ICR Treatment Study Summary Report

GAC RSSCT Bench Scale Study For Compliance with the Information Collection Rule

Conducted during the period of March 23, 1998 through
January 6, 1999

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Central Plant 1 & 2 , ICR # 435

Attachments: 1 diskette containing the *Data Collection Spreadsheets*

I. Conclusions and Recommendations

<u>Conclusions</u>

1. The granular activated carbon (GAC) rapid small scale column test (RSSCT) studies performed indicate that total organic carbon (TOC) levels can be consistently lowered in the presedimentation basin effluent water with GAC beds with minimal impact from seasonal variation. Some of this consistency is due the presedimentation pretreatment already in place at the plant.

2. The RSSCT studies also indicate that the low TOC water produced by GAC columns causes a shift in the production of Trihalomethanes (THMs) species and Haloacetic Acids (HAAs) species from being more of the chlorinated species to more of the brominated species.

3. High bromide levels (> 100 ppb Br-) in low TOC (<2 ppm TOC) water can produce higher level THMs than in water with high TOC (>2 ppm TOC). Lowering TOC levels with GAC treatment may produce higher THMs.

<u>Recommendations</u>

1. The application of GAC technology for the purpose of DBP precursor removal appears to have minimal benefit and may even be detrimental when ambient bromide levels are elevated. The shift from chlorinated species to brominated species after GAC treatment maybe detrimental because of the higher health risks believed to be associated with brominated compounds.

2. Current precursor removal at Central Plant 1&2 represented by the column influent water did not produce significantly higher DBPs than GAC treated waters in any of the four seasonal runs. Current disinfection practices meet Surface Water Treatment Rule (SWTR) and regulatory THM requirements. Current treatment and disinfection practices also appear to be capable of meeting the Stage 1 Disinfectant/Disinfection By-product (D/DBP) Rule requirements and Interim Enhanced Surface Water Treatment Rule (IESWTR) requirements. Additional efforts in optimizing current disinfection practices should enable this plant to meet the projected MCLs of the Stage 2 D/DBP Rule.

3. If GAC treatment for DBP precursor removal is a considered a future treatment option for reducing DBP precursor levels at Central Plants 1 & 2, further studies should be performed with low TOC levels and high bromide levels to characterize conditions which produce higher concentrations of brominated DBPS.

II. Background Information

Location and Source

St. Louis County Water Company Central County Plant 1 & 2 is located at 901 Hog Hollow Road in Chesterfield, Missouri. The plant withdraws water from the Missouri River with intake structures constructed at a location 36 miles above the point the Missouri River empties into the Mississippi River. The Missouri River drains 524,000 square miles of area in the upper Midwest. The upper half of the Missouri River flow is extensively controlled by a series of US Army Corps of Engineer dams while the lower main stem is essentially free flowing for over 700 miles.

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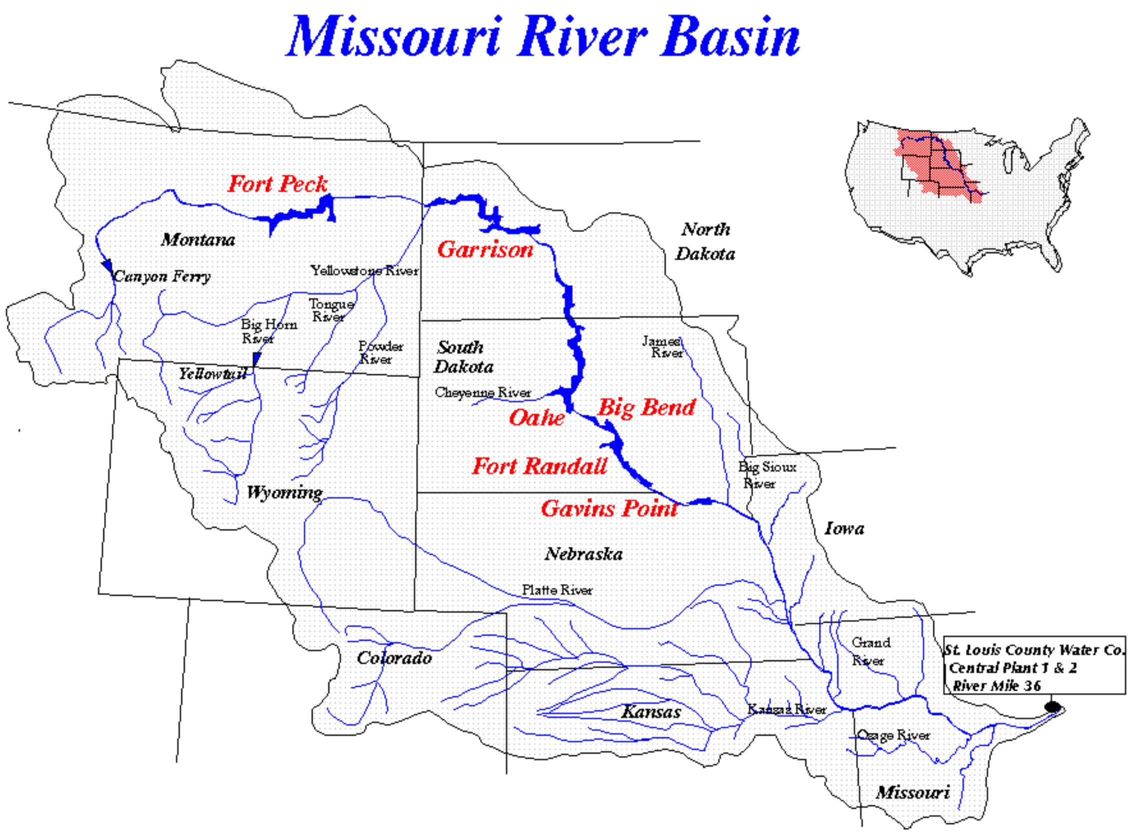


Figure 2.1 Missouri River Basin and Location of SLCWC Central Plant 1 & 2

The mean river flow, as measured 80 miles upstream at Hermann, Missouri, is 99,300 cubic feet per second (CFS). The flow can range from as low as 50,000 CFS or as high as 300,000 CFS. The water quality is variable and is dependent on weather conditions that occur in the lower Missouri River basin. The water quality characteristics vary significantly throughout the year with seasonal extremes in both physical and chemical parameters.

Table 2.1 Influent & Effluent Water Quality Central Plant 1 & 2
1998 ICR Monitoring Data

Influent Water Quality Data						
Parameter	**Units**	**Average**	**Std Dev**	**Min**	**Max**	**Count**
Temperature	C	17.4	7.04	7.1	26.7	12
pH	Unit	8.28	0.04	8.2	8.3	12
Turbidity	NTU	137	134	23	492	12
Alkalinity	mg/L as $CaCO_3$	154	28.9	106	220	12
Total Hardness	mg/L as $CaCO_3$	208	55	132	334	12
Calcium Hardness	mg/L as $CaCO_3$	137	21.3	95	162	12
TOC	mg/L	3.78	0.61	2.78	5.12	12
UV_{254}	cm^{-1}	0.19	0.08	0.09	0.4	12
Bromide	µg/L	0.12	0.11	0.02	0.15	12
TSUVA	L/(mg*m)	4.95	1.22	3.15	7.81	12

Finished Water Quality Data						
Item	**Units**	**Average**	**Std Dev**	**Min**	**Max**	**Count**
Temperature	C	18.7	8.21	7	31	12
pH	unit	9.67	0.11	9.5	9.8	12
Turbidity	NTU	0.11	0.03	0.07	0.15	12
TOC	mg/L	2.8	0.12	2.28	3.65	12
UV_{254}	cm^{-1}	0.08	0.02	0.057	0.109	12
DS-THM4	µg/L	21.1	26.5	3.84	60.6	4
DS-HAA5	µg/L					
DS-HAA6	µg/L	21	8.57	13.6	32.2	4

DS – Distribution System

Treatment Plant Description

Central Plant 1 & 2 treatment plant utilizies multiple stages of treatment to produce drinking water from the Missouri River. The plant contains four process trains that normally work in parallel with each other, except when maintenance is being performed. The treatment scheme at Central Plant 1 & 2 involves lime softening, presedimentation, two stages of flocculation and sedimentation, and sand filtration. PAC is added as needed to reduce taste and odor and to reduce herbicide levels in the spring/summer runoff. Fluoride is added to increase ambient levels to about 1 ppm in the finished water. Polyphosphate is added to the second stage sedimentation to inhibit cementation of filter media. Filter aid is added to enhance filter performance.

The free chlorine/chloramine disinfection process at Central Plant 1 & 2 takes on two separate modes that is dependent on water temperature. Chlorine is fed to a rapid mix area located at the presedimentation basin effluent. This chlorine feed point is used at all temperatures. The ammonia feed point is altered depending on the water temperature. This disinfection scheme produces an abbreviated free chlorine contact time in warm waters and an extended free chlorine contact time in cold waters.

When the source water temperature is greater than 50^{o} F (10^{o} C), the ammonia is fed immediately after the chlorine feed at the rapid mix area allowing minimal free chlorine contact time. A chloramine residual is formed by this ammonia addition and the resultant contact time at this temperature is sufficient to meet SWTR CT requirements at these warmer temperatures and at normal plant flow rates. This configuration helps minimize DBP production by limiting free chlorine contact time at higher water temperatures.

When the source water temperature is less than 50^{o} F (10^{o} C), the ammonia is fed later in the treatment basin after the first stage of flocculation and settling. This configuration allows for greater free chlorine contact time in the primary mix and settling areas. At the second mix influent, ammonia is fed to produce a chloramine residual in the remainder of the treatment basin. The extended free chlorine contact time allows required SWTR CTs to be met at lower water temperatures. When the water temperature is cooler, the DBPs formation reaction with free chlorine is slowed so that the DBP concentrations are not extreme. By utilizing these two modes of disinfection, SWTR CT requirements can be met and DBP formation can be minimized. These two modes of disinfection are illustrated in treatment plant schematics in Figures 2-2 and 2-3.

Figure 2-2 Central Plant 1 & 2 Temperature > 50 ºF

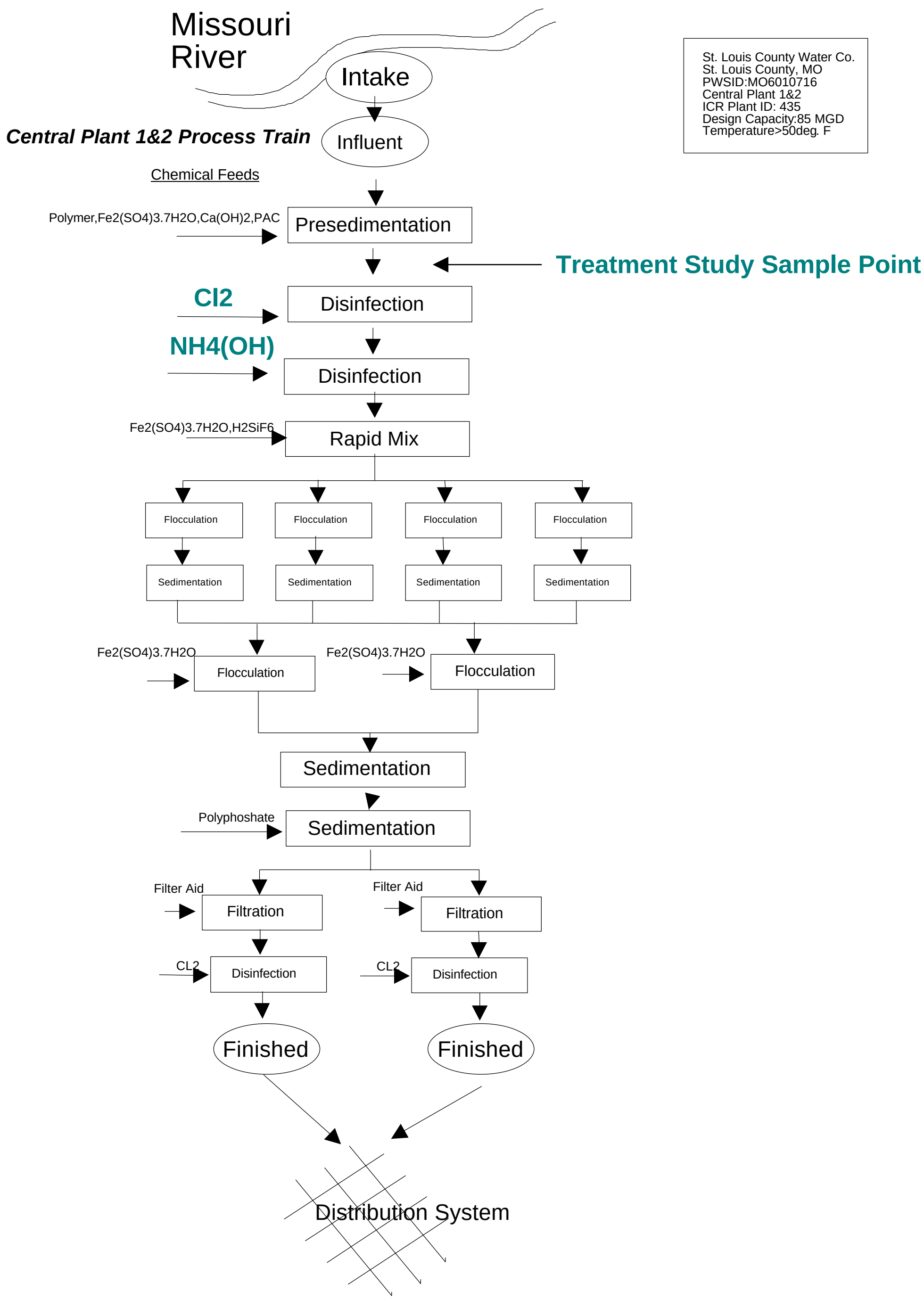
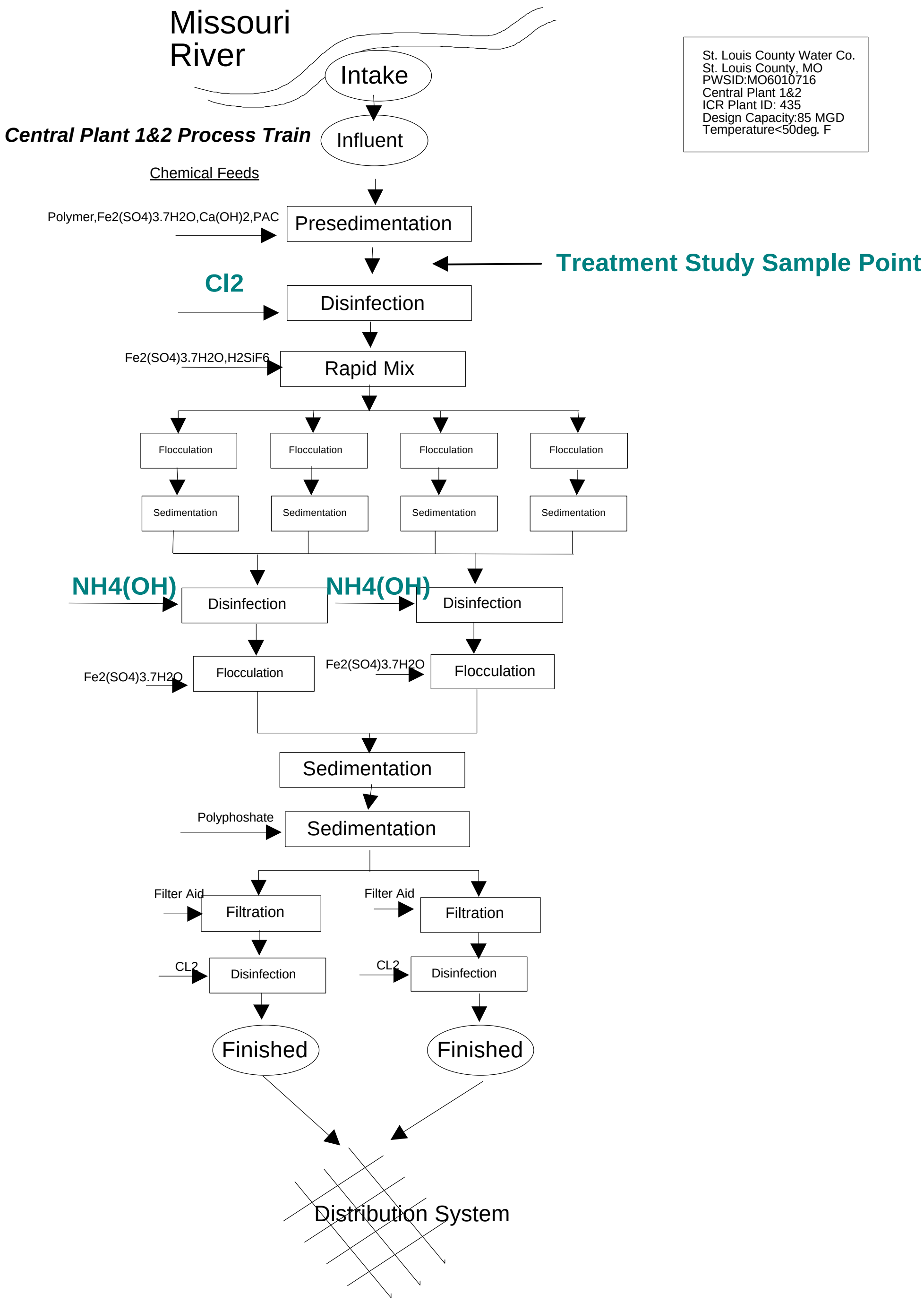


Figure 2-3 Central Plant 1 and 2 Temperature < 50 °F



Treatment Plant Design Information

Presented on pages 8 –12 is the information presented in the A.2 Design Plant Parameters for each of the four process trains in Central Plant 1 & 2 as reported to the ICR Water Utility Database System during the 18 months of ICR monitoring. The A.3 Design Plant Chemical Parameters table is on page 13.

A.2—Design Plant Parameters

PWS Name: ST. LOUIS COUNTY WATER COMPANY
PWS ID: MO6010716
Treatment Plant Name: Central Plant 1 & 2
Historical Min. Water Temperature (deg. C): 1.0
ICR Treatment Plant ID: 435
Treatment Plant Category: SOFT
Water Resource Type: Flowing stream

State Approved Plant Capacity (MGD): 85.0
Latitude (degrees, minutes, seconds): 90^{0}32’5”
River Reach Miles: 36.0
Water Resource Name: Missouri River
Intake Name: Central Plant 1 intake

Table A.2—Design Plant Parameters

Process Train Name: Central Plant 1 & 2 #1 Process Train

Unit Process	Process Description
Presedimentation	Surface Area (ft2): 112,820 Liquid Volume (gal): 16,400,000
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 4.20
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is above 50 ^{o} F only)
Rapid Mix	Type of Mixer: ME Baffling Type: PF Liquid Volume (gal): 18,850 Mean Velocity Gradient (sec-1): 748.0
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 549,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 37 Stage Liquid Volume (gal): 78,839 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 29 Stage Liquid Volume (gal): 189,214 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 27 Stage Liquid Volume (gal): 280,947
Sedimentation	Surface Area (ft2): 62,900 Liquid Volume (gal): 4,500,000 Baffling Type: AV
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is under 50 ^{o} F only)
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 3,885,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 20 Stage Liquid Volume (gal): 3,885,000
Sedimentation	Surface Area (ft2): 413,000 Stage Means Velocity Gradient (sec-1): Baffling Type: PR
Sedimentation	Surface Area (ft2): 404,044 Stage Means Velocity Gradient (sec-1): Baffling Type: UN
Filtration	Surface Area (ft2): 10,176 Liquid Volume (gal): 797,024 Total Media Depth (in): 27 Media Type: SAND Minimum Water Depth to top of Media (ft): 3.0 Depth From Top of Media To Top of Backwash Trough (ft): 3.0
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 0.36 (As needed to maintain 2.0 ppm residual)

Table A.2—Design Plant Parameters (continued)

Process Train Name: Central Plant 1 & 2 #2 Process Train

Unit Process	Process Description
Presedimentation	Surface Area (ft2): 112,820 Liquid Volume (gal): 16,400,000
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 4.20
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is above 50 ^{o} F only)
Rapid Mix	Type of Mixer: ME Baffling Type: PF Liquid Volume (gal): 18,850 Mean Velocity Gradient (sec-1): 748.0
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 600,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 37 Stage Liquid Volume (gal): 86,163 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 29 Stage Liquid Volume (gal): 206,791 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 27 Stage Liquid Volume (gal): 307,046
Sedimentation	Surface Area (ft2): 49,932 Liquid Volume (gal): 3,824,000 Baffling Type: AV
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is under 50 ^{o} F only)
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 3,885,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 20 Stage Liquid Volume (gal): 3,885,000
Sedimentation	Surface Area (ft2): 413,000 Stage Means Velocity Gradient (sec-1): Baffling Type: PR
Sedimentation	Surface Area (ft2): 404,044 Stage Means Velocity Gradient (sec-1): Baffling Type: UN
Filtration	Surface Area (ft2): 10,176 Liquid Volume (gal): 797,024 Total Media Depth (in): 27 Media Type: SAND Minimum Water Depth to top of Media (ft): 3.0 Depth From Top of Media To Top of Backwash Trough (ft): 3.0
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 0.36 (As needed to maintain 2.0 ppm residual)

Table A.2—Design Plant Parameters (continued)

Process Train Name: Central Plant 1 & 2 #3 Process Train

Unit Process	Process Description
Presedimentation	Surface Area (ft2): 112,820 Liquid Volume (gal): 16,400,000
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 4.20
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is above 50 ^{o} F only)
Rapid Mix	Type of Mixer: ME Baffling Type: PF Liquid Volume (gal): 18,850 Mean Velocity Gradient (sec-1): 748.0
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 703,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 37 Stage Liquid Volume (gal): 100,954 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 29 Stage Liquid Volume (gal): 242,290 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 27 Stage Liquid Volume (gal): 359,756
Sedimentation	Surface Area (ft2): 58,518 Liquid Volume (gal): 5,261,000 Baffling Type: AV
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is under 50 ^{o} F only)
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 3,885,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 20 Stage Liquid Volume (gal): 3,885,000
Sedimentation	Surface Area (ft2): 413,000 Stage Means Velocity Gradient (sec-1): Baffling Type: PR
Sedimentation	Surface Area (ft2): 404,044 Stage Means Velocity Gradient (sec-1): Baffling Type: UN
Filtration	Surface Area (ft2): 10,176 Liquid Volume (gal): 797,024 Total Media Depth (in): 27 Media Type: SAND Minimum Water Depth to top of Media (ft): 3.0 Depth From Top of Media To Top of Backwash Trough (ft): 3.0
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 0.36 (As needed to maintain 2.0 ppm residual)

Table A.2—Design Plant Parameters (continued)

Process Train Name: Central Plant 1 & 2 #4 Process Train

Unit Process	Process Description
Presedimentation	Surface Area (ft2): 112,820 Liquid Volume (gal): 16,400,000
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 4.20
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is above 50 ^{o} F only)
Rapid Mix	Type of Mixer: ME Baffling Type: PF Liquid Volume (gal): 18,850 Mean Velocity Gradient (sec-1): 748.0
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 2,165,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 37 Stage Liquid Volume (gal): 380,941 Stage Sequence Number: 2 Stage Mean Velocity Gradient (sec-1): 29 Stage Liquid Volume (gal): 714,265 Stage Sequence Number: 3 Stage Mean Velocity Gradient (sec-1): 27 Stage Liquid Volume (gal): 1,071,398
Sedimentation	Surface Area (ft2): 121,924 Liquid Volume (gal): 21,780,000 Baffling Type: AV
Disinfectant Addition	Chemical Code: NH3H Measurement Formula: NH4(OH) Dose Rate (mg/L): 0.95 (When temperature is under 50 ^{o} F only)
Flocculation Basin	Type of Mixer: ME Liquid Volume (gal): 3,885,000 Baffling Type: AV Stage Sequence Number: 1 Stage Mean Velocity Gradient (sec-1): 20 Stage Liquid Volume (gal): 3,885,000
Sedimentation	Surface Area (ft2): 413,000 Stage Means Velocity Gradient (sec-1): Baffling Type: PR
Sedimentation	Surface Area (ft2): 404,044 Stage Means Velocity Gradient (sec-1): Baffling Type: UN
Filtration	Surface Area (ft2): 10,176 Liquid Volume (gal): 797,024 Total Media Depth (in): 27 Media Type: SAND Minimum Water Depth to top of Media (ft): 3.0 Depth From Top of Media To Top of Backwash Trough (ft): 3.0
Disinfectant Addition	Chemical Code: CL2 Measurement Formula: CL2 Dose Rate (mg/L): 0.36 (As needed to maintain 2.0 ppm residual)

Table A.3—Design Plant Chemical Parameters

PWS Name: ST. LOUIS COUNTY WATER COMPANY
PWS ID: MO6010716
Treatment Plant Name: Central Plant 1 & 2
ICR Treatment Plant ID: 435
Treatment Plant Category: SOFT

	Central Plant 1 & 2
Unit Process	Chemical Feed
Presedimentation	Powdered activated carbon Organic polymer – coagulant aid Ferric sulfate Calcium hydroxide
Disinfectant Addition	Chlorine gas
Disinfectant Addition	Ammonium hydroxide (When temperature is above 50 ^{o} F only)
Rapid Mix	Hydrofluorosilic acid Ferric sulfate
Sedimentation	
Disinfectant Addition	Ammonium hydroxide (When temperature is under 50 ^{o} F only)
Flocculation Basin	Ferric sulfate
Sedimentation	
Sedimentation	Other chemical
Filtration	Organic polymer – filter aid
Disinfectant Addition	Chlorine gas (As needed to maintain 2.0 ppm residual)

Treatment Challenges Facing Plant

Treatment challenges include removal of suspended solids up to 3000 mg/L, stabilizing fluctuating carbonate hardness, balancing disinfection and DBP formation, reducing color, tastes and odors, and minimizing herbicides levels. Changes in raw water quality are responded to by altering chemical feed rates to produce a consistent finished water that meets drinking water requirements.

III. Materials And Methods

Pretreatment to Bench Study

At Central Plant 1 & 2 ,Missouri River water is pumped from the river about one quarter of mile through intake mains. At the pump bowl a cationic polymer is added to begin the coagulation process. Just prior to reaching the presedimentation, basin ferric sulfate and powder activated carbon (if necessary) are injected into the intake flow. The water enters at the center bottom of the presedimentation basin and flows up through a center column where calcium hydroxide is applied. The water flows out of the center through laundry arms which radiate from its circumference into an expanded circular settling area. The settled water is decanted over an overflow weir into a collection flume which flows around and out of the presedimentation basin into the rapid mix flume.

With each quarterly sample run, approximately 400 gallons of water was collected for this bench study from the effluent of Central Plant 1 & 2 presedimentation basin effluent several days prior to the start of the column runs. Water was pumped from presedimentation flume with a portable gas pump through a 1 micron wound fiber filter into two 250 gallon plastic storage tanks. Filtration of the sample with the 1 micron filter was necessary because presedimentation effluent samples yield a turbidity between 3-5 NTU and would have clogged GAC columns prematurely.

The collected water was transported to the Central Plant 1 & 2 filtration building where it was stored until an aliquot was transferred to a 50 gallon polyethylene tank in the laboratory from which both the 10 and 20 minute EBCT GAC columns withdrew water for the quarterly runs.

Table 3.1 Design Data for Each Pretreatment Process

Unit Process	Process Description
Presedimentation	Surface Area (ft2): 112,820 Liquid Volume (gal): 16,400,000

Unit Process	Chemical Feed
Presedimentation	Powdered activated carbon Organic polymer – coagulant aid Ferric sulfate Calcium hydroxide

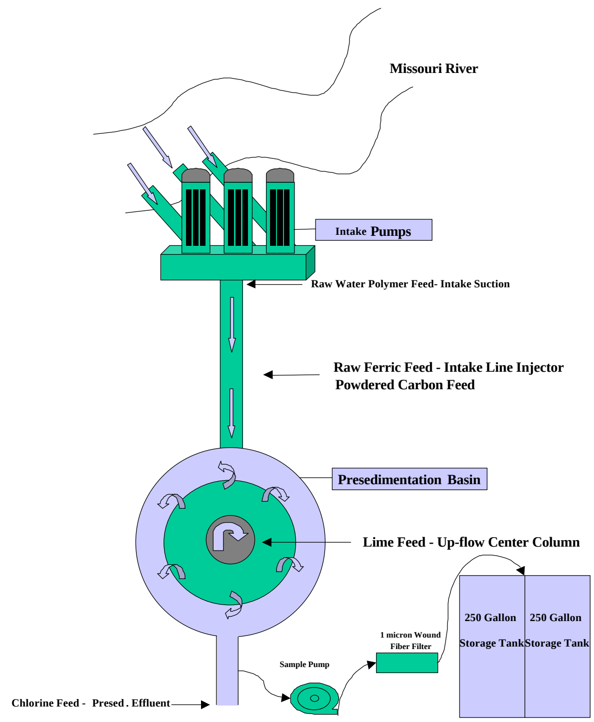


Figure 3.1 Schematic of Pretreatment System Used Prior to Bench Scale RSSCT Study

Fluctuations in the Missouri River quality caused by the climatic conditions are responded to by adjusting plant chemical dosages. A fairly consistent pH of 10.0 to 10.2 and a turbidity of 3-5 NTU are maintained at the presedimentation effluent so that the remainder of plant processes are provided with water amenable to meet plant effluent goals. Figure 3.2 illustrates the Total Organic Carbon (TOC) levels measured on the Missouri River and the Central Plant presedimentation basin effluent in 1998. The Missouri River TOC fluctuates between 3 and 9 ppm TOC in response to runoff events in the lower Missouri River basin. Presedimentation basin treatment modulates the Missouri River TOC levels in the range of 2-3 ppm TOC.

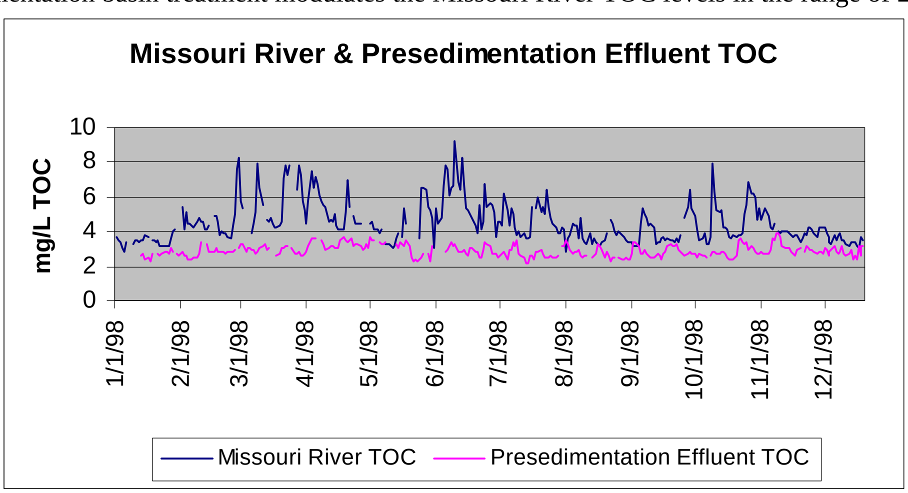


Figure 3.2 Missouri River TOC and TOC after Presedimentation Basin Treatment

Equipment Used for Bench Study

The equipment to run the RSSCT test was purchased as a kit from Process Optimization Services of Lakewood, Colorado. The Model ICR-10/20 kit consisted of an easy to assemble system that was configured with two pumps and columns so that the 10 and 20 minute EBCT tests could be performed simultaneously. Equipment documentation is contained on pages 40-41 and a schematic of the systems is in Figure 3.4.

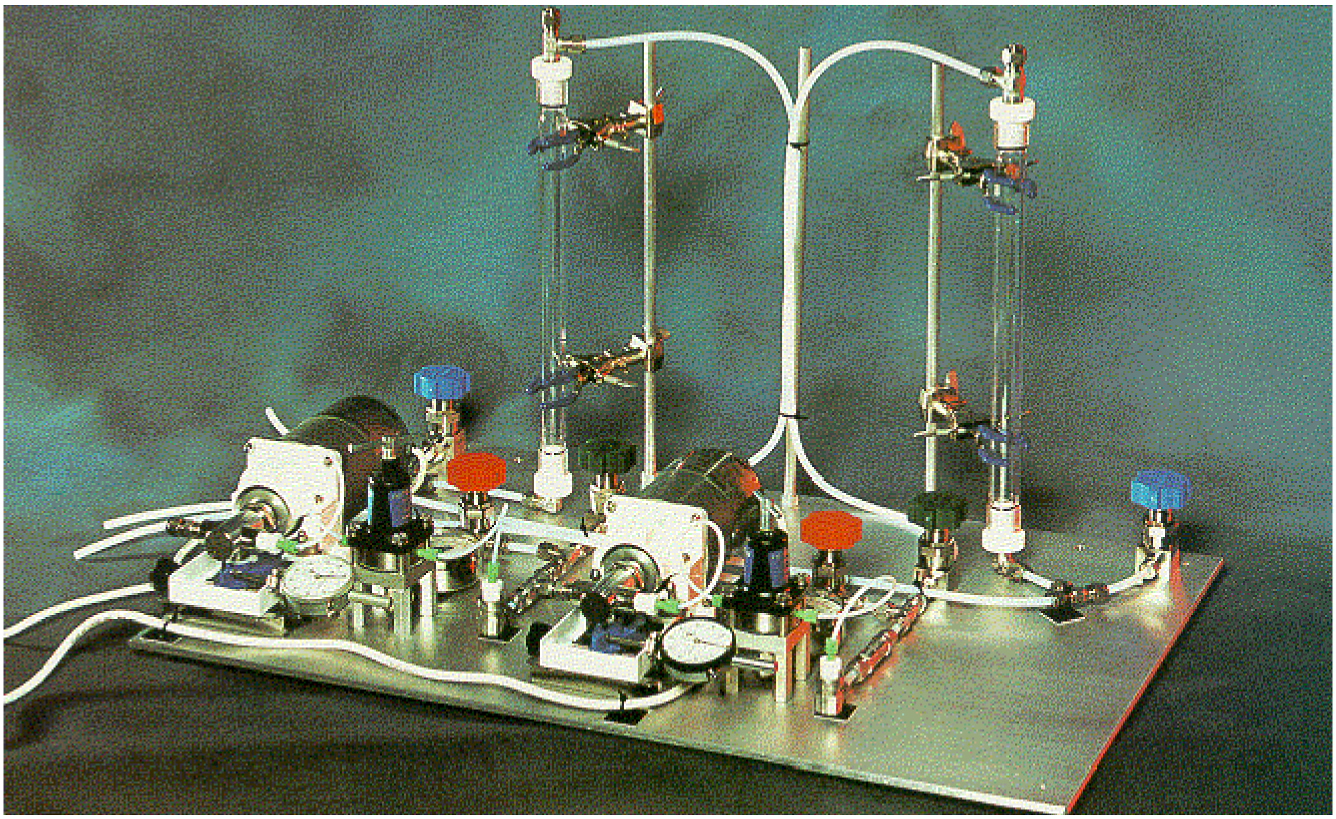


Figure 3.3 Photograph of Process Optimization Services Model ICR-10/20 RSSCT Kit

Process Optimization Services was also commissioned to acquire and prepare the granular activated carbon (GAC) to satisfy the requirements of the ICR Bench Scale Study. Hydrodarco 3000 GAC was acquired from the American Norit Company, ground, and wet sieved to produce a 60 x 80 mesh size GAC for packing into the 20 and 10 minute bed columns. The kit was assembled and leak tested per the manufacturer's instructions.

GAC densities were determined, the calculated masses of GAC for the 10 minute and 20 minute bed columns were weighed, wetted and loaded into the glass columns. Reagent water was pumped through systems to adjust the pumps for flow rates of 12 milliliters per minute. Both the 10 and 20 minute EBCT columns were fed from same 50 gallon feed tank which was refilled every 3-5 days from the larger holding tanks located in the filtration building. A practice run was performed on the 10 minute EBCT prior to the required runs to familiarize staff with the RSSCT kit operations and to develop an estimation of what the TOC removal curve and total run time would be.

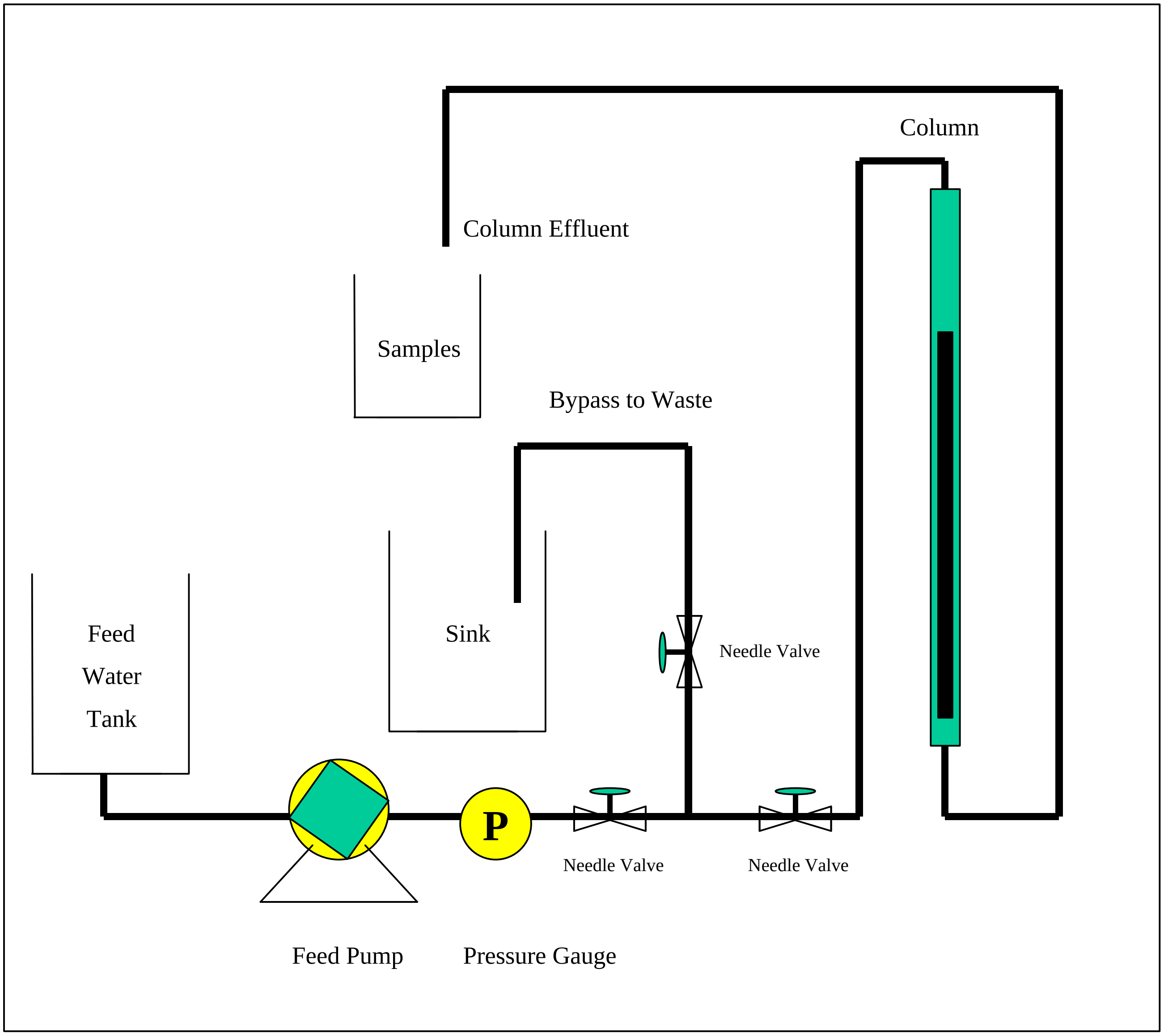


Figure 3.4 Schematic of 10 or 20 Minute Bench Scale RSSCT System

Experimental Design

The RSSCT bench runs were performed on both the 10 and 20 minute EBCT columns in each of the four seasons in 1998 to evaluate the impact of seasonal variation on TOC removal and DBP formation as documented in Table 3.2. The Missouri River drains a large land area with diverse land uses. The quality of water can vary depending on where and when precipitation events fall. The origin and composition of dissolved organic matter may vary due the varied types of land areas within the river basin. The TOC removal efficiency for each the columns was evaluated for seasonal variation of the TOC composition.

Table 3.2 Experimental Design

Season/Quarter	Pretreatment	EBCT, min
Spring/1st	Presedimentation 1u wound fiber filter	10 & 20
Summer/2nd	Presedimentation 1u wound fiber filter	10 & 20
Autumn/3rd	Presedimentation 1u wound fiber filter	10 & 20
Winter/4th	Presedimentation 1u wound fiber filter	10 & 20

Temperatures on the Missouri River range from 1^{o} to 28^{o} Celsius. This wide range in temperature has a significant effect on the formation of disinfection byproducts. Simulated distribution system (SDS) temperature conditions were maintained near typical tap temperatures observed under plant conditions. An illustration of typical tap temperatures and the average SDS incubation temperatures for each the seasonal runs are shown in Figure 3.5.

Figure 3.5 Central Plant 1 & 2 Tap Temperature and Study SDS Temperature Conditions

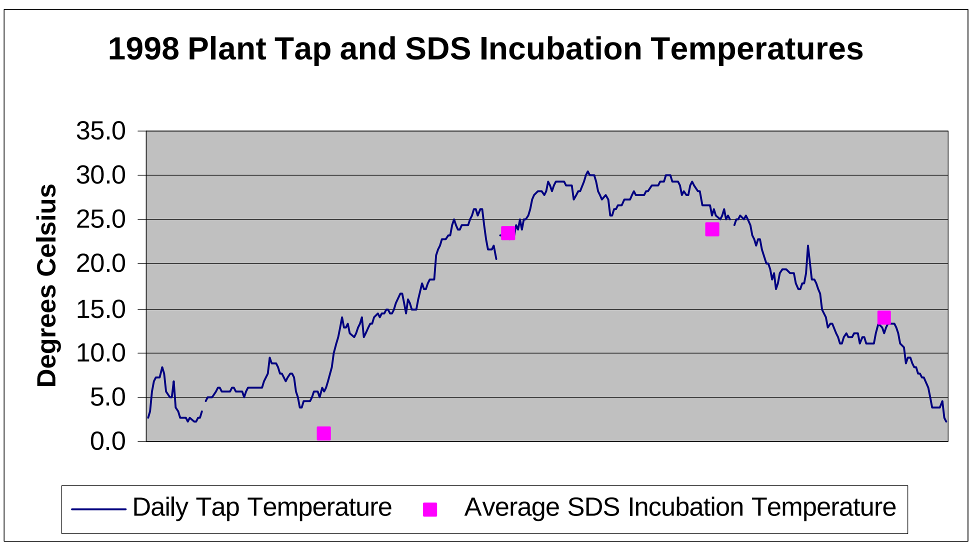


Table 3.3 Analytical Methods and Minimum Reporting Levels

Analyte	Method	SLCWC Laboratory Minimum Reporting Level	Environmental Health Laboratories Minimum Reporting Level
Alkalinity	SM 2320 B	5 mg/L CaCO3	
Ammonia	SM 4500-NH3 D	0.10 mg/L NH3-N	
Bromide	EPA 300.0	10 ug/L	
Calcium Hardness	SM 3500-Ca D	10 ug/L	
Chlorine Residual	SM 4500-Cl D	0.2 mg/L	
BCAA, DBAA, DCAA, MBAA, MCAA, TCAA	SM 6251B	1.0 ug/L, 2.0 ug/L for MCAA	1.0 ug/L, 2.0 ug/L for MCAA
pH	EPA 150.1	N/A	
Temperature	SM 2550B	N/A	
CHCl3, BDCM, DBCM, CHBr3	EPA 551.1	0.5 ug/L	1.0 ug/L
Total Hardness	SM2340 C	5 mg/L CaCO3	
TOC	SM 5310 C	0.5 mg/L	
TOX	SM 5320 B	50ug/L	50ug/L
Turbidity	EPA 180.1	0.5 NTU	
UV 254	SM 5910	0.009 cm^{-1}	

Addresses for Analytical Laboratories

St. Louis County Water Company
555 N. New Ballas Suite 100
St. Louis, MO 63141

ICR Lab ID #: ICRMO001
Contact: Paul Keck
Phone: (314) 993-8003
Fax: (314) 993-3569

Environmental Health Laboratories
110 South Hill Street
South Bend, Indiana 46617

ICR Lab ID #: ICRIN004
Contact: Richard Radcliff
Phone: (219) 233-4777
Fax: (219) 233-8207

IV. Results And Discussion

Problems Encountered

There were only two problems during the four quarters of the RSCCT test kit runs. During the test run prior to the four quarterly runs, air became entrapped in the top of the column. To remediate this problem, the column effluents were elevated to a level above the top of the columns and air was bled out of the columns by loosening the fittings at the top of the columns.
The 20 minute EBCT column exhibited some variable flow rates and was adjusted as needed. This pump was switched to the 10 minute EBCT column which had the shorter column run.

Water Quality Data of Pretreated Feed Water

Pretreated feed water quality for the bench scale study parallels the discussion of the water quality after pretreatment in the full scale plant. Chemical dosages are adjusted to maintain pH and turbidity ranges to produce water despite the variable raw water quality. As discussed earlier, presedimentation basin TOC levels modulate in the 2-3 ppm range. Calcium and hardness values vary some but not to the extremes seen in the raw water. This treatment regulates these parameters regardless of the season. Summaries of pretreated influent water for the 10 & 20 minute EBCT are in Tables 4.1 and 4.2.

Table 4.1 Water Quality of Pretreated Influent 10 Minute EBCT

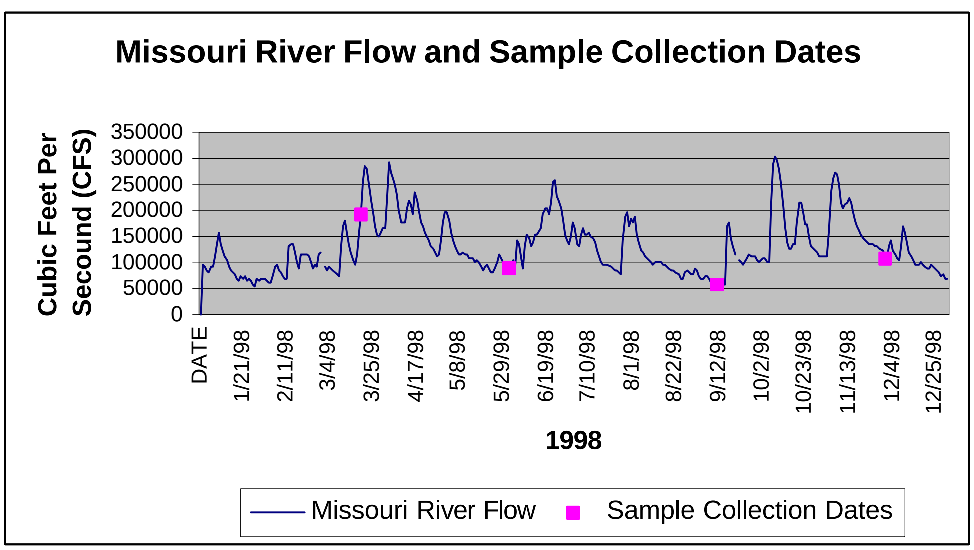
Water Quality Parameter	Spring Average (SD)	Summer Average (SD)	Autumn Average (SD)	Winter Average (SD)
Temperature (^oC)	20.8 (6.3)	23.0 (4.35)	23.0 (4.35)	22.0 (4.55)
pH	9.33 (1.24)	9.13 (4.94)	9.43 (2.45)	9.53 (1.60)
Turbidity (NTU)	0.38 (44.91)	0.30 (4.71)	0.21 (45.43)	0.63 (66.06)
Alkalinity (mg/L as $CaCO_3$)	45	44	51	52
Calcium Hardness (mg/L as $CaCO_3$)	53.0	64.9	54.4	51.9
Total Hardness (mg/L as $CaCO_3$)	103.0	112.0	121.5	118.0
Bromide (ug/L)	75	47	136.5	70.5
TOC (mg/L)	3.14 (4.47)	3.32 (8.67)	2.64 (4.56)	2.95
UV_{254} (cm^{-1})	0.068 (1.05)	0.085 (5.54)	0.073 (8.33)	0.085 (2.46)
Incubation Temperature (^oC)	1	23	16	14.0
SDS-THM4 (ug/L)	43.65 (57.61)	26.29 (24.77)	41.5 (14.63)	56.43 (6.46)
SDS-HAA5 (ug/L)	14.2	17.67 (6.75)	22.1 (9.92)	21.93 (8.21)
SDS-HAA6 (ug/L)	18.25	21.60 (8.93)	29.00 (6.22)	27.0 (7.04)
SDS-TOX ug/ Cl^-/L	144.03 (32.37)	190.9 (7.24)	110.73 (30.35)	195.97 (10.86)
SDS-Chlorine Demand (mg/L)	No Data	1.53 (9.96)	1.6	1.57 (13.29)

Table 4.2 Water Quality of Pretreated Influent 20 Minute EBCT

Water Quality Parameter	Spring Average (SD)	Summer Average(SD)	Autumn Average(SD	Winter Average(SD)
Temperature (^oC)	21.7 (2.6)	23.0	22.7	22.0 (4.55)
pH	9.33 (1.24)	9.07 (6.07)	9.37 (3.26)	9.53 (1.60)
Turbidity (NTU)	0.39 (42.37)	0.32 (2.24)	0.21 (45.43)	0.63 (66.06)
Alkalinity (mg/L as $CaCO_3$)	45	44	51	52
Calcium Hardness (mg/L as $CaCO_3$)	53.5	64.9	54.4	51.9
Total Hardness (mg/L as $CaCO_3$)	103.0	112.0	121.5	118.0
Bromide (ug/L)	75.0	47	136.5	70.5
TOC (mg/L)	3.07 (3.28)	3.29 (9.16)	2.69 (7.11)	2.95
UV_{254} (cm^{-1})	.069 (3.03)	.087 (7.51)	0.071 (4.51)	0.085 (2.46)
Incubation Temperature (^oC)	1	22.3	16	14.0
SDS-THM4 (ug/L)	32.82 (41.03)	26.90 (20.35)	45.7 (24.0)	56.43 (6.46)
SDS-HAA5 (ug/L)	15.73 (24.53)	19.03 (16.47)	22.43 (12.24)	21.93 (8.21)
SDS-HAA6 (ug/L)	20.23 (28.57)	21.73 (7.83)	29.77 (10.42)	27.0 (7.04)
SDS-TOX ug/ Cl^-/L	151.17 (37.89)	215.33 (8.63)	137.27 (9.39)	195.97 (10.86)
SDS-Chlorine Demand (mg/L)	0.9	1.53 (9.96)	1.67 (6.93)	1.57 (13.29)

Bromide is unaffected by this pretreatment and variations in raw water are carried into the treatment basin. During low runoff periods bromide levels in Missouri River increase. The autumn/4th quarter sample collection represents one of these low runoff periods in 1998.

Figure 4.1 Missouri River Flow and Sample Collection Dates for the Four Seasonal Studies



DBP Data and Data Analysis

1st Quarter Precursor and D/DBP Result

Breakthrough curves for the 10 minute EBCT column, the 20 minute EBCT column, and the column feed water for TOC and UV254 are illustrated on pages 24-25. The curves demonstrate normal breakthrough curves for the two columns, with the 20 minute EBCT column exceeding the 70% breakthrough point in twice the time of the 10 minute EBCT column. Influent levels exceed all effluent levels by a fairly consistent amount.

THM4, HAA5, and TOX exhibit the same formation trends. There is a set of elevated levels for all three groups between the 50 and 75 day points on the curve. The chlorine residual curve exhibits almost the mirror image of this aberration. This indicates that there may have been some variation in the SDS incubation conditions which caused this increased formation of DBPs and the increase in chlorine demand.

Examination of the individual species of THMs and HAAs illustrates the shift from the formation of the more chlorinated DBPs to the more brominated DBPs after water has been passed through GAC columns which has been documented . [1-3]

The relative abundance of Trihalomethanes is:

Influent Water – CHCL3>BDCM>DBCM>CHBR3
Column Effluent – BDCM>DBCM>CHCL3>=CHBR3

The relative abundance of Haloacetic Acids is:

Influent Water – DCAA>TCAA>DBAA
Column Effluent – DCAA>=DBAA>TCAA

2nd Quarter Precursor and D/DBP Result

Breakthrough curves for the 10 minute EBCT column, the 20 minute EBCT column, and the column feed water for TOC and UV254 are illustrated on pages 26-27. The curves demonstrate normal breakthrough curves for the two columns with the 20 minute EBCT column exceeding the 70% breakthrough point in twice the time of the 10 minute EBCT column. Influent levels exceed all effluent levels by a fairly consistent amount.

THM4, HAA5, and TOX exhibit the same formation trends. After the 75 day point DBP levels are variable and decrease. SDS chlorination pH levels also fall about this same time, possibly explaining this decreased DBP formation. Due to a miscommunication the first few SDS incubations were performed at a temperature of 4^{o} Celsius. This was then corrected to approximately 24^{o} Celsius for the remainder of the run.

Examination of the individual species of THMs and HAAs shows the shift from the formation of the more chlorinated DBPs to the more brominated DBPs for the 20 minute EBCT column. The 10 minute EBCT column displays results resembling the influent water for both THMs and HAAs.

3rd Quarter Precursor and D/DBP Result

Breakthrough curves for the 10 minute EBCT column, the 20 minute EBCT column, and the column feed water for TOC and UV254 are illustrated on pages 28-29. The curves demonstrate normal breakthrough curves for the two columns, with the 20 minute EBCT column exceeding the 70% breakthrough point in twice the time of the 10 minute EBCT column.   Influent levels exceed all effluent levels by a fairly consistent amount.

Column effluent SDS THM4 levels were higher than influent SDS THM4 levels for both the 10 & 20 minute columns and somewhat erratic. The THM4 levels were also higher than previous quarterly column runs. This increase is do to the increased levels of the brominated THM species. Other researchers have documented this increase of brominated species with lower TOC levels and higher bromide levels. [1-3] SDS HAA5 formation was also increased, but the 10 & 20 minute EBCTcolumn levels were below the SDS influent levels.

Examination of the individual species of THMs shows a dramatic increase in the production of bromoform. Bromoform is elevated from the fourth most abundant rank up to the first and second position. Chloroform falls to the least abundant species. This significant increase was produced when feed water bromide levels were at levels of 137 ppb, which is 2-3 time higher than in previous quarters.

The relative abundance of Trihalomethanes in the autumn run is:

Influent Water – CHCL3=BDCM=DBCM>CHBR3
Column Effluent – DBCM>=CHBR3>BDCM>=CHCL3

Examination of the individual species of HAAs shows a dramatic increase in the production of dibromoacetic acid. Dibromoacetic acid is elevated from the second most abundant rank up to the first position for both columns. Dibromoacetic acid is also elevated from the third position up to the second position for the column influent water.

The relative abundance of Haloacetic Acids in the autumn is:

Influent Water – DCAA>DBAA>TCAA
Column Effluent – DBAA>=DCAA>TCAA

The elevated bromide levels and the lower TOC levels produced by the GAC columns appear to promote the formation of the brominated DBPs.   In this quarterly run, SDS THM4 levels for the column effluents exceeded the SDS THM4 levels for the influent. This indicates GAC treatment during periods of high ambient bromide levels may be detrimental in controlling DBP levels. Further investigations at these higher bromide levels would be necessary prior to any consideration on the use of GAC for DBP precursor removal.

4th Quarter Precursor and D/DBP Result

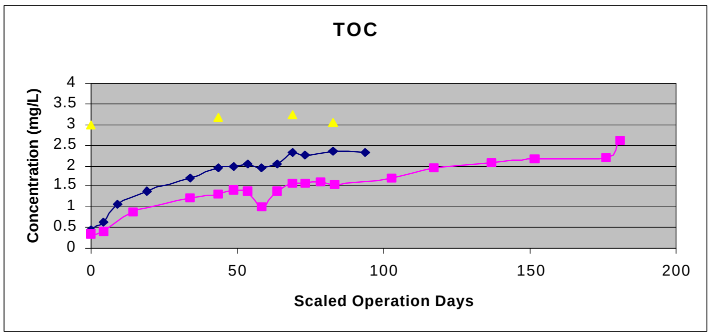
Breakthrough curves for the 10 minute EBCT column, the 20 minute EBCT column, and the column feed water for TOC and UV254 are illustrated on pages 30-31. The curves demonstrate normal breakthrough curves for the two columns, with the 20 minute EBCT column exceeding the 70% breakthrough point in twice the time of the 10 minute EBCT column.   Influent levels exceed all effluent levels by a fairly consistent level.

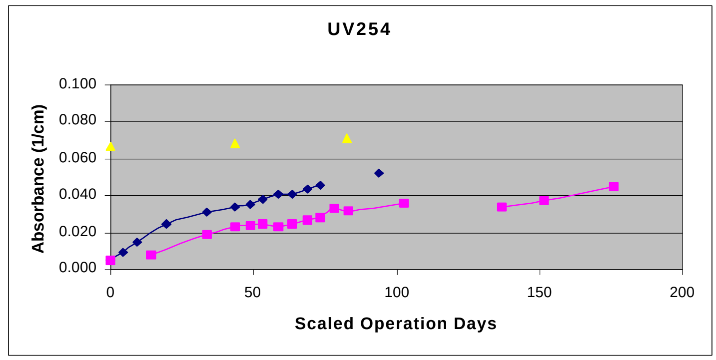
THM4, HAA5, and TOX exhibit the typical formation trends. Influent THM4 levels returned to levels above the column effluent levels.

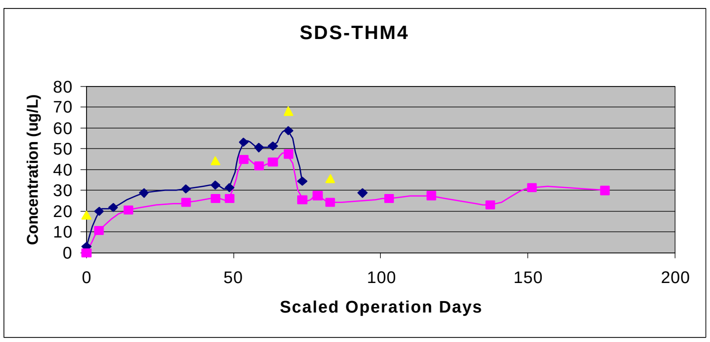
Examination of the individual species of THMs indicate that early in the column run when TOC levels are low, the brominated species are predominate. As TOC levels increase through the run, the species distribution reverts back to the more chlorinated species, especially chloroform. Bromoform levels decrease throughout the run. Under winter conditions. this cross over occurred when TOC levels climbed back to 1.5 ppm for both the 10 & 20 minute EBCT columns.

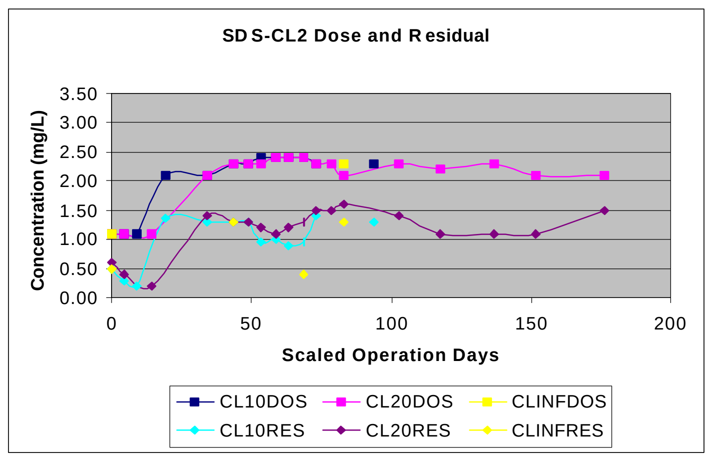
Examination of the individual species of HAAs also indicates that this species predomination shift occurred with DBAA and DCAA. Again, the lower level TOC favored formation of the DBAA, and the higher levels favored DCAA formation.

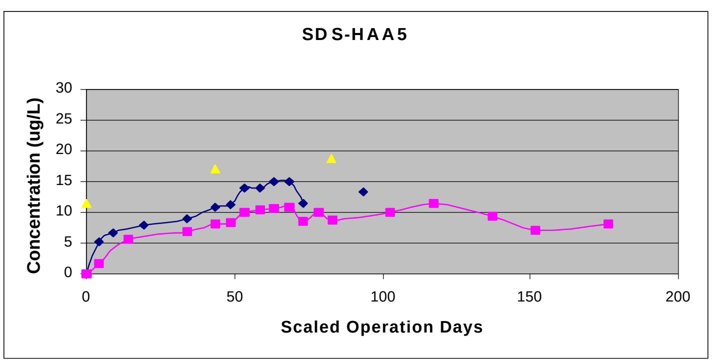
1st Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

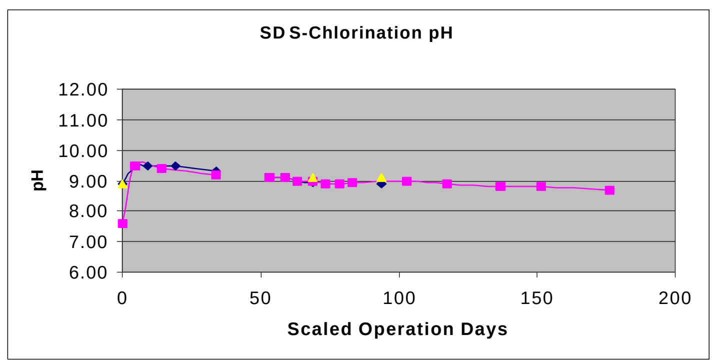


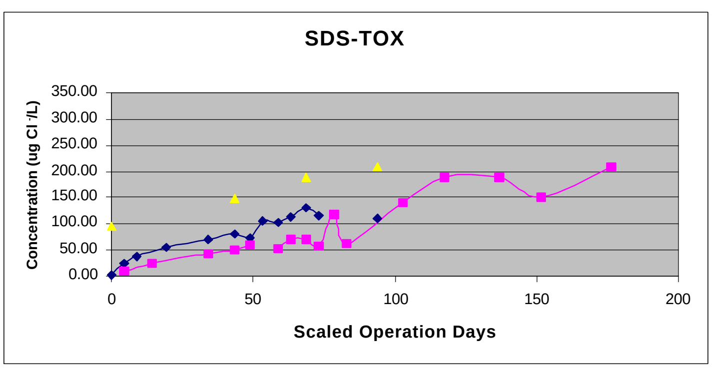


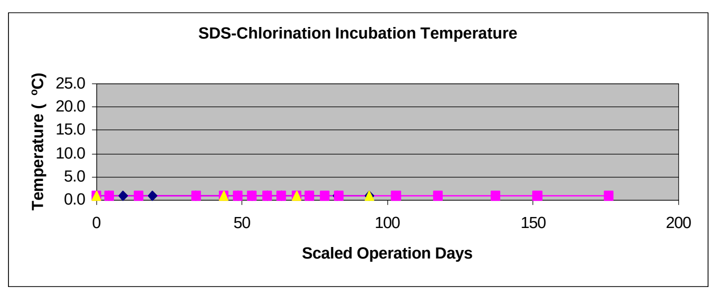






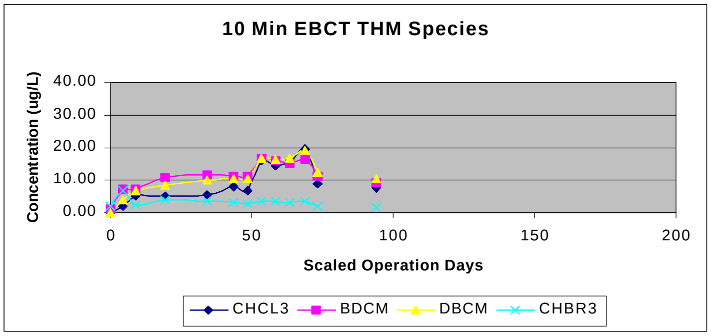


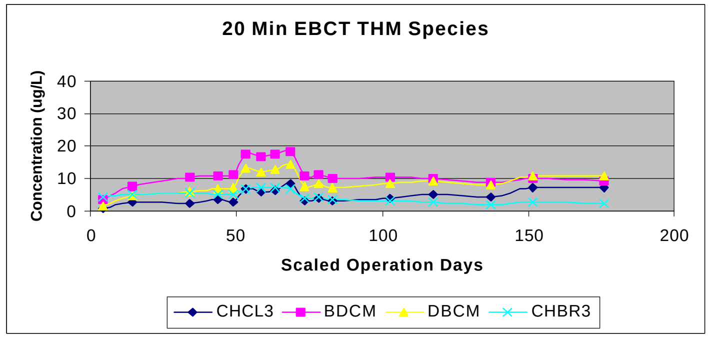


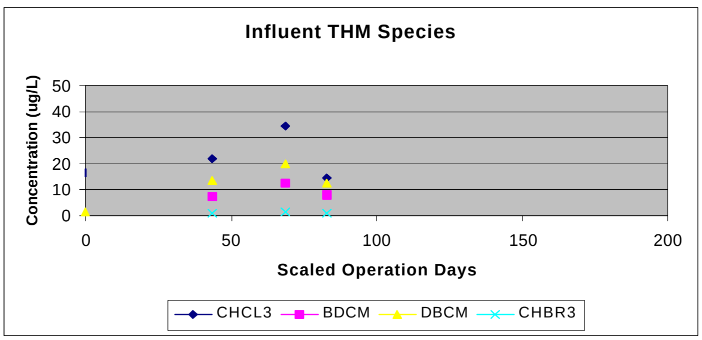


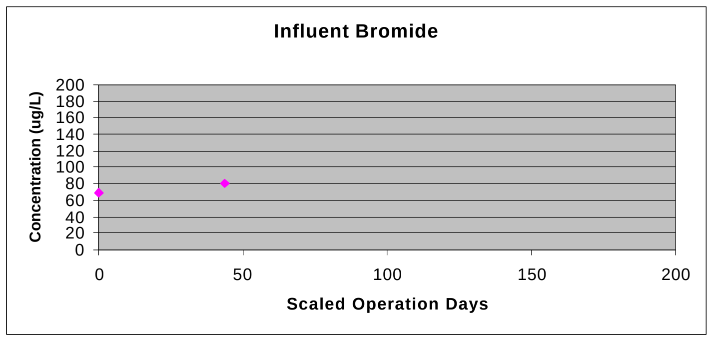
1st Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

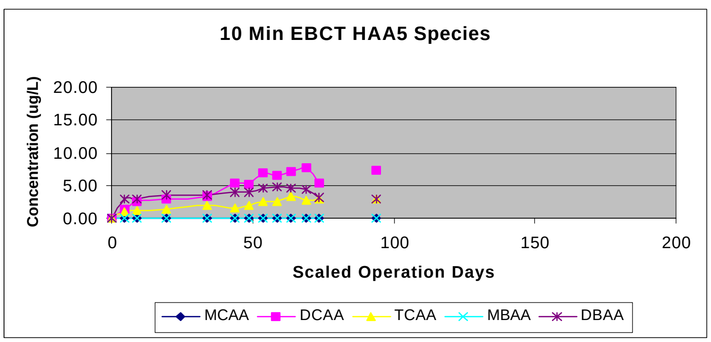
10 Min. EBCT — 20 Min. EBCT — Influent

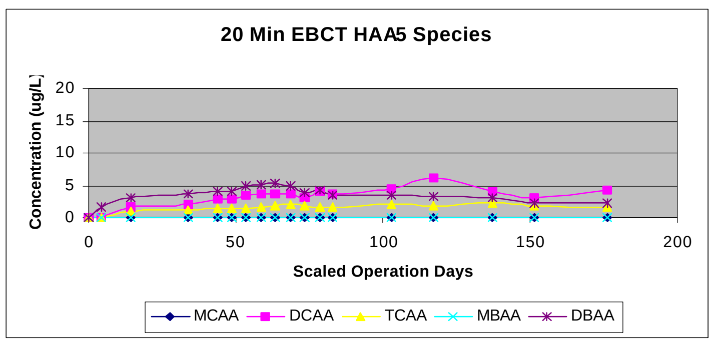


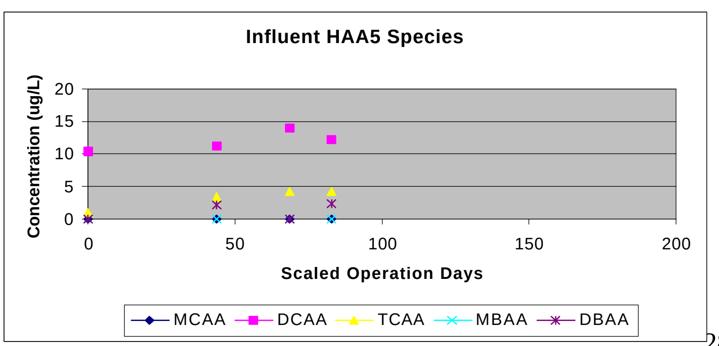




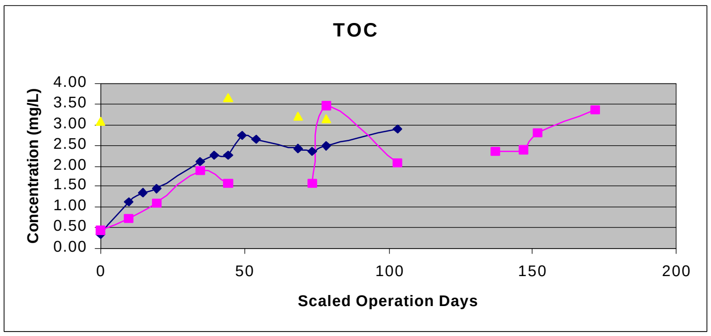


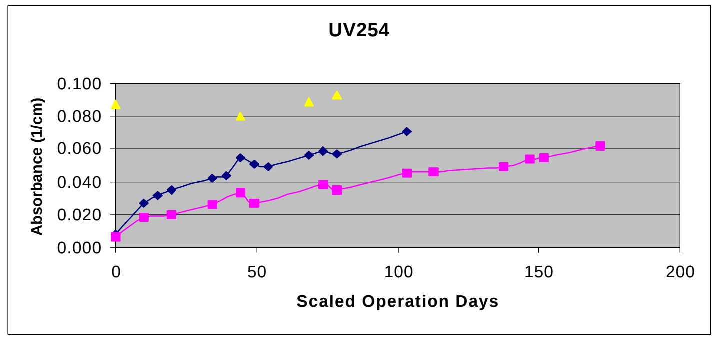


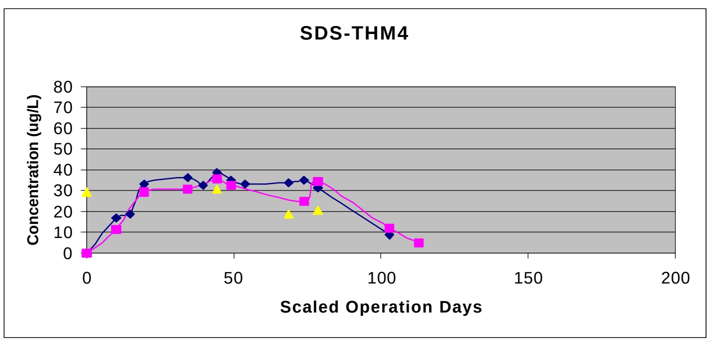


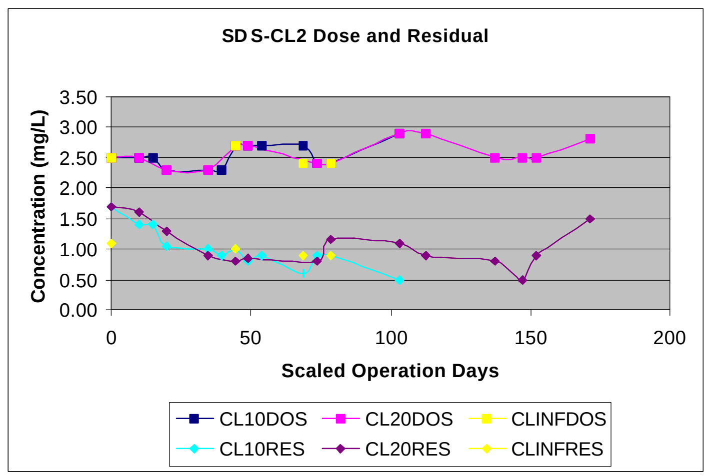


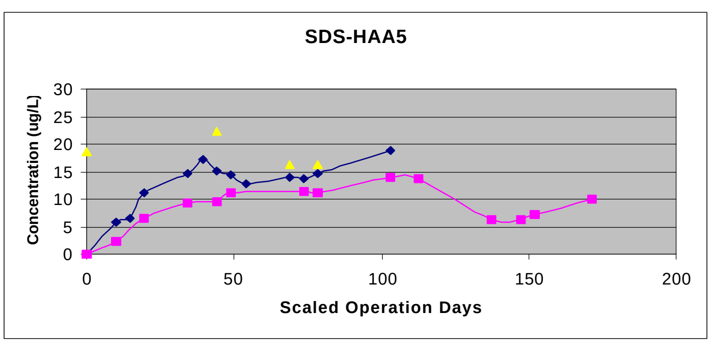
2nd Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

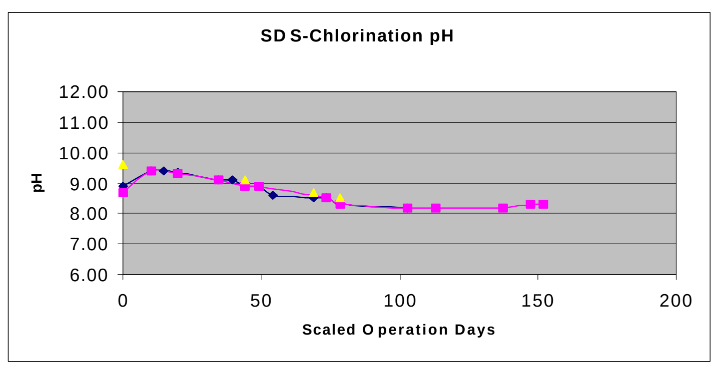


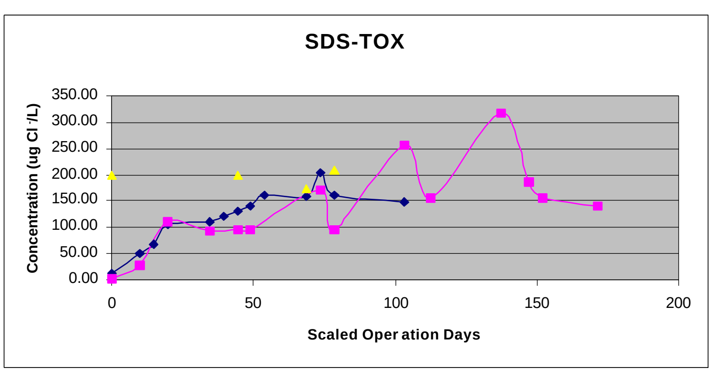


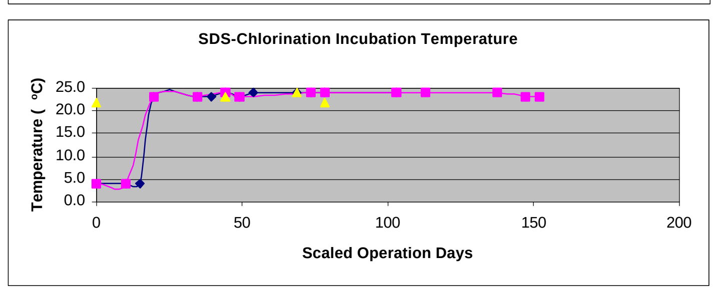




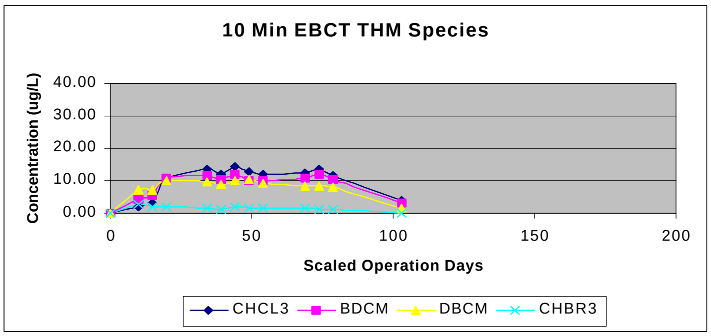


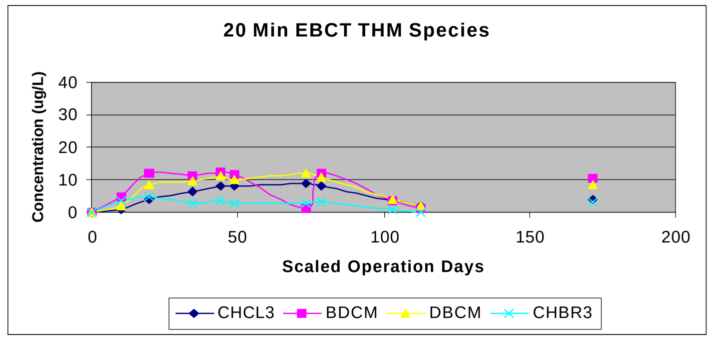


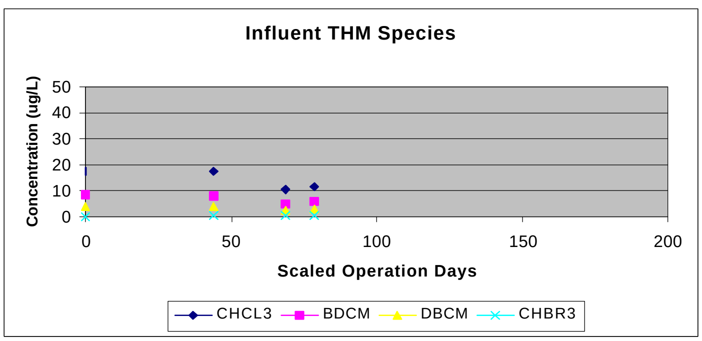


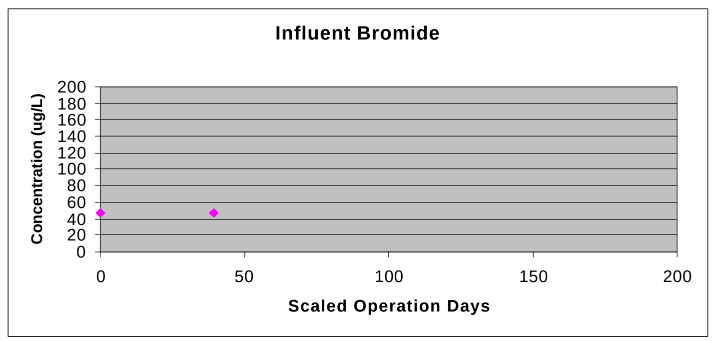


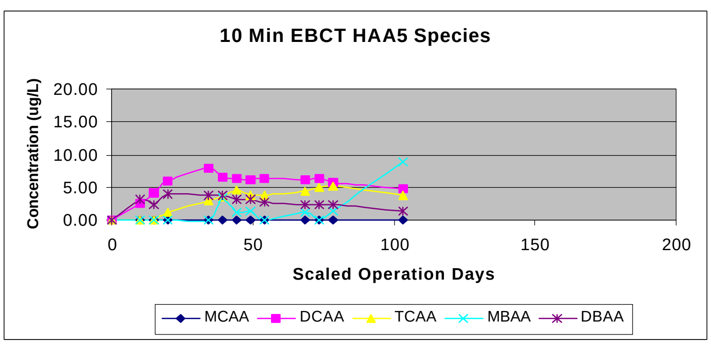
2nd Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

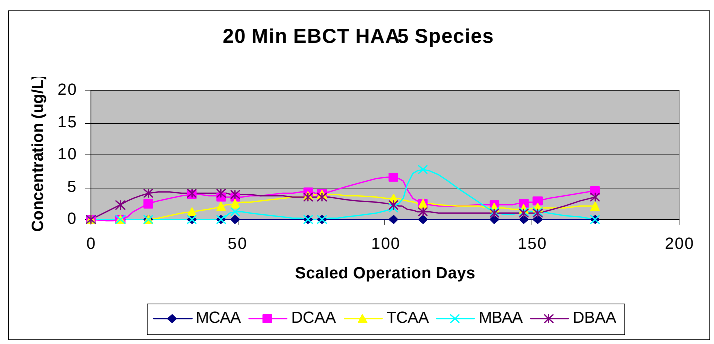


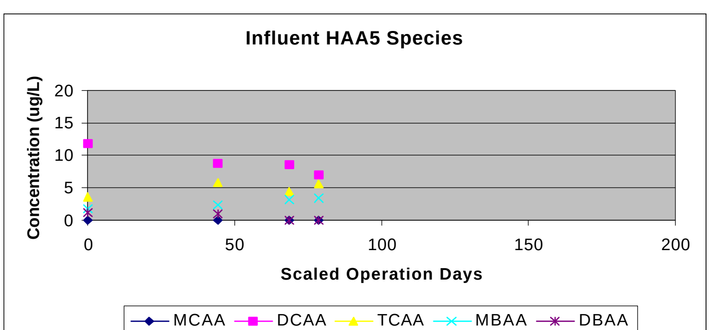






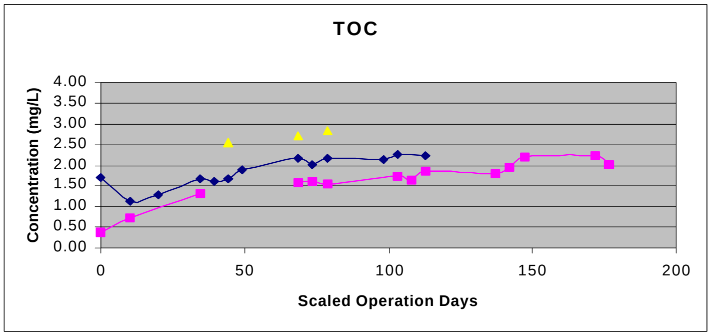


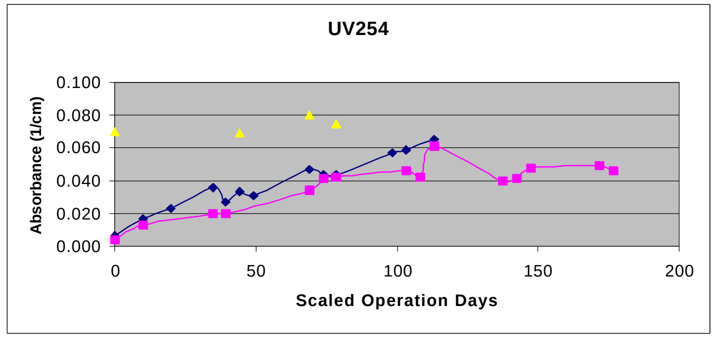


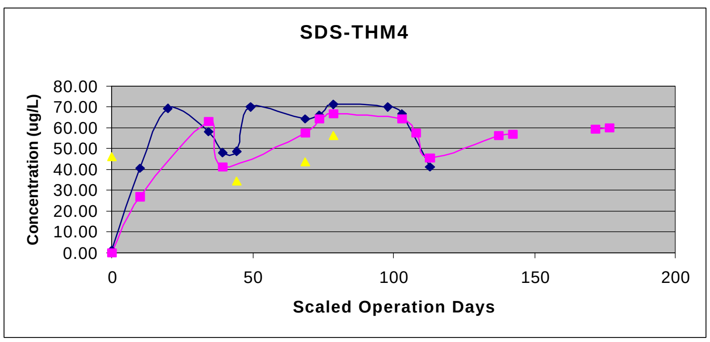


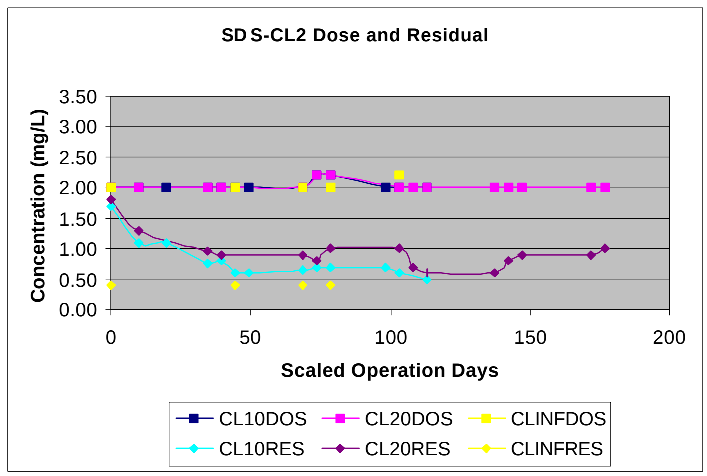
3rd Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

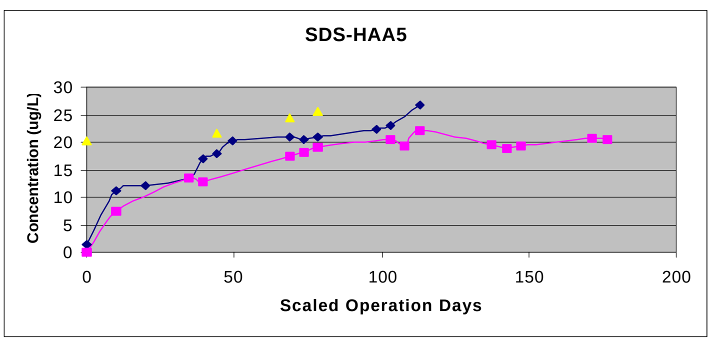
10 Min. EBCT — 20 Min. EBCT — Influent

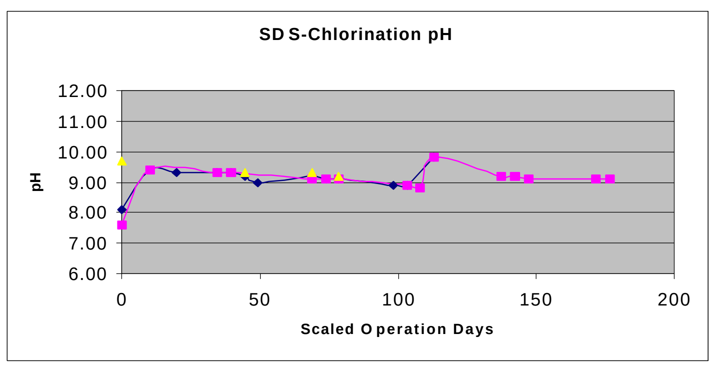


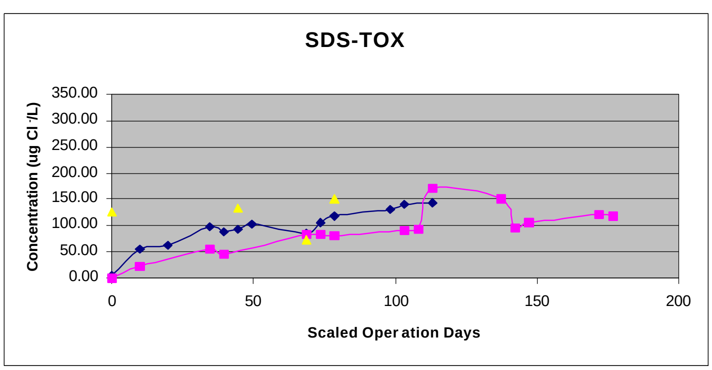


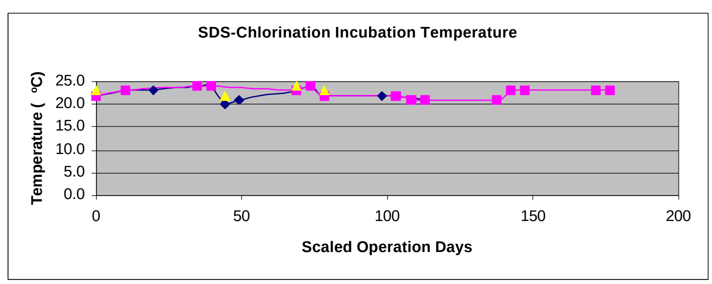






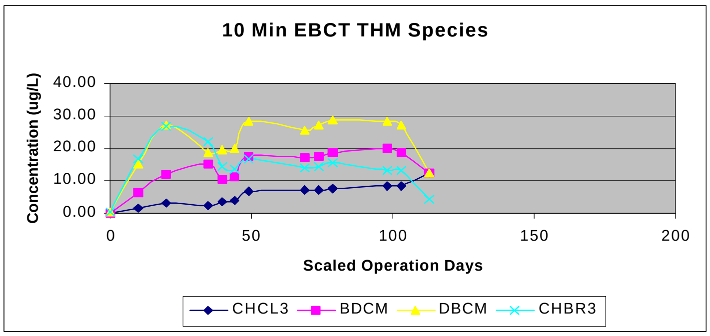


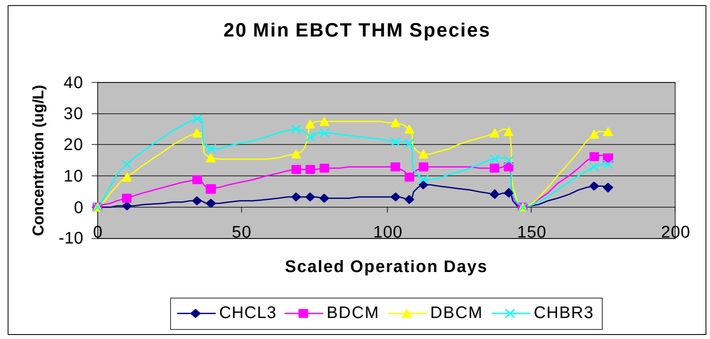


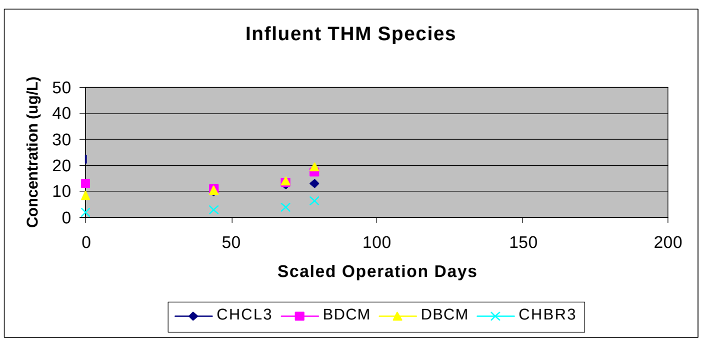


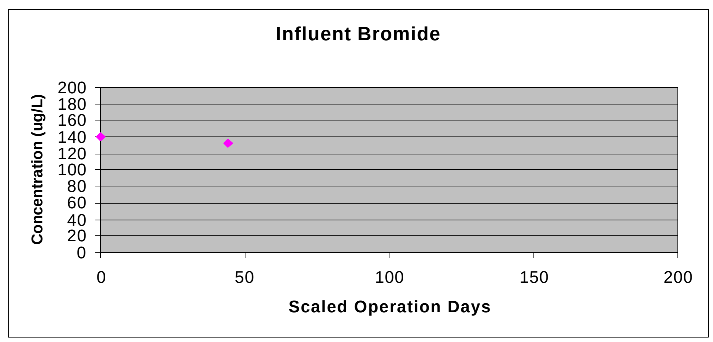
3rd Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

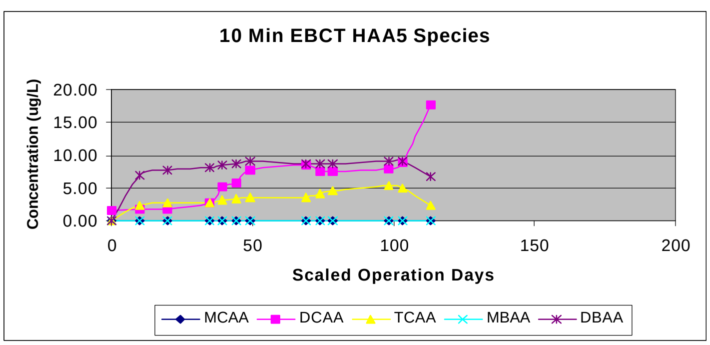
10 Min. EBCT — 20 Min. EBCT — Influent

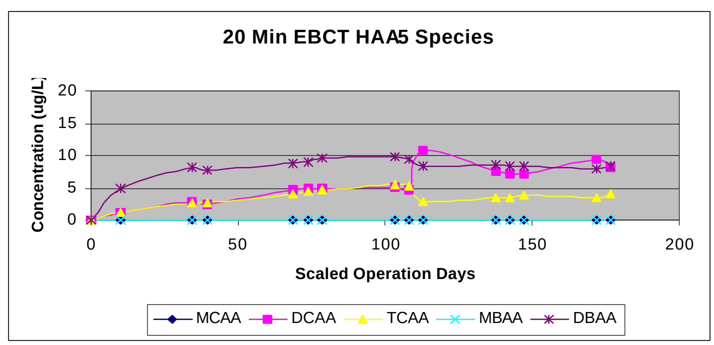


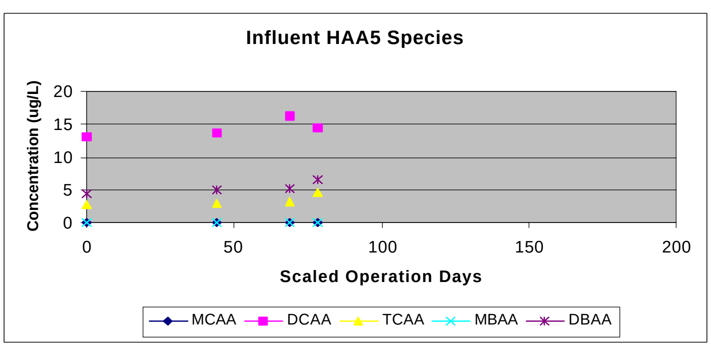




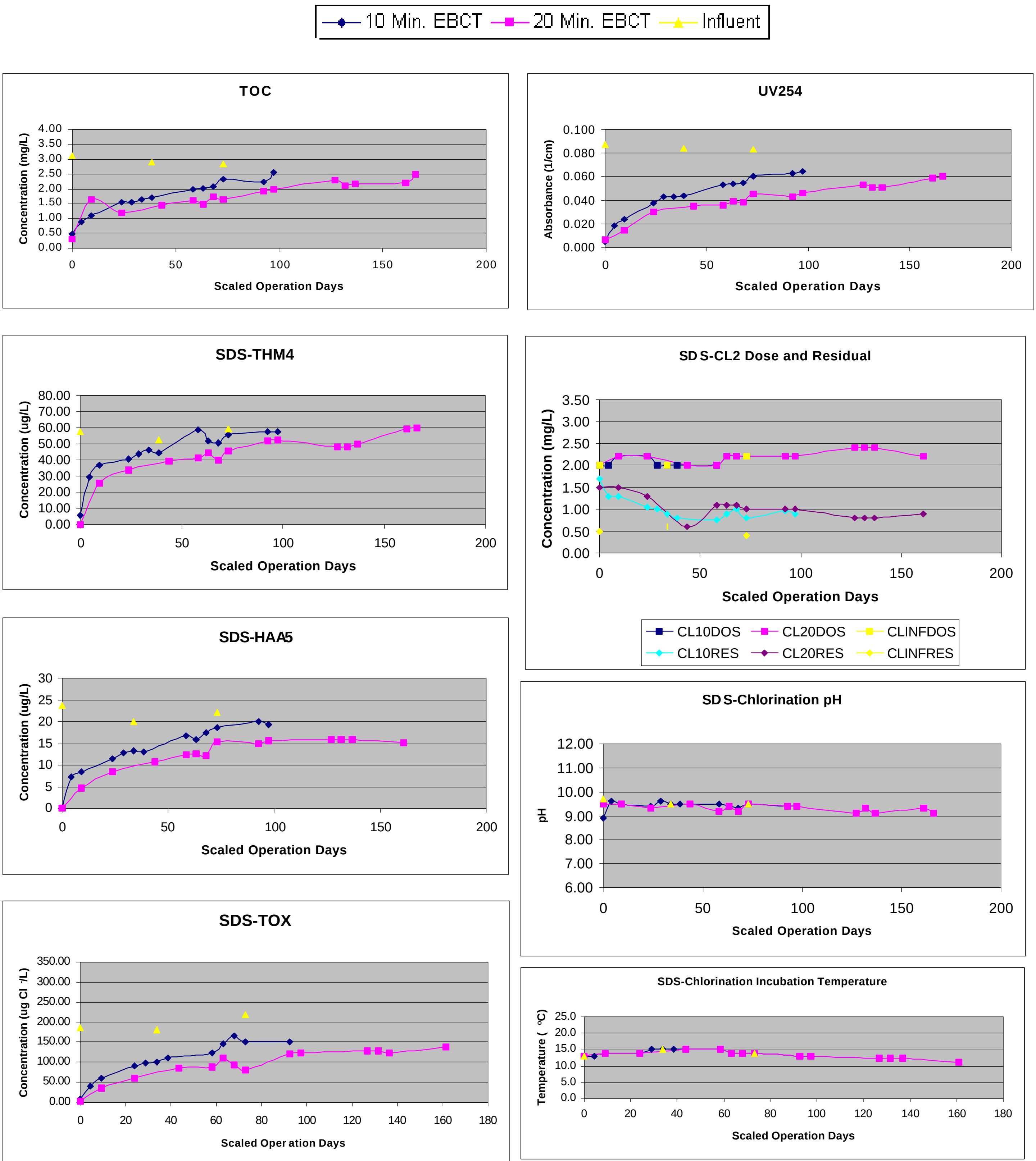






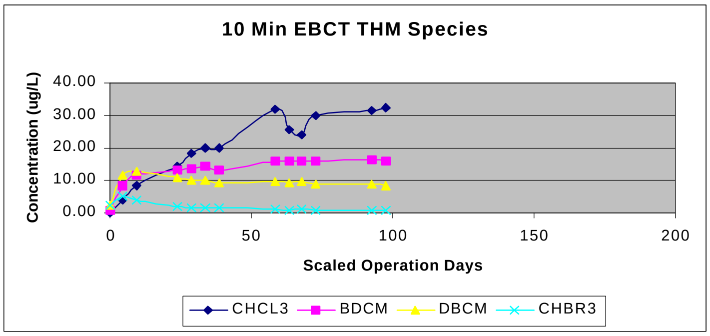


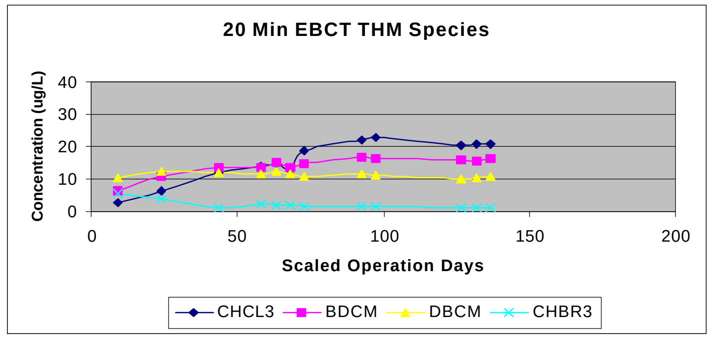
4th Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

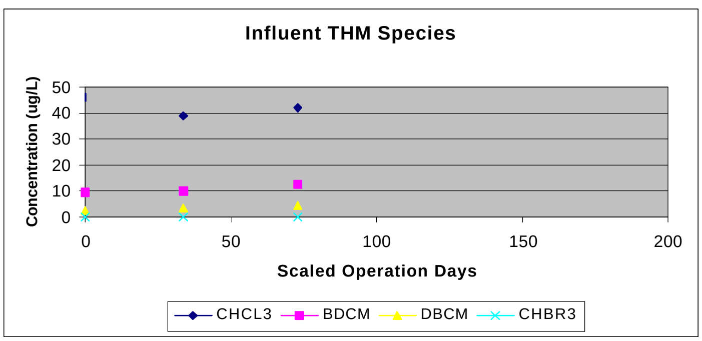


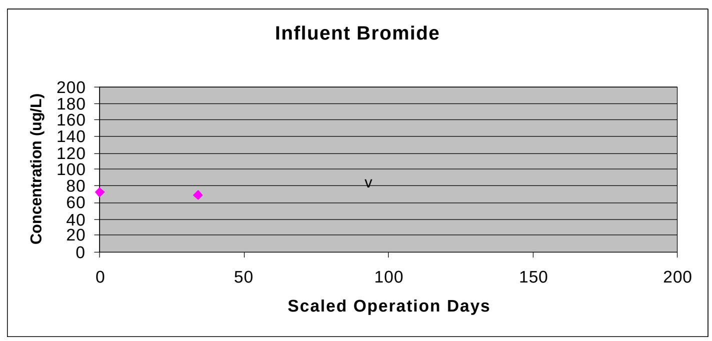
4th Quarter
Precursor and D/DBP Results
Bench-Scale RSSCT Treatment Study

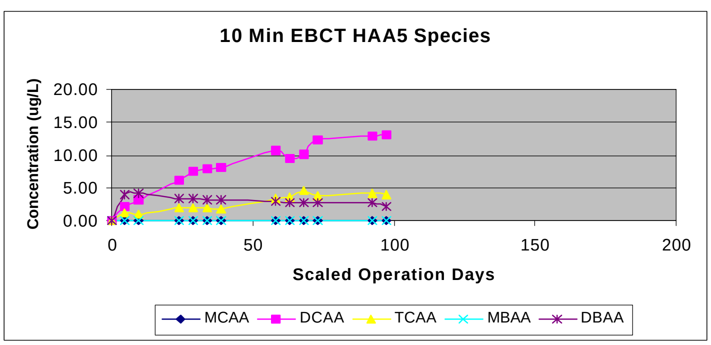
10 Min. EBCT 20 Min. EBCT Influent

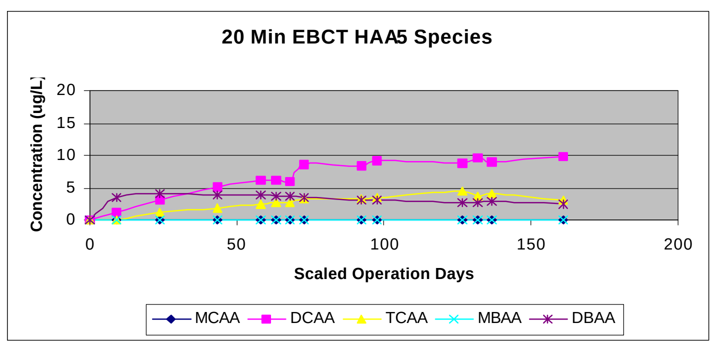


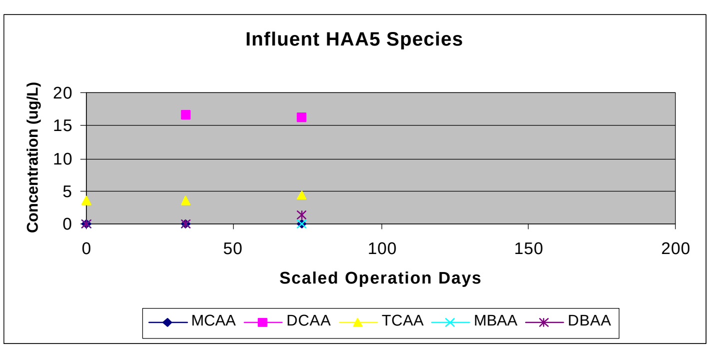












Breakthrough Levels Defined by THM4 and HAA5 Levels

In Tables 4.3 and 4.4 breakthrough levels defined by exceeding various levels of THM4 and HAA5 values are tabulated. The current THM maximum contaminant level (MCL) is 100 ug/L. The upcoming Stage 1 D/DBP Rule has THM4 and HAA5 MCLs set at 80 ug/L and 60 ug/, respectively. The projected Stage 2 D/DBP Rule has The THM MCL at 40 and the HAA MCL at 30. Break through levels were set at values 10% below MCL levels. At the bottom of each table are the SDS levels for column effluent water which is given for reference.

Neither effluent sample nor the influent water SDS sample exceeded an HAA5 level of 27 ug/L.

Neither effluent sample nor the influent water SDS sample exceeded an THM4 level of 72 ug/L. Three 10 minute EBCT quarterly runs, one 20 minute EBCT quarterly run, and one influent water quarterly run exceeded the THM4 level of 54 ug/L.

Three 10 minute EBCT quarterly runs, three 20 minute EBCT quarterly runs, and three influent water quarterly runs exceeded the THM4 level of 36 ug/L The runs associated with low run times produced the higher brominated THMs. This suggests that the use of GAC to lower TOC levels may prove counter productive when ambient bromide levels are elevated.

Table 4.3 Value of Listed Parameter When Breakthrough Criterion is Met

First Quarter 10 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	69	9891	2.27	58.5	15	-	132
SDS-THM4 = 36 ug/L	53	7680	2.05	53	14.05	-	160.5
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			3.14	43.7	15.7		141

Second Quarter 10 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	-	-	-	-	-	-	-
SDS-THM4 = 36 ug/L	-	-	-	-	-	-	-
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			3.32	26.3	17.7		191

Third Quarter 10 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	19.8	2849	1.29	69.7	12.1	-	62.4
SDS-THM4 = 36 ug/L	10	1439	1.13	40.5	11.1	-	56.5
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			2.64	41.5	22.1		111

Fourth Quarter 10 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	58.2	8378	1.99	59	16.8	-	124.15
SDS-THM4 = 36 ug/L	9.23	1329	1.1	36.74	8.3	-	61.1
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			2.95	56.4	21.9		196

Table Value of Listed Parameter When Breakthrough Criterion is Met

First Quarter 20 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	-	-	-	-	-	-	-
SDS-THM4 = 36 ug/L	53.4	3840	1.39	44.7	9.9	-	N/A
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			3.07	32.8	15.7		151

Second Quarter 20 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	-	-	-	-	-	-	-
SDS-THM4 = 36 ug/L	-	-	-	-	-	-	-
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			3.29	26.9	19.0		215

Third Quarter 20 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	34.5	2481	1.32	63.28	13.6	-	54.65
SDS-THM4 = 36 ug/L	34.5	2481	1.32	63.28	13.6	-	54.65
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			2.69	45.7	22.4		137

Fourth Quarter 20 Minute EBCT Column

Break through criterion	Run Time (days)	Throughput (Bed Vol.)	TOC (ug/L)	SDS-THM4 (ug/L)	SDS-HAA5 (ug/L)	SDS-HAA6 (ug/L)	SDS-TOX (ug CL/L)
SDS-THM4 = 90 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 72 ug/L	-	-	-	-	-	-	-
SDS-THM4 = 54 ug/l	-	-	-	-	-	-	-
SDS-THM4 = 36 ug/L	43.6	3131	1.44	39.1	10.8	-	85.2
SDS-HAA5 = 54 ug/l	-	-	-	-	-	-	-
SDS-HAA5 = 27 ug/L	-	-	-	-	-	-	-
Influent Avg. Values			2.95	56.4	21.9		196

Impact of Seasonal Variability

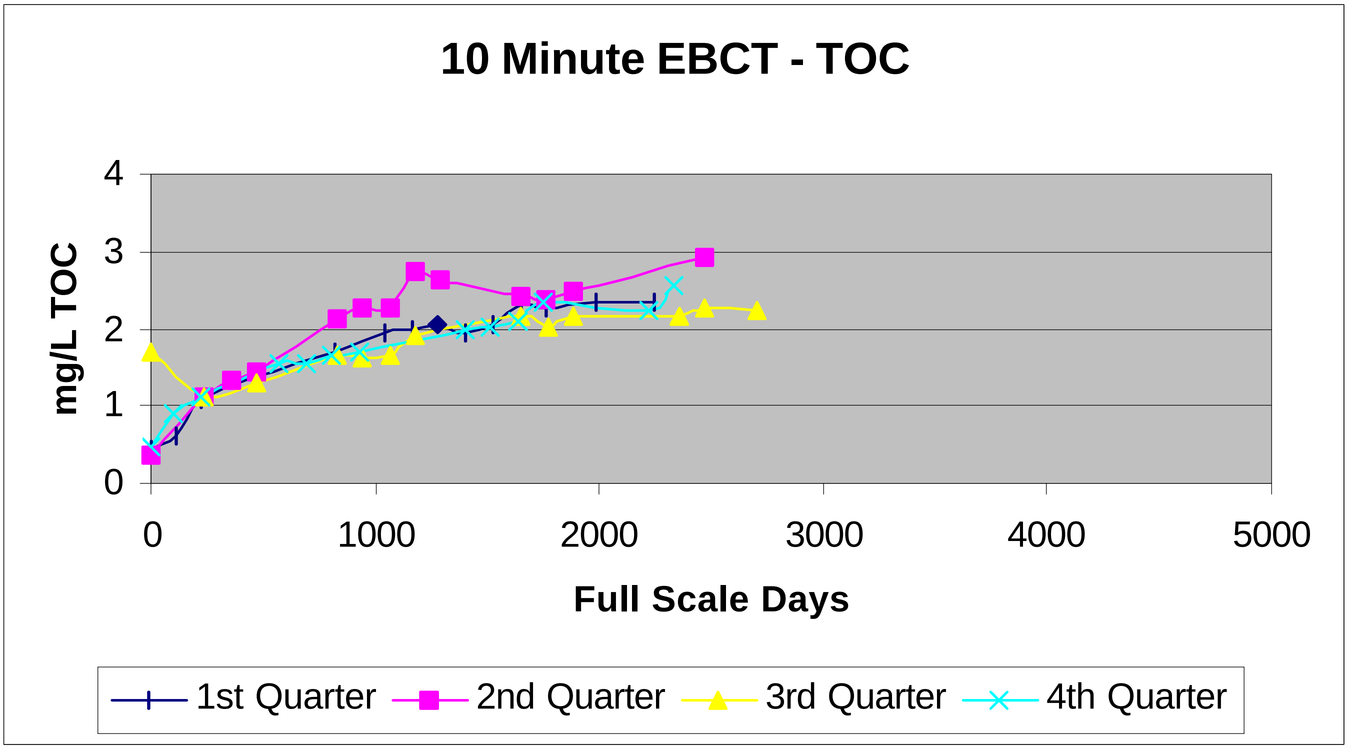
Seasonal variation in the TOC removal with the 10 and 20 EBCTminute bed GAC columns was minimal. This is illustrated by the overlay of the four seasonal runs for both columns on page 36. The second quarter (spring) TOC levels run slightly above others. The influent TOC levels were slightly higher in that spring run.

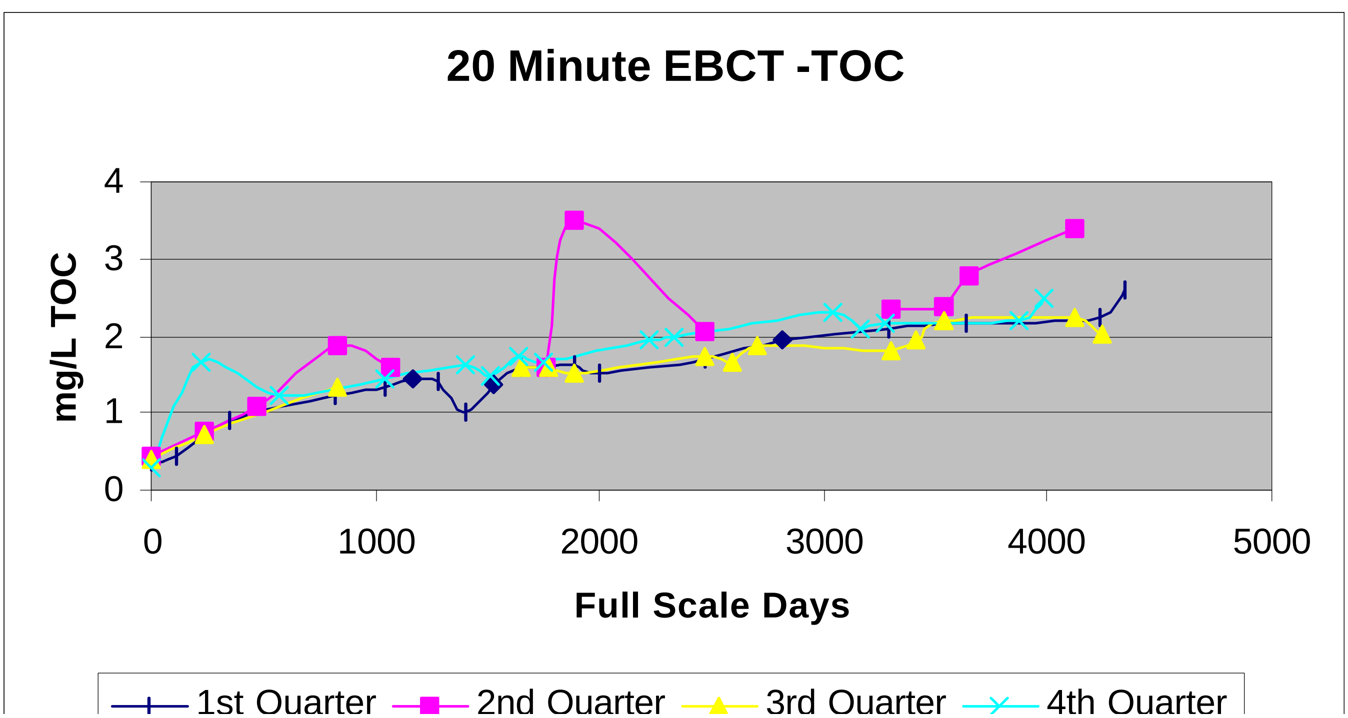
Seasonal variation in THM4 formation in SDS samples is notable and illustrated on page 37. The third quarter (autumn) run exhibits higher THM4 levels for both columns. This is primarily attributed to the higher levels of brominated THMs.

Seasonal variation in the HAA5 formation in SDS samples is also notable to lesser extent than THMs and this is illustrated on page 38. The third quarter (autumn) run exhibits higher HAA5 levels for both columns. This is primarily attributed to the higher levels of brominated HAAs.

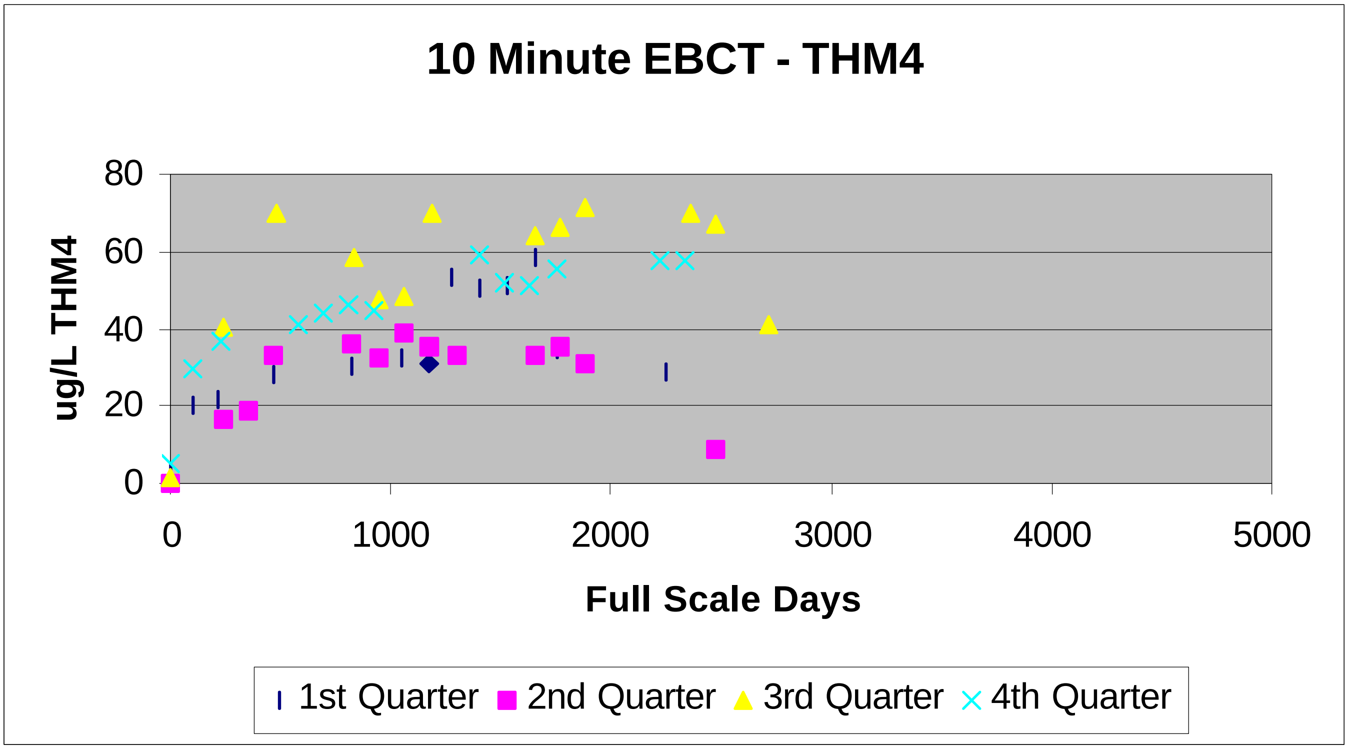
There appears to have been four major parameters in the four RSSCT runs that appear to affect the production of THMs and HAAs. Those parameters are TOC levels, bromide levels, and chlorination pH, and incubation temperature.

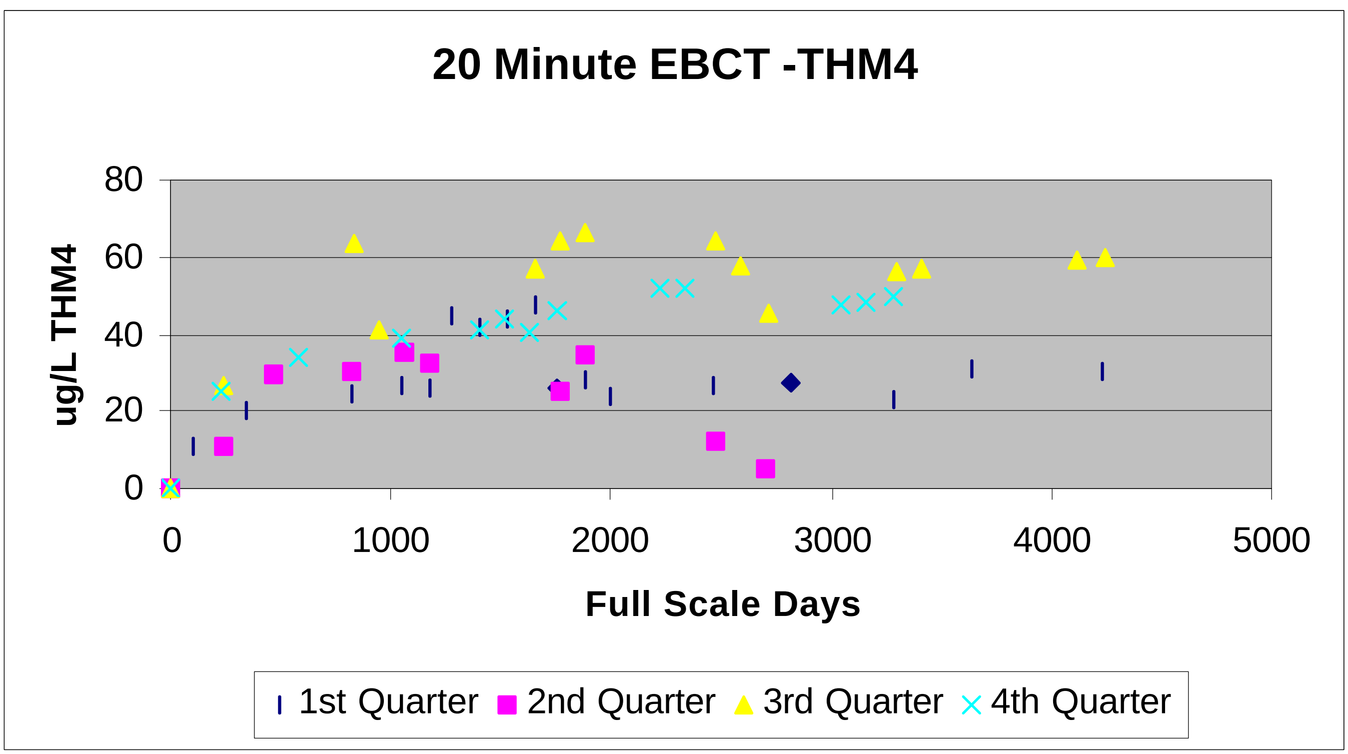
Seasonal Variability in Effluent TOC



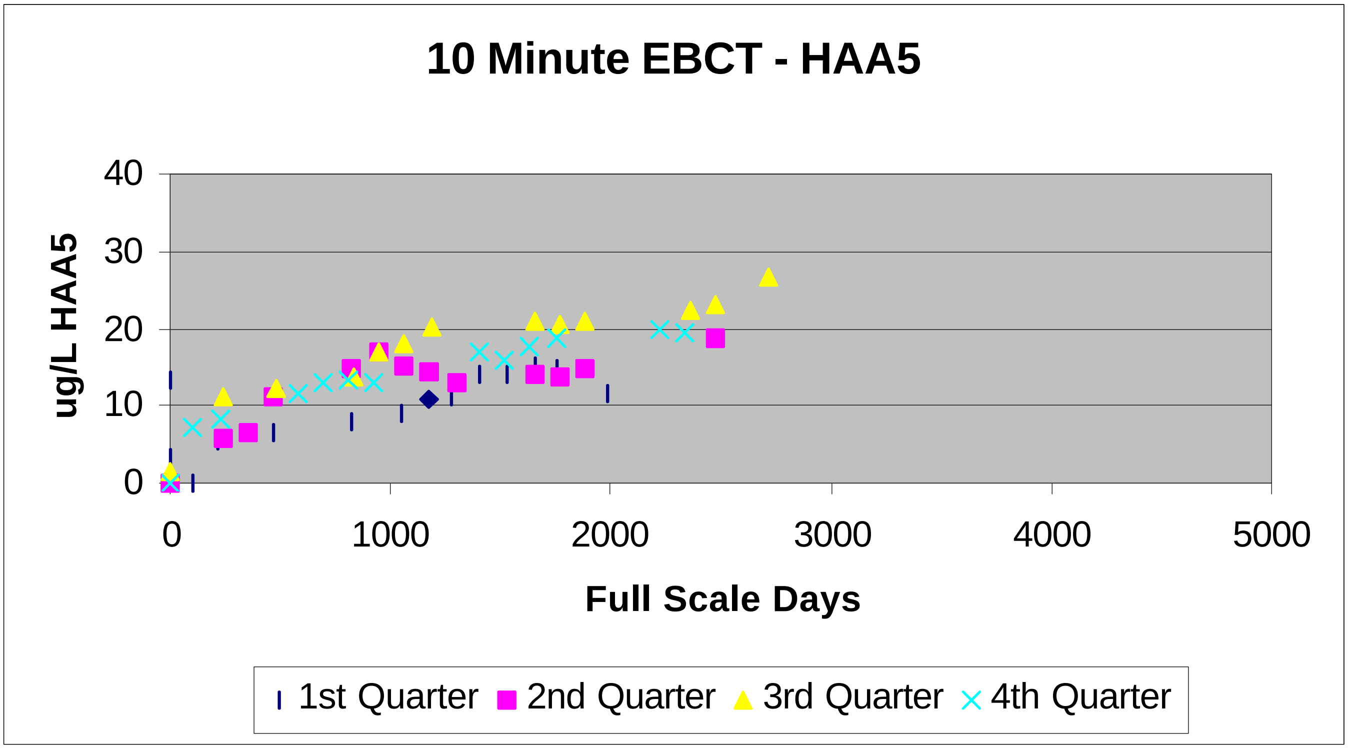


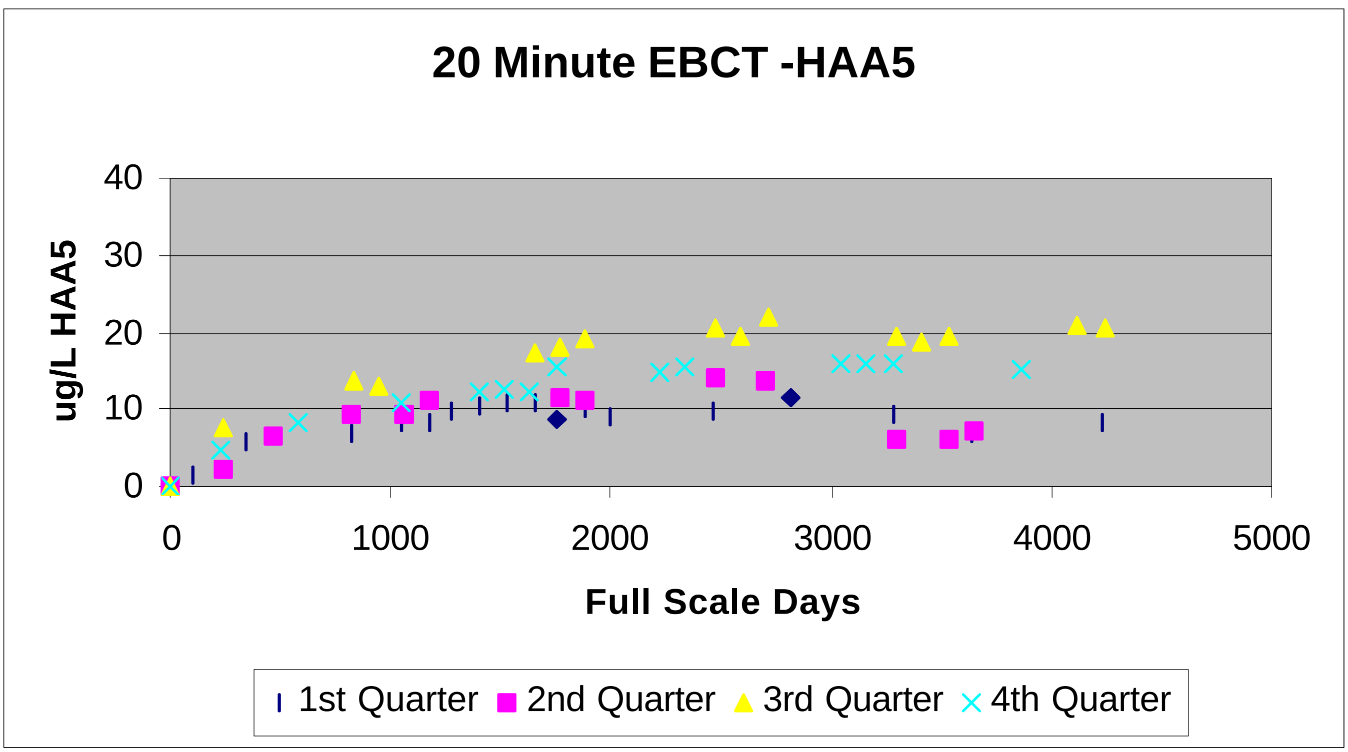
Seasonal Variability in Effluent SDS THM4





Seasonal Variability in Effluent SDS HAA5





Summary of Significant Results

1. GAC beds can be utilized to lower TOC levels consistently through seasonal variations.

2. The combination of low TOC levels and higher bromide levels shifts the production of both THMs and
HAAs from chlorinated species to brominated species.

3. Low TOC levels produced from the GAC beds and high ambient bromide levels together can elevate THMs higher than water which was not pretreated through the GAC beds. This may negatively impact the run time for GAC beds installed for the goal of meeting lower THM MCLs during periods when ambient bromide levels are high.

References

1. SUMMERS, R.S. ET AL. Effect of Separation Process on the Formation of Brominated THMs. *Jour. AWWA*, 85:1:88 (Jan. 1993)

2. SYMONS, J.M. ET AL. Measurement of THM and Precursor Concentrations Revisited - The Effect of Bromide Ion. *Jour. AWWA*, 85:1:51 (Jan. 1993)

3. POURMOGHADDAS, H. Effect of Bromide Ion on Formation of HAAs During Chlorination. *Jour. AWWA*, 85:1:82 (Jan. 1993)

RAPID SMALL-SCALE COLUMN TEST KITS

Model ICR-10/20

This rapid small-scale column test (RSSCT) kit is designed to meet the requirements specified in the *ICR Manual for Bench and Pilot-Scale Treatment Studies* (EPA 814-B-96-003). Effluent produced from this kit simulates the performance of full scale granular activated carbon (GAC) systems with 10 and 20 minutes of empty bed contact time (EBCT). The kit contains two separate minicolumn and pump assemblies designed to operate in parallel drawing from the same source water. The assemblies come mounted on the support base. Customer assembly is simple and can be accomplished with a pair of adjustable wrenches. The pumps are 120 volt single phase. Ten feet of influent and effluent 1/4" tubing are standard; other lengths upon request.

Kit contents:
- Pumps (2), positive displacement, adjustable speed with indication.
- Minicolumns (2), one for 10 minute EBCT and one for 20 minute EBCT.
- Pulsation dampener (2).
- Pressure indication (2).
- Pressure relief valves (2).
- Manual air release feature (2).
- Interconnecting tubing and fittings.
- Aluminum support base with rods (3) and clamps (4).
- Influent and effluent tubing with terminal fittings (2 sets).
- Valves for isolation, back-pressure, and sampling (optional).
- Assembly instructions.
- Operating instructions.

PROCESS OPTIMIZATION SERVICES

Key Assumptions

The Model ICR-10/20 RSSCT (Rapid Small-Scale Column Test) kit is designed to meet the requirements specified in the ***ICR Manual for Bench and Pilot-Scale Treatment Studies (EPA 814-b-96-003).*** This kit has been designed based on the equations published in the ICR documents.

The scaling equations used for this RSSCT design have been developed based on dimensional analysis to maintain similitude to the full scale GAC system. The equations, published in the document above as well as the manual entitled ***ICR Treatment Studies Data Collection Spreadsheets User's Guide (EPA 815-B-97-002),*** assume that intraparticle diffusivity varies with particle size (i.e., proportional diffusivity). The Model ICR-10/20 kit has been designed based on the equations published in the ICR documents and therefore reflect a proportional diffusivity approach. The proportional diffusivity approach may or may not be applicable to other contaminant matrices so care should be exercised in utilizing the kit provided (with operational parameters stated herein) in other situations. The user that wishes to learn more about RSSCT design assumptions is encouraged to seek out the references cited in the ICR publications.

The Model ICR-10/20 RSSCT kit is not equipped with a filtration device to protect against excessive headloss build-up due to the presence of turbidity/suspended solids. Accordingly, pretreatment of the water, either on a batch or continuous basis, is the responsibility of the user. The user is encouraged to refer to page 2-12 of the ***ICR Manual for Bench and Pilot-Scale Treatment Studies (EPA 814-b-96-003)*** for guidance on acceptable filtration methods prior to RSSCT studies.

The full size carbon crushed for use in the Model ICR-10/20 RSSCT kit has been prepared to minimize headloss buildup by the use of an elutration sieve washing procedure. This method physically restrains the desired particle sizes while allowing undesirable smaller particles contributing to excessive headloss build-up to float away. This methodology is employed to avoid high headloss conditions associated with small RSSCT column diameters containing small mesh size carbons.