ICR Treatment Study Summary Report

Evaluation of Granular Activated Carbon Using Pilot Scale Testing for Compliance with the Information Collection Rule

Conducted during the period April 29, 1998 to November 18, 1998

Prepared by:

Charlotte Smith & Associates, Inc.
PO Box 629
Orinda, California 94563
(925) 377-1891

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For:

Northwest Potable Water Treatment Plant
Hillsborough County Water Department
925 Twiggs Street Road
Tampa, Florida 33602-3553
(813) 272-5977
(813) 272-5589

Attachments:
1 diskette containing the *ICR Treatment Study Data Collection Spreadsheets*, the *ICR Treatment Study Summary Report Spreadsheets and this report*

ICR Treatment Study Summary Report

Hillsborough County Water Department

Summary

According to the requirements of the Information Collection Rule, a pilot-scale GAC study was conducted for the Hillsborough County. The purpose of the study was to evaluate the reduction in disinfection by-product precursors and simulated disinfection by-products afforded by GAC filtration over time. The pilot plant was identical to the one built for Pasco County Utilities. In that study, the Utilities Laboratory conducted 2 weeks of TOC monitoring, from the influent and 10 minute and 20 minute EBCT effluent taps, before media was installed in the filters. The purpose of this preliminary study was to demonstrate that the pilot plant materials do not contribute organic carbon to the water.

Based on the findings from the Pasco County study, UV disinfection was implemented at the onset of the first run. The plant effluent TOC concentration was 50% of the influent concentration after 29 days in the first run. A second UV disinfection unit was installed in series for the second run. In the second run, the plant effluent TOC concentration reached 50% of the influent concentration also after 29 days.

The pilot study demonstrated that GAC filtration is not viable without significant pretreatment. Future efforts of the County to control disinfection by-products should involve a treatablity study aimed at simultaneous control of sulfide and organic carbon. Alternative disinfection (i.e. chloramines) will likely lead to continued regulatory compliance in the short-term.

Background

The existing Northwest Potable Water Treatment Plant, receives untreated groundwater from the West Coast Regional Water Supply Authority. At the plant the water is pumped to slat tray aerators for the removal of hydrogen sulfide. After the water cascades over the aerators, chlorine is added for disinfection. The water is then held on site for storage and to ensure adequate distribution system pressure. A schematic of the Treatment Plant is shown as Figure 1.

FULL SCALE SCHEMATIC DIAGRAM
HILLSBOROUGH COUNTY WATER DEPARTMENT

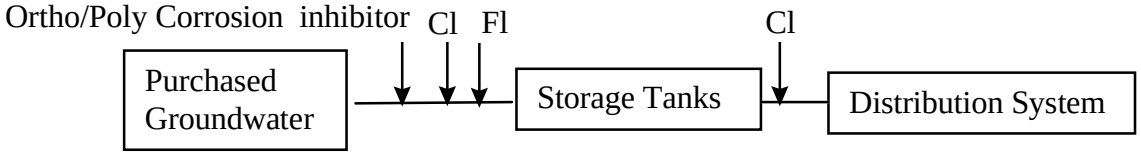

Figure 1

The utility obtained to services of Charlotte Smith & Associates, Inc. to design, construct and supervise the operation of a pilot scale GAC filter plant for compliance with the Information Collection Rule. Camp Dresser & McKee, Inc. collected samples and monitored the flow rate and pressure guages. CDM also maintained the pilot by cleaning the UV lamp on a regular basis. Figure 2 shows the field engineer cleaning the UV bulb using CLR™, a household solvent designed to dissolve calcium and iron deposits. Field notes were kept to document these monitored values, the frequency of lamp maintenance and any other unusual observations in the field. The field notes are contained in Appendix 1.

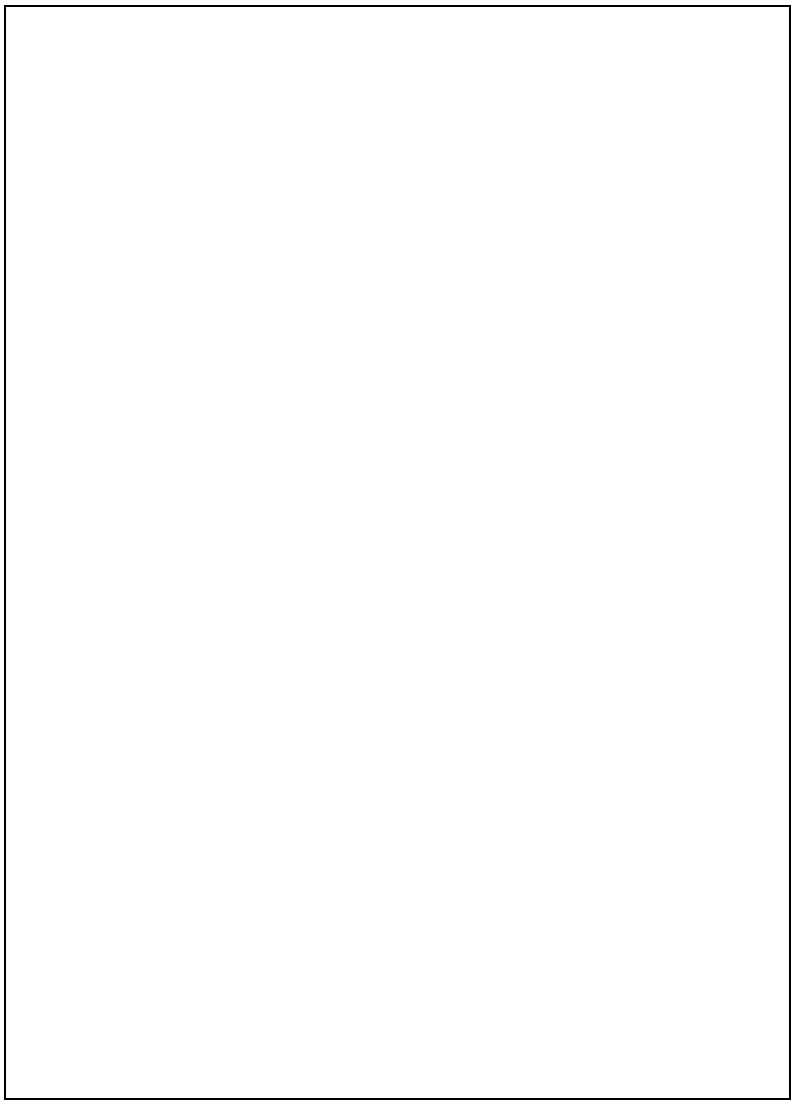

Figure 2: Juan Mercado, P.E. cleaning a UV light bulb.

Materials & Methods

Description of the Pilot Plant

The pilot plant was constructed of CPVC. CPVC was used rather than PVC due to the presence of hydrogen sulfide in the source water. The GAC pilot columns were 5.75 inch ID, and 8 feet high. All joints and connections were thermo-welded, threaded, or flanged with Teflon gaskets. No glue or solvents were employed in the construction of the pilot plant. Flow was controlled using a Kates™ flow rate controller for precise control.

The pilot plant obtained water from the same inlet pipe which feeds water to the existing plant. Water in the existing plant is chlorinated before distribution to the consumers. Additionally, fluoride and a poly/orthophosphate blended product for corrosion control are added Discussions with USEPA led to the conclusion that the best location for the pilot plant was directly off of the raw water inlet tap.

A check valve was placed at the inlet tap. Sample taps were located at the inlet, after the 10 minute EBCT column and after the 20 minute EBCT column. Water flows through ¾ inch CPVC and valves which can be closed to allow for backwash. A by-pass valve between the two pilot columns

allows for independent backwashing of the columns. The valves have EPDM seals. Unions have EPDM o-rings and the water meters have teflon washers. The flow rate controller is made of 316 stainless steel with teflon seals. The pilot plant is pictured in Figure 3. Figure 4 is a schematic diagram of the pilot plant.

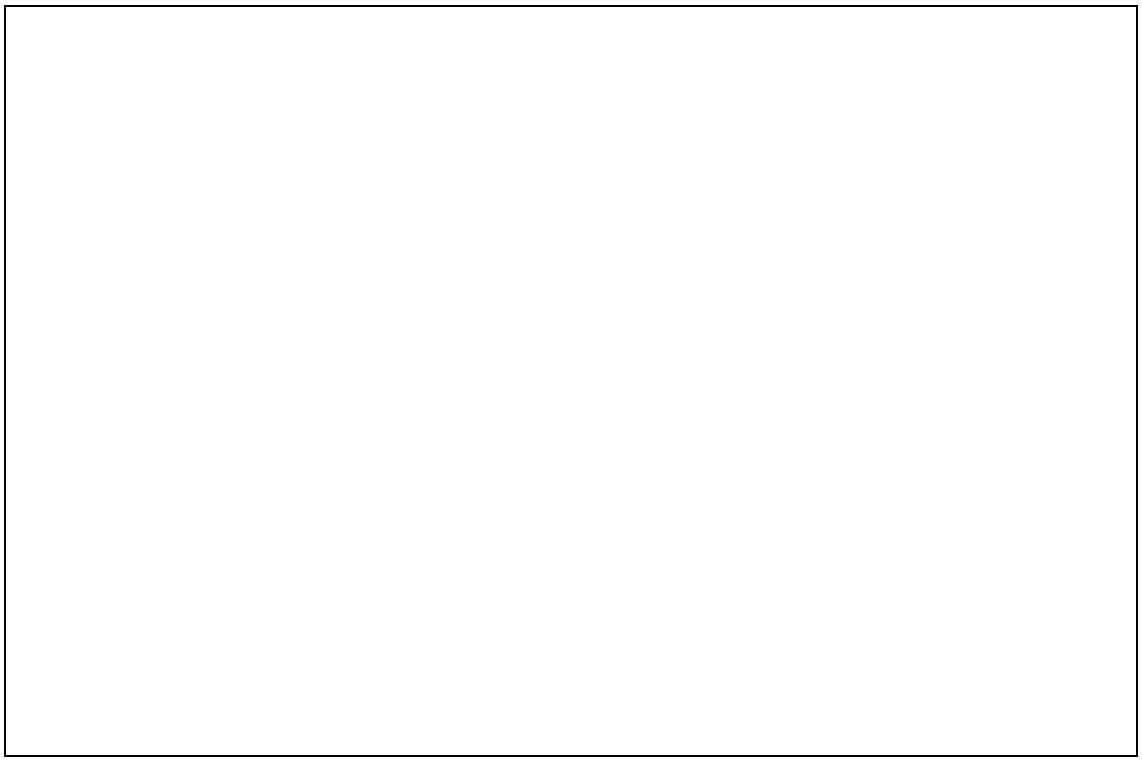

Figure 3: Pilot plant

A Trojan Advantage 5™ ultraviolet light was installed in an effort to limit the inoculation of the GAC filters by microbes present in the source water. This unit has a rated dose of 22,000 uW•sec/cm^2. For the second run a second (identical) UV system was installed in series to double the dose.

Start-up and Operation

The identical Pasco County pilot plant operated without GAC for two weeks to demonstrate that the materials in the pilot plant do not contribute organic carbon to the process stream. The following TOC data from that study indicates that equivalent TOC values exist for the influent, 10 minute EBCT effluent, and 20 minute EBCT effluent:

PILOT PLANT TOC DATA

DATE:	10/27/97		10/28/97		10/29/97		10/30/97		10/31/97	
	Init.	Dup.	Init.	Dup.	Init.	Dup.	Init.	Dup.	Init.	Dup.
INFLUENT	3.7	3.5	3.7	3.5	3.6	3.5	3.6	3.6	3.6	3.5
10 MINUTE EBCT EFFLUENT	3.6	3.7	3.7	3.6	3.8	3.4	3.8	3.8	3.8	3.7
20 MINUTE EBCT EFFLUENT	3.7	3.5	3.6	3.6	4.0	3.9	3.6	3.6	3.8	3.8

PILOT PLANT SCHEMATIC DIAGRAM
HILLSBOROUGH COUNTY WATER DEPARTMENT

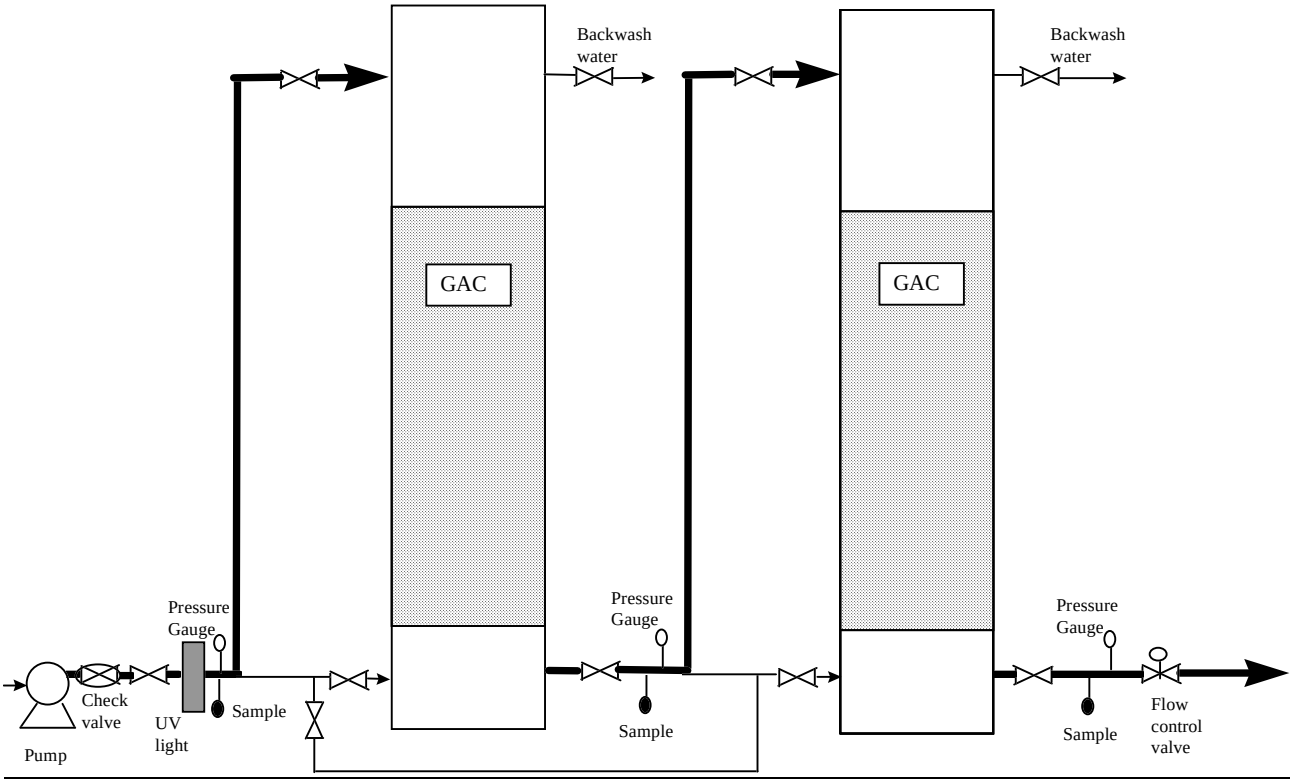

Figure 4

Operating Conditions

The GAC depth was calculated to achieve an empty bed contact time of 10 minutes and 20 minutes. Calgon Filtrasorb™, which is bituminous GAC was used as the media. This media is 8 by 16 US standard mesh. The plant was operated at 3 gpm/ft^2. Additional information is contained in the *Treatment Study Spreadsheets*.

Due to the large size of the media, headloss did not significantly increase over the course of the study. The UV lamp was examined on a regular basis. CLR™, a household solvent designed to dissolve calcium and iron deposits was used to clean the lamp. Field notes were kept to document these monitored values, the frequency of lamp maintenance and other observations.

Monitoring Plan

According to the requirements of the ICR, samples were taken from each sample tap for the following parameters. Three duplicate samples from each tap were also taken.

INFLUENT	GAC EFFLUENT @ 10 MINUTE EBCT	GAC EFFLUENT @ 20 MINUTE EBCT
pH	pH	pH
alkalinity	alkalinity	alkalinity
turbidity	turbidity	turbidity
temperature	temperature	temperature
total hardness	total hardness	total hardness
calcium hardness	calcium hardness	calcium hardness
ammonia	ammonia	ammonia
bromide		
total organic carbon	total organic carbon	total organic carbon
UV-254	UV-254	UV-254
trihalomethanes[1]	trihalomethanes[1]	trihalomethanes[1]
haloacetic acids[2]	haloacetic acids[2]	haloacetic acids[2]
total organic halides	total organic halides	total organic halides
chlorine demand	chlorine demand	chlorine demand

From: Table 4-0 of the ICR Manual for Bench- and Pilot-Scale Treatment Studies (EPA 814-B-96-003).

Notes: [1] CHCl3, CHBrCl2, CHBr2Cl, CHBr3

[2] MCAA, DCAA, TCAA, MBAA, DBAA, BCAA

Sample analysis

Water samples were collected according to Standard Methods by CDM. The Utility's Laboratory analyzed the samples, and prepared a split sample for SDS studies. For the SDS studies, duplicate samples were spiked with chlorine to obtain target residual levels. Temperature was maintained by placing the samples in a calibrated incubator. The following table indicates the target SDS conditions:

TARGET SDS CONDITIONS

PARAMETER	VALUE
Chlorine residual	0.5 -1.5 mg/L
Temperature	26-28 ^{o}C
Time	24 hours
pH	7.4 - 7.6

Quality Assurance/Quality Control

The study included 3 sets of field duplicates. Laboratory quality control data is contained in the *ICR Treatment Study Summary Report Spreadsheets*, (attached on diskette). During this study the laboratory was also fulfilling the requirements of the 18 month ICR monitoring and sample analysis, including performance evaluation (PE) tests.

Results

Seasonal Variability

Both Hillsborough County and Pasco County obtain water from the West Coast Regional Water Supply Association. The following TOC data from the Pasco study are provided to shows that there is no seasonal variability in the source water. These data were previously sent to the USEPA and it was agreed that analysis of seasonal variability was not required for this utility.

Month and Year	TOC (mg/L)
October 1996	3.5
November 1996	3.4
December 1996	3.2
January 1997	4.4
February 1997	3.4
March 1997	3.6
April 1997	3.6
May 1997	4.1
June 1997	4.0
July 1997	3.4
August 1997	3.4
September 1997	3.8

Full Scale Data

The full scale water quality for relevant parameters are shown below. These data were extracted from the 18 month ICR Water Utility Database which covers the period July 1997 to December 1998.

Full-Scale Influent Water Quality Data						
Item	**Units**	**Average**	**Std Dev**	**Min**	**Max**	**Count**
Temperature	C	24.5	2.2	21.0	29.7	18
pH	Unit	7.3	0.3	6.6	7.6	18
Turbidity	ntu	0.3	0.2	0.1	0.7	18
Alkalinity	mg/L as $CaCO_3$	195.7	9.3	184.0	214.0	18
Total Hardness	mg/L as $CaCO_3$	207.5	13.6	196.0	253.0	18
Calcium Hardness	mg/L as $CaCO_3$	178.7	8.1	166.0	195.0	18
TOC	mg/L	3.0	0.2	2.7	3.3	18
UV_{254}	1/cm	0.1	0.0	0.1	0.1	18
Bromide	µg/L	3.5	1.3	1.4	6.8	18
TSUVA*	L/(mg*m)	3.3	0.3	2.8	3.9	18

Full-Scale Finished Water Quality Data						
Item	**Units**	**Average**	**Std Dev**	**Min**	**Max**	**Count**
Temperature	C	24.5	0.9	22.1	26.1	18
pH	unit	7.3	0.2	6.8	7.6	18
Turbidity	ntu	0.2	0.2	0.0	0.9	18
TOC	mg/L	2.9	0.1	2.7	3.2	18
UV_{254}	1/cm	0.1	0.2	0.1	0.8	18
DS-THM4	µg/L	70.2	7.8	57.0	86.7	24
DS-HAA6	µg/L	75.4	16.0	47.4	103.9	24

Pilot Study Run #1

The first run was initiated on April 27, 1998 and terminated on August 18, 1998. A total of 17 sets of samples (with three field duplicates) were taken. The two extra sets were taken to make up for DBP data missing from the database. Data were input to the *Treatment Study Spreadsheets* which are included with the submission of this report on diskette. The following tables summarize the DBP precursors and DBP results of the study for Run #1:

INFLUENT WATER QUALITY	**TOC mg/L**	**pH**	**UV_{254} 1/cm**	**SUVA L/(mg*m)**	**Bromide ug/L**	**SDS TOX mg/L**	**SDS THM4 mg/L**	**SDS HAA5 mg/L**	**SDS HAA6 mg/L**
Mean	3.0	7.5	0.1	3.1	4.3	325.8	81.6	62.5	66.2
Standard Deviation	0.2	0.1	0.0	0.1	1.6	68.7	18.0	28.0	29.3
Count	17	16	17	17	16	12	15	15	15
Minimum	2.8	7.3	0.1	2.8	0.0	260.0	30.5	0.0	0.0
Maximum	3.5	7.7	0.1	3.4	0.1	520.0	98.9	106.2	111.5

10 Min Effluent WATER QUALITY	**TOC mg/L**	**pH**	**UV_{254} 1/cm**	**SUVA L/(mg*m)**	**SDS TOX mg/L**	**SDS THM4 mg/L**	**SDS HAA5 mg/L**	**SDS HAA6 mg/L**
Mean	2.7	7.5	0.1	2.8	335.8	61.9	47.4	50.6
Standard Deviation	0.6	0.1	0.0	0.2	215.6	27.0	33.1	34.8
Count	15	15	17	15	15	16	17	17
Minimum	1.0	7.3	0.0	2.4	27.0	1.2	0.0	0.0
Maximum	3.5	7.6	0.1	3.3	730.0	87.7	98.7	102.0

20 Min Effluent WATER QUALITY	**TOC mg/L**	**pH**	**UV_{254} 1/cm**	**SUVA L/(mg*m)**	**SDS TOX mg/L**	**SDS THM4 mg/L**	**SDS HAA5 mg/L**	**SDS HAA6 mg/L**
Mean	1.8	7.5	0.0	2.8	233.5	42.2	33.8	37.0
Standard Deviation	0.5	0.1	0.0	0.5	156.6	24.4	19.2	20.8
Count	15	15	17	15	13	16	17	17
Minimum	0.5	7.3	0.0	1.5	65.0	1.1	0.0	0.0
Maximum	2.4	7.7	0.1	3.5	580.0	68.8	67.5	73.1

Ammonia & Bromide

Figures 5 & 6 show the ammonia and bromide levels at the samples taps during the first run. Although there is some fluctuation in the ammonia concentration, it is unlikely that this variation contributed enough disinfectant demand to explain fluctuations in the DBP results. Bromide values ranged from 2.1 to 6.9 ug/L, which explains the low concentration of brominated by-products.

TOC

Figure 7 shows the TOC concentrations at the influent, and after 10 and 20 minute EBCT columns. Influent water TOC varied from 2.8 to 3.5 mg/L. Figure 8 shows the breakthrough of organic carbon during the run. In the first run, organic carbon broke through the 10 minute column (at 70%) after just 696 hours (29 days) and in the 20 minute column (at the 70% level), after 1872 hours (78 days). According to the formulas provided by the USEPA the expected filter run time to reach 50% breakthrough, given the source water TOC concentration was 4596 hours. Fifty percent breakthrough occurred in the 20 minute column at 1586 hours (66 days).

UV-254

A surrogate parameter for organic carbon is UV-254. The results of the influent, 10 and 20 minute EBCT effluents' UV-254 values are shown it Figure 9. Influent UV-254 values ranged from 0.089 to 0.105 cm^{-1}, and follow the same general pattern as the TOC data.

SDS Conditions

Figure 10 shows the SDS chlorine dose and residual concentrations. Figures 11 and 12 show the SDS pH and temperature conditions. As depicted in these graphics and the following tables, the target conditions were generally met. If target conditions could not achieved the sample was not analyzed for disinfection by-products. This happened once during the study. To compensate, an extra set of samples were collected and analyzed. As expected, the mean disinfectant demand is lowest in the 20 minute EBCT column.

INFLUENT WATER QUALITY	**Cl dose mg/L**	**Cl residual mg/L**	**Cl2 demand mg/L**	**SDS temp. °C**	**SDS pH**	**incubation time (hr)**
Mean	9.5	1.5	8.1	27.7	7.5	24.1
Standard Deviation	0.7	0.6	1.1	2.0	0.2	0.5
Count	16	15	16	16	15	15
Minimum	8.5	0.1	7.0	24.5	7.0	24.0
Maximum	10.7	2.6	10.7	30.3	7.7	26.0

10 Min Effluent WATER QUALITY	**Cl dose mg/L**	**Cl residual mg/L**	**Cl2 demand mg/L**	**SDS temp. °C**	**SDS pH**	**incubation time (hr)**
Mean	7.5	1.6	5.9	27.4	7.5	24.1
Standard Deviation	2.5	0.3	2.3	1.9	0.2	0.5
Count	16	16	16	16	16	16
Minimum	1.7	1.2	0.4	24.5	7.0	24.0
Maximum	9.5	2.4	7.7	30.0	7.7	26.0

20 Min Effluent WATER QUALITY	Cl dose mg/L	Cl residual mg/L	Cl2 demand mg/L	SDS temp. °C	SDS pH	incubation time (hr)
Mean	6.7	1.6	5.1	27.7	7.5	24.1
Standard Deviation	2.2	0.5	2.1	2.0	0.2	0.5
Count	16	16	16	16	16	16
Minimum	1.7	0.4	0.4	24.5	7.0	24.0
Maximum	9.0	2.5	7.2	30.3	7.7	26.0

SDS-DBP

Figure 13 illustrates the TOX values produced from influent and effluent samples. Figures 14 and 15 show the SDS-THM4, and SDS-HAA6 results. The DBP data is consistent with the TOC and UV-254 data. As precursor (organic carbon) concentrations increased, DBP concentrations increased. For the most part, fluctuations in DBP levels are consistent with observed fluctuations in precursor concentrations. DBP concentrations reached a steady state in the second half of the study.

THM Species

Figures 16, 17, and 18 show the individual THM species for the influent, 10 and 20 minute effluent samples respectively. As expected, chloroform is the predominant constituent.

HAA Species

Figures 19, 20, and 21 illustrate the individual HAA species. Trichloracetic acid and dichloracetic acid constitute the majority of the haloacetic acid formation.

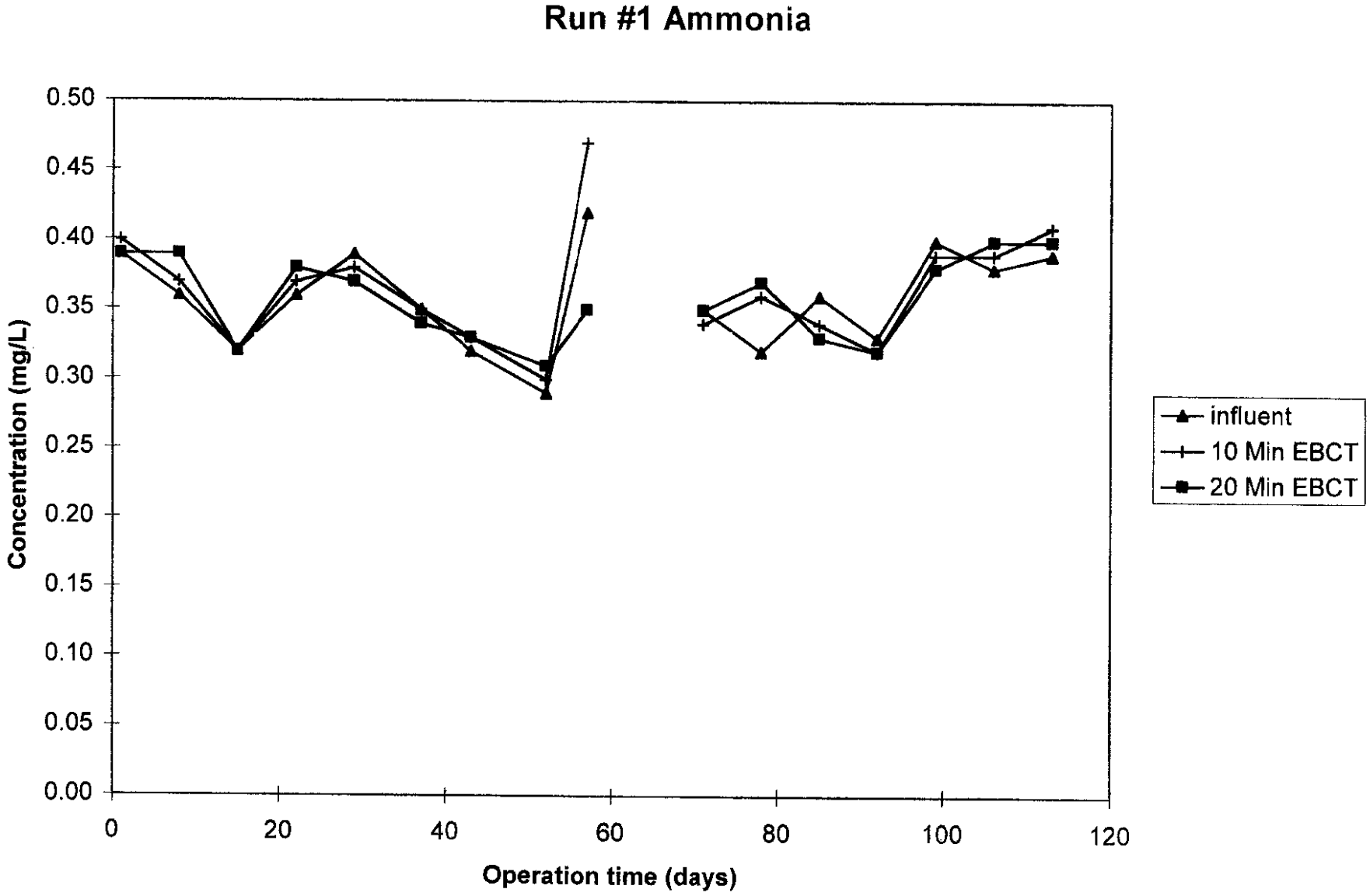
Run #1 Ammonia
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Concentration (mg/L)
0
20
40
60
80
100
120
Operation time (days)
influent
10 Min EBCT
20 Min EBCT

Figure 5

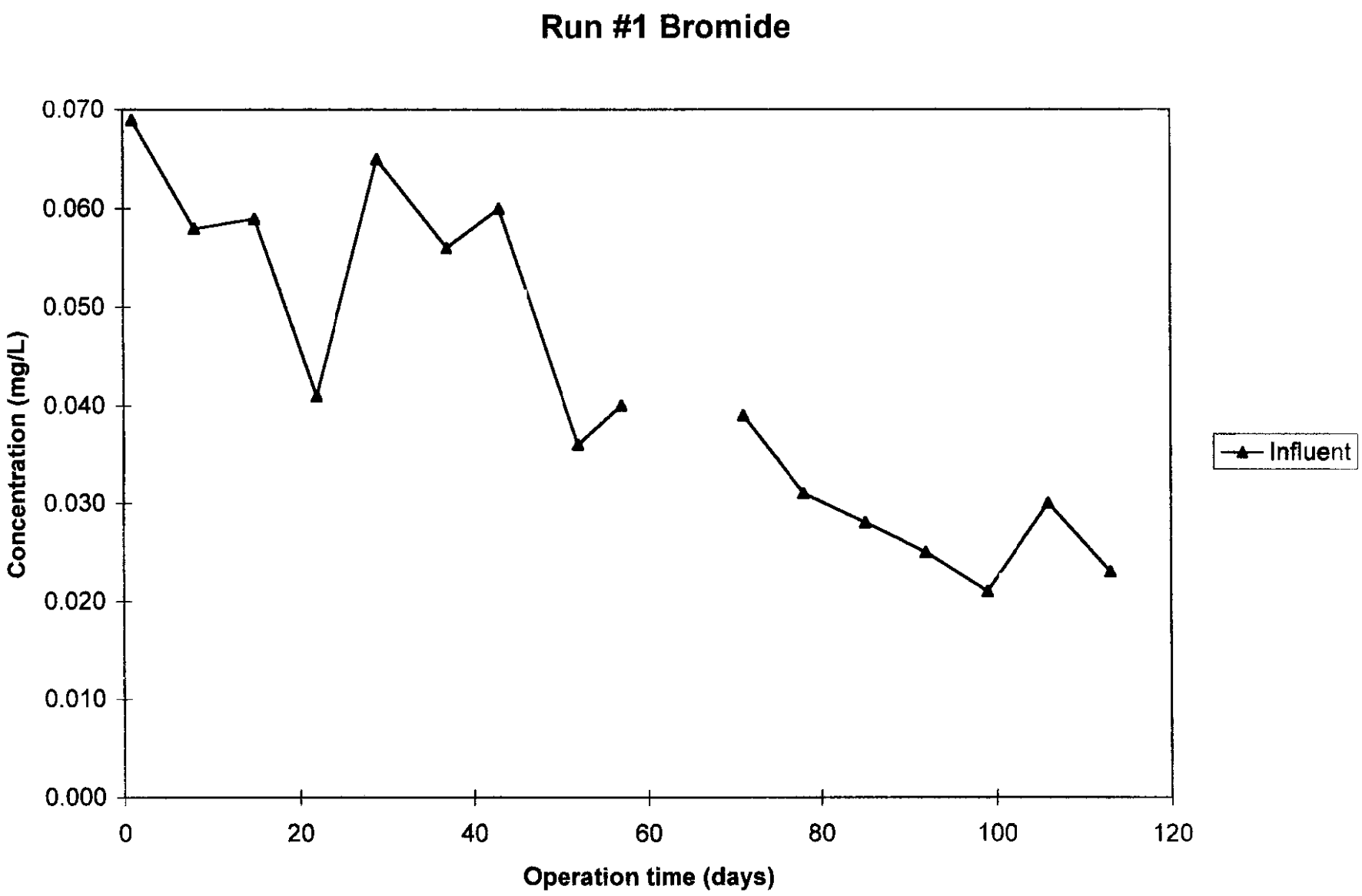
Run #1 Bromide
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Concentration (mg/L)
0
20
40
60
80
100
120
Operation time (days)
Influent

Figure 6

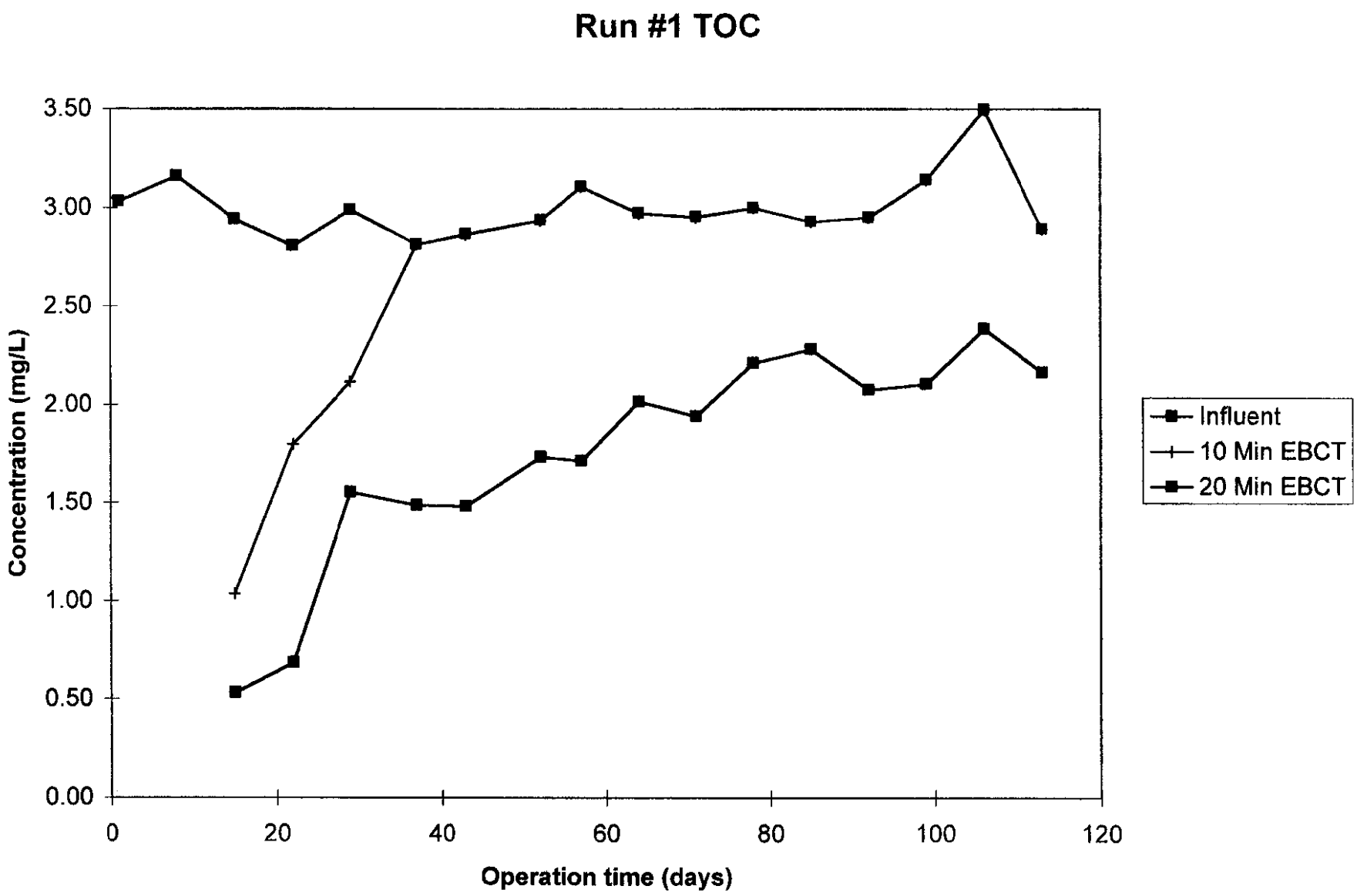
Run #1 TOC
Concentration (mg/L)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
20
40
60
80
100
120
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 7

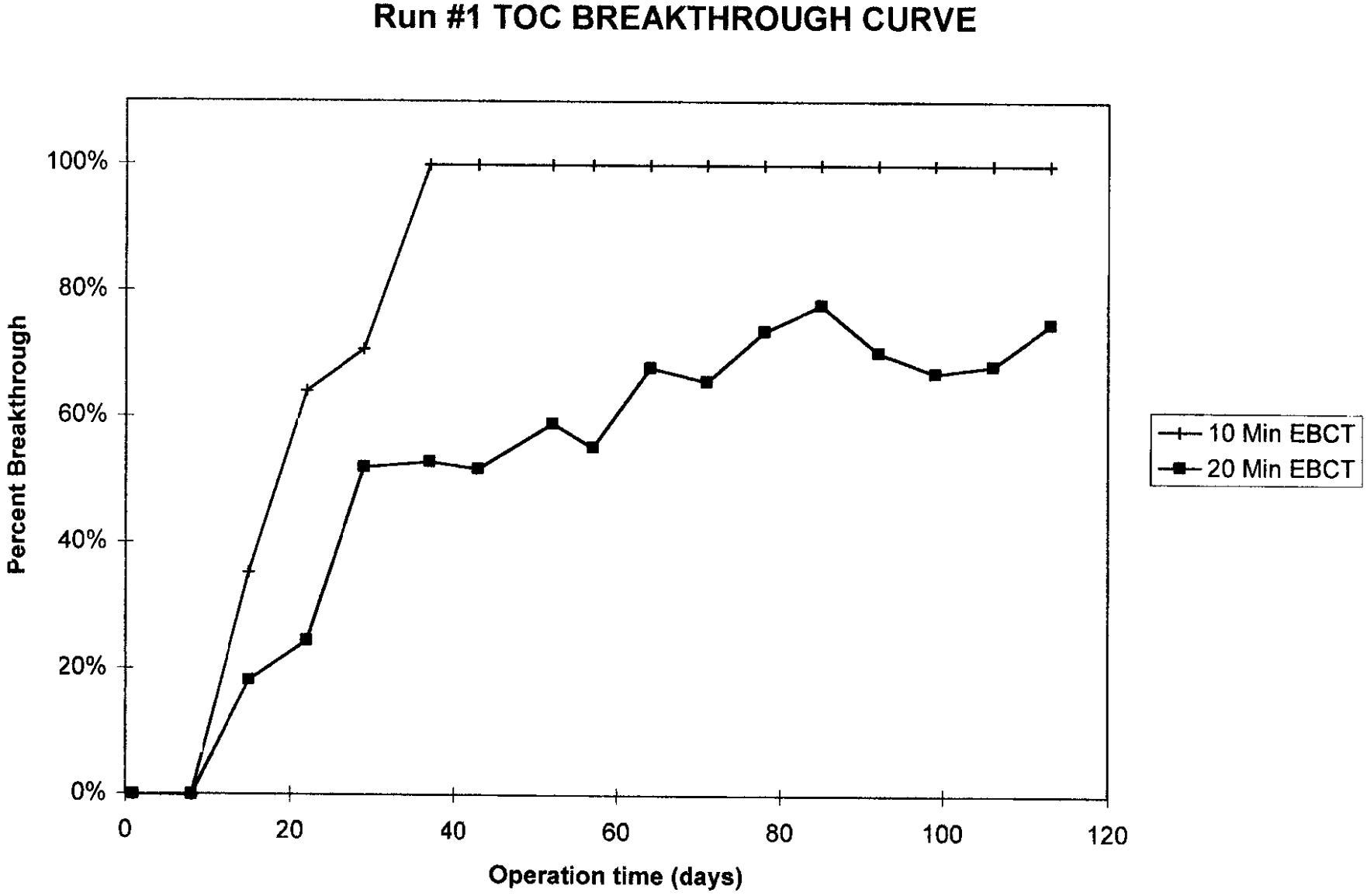
Run #1 TOC BREAKTHROUGH CURVE
Percent Breakthrough
100%
80%
60%
40%
20%
0%
0
20
40
60
80
100
120
Operation time (days)
10 Min EBCT
20 Min EBCT

Figure 8

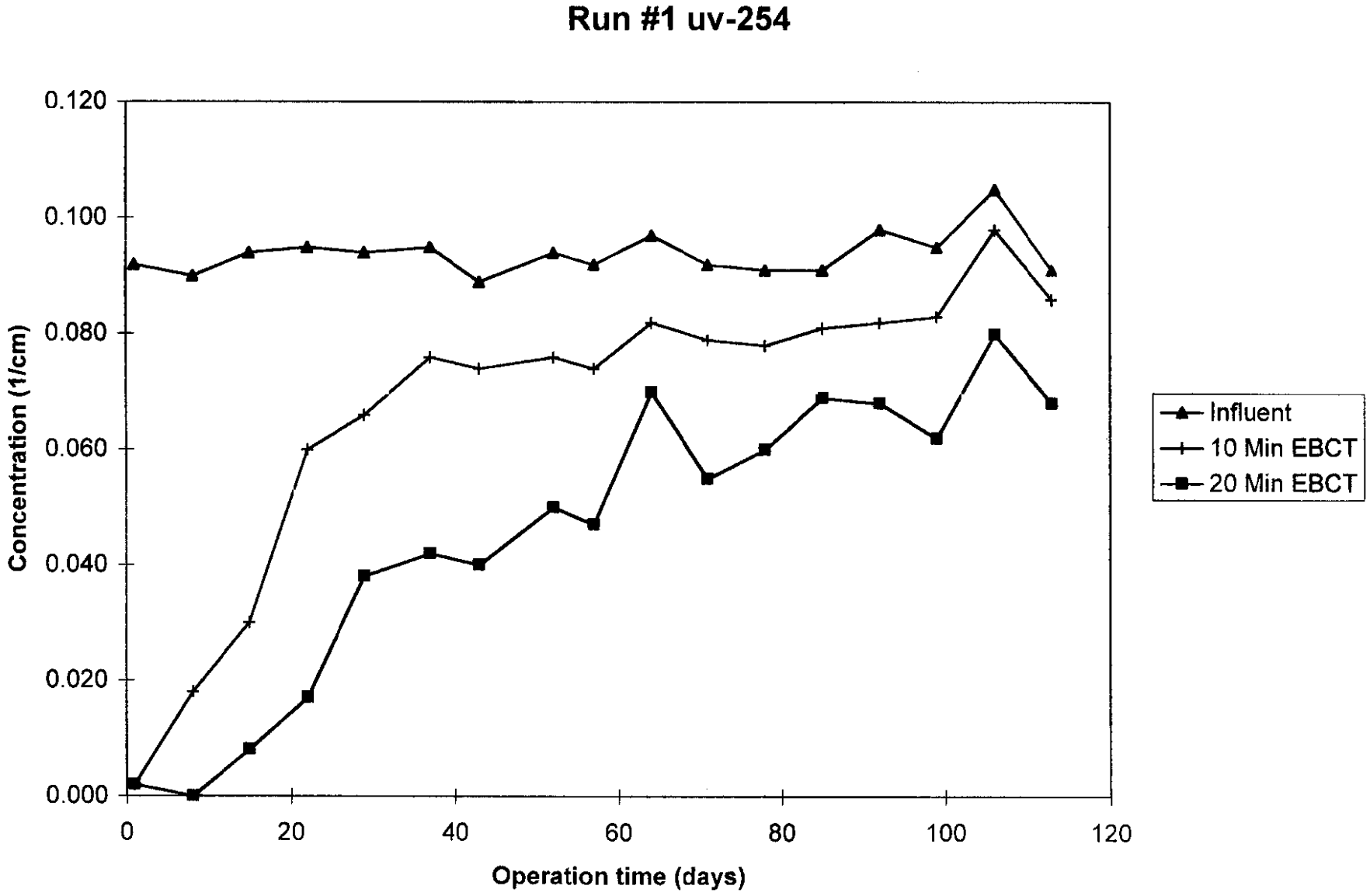
Run #1 uv-254
0.120
0.100
0.080
0.060
0.040
0.020
0.000
Concentration (1/cm)
0
20
40
60
80
100
120
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 9

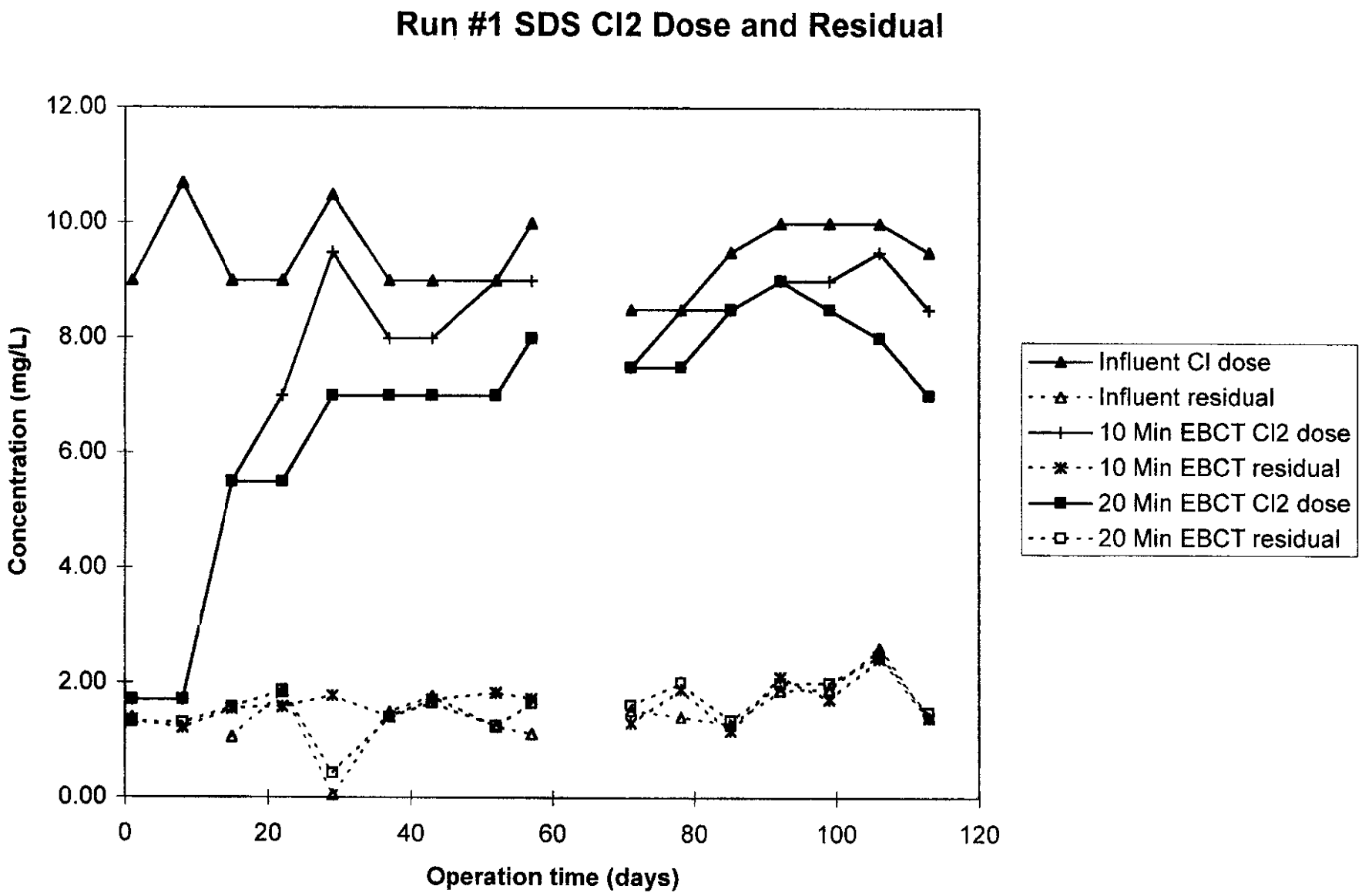
Run #1 SDS Cl2 Dose and Residual
Concentration (mg/L)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
20
40
60
80
100
120
Operation time (days)
Influent Cl dose
Influent residual
10 Min EBCT Cl2 dose
10 Min EBCT residual
20 Min EBCT Cl2 dose
20 Min EBCT residual

Figure 10

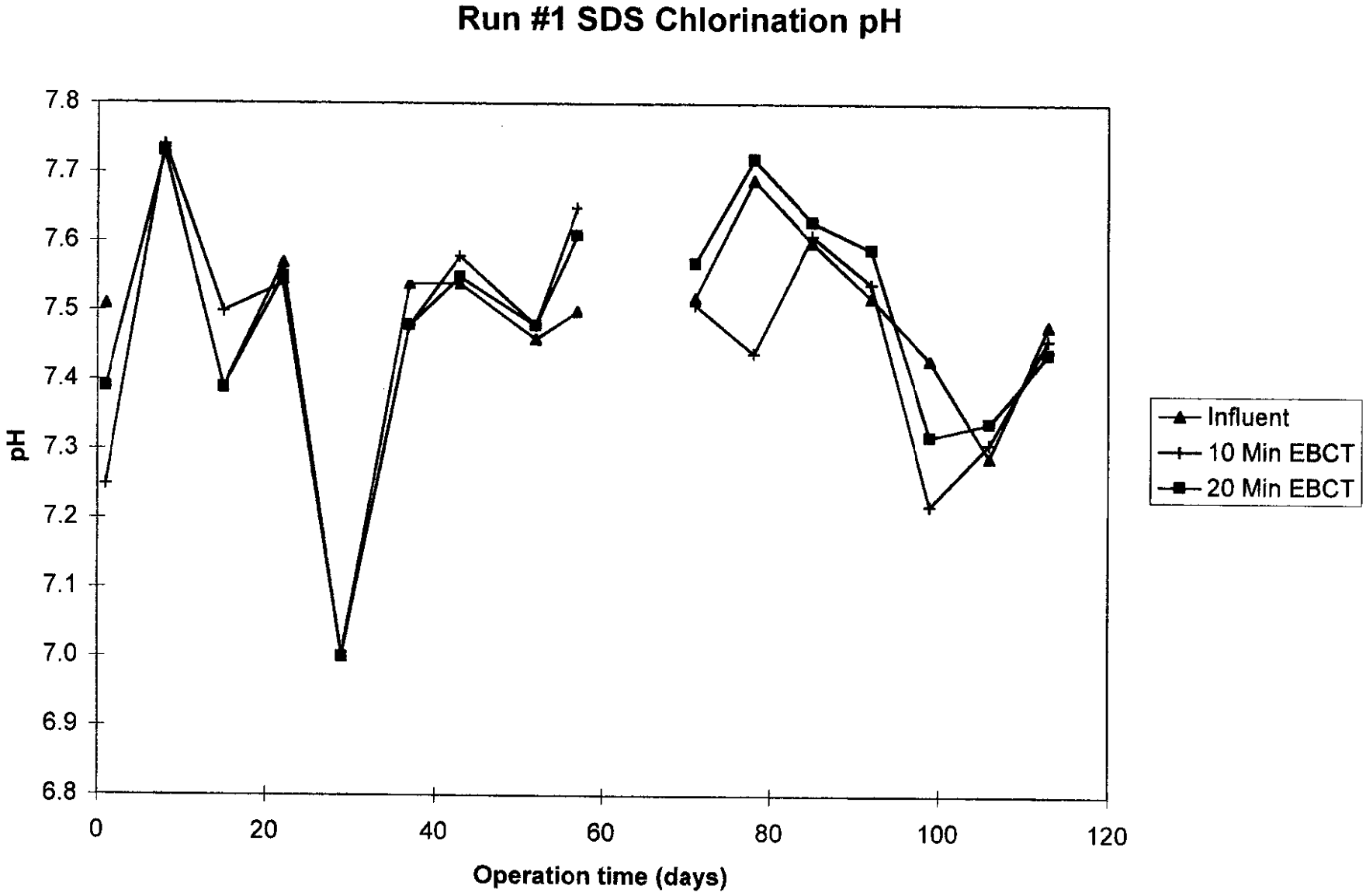
Run #1 SDS Chlorination pH
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
pH
0
20
40
60
80
100
120
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 11

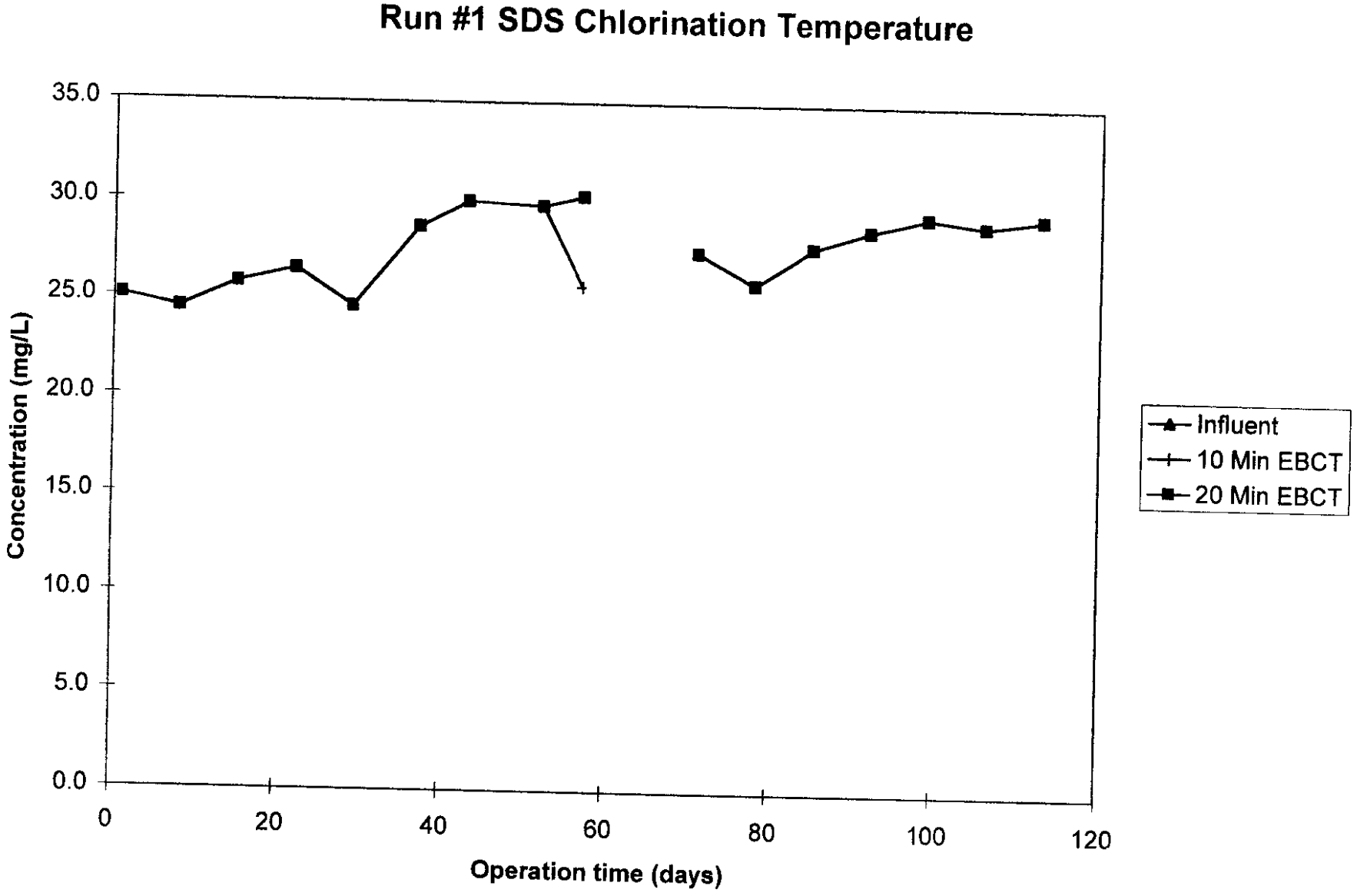
Run #1 SDS Chlorination Temperature
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Concentration (mg/L)
0
20
40
60
80
100
120
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 12

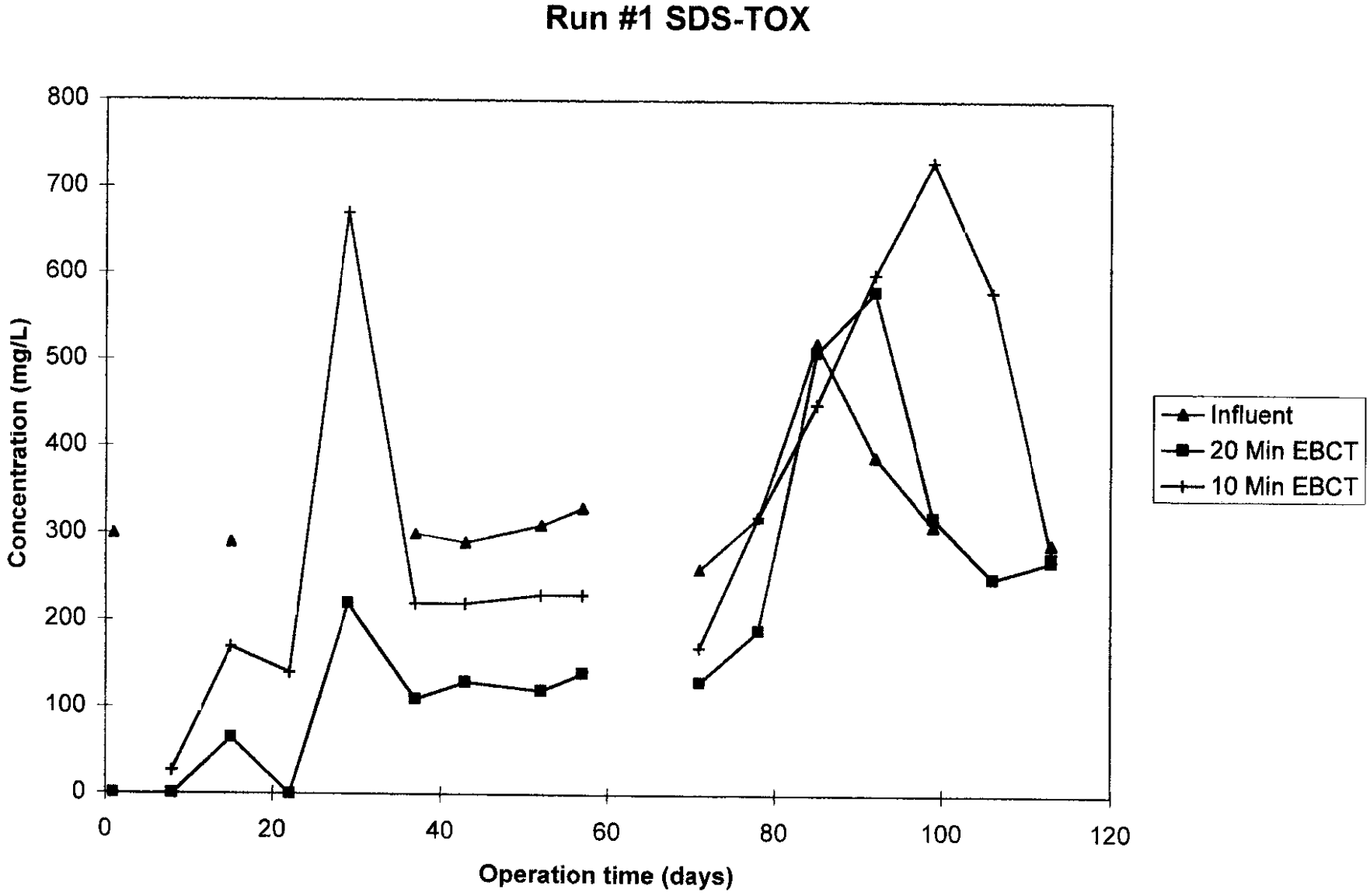
Run #1 SDS-TOX
800
700
600
500
400
300
200
100
0
Concentration (mg/L)
0
20
40
60
80
100
120
Operation time (days)
Influent
20 Min EBCT
10 Min EBCT

Figure 13

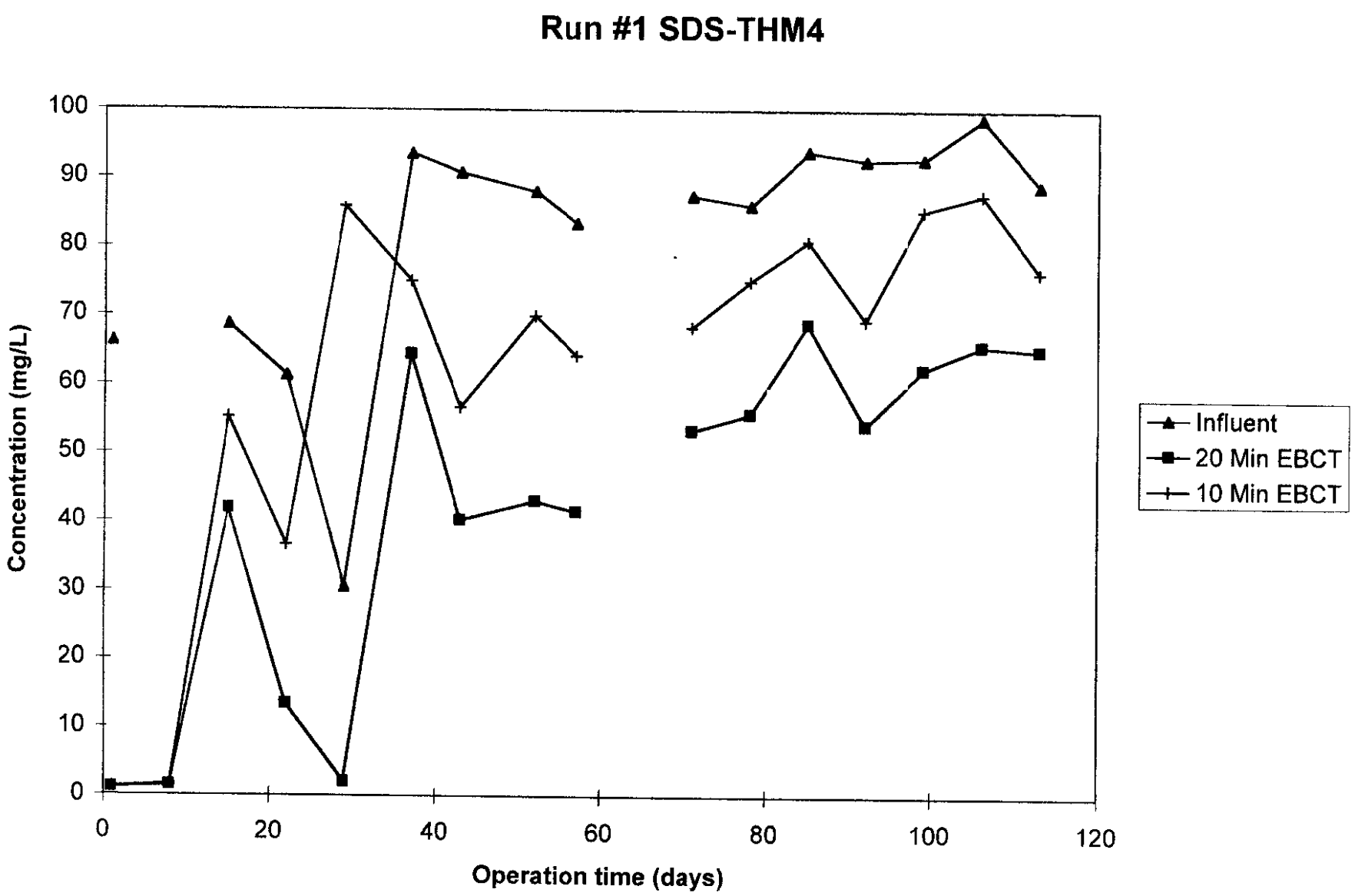
Run #1 SDS-THM4
Concentration (mg/L)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Operation time (days)
Influent
20 Min EBCT
10 Min EBCT

Figure 14

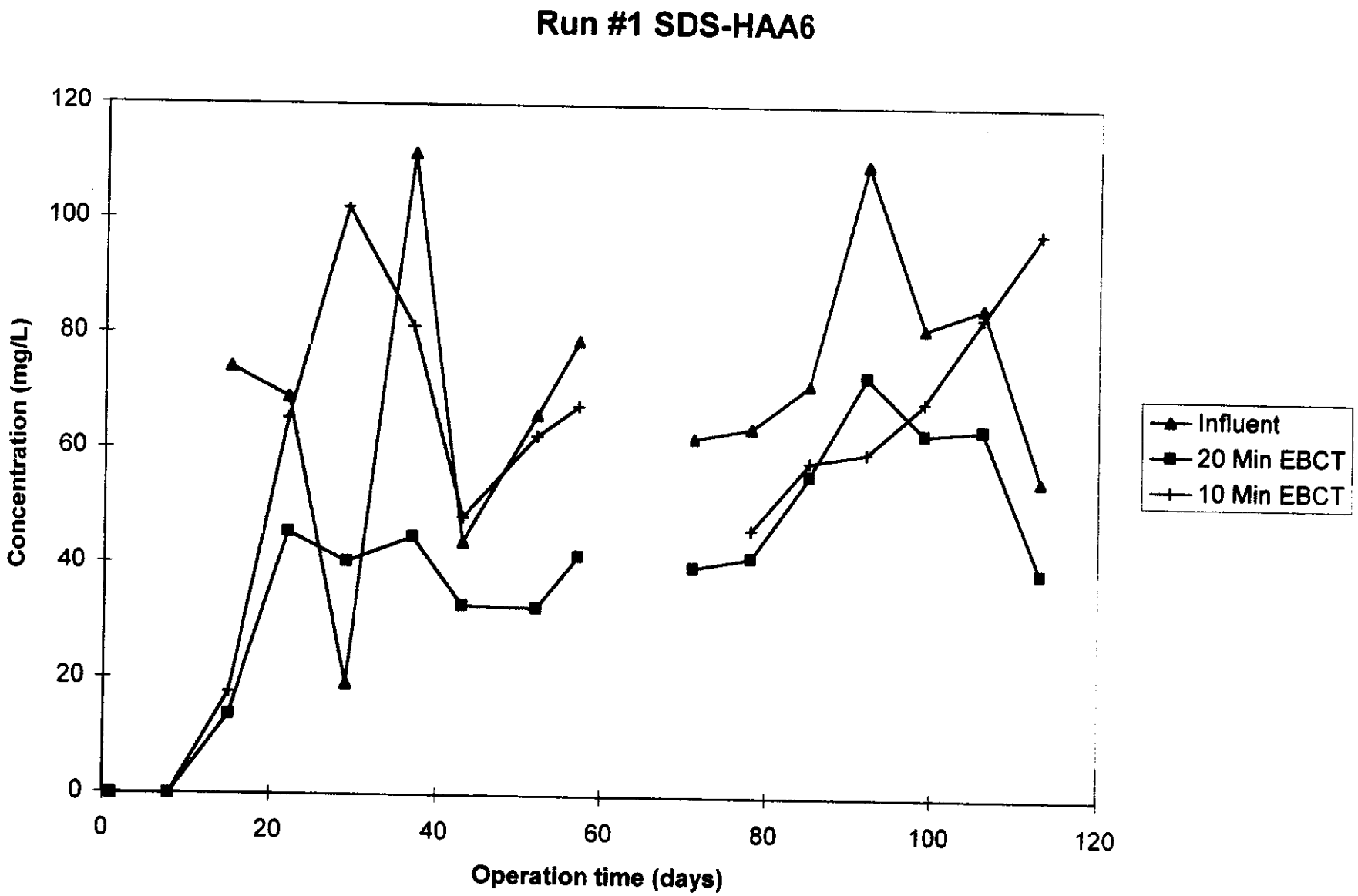
Run #1 SDS-HAA6
Concentration (mg/L)
120
100
80
60
40
20
0
0
20
40
60
80
100
120
Operation time (days)
Influent
20 Min EBCT
10 Min EBCT

Figure 15

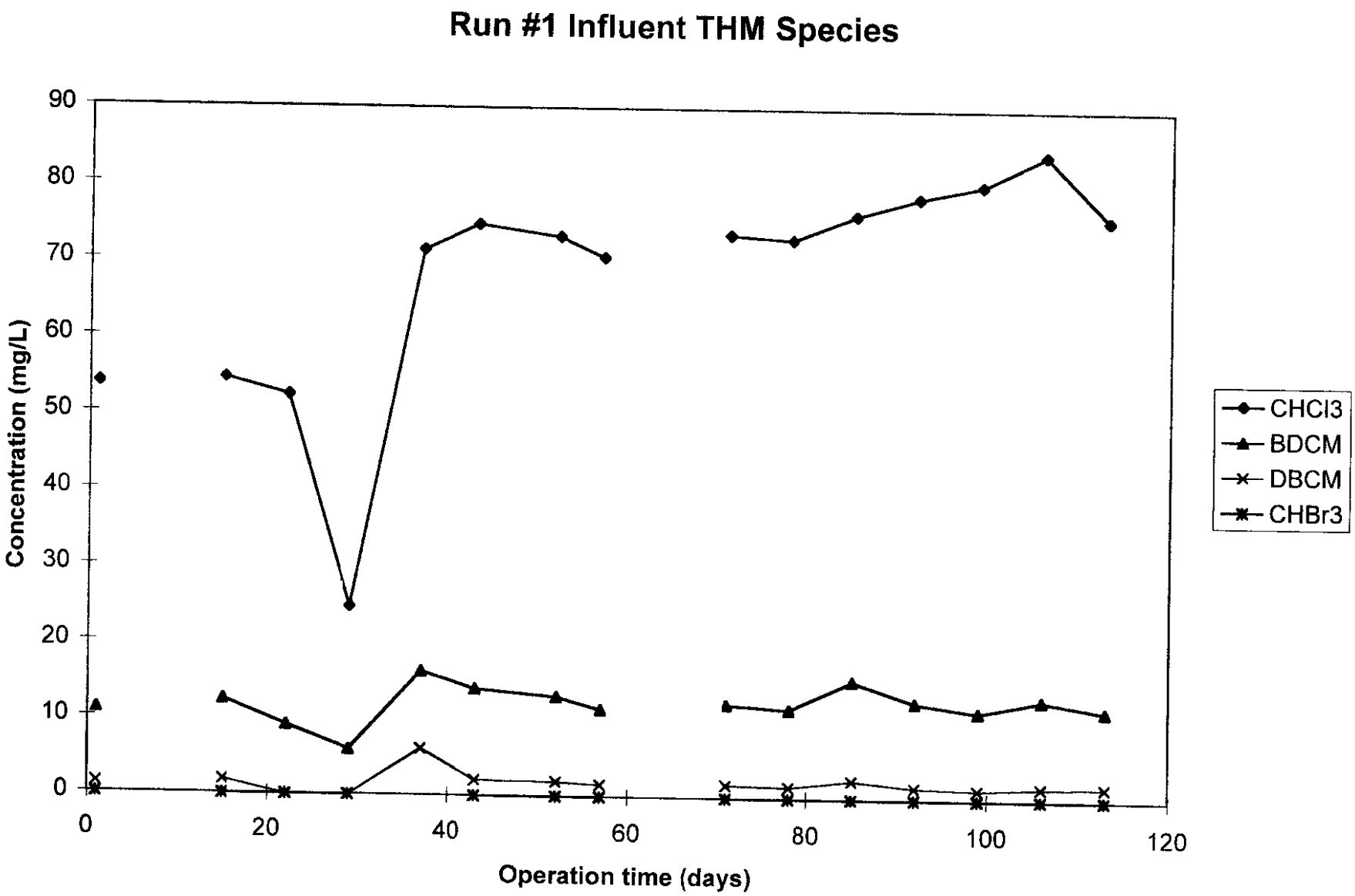
Run #1 Influent THM Species
Concentration (mg/L)
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Operation time (days)
CHCl3
BDCM
DBCM
CHBr3

Figure 16

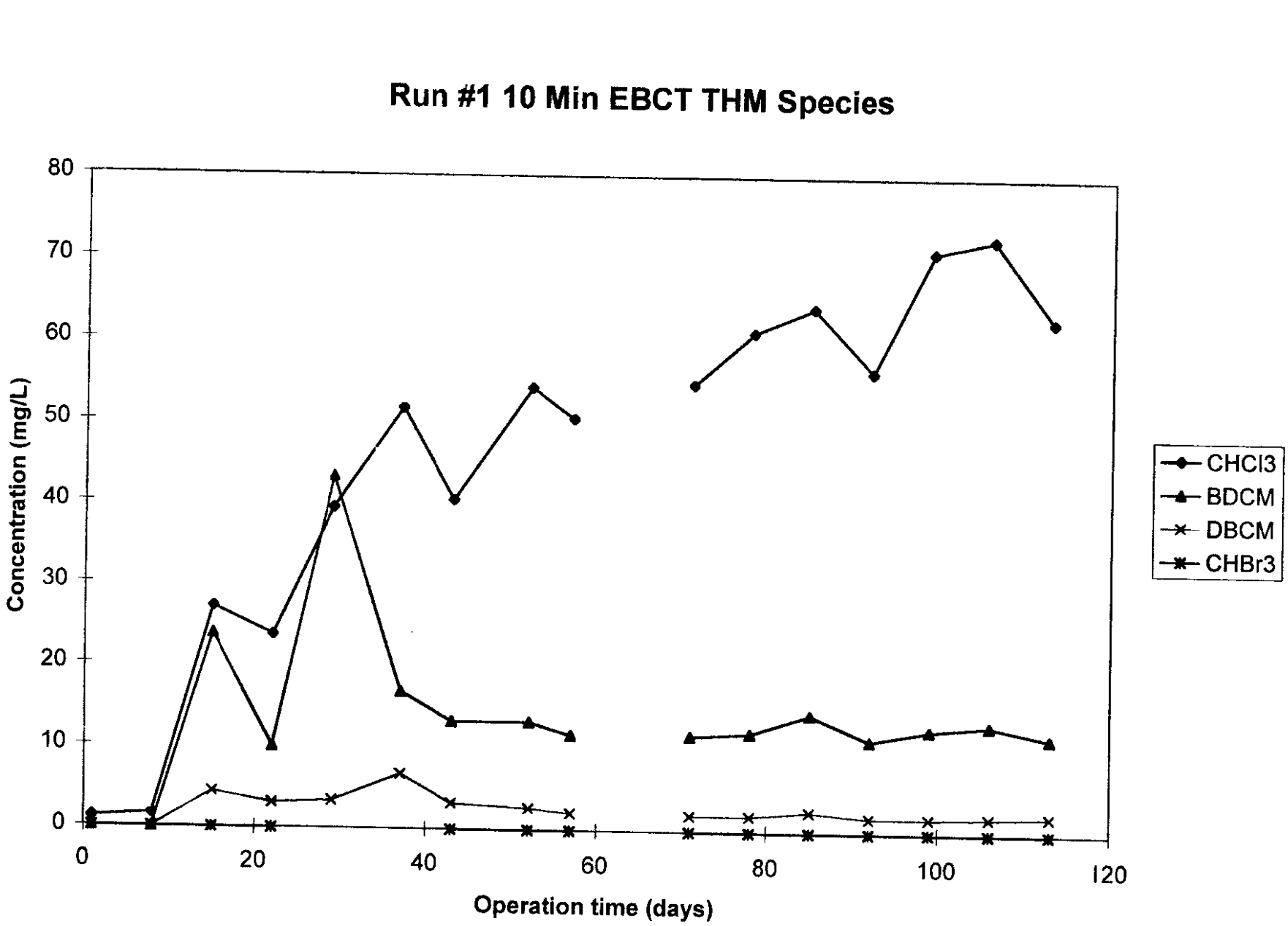
Run #1 10 Min EBCT THM Species
Concentration (mg/L)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Operation time (days)
CHCl3
BDCM
DBCM
CHBr3

Figure 17

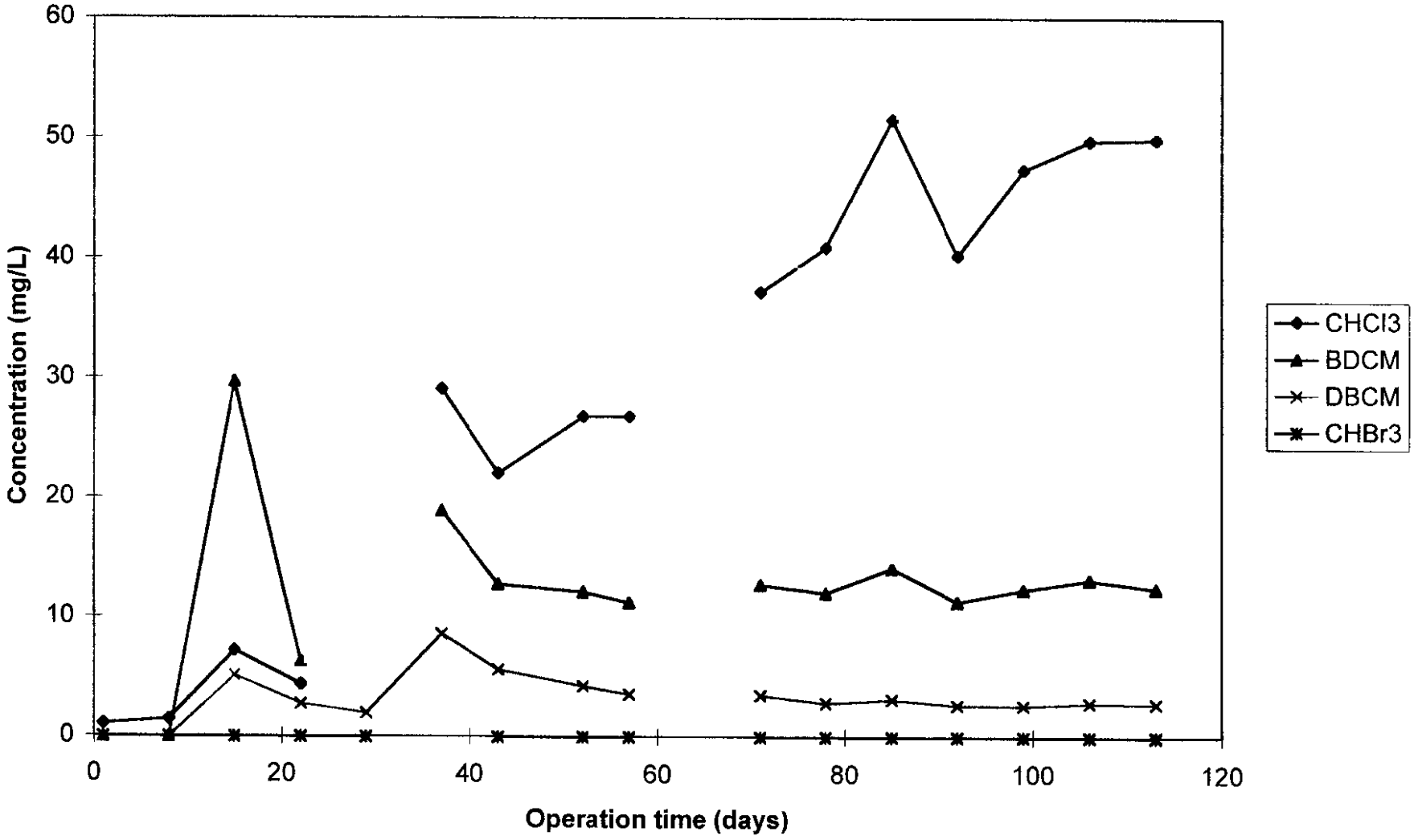
Run #1 20 Min THM Species
Concentration (mg/L)
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Operation time (days)
CHCl3
BDCM
DBCM
CHBr3

Figure 18

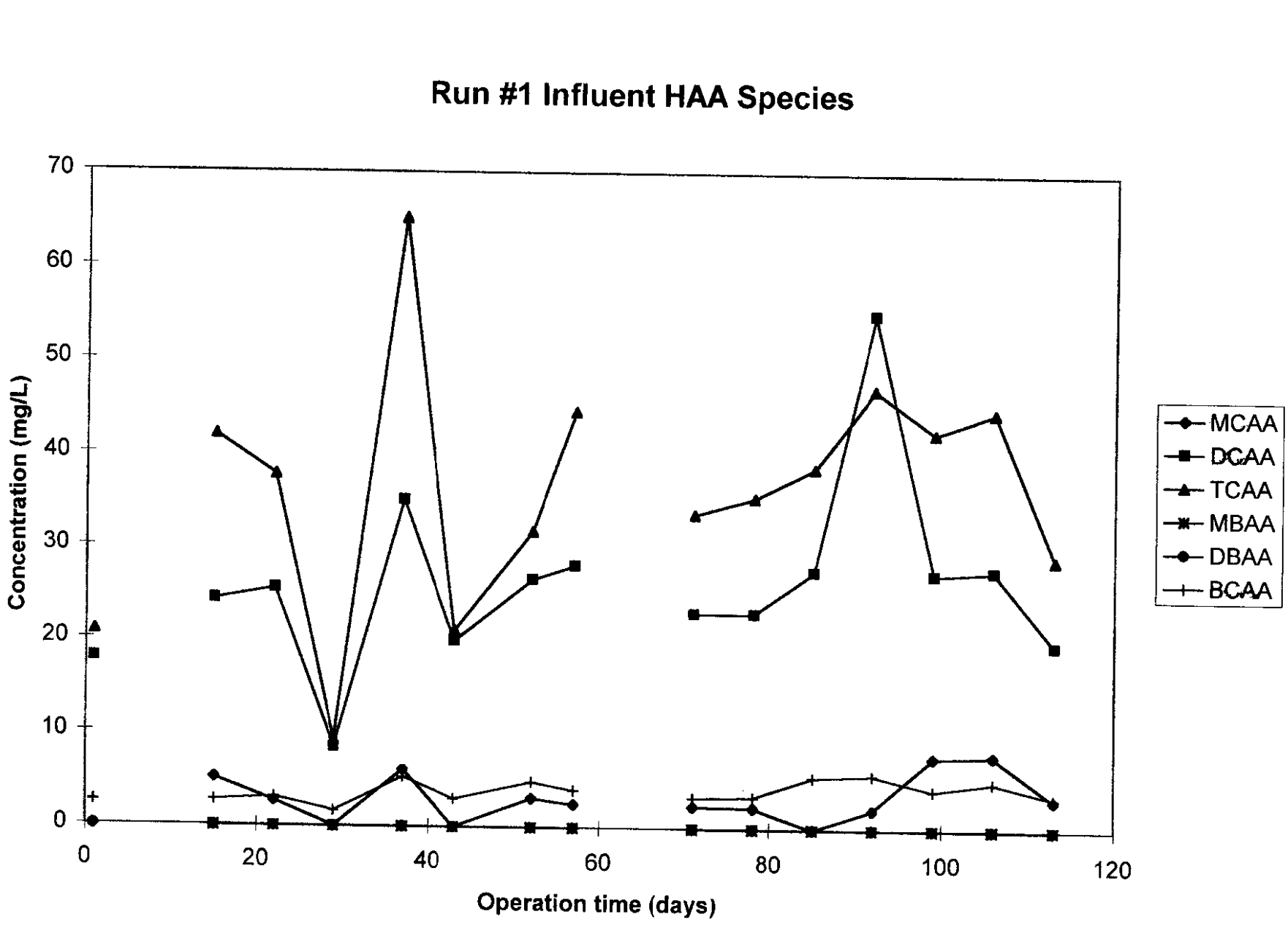
Run #1 Influent HAA Species
Concentration (mg/L)
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Operation time (days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

Figure 19

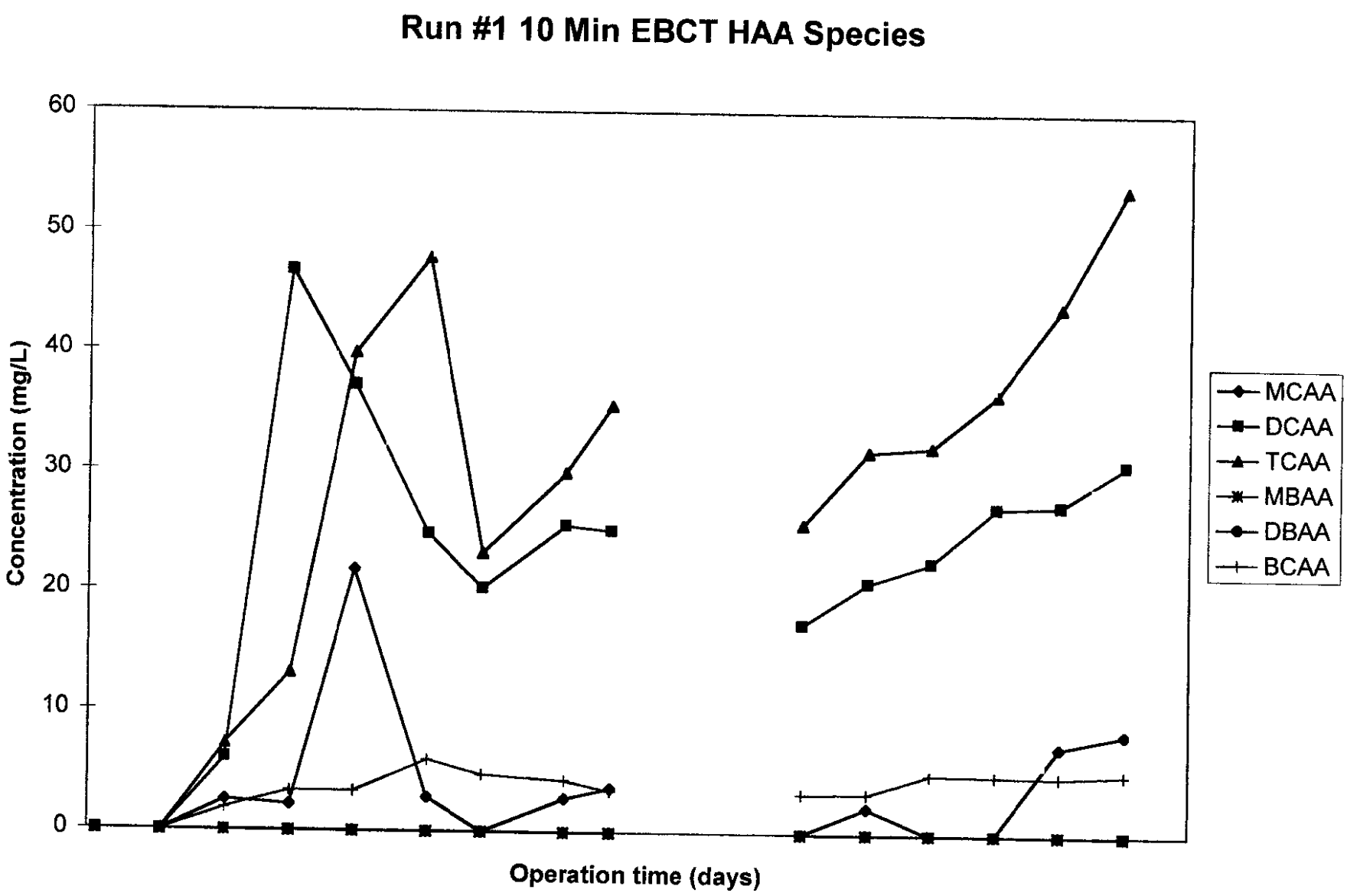
Run #1 10 Min EBCT HAA Species
60
50
40
30
20
10
0
Concentration (mg/L)
Operation time (days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

Figure 20

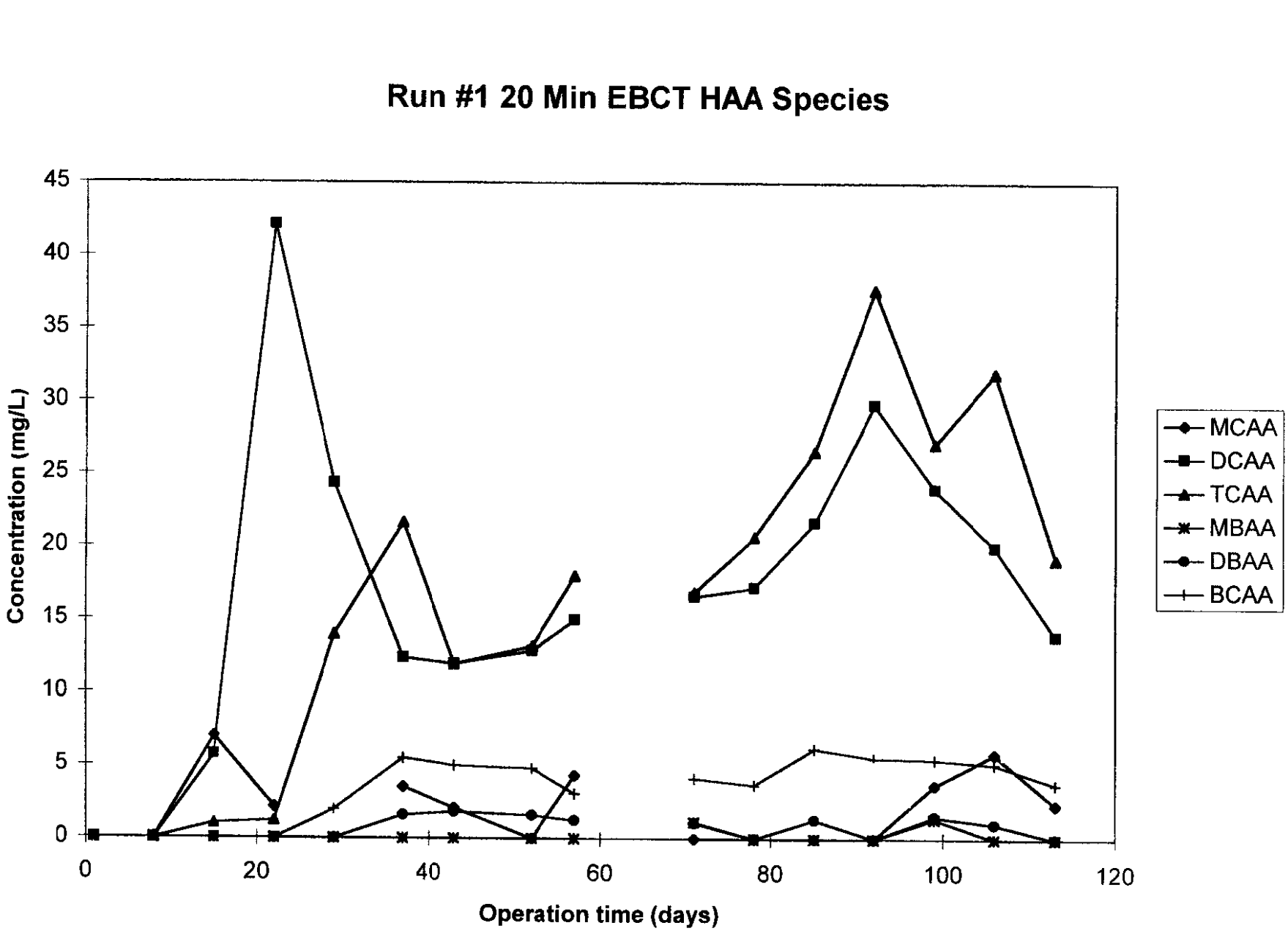
Run #1 20 Min EBCT HAA Species
Concentration (mg/L)
45
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
Operation time (days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

Figure 21

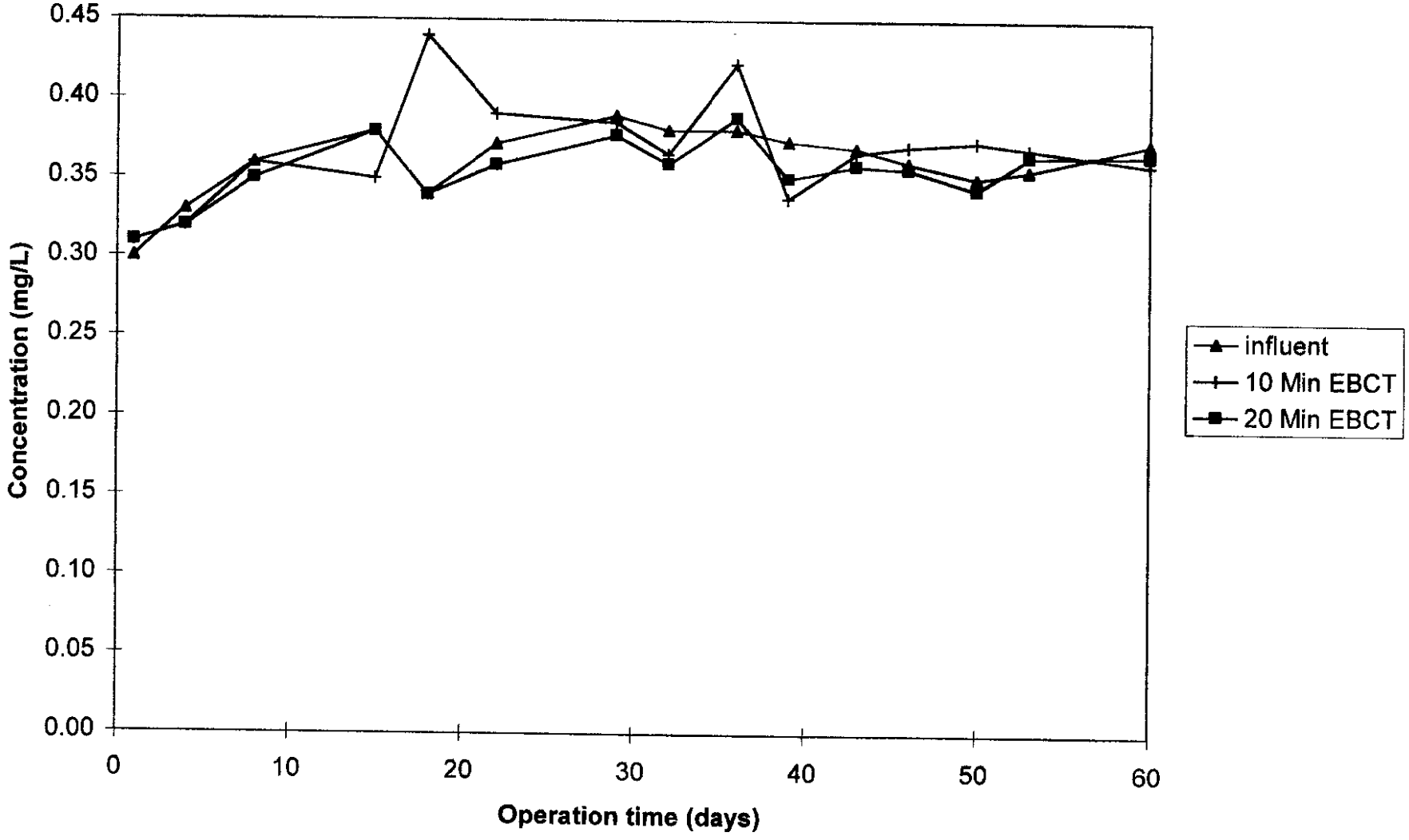
Run #2 Ammonia
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Concentration (mg/L)
0
10
20
30
40
50
60
Operation time (days)
influent
10 Min EBCT
20 Min EBCT

Figure 22

Pilot Study Run #2

The second run was initiated on September 14, 1998 and terminated on November 12, 1998. Fifteen sets of samples (with three field duplicates) were taken by the utility. On October 8, the UV systems was damaged by rains and floods associated with Hurricane Mitch. This hurricane was noted for the devastation in Honduras and other countries in Central America. Its weather pattern also reached into central Florida. After discussion with the treatment study coordinator, the plant was restarted and a new system was ordered. On October 29, 1999 a new UV system was installed and was in place for the remaining 4 samples. Data from the second run were input to the *Treatment Study Spreadsheets* which are included with the submission of this report on diskette.

Ammonia & Bromide

Figures 22 & 23 shows the ammonia and bromide levels at the samples taps the second run. The data in consistent with the first run.

TOC

Figure 24 shows the TOC concentrations at the influent, and after 10 and 20 minute EBCT columns. Influent water TOC varied from 2.8 to 3.3 mg/L. Figure 25 shows the breakthrough of organic carbon during the run. In the second run, organic carbon broke through (at the 70% level) at 528 (22 days) in the 10 minute EBCT column. This was before the failure of the UV systems. During the study, the 20 minute EBCT effluent TOC concentration did not reach 70% of the influent concentration. Instead it reached a steady-state, fluctuating between 60% and 68% of the influent concentration. The following tables summarize the DBP precursor and simulated DBP concentrations for the second run.

INFLUENT WATER QUALITY	**TOC mg/L**	**pH**	**UV_{254} 1/cm**	**SUVA L/(mg*m)**	**Bromide ug/L**	**SDS TOX mg/L**	**SDS THM4 mg/L**	**SDS HAA5 mg/L**	**SDS HAA6 mg/L**
Mean	3.0	7.5	0.1	3.1	0.0	304.0	83.7	76.8	76.8
Standard Deviation	0.1	0.1	0.0	0.2	0.0	66.4	17.6	16.6	16.6
Count	15	15	15	15	14	15	15	15	15
Minimum	2.8	7.2	0.1	2.7	0.0	220.0	61.9	46.5	46.5
Maximum	3.3	7.6	0.1	3.3	0.1	470.0	118.0	107.3	107.3

10 Min Effluent WATER QUALITY	**TOC**	**pH**	**UV_{254}**	**SUVA**	**SDS TOX**	**SDS THM4**	**SDS HAA5**	**SDS HAA6**
Mean	2.2	7.4	0.1	3.0	197.2	50.0	50.9	51.1
Standard Deviation	0.6	0.1	0.0	0.3	68.0	13.4	13.4	13.4
Count	15	15	15	15	13	15	15	15
Minimum	0.4	7.2	0.0	2.5	44.0	15.0	27.4	27.4
Maximum	2.8	7.6	0.1	3.6	320.0	65.3	71.8	71.8

20 Min Effluent WATER QUALITY	TOC mg/L	pH	UV_{254} 1/cm	SUVA L/(mg*m)	SDS ug/L	SDS THM4 mg/L	SDS HAA5 mg/L	SDS HAA6 mg/L
Mean	1.3	7.4	0.0	2.1	136.9	27.2	20.2	23.3
Standard Deviation	0.7	0.1	0.0	1.2	61.6	15.9	12.6	13.4
Count	15	15	13	15	13	15	15	15
Minimum	0.3	7.2	0.0	0.0	28.0	0.0	0.0	0.0
Maximum	2.1	7.5	0.1	3.8	260.0	46.5	46.5	51.0

UV-254

The results of the influent, 10 and 20 minute EBCT effluents' UV-254 values are shown it Figure 26. Influent UV-254 values ranged from 0.085 to 0.099 cm^{-1}. These values are similar to those of the first run and indicate that the organic carbon derived from humic matter in the source water is stable.

SDS Conditions

Figure 27 shows the SDS chlorine dose and residual concentrations. Figures 28 and 29 show the SDS pH and temperature conditions. The following tables summarize the SDS conditions for the second run.

INFLUENT WATER QUALITY	Cl dose mg/L	Cl residual mg/L	Cl2 demand mg/L	SDS temp. mg/L	SDS pH	incubation time (hr)
Mean	8.9	1.6	7.2	27.0	7.5	24.0
Standard Deviation	0.5	0.2	0.6	1.0	0.1	0.0
Count	15	15	15	15	15	15
Minimum	8.0	1.2	6.3	24.1	7.4	24.0
Maximum	9.5	2.2	8.0	28.3	7.6	24.0

10 Min Effluent WATER QUALITY	Cl dose mg/L	Cl residual mg/L	Cl2 demand mg/L	SDS temp. mg/L	SDS pH	incubation time (hr)
Mean	7.1	1.5	5.6	27.0	7.5	24.0
Standard Deviation	1.2	0.5	1.1	1.0	0.1	0.0
Count	15	14	15	15	15	15
Minimum	3.5	0.4	3.1	24.1	7.4	24.0
Maximum	8.5	2.4	7.5	28.3	7.7	24.0

20 Min Effluent WATER QUALITY	Cl dose mg/L	Cl residual mg/L	Cl2 demand mg/L	SDS temp. mg/L	SDS pH	incubation time (hr)
Mean	5.9	1.6	4.3	27.0	7.5	24.0
Standard Deviation	0.9	0.4	0.7	1.0	0.1	0.0
Count	15	15	15	15	15	15
Minimum	3.5	0.5	3.0	24.1	7.4	24.0
Maximum	7.0	2.5	5.1	28.3	7.7	24.0

SDS-DBP

Figure 30 illustrates the TOX values produced from influent and effluent samples. Figures 31 and 32 show the SDS-THM4, and SDS-HAA6 results. As in the first run the DBP graphics are consistent with the TOC and UV-254 data. As precursor (organic carbon) concentrations increased, DBP concentrations increased.

THM Species

Figures 33, 34, and 35 show the individual THM species. Again, chloroform is the predominant constituent.

HAA Species

Figures 36, 37, and 38 illustrate the individual HAA species. Trichloracetic acid and dichloracetic acid constitute the majority of the haloacetic acid formation during the second run.

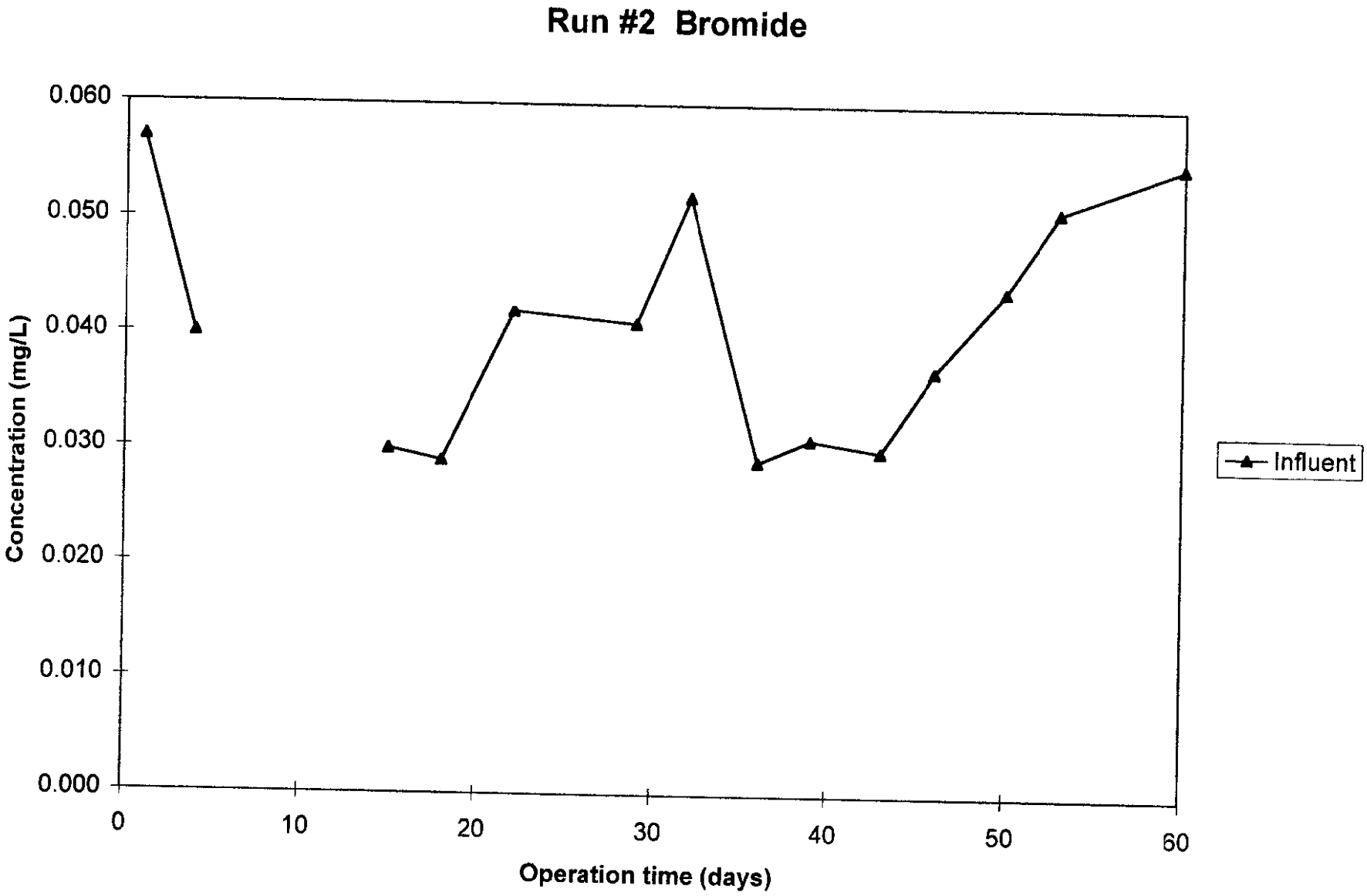
Run #2 Bromide
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Concentration (mg/L)
0
10
20
30
40
50
60
Operation time (days)
Influent

Figure 23

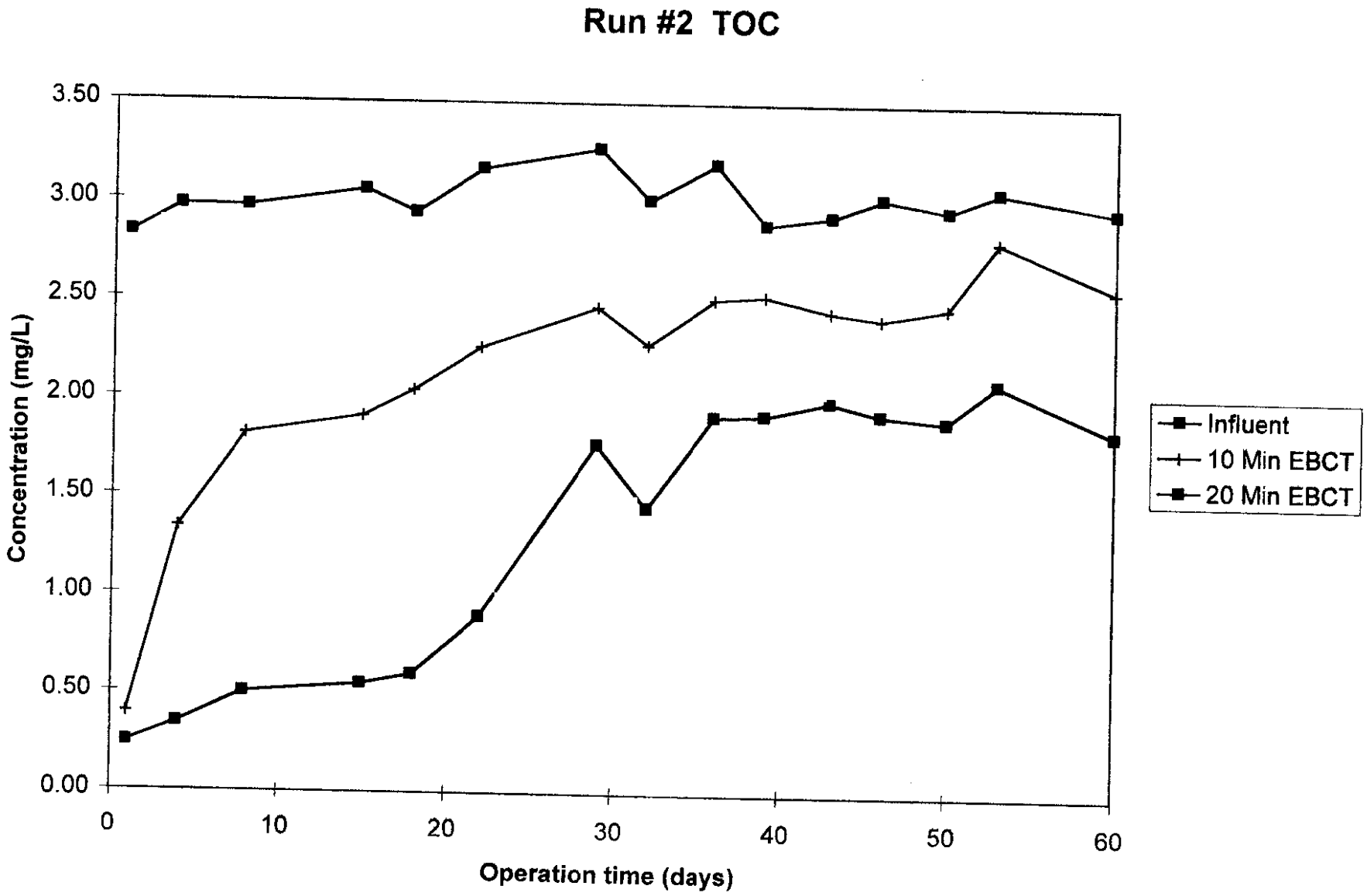
Run #2 TOC
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Concentration (mg/L)
0
10
20
30
40
50
60
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 24

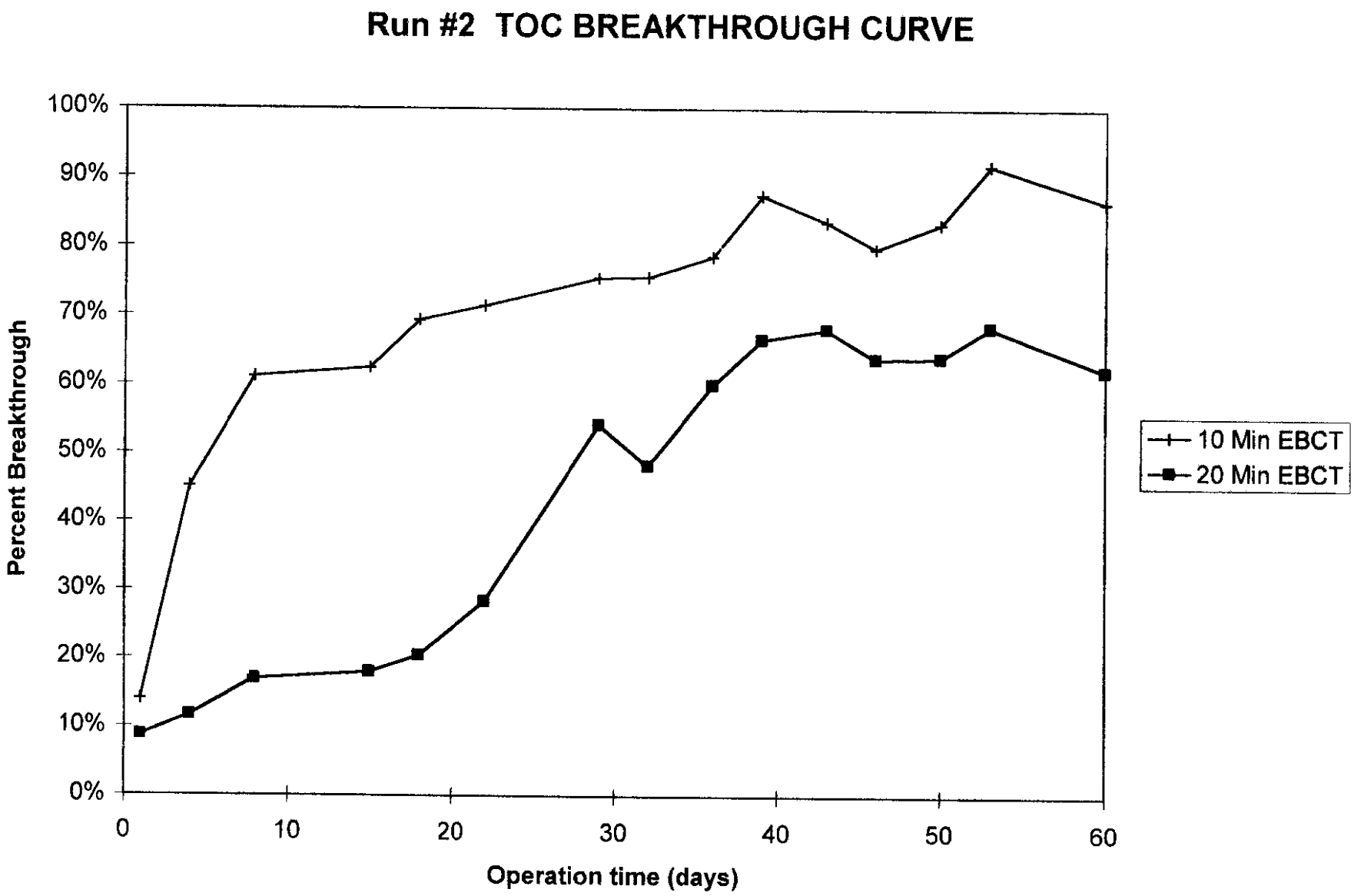
Run #2 TOC BREAKTHROUGH CURVE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent Breakthrough
0
10
20
30
40
50
60
Operation time (days)
10 Min EBCT
20 Min EBCT

Figure 25

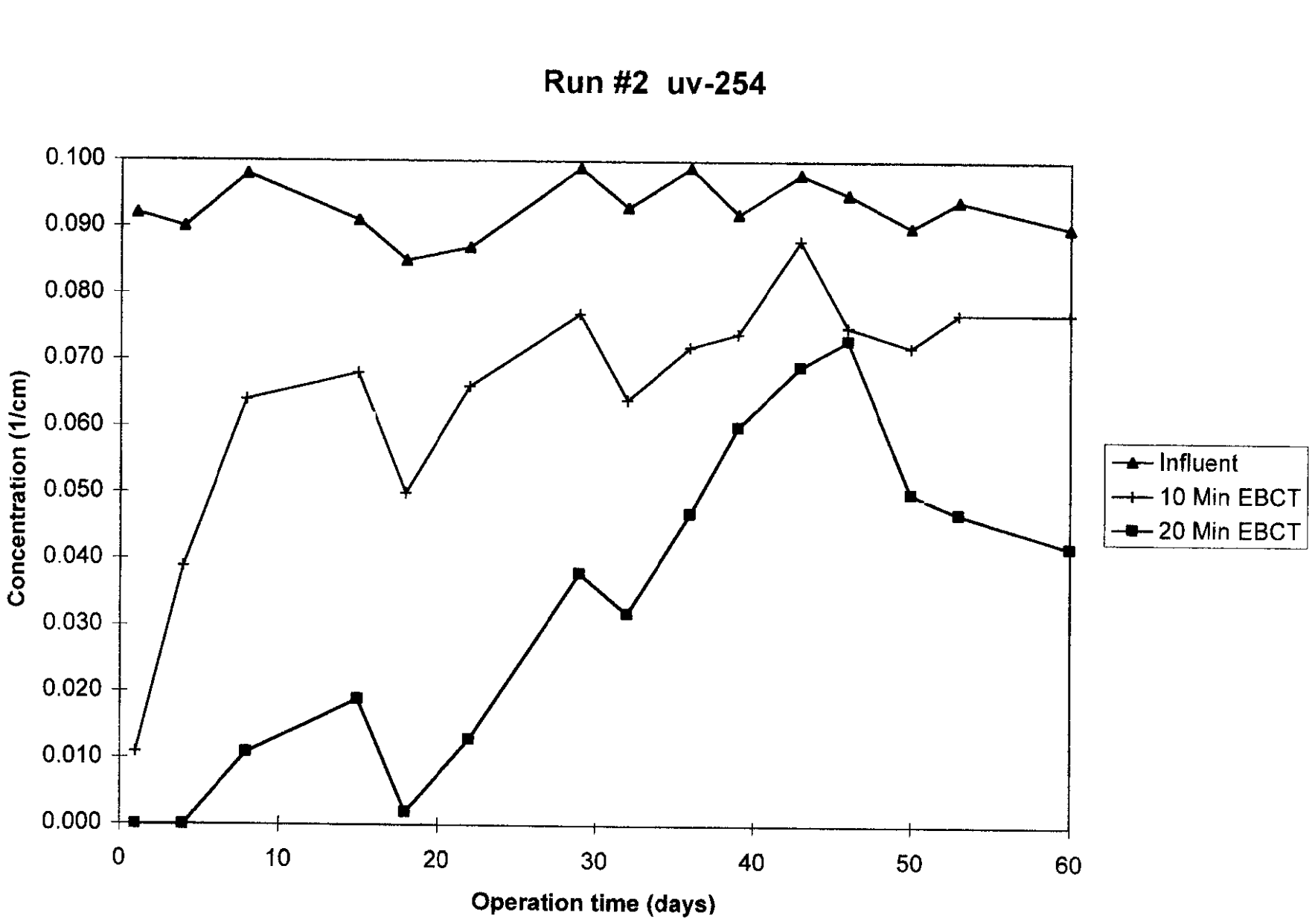
Run #2 uv-254
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Concentration (1/cm)
0
10
20
30
40
50
60
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 26

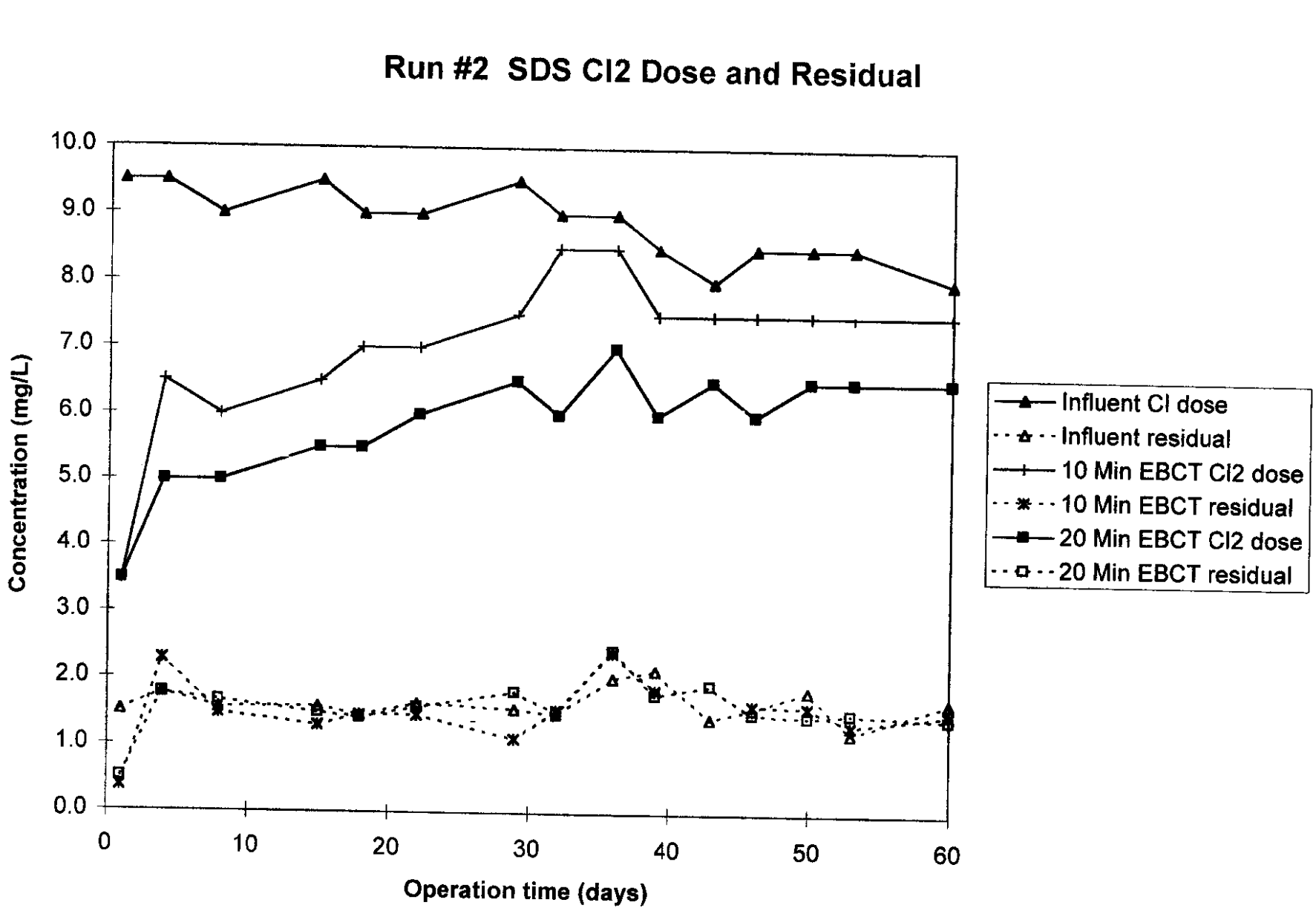
Run #2 SDS Cl2 Dose and Residual
Concentration (mg/L)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
10
20
30
40
50
60
Operation time (days)
Influent Cl dose
Influent residual
10 Min EBCT Cl2 dose
10 Min EBCT residual
20 Min EBCT Cl2 dose
20 Min EBCT residual

Figure 27

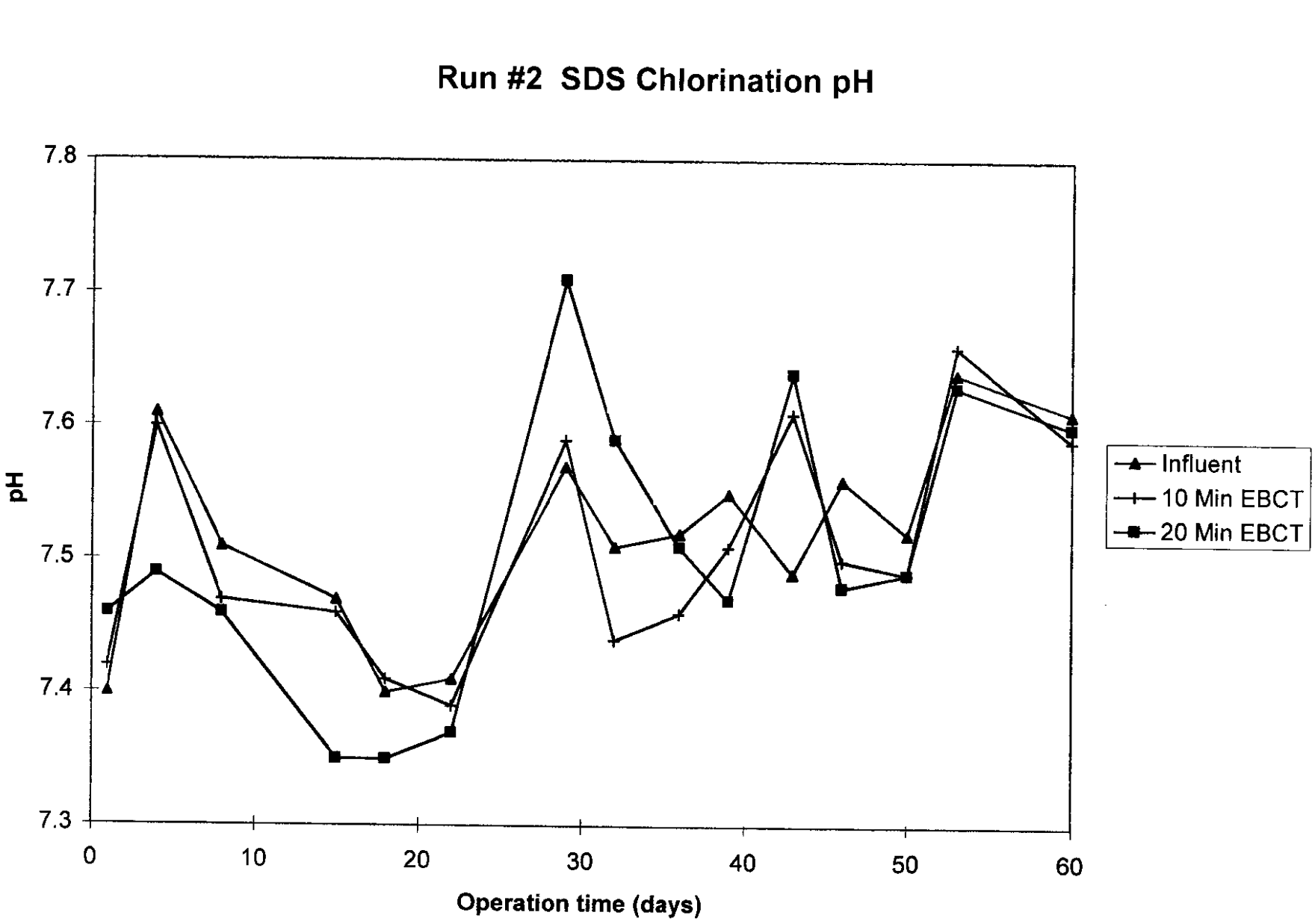
Run #2 SDS Chlorination pH
7.8
7.7
7.6
7.5
7.4
7.3
pH
0
10
20
30
40
50
60
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 28

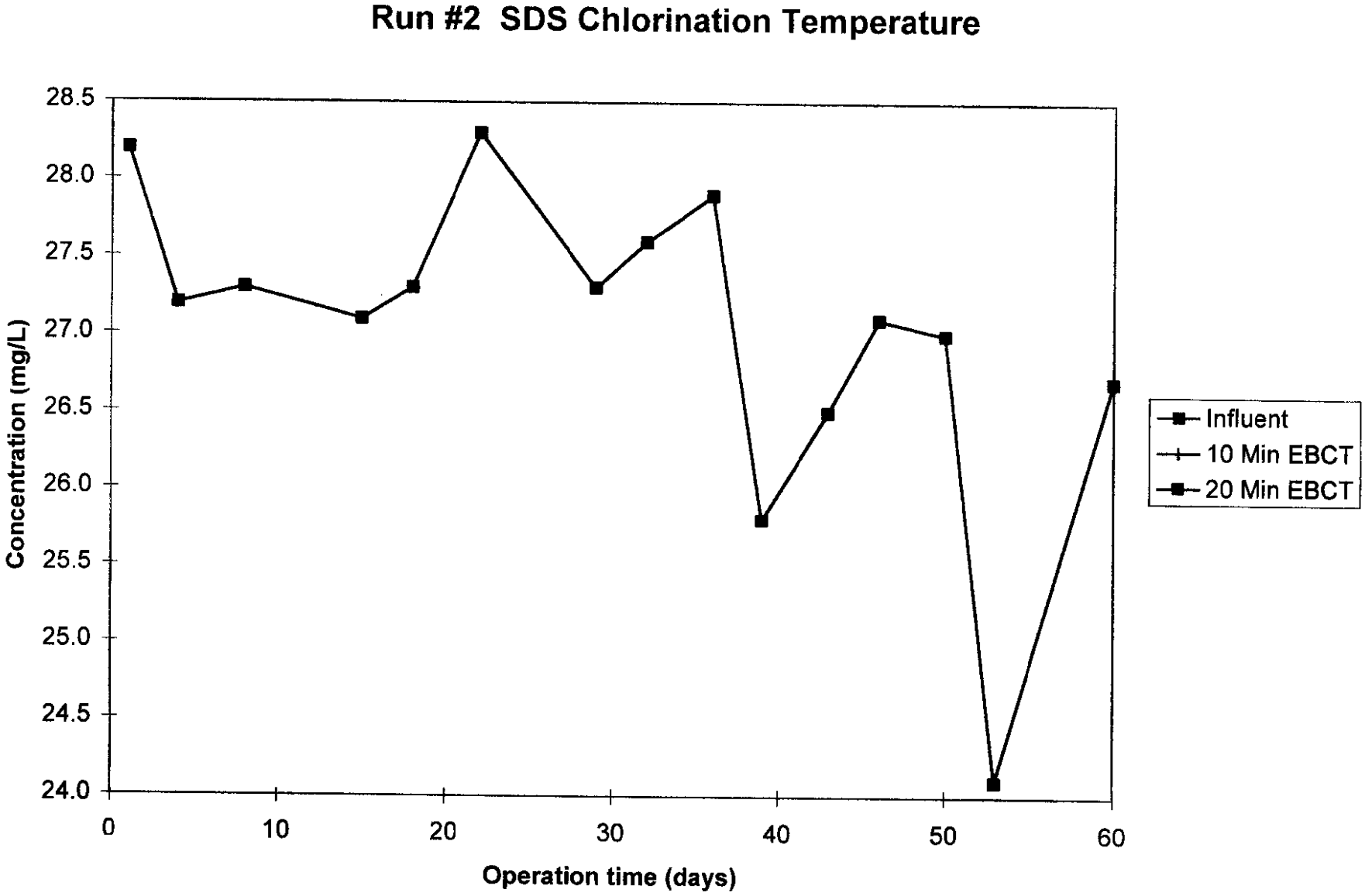
Run #2 SDS Chlorination Temperature
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
24.5
24.0
Concentration (mg/L)
0
10
20
30
40
50
60
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 29

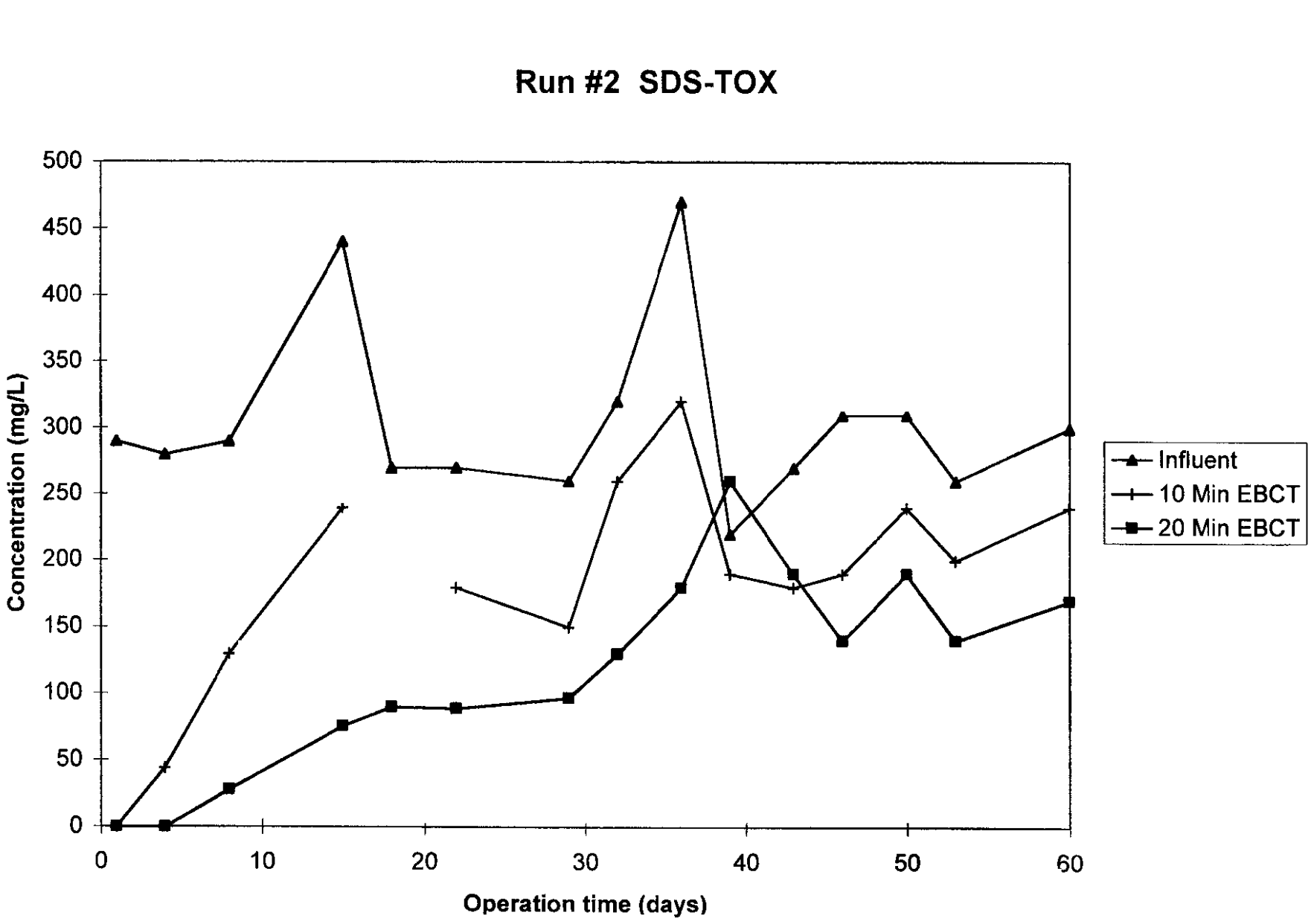
Run #2 SDS-TOX
Concentration (mg/L)
500
450
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 30

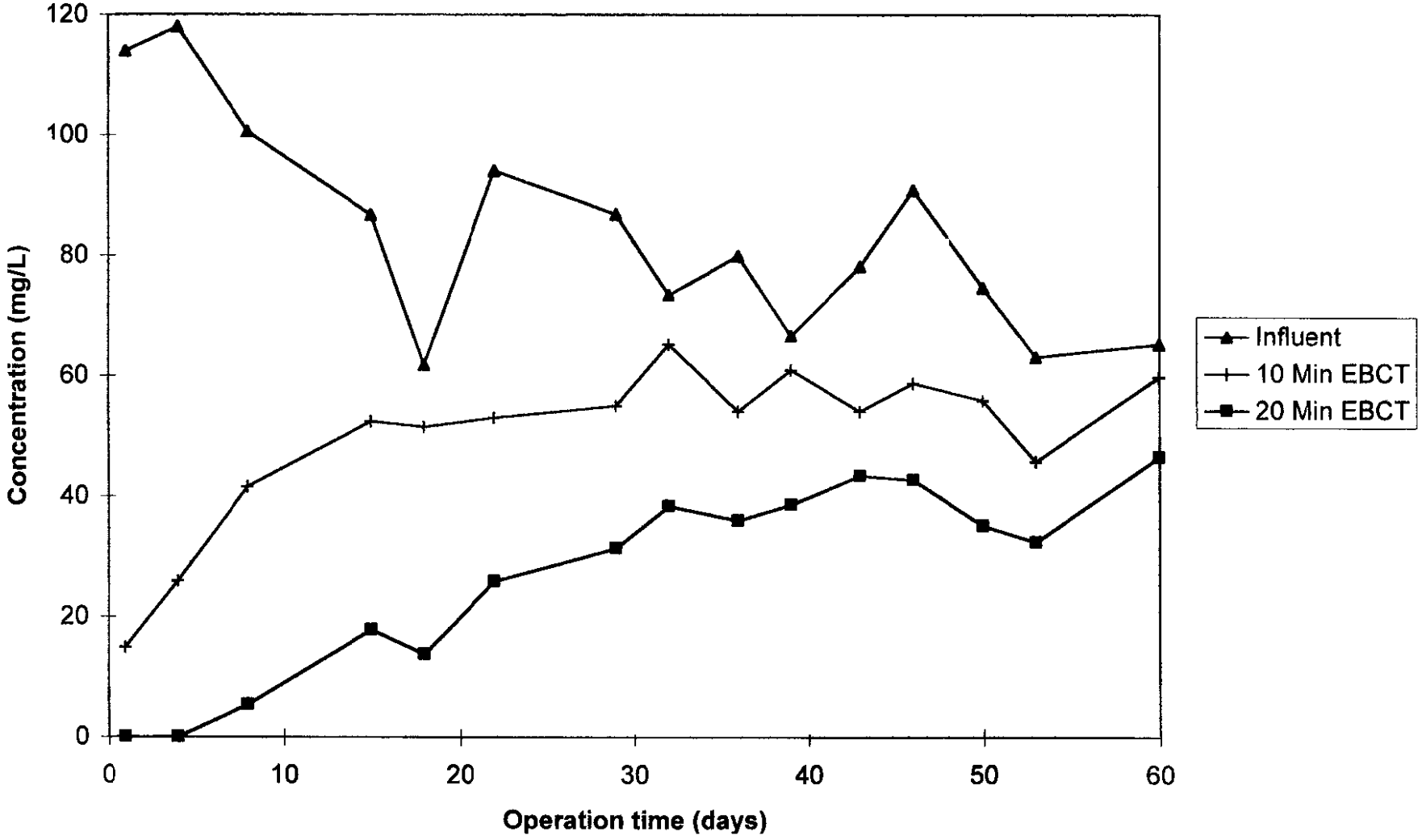
Run #2 SDS-THM4
Concentration (mg/L)
120
100
80
60
40
20
0
0
10
20
30
40
50
60
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 31

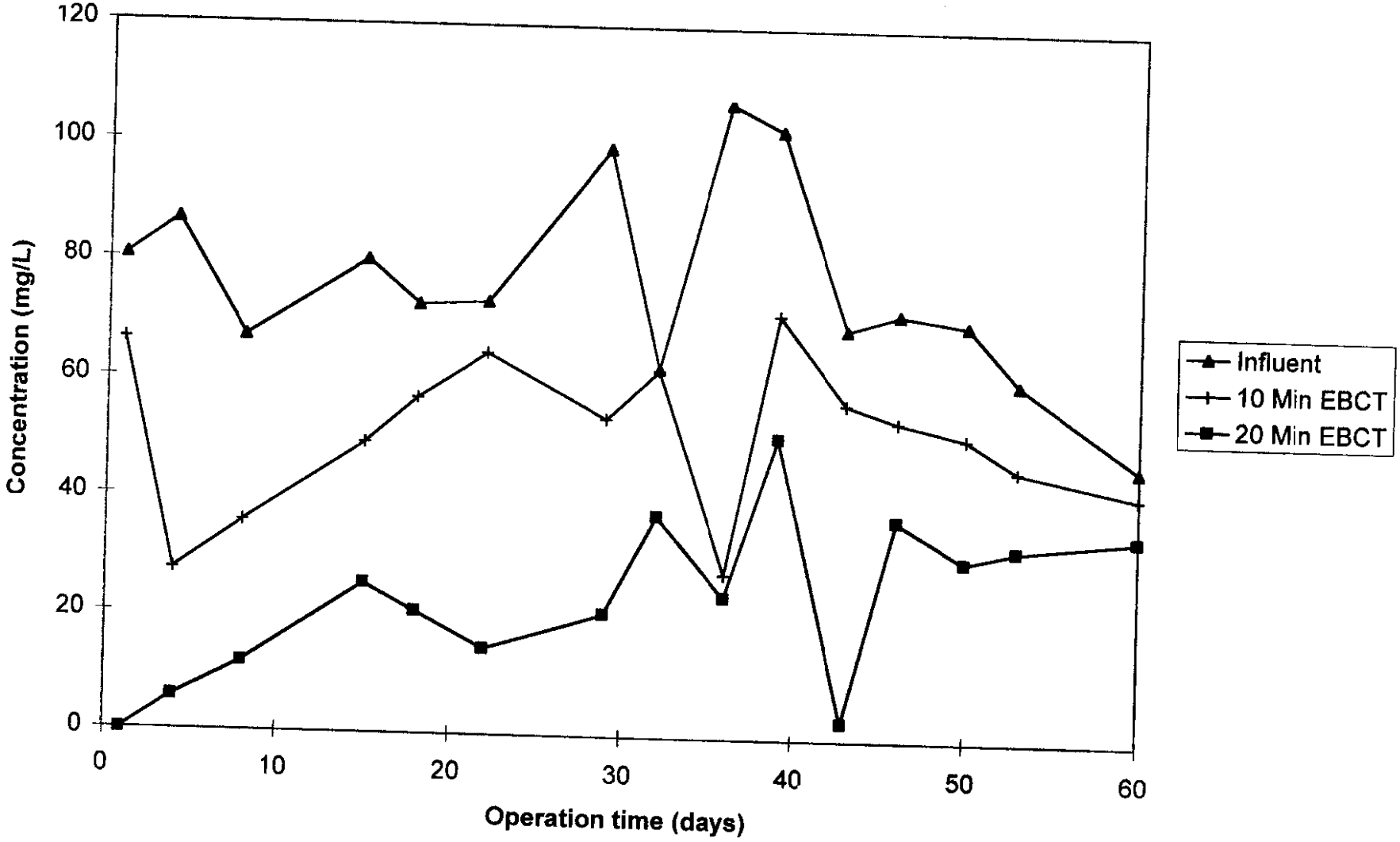
Run #2 SDS-HAA6
120
100
80
60
40
20
0
Concentration (mg/L)
0
10
20
30
40
50
60
Operation time (days)
Influent
10 Min EBCT
20 Min EBCT

Figure 32

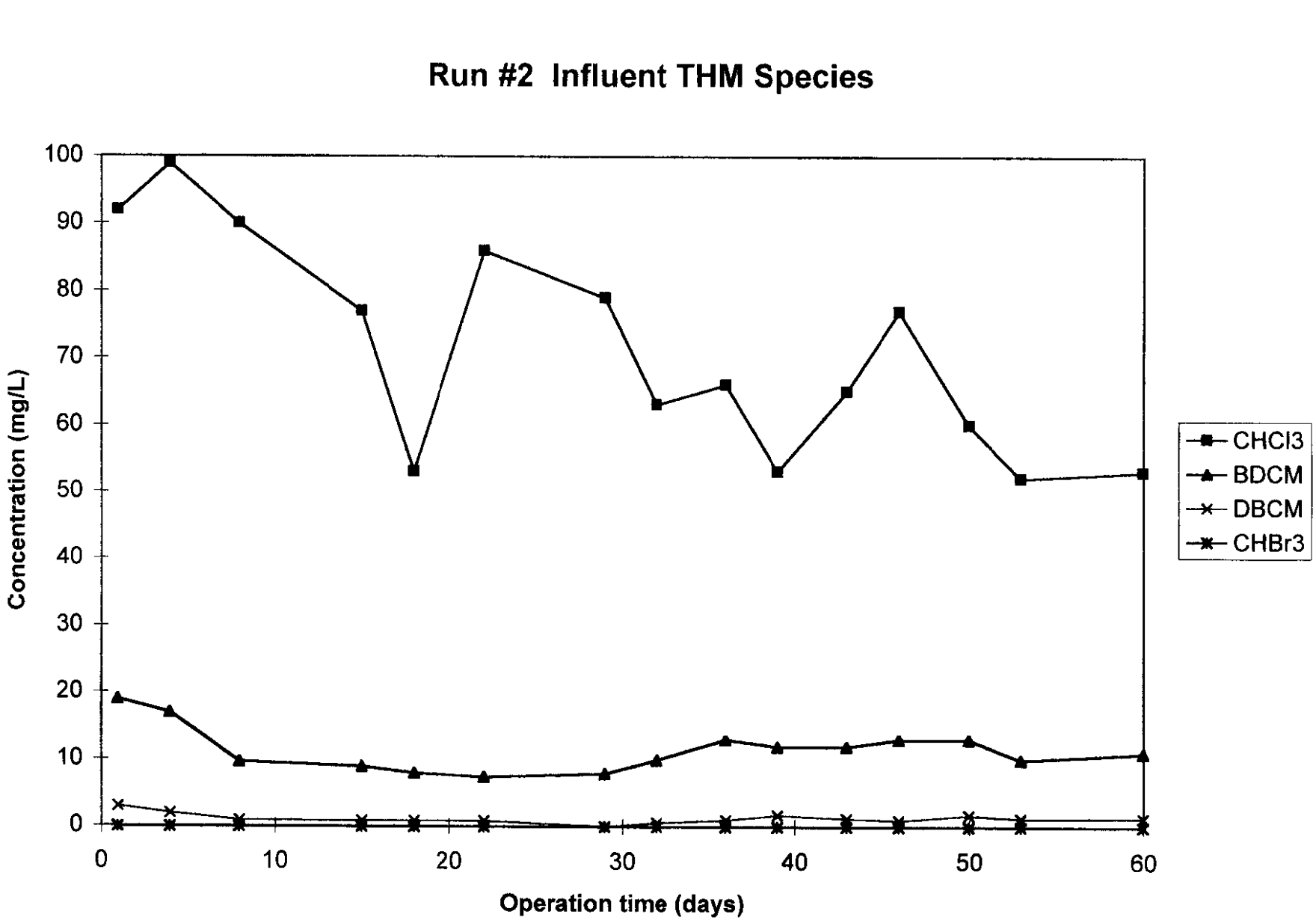
Run #2 Influent THM Species
Concentration (mg/L)
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Operation time (days)
CHCl3
BDCM
DBCM
CHBr3

Figure 33

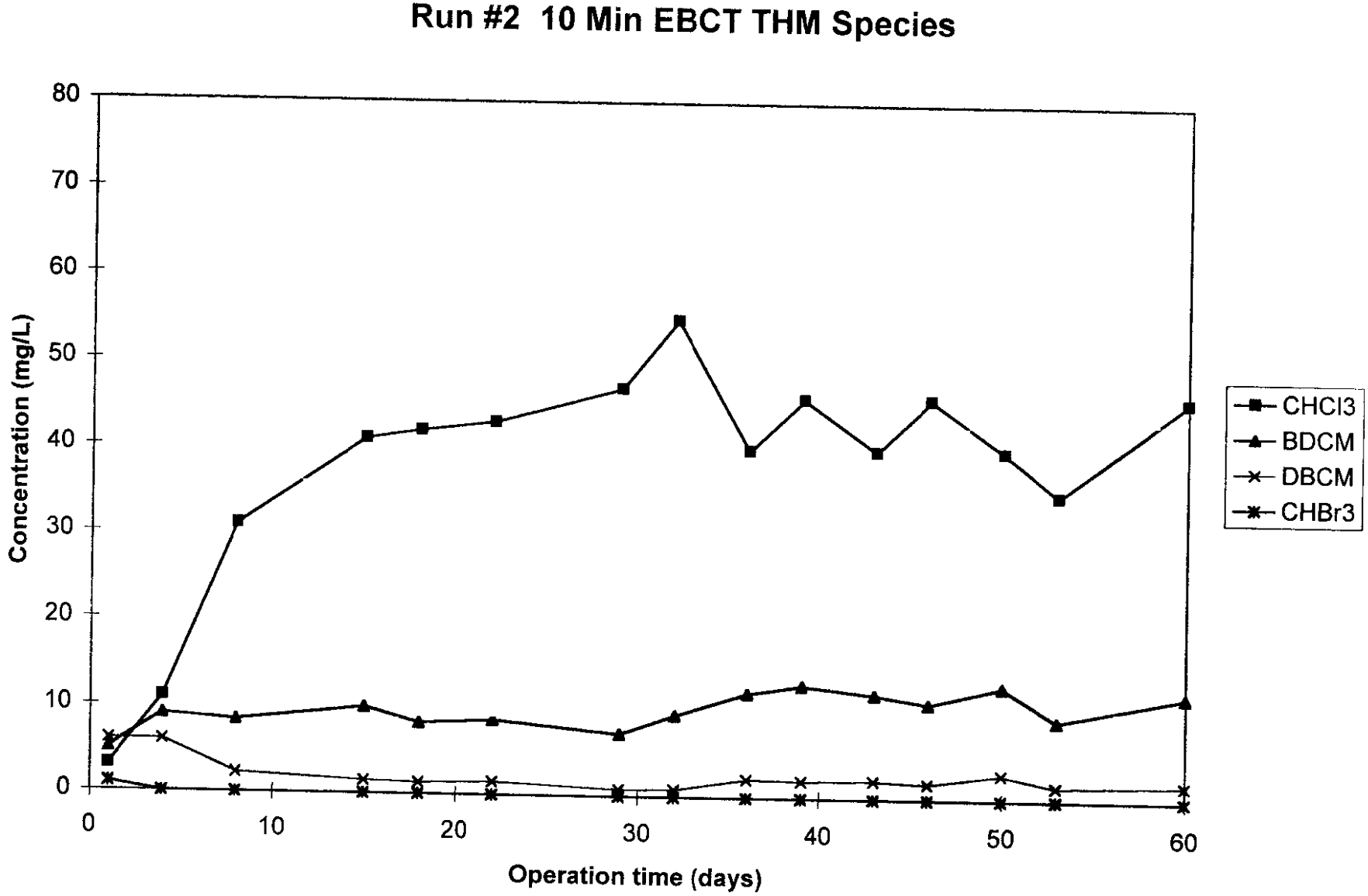
Run #2 10 Min EBCT THM Species
Concentration (mg/L)
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Operation time (days)
CHCl3
BDCM
DBCM
CHBr3

Figure 34

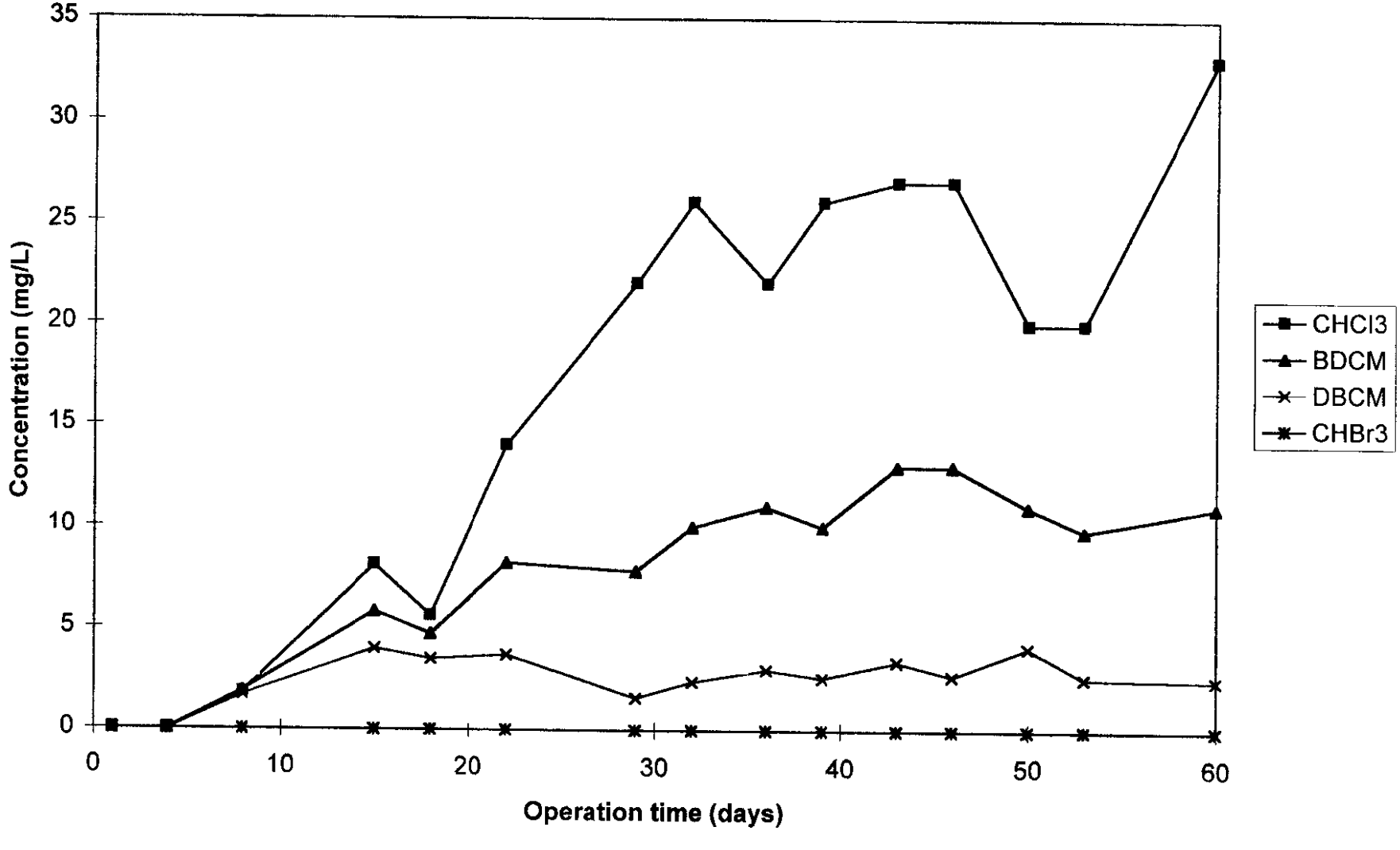
Run #2 20 Min THM Species
Concentration (mg/L)
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
Operation time (days)
CHCl3
BDCM
DBCM
CHBr3

Figure 35

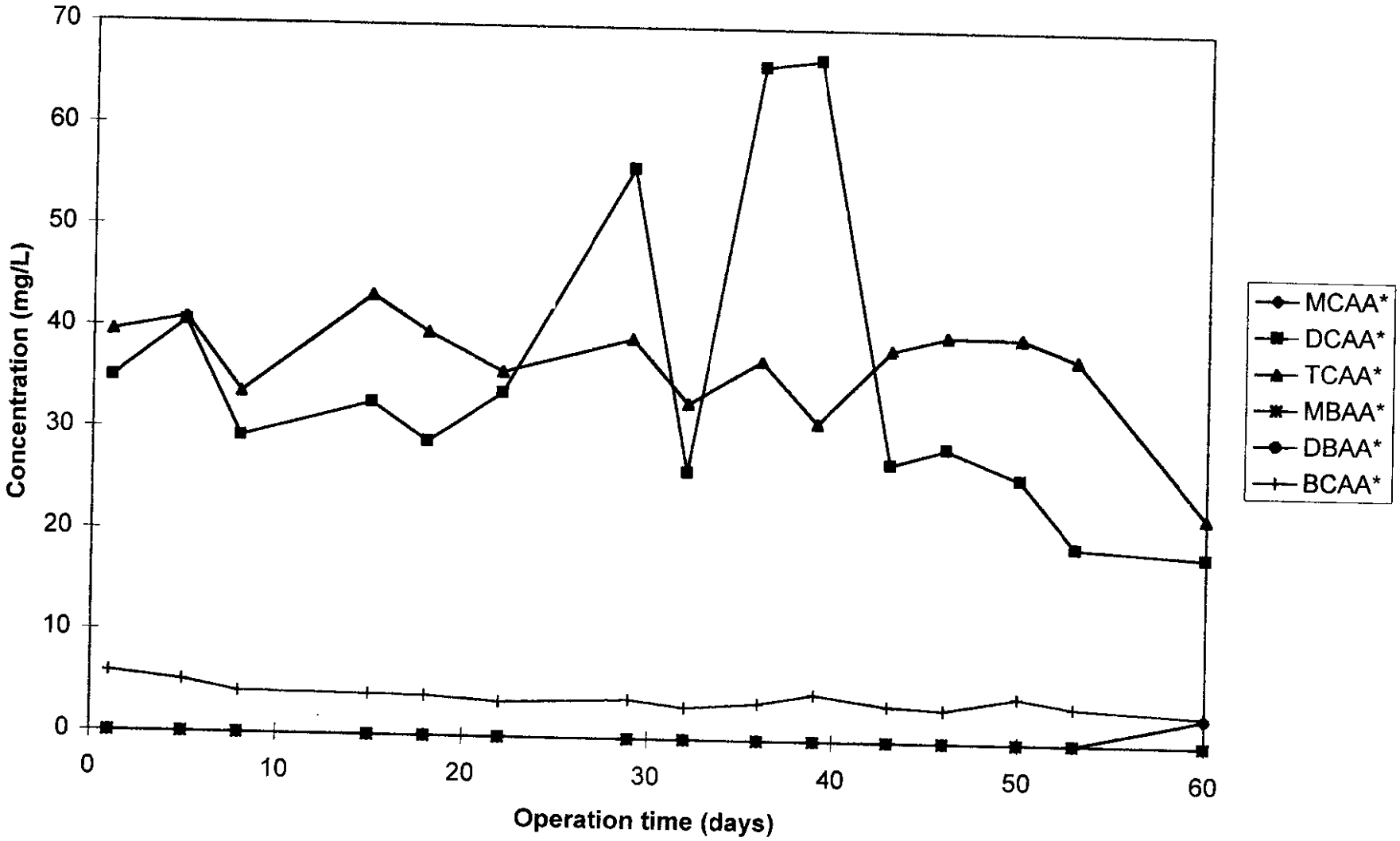
Run #2 Influent HAA Species
Concentration (mg/L)
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Operation time (days)
MCAA*
DCAA*
TCAA*
MBAA*
DBAA*
BCAA*

Figure 36

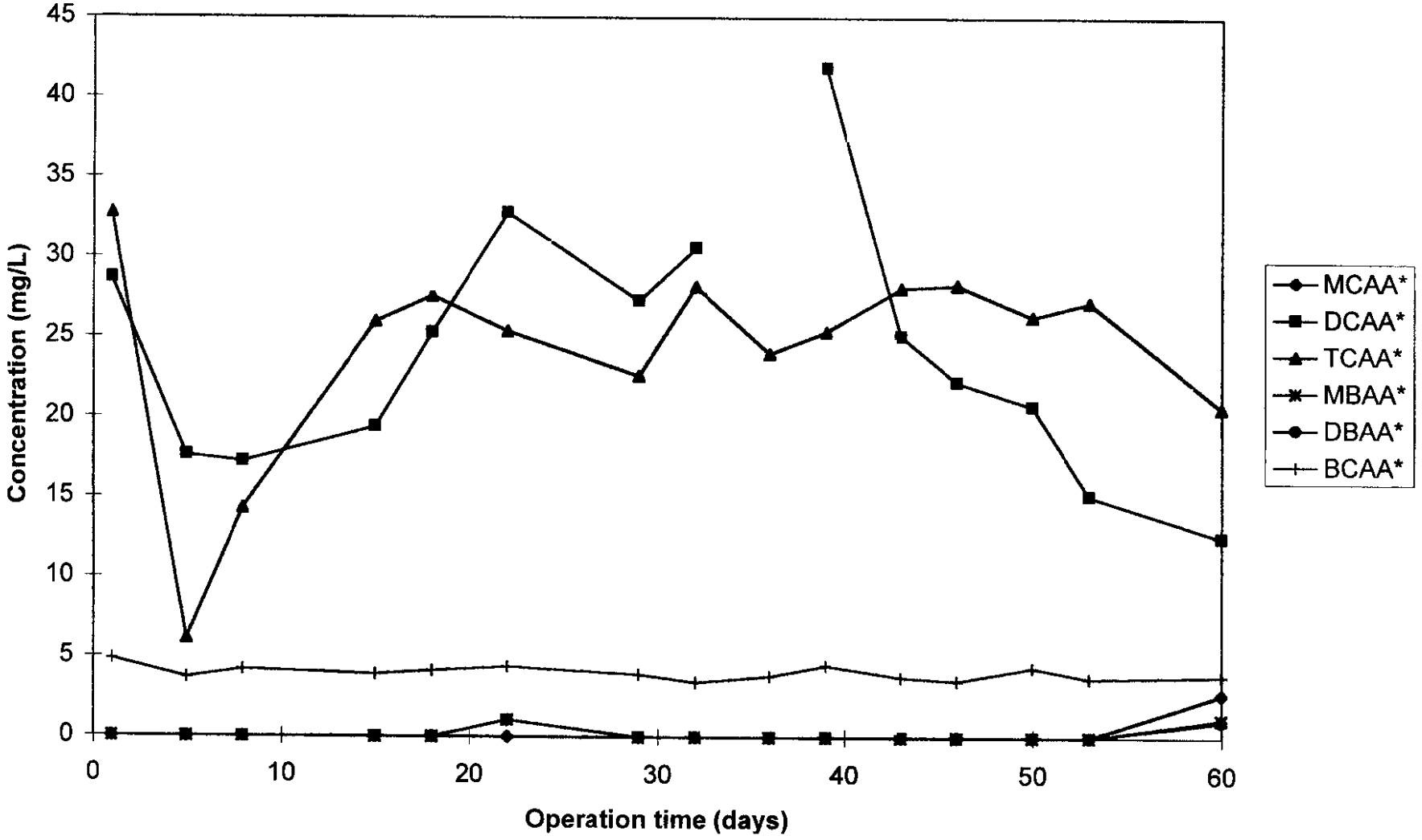
Run #2 10 Min EBCT HAA Species
Concentration (mg/L)
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
Operation time (days)
MCAA*
DCAA*
TCAA*
MBAA*
DBAA*
BCAA*

Figure 37

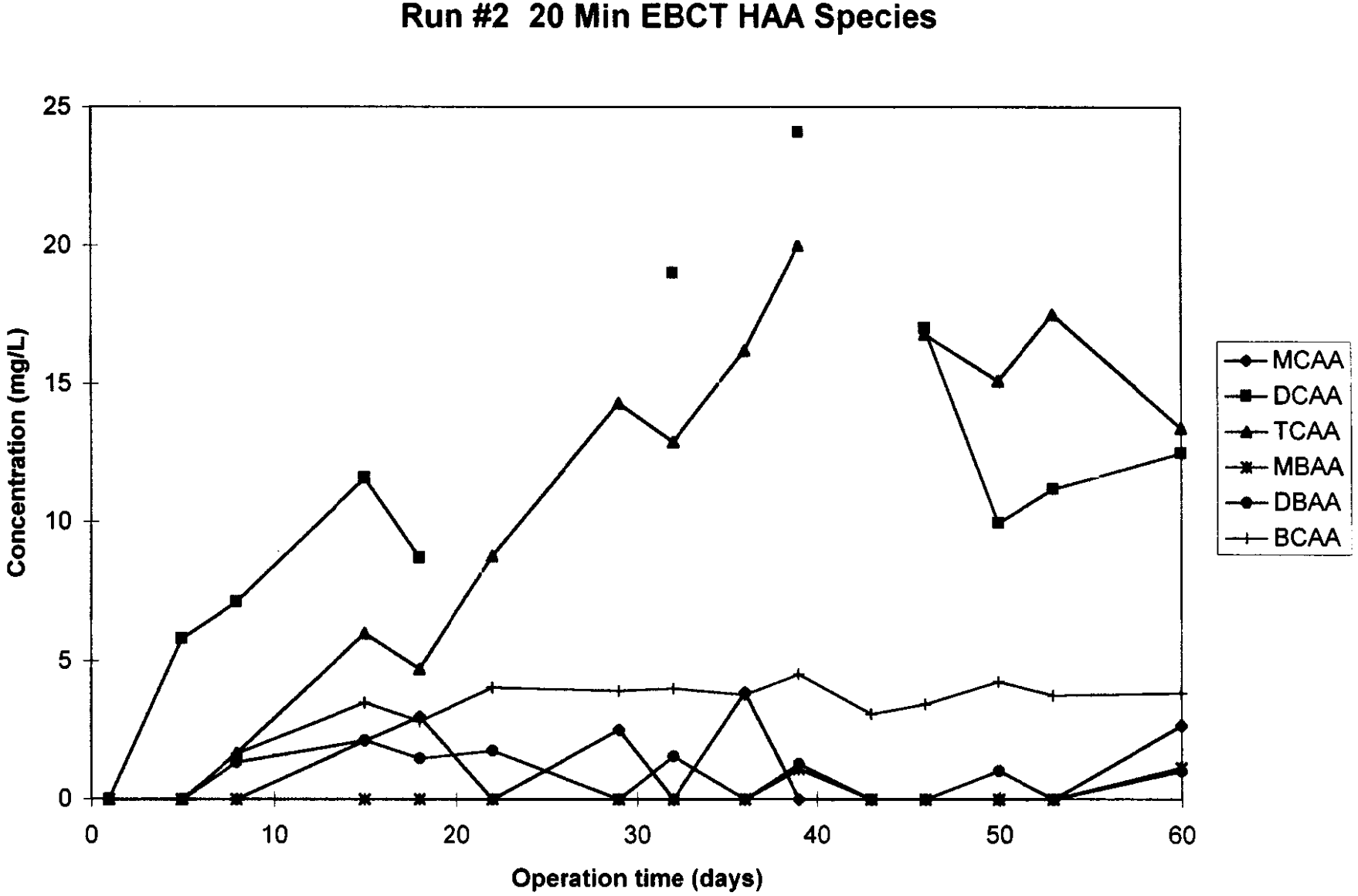
Run #2 20 Min EBCT HAA Species
Concentration (mg/L)
25
20
15
10
5
0
0
10
20
30
40
50
60
Operation time (days)
MCAA
DCAA
TCAA
MBAA
DBAA
BCAA

Figure 38

Discussion and Conclusions

Based on the findings of the Pasco County ICR treatment study it was known that disinfection would be required to control the microbial population in the source water. Both systems purchase water from the West Coast Regional Water Supply Authority. Ultraviolet light was chosen as a disinfectant since it has been shown to be effective in a variety of groundwater applications, and it does not affect DBP formation. An article by Parrotta et. al (*JAWWA*, Feb. 1998, p71) cited multiple studies on the efficacy of UV for disinfecting various microbes. However these studies did not examine the efficacy of UV disinfection on filamentous organisms. Sulfur oxidizing bacteria are similar in morphology to filamentous iron oxidizing bacteria which are common in groundwaters throughout the country. The results of the pilot study show the need for a better understanding of appropriate applications of UV technology for disinfection, especially if UV is considered a best available technology for groundwater systems.

For Run #1, one ultraviolet unit was installed. The unit was comparable to that recommended by the manufacturer for flow rates 10 times that of the pilot plant, and was identical to the one used for Pasco County's second run, where it was found to be somewhat effective in inhibiting the growth of sulfur oxidizing bacteria. In the Pasco Study, there was a five-fold increase in filter run time to breakthrough, when compared to the pilot run without UV disinfection.

According to the formulas provided by the USEPA, the expected filter run time to reach 50% breakthrough, given the source water TOC concentration was 4596 hours. Fifty percent breakthrough occurred in the 20 minute column at 696 hours (29 days) in both runs. In Hillsborough County's first run, organic carbon broke through the 10 minute column (at the 70% level) after just 696 hours (29 days) and in the 20 minute column (at the 70% level), after 1872 hours (78 days). In the second run, (where two UV systems were used in series) organic carbon broke through (at the 70% level) at 528 hours (22 days) in the 10 minute EBCT column. This was before the failure of the UV systems. In the second run, the 20 minute EBCT effluent TOC concentration did not reach 70% of the influent concentration. Instead it reached a steady-state, fluctuating between 60% and 68% of the influent concentration. The similarity in breakthrough time (to reach 50% of the influent concentration) for the first and second runs shows that once the bacteria have colonized the media, increasing the dose is not of value. This is logical since UV does not carry a disinfectant residual onto the media. A fact which is considered the one of the major limitations of this technology.

Since the natural organic matter in this groundwater was not characterized, it is impossible to say how much of the fluctuations in TOC and disinfection by-products, and early breakthrough are attributable to the nature of the organic matter and how much to microbial colonization of the media. The following tables shows that sulfide was present in the effluent and both columns.

HILLSBOROUGH COUNTY PILOT PLANT SULFIDE DATA

Date	Influent before UV	Influent after UV	After 10 min column	After 20 min column
6/16/98	0.319	0.293	0.286	0.354
6/23/98	0.302	0.301	0.291	0.361
7/7/98	0.317	0.299	0.289	0.351
7/24/98	0.302	0.297	0.285	0.352

Whether the bacteria coated the carbon grains, reducing the number of adsorption sites for the natural organic matter, or produced by-products that were preferentially adsorbed by the carbon, is speculative. The mechanism for breakthrough was beyond the scope of this study. Figure 39 shows the sulfur oxidizing bacteria identified from the pilot plant at the end of the study. Appendix 2 provides the laboratory report on organisms isolated from the plant at the end of the study.

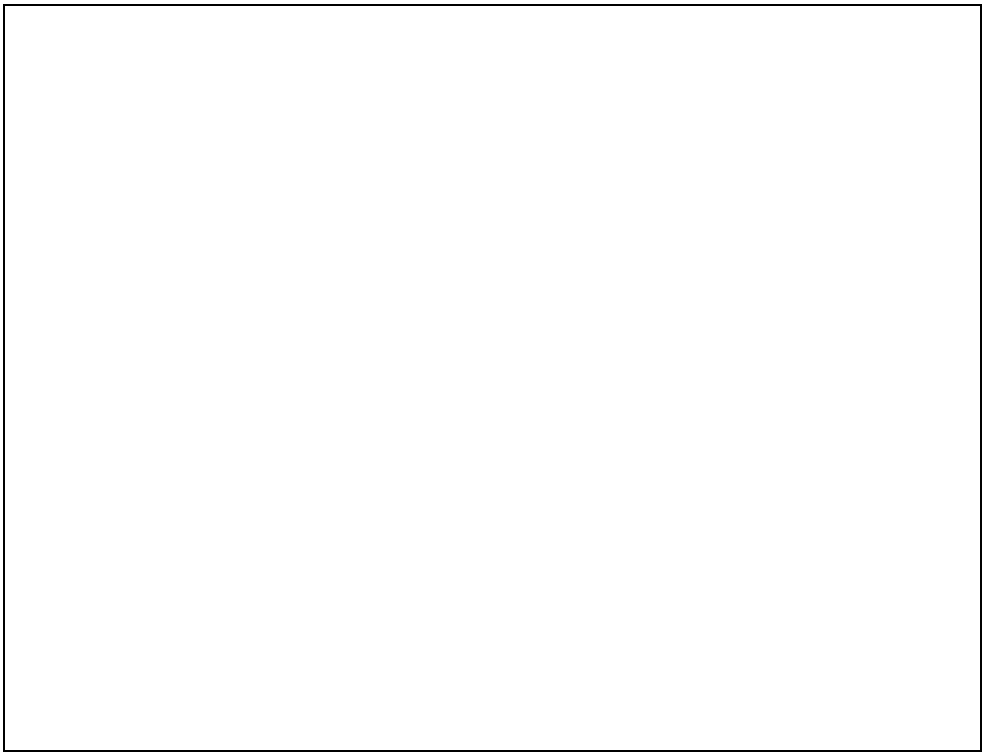

Figure 39: *Thiothrix.* CH Dianostic, Inc.

The goal of this study, which was to provide data to the EPA on removal of organic carbon and formation of disinfection by-products when GAC filtration is applied to a potable water supply, was accomplished. Additionally, in this case it is evident that GAC filtration can not be applied without pre-treatment to control the microbial population of the source water. Although GAC is capable of reducing DBP precursors, and therefore DBP formation, GAC filtration alone would not be a viable alternative for DBP control. The utility is planning on converting to chloramines for Stage I DBP Rule compliance. Future studies to evaluate operational alternatives should consider the data contained in this report.

HILLSBOROUGH COUNTY
PILOT PLANT DATA
NORTHWEST WATER TREATMENT PLANT

Spreadsheet Prepared by Juan Carlos Mercado, Camp Dresser & Mckee

Date	Time	Gage 1 (psi)	Gage 2 (psi)	Gage 3 (psi)	Flow to Date (gal)	Air Release 1	Air Release 2	Green Light on UV	Green light on UPS	Condition of UV Bulb	Comments
4/27/98	8:39	14.9	12.1	9.9	4,569.2	yes	yes	yes	yes	not checked	
4/27/98	17:00	17.0	14.0	11.9	4,616.8	yes	yes	yes	yes	not checked	
4/28/98	8:55	18.9	16.1	14.0	4,868.4	yes	yes	yes	yes	fairly clean	UV bulb cleaned
4/29/98	11:45	19.0	16.0	14.1	5,520.3	yes	yes	yes	yes	not checked	
5/5/98	9:20	21.0	19.5	16.5	8,630.3	yes	yes	no	yes	not working	plant shut down until new bulb arrives
5/6/98	13:10	19.0	19.5	17.0	8,662.3	yes	yes	yes	yes	new	restarted plant with new UV bulb @ 13:45
5/12/98	9:10	18.5	17.5	15.0	11,292.5	yes	yes	yes	yes	not checked	all filters were changed, (strong odor from filter 1)
5/19/98	9:45	18.0	17.5	15.5	14,184.0	yes	yes	yes	yes	fairly clean	white looking film developed inside of both ARV's.**
5/26/98	9:20	16.0	15.5	15.0	18,195.5	yes	yes	yes	yes	not checked	filters 1 and 2 replaced
6/3/98	9:00	18.0	16.5	15.0	24,849.5	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced
6/9/98	9:15	17.5	17.0	16.0	29,873.5	yes	yes	yes	yes	fairly clean	filters 1 and 2 replaced
6/16/98	9:30	17.0	16.5	16.0	35,724.5	yes	yes	yes	yes	not checked	sampling for sulfides was conducted (see results below)
6/23/98	9:30	17.5	16.5	16.0	41,521.5	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced
7/7/98	9:30	17.0	16.0	16.0	47,071.5	yes	yes	yes	yes	not checked	filters 1 and 2 replaced
7/14/98	9:30	17.5	16.5	16.5	54,021.5	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced
7/21/98	10:30	19.3	16.5	14.0	64,880.0	yes	yes	yes	yes	not checked	J. Mercado will measure sulfide levels on 7/24/98
7/28/98	9:30	18.5	16.5	16.0	71,885.5	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced
8/4/98	9:30	18.0	17.0	16.5	77,137.0	yes	yes	yes	yes	not checked	filters 1 and 2 replaced
8/11/98	9:30	18.5	17.0	17.0	82,395.5	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced
Second Half of Sampling Period											
9/14/98	10:00	22.5	20.0	18.0	563.5	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced, UV 1 and 2 cleaned
9/17/98	9:00	22.0	19.5	18.0	2,715.0	yes	yes	yes	yes	not checked	filters 1 and 2 replaced
9/21/98	9:00	21.0	20.0	19.0	5,585.0	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced, UV 1 and 2 cleaned
9/24/98	9:00	22.0	19.5	19.0	6,680.0	no	no	yes	yes	not checked	hose going out of UV # 2 had to reconnected. No samples were taken
9/28/98	9:30	21.0	20.5	19.5	9,680.0	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced, UV 1 and 2 cleaned
10/1/98	9:30	21.0	20.0	19.5	11,840.0	yes	yes	yes	yes	not checked	filters 1 and 2 replaced
10/5/98	10:30	19.0	19.0	18.5	14,840.6	yes	yes	yes	yes	fairly clean	filters 1 , 2 and 3 replaced, UV 1 and 2 cleaned
10/8/98	9:30	19.0	19.0	18.5	17,084.5	yes	yes	no	no	Not Working	plant shut down
10/9/98	15:00	19.0	18.5	18.5	17,085.5	yes	yes	no	no	Not Working	plant restarted w/o UV system
10/12/98	9:30	19.0	19.0	18.5	20,113.0	yes	yes	no	no	Not Working	filters 1 and 2 replaced
10/15/98	9:30	21.0	20.5	19.5	20,833.0	yes	yes	no	no	Not Working	filter 3 replaced
10/19/98	9:30	19.0	19.0	18.5	23,780.0	yes	yes	no	no	Not Working	filters 1 and 2 replaced
10/22/98	9:45	19.0	18.5	18.5	25,930.0	yes	yes	no	no	Not Working	filters 1 and 2 and 3 replaced
10/27/98	9:15	19.0	18.5	18.5	29,580.0	yes	yes	no	no	Not Working	filters 1 and 2 replaced
10/29/98	9:20	20.0	19.5	18.5	31,040.0	yes	yes	yes	yes	clean	UV system restarted with new equipment, all filters repaiced
11/2/98	9:15	20.0	19.0	19.0	33,290.0	yes	yes	yes	yes	fairly clean	filter 3 replaced
11/5/98	9:30	19.0	19.0	19.0	35,110.0	yes	yes	yes	yes	not checked	filters 1 and 2 replaced
11/12/98	9:20	19.5	19.0	19.5	40,150.5	yes	yes	yes	yes	fairly clean	Pilot plant last sampling event

Filter 1= Influent filter
Filter 2 = Filter after UV
Filter 3 = Filter after 20 min column
** = Filters 1 and 2 changed

APPENDIX 2

CED Diagnostic
& CONSULTING SERVICE, INC.

MEMO

To: Charlotte Smith

From: Tricia Klonicki

Date: Wednesday, November 4, 1998

Subject: Organism identification

Charlotte -

The following algae were observed in the samples: cyanophytes - *Lyngbya* and *Oscillatoria* and pennate diatoms - *Nitzschia*. The red colored areas were the result of a bacteria.

Following are the results of Dr. Donald Klein's analyses:

> Type II *Thiothrix* - based on presence of narrow (<1.2 µM) long filaments, which contained elemental sulfur granules and which were attached by holdfasts to the interior of floc materials. Also gonidia were observed to be present on the ends of several of the filaments.

Please call if you have any questions.

14 S.E. Nineteenth Street ● Loveland, CO 80537 ● PH: 970.667.9789 ● FAX: 970.667.9719