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Thomas Peters

V. Dean Adams

Dennis B. George

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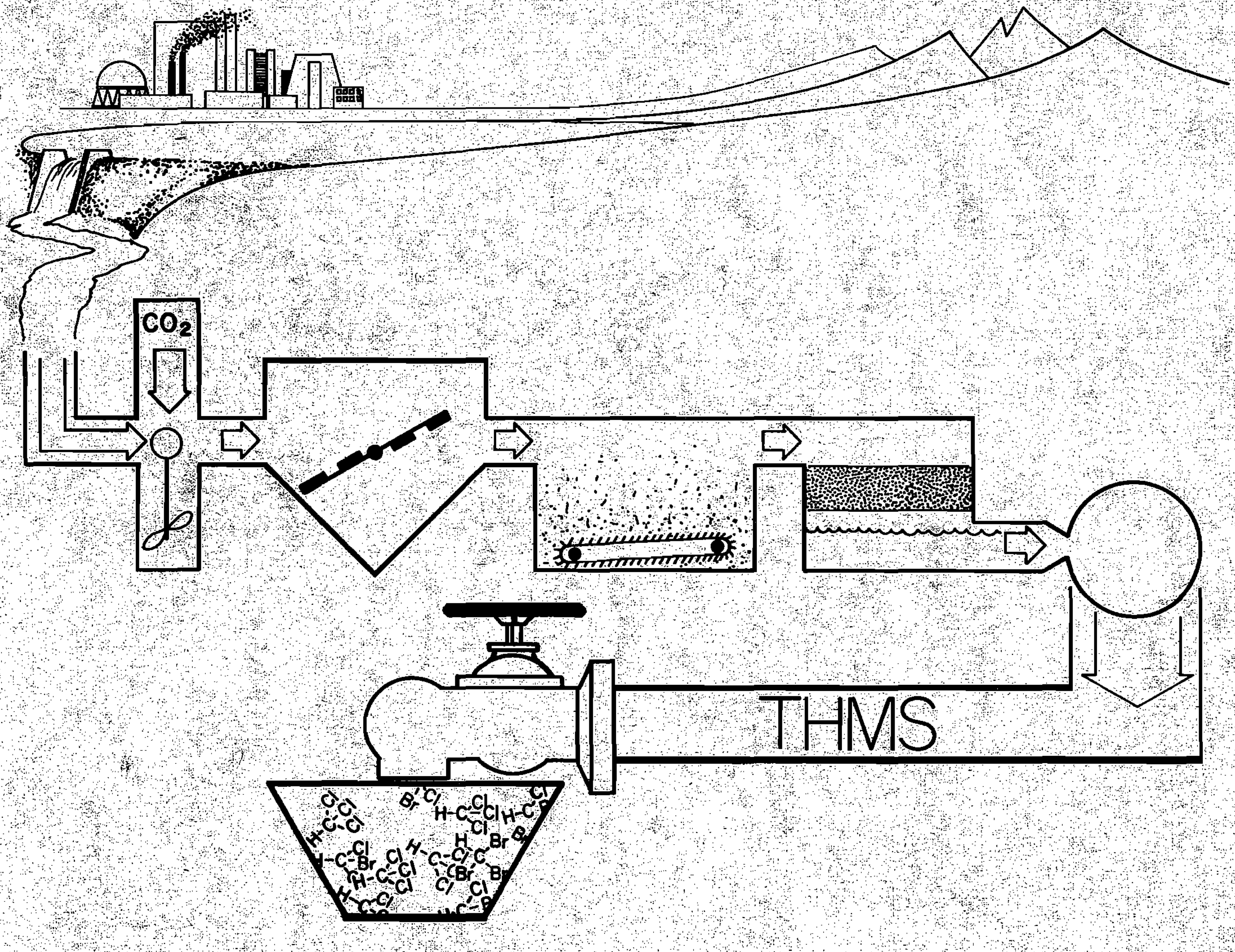

Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, Utah 84322

December 1981

WATER QUALITY SERIES
UWRL/Q-81/05

THE OCCURRENCE OF TRIHALOMETHANE COMPOUNDS IN SALT LAKE CITY AND OGDEN, UTAH, DRINKING WATER SUPPLIES

by

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ABSTRACT

A purge and trap, gas chromatography system was developed to analyze for trihalomethane (THMs) compounds at the ppb (parts per billion) level in drinking water. Monthly influent and effluent samples were taken from three Weber Basin Water Conservancy District treatment plants, three Salt Lake City water treatment plants, and one Salt Lake Metropolitan water treatment plant. In addition tap water samples were taken at various business and residential locations in Salt Lake City, Utah, and Ogden, Utah. All samples were analyzed for trihalomethanes and total organic carbon (TOC). In addition to monthly sampling, a comparison of the production of THMs during post and prechlorination of water at the Parleys Water Treatment Plant in Salt Lake City was conducted. Moving the point of chlorination within the treatment plant did not appear to reduce trihalomethane levels in the finished product. Highest trihalomethane levels (84 µg/l) occurred in the summer months with the lowest levels (<1 µg/l) recorded in the winter.

The chemical form of the THMs varied from chloroform to the more brominated hydrocarbon from late winter through spring.

ACKNOWLEDGMENTS

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The authors would also like to acknowledge the excellent cooperation and valuable technical assistance of Mr. Robert Hensley, Superintendent of treatment plants, Weber Basin Water Conservancy District; Mr. James F. Robinson, Superintendent, Ogden City Water Department; Mr. Richard Sherwood, Superintendent, Salt Lake City Water Department; Mr. Vaughn B. Wonnacott, General Manager, Metropolitan Water District of Salt Lake City; Mr. Richard Nelson, operator, Little Cottonwood Water Purification Plant; and Mr. Ron Lee, operator, Parleys Water Purification Plant.

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INTRODUCTION

The widespread practice of chlorinating potable water supplies in the United States has been found to be responsible for the production of chlorinated organics, with particular attention having been given the trihalomethanes (Figure 1) (Trussell and Umphres 1978). The trihalomethanes (chloroform, dichlorobromomethane, dibromochloromethane, and bromoform) found in water systems have been linked to elevated cancer cases. Chloroform (the most common trihalomethane) is a proven carcinogen (Cotruvo and Wu 1978).

Trihalomethanes in drinking water supplies are formed by the reaction of chlorine (used to disinfect against biological contamination) with certain naturally occurring organic precursors (Rook 1974). These organic precursors are probably complex alkali-soluble compounds such as fulvic and humic acids (Rook 1974; Oden 1919).

Recent United States Environmental Protection Agency (USEPA) regulations specify a 100 µg/l total trihalomethane limit in culinary water serving communities with 10,000 residents or more (Federal Register 1979). Methods of treatment to stay within this 100 µg/l maximum contaminant level (MCL) include using granular activated carbon as the filter media at water treatment plants (the most costly removal method), using alternate disinfectants such as ozone, or moving the point of chlorination towards the end of the treatment train thereby chlorinating smaller quantities of the precursors (Siemak et al. 1979).

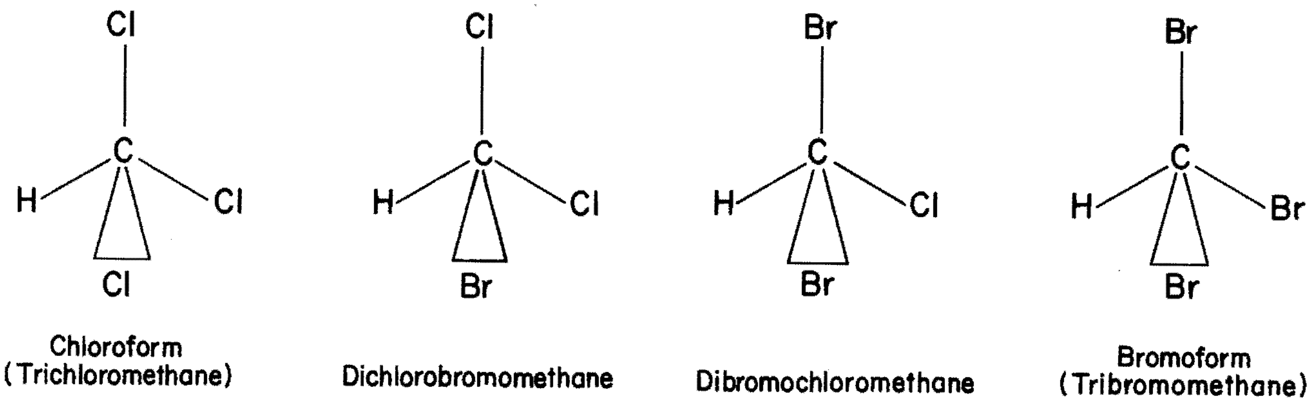

Figure 1. The four trihalomethanes.

OBJECTIVES

The overall objective of this study was to evaluate the presence of trihalomethanes in drinking water distributed in Ogden City and Salt Lake City, Utah, to determine whether the regulatory limits were being exceeded and what should be done to deal with any identified problems.

The following specific objectives of the study were accomplished:

1. Develop the necessary instrumentation to detect the four trihalomethanes (chloroform, dichlorobromomethane, dibromochloromethane, and bromoform) at the 1 μg/l detection level and subsequently certify the Utah Water Research Laboratory with the USEPA for the analysis of total trihalomethanes (TTHMs).

2. Begin monthly sampling of the drinking water plants serving the cities of Salt Lake and Ogden and simultaneously begin sampling of additional selected sites throughout these cities.

3. Investigate methods of reducing the levels of TTHMs in the affected areas.

4. Determine, based on the data collected, if Salt Lake City and Ogden will meet the USEPA proposed 100 μg/l THMs regulation.

LITERATURE REVIEW

Definitions

The following definitions, based on the literature reviewed, are used in this study.

1. Trihalomethanes (THMs) - The four trihalomethanes that require monitoring under EPA's regulation are chloroform, dichlorobromomethane, dibromochloromethane and bromoform. Iodinated trihalomethane compounds are not included.

2. Total trihalomethanes (TTHMs) - The sum in μg/l of all trihalomethanes found in a given sample.

3. Instantaneous total trihalomethane (inst-TTHM) - As long as free chlorine and trihalomethane precursors are present in the water, additional trihalomethanes will continued to be formed. The inst-TTHM is the total trihalomethane measured if the collected sample is immediately preserved by adding sufficient ascorbic acid or sodium thiosulfate to quench the free chlorine present and prevent further trihalomethane formation. This is the test used to determine whether a sample meets the 100 μg/l MCL established by the EPA.

4. Seven-day total trihalomethane (7-day TTHM) - The TTHM measured when samples are not preserved but stored at 25°C for 7 days before analyzing to allow the free chlorine present to react completely with the precursors.

5. Maximum trihalomethane potential (MTP) - This test, also referred to as the terminal total trihalomethane test (term-TTHM) involves rechlorination of unpreserved samples to 15 mg/l of chlorine. The samples are then stored for 7 days at 25°C. After 7 days, a free chlorine residual must be present before the test is valid and the sample analyzed (Federal Register 1979).

Literature Reviewed

One of the major health advances of this century has been the great reduction in the incidence of waterborne diseases through the practice of chlorinating potable water supplies. Chlorination, however, can cause the formation of potentially dangerous organic compounds in drinking water supplies. The problem became well known through a series of articles by the Environmental Defense Fund linking cancer mortality in New Orleans to organic contaminants (Harris and Breecher 1974). The ensuing controversy generated by these reports prompted the United States Environmental Protection Agency (USEPA), at the request of local authorities, to examine these findings. On November 8, 1974, the USEPA released its report confirming the existence of 66 organic chemical compounds in New Orleans' potable water supply (USEPA 1974). The report was made public just two days after release of another report citing drinking water supplies as the prime suspect in many cancer related deaths in New Orleans (Environmental Defense Fund 1974). The two reports generated widespread public reaction both in and out of the scientific community (Marx 1974). Some authors were skeptical of the statistical information presented and felt a much more comprehensive risk assessment would be required (DeRoven and Diem 1975) to reach firm conclusions. Later the Environmental Defense Fund conceded that "Statistical studies by themselves cannot establish causality" (Page et al. 1976). Actual risk assessment has been difficult (Stokinger 1977; National Academy of Sciences 1977; Jolly 1978; Federal Register 1979); but caution seems justified, at least from the USEPA's point of view. Furthermore, the problem of chlorinated organics in drinking water is not peculiar to the New Orleans area (Cotruvo and Wu 1978). In order to determine the extent of the problem the first nationwide survey of organics in drinking water supplies was undertaken and confirmed the existence of varying concentrations of 1,2 dichloroethane, carbon tetrachloride, and four trihalomethanes (chloroform, bromoform, dichlorobromomethane, and dibromochloromethane) in 80 U.S. public water supplies (Symons et al. 1975). Later a second major nationwide study was conducted in 113 cities to examine the trihalomethane problem further (USEPA 1978b). In both studies, it was demonstrated that the trihalomethanes (THMs) were by far the most frequent organic contaminant. The evidence was sufficient to prompt the USEPA to propose a 100 μg/l maximum contaminant level (MCL) on the THMs in communities greater than 10,000 in population (Federal Register 1979).

The formation of trihalomethanes appears to be a direct result of chlorinating raw water supplies at drinking water treatment plants (Bellar et al. 1974). Naturally occurring alkali-soluble organic compounds that impart a color to the water are the suspected precursors (Rook 1974). These compounds (also referred to as "yellow acids" and "humus") are divided by molecular size into three groups: fulvic acids (molecular weight less than 1000), hymatamelanic acids (molecular weight between 1000 and 100,000), and humic acids (molecular weight greater than 100,000) (Oden 1919). Several studies have indicated that the heavier humic acids produce higher yields of chloroform than the lighter fulvic acids (Babcock and Singer 1977). Rook (1976) contends that fulvic acid, which imparts color to the source water, is primarily responsible for haloform formation.

Further analysis indicated that the sites on these smaller molecular weight compounds most susceptible to halogenation are the meta dihydroxylated benzene moieties (Rook 1977). Figure 2 illustrates the proposed mechanism, indicating that a hydroxide ion is necessary to initiate the reaction at "1" and suggesting that elevated pH favors haloform formation (Rook 1976, 1977). More recent investigation utilizing model humic derivatives suggests that orcinol, resorcinol, 3,5-dihydroxybenzoic acid, 3-methoxy-4-hydroxycinnamic acid, and 3,5-dimethoxybenzoic acid produce chloroform as the major product upon chlorination (Norwood et al. 1980). Recent literature has indicated that organics derived from lysed cells of green algae and blue-green algae upon chlorination may produce higher molar yields of THMs than reported for model humic compounds (Hoehn et al. 1980).

The occurrence of THMs appears to be a function of 1) time, 2) pH, 3) bromide concentration, 4) chlorine addition, and 5) temperature. Samples stored for a period of time have somewhat higher total trihalomethane (TTHMs) concentrations than samples analyzed immediately after chlorination. Thus an instantaneous TTHM (inst-TTHM) test (using ascorbic acid or thiosulfate as a preservative) and a maximum trihalomethane potential (MTP) test (samples rechlorinated and stored for 7 days at 25°C) are both used. The difference between the inst-TTHM and the MTP is referred to as the "haloform potential" of the sample (Stevens and Symons 1977, Federal Register 1979).

The effect of pH is also important. Work done at the Contra Costa County Water District in California reports that reducing the pH level from 9.0 to 7.0 may reduce TTHM formation by as much as 50 percent (Lange and Kawoczynski 1978). This may be due, as

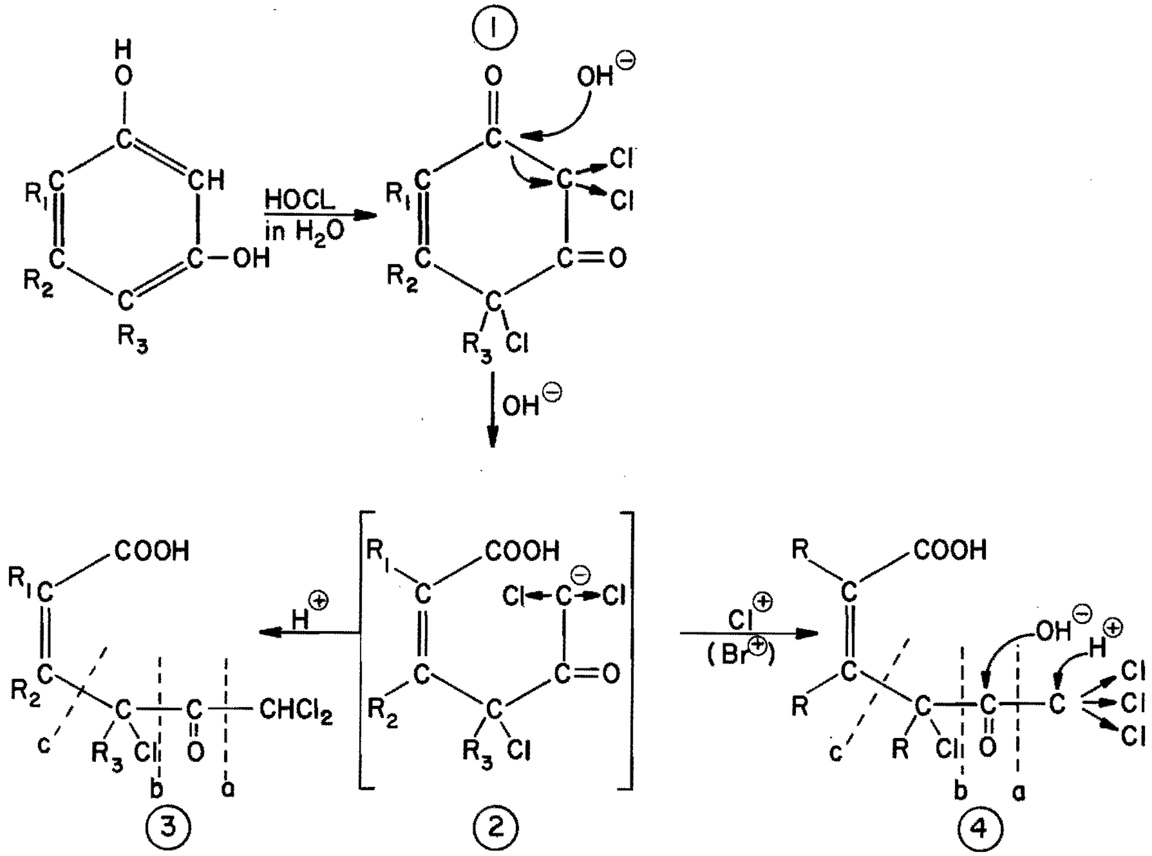

Figure 2. Proposed degradation pathways of fulvic acids and resorcinol (Rook 1977).

indicated previously, to a lower concentration of the OH ions necessary to activate the proposed haloform reaction (Rook 1976).

Besides time and pH, the bromide concentration of the source water may play an important role in haloform formation (Kleopfer 1976). It appears that an increase in bromide concentration results in TTHM levels far above that for an equivalent increase in chlorine dosage (Lange and Kawoczynski 1978). Apparently, in the presence of chlorine, bromide is oxidized to active intermediates such as Br_2, HOBr, OBr^-, and BrCl. These brominated intermediates have greater kinetic rates than chlorine intermediates thereby producing elevated levels of the brominated trihalomethanes and a marked reduction of chloroform (Carpenter and Macalady 1978; Trussell and Umphres 1978).

Chlorine dosage appears to be an important factor only up to the point at which a residual is maintained. Since TTHMs is a function of precursor concentration once a residual is established, it is assumed that the TTHMs level will remain the same regardless of the chlorine dosage above that residual (Stevens and Symons 1977). Temperature, as in other chemical reactions, simply accelerates the trihalomethane rate of reaction (Stevens and Symons 1977).

The proposed regulations governing the control of THMs imply required installation of granular activated carbon (GAC) for filtration in drinking water treatment plants serving over 10,000 population and failing to meet the 100 µg/l TTHMs limit (Federal Register 1979). Although GAC filtration may be 60 to 90 percent effective in reducing TTHMs and total organic carbon, its costs are staggering. A typical utility serving 1,000,000 people would require capital expenditures of nearly $6,900,000 (1981 dollars) increasing annual per capita treatment costs by $6.90 (Gillies 1978).

There are alternatives to the use of GAC filters in drinking water treatment plants. Coagulants can reduce total organic carbon (TOC) levels in water. Sedimentation of chemical floc followed by chlorination (post chlorination) appears to be very effective in reducing effluent THMs formation (Babcock and Singer 1979; Kavanaugh 1978; Kavanaugh et al. 1980; Oliver and Lawrence 1979). In addition to optimizing coagulation practices and post-chlorinating, the use of a pretreatment oxidant such as potassium permanganate may reduce trihalomethanes by oxidizing the precursors (Singer et al. 1980).

Reduction of TTHMs in drinking water supplies may also be accomplished by use of an alternate disinvectant. The substitution of chloramines as a disinfectant reportedly reduces TTHMs by 75 percent but does not appear to be as effective a disinfectant (Norman et al. 1980). Under the proposed federal regulations (Federal Register 1979), chloramines cannot be used as the primary disinfectant and thus must be used in conjunction with chlorine. Chlorine dioxide, another disinfectant, may be used as a primary disinfectant and appears to result in TTHM formation as much as 90 percent less (Blanck 1979; USEPA 1978a).

One alternative for disinfection is the use of ozone. With an oxidation potential of 2.07 V, only fluorine, among the water treatment additives, is greater in oxidative strength (Rice et al. 1981). Ozone must be generated on site, a process usually accomplished by the discharge of 5,000 V to 30,000 V between electrodes separated by an electric layer through which a flow of air or oxygen is passed (Weber 1972). Heat favors the decomposition of ozone back to oxygen thus a cooling system must be employed to increase the overall efficiency (Metcalf and Eddy 1979).

Because of its oxidative capacity, ozone is unsurpassed for bacterial and viral inactivation (Weber 1972). Bactericidal destruction by ozone occurs over a very short period of time (2-5 min.), and any remaining ozone is gone within 7 or 8 minutes (AWWA Committee Report 1978). Further, ozone's bactericidal action is little affected by changes in temperature. Weaker oxidants such as chlorine depend upon longer contact time and higher concentration for the same kill rate (Rice et al. 1981). Recent studies have also shown that a free ozone residual of 0.05 to 0.45 mg/l was sufficient to inactivate poliovirus within 2 minutes while free chlorine residuals of 0.5 to 1.0 mg/l at pH 6.9 required 1.5 to 2.0 hours for the same virus inactivation (Farooq et al. 1977). Ozone as a disinfectant has the disadvantage of not leaving a residual; therefore chlorine is generally also added as the terminal disinfectant but in concentrations much less than normally used (Trussell and Umpres 1978). Recent studies have shown, however, that ozone can be used as the sole disinfectant if the following criteria are met (Miller et al. 1978).

1. The distribution system is short and the residence time of treated water in the system is also short.

2. Ammonia is absent and dissolved organic carbon is less than 0.2 mg/l.

3. The temperature of the treated water is low, so as to reduce the potential of bacterial regrowth.

The recent concern over chlorinated organics (particularly trihalomethanes) in drinking water has made ozone more attractive as a disinfectant. Ozonation as a sole disinfectant does not produce trihalomethanes (Siemak et al. 1979). Ozonation of a raw water source followed by a small chlorine dose (post chlorination) reduces TTHMs if the water is at or below pH 8.0 (Riley et al. 1978). The process of using ozone as a "predisinfectant" to chlorine addition appears to lower trihalomethane levels by oxidizing the precursors (Carns and Stinson 1978; Barnett and Trussell 1978).

The use of ozone as a pretreatment to oxidize organic compounds, however, has other problem by-products. Ozonation of alcohols (ethanol) produced materials with mutagenic activity that can be associated with hydroperoxide formation (Simmon and Spanggord 1979). Humic acids when exposed to ozone tend to form carboxylic acids whose further reactivity in the treatment process has not been established (National Academy of Sciences 1979). Additional studies involving ozonation of fulvic and humic acids report formaldehyde and formic acid as common by-products (Powell 1977). A more serious problem occurs with ozonation of pesticides, particularly Parathion and Malathion, whose by-products (OXONS) are more toxic than the original starting compounds (National Academy of Sciences 1979).

Another and more prohibitive problem with ozonation is cost. Ozonation (plus residual disinfectant) for systems serving over one million in population would need initial equipment capital expenditures of 9.6 million dollars with an annual per capita cost range of $.63 to $1.50. This is much more expensive than chlorination per capita costs of $.45 to $.75 with no initial capital expenditures (1981 dollars; Gillies 1978).

MATERIALS AND METHODS

Trihalomethane Analysis

To analyze for the four trihalomethanes (chloroform, dichlorobromomethane, dibromochloromethane, and bromoform) at the μg/l level, a system incorporating an organics concentration step followed by gas chromatography utilizing an electron capture detector was required. Figure 3 indicates the flow diagram for this procedure. The TEKMAR LSC-1[1] liquid sample concentrator was used for the concentration of the trihalomethanes from drinking water samples, and a HEWLETT PACKARD[2] 5750 gas chromatograph with a Ni^{63} electron capture detector was used to determine the trihalomethanes.

The procedure followed was stepwise:

1) Using the TEKMAR Concentrator, a 5 ml aliquot of sample was purged for 12 minutes with nitrogen gas at a rate of 30 ml/min. This step strips the volatile organics from the water sample and deposits them onto a 15.24 cm by 0.32 cm diameter column packed with TENAX GC.[3]

2) The TENAX column was then rapidly heated to 180°C for 10 minutes to thermally desorb the trapped organics onto a 1.83 m., 0.32 cm analytical column packed with 0.2 percent carbowax on 1500 carbopack C (Supelco[4]). Helium, at a flowrate of 33 ml/min, was used as both the carrier and desorb gas.

3) The analytical column was then temperature programmed from 60°C to 160°C at 10°C/min to provide maximum resolution. The electron capture detector was maintained at 250°C with a 40 ml/min mixture of 90 percent Argon 10 percent methane purge gas delivered

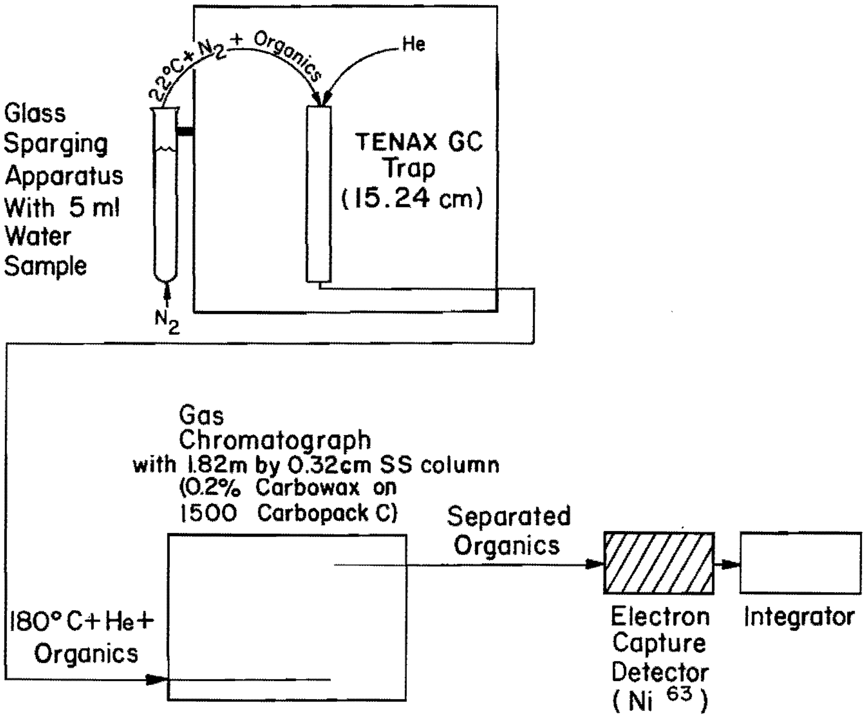

Figure 3. Purge and trap with gas chromatograph for the analysis of trihalomethanes.

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[1] TEKMAR Company, Cincinnati, Ohio.

[2] Hewlett Packard, Avondale, Pennsylvania.

[3] TENAX G. C., Alltech Assoc., Arlington Heights, Ill.

[4] Supelco Inc., Bellefonte, Pennsylvania.

at the detector to provide maximum linearity. Figure 4 indicates a typical 20 μg/l standards chromatogram while Figure 5 shows a standard curve for the four THMs.

The purge and trap technique used for the analysis of trihalomethanes is not without its problems. For routine analysis the following modifications of the original manufacturers specifications were employed.

1) Originally the concentrator trap contained 10.16 cm of TENAX GC and 5.08 cm of silica gel. As silica gel absorbs water readily, it tended to desorb water vapor onto the analytical column thus damaging the integrity of the system. The purpose of the silica gel was to trap compounds whose boiling point was below 50°C. As all the trihalomethanes have boiling points well above 50°C, the silica gel was considered unnecessary and the traps were packed with 15.24 cm of TENAX GC to avoid this problem.

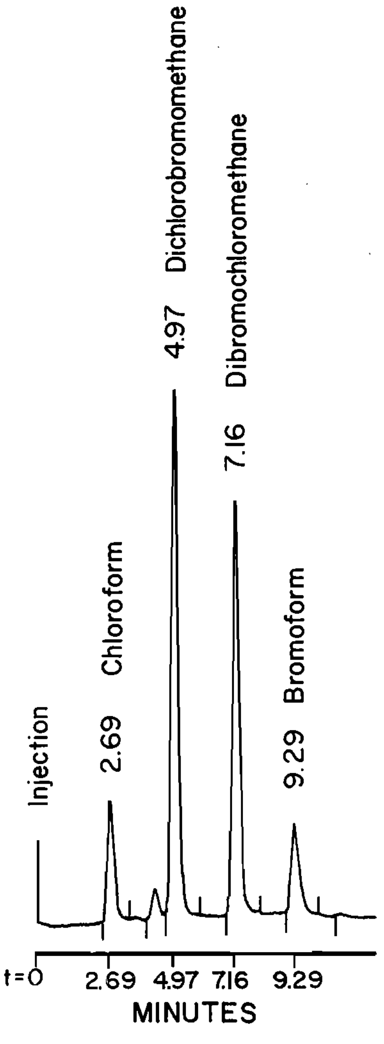

Figure 4. Typical chromatogram of a 20 μg/l trihalomethane standard with the numbers above the peaks indicating the retention times.

2) The desorbed organics were originally transported from the concentrator to the analytical column in the G.C. oven through 1.22 meters of teflon tubing. This was later changed to 40.3 cm of 0.32 cm (i.d.) nickel tubing to eliminate extra peaks (ghost peaks) whose source was in the teflon tubing.

3) The original desorbtion time was 3-4 minutes. To provide for replicable retention times and to sharpen later eluting peaks, a desorb time of 10 minutes was incorporated.

4) Both the concentrator TENAX trap and the analytical column had to be conditioned for the mixture to be separated. Conventional column conditioning overnight with helium destroyed the integrity of this conditioning and gave broad, unresolved peaks. By desorbing the trap at 200°C while simultaneously heating the analytical column to 160°C for 30 minutes, the system was readied for daily use. This also provided for any pressure changes within the many valves and transfer lines inherent to the system.

Quality Assurance

The Utah Water Research Laboratory certified its trihalomethane analysis with the state and EPA in March of 1980. In addition, internal trihalomethane audits were conducted on a quarterly basis to assist in maintaining the accuracy of the analysis. The data may be found in Appendix D.

Total Organic Carbon Analysis

In an attempt to determine potential precursor loadings, total organic carbon was analyzed at the treatment plants under study. Five ml aliquots of sample were placed in precombusted ampules with 0.2 mls of 10 percent phosphoric acid and 0.2 g potassium persulfate. Inorganic carbon is then purged out with oxygen and the ampules sealed. Ampules are autoclaved for 4 hours. Samples are then analyzed for CO_2 using an Oceanographic International Carbon Analyzer (Menzel and Vaccaro 1964).[5]

Forty ml sampling vials with screw-on teflon lined tops, obtained from Supelco Inc., were used in sampling for both the total trihalomethanes (TTHMs) and total organic carbon (TOC) analyses. The vials were precombusted at 350°C in a muffle furnace for 2 hours prior to each sampling procedure. Samples collected contained no air space above the aqueous phase that could invalidate the test (Federal Register 1979).

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[5] Oceanographic International, College Station, Texas.

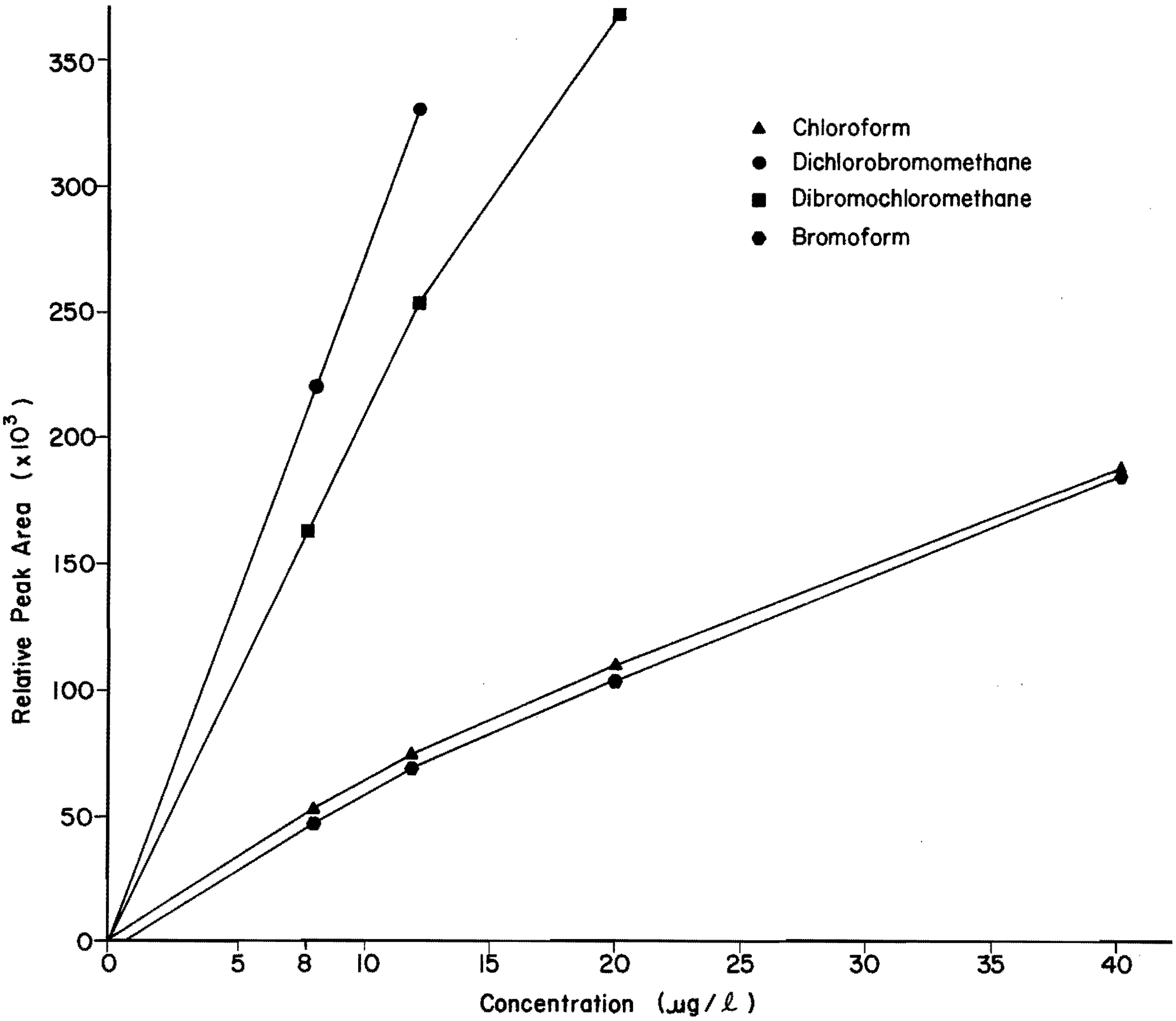

Figure 5. Standard curves for trihalomethane standards.

Sampling Procedures

To determine the source of trihalomethane levels in drinking water supplies in Salt Lake City and Ogden City all treatment plants serving these communities were sampled. Monthly 40 ml grab samples were taken at each site. One influent and one effluent sample was taken and preserved with 2-4 mg/40 ml of L-ascorbic acid to quench any residual chlorine and arrest TTHMs formation thus providing an instantaneous TTHM sample. Samples for inst-TTHM were then cooled to 4°C and analyzed within one week. L-ascorbic acid, used in conjunction with teflon top glass sampling vials, provides storage time for a week with no interferences or sample degradation (Kissinger and Fritz 1976). One effluent sample was taken and stored for 7 days at 25-30°C with no preservation to allow the chlorination reaction and subsequent TTHM formation to go to completion. Total organic carbon samples were obtained at the influent and effluent of the treatment plants for possible determination of precursor loadings.

Several business and residential sampling sites were chosen to determine the levels of trihalomethane exposure to Salt Lake City and Ogden City residents. These sample sites were chosen to represent the water distribution network in these communities by city water officials and treatment plant operators. The samples were analyzed for instantaneous trihalomethanes.

Sample Site Description

Salt Lake City treatment plants (see Figure 6)

1) Metropolitan Water District of Salt Lake.

The Little Cottonwood Treatment Plant is a major supplier of water to Salt Lake City and County, particularly during periods of high use. It has capacity of 105 MGD and treats water from Little Cottonwood Creek and Deer Creek Reservoir. Depending on the quality at a given time of the Deer Creek influent, the chlorine may be added at Deer Creek Reservoir near the aqueduct intake entrance, at rapid mix, and/or just before filtration.

2) Salt Lake City Water Department.

Salt Lake City operates three major conventional drinking water treatment plants. Figure 7 illustrates a typical conventional water treatment facility. All three chlorinate solely at the rapid mix process. Parleys Treatment Plant has a capacity of 32 MGD and treats water from Mountain Dell Reservoir, located directly upstream from the plant. Big Cottonwood treatment plant has a capacity of 42 MGD. Its influent water source is Big Cottonwood Creek. City Creek water treatment plant has a capacity of 15 MGD. Its influent source is City Creek.

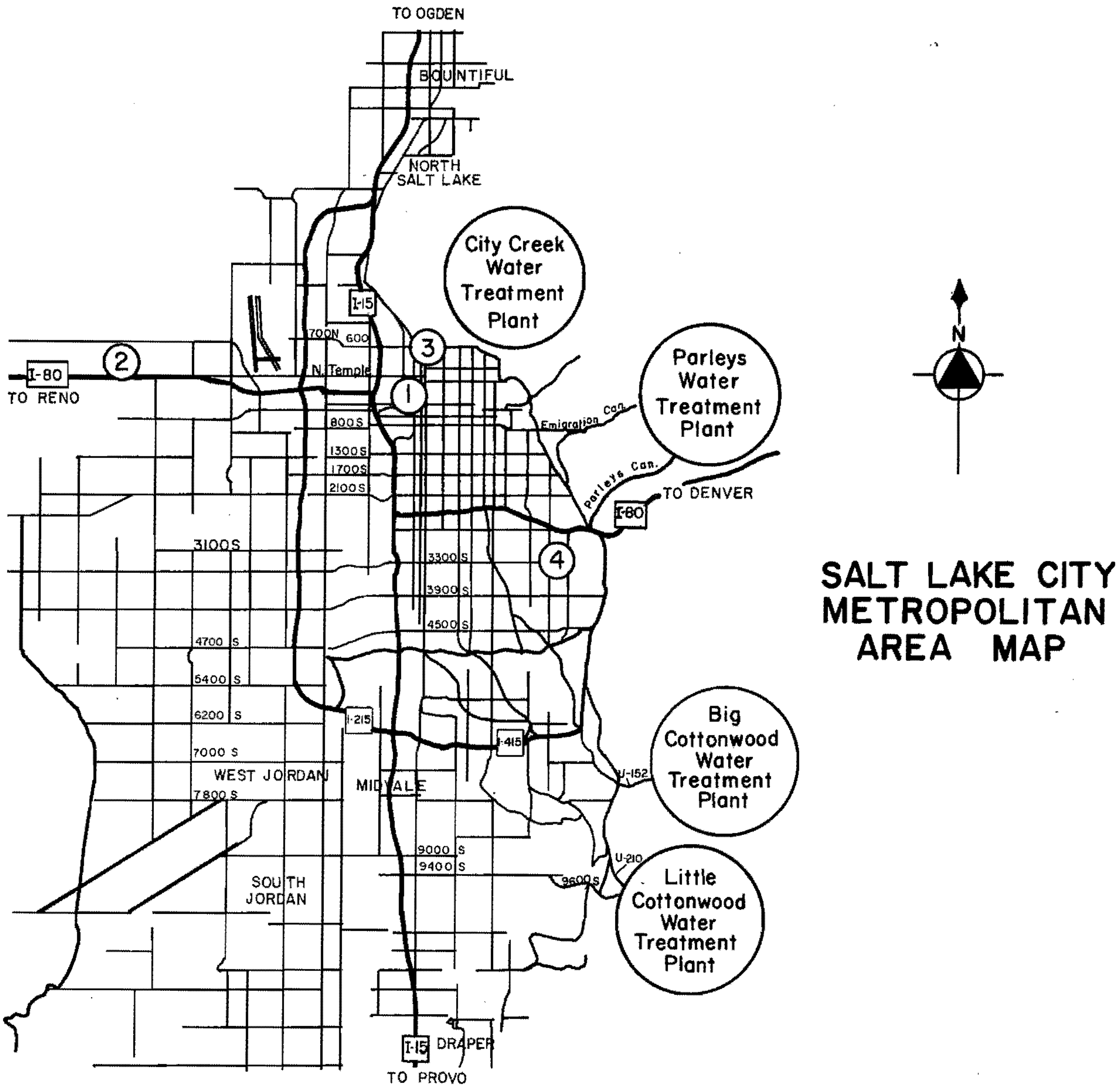

Figure 6. Salt Lake City metropolitan area map.

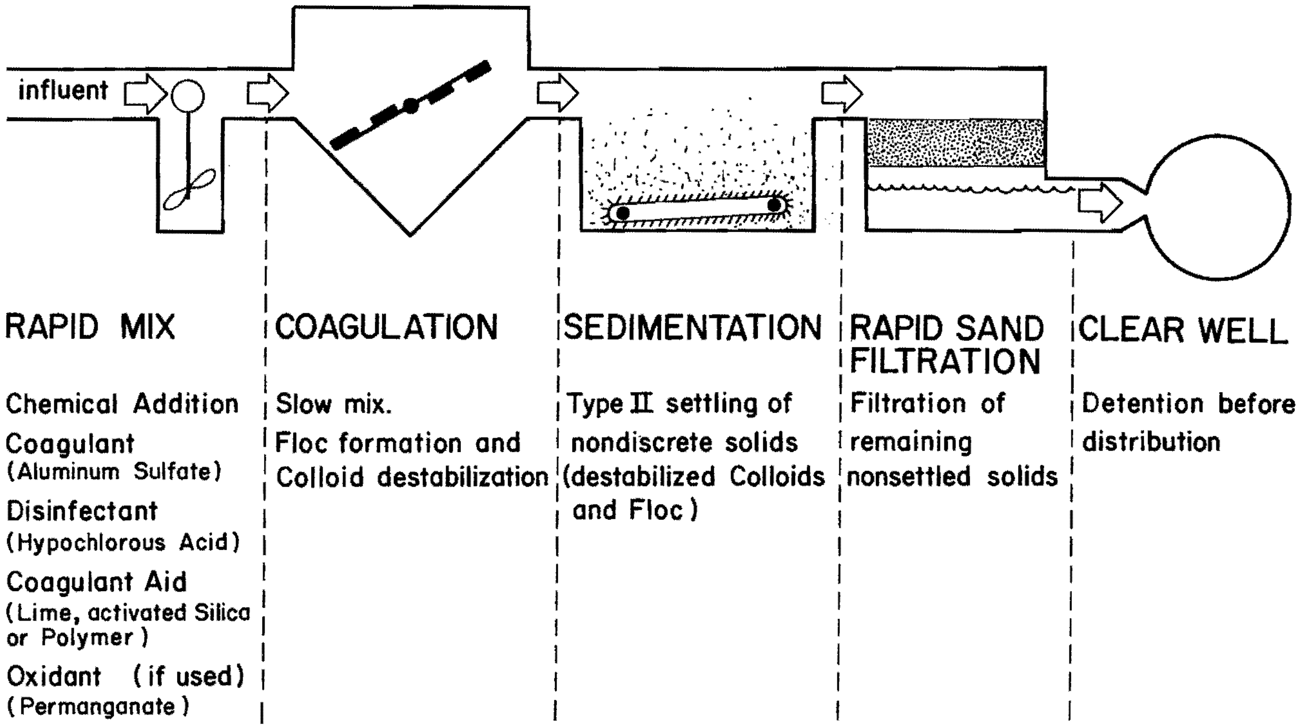

Figure 7. Typical conventional water treatment facility.

The four locations (see Figure 6) that were selected to represent the treated water in Salt Lake City were:

1) Salt Palace (100 S. West Temple)

2) Salt Lake International Center (5300 West N. Temple)

3) State Capitol Building

4) 2475 East 3300 South

Ogden City water system (see Figure 8)

Ogden City, in addition to well water, receives treated water from Weber Basin Water Conservancy District (WBWCD). The district retains three major plants that service Ogden and surrounding communities (WBWCD #2, 14.2 MGD; #3, 27 MGD, #4, 6.5 MGD). All WBWCD plants chlorinate the water at both rapid mix and near the entrance to their filtration units. Permanganate addition at the rapid mix basin is used regularly to maintain effluent quality. All three plants obtain water from the Weber River.

The five locations (see Figure 8) that were selected to represent treated water service to Ogden City residents were:

1) McKay Dee Hospital (3905 Harrison Blvd)

2) Court House (2504 Washington)

3) 14th Street and Washington Ave

4) 522 Harrison

5) 36 South and Riverdale Road

Post and prechlorination comparisons

To determine the effect of post chlorination (chlorination at the entrance to the filters) as opposed to prechlorination (chlorination at rapid mix) on TTHMs formation a diurnal, 7-day, sampling procedure at the Parleys water purification plant was undertaken. Figure 9 shows the schematic for this process.

Samples to determine an instantaneous TTHM and a 7-day TTHM were collected every 8 hours after filtration on the post chlorination side, pre-chlorination side, and after the clearwell. Six samples (two sampling) sets were reinocculated with excess chlorine, stored for 7 days at 25°C, checked for a chlorine residual, and analyzed for TTHMs. This gives the maximum trihalomethane potential.

Trihalomethane formation as a function of unit operation was evaluated by collecting sample after rapid mix, coagulation, sedimentation, filtration and final effluent at the Parleys water treatment facility. The measurements at these points not only detail THMs formation but also define trihalomethane formation with process time.

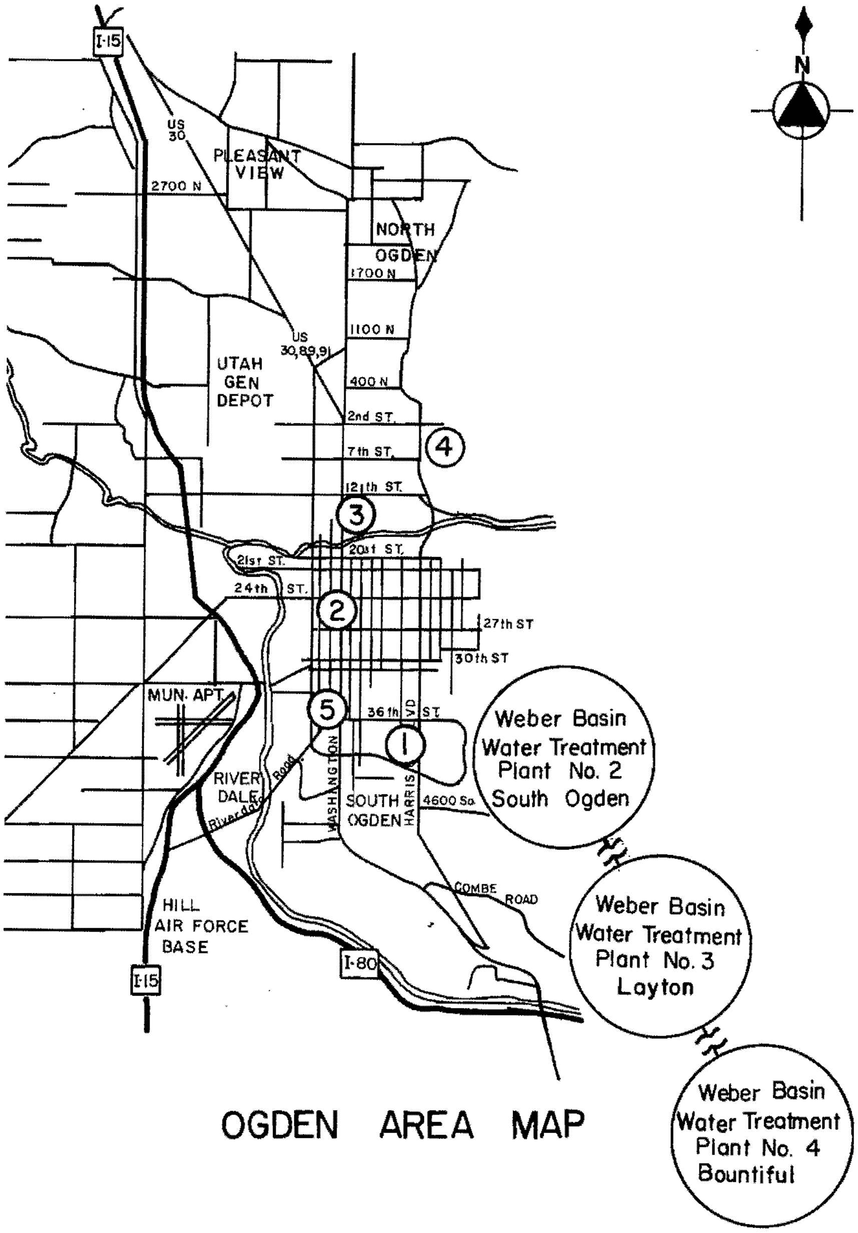

Figure 8. Ogden area map.

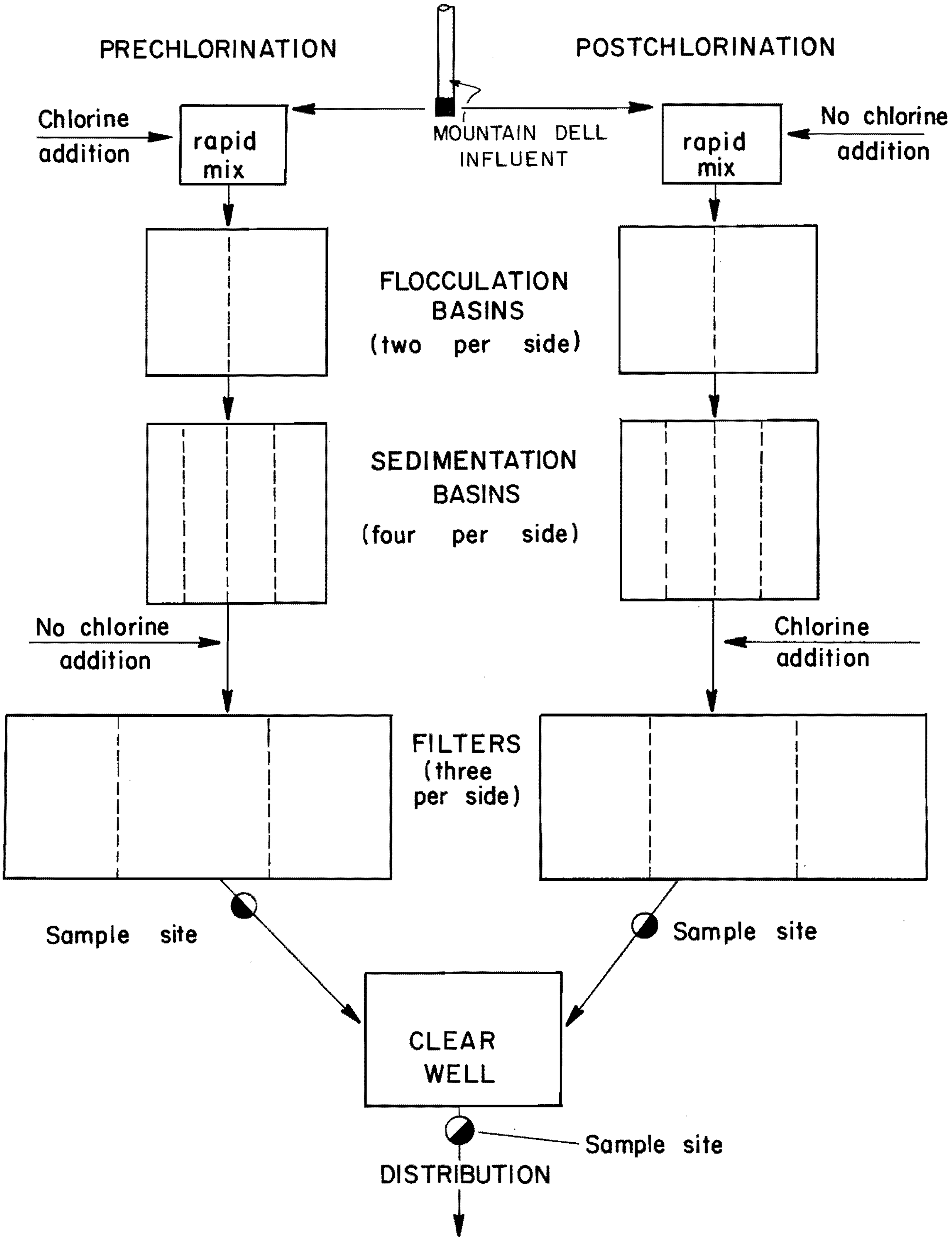

Figure 9. Schematic process for post versus prechlorination at Parleys Water Purification Plant.

RESULTS AND DISCUSSION

Trihalomethane and total organic carbon levels were analyzed in water collected from drinking water treatment plants and in water delivered to various business and residential locations by the distribution networks of Salt Lake City and Ogden. Samples were analyzed for total organic carbon, in addition to the trihalomethanes, to provide data on potential precursor loadings.

In both cities less than 1 µg/l total trihalomethanes were detected in the unchlorinated raw water, but significant amounts (though still well within the legal standards)of trihalomethanes were present in treated drinking water supplies. Chloroform was the dominant species present in drinking water from Ogden City and Salt Lake City (80 - 95 percent) followed by dichlorobromomethane and lesser amounts of dibromochloromethane with no bromoform detected. Traces of carbon tetrachloride (not a trihalomethane) were found in many of the samples analyzed but in concentrations not exceeding 2-4 µg/l.

Salt Lake City

Salt Lake City and Salt Lake County distribute treated surface water year round from a network of four drinking water treatment plants (City Creek, Parleys, Big Cottonwood, and Little Cottonwood) and supplement surface sources as needed with nonchlorinated water wells. Due to the complexity of the distribution system, it is not possible to isolate any one treatment plant supply as serving a specific residential or business sampling location (Sherwood, personal communication 1979).

The City Creek water purification plant treats 15 million gallons of water per day (MGD). No total trihalomethanes (TTHMs) were detected in the influent water. TTHMs levels in the plant product water never exceeded 100 µg/l. Only minor fluctuations occurred in the consistently low instantaneous total trihalomethane (inst-TTHM) measurements (not exceeding 27 µg/l) over the sampling period (Figure 10). Seasonal variation in inst-TTHM did not appear to exist, and the variability noted was probably a result of daily fluctuation in inst-TTHM. The total organic carbon (TOC) in the influent to City Creek did show a seasonal pattern (Figure 10). The February high in TOC followed by subsequent monthly decreases seems to relate to the spring runoff pattern.

Seven-day TTHM (an indication of maximum TTHMs level with a given chlorine dose) reached a maximum of 78 µg/l during May 1980 and subsequently decreased through August (Appendix A). Although the data for this analysis were from April 1980 to August 1980 only, the trend suggests a decrease in precursor loadings during summer months.

The percent of each individual THM determined from the inst-TTHM measurements is shown in Figure 11. Chloroform comprised the largest percentage of inst-TTHM followed by dichlorobromomethane and traces of dibromochloromethane. No bromoform was detected. During the spring runoff period, the chloroform percentage increased and brominated compounds decreased.

Parleys Water Purification Plant, a 32 MGD treatment plant operated by Salt Lake City, is located up Parleys Canyon 6 miles east of Salt Lake City on I-80. Its raw water source is Mountain Dell Reservoir located directly east of this facility. Mountain Dell Reservoir receives some runoff from a municipal golf course located just east of the reservoir, but no recreational use is allowed on the reservoir itself. The reservoir experiences eutrophication problems in summer months (Sherwood, personal communication 1979) and is treated with copper sulfate on a regular basis during the summer months.

Figures 12 and 13 show the trihalomethane and TOC data for water produced at Parleys. This plant was off line from November 1979 through March of 1980. Both inst-TTHM and the 7-day TTHM follow a similar pattern from April through August. The temporal variation of influent total organic carbon levels contrasted with the variations in trihalomethane levels. May had the largest inst-TTHM (43 µg/l) and 7-day TTHM 74 µg/l) levels. Inst-TTHM and 7-day TTHM levels decreased through the summer months. The high TTHMs levels in May could have been due to natural turnover within the reservoir generating larger precursor loadings to the treatment plant. The total organic carbon levels measured in May, however, do not substantiate an increase in precursor load. As shown in Figure 13, chloroform was the dominate species at this facility. The chloroform percentage reached a maximum of 80 in April and May 1980 with subsequent decreases in chloroform and increases in dichlorobromomethane in later summer months.

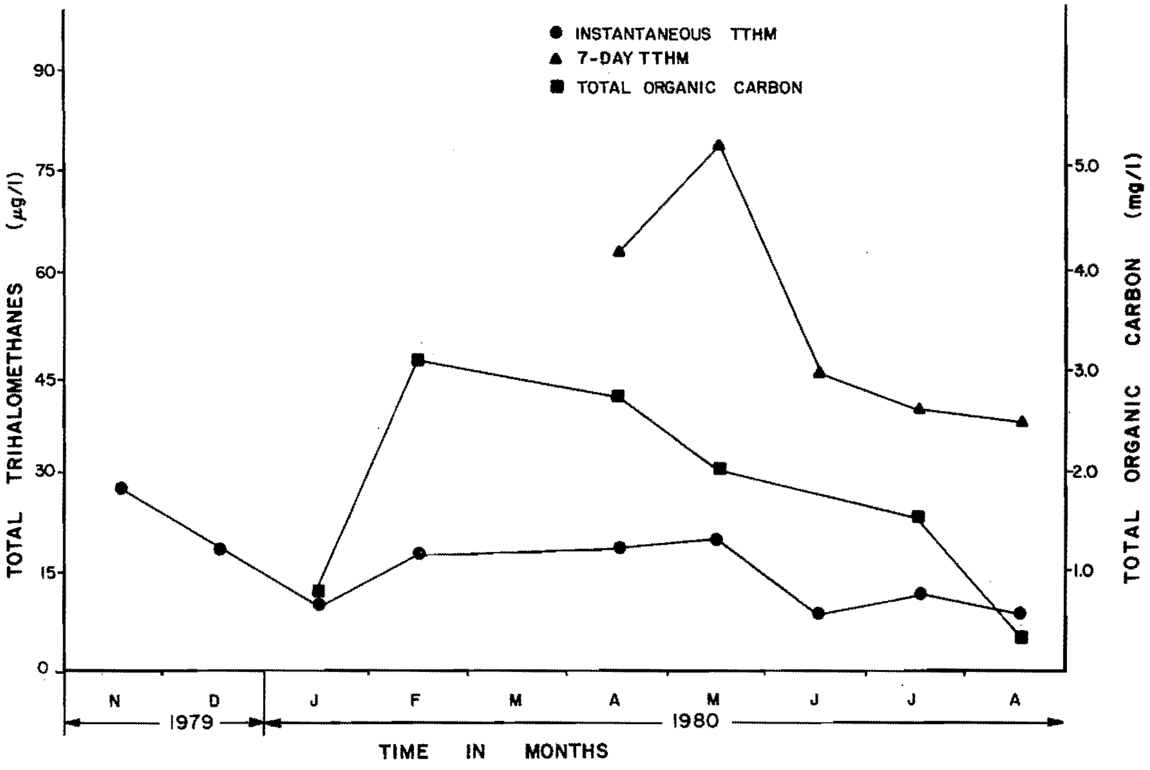

Figure 10. Effluent trihalomethanes and influent total organic carbon at the City Creek Water Purification Plant. (The March samples were not collected and analyzed due to a severe snowstorm.)

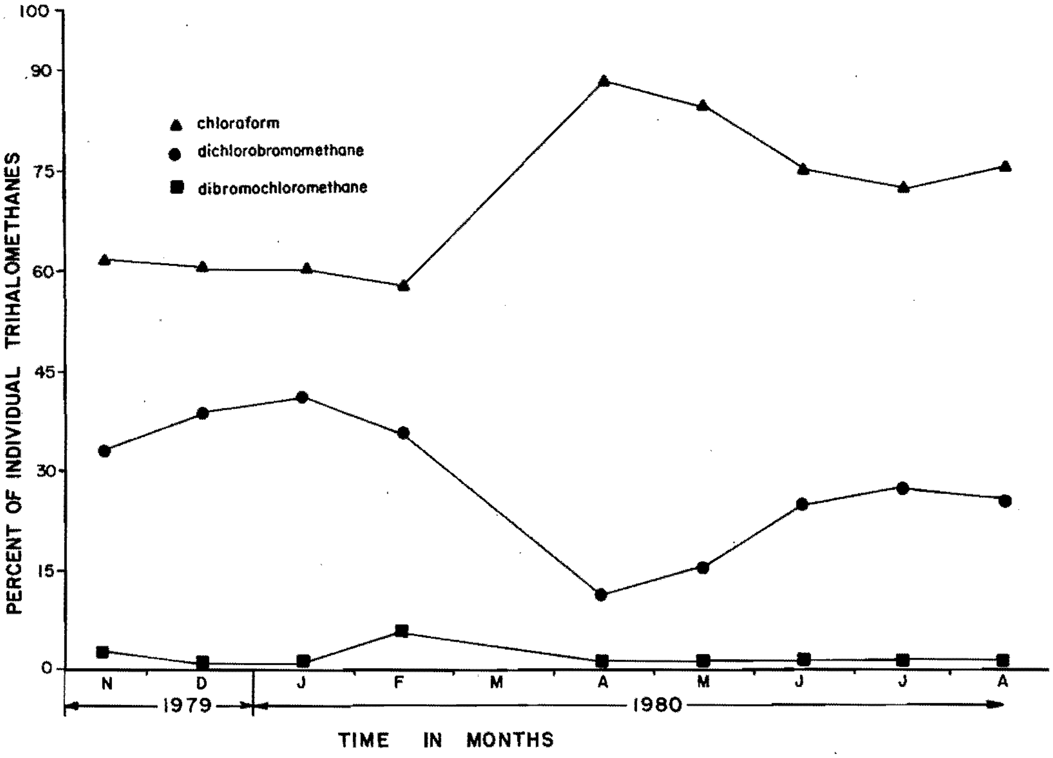

Figure 11. Percent of individual trihalomethanes in the effluent at the City Creek Water Purification Plant.

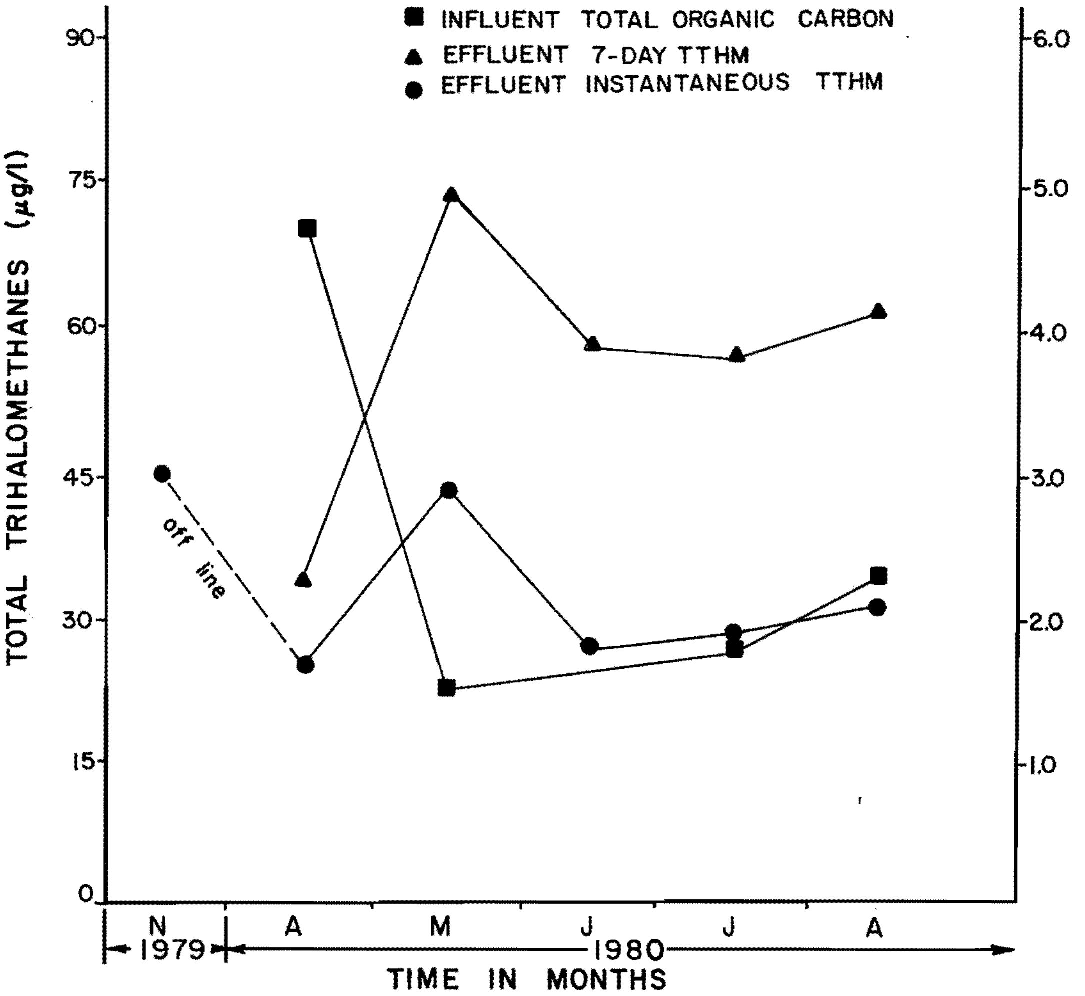

Figure 12. Effluent trihalomethanes and influent total organic carbon at the Parleys Water Purification Plant.

Big Cottonwood Water Purification Plant treats 42 MGD of water from Big Cottonwood Creek. Figures 14 and 15 show the trihalomethane and total organic carbon data for this facility. The total organic carbon reached a maximum of 6.4 mg/l in February 1980 with subsequent monthly fluctuations through August (Figure 14). The inst-TTHM reached a February low of 8 μg/l with monthly increases until a maximum in May of 29 μg/l. Big Cottonwood's water contained a maximum 7-day TTHM of 68 μg/l in June, and concentrations subsequently decreased through August. Influent total organic carbon levels did not follow either inst-TTHM or the 7-day TTHM.

The percent of individual inst-TTHM produced at Big Cottonwood is shown in Figure 15. Chloroform comprises the largest percentage of inst-TTHM followed by dichlorobromomethane and dibromochloromethane. No bromoform was detected. The first two were approximately equal in February, but beginning in March 1980, chloroform percentage increased while brominated compounds percentage decreased. From April through August no dibromochloromethane was dectected. June provided the largest percentage of chloroform (95 percent inst-TTHM) at Big Cottonwood's inst-TTHM effluent.

Salt Lake Metropolitan Water District's 105 MGD Little Cottonwood Water Treatment Plant supplies a major portion (60 to 70 percent peak use) of Salt Lake County's potable water supply. The plant has two influent sources, Little Cottonwood Creek and Deer Creek Reservoir. Water is transported 42 miles from Deer Creek Reservoir via an aqueduct. Of the two influents, Deer Creek aqueduct water is the larger source (three to four times that of Cottonwood Creek) during summer months. Deer Creek Reservoir water is of much poorer quality than the Cottonwood Creek influent (Nelson, personal communication 1980). The reservoir requires copper sulfate treatment during the summer months to suppress algal growth. Chlorination is required regularly at the entrance to the Deer Creek aqueduct to

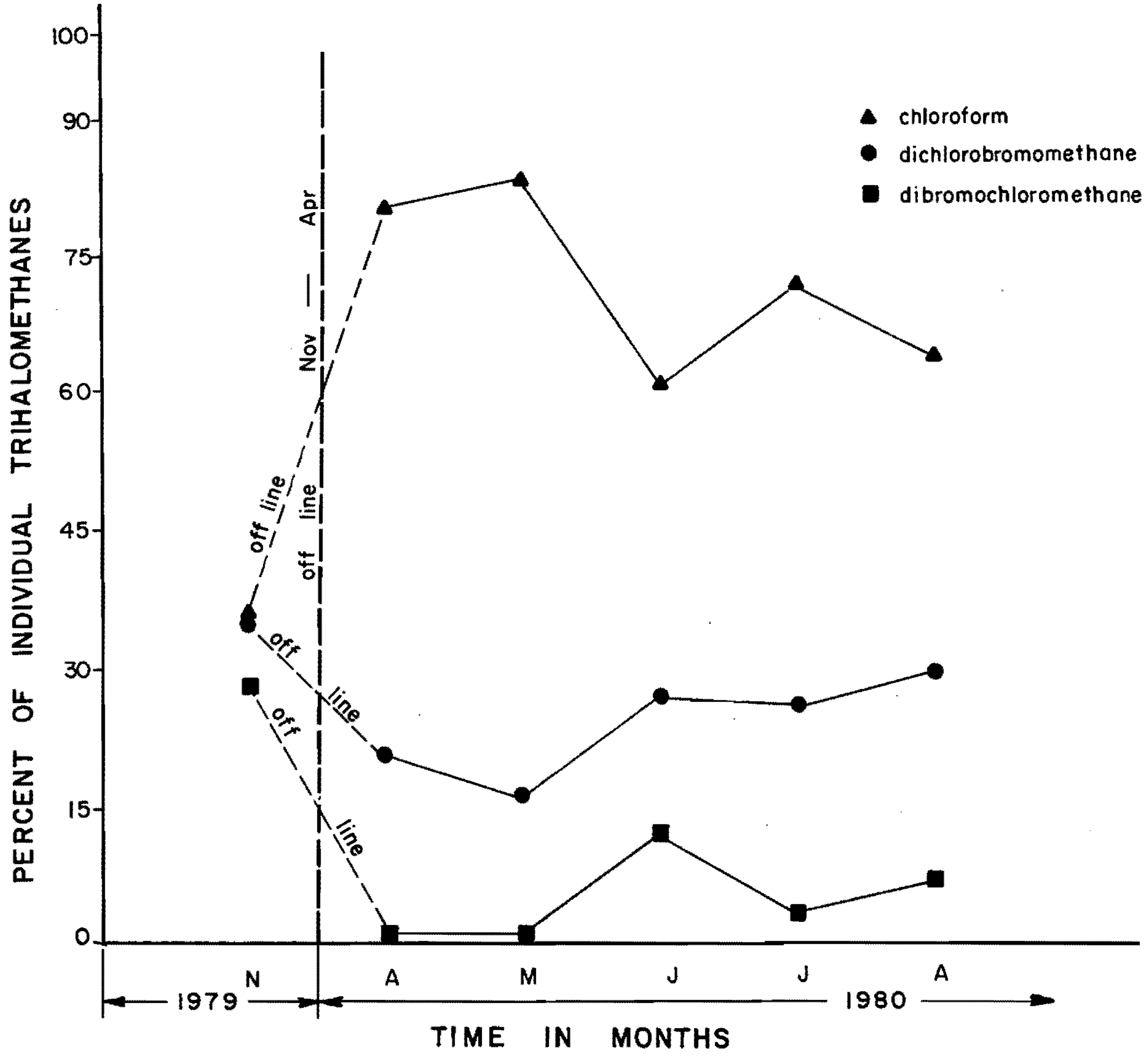

Figure 13. Percent of individual trihalomethanes in the effluent at the Parleys Water Purification Plant.

minimize taste and odor problems. This practice is not required on the higher quality Little Cottonwood Creek influent. Due to chlorination of the Deer Creek water, the Little Cottonwood Water Treatment Plant influent contains trihalomethanes. TTHMs levels in the Deer Creek aqueduct influent to the treatment plant are presented in Appendix A.

Deer Creek aqueduct influent has the higher TOC levels of the two influent sources (Figure 16). In fact, it has the highest TOC level of any water source to a treatment plant in the Salt Lake system. TOC data for the Deer Creek aqueduct influent reached two maxima, February 1980 (5.4 mg/l) and June 1980 (100 mg/l). As February (along with October) is one of the two reservoir turnover periods (Anderson et al. 1976), the spring turnover may explain the 5.4 mg/l TOC. The extremely high June level (100 mg/l) may be a result of one of the algal blooms commonly experienced at this reservoir (Nelson, personal communication 1980).

The inst-TTHM for the Little Cottonwood plant reached a maximum (55 μg/l) in March 1980. Subsequent inst-TTHM levels decreased through May followed by gradual increases through June and July reaching another maximum of 60 μg/l in August. The Little Cottonwood Plant consistently had the highest inst-TTHM levels of the Salt Lake water treatment plants.

The fact that the total organic carbon data did not follow the inst-TTHM data (the pattern also seen for the other Salt Lake treatment plants) is probably an indication that only a small fraction of the TOC is responsible for the formation of

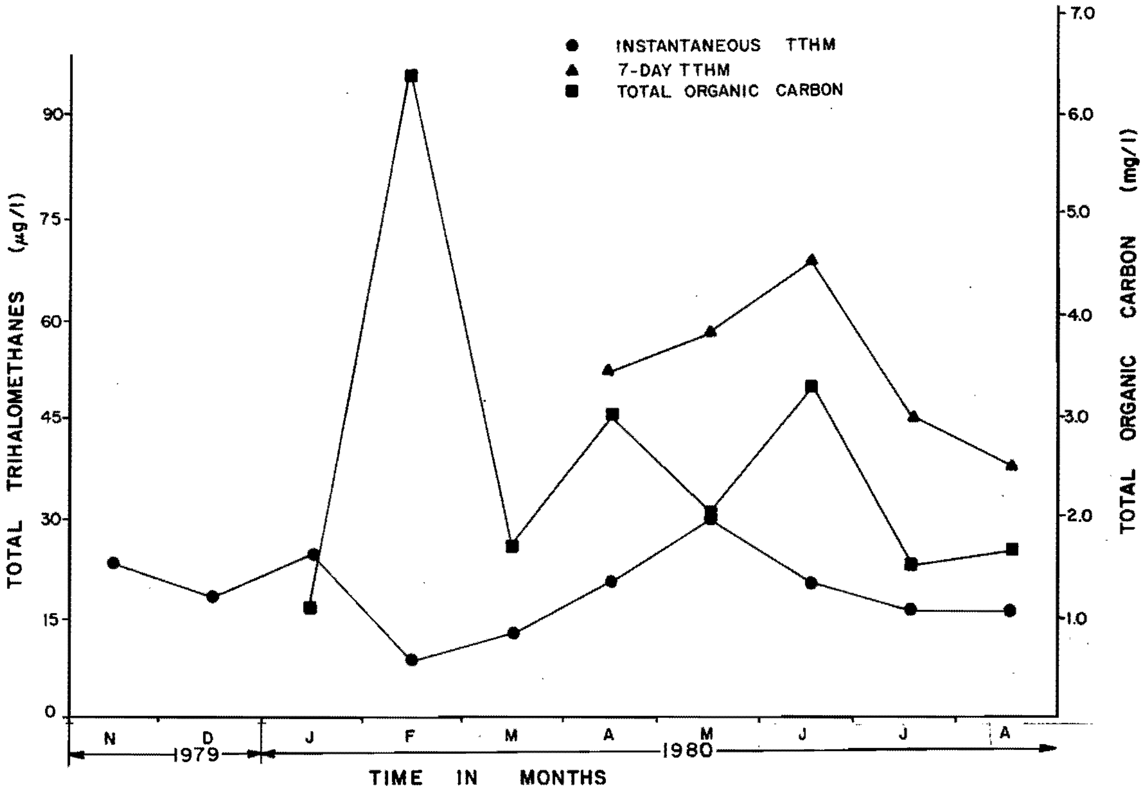

Figure 14. Influent total organic carbon and effluent trihalomethanes at the Big Cottonwood Water Purification Plant.

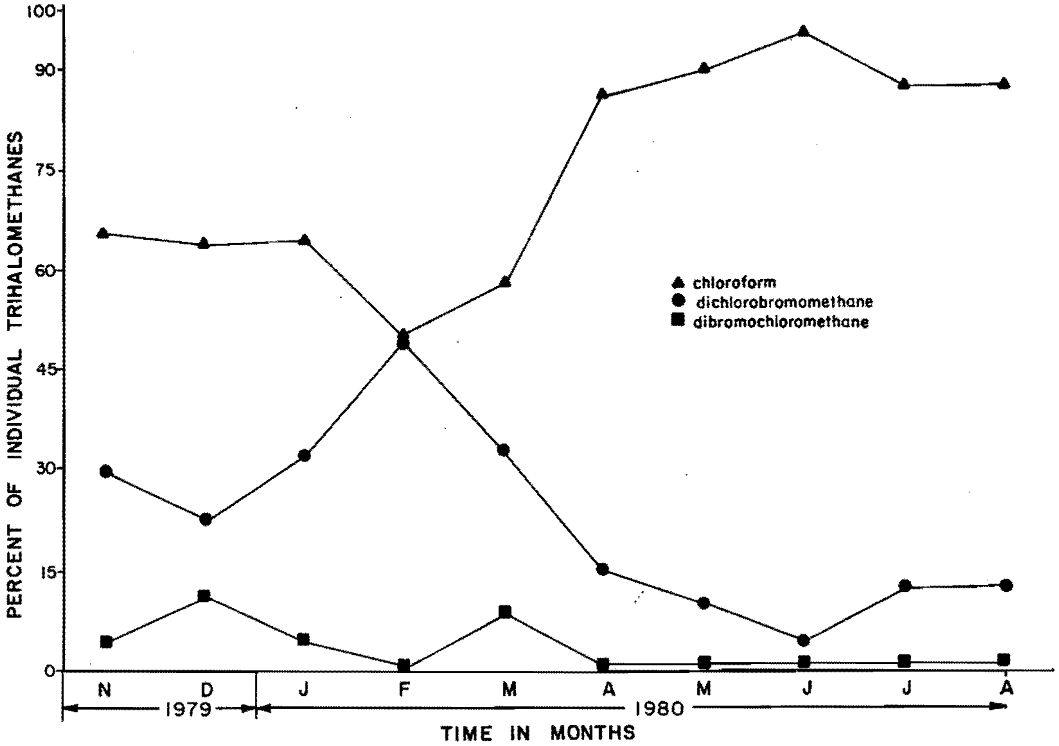

Figure 15. Percent of individual trihalomethanes in the effluent at the Big Cottonwood Water Purification Plant.

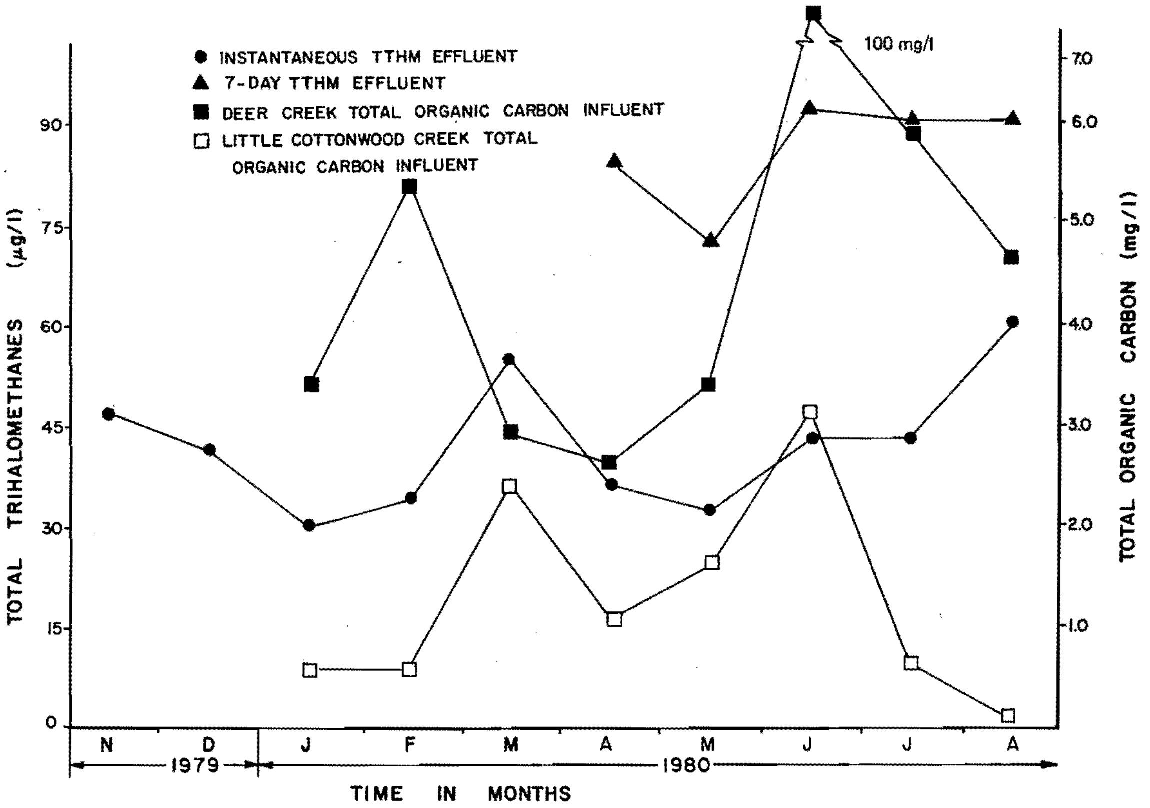

Figure 16. Influent total organic carbon and effluent trihalomethanes at the Little Cottonwood Water Purification Plant.

trihalomethanes. The 7-day total trihalomethane data shown in Figure 16 reached a maximum concentration in June of 92 μg/l and remained near this concentration in July and August. However, since only five 7-day TTHM data points were obtained, more data are needed to display any seasonal pattern. Again, as with the inst-TTHM, this plant has the highest 7-day TTHM of any Salt Lake water treatment plant under study.

Figure 17 represents the percent of individual inst-TTHM in the effluent of the Little Cottonwood Treatment Plant. As displayed and consistent with the other Salt Lake water treatment plants, chloroform levels increased and brominated compounds decreased beginning in March. As spring turnover takes place at approximately this time, the trend may be due to different or increased loading due to the turnover. This pattern continued through the spring and summer months reaching a maximum of 89 percent chloroform and only 11 percent dichlorobromomethane in August. No other brominated compound except dichlorobromethane appeared in any samples after April.

Mean inst-TTHM concentrations at the selected Salt Lake City business and residential sample sites are shown in Figure 18. These sites can receive treated water from any of the four treatment plants. During periods of low streamflow (particularly winter months), these sites may receive unchlorinated well water thus lowering the inst-TTHM to below the 1 μg/l instrument limit established for this study. The time required to deliver the treated water from the plant to the tap water site allows longer chlorine contact time resulting in higher inst-TTHM than recorded at any of the treatment plant effluents. During the study period, the mean inst-TTHM level measured at these sites never reached the 100 μg/l, USEPA proposed TTHMs limit, and only once during the 14-month study period did the mean concentration exceed 50 μg/l TTHMs (July 1980). Water samples obtained in July of 1979 and July of 1980 contained the highest average inst-TTHM levels (46 μg/l and 52 μg/l, respectively) while the winter months of January, February, and March showed the lowest concentration of inst-TTHM. During these months many of the sample sites were receiving unchlorinated well water (inst-TTHM <1 μg/l), accounting for the low mean.

Of the sample sites selected, the Salt Lake International Center (the furthest examined point in the city's distribution network) consistently had the highest inst-TTHM, indicating continued THMs formation with longer chlorine contact time. The maximum measure value was 82 μg/l (July 1980).

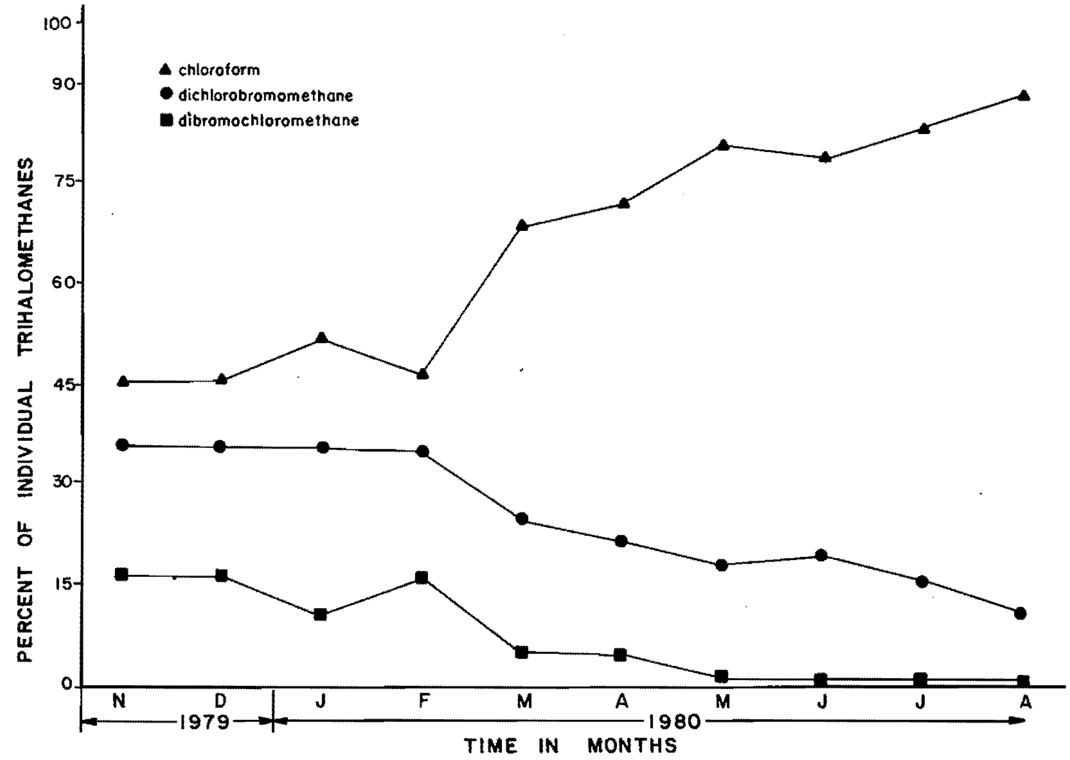

Figure 17. Percent of individual trihalomethanes in the effluent at the Little Cottonwood Water Purification Plant.

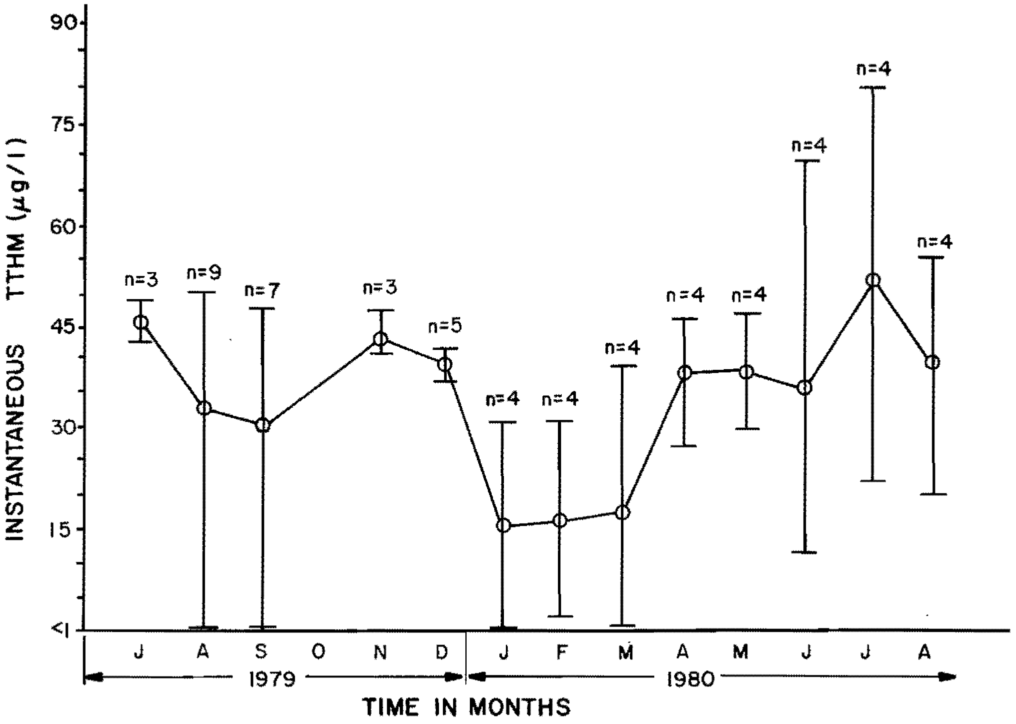

Figure 18. Mean instantaneous trihalomethane exposure level to selected business and residential sites in Salt Lake City, Utah. (n = number of samples collected and analyzed on one sampling trip during the month for the individual business and residential sites.)

Of the four Salt Lake City treatment plants, the Little Cottonwood Water Treatment Plant generally had the highest inst-TTHM and 7-day TTHM. However, at no time did any of these four treatment facilities or any residential or commercial sample sites ever exceed the proposed USEPA's 100 μg/l MLC limit on THMs. Only twice did the Little Cottonwood Water Treatment Plant exceed 50 percent of the required limit.

All treatment plants under study in Salt Lake showed a significant increase (more than double) in the 7-day TTHM as opposed to the inst-TTHM. This indicates the THMs formation potential within the distribution system.

All four treatment facilities show higher percentages of chloroform than of the brominated THMs with the relative advantage steadily increasing after March. This tends to show that formation favors the more chlorinated THMs over the brominated THMs particularly during the summer months. Changes in precursor type (possibly due to spring and fall events in the watersheds) or bromide availability may account for this seasonal fluctuation.

Ogden

Ogden City receives treated water from two of the three conventional water treatment plants operated by the Weber Basin Water Conservancy District (WBWCD). In addition, Ogden City relies heavily on unchlorinated well water to supplement this source (Robinson, personal communication 1979). The three Weber Basin plants (No. 2, 3, and 4) in addition to some chlorinated groundwater serve 220,000 residents along the Wasatch Front from Ogden to and including North Salt Lake. The raw water source for these plants may include Weber River and Ogden River. In addition, Wasatch Front streams deliver water to these plants via an aqueduct system. All plants incorporate permanganate at rapid mix to control taste and odor with chlorine added at rapid mix and again at the entrance to the filtration system. Peak chlorination periods are generally during July and August (Hensley, personal communication 1979).

Trihalomethane and total organic carbon data for Weber Basin's plant No. 2 are represented graphically in Figures 19 and 20. This plant was off-line during much of the winter, therefore seasonal patterns were difficult to establish. From April 1980 through July, the inst-TTHM followed the 7-day TTHM with both reaching a maximum in July of 70 μg/l and 85 μg/l, respectively. During this same period, the influent total organic carbon levels decreased from 10.1 mg/l in April to 5.1 mg/l in July.

The percent of individual THMs (Figure 20) shows higher chloroform percentages during the summer months than in November and December 1979. Chloroform reached a maximum of 86 percent of inst-TTHM in July 1980. Only one other THMs was present, dichlorobromomethane, which comprised 14 percent of the total.

Figures 21 and 22 represent the data for Weber Basin's Plant No. 3 located at 2837 E. Highway 193 in Layton. The inst-TTHM reached its maximum of 45 μg/l in December 1979 and subsequently decreased through February 1980. From February 1980 until the end of the sampling period in July 1980 the inst-TTHM gradually increased to a second maximum of 41 μg/l. The 7-day total THMs represented in Figure 21 tended to remain at 60 μg/l except in May where the term-THMs and the inst-TTHM were 27 μg/l and 26 μg/l, respectively. This is probably experimental error caused by contaminating 7-day TTHM with L-ascorbic acid. It is very unlikely further THMs formation would not occur in an incubated sample carrying a chlorine residual or that particular sample may not have had a chlorine residual which would explain such a result.

Influent total organic carbon for plant No. 3 shows a maximum in April 1980 of 19.8 mg/l with subsequent decreases through July. Influent TOC does not appear to match effluent TTHMs. Figure 22 presents the percent of individual inst-TTHM in the effluent of plant No. 3. Beginning in February 1980 and continuing through July, chloroform becomes the increasingly dominant trihalomethane. Maximum concentrations of chloroform were reached (86 percent of the total inst-trihalomethanes) by July 1980 with the remaining 14 percent composed of dichlorobromo methane. No higher order brominated compounds were present during the summer sampling period. Thus, the highest percentage of brominated trihalomethanes occurred during the fall and chloroform was the dominant species in late spring and summer months.

Weber Basin Plant No. 4, located at 38 North Davis Blvd., Bountiful, does not directly serve the Ogden area. It provides drinking water for nearly 40,000 residents in the North Salt Lake-Bountiful area. Figures 23 and 24 show the variation in trihalomethane and total organic carbon data for this facility. From Figure 23 it can be seen that the maximum total organic carbon levels occurred in April 1980 (18.8 mg/l) with subsequent decreases through July. Inst-TTHM remained below 25 μg/l during late winter months. These levels began increasing in April 1980 until a maximum level (58 μg/l) was measured in July. Only three data points exist for the 7-day TTHM, and a maximum of 94 μg/l occurred in July 1980.

The percent of individual inst-TTHM for this water treatment facility is shown in Figure 24. The chloroform percentage started to increase beginning in March 1980 while the brominated inst-TTHM decreased. From March through July, only one brominated compound, dichlorobromomethane, was detected. During this period nearly 85 percent of the trihalomethanes were in the form of chloroform.

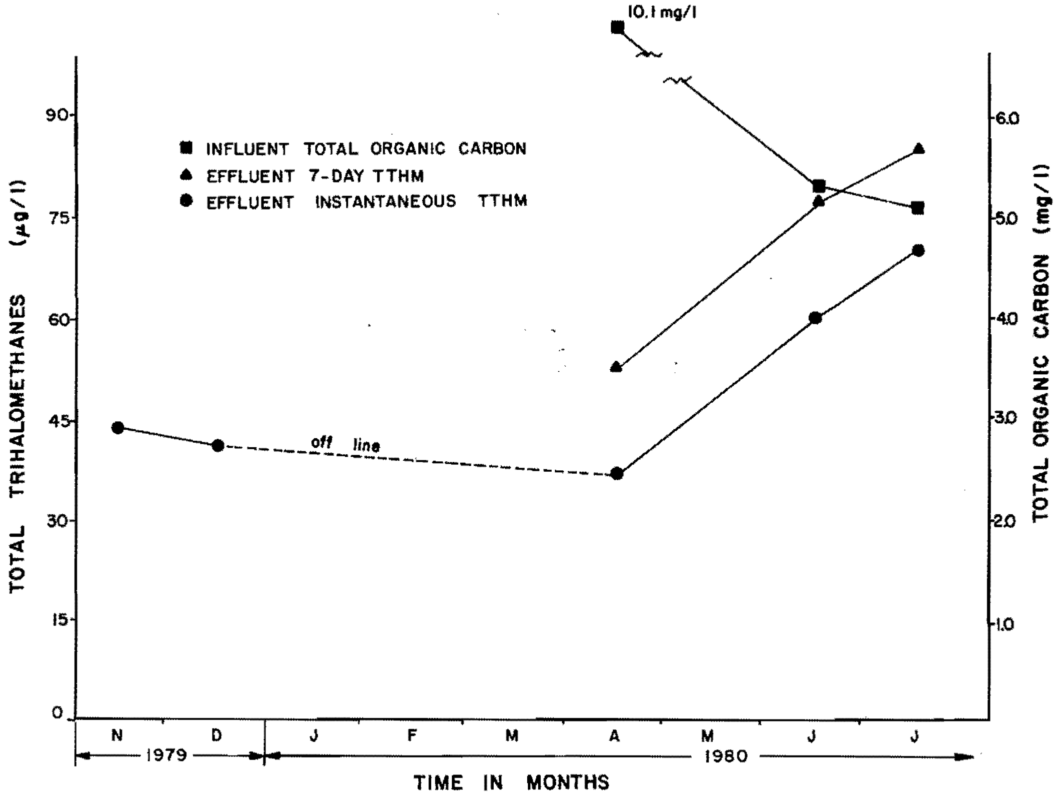

Figure 19. Influent total organic carbon and effluent trihalomethanes at the WBWCD plant No. 2 water purification facility.

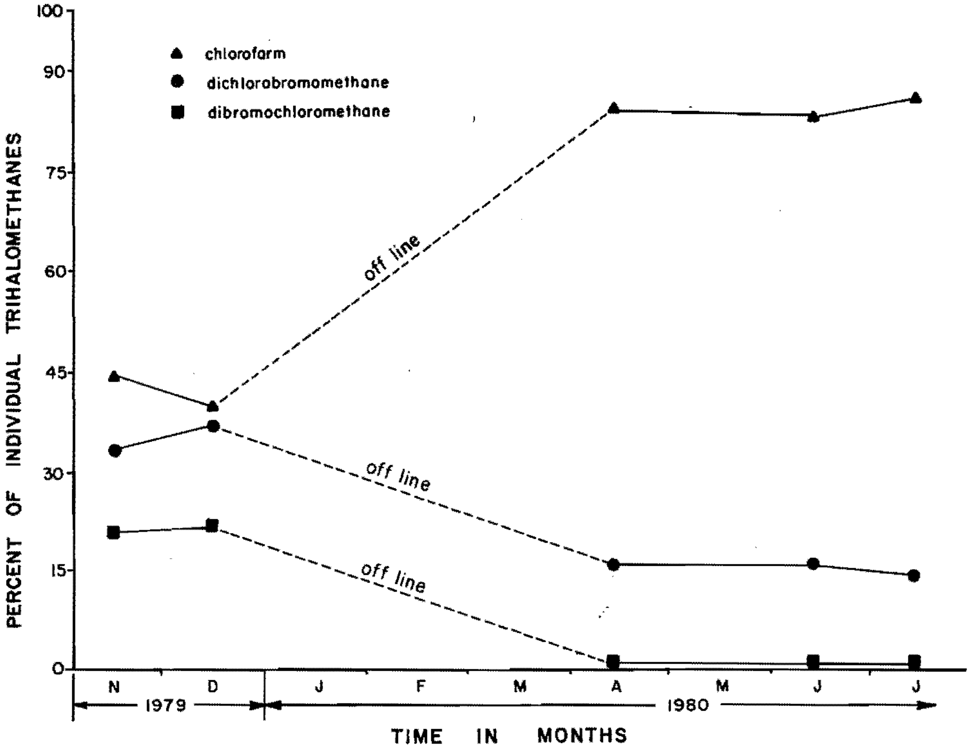

Figure 20. Percent of individual trihalomethanes in the effluent at the WBWCD plant No. 2 water purification facility.

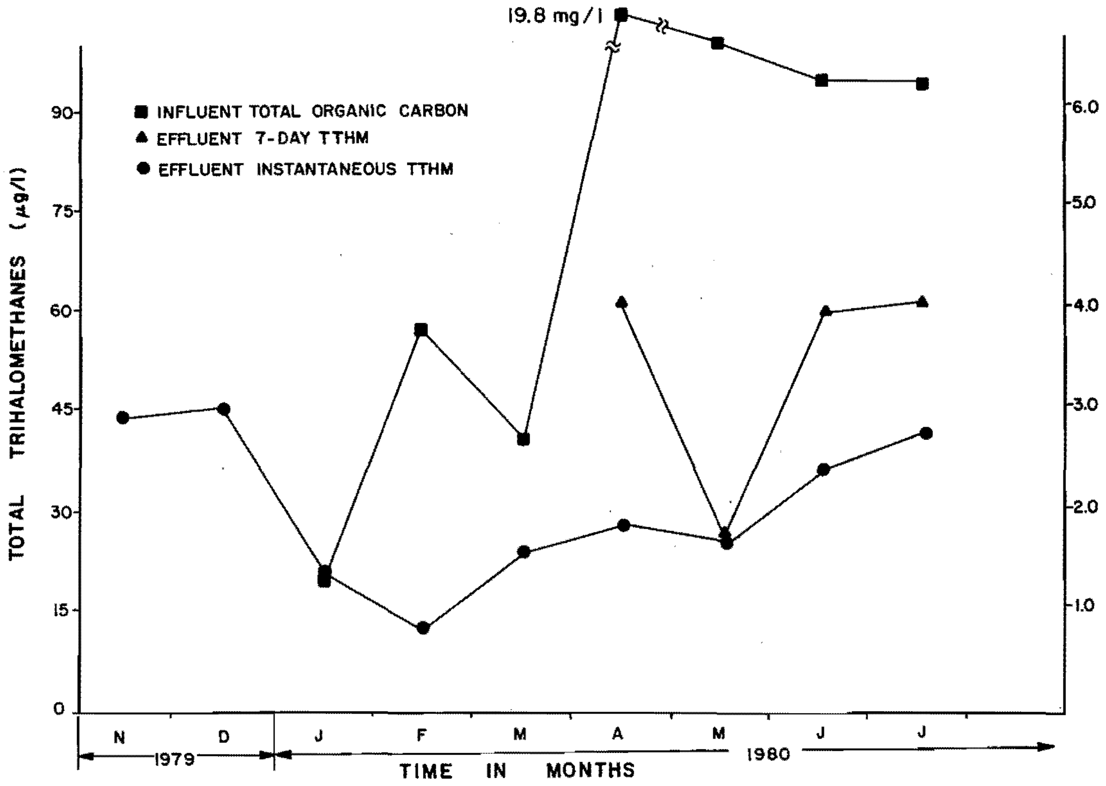

Figure 21. Influent total organic carbon and effluent trihalomethanes at WBWCD plant No. 3 water purification facility.

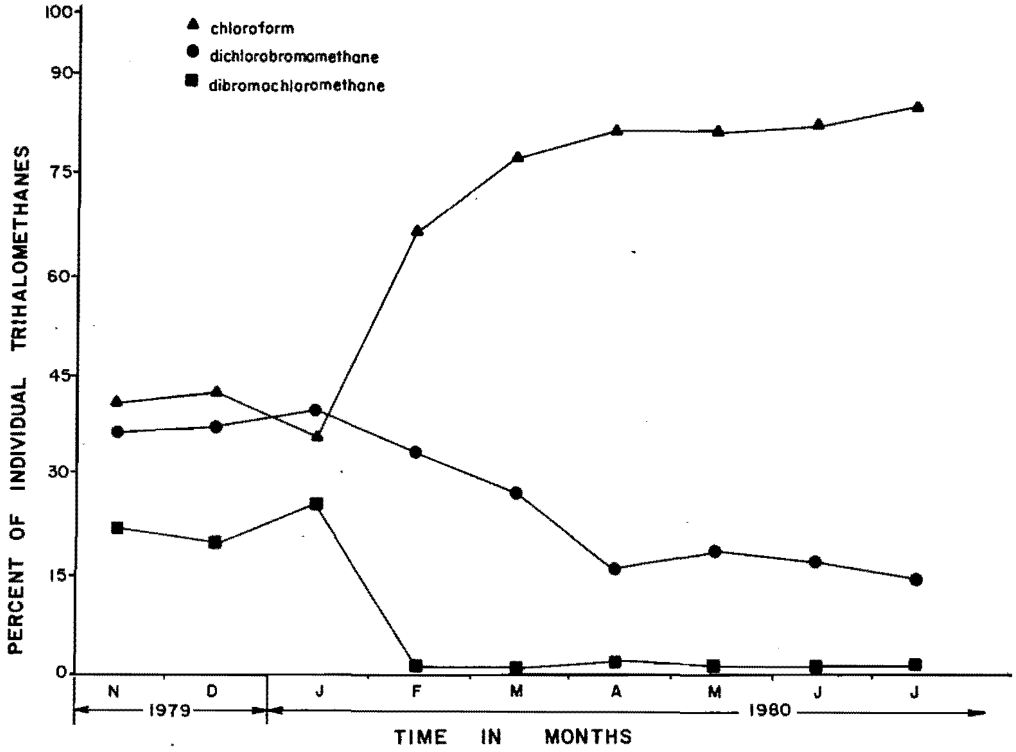

Figure 22. Percent of individual trihalomethanes in the effluent at WBWCD plant No. 3 water purification facility.

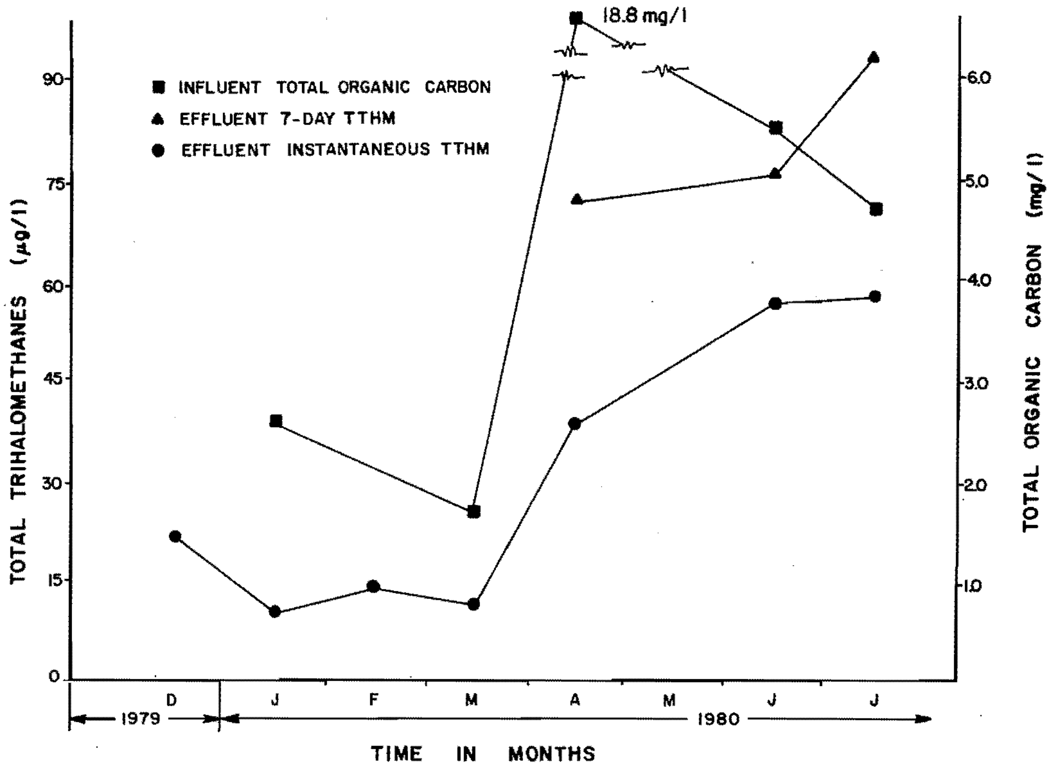

Figure 23. Influent total organic carbon and effluent trihalomethanes at WBWCD plant No. 4 water purification facility.

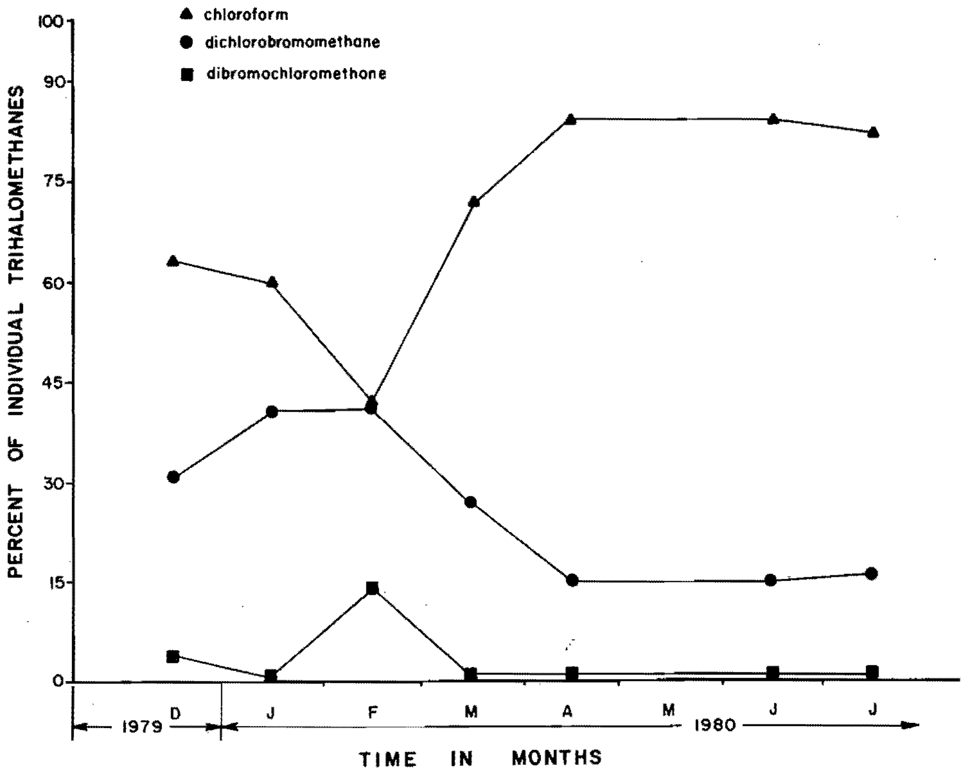

Figure 24. Percent of individual trihalomethanes in the effluent at WBWCD plant No. 4 water purification facility.

Residential sites sampled contained a maximum mean inst-TTHM concentration of 68 µg/l and a maximum measurement of 84 µg/l (Figure 25). The TTHMs originated from chlorinated effluents from WBWCD plants No. 2 and/or 3 mixed with Ogden City unchlorinated well water. Inst-TTHM exposure levels remained relatively low during the winter and spring months and increased to a peak of 55 µg/l in July 1980. The summer increase in water demand brought an increase in chlorinated treated surface water as opposed to nonchlorinated, THMs free, well water and accounted for the increase in THMs. Further, both treatment plants No. 2 and 3 tend to have elevated inst-TTHM and 7-day TTHM that contribute to this summer increase. The mean inst-TTHM concentration at no time exceeded the 100 µg/l level. During the July 1980 sampling period, McKay Dee Hospital sample site (No. 1 on Figure 8) had 82 µg/l inst-TTHM which was the highest level measured at any Ogden sample site. At the same time WBWCD plant No. 2 had a 7-day TTHM of 85 µg/l while WBWCD plant No. 3 had only 60 µg/l for its 7-day TTHM. Thus WBWCD plant No. 2 could have supplied McKay Dee hospital exclusively and with a residence time long enough to provide its maximum THM potential.

None of the three WBWCD treatment plants showed detectable THMs in their raw water source. Chlorination alone was responsible for the THMs found in the effluents. Culinary water produced by the three WBWCD water treatment plants never contained either inst-TTHM or 7-day TTHM which exceeded the proposed 100 µg/l USEPA MCL THMs limit.

Water from all three plants sampled show large increases in percentages of chloroform with subsequent decreases in percentages of brominated trihalomethanes beginning in February or March. As in the Salt Lake area, the ranking in occurrence of individual trihalomethanes was: chloroform > dichlorobromomethane > dibromochloromethane with no bromoform being detected. This pattern suggests either a decrease in available bromide or a change in precursor type that reduces brominated THMs in spring and summer months.

Post Chlorination versus Prechlorination for Trihalomethane Reduction: A 7-Day Diurnal Study

A 7-day, diurnal, simultaneous study comparing post with prechlorination was undertaken at the Parleys Water Purification Plant to determine the relative effects of post (chlorination at the entrance to the filters) as opposed to prechlorination (chlorination near rapid mix) on TTMs production. In addition, permanganate was added at a dose of 0.3 mg/l (determined by plant personnel) near rapid mix on the post chlorination side during the last 40 hours of the study to determine if a pretreatment oxidant would reduce trihalomethane precursors. The chlorine dosage was 2.0 mg/l for both post and prechlorination.

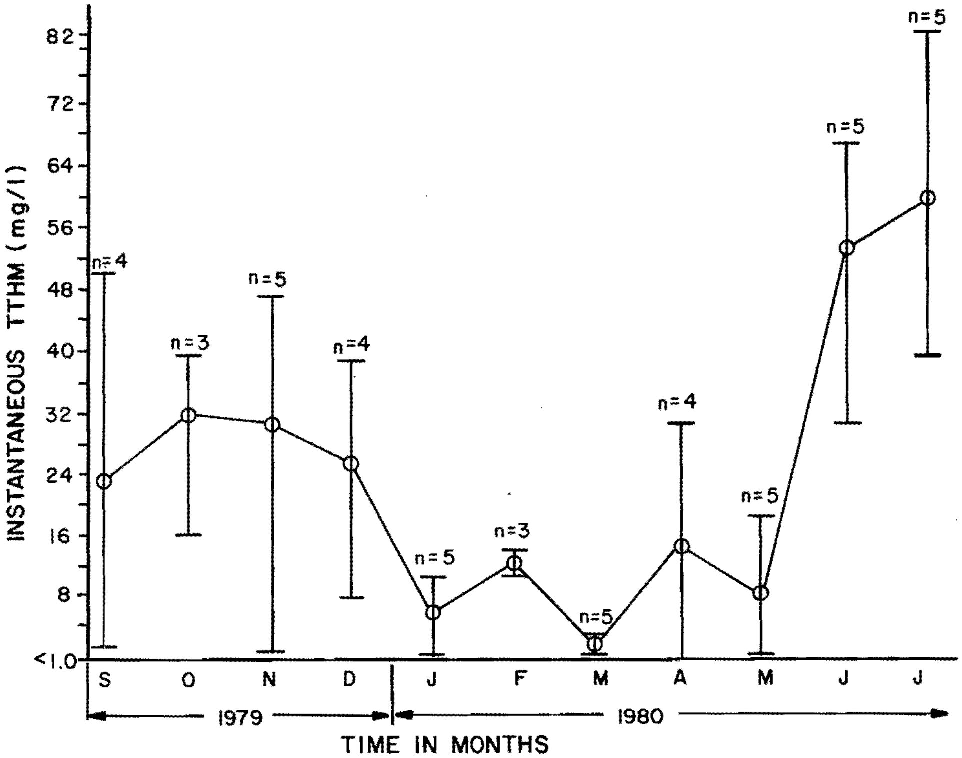

Figure 25. Mean trihalomethane exposure levels to selected Ogden City business and residential sites. (n = number of samples collected and analyzed on one sampling trip during the month for the individual business and residential sites.)

Inst-TTHM and TOCs were taken (grab samples) after each unit process to establish trihalomethane formation during the treatment process (Appendix Table C-1). No THMs were detected in the influent to Parleys. Data plotted in Figure 26 indicate that 15 minutes after adding chlorine, 3 μg/l TTHMs were present. After coagulation (45 minutes into the process) the inst-TTHM increased to 11 μg/l. Further increases occurred up through filtration to bring the maximum inst-TTHM to 50 μg/l. Inst-TTHM measured in the finished water were 26 μg/l, about half the level contained in the sample taken after filtration. Turbulence through the launder and into the clearwell may possibly have volatized some of the organics. All samples were collected within 5 minutes of each other; thus, any change in the influent quality 4 to 5 hours before these samples were collected could result in different unit processes treating different water qualities. However, since the TOCs for Parleys appear to remain fairly constant during the summer months, the possible error was not considered significant. The data also indicated a decrease in total organic carbon from 4.25 mg/l at the rapid mix basin to a finished concentration of 2.82 mg/l TOC.

Trihalomethane formation at Parleys was the direct result of chlorination immediately prior to the rapid mix basin (Figure 26) and the trihalomethanes formed throughout the 255 minute purification process. Figure 27 and 28 present a comparison of post chlorination versus prechlorination in the production of trihalomethanes. The prechlorination inst-TTHM were consistently higher than the post chlorination TTHMs with the exception of two cases, on August 12 at 4:00 AM and August 14, 1980 at 12:00 noon (Figure 27). Permanganate addition on the post chlorination side, beginning at 8:00 PM on August 15 and continuing through August 17, 1980, at 12:00 noon, appeared to have no effect on the post chlorination inst-TTHM. The trend that under identical chlorine dosages prechlorination consistently resulted

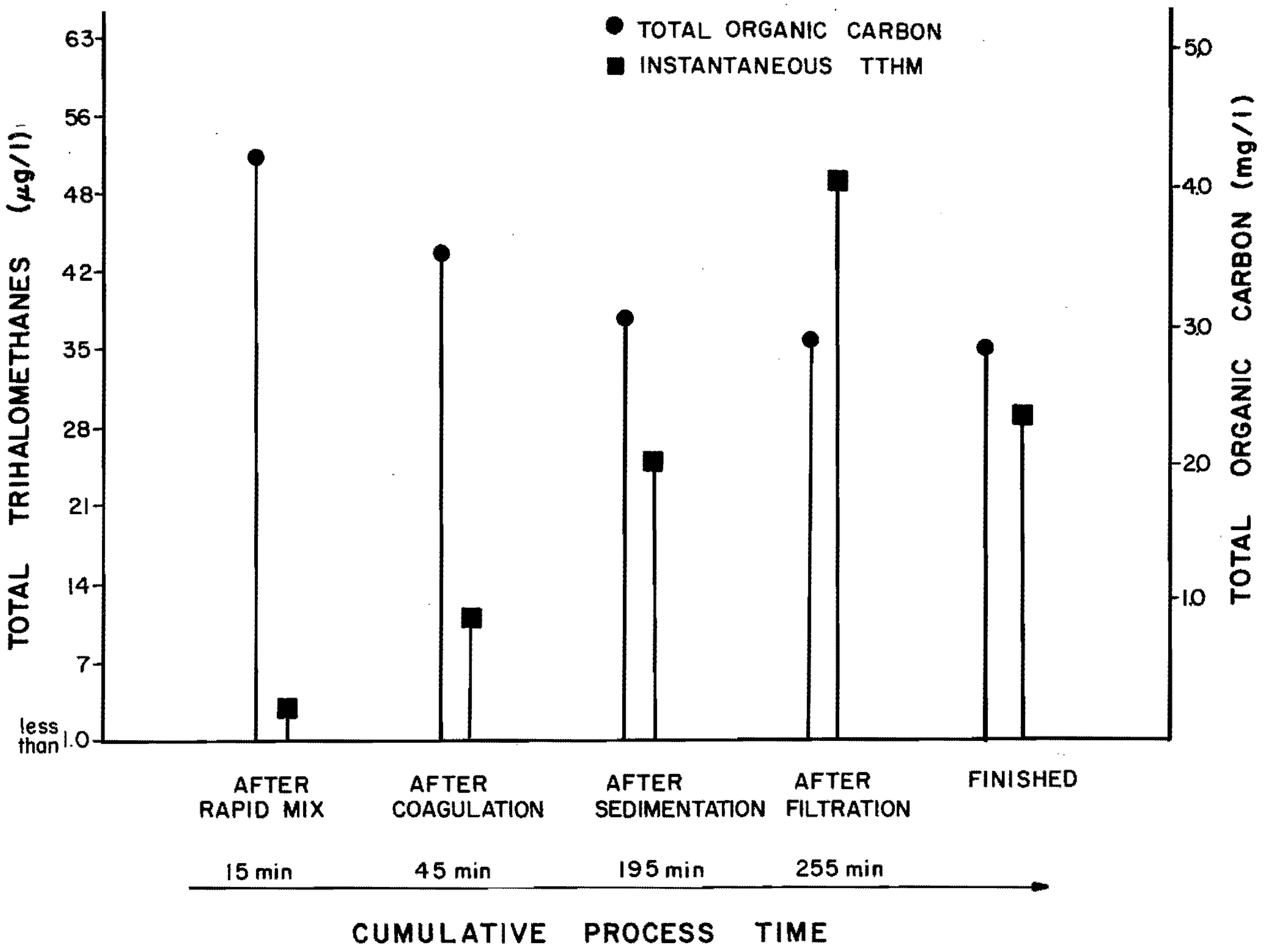

Figure 26. Total organic carbon removal and trihalomethane formation after each unit process at Parleys Water Purification Plant.

in higher measurements of inst-TTHM than did post chlorination since the contact time from prechlorination to sampling was 255 minutes compared with only 60 minutes for post chlorination. When these samples were allowed to equilibrate for 7-days, a different pattern emerged (Figure 28).

Under identical chlorine dosages of 2 mg/l, the 7-day TTHM with post chlorination side were consistently higher than those with prechlorination, in some cases nearly twice as high. After 7-days none of sixteen 7-day TTHM samples randomly checked had any chlorine residual. Thus to determine if the precursor demand for chlorine was satisfied two sets of samples (August 16 at 4:00 AM and August 17 at 4:00 AM) were reinoculated with an excess chlorine dosage and allowed to incubate for 7-days. After 7-days a chlorine residual was shown to be present (thus the test measured maximum trihalomethane potential; MTP). Figure 28 shows that both rechlorinated MTP sample sets were 162 µg/l TTHMs for post chlorination and 155 µg/l for TTHMs prechlorination on August 16 at 4:00 AM. August 17 at 4:00 AM, MTP levels were 158 post chlorination TTHMs and 148 µg/l prechlorination TTHMs. These differences are negligible and show no difference between post and prechlorination at Parleys. Further, the addition of 0.3 mg/l permanganate on the post chlorination side, beginning August 15 at 8:00 PM and continuing through August 17 at 12:0 noon, did not appear to make a significant difference in TTHMs formation between the post and prechlorination side.

It appears that prechlorination produced higher inst-TTHM than post chlorination (Figure 27) due to the longer chlorine contact time. Further, the 7-day post chlorination TTHMs were consistently higher

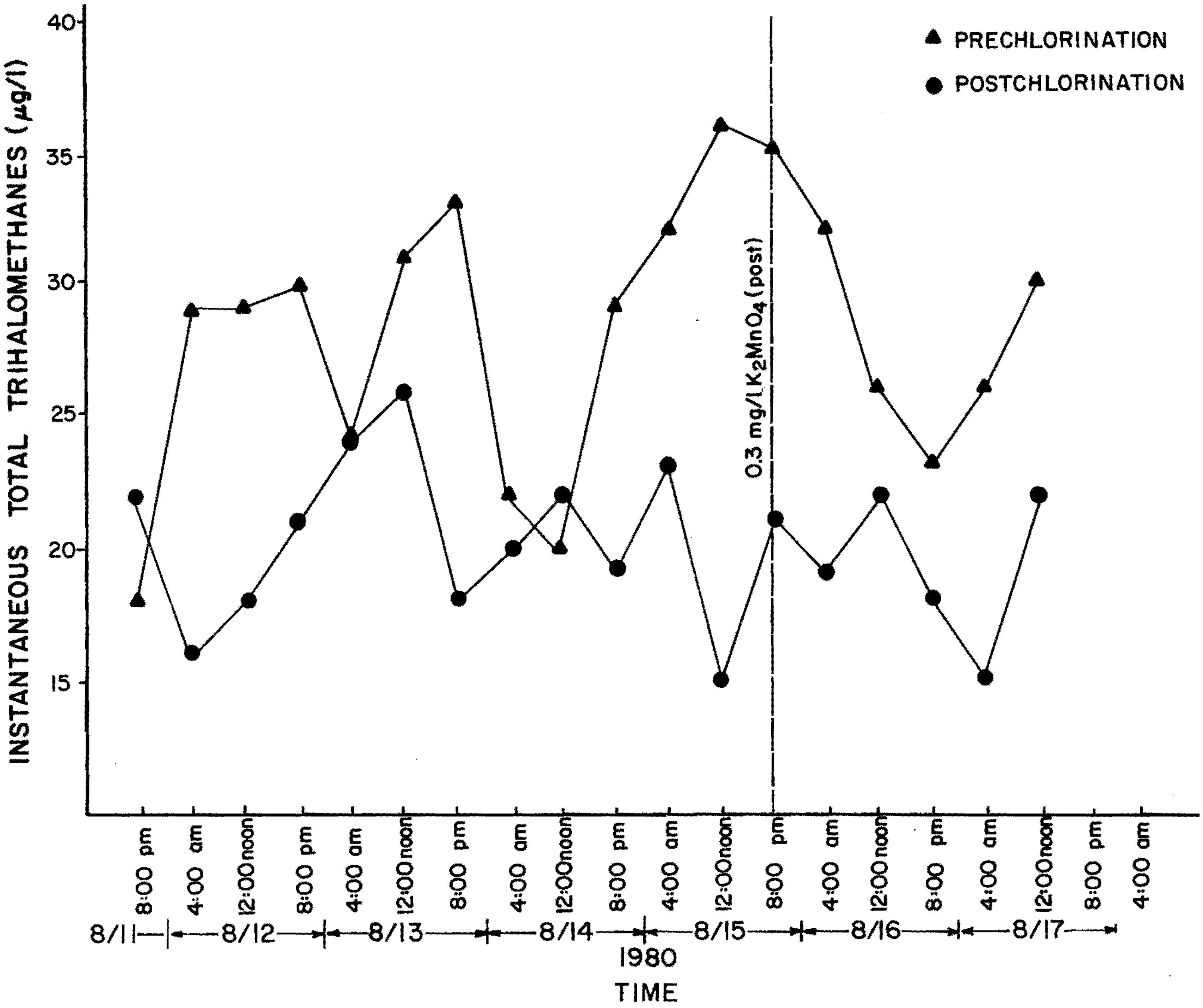

Figure 27. Prechlorination versus post chlorination in the formation of inst-trihalomethanes at the Parleys Water Purification Plant (with 0.3 mg/l permanganate addition).

than the 7-day prechlorination TTHMs, possibly because some of the 2 mg/l applied chlorine dosage was removed during coagulation and sedimentation by sorbtion on the floc leaving less chlorine to go into forming THMs. This hypothesis is supported by the observation that upon rechlorination the two sample sets ended with very similar THMs levels.

Figure 29 presents the inst-TTHM levels in the effluent at Parleys during the diurnal sampling. A great deal of fluctuation was observed with inst-TTHM levels ranging from a low of 17 μg/l to a high of 63 μg/l. The inst-TTHM concentrations in the effluent more than tripled in one 24-hour period. Permanganate addition beginning at 8:00 PM on August 15 did not appear to reduce inst-TTHM in the effluent.

Seven-day TTHM levels in the effluent from Parleys during the diurnal study are represented in Figure 30. The fluctuations were smaller. A 94 μg/l TTHMs maximum occurred at 4:00 AM on August 15, and a 56 μg/l TTHMs minimum occurred at 8:00 PM on August 16. A maximum trihalomethane potential test (MTP) was performed on the 4:00 AM August 16 and 17 on the effluent samples. The August 16 sample had a MTP of 146 μg/l while the August 17 sample contained 150 μg/l. When samples were rechlorinated and the haloform reaction was allowed to go to completion,

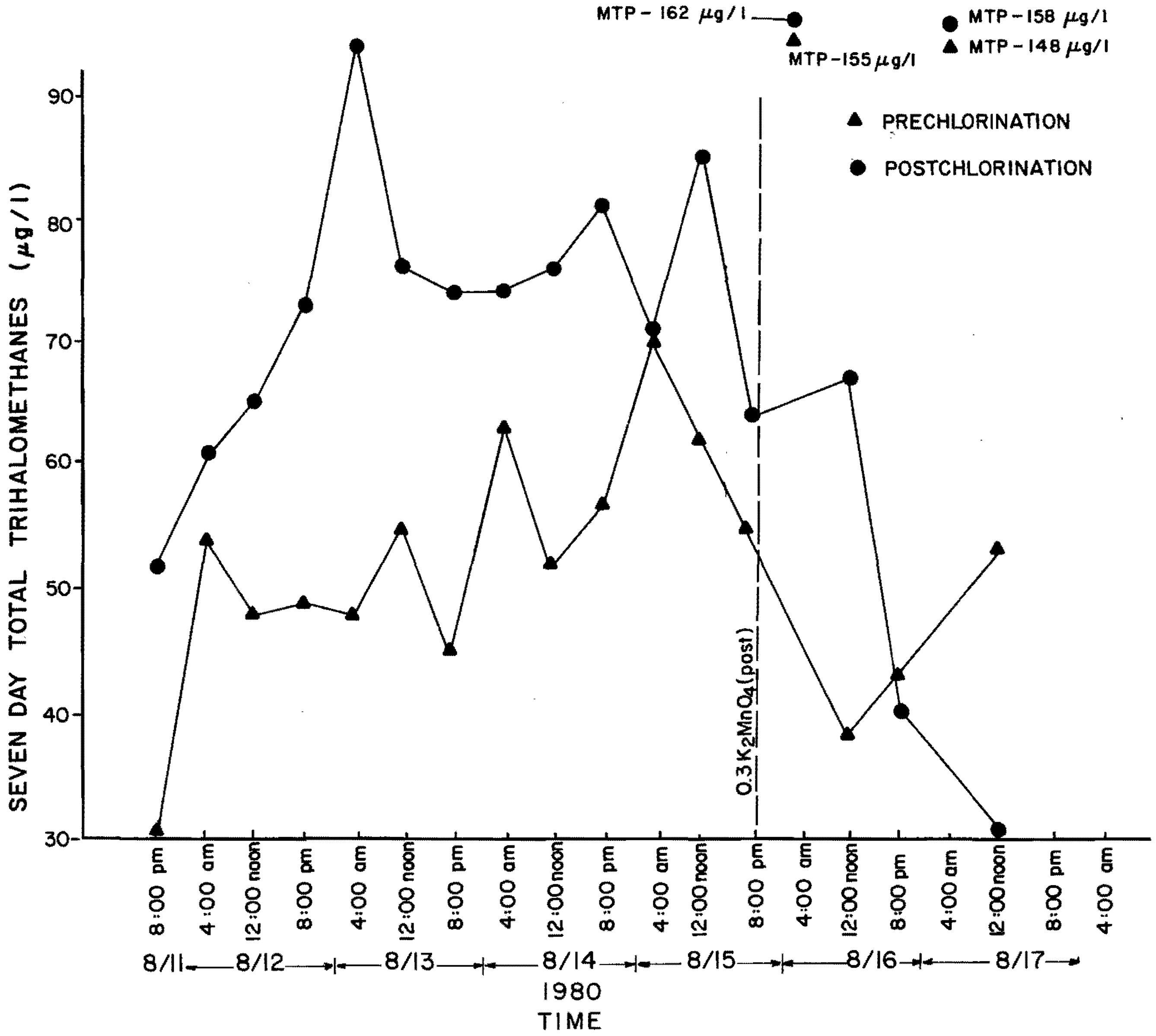

Figure 28. Prechlorination versus post chlorination in the formation of 7-day trihalomethanes at the Parleys Water Purification Plant.

there was little fluctuation in day to day precursor loadings. Therefore, the fluctuation of the inst-TTHM in the plants effluent may have been due to other parameters such as process time, temperature, or the amount of free chlorine residual on a given day.

Total Organic Carbon and Trihalomethane Formation

Linear regression analyses (to relate TOC to THMs formation) of total organic carbon in mg/l on trihalomethane in μm/l (TTHMs concentration as micromolar rather than microgram) in the effluent of the treatment plants are shown in Figures 31 and 32. The inst-TTHM versus TOC (Figure 31) has a somewhat better correlation ($r^2 = 0.438$) (Figure 31) than the 7-day TTHM versus TOC ($r^2 = 0.333$) (Figure 32). Both plots were significant at the 1 percent confidence level. Application of these curves has the major drawback that the TTHMs formed should be a function of influent quality rather than effluent quality since the chlorination takes place at the influent. Regressions of influent TOC on effluent TTHMs did not provide acceptable correlations (r^2 were less than 0.10). This may be explained by further analysis of Figure 26.

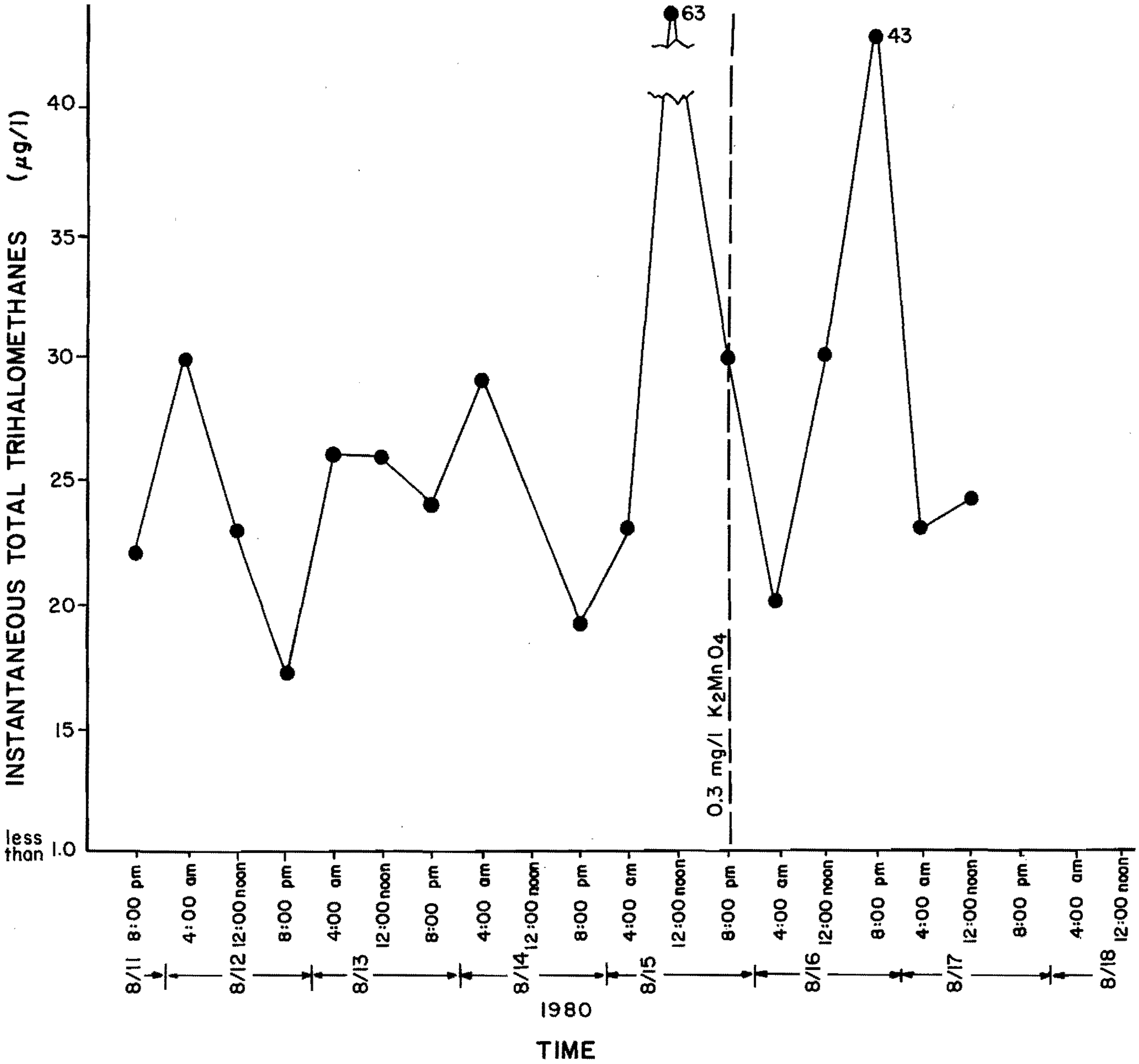

Figure 29. Effluent inst-trihalomethanes at the Parleys Water Purification Plant over a 7-day period (with 0.3 mg/l permanganate addition).

Most of the TOC removed is accomplished early in the treatment process (76 percent by the end of sedimentation). However, most of the TTHMs formation (62 percent) occurs after the sedimentation process. Thus, the TOC fraction not removed in the treatment process is responsible for a large portion of the THMs formed within the treatment facility. This suggests that a "soluble TOC" (TOC not removed by the physical unit process within a treatment plant) and a "nonsoluble TOC" (TOC fraction removed by the physical unit process within a treatment plant) exists. By reducing the total organic carbon in the effluent at the treatment plant, it may be possible to lower both inst-TTHM and 7-day TTHM. This may be possible by more efficient in-plant treatment processes or intensive precursor management and protection of the influent raw water source.

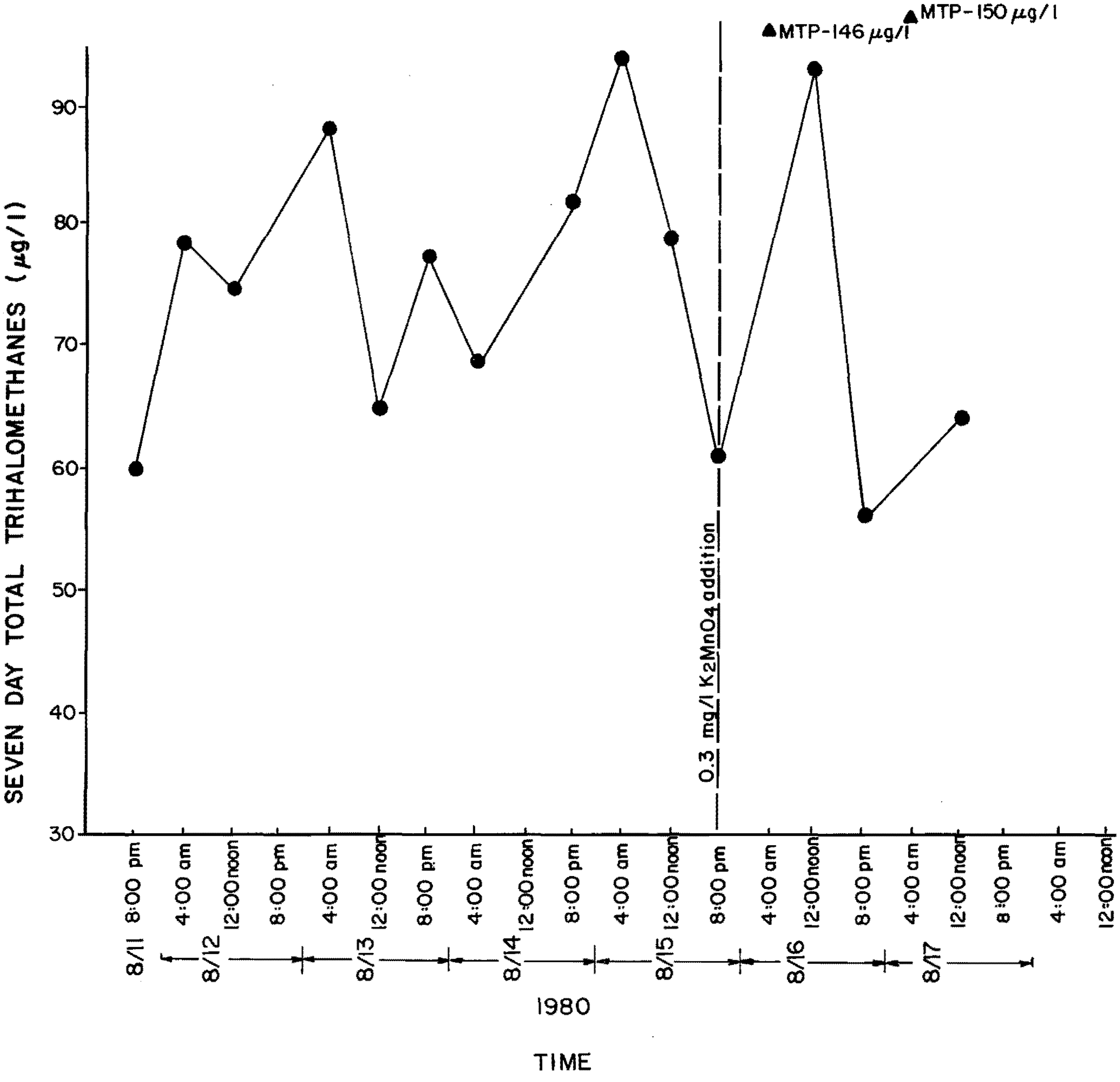

Figure 30. Effluent 7-day trihalomethanes at the Parleys Water Purification Plant over a 7-day period (with 0.3 mg/l permanganate addition).

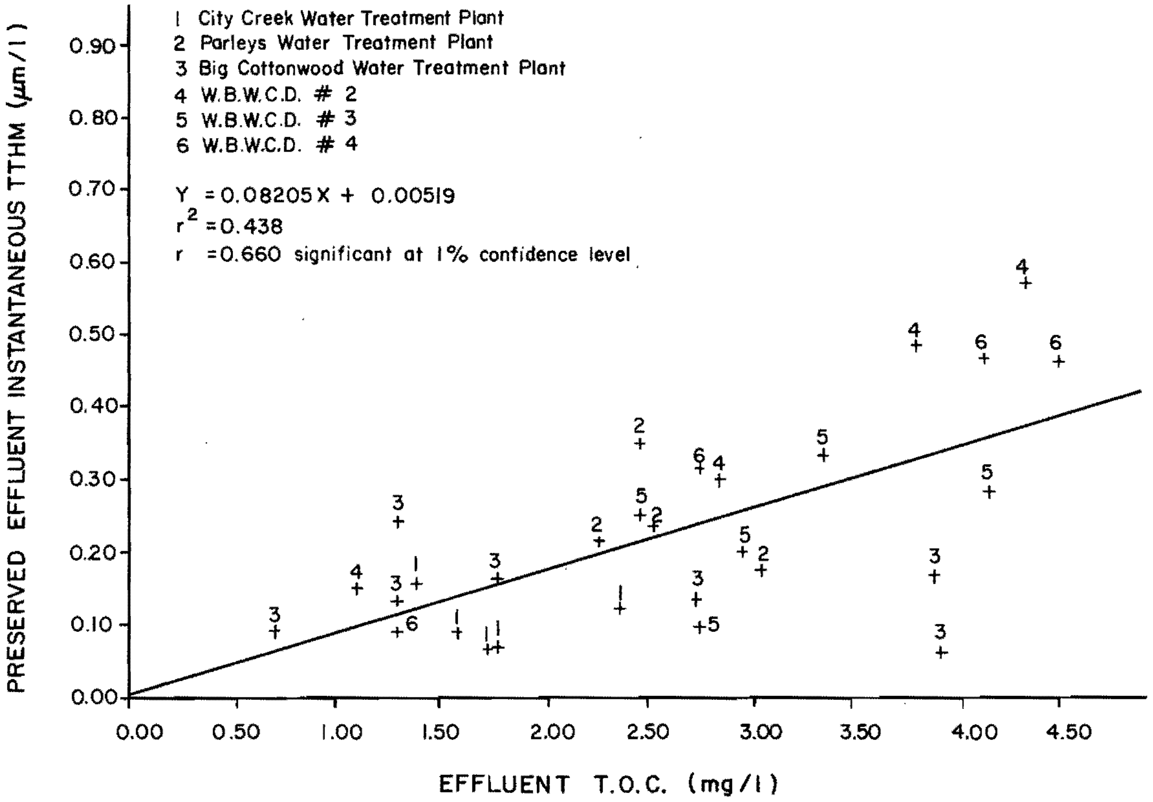

Figure 31. Effluent treatment plant inst-trihalomethanes as μm/l versus treatment plant effluent total organic carbon as mg/l.

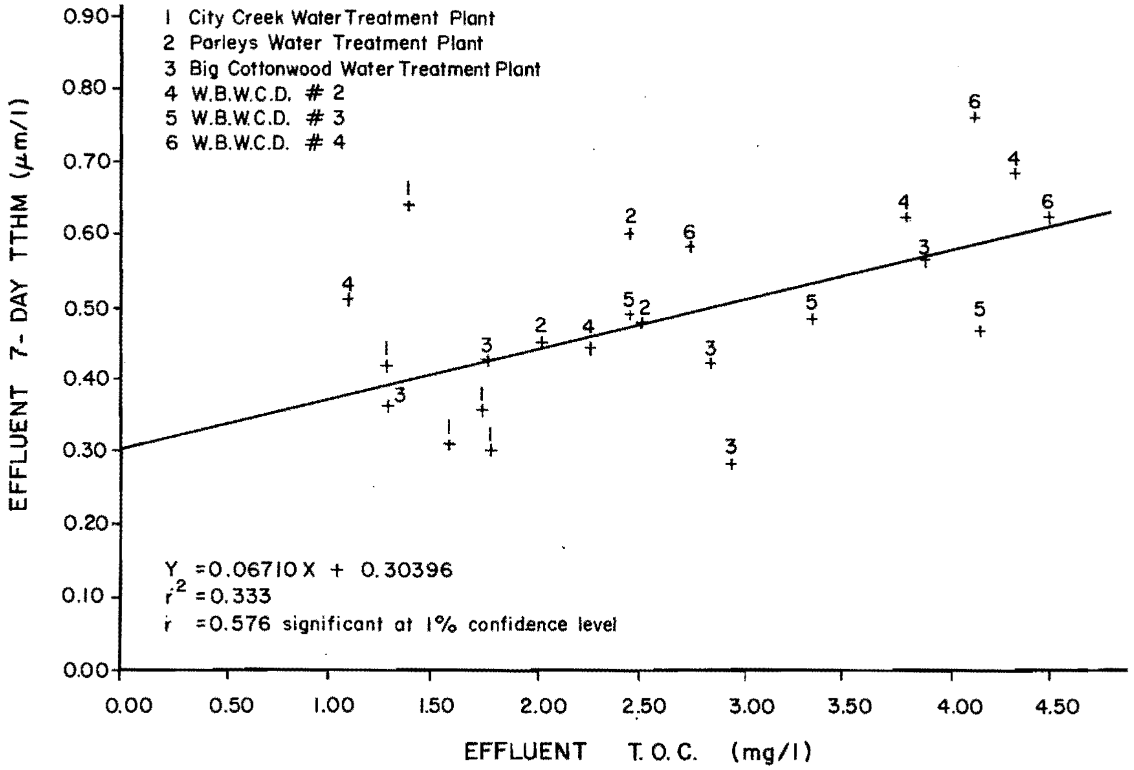

Figure 32. Effluent treatment plant 7-day trihalomethanes versus treatment plant effluent total organic carbon as mg/l.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

A one-year study of trihalomethane and total organic carbon levels in Salt Lake City and Ogden City, Utah, drinking water supplies and treatment plant effluents was undertaken. In addition, methods to lower trihalomethane levels by moving the point of chlorination and adding a pretreatment oxident were studied. From the results, the following conclusions are derived.

1. Trihalomethanes are not found above 1 μg/l in nonchlorinated raw water supplies to any treatment plant under study. Therefore, THMs found in the effluent of the treatment plants under study are the direct result of chlorination.

2. With the exception of nonchlorinated water supplies, trihalomethanes (mostly chloroform) were found in all treatment plant effluents, residential and commercial sample sites in Ogden and Salt Lake City. Inst-TTHM levels ranged from a low of 2 μg/l to a high of 84 μg/l inst-TTHM.

3. Trihalomethanes can increase with increasing chlorine contact time in a distribution system by as much as 100 percent in a 7-day period based upon the 7-day TTHM procedure.

4. Beginning in late winter and continuing through the spring and summer months (1979-1980), chloroform comprises 70 to 90 percent of the total inst-TTHM in the effluents of all treatment plants under study.

5. Trihalomethane levels increase significantly in late spring and summer months. Water samples collected in July indicated the highest average THMs exposure levels to Salt Lake and Ogden residents.

6. The Little Cottonwood water treatment plant consistently maintains the highest effluent inst-TTHM and 7-day TTHM of the four Salt Lake treatment plants under study.

7. The USEPA proposed 100 μg/l average on TTHM was never exceeded in Salt Lake City or Ogden City, Utah. Distribution points further from the treatment plants than those tested, however, may be exposed to 7-day TTHM levels that may approach the 100 μg/l MCL.

8. A significant correlation at the 0.01 confidence level exists for effluent inst- and 7-day TTHM in μm/L versus effluent total organic carbon in mg/l.

9. Neither moving the point of chlorination from rapid mix to just before the filters, nor the addition of permanganate at 0.3 mg/l reduces TTHMs at the effluent to Parleys treatment plant as shown by the diurnal study.

10. Inst-TTHM concentration in the effluent at Parleys treatment plant may fluctuate by a factor of three within a 24-hour period.

Recommendations

Based on an evaluation of the results presented for this investigation and a review of the literature, the following recommendations are made.

1. Elevated levels of inst-TTHM and 7-day TTHM in the Salt Lake sample sites (particularly during summer months) appear to result from the chlorination of Deer Creek Reservoir water at the aqueduct and at the Little Cottonwood Water Treatment Plant. If the TOC quality of this influent degenerates further, it may result in the failure of the Salt Lake area to meet a 100 μg/l TTHMs MCL during the summer. The following suggestions may alleviate further problems:

   a. Water flowing into the Deer Creek Reservoir should be investigated to determine if high TOC loads exist.

   b. Chlorine pretreatment of Deer Creek Reservoir water (with subsequent 12-hour contact time in the aqueduct before entering the treatment plant) may be aggravating the problem at the Little Cottonwood treatment plant. Substitution of another pretreatment oxidant during the summer months may reduce summer TTHMs at this facility. This would need to be verified by laboratory chlorination test conducted on pretreated (i.e., permanganate, ozone, etc.) Deer Creek water samples that have been subjected to jar tests.

2. Watershed and agriculture runoffs and various reservoir sources to affected treatment plants should be analyzed for TOC to determine precursor loadings and if the seasonal runoff events affect trihalomethane levels at the treatment plants.

3. Weber Basin Water Conservancy District treatment plants and Ogden City are responsible for TTHMs in Ogden City. TTHMs levels at these treatment plants (and sub-

sequently in Ogden City) could be lowered in the summer months by better source protection of the Weber River and its drainage areas. Agricultural runoff may contain high amounts of THMs precursors.

4. Bromide concentrations should be analyzed at the treatment plant influents to determine the source and seasonal variations of the brominated trihalomethanes.

5. The post versus prechlorination study at Parleys provided excellent data on TTHMs development in a treatment plant. This study should be duplicated using one side of the plant as a control while trying different processes on the experimental side (i.e., higher coagulant dosage, oxidants, polymer, etc.) to determine TTHMs reduction.

6. Salt Lake City's stream fed treatment plants (Big Cottonwood and City Creek) maintained the lowest TTHMs of any water treatment plant under study. This is partially due to intensive source protection programs that should not be compromised if TTHMs are to be kept at a minimum.

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APPENDIX A

SALT LAKE CITY AREA TRIHALOMETHANES AND TOTAL ORGANIC CARBONS

Table A-1. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of July (1979).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Trolley Square	30	15	2.0	< 1	47	
City Hall	29	14	2.0	< 1	45	
Salt Palace	35	13	< 1	< 1	48	

Table A-2. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of August (1979).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
33 S. 33 E.	14	6	<1	< 1	20	
City Hall	24	13	2	< 1	39	
Capitol Building	12	6	1.0	< 1	19	
Woods Cross	11	5	1	<1	17	
City Hall	25	11	1	< 1	37	
Cottonwood	< 1	< 1	< 1	<1	< 1	
U. of U. Kennecott	30	9	< 1	<1	39	
1620 W. 100 S.	38	12	<1	< 1	50	
Main at 1st S.	34	14	1	<1	49	

Table A-3. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of September (1979).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES μg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Capitol Building	16	9	2	< 1	27	
Woods Cross	< 1	< 1	< 1	< 1	< 1	
Temple Square	5	3	<1	< 1	8	
City Hall	25	15	7	< 1	47	
Univ. of Utah Kennecott	17	13	7	< 1	37	
Granger	19	10	2	< 1	31	
Cottonwood	21	11	1	< 1	34	

Table A-4. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of November (1979).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES μg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Little Cottonwood Treatment Plant effluent	19	15	7	<1	41	
Little Cottonwood Treatment Plant (Little Cottonwood Creek) influent	< 1	< 1	< 1	<1	< 1	
Little Cottonwood Treatment Plant (Deer Creek) influent	21	15	8	< 1	44	
Big Cottonwood Treatment Plant influent	< 1	< 1	<1	< 1	< 1	
Big Cottonwood Treatment Plant effluent	11	4	2	< 1	17	
City Creek Treatment plant effluent	11	7	< 1	< 1	18	
Salt Lake International Center	21	14	3	<1	38	
10 W. at N. Temple	22	15	5	<1	42	
Salt Palace	20	15	5	< 1	40	
Univ. of Utah Kennecott Research Building	21	16	5	<1	42	
10 N. and 9th West	22	15	5	<1	42	

Table A-5. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of December (1979).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/l (TOTAL ORGANIC CARBON)
Big Cottonwood Treatment Plant (effluent)	15	7	1	< 1	23	
Big Cottonwood Treatment Plant Influent	< 1	< 1	< 1	< 1	< 1	
Parley Treatment Plant effluent	16	16	13	< 1	45	
Little Cottonwood Plant Cottonwood Creek influent	1.0	< 1	< 1	< 1	1.0	
Little Cottonwood Plant Deer Creek influent	12	8	< 1	< 1	20	
Little Cottonwood Plant effluent	22	17	8	< 1	47	
Little Cottonwood 33 So. Reservoir influent	22	17	9	< 1	48	
Salt Lake International 100 N. 5000 W.	20	16	10	< 1	46	
Sears (SLC) 754 S. State	19	15	6	< 1	40	
SLC Water Company 1530 S. W. Temple	21	15	5	< 1	41	
Little Cottonwood 33 So. Reservoir effluent	23	17	9	< 1	48	

Table A-6. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of January (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/l (TOTAL ORGANIC CARBON)
Little Cottonwood Treatment Plant Little Cottonwood Creek influent	< 1	< 1	< 1	< 1	< 1	
Little Cottonwood Treatment Plant, Deer Creek Influent	13	17	4	< 1	34	
Little Cottonwood Treatment Plant effluent	16	11	3	< 1	30	
Little Cottonwood Treatment Plant, 33 S. Reservoir effluent	19	12	4	< 1	35	
Univ. of Utah Special Events Center	< 1	< 1	< 1	< 1	< 1	
Salt Palace	17	10	4	< 1	31	
Big Cottonwood influent	< 1	< 1	< 1	< 1	< 1	
Big Cottonwood effluent	16	8	1	< 1	25	
City Creek Plant influent	< 1	< 1	< 1	< 1	< 1	
City Creek Plant effluent	6	4	< 1	< 1	10	
Salt Lake International Center	15	9	2	< 1	26	
33 S. 33 East (SLC)	2	1	< 1	< 1	3	

Table A-7. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of February (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB) CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Little Cottonwood Treatment Plant, Little Cottonwood Creek influent	< 1	<1	<1	< 1	< 1	0.6
Little Cottonwood Treatment Plant, Deer Creek Influent	17	12	4	< 1	33	5.4
Little Cottonwood Treatment Plant effluent	16	12	6	< 1	34	3.9
Little Cottonwood Treatment Plant 33 S. Reservoir	20	12	5	<1	37	8.1
City Creek Treatment Plant influent	< 1	< 1	<1	< 1	< 1	3.1
City Creek Treatment Plant effluent	10	6	1	< 1	17	2.4
Big Cottonwood Treatment Plant influent	< 1	< 1	< 1	< 1	< 1	6.4
Big Cottonwood Treatment Plant effluent	4	4	< 1	< 1	8	4.0
33 S. and 33 E.	2	1	< 1	< 1	3	1.1
Univ. of Utah Special Events Center	2	1	< 1	<1	3	2.1
Salt Lake International Center	20	10	2	<1	32	4.2
Salt Palace	15	10	6	< 1	31	7.0

Table A-8. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of March (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB) CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Little Cottonwood Treatment Plant, Little Cottonwood Creek influent	25	7	2	< 1	34	2.4
Little Cottonwood Treatment Plant, Deer Creek influent	29	11	2	<1	42	2.9
Little Cottonwood Treatment plant effluent	38	14	3	<1	55	2.3
Big Cottonwood influent	< 1	<1	< 1	<1	<1	1.7
Big Cottonwood effluent	7	4	1.0	< 1	12	0.7
Salt Palace	27	9	3	< 1	39	1.0
Salt Lake City City Creek Reservoir	11	3	< 1	< 1	14	0.9
Univ. of Utah (Dormitory)	< 1	< 1	< 1	< 1	< 1	0.4
2475 East 3300 South	19	6	1.0	< 1	26	1.0
Salt Lake International Center	22	7	3	< 1	32	2.0

Table A-9. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of April (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^3	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Little Cottonwood Treatment Plant, Deer Creek influent	22	8	2	< 1	32	2.6
Little Cottonwood Treatment Plant, Little Cottonwood Creek, influent	< 1	< 1	< 1	< 1	< 1	1.1
Little Cottonwood Treatment Plant effluent	26 / 62	8 / 16	2 / 6	< 1 / <1	36 / 84	2.0
City Creek effluent	/ 56	/ 6	/ <1	/ < 1	/ 62	
Big Cottonwood Plant influent	< 1	< 1	< 1	< 1	<1	3.0
Big Cottonwood Plant effluent	17 / 46	3 / 6	< 1 / < 1	< 1 / <1	20 / 52	1.8
2475 East 3300 South	30	6	< 1	< 1	36	2.3
Univ. of Utah (Engineering Building)	14	8	5	<1	27	
Salt Lake City International Center	31	7	1	3	42	1.2
Salt Palace	31	13	3	< 1	47	

Table A-10. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of May (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^3	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Little Cottonwood Water Treatment Plant, Deer Creek Influent	38	17	2	< 1	57	3.4
Little Cottonwood Water Treatment Plant, Little Cottonwood Creek Influent	< 1	< 1	<1	<1	< 1	1.6
Little Cottonwood Water Treatment Plant Effluent	26 / 60	6 / 11	< 1 / 1	< 1 / < 1	32 / 72	1.8
Parleys, Big Cottonwood and City Creek Water Treatment Plants Influent	<1	< 1	< 1	< 1	<1	1.5 2.0 2.0
Parleys Water Treatment Plant Effluent	36 / 64	7 / 10	< 1 / < 1	< 1 / < 1	43 / 74	2.5
City Creek Water Treatment Plant Effluent	16 / 70	3 / 8	< 1 / <1	< 1 / < 1	19 / 78	1.4
Big Cottonwood Water Treatment Plant Effluent	26 / 51	3 / 6	< 1 / < 1	< 1 / <1	29 / 57	1.3
Salt Palace	30	4	< 1	<1	34	
Capitol Building	23	4	< 1	< 1	27	1.6
3300 S. 2475 E.	39	8	< 1	<1	47	2.3
Salt Lake International Center	42	6	< 1	< 1	48	

Table A-11. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of June (1980).

SAMPLE LOCATION (inst. THM / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/l (TOTAL ORGANIC CARBON)
Little Cottonwood Water Treatment Plant, Aqueduct intake at Deer Creek Res. before chlorination	< 1	< 1	<1	<1	< 1	
Little Cottonwood Water Treatment Plant, Deer Creek Influent	34 46	10 12	< 1 < 1	<1 < 1	44 58	100
Little Cottonwood Water Treatment Plant, Little Cottonwood Creek Influent	< 1	< 1	< 1	< 1	<1	3.11
Little Cottonwood Water Treatment Plant Effluent	34 78	9 13	< 1 1	< 1 <1	43 92	
Parleys, City Creek and Big Cottonwood Water Treatment Plant Influents	<1	< 1	< 1	<1	<1	3.25
Parleys Water Treatment Plant Effluent	16 46	7 11	3 1	<1 < 1	26 58	
Big Cottonwood Water Treatment Plant Effluent	19 64	1 4	<1 <1	< 1 < 1	20 68	3.96
City Creek Water Treatment Plant Effluent	6 38	2 6	< 1 < 1	< 1 < 1	8 44	1.76
Salt Lake International Center	60	10	< 1	< 1	70	1.15
3300 S. 2475 E.	34	6	< 1	< 1	40	2.58
Capitol Building	9	3	<1	< 1	12	2.43
Salt Palace	17	5	<1	<1	22	

Table A-12. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of July (1980).

SAMPLE LOCATION (inst. THM / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/l (TOTAL ORGANIC CARBON)
Little Cottonwood Water Treatment Plant, Little Cottonwood Creek Influent	<1	< 1	<1	< 1	<1	0.6
Little Cottonwood Water Treatment Plant, Deer Creek Influent	50 54	9 9	<1 < 1	< 1 < 1	59 63	5.9
Little Cottonwood Water Treatment Plant Effluent	36 80	7 10	< 1 < 1	< 1 < 1	43 90	3.5
City Creek, Parleys and Big Cottonwood Water Treatment Plants Influents	< 1	< 1	< 1	< 1	<1	1.5 1.9 1.5
Parleys Water Treatment Plant Effluent	20 42	7 13	1 2	< 1 <1	28 57	2.3
City Creek Water Treatment Plant Effluent	8 32	3 6	< 1 <1	<1 < 1	11 38	1.6
Big Cottonwood Water Treatment Plant Effluent	14 40	2 4	< 1 <1	<1 < 1	16 44	1.3
Salt Palace	25	7	3	< 1	35	1.2
33 S. and 25 E.	60	10	<1	< 1	70	2.2
Salt Lake International Center	70	11	1	< 1	82	1.8
Capitol Building	16	5	< 1	<1	21	

Table A-13. Salt Lake City area trihalomethanes and total organic carbons (when available) for the month of August (1980).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Little Cottonwood Water Treatment Plant, Cottonwood Creek Influent	<1	< 1	< 1	< 1	< 1	0.06
Little Cottonwood Water Treatment Plant, Deer Creek Influent	52	7	< 1	< 1	59	4.62
Little Cottonwood Water Treatment Plant, effluent	53 80	7 10	< 1 < 1	< 1 < 1	60 90	2.59
City Creek, Parleys and Big Cottonwood Treatment Plants, influent	< 1	< 1	< 1	< 1	< 1	0.29 2.28 1.64
City Creek Water Treatment Plant Effluent	6.0 33	2 4	< 1 <1	<1 <1	8 37	1.80
Big Cottonwood Water Treatment Plant, effluent	14 34	2 3	< 1 < 1	< 1 <1	16 37	2.9
Parleys Water Treatment Plant, Effluent	20 44	9 14	2 4	<1 <1	31 62	2.57
Salt Lake International Center	50	6	< 1	< 1	56	3.40
Salt Palace	34	6	1	< 1	41	1.21
2475 E. 33 So.	19	2	< 1	<1	21	44.8

APPENDIX B

OGDEN AREA TRIHALOMETHANES AND TOTAL ORGANIC CARBONS

Table B-1. Ogden area trihalomethanes and total organic carbons (when available) for the months of July, August, and September (1979).

SAMPLE LOCATION (inst. THM / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
(July) Court House	13	10	3	< 1	26	
(August) Ogden, 24th Street	1.0	<1	<1	<1	1.0	
Ogden Federal Building	30	14	1	<1	45	
(September) Ogden Federal Building	25	16	8	< 1	49	
No. Ogden, I-15 Exit	< 1	< 1	< 1	<1	< 1	
Ogden Stock Yards	18	12	2	<1	32	
Weber State	2	4	3	< 1	9	

Table B-2. Ogden area trihalomethanes and total organic carbons (when available) for the month of October (1979).

SAMPLE LOCATION (inst. THM / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
23rd Street Storage Reservoir	3	7	6	< 1	16	
McKay Dee Hospital 3850 Harrison	18	14	5	< 1	37	
Water District Office 30th Street	18	15	5	< 1	38	

Table B-3. Ogden area trihalomethanes and total organic carbons (when available) for the month of November (1979).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plant No. 3 Influent	< 1	< 1	< 1	< 1	< 1	
WBWCD Plant No. 3 Effluent	18	16	10	< 1	44	
WBWCD Plant No. 2 Effluent	17	13	8	< 1	38	
Center and Main St. Farmington	17	16	11	< 1	45	
3rd North and Main Kaysville	16	14	9	< 1	39	
Ogden Airport	19	16	9	< 1	44	
450 South Clearfield	18	15	10	< 1	43	
44 So. and Washington Blvd.	1	< 1	<1	<1	1	

Table B-4. Ogden area trihalomethanes and total organic carbons (when available) for the month of December (1979).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Treatment Plant No. 3, Influent	< 1	< 1	< 1	< 1	< 1	
WBWCD Treatment Plant No. 3, Effluent	19	17	9	<1	45	
WBWCD Treatment Plant No. 2, Influent	< 1	< 1	<1	<1	< 1	
WBWCD Treatment Plant No. 2, Effluent	16	15	9	<1	40	
WBWCD Treatment Plant No. 4, Influent	< 1	<1	< 1	<1	< 1	
WBWCD Treatment Plant No. 4, Effluent	14	7	1.0	< 1	22	
14th St. and Washington	3	9	6	< 1	18	
522 Harrison	< 1	6	3	< 1	9	
30th and Harrison	11	13	8	< 1	32	
36 South Riverdale Rd.	15	13	10	< 1	38	

Table B-5. Ogden area trihalomethanes and total organic carbons (when available) for the month of January (1980).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plant No. 3 Influent	< 1	< 1	< 1	< 1	< 1	1.3
WBWCD Plant No. 3 Effluent	7	8	5	< 1	20	
WBWCD Plant No. 4 Influent	< 1	< 1	< 1	< 1	< 1	2.6
WBWCD Plant No. 4 Effluent	6	4	< 1	< 1	10	
522 Harrison Ogden	< 1	< 1	< 1	< 1	< 1	
14th and Washington	2	3	2	< 1	7	
36 St. and Riverdale Rd.	1	2	2	< 1	5	
Ogden Federal Building	2	7	3	< 1	12	
McKay Dee Hospital	1	3	3	< 1	7	

Table B-6. Ogden area trihalomethanes and total organic carbons (when available) for the month of February (1980).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^s	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plant No. 4	< 1	< 1	< 1	< 1	< 1	
WBWCD Plant No. 4 Effluent	6	6	2	< 1	14	
WBWCD Plant No. 3 Influent	< 1	< 1	< 1	< 1	< 1	3.8
WBWCD Plant No. 3 Effluent	8	4	< 1	< 1	12	2.8
McKay Dee Hospital	3	5	4	< 1	12	5.3
36 S. and Riverdale Rd.	3	5	3	< 1	11	1.4
14th Street and Washington	7	4	3	< 1	14	1.5

Table B-7. Ogden area trihalomethanes and total organic carbons (when available) for the month of March (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plant No. 3 Influent	<1	< 1	< 1	< 1	<1	2.7
WBWCD Plant No. 3 Effluent	15	6	2	<1	23	3.1
WBWCD Plant No. 4 Influent	< 1	< 1	< 1	<1	<1	1.7
WBWCD Plant No. 4 Effluent	8	3	< 1	< 1	11	1.3
Ogden Federal Building	< 1	1.0	1.0	< 1	2.0	< 0.1
36 S. and Riverdale Rd.	< 1	1.0	1.0	< 1	2.0	0.3
McKay Dee Hospital	<1	1.0	1.0	<1	2.0	0.3
522 Harrison	< 1	<1	<1	<1	< 1	0.8
14th and Washington	< 1	10	1.0	<1	2.0	< 0.1

Table B-8. Ogden area trihalomethanes and total organic carbons (when available) for the month of April (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plant No. 2, 3, 4 Influent	< 1	< 1	< 1	< 1		10.1 19.8 18.8
WBWCD Plant No. 2 Effluent	31 44	6 8	< 1 < 1	< 1 < 1	37 52	2.9
WBWCD Plant No. 3 Effluent	22 50	5 10	< 1 1.0	< 1 <1	27 61	2.5
WBWCD Plant No. 4 Effluent	33 62	6 10	< 1 < 1	< 1 <1	39 72	2.8
522 Harrison Ave.	< 1	<1	< 1	< 1	< 1	<0.5
McKay Dee Hospital	27	6	< 1	<1	33	2.1
36 St. and Riverdale Rd.	20	5	< 1	<1	25	3.8
14th and Washington	< 1	< 1	< 1	< 1	< 1	< 0.5

Table B-9. Ogden area trihalomethanes and total organic carbons (when available) for the month of May (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB) CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM[a]	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plant No. 3 Influent	<1	<1	< 1	< 1	< 1	6.6
WBWCD Plant No. 3 Effluent	21 22	5 5	< 1 < 1	< 1 < 1	26 27	
522 Harrison Ave.	< 1	< 1	< 1	< 1	<1	0.6
14th and Washington Ave.	< 1	< 1	< 1	< 1	<1	<0.5
36 S. and Riverdale Rd.	7.0	1.0	< 1	< 1	8	1.4
McKay Dee Hospital	10	2	<1	<1	12	0.8
Ogden Courthouse	13	5	3	< 1	21	1.3

Table B-10. Ogden area trihalomethanes and total organic carbons (when available) for the month of June (1980).

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB) CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM[a]	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plants No. 2, 3, and 4, Influent	< 1	<1	< 1	< 1	< 1	5.28 6.23 5.53
WBWCD Plant No. 2 Effluent	50 66	10 11	< 1 < 1	<1 < 1	60 77	3.86
WBWCD Plant No. 3 Effluent	29 48	6 10	<1 <1	< 1 < 1	35 58	4.23
WBWCD Plant No. 4 Effluent	48 66	9 11	< 1 <1	<1 <1	57 77	4.57
McKay Dee Hospital	58	10	< 1	< 1	68	4.12
Ogden Federal Building	32	6	< 1	<1	38	2.30
14th St. and Washington	48	8	<1	< 1	56	1.87
36 So. and Riverdale Rd.	50	8	<1	< 1	58	4.11
522 Harrison Ave.	25	5	<1	< 1	30	2.08

Table B-11. Ogden area trihalomethanes and total organic carbons (when available) for the month of July (1980).

SAMPLE LOCATION Inst. THM / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
WBWCD Plants No. 2, 3, and 4, Influent	< 1	< 1	< 1	<1	< 1	5.1 6.2 4.7
WBWCD Plant No. 2 Effluent	60 72	10 13	<1 < 1	<1 < 1	70 85	4.4
WBWCD Plant No. 3 Effluent	35 50	6 10	< 1 < 1	< 1 < 1	41 60	3.4
WBWCD Plant No. 4 Effluent	48 80	10 14	< 1 < 1	< 1 < 1	58 94	4.2
McKay Dee Hospital	68	13	1	< 1	82	
Ogden Federal Building	36	6	< 1	< 1	42	
14th St. and Washington	34	5	< 1	< 1	39	
522 Harrison Ave.	38	6	< 1	<1	44	
36 So. and Riverdale Rd.	62	9	< 1	< 1	71	

APPENDIX C

DATA FOR PARLEYS WATER TREATMENT PLANT

Table C-1. Trihalomethane and total organic carbon after each unit process at the Parleys water treatment plant (August 1980).

SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
Parleys Influent	< 1	< 1	< 1	< 1	< 1	3.56
Parleys after rapid mix	3 37	< 1 8	< 1 1	< 1 < 1	3 46	4.25
Parleys after coagulation	8 30	3 9	< 1 1	< 1 < 1	11 40	3.59
Parleys after sedimentation	19 50	6 11	< 1 1	< 1 < 1	25 62	3.14
Parleys after filter	38 42	11 12	1 1	< 1 < 1	50 55	2.95
Parleys effluent	22 44	7 11	< 1 1	< 1 < 1	29 56	2.82

Table C-2. Trihalomethane data for a post versus prechlorination process at the Parleys water treatment plant (August 1980).

Prechlorination - (Pre) Post chlorination - (Post) Effluent-(Finished) SAMPLE LOCATION inst. THM I / S.D. THM	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
August 11 - Post 8:00 p.m.	17 37	5 12	< 1 3	< 1 < 1	22 52	
August 11 - Pre 8:00 p.m.	14 15	4 4	< 1 < 1	< 1 < 1	18 19	
August 11 - Finished 8:00 p.m.	19 44	3 13	< 1 3	< 1 < 1	22 60	
August 12 - Post 4:00 a.m.	12 44	4 14	< 1 3	< 1 < 1	16 61	
August 12 - Pre 4:00 a.m.	20 39	7 12	2 3	< 1 < 1	29 54	
August 12 - Finished 4:00 a.m.	21 58	7 16	2 5	< 1 < 1	30 79	
August 12 - Post 12:00 noon	13 47	4 14	1 4	< 1 < 1	18 65	
August 12 - Pre 12:00 noon	20 34	7 11	2 3	< 1 < 1	29 48	
August 12 - Finished 12:00 noon	16 55	6 16	1 4	< 1 < 1	23 75	
August 12 - Post 8:00 p.m.	15 53	5 16	1 4	< 1 < 1	21 73	
August 12 - Pre 8:00 p.m.	21 34	7 12	2 3	< 1 < 1	30 49	
August 12 - Finished 8:00 p.m.	14	3	< 1	< 1	17	

Table C-2. Continued.

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
August 14 - Post 12:00 noon	16 / 56	5 / 16	1 / 4	< 1 / < 1	22 / 76	
August 14 - Pre 12:00 noon	16 / 37	4 / 12	<1 / 3	<1 / < 1	20 / 52	
August 14 - Finished 12:00 noon						
August 14 - Post 8:00 p.m.	13 / 59	5 / 18	1 / 4	< 1 / < 1	19 / 81	
August 14 - Pre 8:00 p.m.	21 / 40	7 / 14	1 / 3	< 1 / < 1	29 / 57	
August 14 - Finished 8:00 p.m.	15 / 60	3 / 18	< 1 / 4	<1 / < 1	19 / 82	
August 15 - Post 4:00 a.m.	15 / 51	6 / 16	2 / 4	< 1 / < 1	23 / 71	
August 15 - Pre 4:00 a.m.	22 / 51	8 / 15	2 / 4	<1 / <1	32 / 70	
August 15 - Finished 4:00 a.m.	19 / 68	4 / 21	<1 / 5	< 1 / <1	23 / 94	
August 15 - Post 12:00 noon	11 / 59	4 / 20	< 1 / 6	< 1 / < 1	15 / 85	
August 15 - Pre 12:00 noon	25 / 44	9 / 14	2 / 4	< 1 / <1	36 / 62	
August 15 - Finished 12:00 noon	44 / 56	15 / 18	4 / 5	<1 / <1	63 / 79	

Table C-2. Continued.

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{s}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
August 13 - Post 4:00 a.m.	17 / 70	6 / 18	1 / 4	< 1 / < 1	24 / 92	
August 13 - Pre 4:00 a.m.	17 / 34	6 / 11	1 / 3	<1 / < 1	24 / 48	
August 13 - Finished 4:00 a.m.	19 / 66	6 / 18	1 / 4	< 1 / <1	26 / 88	
August 13 - Post 12:00 noon	19 / 56	6 / 16	1 / 4	< 1 / < 1	26 / 76	
August 13 - Pre 12:00 noon	23 / 39	7 / 13	1 / 3	<1 / < 1	31 / 55	
August 13 - Finished 12:00 noon	18 / 48	6 / 14	2 / 3	< 1 / < 1	26 / 65	
August 13 - Post 8:00 p.m.	14 / 54	4 / 16	<1 / 4	< 1 / < 1	18 / 74	
August 13 - Pre 8:00 p.m.	23 / 32	8 / 11	2 / 2	<1 / <1	33 / 45	
August 13 - Finished 8:00 p.m.	17 / 58	6 / 16	1 / 4	< 1 / < 1	24 / 78	
August 14 - Post 4:00 a.m.	16 / 54	4 / 16	<1 / 4	< 1 / < 1	20 / 74	
August 14 - Pre 4:00 a.m.	17 / 45	5 / 14	< 1 / 4	<1 / < 1	22 / 63	
August 14 - Finished 4:00 a.m.	20 / 58	7 / 17	2 / 4	<1 / <1	29 / 79	

Table C-2. Continued.

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{a}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
August 15 - Post 8:00 p.m.	14 / 44	6 / 16	1 / 4	< 1 / < 1	21 / 64	
August 15 - Pre 8:00 p.m.	25 / 39	8 / 13	2 / 3	< 1 / <1	35 / 55	
August 15 - Finished 8:00 p.m.	20 / 43	8 / 14	2 / 4	<1 / <1	30 / 61	
August 16 - Post 4:00 a.m. (seven day test is a MTP)	13 / 132	5 / 24	1 / 6	<1 / <1	19 / 162	
August 16 - Pre 4:00 a.m. (seven day test is a MTP)	22 / 128	8 / 23	2 / 4	<1 / < 1	32 / 155	
August 16 - Finished 4:00 a.m. (seven day test is a MTP)	16 / 118	4 / 23	<1 / 5	<1 / < 1	20 / 146	
August 16 - Post 12:00 noon	14 / 47	6 / 16	2 / 4	< 1 / <1	22 / 67	
August 16 - Pre 12:00 noon	17 / 25	7 / 10	2 / 3	<1 / <1	26 / 38	
August 16 - Finished 12:00 noon	20 / 68	8 / 20	2 / 5	<1 / <1	30 / 93	
August 16 - Post 8:00 p.m.	12 / 26	5 / 11	1 / 3	<1 / <1	18 / 40	
August 16 - Pre 8:00 p.m.	19 / 29	4 / 11	< 1 / 3	< 1 / < 1	23 / 43	
August 16 - Finished 8:00 p.m.	36 / 38	7 / 14	< 1 / 4	< 1 / < 1	43 / 56	

Table C-2. Continued.

SAMPLE LOCATION (inst. THM I / S.D. THM)	TRIHALOMETHANES µg/l(PPB)					
	CHLOROFORM	DICHLOROBROMOMETHANE	DIBROMOCHLOROMETHANE	BROMOFORM	TOTAL THM^{a}	T.O.C. mg/ℓ (TOTAL ORGANIC CARBON)
August 17 - Post 4:00 a.m. (seven day test is a MTP)	11 / 128	4 / 24	< 1 / 6	<1 / <1	15 / 158	
August 17 - Pre 4:00 a.m. (seven day test is a MTP)	17 / 122	7 / 22	2 / 4	< 1 / < 1	26 / 148	
August 17 - Finished 4:00 a.m. (seven day test is a MTP)	19 / 124	4 / 22	< 1 / 4	< 1 / < 1	23 / 150	
August 17 - Post 12:00 noon	14 / 21	6 / 7	2 / 2	<1 / <1	22 / 30	
August 17 - Pre 12:00 noon	20 / 37	8 / 13	2 / 3	<1 / <1	30 / 53	
August 17 - Finished 12:00 noon	20 / 45	4 / 15	< 1 / 4	< 1 / < 1	24 / 64	

APPENDIX D

QUALITY ASSURANCE DATA

Table D-1. Quality assurance data.

	EPA Audit[1] WS-006 March 1980		Internal Quality Control 3rd Qtr. 1980	Internal[2] Quality Control 4th Qtr. 1980	EPA Audit[2] WS-007 December 1980	
	Sample 1	Sample 2	Sample 1 WP1278	Sample 2 WP1278	Sample 1	Sample 2
Chloroform (μg/l)						
"True" value	7.46	93.2	11.0	45.6	14.9	44.7
Acceptable range	5.97-8.95	74.6-112.	8.8-13.2	36.5-54.7	12.-18.	36.-54.
Reported value	6.5	100.	11.20	33.5	12.8	39.6
Acceptable (yes or no)	yes	yes	yes	no	yes	yes
Bromoform (μg/l)						
"True" value	81.8	12.3	2.8	10.4	24.5	61.4
Acceptable range	65.4-98.2	9.84-14.8	2.1-3.5	8.3-12.5	20.-29.	49.-74.
Reported value	90	14.	3.2	8.6	23.0	56.8
Acceptable (yes or no)	yes	yes	yes	yes	yes	yes
Bromodichloromethane (μg/l)						
"True" value	42.5	4.72	1.7	8.6	94.4	18.9
Acceptable range	34.0-51.0	3.78-5.66	1.3-2.1	6.9-10.3	76.-110.	15.-23.
Reported value	40.5	6.5	2.12	7.3	67.4	19.6
Acceptable (yes or no)	yes	no	yes	yes	no	yes
Dibromochloromethane (μg/l)						
"True" value	17.0	50.9	2.4	12.0	11.3	84.8
Acceptable range	13.6-20.4	40.7-61.1	1.8-3.0	9.6-14.4	9.-14.	68.-100.
Reported Value	19.5	70.	3.01	9.2	10.4	75.2
Acceptable (yes or no)	yes	no	yes	no	yes	yes
Total THM (μg/l)						
"True" value	148.8	161.1	17.9	76.6	145.1	209.8
Acceptable range	119.-179.	129.-193.	14.3-21.5	61.3-91.9	120.-170.	170.-250.
Reported value	156.	190.	19.53	58.6	113.6	191.2
Acceptable (yes or no)	yes	yes	yes	no	no	yes

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[1] At this time no internal quality control samples for trihalomethanes were available to run in conjunction with the EPA audit samples.

[2] At the time that fourth quarter internal quality controls and EPA audit WS-007 were being run we were experiencing some problems with the gas chromatograph. Due to time constraints and depletion of the sample supplies, the data had to be sent in anyway. We have since received a letter listing our laboratory as being certified to perform trihalomethane analyses.