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**THE EVALUATION OF THE LOS ALAMOS TRANSPORTABLE
GAS CHROMATOGRAPH/ION TRAP DETECTOR. OPERABLE
UNIT #2, EG&G ROCKY FLATS PLANT. AUGUST 5, 1991 -
AUGUST 8, 1991.**

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INTRODUCTION:

This report describes the demonstration and evaluation of the transportable gas chromatograph/ion trap detector (GC/ITD) from August 5, 1991 to August 8, 1991 at Operable Unit #2 at the Rocky Flats Plant (RFP). Operable Unit #2 (OU-2) is a pilot system developed by Riedel Environmental Services to purify surface water from the South Walnut Creek Basin at RFP. Water is pumped from the creek to a holding tank. From the holding tank, water is pumped through a bag filter to remove particulate matter, then through two consecutive beds of granulated activated charcoal (GAC). The purified water is returned to the creek. OU-2 has been in operation since May, 1991.

The transportable GC/ITD has been developed by the Analytical Chemistry Group, CLS-1, at Los Alamos National Laboratory (LANL) for the field analysis of volatile organic compounds in soil and water. The gas chromatograph (GC) is a slightly modified unit from SRI Instruments. Mass spectral analysis of compounds eluting from the GC is accomplished with a Finnigan Ion Trap Detector (ITD). A turn-key operating system has been incorporated into the instrument so that the instrument can be operated by personnel with minimal technical background.

Evaluation of the GC/ITD at RFP was a significant achievement. We strongly felt that a field evaluation of this instrument at Los Alamos would only be a small step away from our laboratory work. Although field testing at either site would certainly have provided "real" samples for analysis, evaluation of the transportable GC/ITD at Rocky Flats allowed us to address several key issues related to field use: (1) the logistics of transporting the instrument nearly 400 miles to another facility; (2) instrument set-up and testing at an unfamiliar site; and (3) the opportunity to interact with personnel who were unacquainted with the GC/ITD technology. To put the first two issues into perspective, we have five ion trap instruments in our laboratory; a misplaced widget or an instrument malfunction during field evaluation could be quickly remedied at LANL with available resources. A similarly trivial problem at Rocky Flats could have forestalled field evaluation altogether. The third issue is vital. If we are to provide this technology to other DOE facilities, we must gain experience in teaching people how to use the instrument and we must have their input back to improve the user-interface of the GC/ITD.

Finally, we wish to acknowledge the people who contributed to the success of this evaluation: Calvin Martell (LATO), Darwin Baxter and Dennis Pontius (RFP), and David McClellan (Riedel). We would also like to thank Mike Obel and Bill Post (Riedel) for their help and hospitality.

INSTRUMENT OPERATION:

A typical analysis with the transportable GC/ITD requires less than 30 minutes. This is accomplished by staggering the analyses, i.e., as one analysis nears completion, the next is started. Water analysis with this instrument follows conventional purge and trap gas chromatography/mass spectrometry methodologies. Five ml of water are aliquoted into a glass sample tube. The tube is then attached to the purge and trap sampling unit and heated to 80° C while the water is purged with helium. Volatile organic compounds in the water are swept into an adsorbent trap (Tenax) by the helium. At the completion of the 6 min purge cycle, the Tenax trap is rapidly heated and backflushed with helium to deliver the desorbed organic compounds to the gas chromatograph. Elution of the mixture of VOCs through the gas chromatograph separates the individual compounds, which in turn enter the ion trap detector for mass spectral analysis. The ion trap acquires mass spectra at the rate of 1 per second. The term "scan" refers to one these mass spectra (e.g., scan #1 is the first mass spectrum acquired in the analysis). Each mass spectrum consists of intensity versus mass data for the ionized compound and its charged fragments. To a first approximation, each organic compound has a unique mass spectrum (this is not always the case as will be discussed below). Compounds are identified by computerized matching of sample mass spectra with spectra contained in the ion trap mass spectral library. The ion trap data system then sums intensity values (ion currents) of every peak (above some user defined intensity threshold) in each mass spectrum acquired by the ion trap. This summed, or reconstructed, ion current is plotted as a function of elapsed time from the beginning of the analysis. This plot is called a reconstructed ion chromatogram and shows the total amount of each compound as it elutes from the gas chromatography column. Although there are exceptions, each compound elutes from the gas chromatograph at a unique time. This "retention time" may also be used to identify compounds by comparing the retention time (t_r) of the unknown to the retention times for known (calibration) compounds. To quantify the concentration of each individual VOC in the sample, the area of the peak for that compound in the reconstructed ion chromatogram (RIC) is compared to the area of the RIC peak for a known amount of that compound.

EVALUATION STRATEGY:

The evaluation and demonstration of the transportable GC/ITD consisted of four parts: (1) analysis of water samples at OU-2, (2) technology demonstration at RFP, (3) analysis of duplicate samples with the GC/ITD at LANL, and (4) analysis of duplicate samples with independent instrumentation and personnel at LANL.

ROCKY FLATS:

Mary Cisper and Phil Hemberger brought the transportable GC/ITD and all ancillary equipment and chemical standards to the Rocky Flats Plant in a Ford Explorer. Vehicle unloading began at 1030 hours on August 5. The GC/ITD was set up in the OU-2 trailer and was operating by 1130 hours that day. The ion trap detector was then tuned for mass accuracy. Analysis of a sample blank that afternoon indicated no significant background interferences other than a minute amount of toluene that is normally present. The gas chromatograph and ion trap were baked overnight at ca. 200° C.

We selected 13 different volatile organic compounds (VOCs) to use for instrument calibration at Rocky Flats. These compounds and their respective retention times are listed in Table 1. Fluorobenzene and chlorobenzene were used as internal standard and

surrogate compound, respectively. A list of all compounds used in this evaluation is given in Table 2. These compounds are assigned numbers that can be used to identify peaks in the following reconstructed ion chromatograms. A reconstructed ion chromatogram for a calibration mixture containing the compounds listed in Table 1 at the 100 part-pre-billion (ppb) level is shown in Figure 1. Although each compound (except fluorobenzene and chlorobenzene) is present in the same concentration for each calibration mixture, it is obvious that the peak areas differ for the compounds. These peak areas differ for many reasons, but the primary reasons are (1) different ionization efficiencies and (2) different storage and detection efficiencies in the ion trap. To account for these differences, one can determine sensitivity factors for each compound relative to a selected compound; establish a calibration curve for that compound; and, using the sensitivity factors to normalize the peak areas of the other compounds to the selected compound, determine unknown concentration by comparison of its normalized peak area to that of the standard. A more rigorous method is to establish a calibration curve for each individual compound. The peak area data at each concentration (from 1 ppb to 100 ppb) for every standard compound are used to derive a working calibration curve for that compound. This quantitation method has been our standard laboratory method.

Analyses at OU-2 adhered to our laboratory method. A series of calibration standards (containing the 13 VOCs from 1 ppb to 100 ppb) was prepared in the morning of August 6. These standards were kept in an ice box during calibration to prevent the loss of volatile compounds. Freshly prepared standards were always used in following days for instrument calibration. Every standard was spiked with 40 ppb of fluorobenzene and chlorobenzene. Analysis of these standards with the GC/ITD provided calibration curves of instrument response versus concentration for each compound in the standard mixtures. Working calibration curves were generated through the ITD software. Examples of calibration curves obtained in this fashion are shown in Figure 2. Correlation of instrument response for unknown compounds in the OU-2 samples against these working calibration curves would provide quantitative data for the concentration of each impurity in the samples.

Table 3 lists all the standards, blanks, and samples that were analyzed over a two-and-a-half day period from August 6 to August 8, 1991. Blanks were analyzed often to ensure there was no sample carryover. Each sample standard was spiked with 40 ppb of fluorobenzene and chlorobenzene.

Water samples were collected at three sampling points at OU-2 by Riedel personnel on August 6. These samples are designated as: AS1 -- influent (water sampled between the bag filter and the first GAC unit); AS2 -- intermediate (water sampled between the two GAC units); and AS3 -- effluent (purified water sampled after the second GAC unit).

A reconstructed ion chromatogram from the analysis of AS1 is shown in Figure 3. The large peak from the OU-2 influent samples (AS1) at $t_r = 604$ s provoked our immediate interest. A mass spectral library search identified the peak as *trans*-1,2-dichloroethylene, eliminating the possibility that the peak at $t_r = 604$ s was methyl ethyl ketone, which has a similar retention time ($t_r = 600$ s). However, *trans*-1,2-dichloroethylene elutes at $t_r = 455$ s. We surmised that this anomalous peak was caused by another isomer of dichloroethylene that was not in the suite of calibration compounds.

To verify that the anomalous peak at $t_r = 604$ s was not *trans*-1,2-dichloroethylene, a fresh AS1 sample was spiked with a known amount of *trans*-1,2-dichloroethylene prior to analysis. The *trans*-1,2-dichloroethylene added as the spike eluted at $t_r = 456$ s and the unidentified peak still eluted at $t_r = 601$ s (Figure 4). The next step was to compare the

retention time for the unknown peak to those of known dichloroethylene isomers. Retention times for the three dichloroethylene isomers (1,1-dichloroethylene, *trans*-1,2-dichloroethylene, and *cis*-1,2-dichloroethylene) were measured by analysis of Supelco TCL Mix #5 standard (Supelco catalog number 4-8455). The total ion chromatogram for a 100 ppb standard made from TCL Mix #5 is shown in Figure 5. Although the Supelco TCL Mix #5 contains 10 different VOCs, we were able to observe only 6 of those compounds. The 4 remaining compounds (bromomethane, chloromethane, chloroethane, and vinyl chloride) have boiling points ranging from -24°C to 4°C and require sub-ambient temperature operation for chromatographic analysis. Because of the added complexity of sub-ambient operation and the relative scarcity of these compounds in DOE operations, we decided to sacrifice the ability to analyze these compounds and start the gas chromatography cycle at 35°C. Retention times are summarized in Table 4. Previous work at Los Alamos had established that 1,1-dichloroethylene eluted before *trans*-1,2-dichloroethylene ($t_r = 464$ s). The peak eluting near $t_r = 600$ s could then be assigned to *cis*-1,2-dichloroethylene; subsequent work at Los Alamos confirmed this assignment. Figure 6 clearly demonstrates the similarity among the mass spectra for the three isomers of dichloroethylene. This is a textbook example of an instance where a compound must be identified on the basis of its retention time rather than its mass spectrum.

We planned to use the calibration data obtained at RFP on August 6 to quantify the concentration of the VOCs in the Rocky Flats samples; however, a significant run to run variation in peak areas for the internal standard (fluorobenzene) was observed. Since the fluorobenzene response is necessary to compare sample data against calibration data, we were not able to calculate the VOC concentrations in the water samples as intended. Fluorobenzene was chosen as an internal standard because it does not interfere with either the chromatography or mass spectrometry of other volatile compounds. However, fluorobenzene is very insoluble in water and is usually dissolved in methanol prior to its addition to aqueous samples. Our earlier work at Los Alamos revealed the propensity of methanol to participate in ion-molecule reactions with VOCs in the ion trap. These ion-molecule reactions often diminish the reliability of compound identification and quantitation with the ion trap and, accordingly, the presence of methanol in the internal standard spike and calibration standards was reduced as much as possible. It is possible that the peak area variability of fluorobenzene is due to insufficient solubilization in water and/or matrix effects.

Four other VOCs were found in the influent samples. On the basis of both retention times and positive mass spectral library matches, these compounds were identified as chloroform, carbon tetrachloride, trichloroethylene, and tetrachloroethylene (Table 5). The response of the GC/ITD to these compounds is evident in Figure 3. An analysis of high purity water with the GC/ITD (Figure 7) shows no indication of these compounds and eliminates the possibility that these compounds are present as background contaminants in the GC/ITD.

LOS ALAMOS:

Our original plans were to repeat the calibration work (and include *cis*-1,2-dichloroethylene), to investigate the fluorobenzene response problem, and to re-analyze and quantify the contaminant VOCs in the Rocky Flats water samples. However, the field evaluation showed the need to improve access to the instrument and to eliminate unnecessary components. Appropriate mechanical and electrical and design modifications were made to the GC/ITD on our return to LANL. These modifications

and Tiger team preparations delayed the investigation of the OU-2 samples and evaluation of the data obtained at Rocky Flats.

The field work at Rocky Flats clearly demonstrated the need for an alternative quantitation method; the method of standard addition was used for the samples analyzed with the GC/ITD at LANL. In this analytical method, the sample is analyzed, as received and analyzed after being spiked with a known amount of analyte. The amount of analyte in the original sample is calculated by comparison of peak heights (or areas) in the spiked and unspiked sample. This method obviates the analysis of separate calibration standards and bypasses anomalies from matrix differences.

Quantitative results for *cis*-1,2-dichloroethylene, the major contaminant in the influent samples, is reported in Table 6. Statistical analysis of the influent data is presented in Table 7. Dixon's Q test for outliers at the 96% confidence level on the three influent data subsets indicated that no values could be rejected. It should also be noted here that the charcoal filtration beds at OU-2 appear to be successfully removing volatile organics from the influent stream. The reconstructed ion chromatograms from samples AS1, AS2, and AS3 are shown in Figure 8. These data clearly show the reduction of the VOCs in the water during the purification process. These data can also be presented as a graph displaying peak area versus sampling position (Figure 9). For these graphs, the amount of contaminant in the influent water (AS1) was displayed as 100%; the amount of each contaminant in the samples in the two subsequent sampling positions (AS2 and AS3) is displayed relative to 100%. The efficiency of the GAC units in removal of VOCs is higher for the larger compounds (tetrachloro-, trichloro-, and dichloroethylene).

The concentrations of the four other VOCs (tetrachloroethylene, trichloroethylene, carbon tetrachloride, and chloroform) in the Rocky Flats influent samples were quantified using the standard addition method (Table 8). That is, the analyte response (normalized to the internal standard) in the unspiked sample was compared to normalized analyte response when 10 ppb of each of the four VOCs was added. No statistical data were generated for these results. However, at these very low concentrations, it would be save to assume that the relative uncertainties are greater than those given in Table 7 for the determination of *cis*-1,2-dichloroethylene at the 40 ppb level.

As planned, we shared the OU-2 water samples with another analytical laboratory in our group to obtain an independent in-house analysis. Delays here have been encountered due to unanticipated equipment transfer and set-up and Tiger team preparations. These independent analyses are now underway.

SUMMARY:

We believe that the field evaluation of the transportable GC/ITD was very successful. The analysis of "real" samples pointed out the need for less ambiguous calibration methods. The method of standard addition has been applied to RFP samples brought back to LANL and preliminary results are very encouraging. Instrument reliability was excellent and no problems were encountered either during transportation or during operation at OU-2. We discovered that some instrument operations, which are tolerable in our laboratory, were a nuisance during field use. The instrument has been appropriately modified to address those problems. We discovered that a combination of both on-line and off-line data analysis will provide the best compromise between real-time data reporting and accuracy of results. Finally, we had a wonderful opportunity to show other people how to operate the transportable GC/ITD. Seven different people

hands-on operated the GC/ITD. Two of these people were equipment operators from Riedel who had little or no experience with analytical instrumentation.

Immediate plans for the future for the transportable GC/ITD include a rigorous examination of the standard addition method for the analysis of volatile organic compounds and further field method development. We will also examine more soluble compounds as candidates for internal standards. We have implemented the technique of axial modulation in the ion trap, which should enhance sensitivity, and we are now evaluating this modification. A return visit to the Rocky Flats for more extensive evaluation is planned for early November, 1991.

TABLE 1. Calibration compounds and their retention times.

Compound	Retention time (seconds) ¹
Acetone	346
<i>trans</i> -1,2-Dichloroethylene	455
Methyl ethyl ketone	600
Chloroform	635
1,1,1-Trichloroethane	664
Carbon tetrachloride	690
Benzene	708
1,2-Dichloroethane	708
Fluorobenzene	739
Trichloroethylene	782
Methyl isobutyl ketone	887
Toluene	915
Tetrachloroethylene	977
Chlorobenzene	1059
<i>p</i> -Xylene	1084

1) Average t_r over 5 runs. The percent relative standard deviation for any average is less than 0.6%.

TABLE 2. Compound listing with identification numbers.

ID No.	Compound
1	Acetone
2	<i>trans</i> -1,2-Dichloroethylene
3	Methyl ethyl ketone
4	Chloroform
5	1,1,1-Trichloroethane
6	Carbon tetrachloride
7	Benzene
8	1,2-Dichloroethane
9	Fluorobenzene
10	Trichloroethylene
11	Methyl isobutyl ketone
12	Toluene
13	Tetrachloroethylene
14	Chlorobenzene
15	<i>p</i> -Xylene
16	<i>cis</i> -1,2-Dichloroethylene
17	1,1-Dichloroethylene
18	Methylene Chloride
19	Bromodichloromethane
20	Dibromochloromethane

TABLE 3. Listing of standards, samples, and blanks, 8/5/91-8/8/91.

Filename	Sample Type
RFBLNK2	Pure water
RF1#1	1 ppb VOC standard
RF3#1	3 ppb VOC standard
RF10#1	10 ppb VOC standard
RF30#1	30 ppb VOC standard
RF100#1	100 ppb VOC standard
RFBLNK3	Pure water
RFSMPL1	Effluent (AS3)
RFSMPL2	Intermediate (AS2)
RFSMPL3	Influent (AS1)
RFBLNK4	Pure water
RFBLNK5	Pure water
RFSMPL4	Effluent (AS3)
RFSMPL5	Intermediate (AS2)
RFSMPL6	Influent (AS1)
RFSMPL7	AS1 with <i>trans</i> -1,2-dichloroethylene spike
RFBLNK6	Pure water
RFSMPL8	Effluent (AS3)
RFSMPL9	Intermediate (AS2)
RFSMPL10	Influent (AS1)
RFBLNK7	Pure water
RF30#2	30 ppb VOC standard
RFBLNK8	Pure water
RFMIX#5	100 ppb Supelco TCL Mix #5
RFSMPL11	Creek water
RFBLNK9	Pure water

TABLE 4. Retention times for 3 dichloroethylene isomers.

<u>Dichloroethylene isomer</u>	<u>Retention time (sec)</u>
1,1-dichloroethylene	339
<i>trans</i> -1,2-dichloroethylene	464
<i>cis</i> -1,2-dichloroethylene	611

TABLE 5. Retention times for minor sample contaminants.

<u>Compound</u>	<u>Retention time (sec)</u>
Chloroform	638
Carbon tetrachloride	692
Trichloroethylene	784
Tetrachloroethylene	978

TABLE 6. Calculated *cis*-1,2-dichloroethylene concentrations in parts-per-billion.

	<u>Date</u>	<u>Influent</u>	<u>Intermediate</u>	<u>Effluent</u>
1)	8/6/91	49	13	3
	8/7/91	42	10	1
	8/7/91	32	12	1
	8/7/91	40		
2)	8/30/91	67		
3)	9/3/91	27		
	9/3/91	33		

The concentration data were determined as follows:

- 1) Analyte response in the sample (normalized to the internal standard) was compared to the normalized instrument response to *cis*-1,2-dichloroethylene in the 100 ppb standard.
- 2) Standard addition method. Normalized analyte response in the sample was compared to normalized analyte response when 25 ppb *cis*-1,2-dichloroethylene was added directly to the sample.
- 3) Standard addition method. Normalized analyte response in the sample was compared to normalized analyte response when 50 ppb *cis*-1,2-dichloroethylene was added directly to the sample.

TABLE 7. Average *cis*-1,2-dichloroethylene concentrations.

	<u>Concentration</u>	<u>%RSD</u>
All data points	42	32
8/6-8/7/91	41	17
8/30 and 9/3/91	43	50

TABLE 8. Other impurities (quantified in influent only).

<u>Analyte</u>	<u>Concentration (ppb)</u>
Chloroform	3 (Note 1)
	2 (Note 2)
Carbon tetrachloride	12 (Note 1)
	7 (Note 2)
Trichloroethylene	11 (Note 1)
	7 (Note 2)
Tetrachloroethylene	12 (Note 1)
	6 (Note 2)

Notes: 1. First determination.
2. Repeat determination.

Chromatogram C:\RF100#1 Acquired: Aug-06-1991 12:36:36
 Comment: 5 ML 100 PPB VOCs (8-6-91); 40 PPB FB & CB
 Scan Range: 1 - 1380 Scan: 1 Int = 1415 e 0:00 100% = 967681

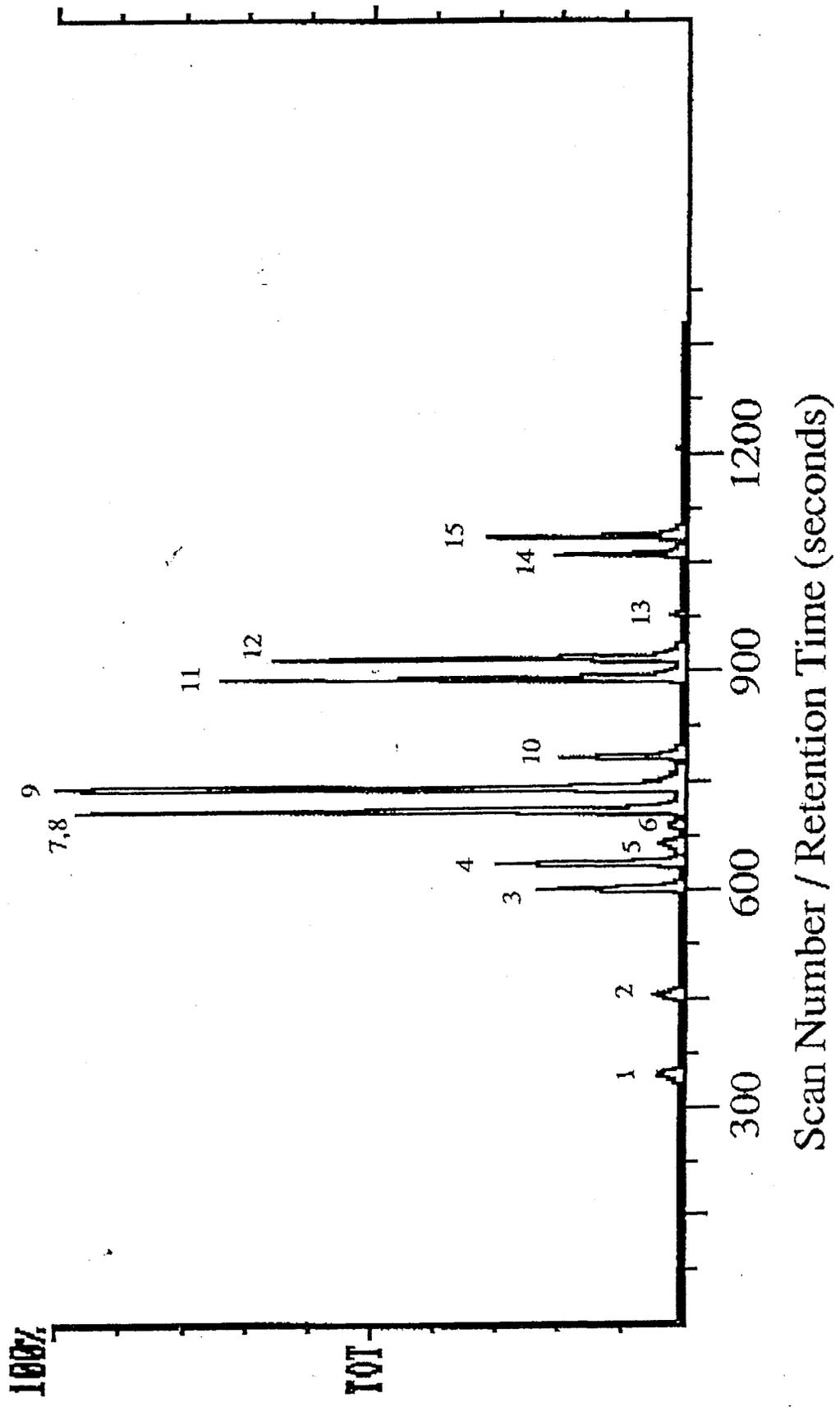


Figure 1. Reconstructed ion chromatogram of a 100 ppb VOC standard (Filename RF100#1). The x-axis units can be taken as either scan number or retention time in seconds (mass spectra were acquired at the rate of 1 scan per second). The y-axis is signal intensity. The ion trap software normalizes the largest peak in the chromatogram to 100% and scales the other peaks accordingly. The full scale intensity is shown in the upper right-hand corner of the chromatogram. In this figure, the full scale intensity is shown as 967681 counts. This intensity will vary from chromatogram to chromatogram depending on the height of the most intense peak.

Calibration Plot (Int Stds) Filename: VOCANUG6 Correlation Coeff: 0.997
 METHYL ETHYL KETONE Compound: 4 of 11 Standard Deviation: 18.415
 (Area of Sample/Area of Standard) vs (Amount of Sample Injected) (Log/Log)

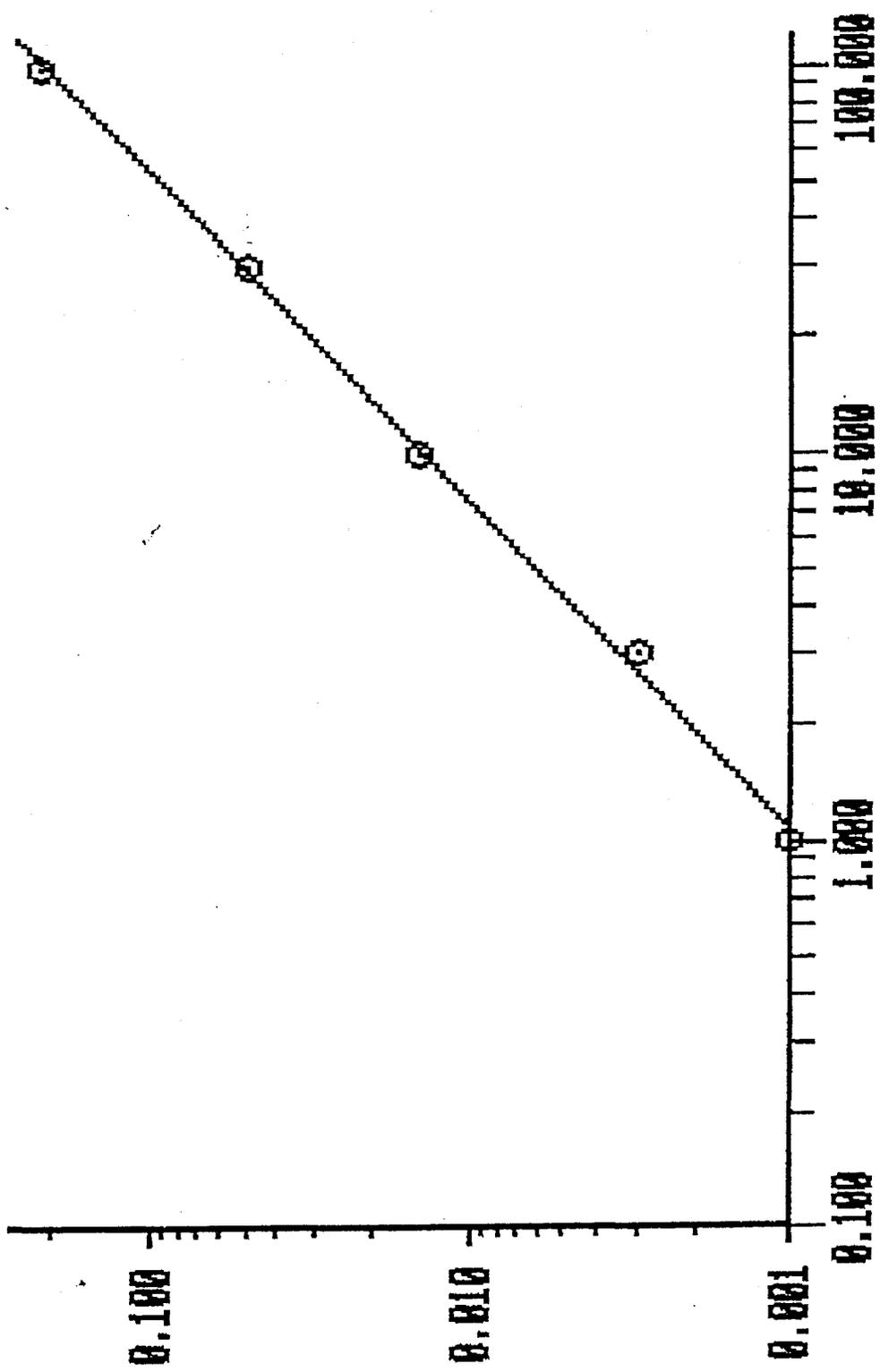


Figure 2a. Calibration curve for methyl ethyl ketone (MEK) from 1 ppb to 100 ppb MEK in 5 ml of water. The x-axis units are in parts-per-billion; the y-axis is plotted as the ratio of the area of the MEK peak to the area of the fluorobenzene peak (internal standard). To determine the concentration of methyl ethyl ketone in an unknown, the unknown sample would be spiked with 40 ppb of fluorobenzene (FB) and analyzed. The MEK/FB ratio in the unknown would then be correlated to MEK concentration using the equation for the line in the calibration curve.

Calibration Plot (Int Stds) Filename: VOCALG6 Correlation Coeff: 0.991
1,2-DICHLOROETHYLENE Compound: 3 of 11 Standard Deviation: 17.962
(Area of Sample/Area of Standard) vs (Amount of Sample Injected) (Log/Log)

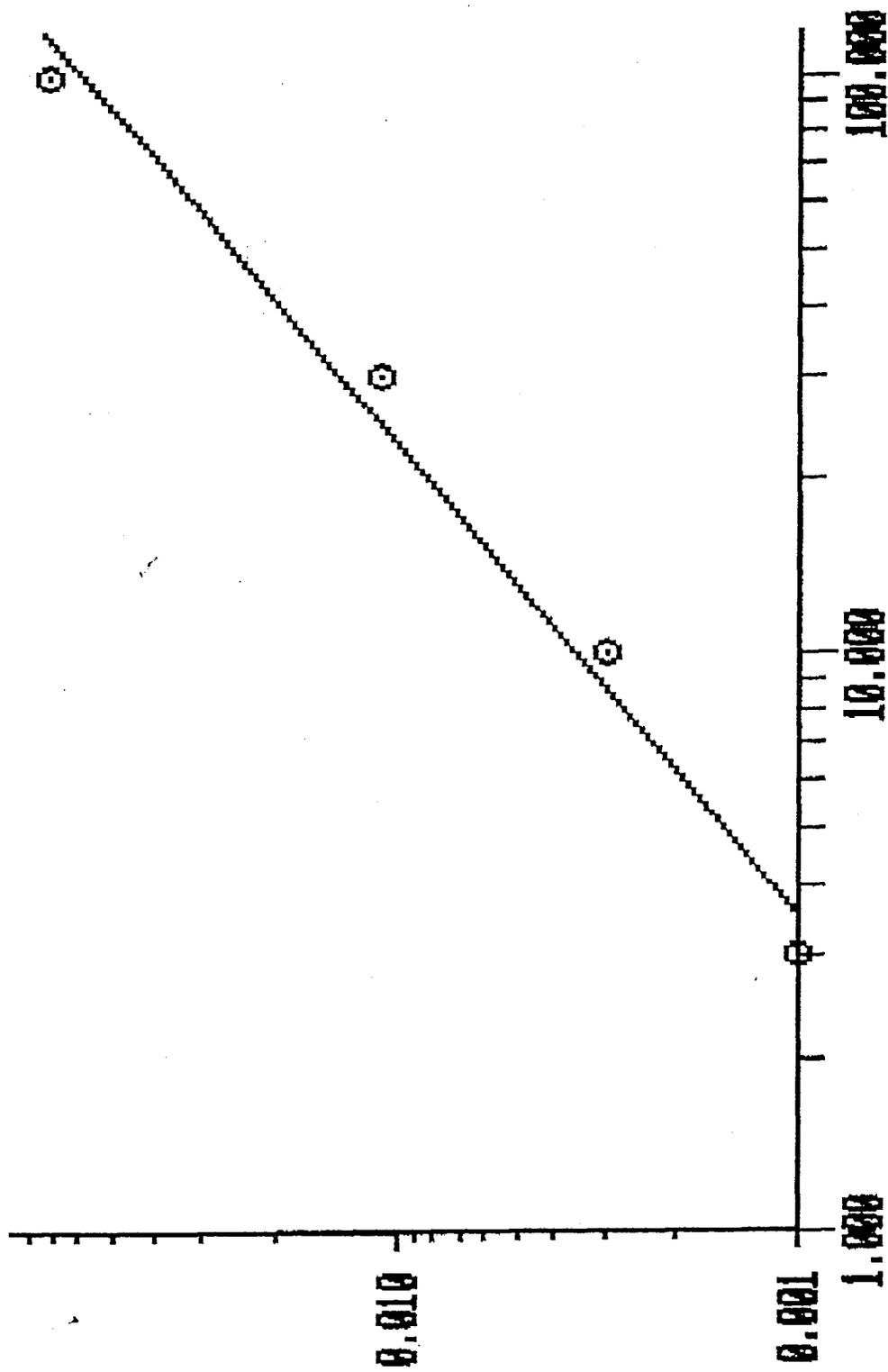


Figure 2b. Calibration curve for *trans*-1,2-dichloroethylene (*t*-DCE) from 1 ppb to 100 ppb *t*-DCE in 5 ml water. The x-axis units are in parts-per-billion; the y-axis is plotted as the ratio of the area of the *t*-DCE peak to the area of the fluorobenzene peak (internal standard).

Chromatogram C:\RFSMPL10 Acquired: Aug-07-1991 15:05:00
 Comment: 5 ML AS1 (INFLUENT, 8 6 91); 40 PPB FB&CB
 Scan Range: 1 - 1380 Scan: 1 Int = 747 @ 0:00 100% = 169277

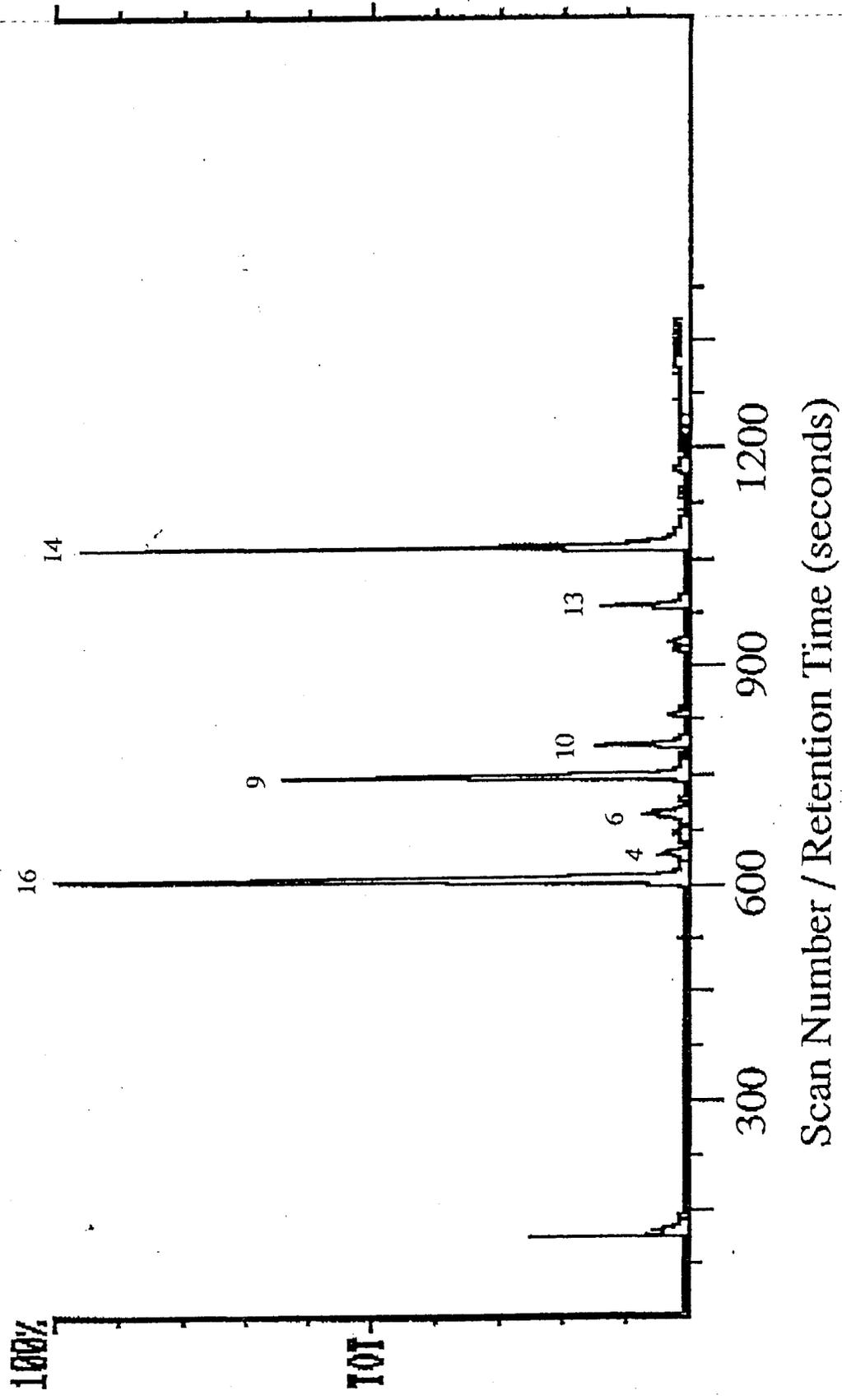


Figure 3. Reconstructed ion chromatogram of a sample of influent water, AS1 (Filename RFSMPL10), spiked with 40 ppb each of fluorobenzene (FB) and chlorobenzene (CB). The unlabeled peak at the left-hand side of the chromatogram is caused by a valve switching. With the exception of FB and CB, the other peaks in this chromatogram are caused by impurities in the water.

Chromatogram C:\RFSMPL7 Acquired: Aug-07-1991 11:42:46
 Comment: 5 ML ASI W DCE SPIKE; 40 PPB FB & CB (8/7/91) @ 0:00 100% = 179758
 Scan Range: 1 - 1380 Scan: 1 Int = 990

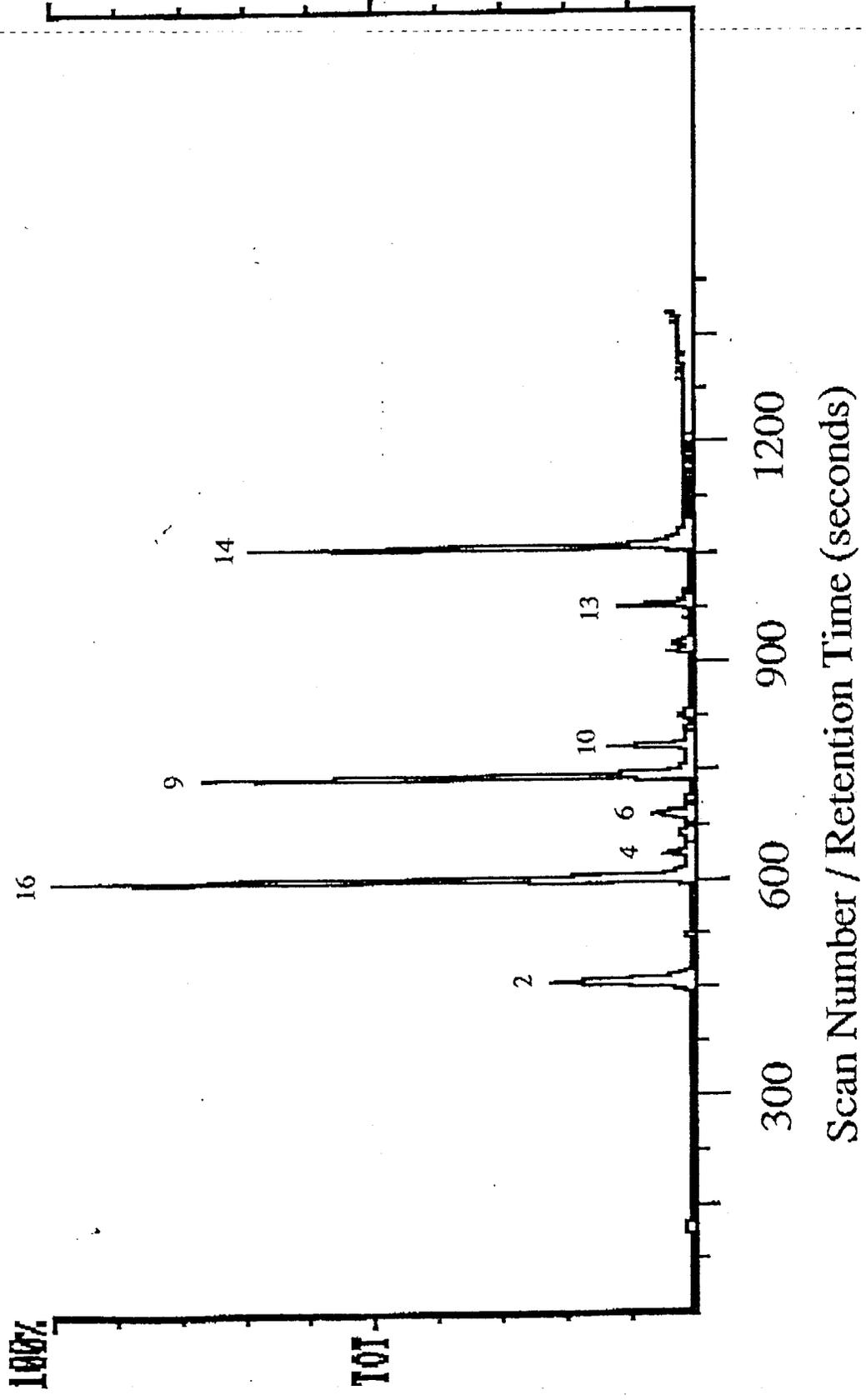


Figure 4. Reconstructed ion chromatogram of a sample of influent water, ASI (Filename RFSMPL7), spiked with 40 ppb each of fluorobenzene (FB) and chlorobenzene (CB) and 100 ppb of *trans*-1,2-dichloroethylene (*t*-DCE). On the basis of retention times alone, it is obvious that the peak at $t_r = 604$ s is not *t*-DCE.

Chromatogram C:RPMIX#5 Acquired: Aug-08-1991 09:35:24
 Comment: SUPELCO TCL MIX #5, 100PPB IN 5 ML HPLC (8/8/91)
 Scan Range: 1 - 1380 Scan: 1 Int = 527 0 0:00 100% = 1243340

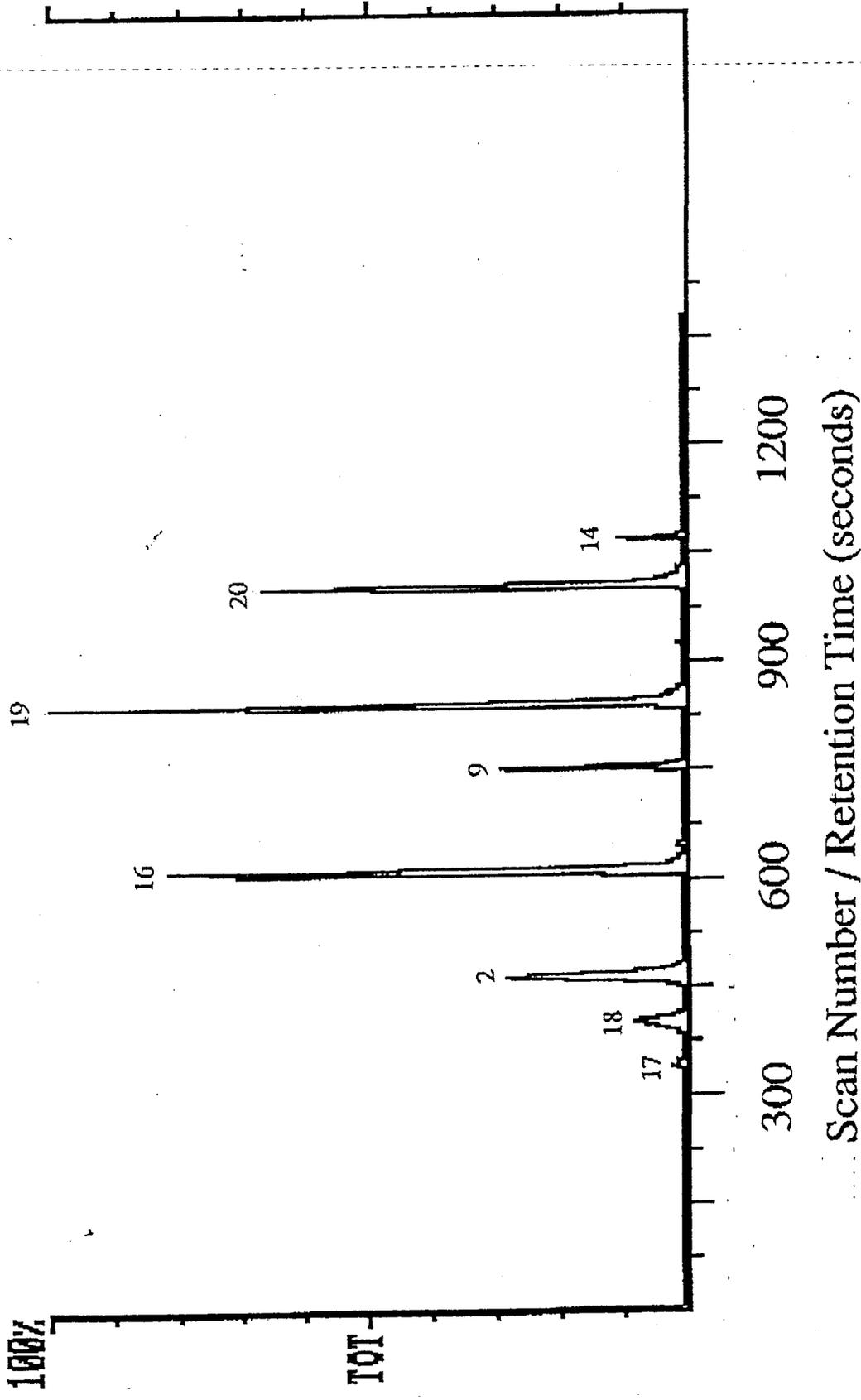


Figure 5. Reconstructed ion chromatogram of 100 ppb of the Supelco Standard TCL Mix #5, spiked with 40 ppb each of fluorobenzene (FB) and chlorobenzene (CB).

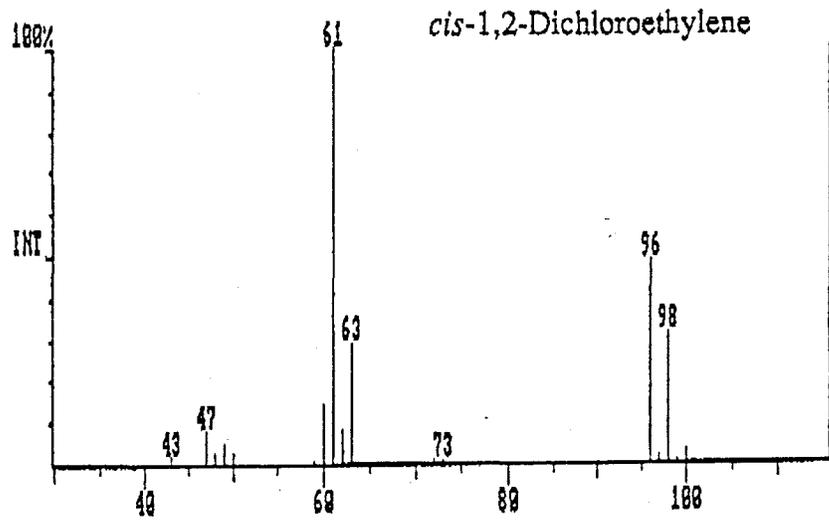
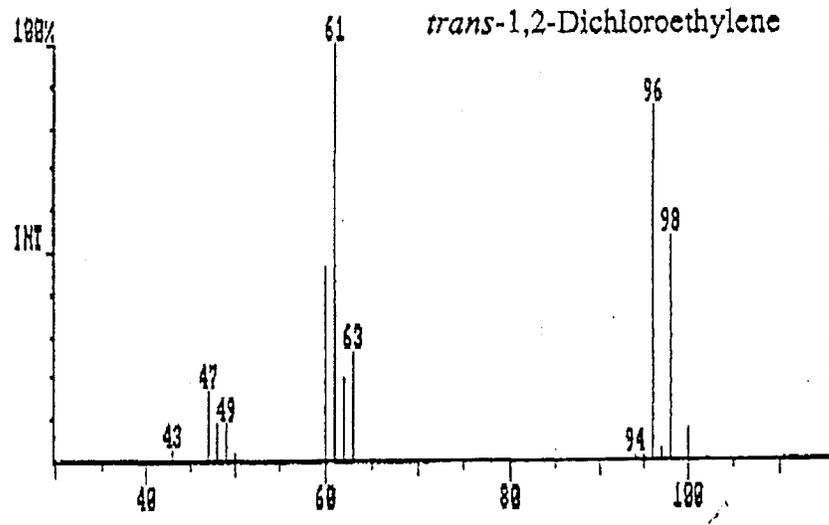
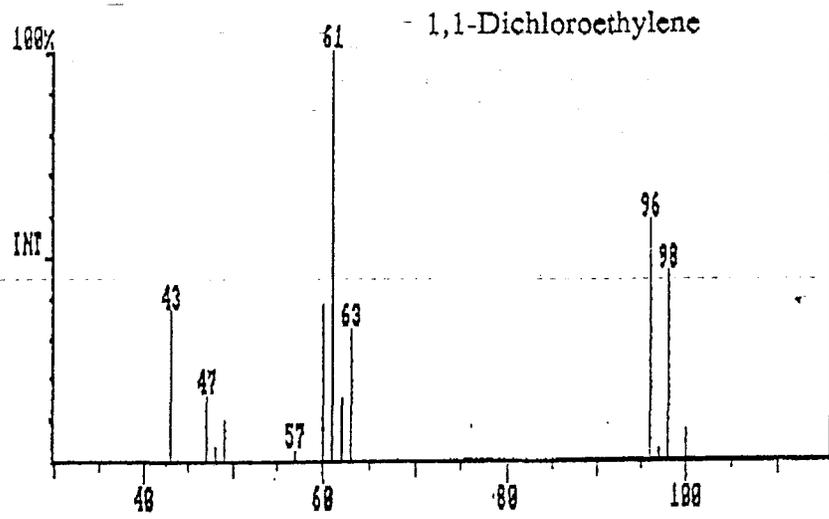


Figure 6. Experimentally obtained mass spectra of 1,1-dichloroethylene, *trans*-1,2-dichloroethylene, and *cis*-1,2-dichloroethylene from the analysis of Supelco Standard TCL Mix #5. These are plotted as normalized fragment ion intensity versus mass-to-charge ratio.

Chromatogram C:\RFBLNK7 Acquired: Aug-07-1991 15:51:11
Comment: 5 ML HPLC H2O Scan: 1 Int = 794 @ 0:00 100% = 8307
Scan Range: 1 - 1380

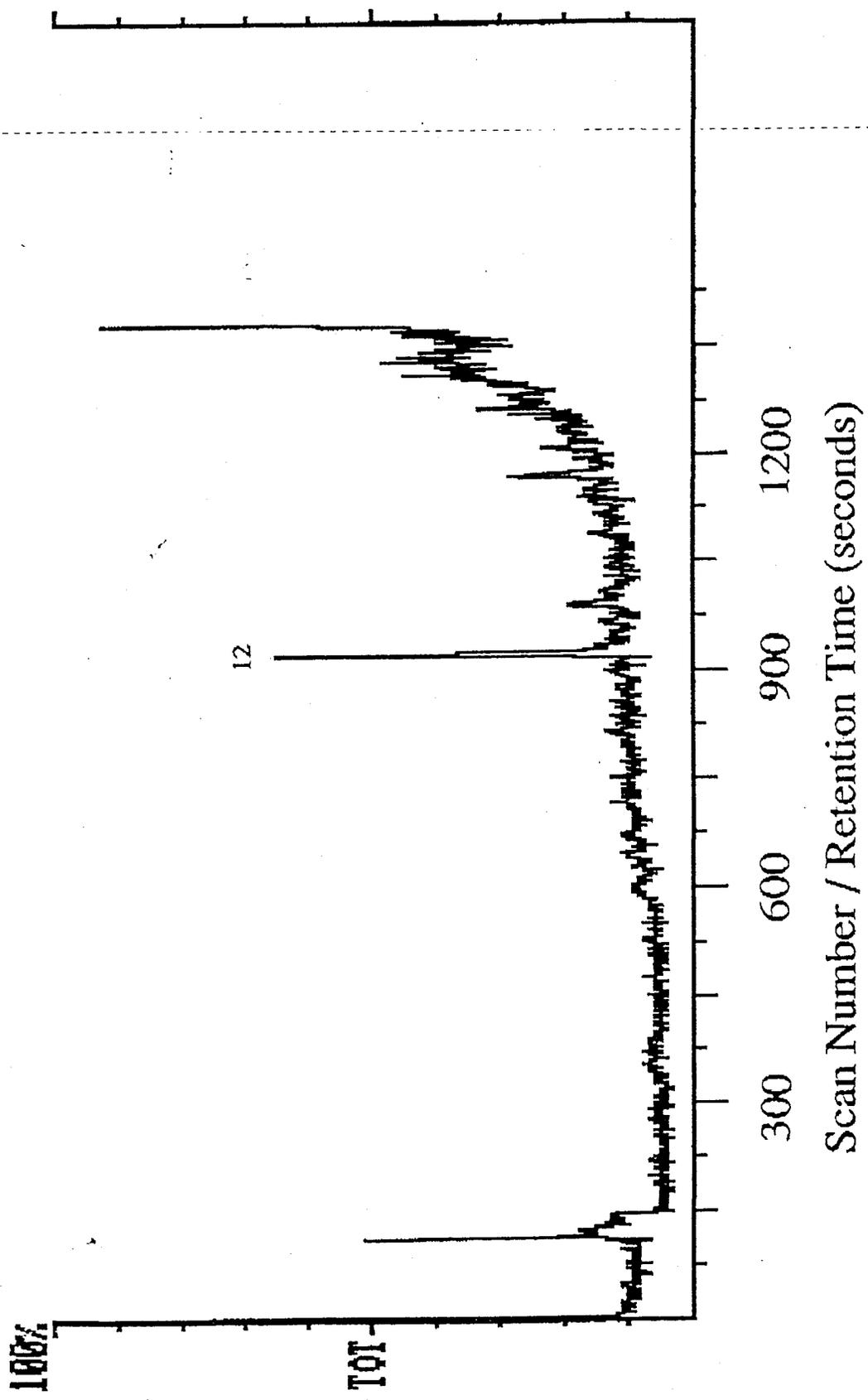


Figure 7. Reconstructed ion chromatogram from the analysis of 5 ml of high purity water. Note that the full scale intensity in this chromatogram is 8300 counts, in contrast to the full scale intensity of 169,000 counts for an AS1 sample (Figure 3). The toluene seems to be part of the permanent background in our instrument; its origin is at this time unknown. There are no peaks at $t_r = 611$ s, 635 s, 690 s, 782 s, and 977 s, which would indicate the presence of *cis*-1,2-dichloroethylene, chloroform, carbon tetrachloride, trichloroethylene, and tetrachloroethylene, respectively, in the instrument background.

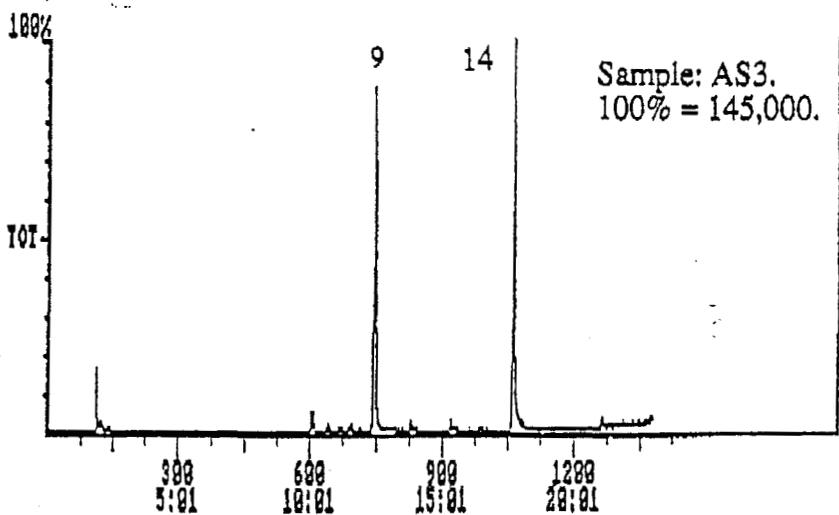
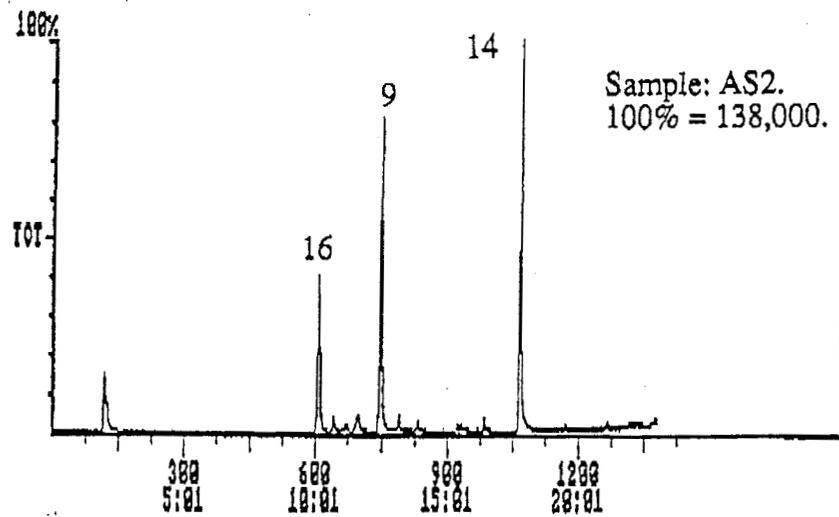
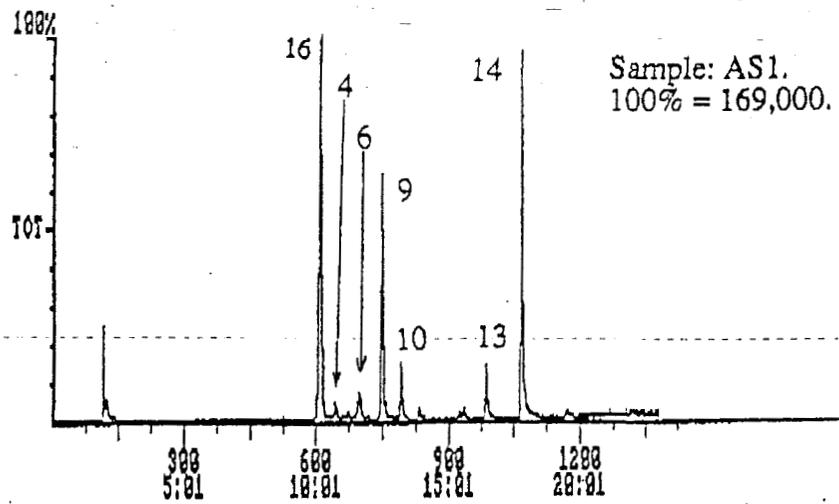


Figure 8. Reconstructed ion chromatogram of samples AS1 (top figure), AS2 (middle figure), and AS3 (bottom figure). These samples were taken from the influent to the GAC units, between the two GAC units and the effluent from the final GAC unit, respectively. The effectiveness of OU-2 in removing these VC is apparent in this figure.

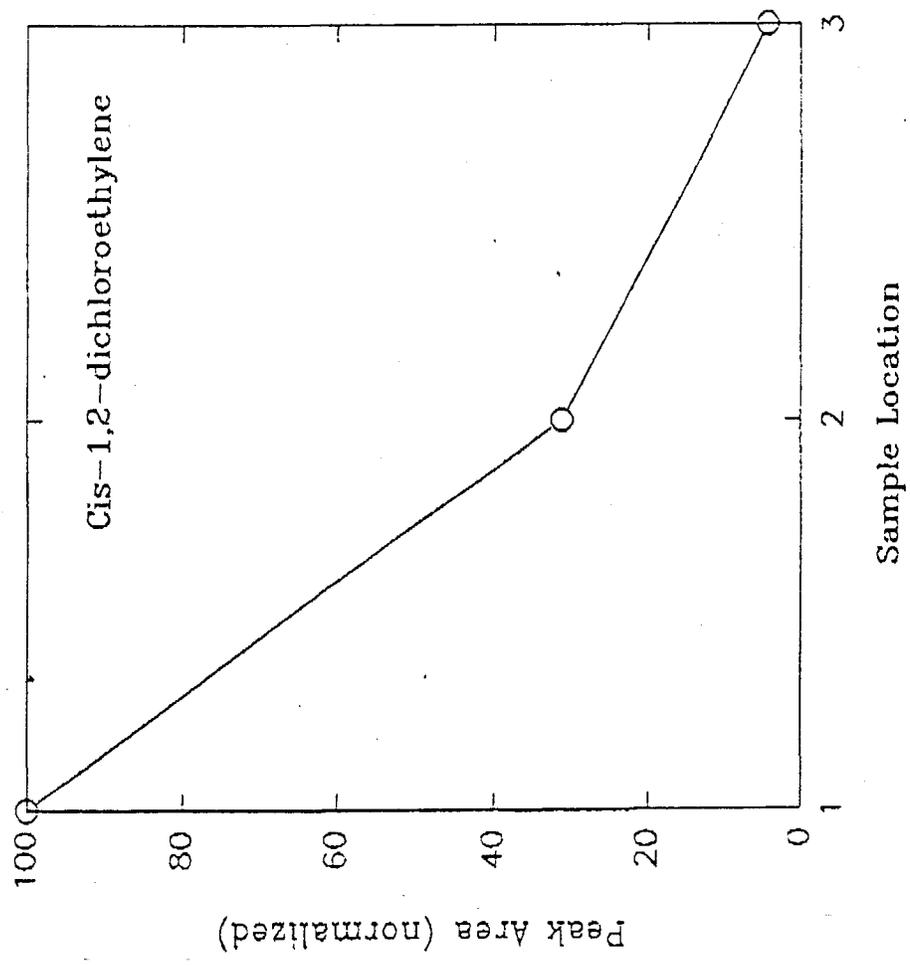


Figure 9a. Plot of relative decrease in cis-1,2-dichloroethylene in samples taken at 3 positions: (1) influent, (2) between the two GAC units, and (3) the effluent.

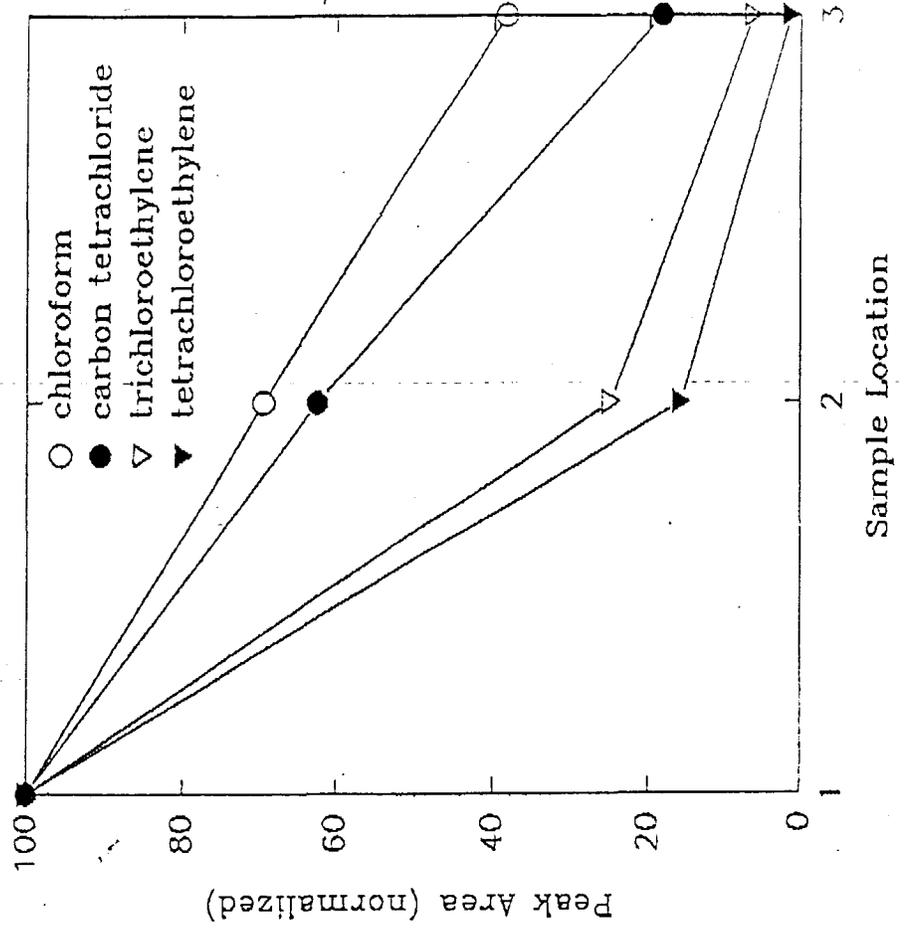


Figure 9b. Plot of relative decrease in chloroform, carbon tetrachloride, trichloroethylene, and tetrachloroethylene in samples taken at 3 positions: (1) influent, (2) between the two GAC units, and (3) the effluent.