Lake

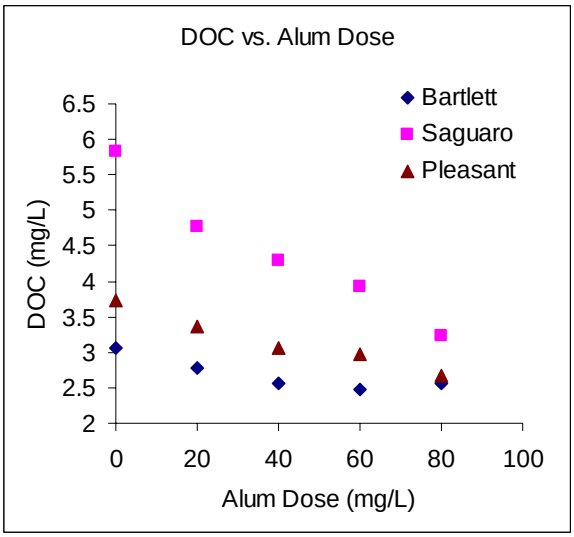
	Units	Jar #1	Jar #2	Jar #3	Jar #4	Jar #5
Coagulant Dose	mg/L	0	20	40	60	80
DOC	mg/L	3.07	2.78	2.57	2.48	2.56
UV 254	1/cm	0.062	0.049	0.040	0.034	0.027
SUVA	L/mg-m	2.0	1.8	1.6	1.4	1.1
pH		8.60	8.03	7.77	7.53	7.38
Br^-	mg/L	0.086	0.086	0.083	0.093	0.084

Saguaro Lake

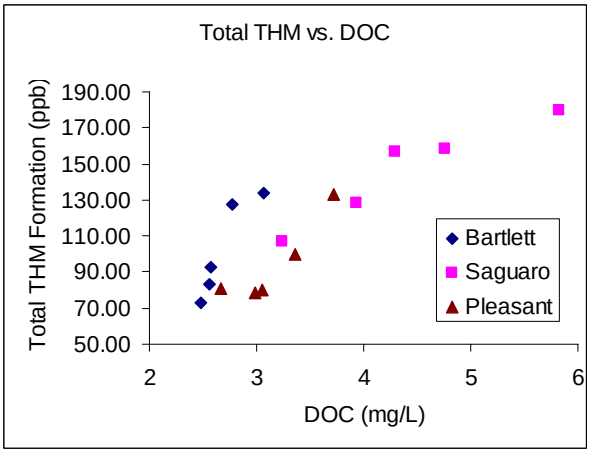
	Units	Jar #1	Jar #2	Jar #3	Jar #4	Jar #5
Coagulant Dose	mg/L	0	20	40	60	80
DOC	mg/L	5.82	4.76	4.29	3.93	3.24
UV 254	1/cm	0.103	0.079	0.061	0.048	0.043
SUVA	L/mg-m	1.8	1.7	1.4	1.2	1.3
pH		8.2	7.86	7.62	7.27	7.21
Br^-	mg/L	0.109	0.109	0.102	0.107	0.104

Lake Pleasant

	Units	Jar #1	Jar #2	Jar #3	Jar #4	Jar #5
Coagulant Dose	mg/L	0	20	40	60	80
DOC	mg/L	3.72	3.36	3.05	2.98	2.66
UV 254	1/cm	0.052	0.037	0.031	0.027	0.033
SUVA	L/mg-m	1.4	1.1	1.0	0.9	1.2
pH		8.2	7.86	7.62	7.27	7.21
Alkalinity	mg/L as $CaCO_3$	150	120	100	97	89
Br^-	mg/L	0.111	0.111	0.111	0.109	0.110



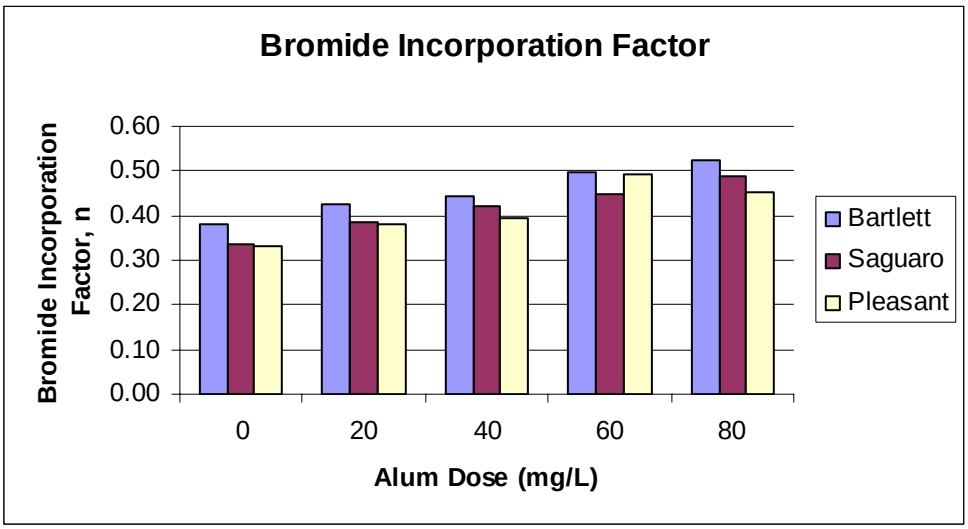
DOC decreases with additional coagulant as expected.



A reduction of the DOC results in lower THM formation.

The current regulations are such that the total of the 4 THM's in the distribution system are not to exceed 80 ppb, and the speciation is not taken into account. Since the health of the consumer is the main consideration attention should be given to the type of THM's that are formed in a given water as the more brominated THM's tend to result in higher health risks. The Bromide Incorporation Factor is a measure of the molar concentration of the brominated THM species over the molar concentration of the total THM's formed.

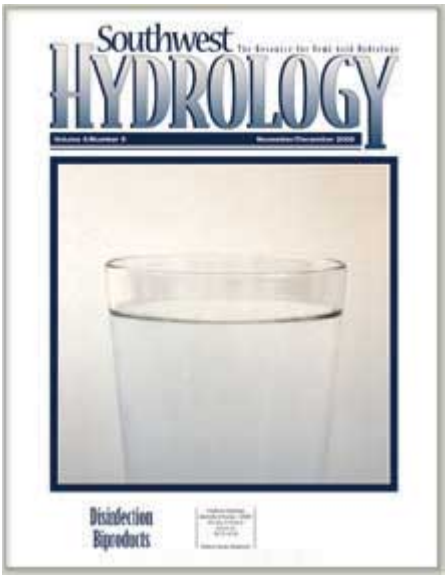
The following graph shows that the BIF increases as the coagulant dose is increased indicating that as the most prominent THM, chloroform, is reduced the ratio of brominated THM's increases. As can be seen from the 3 data tables above that as the coagulant dose is increased the DOC decreases but the amount of Br^- remains unchanged.



Disinfection Byproducts

Volume 5 Number 6 *November/December 2006*

Chemical disinfection of drinking water is arguably one of the greatest advances in human health. However, nothing is perfect. The byproducts that form when disinfectants combine with otherwise harmless compounds in water warrant our attention. Although the carcinogenic nature of some disinfection byproducts (DBPs) was first shown in the 1970s, only a few of the hundreds that have been identified are regulated. What are DBPs? How and where do they form, and how do utilities manage them? How do recent stricter compliance standards affect utilities? What is known about other DBPs besides the few that are federally regulated? And what is the fate of DBPs in the subsurface when treated water is used as recharge water to replenish aquifers? This issue's feature articles help answer such questions.



http://www.swhydro.arizona.edu/archive/V5_N6/

Disinfection By-products in Drinking Water
Paul Westerhoff
August 3, 2006

Published in *Southwest Hydrology* Nov/Dec 2006

Disinfection has been used for over a century and have almost eliminated biological waterborne disease outbreaks in developed countries. However in the 1970's scientists observed the formation of chlorinated organic materials in drinking water systems using chlorine. Thus a need to balance the health benefits of disinfection to prevent acute health risks of waterborne disease outbreaks against the risk of cancer from long-term (chronic) exposure to disinfection by-products (DBPs).

All chemical disinfectants produce organic and/or inorganic DBPs of potential health concern (Table 1). All disinfectants are oxidants. As are result disinfectants oxidize inorganics and organics in water. Disinfectants react with "precursors" in drinking water to produce DBPs. The primary precursors include natural organic matter (NOM) which is generally measured as total organic carbon (TOC), and is a surrogate for NOM which is comprised of roughly 50% carbon, 35% oxygen, 5% hydrogen, 3% nitrogen, and lower amounts of phosphorous, sulfur and trace metals. Bromide is also an important precursor, because bromide is easily oxidized to aqueous bromine ($HOBr/OBr^-$) which is a mild disinfectant but can also react to form bromine-substituted DBPs (e.g., bromoform). Iodide undergoes similar reactions to produce HOI/OI^-, and iodinated DBPs are also of potential health significance (e.g., iodoform). Reactions between common disinfectants that provide residual disinfection capacity in water distribution systems (e.g. free chlorine) and precursors (e.g., NOM) lead to the formation of DBPs (e.g., halogen substituted organics).

Numerous water quality and treatment factors affect DBP formation. The rate and extent of DBP formation are higher as TOC, bromide, temperature, disinfectant dose and contact time with the disinfectant increase. Several mechanistic and empirical models exist and account for these factors. For example the following empirical model predicts total trihalomethane formation (TTHM in μg/L):

$$TTHM = 0.0412\ [TOC]^{1.098}\ [Cl_2]^{0.152}[Br^-]^{0.068}[Temp]^{0.609}[pH]^{1.601}[Time]^{0.263}$$

Where TTHM (in μg/L) is a function of chlorine dose (Cl_2 in mg/L), bromide concentration (Br^- in μg/L), water temperature (Temp in ^oC), pH, and contact time between the chlorine and water (Time in hours). Figure 1 illustrates effects of two key parameters (contact time and seasonal temperature) on TTHM formation. Water treatment plants (WTPs) commonly have 30 to 120 minutes of contact time with chlorine prior to entering the water distribution system (pipes, storage tanks, etc) where contact times range from several hours to days as water is delivered to customer households. Common contact times are 1 to 3 days. A significant percentage of the TTHMs form within the WTP (e.g., 41% of TTHM formed within 4 hours for Figure 1), while the remaining fraction would form in the water distribution systems. Seasonal variations in water quality impact DBP formation. For example, at common summertime temperatures of 25 C (78 F) TTHM concentrations are almost twice those at 10 C for a 24 hour contact time.

TTHMs are the sum of four individual trihalomethanes: chloroform ($CHCl_3$), dichlorobromomethane ($CHCl_2Br$), chlorodibromomethane ($CHClBr_2$), and bromoform ($CHBr_3$). Figure 2 summarizes the TTHM concentrations leaving a conventional water treatment plant for one water utility in central Arizona over a two year period, along with the distribution of individual THM species. High TTHM concentrations generally occur in the summer, as expected due to warmer water temperatures (i.e., Figure 1). However, during the early winter of 2005 heavy rain and snow lead to significant runoff (and flooding). As a result the dissolved organic concentrations increased from < 3 mg/L in 2004 to >4 mg/L in 2005 due to solubilization of soil organic matter; TOC concentrations exceeded 10 mg/L. As a result TTHM concentrations were higher due to TOC in the runoff. In addition, the runoff diluted the salts in the surface water sources, which lowered the bromide concentration by over 50%. As a consequence of lower bromide levels, the distribution of chlorinated and brominated THMs

shifted during the runoff period (early 2005). The lower bromide levels resulted in more chloroform being produced.

Regulatory mandates drive WTP operations and technology changes. Traditionally, THMs, HAAs and many other DBPs were viewed as only posing chronic health risks. As such, THM and HAA compliance was based upon meeting regulatory levels based upon usually four samples collected throughout the water distribution system on a quarterly basis; all the samples were then averaged on a running annual average to comply with the THM and HAA regulations. This permitted averaging of summer (high DBP levels) with winter (low DBP levels) and locations in the distribution system with shorter (low DBP levels) and longer (high DBP levels) contact times. Recent concern over possible acute health risks from DBPs (e.g., spontaneous abortions in women), which recent refined epidemiology studies are now finding unsubstantiated, and social justice issues the new THM and HAA regulations do not permit averaging of concentrations across the entire water distribution system, and the regulations must be met at each sampling location on a running annual average basis. Updates on the newest DBP regulations can be found at http://www.epa.gov/ogwdw/disinfection/stage2/.

Over the past 10-20 years DBP regulations have undergone several changes. In response to more stringent DBP regulations, WTP operations and technology selection has changed. Most WTPs control DBP formation through reduction in DBP precursors (e.g., TOC removal) or alternative disinfection practices. Most WTPs add metal salt coagulants (alum, ferric sulfate), which precipitate as a solid and adsorbs TOC. However, in the southwestern US the characteristics of NOM and high alkalinity of the surface waters results in only modest TOC removals. Consequently, WTPs must consider other technologies that can adsorb TOC (e.g., granular activated carbon), biodegrade TOC (biofiltration), or separate TOC (e.g., ultra- or nano-filtration) before addition of chlorine. Utilities are also considering alternative disinfectants to chlorine, such as ozone, UV irradiation, chloramines, chlorine dioxide. However, each of these have unique DBP issues (e.g., bromate formation during ozonation) or other issues (e.g., UV irradiation does not provide residual disinfection capability in water distribution systems). As regulations change, these and other technologies will be required in order to control DBP formation. Although a few research studies are currently underway in the southwestern US (AwwaRF project #3103: Localized Treatment for disinfection by-products), it has generally not been considered economically favorable to remove DBPs after they have formed.

DBPs will be present in all waters containing chemical disinfectants. The USEPA and researchers have identified >500 different DBPs, although less than a dozen are currently regulated. Ongoing toxicity testing with these emerging DBPs indicates that nitrogen-containing DBPs (e.g., nitromethanes, nitrosamines) pose a significantly greater risk than currently regulated THMs or HAAs, and that strategies implemented to control THMs or HAAs (e.g., switching from chlorine to chloramines) may create higher levels of these potentially more toxic nitrogen-containing DBPs. As a result, it appears that control of DBP formation will continue to be a pressing issue for the water industry.

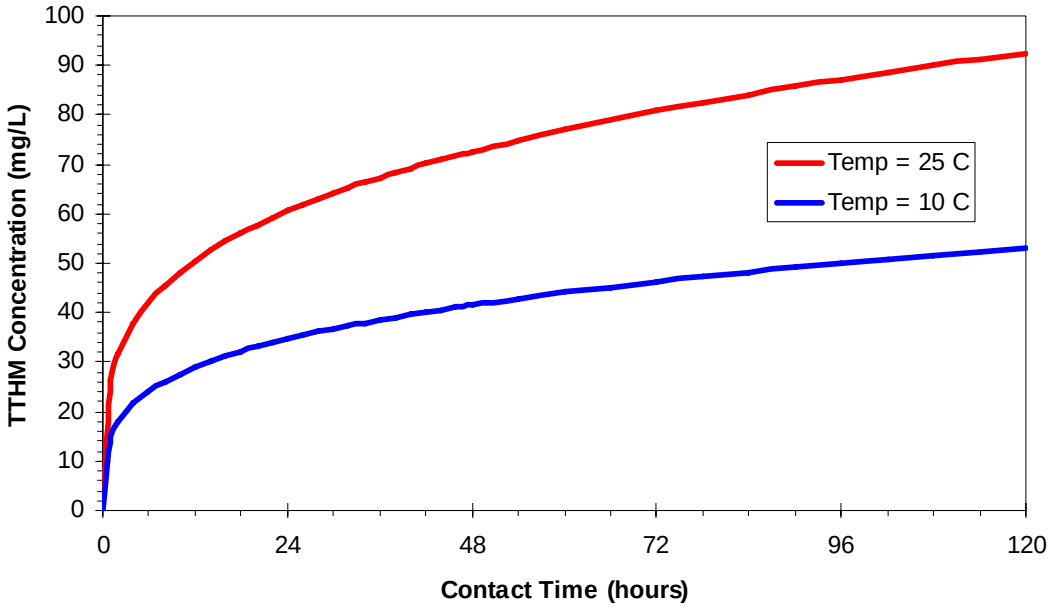


Figure 1 – Formation of total trihalomethanes (TTHM) as a function of time and water temperature (based upon Equation 1 assuming 3 mg/L TOC, 5 mg/L Cl_2 dose, 150 µg/L Br^-, pH 7.5)

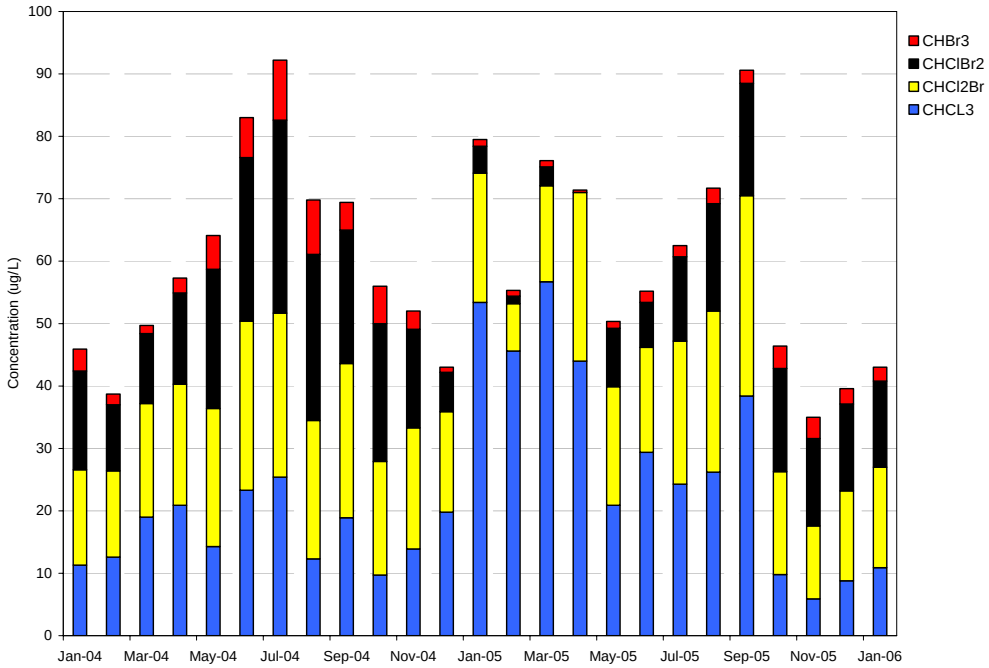


Figure 2 – Sum of four THM species from a effluent of a water treatment plant in central Arizona

Table 1 – Summary of common disinfectants and associated disinfection by-products

Disinfectant	**Disinfectant Efficacy**	**Provides disinfectant residual in water distribution system**	**Dominant DBPs of Regulatory Concern**	**Dominant Precursors for DBP formation**
Ozone (O_3)	High	None	Bromate (BrO_3^-) Aldehydes	Bromide TOC
Free Chlorine ($HOCl/OCl^-$)	Intermediate	Yes	Trihalomethanes Haloacetic acids	Bromide and TOC
Monochloramine (NH_2Cl)	Intermediate	Yes	Nitrosamines	TOC and organic nitrogen
Chlorine Dioxide (ClO_2)	Intermediate	None	Chlorite and chlorate	Decay of chlorine dioxide
UV Irradiation	High	None	None	--