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IDENTIFICATION AND CHARACTERIZATION OF CONSERVATIVE ORGANIC TRACERS FOR USE AS HYDROLOGIC TRACERS FOR THE YUCCA MOUNTAIN SITE CHARACTERIZATION STUDY

FINAL REPORT

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Klaus Stetzenbach
Irene Farnham

Harry Reid Center For Environmental Studies
University of Nevada - Las Vegas

SUMMARY of RESULTS

This is the final report for Identification and Characterization of Conservative Organic Tracers for Use as Hydrologic Tracers for the Yucca Mountain Site Characterization Study. This report contains only major findings and conclusions resulting from this project. Detailed reports of all activities performed for this project were provided to the Project Office every quarter since the beginning of the project.

All of the fluorinated benzoic acids tested behave conservatively in three types of tuff.

The fluorocinnamic acids are not stable enough to be used as tracers.

The fluoro- and chloro-salicylic acids do not behave conservatively in the tuffs.

The pyridone, 2-oxynicotinamide, behaves conservatively in the tuffs.

The fluorobenzoates have relatively low toxicity.

The fluorobenzoates are not mutagens.

Iodide was used successfully as a tracer at the C-wells.

INTRODUCTION

Understanding the three-dimensional movement of ground water is essential from the standpoint of evaluating health risks and also for the remediation of contaminated waters, or waters moving through contaminated soils. Water level measurements provide a general sense of speed and direction, but are too coarse to provide detailed pathways and vertical movement information. Ground water tracers can be used to provide information on direction and speed of water movement, and contaminants that might be conveyed by the water. Tracers can also be used to measure effective porosity, hydraulic conductivity, and dispersivity.

In general, conservative groundwater tracers must be non-sorbing, stable for the duration of the tracer test, non-toxic, and have solubilities several orders of magnitude higher than the detection limit. Although inorganic ions such as chloride, bromide, and iodide are considered to be the best conservative tracers, other classes of tracers are often required to allow for more extensive tracer tests.

Extensive tracer testing is expected to take place at the C-well complex in the Nevada Test Site as part of the Yucca Mountain Site Characterization Project (YMSCP). The C-well complex consists of one pumping well, C3, and two injection wells, C1 and C2, into which tracer will be introduced. Since numerous tracer tests are planned at the C-well complex, more tracers with the above stated properties must be identified. The goal of the research performed at HRC was to provide USGS with numerous tracers to complete these tests.

Several classes of fluorinated organic acids have been evaluated. These include numerous isomers of fluorinated benzoic acids, cinnamic acids, and salicylic acids. Also, several derivatives of 2-hydroxy nicotinic acid (pyridone) have been tested. The stability of these compounds was determined using batch and column tests. Ames testing (mutagenicity/carcinogenicity) was conducted on the fluorinated benzoic acids and a literature review of toxicity of the fluorobenzoates and three perfluoro aliphatic acids was prepared. Solubilities were measured and method development work was performed to optimize the detection of these compounds.

A Quality Assurance (QA) Program was developed under existing DOE and USGS guidelines. The program includes QA procedures and technical standard operating procedures (SOPs). Criteria for field and laboratory tracer activities were established concerning sample storage, calibrations, replicate analyses, and blank determinations.

A tracer test, using sodium iodide, was performed at the C-well complex. HRC chemists performed analyses on site, to provide real time data for the USGS hydrologists, and in the laboratories at UNLV. Over 2,500 analyses were performed.

This report provides the results of the laboratory experiments and literature reviews used to evaluate the potential tracers and reports on the results of the iodide C-well tracer test.

STATEMENT OF PROBLEM

The purpose of this work was to identify and characterize compounds that would act as conservative tracers for use as hydrologic tracers for experiments to be conducted at the C-well complex.

General Outline of Tasks as received from the Department of Energy:

1) Identify candidate tracers for use as conservative tracers.

2) Conduct analytical chemical evaluation of promising candidate tracers by evaluating detection limits with respect to the Yucca Mountain environment.

3) Conduct batch tests on promising candidate tracers to evaluate suitability using a mass balance approach with consideration for time dependence.

4) Conduct column tests on promising candidate tracers with crushed core material and provide qualitative evaluations relative to bromide.

5) Conduct tests for degradation of candidate tracer compounds due to microbial action and chemical reactions under the environmental conditions anticipated at the C well complex. Provide evidence for non-toxicity.

6) Prepare an appropriate level quality assurance program.

7) Report recommendations for field application of conservative organic tracers for hydrologic testing.

RATIONALE FOR CHOOSING POTENTIAL TRACERS

Tracers must have a number of properties to be functional. Regardless of the desired properties, the chemical and physical behavior of a tracer in ground water and the porous medium under study must be understood. Good estimates of tracer behavior can be obtained from laboratory studies. Tracers should have the following properties:

1) Must be water soluble.
2) Should not sorb on the aquifer material (i.e., be conservative).
3) Should be chemically and biologically stable for the duration of the test.
4) Should be foreign to the environment.
5) Should have excellent analytical sensitivity.
6) Should be non-toxic.

There are a relatively limited number of chemicals that meet all of the above described criteria. In general, any organic compound that is ionic or can be ionized at ground water pH values will be soluble enough to be used as a tracer. Most organic acids meet the requirements except for stability. Benzoic acid, an aromatic acid, meets all the above requirements except the one for stability. By substituting halogens, specifically fluorine, for the ring hydrogens, stability can be improved dramatically. Aromatic compounds that have halogen atoms attached to the ring have short and therefore strong bonds between the carbon and halide atom. Carbon-fluorine bonds are the shortest of the carbon halide bonds and are therefore expected to be the strongest and least reactive. As a general rule, it can be stated that more halogen atoms on a molecule, especially fluorine, further increase their stability. Teflon is an example of a perfluorinated compound that is virtually resistant to all chemical attack. Fluorine atoms are similar in size to hydrogens and are therefore not expected to appreciably alter the toxicity of the isomers with respect to the parent compound. Benzoic acid, cinnamic acid, and salicylic acid all occur naturally and are relatively safe when ingested in low quantities. Salicylic acid fluoresces and is therefore expected to have better sensitivity.

Three perfluorinated aliphatic acids, trifluoroacetic acid, pentafluoropropionic acid and heptafluorobutyric acid, meet most of the criteria but, for reasons explained in the toxicity report for perfluorinated aliphatic acids, they were not chosen and will not be discussed further in this report.

METHOD DEVELOPMENT

All the potential tracers tested can be analyzed by high performance liquid chromatography (HPLC). This method was chosen not only because it is precise and sensitive, but also the instruments are field portable and the ground water samples can be injected directly into the instrument with only filtration required. This allows analyses to

be conducted in the field for immediate test results. All the assays for the potential tracers use reversed phase HPLC (C-18) columns, but the solvent compositions and the detectors are specific to each class or sub-class of compounds. A variable wavelength UV detector set between 200 and 230 nm is used for the fluorinated benzoates; the UV detector set at 270 nm is used for the fluorinated cinnamic acids; and a fluorescence detector set at 314 nm (excitation) and 360 nm (emission) is used for the pyridone compounds.

The fluorinated benzoic acids were shown through batch and column tests as well as the toxicity review to be the best candidates for tracer field use. Because of this, a significant effort was placed on optimizing the analytical procedures for these compounds. Ultraviolet detector and liquid chromatographic parameters were determined that provide detection limits within the range required for the analysis of field samples and also to maximize the chromatographic separation of these compounds.

Analytical procedures for the analysis of iodide in field samples were developed. Generally, iodide is quantified using an iodide electrode. This method often does not allow the high precision and accuracy required for the analysis of tracer field samples. A method was developed at the HRC that allows for the use of reverse phase HPLC with UV detection.

HPLC Optimization

Multiple well tracer tests, requiring the use of several tracers, are anticipated at the C-well complex. In order to quantify multiple tracers, each tracer compound must be chromatographically separated from all of the other tracer compounds found within the sample. HPLC conditions were found that allowed for the separation of 15 of the 17 commercially available fluorinated benzoic acids. This separation is shown in the chromatogram in Figure 1. The HPLC conditions are as follows:

Column: Supelco LC-18 reverse phase column (15cm x 4.6mm)
Solvents: KH_2PO_4 Buffer (adjusted to pH = 2.7 with H_3PO_4) Methanol
Gradient: 95% KH_2PO_4 buffer : 5% Methanol to 35% KH_2PO_4 buffer : 65% Methanol over 100 minutes; hold at 35% KH_2PO_4 buffer : 65% Methanol for 20 minutes
Flow Rate: 1.4 mL / min.

Figure 1. HPLC Chromatograms of all commercially available fluorinated and chlorinated benzoic acids.

BATCH TESTING

The batch tests provide information on the stabilities of the potential tracers in an environment that closely simulates that of the C-wells. Mixtures containing these compounds in J-13 water are exposed to three types of tuffs (light, medium, and dark). A 1 to ratio of mass of water to mass of rock was used. The tracer concentrations were at about 5 ppm to allow accurate quantitation.

The tuff material has been identified by DOE geologists as Bullfrog Tuff, a crystal rich, pumiceous, rhyolitic (silica rich) tuff which underlies the Topopah Spring tuff in Yucca Mountain. The samples referred to as light, medium, and dark have been classified as follows: Un-welded "light" tuff, which is light weight, porous, and easily broken; Moderately-welded "medium" tuff, which is semi-porous and contains some dense areas of collapsed pumice fragments; and the Densely-welded "dark" tuff which is hard, very dense, and vitrophyric in nature, and can be classified as an obsidian.

A control is also prepared which contains each of the tracers in J-13 water but no tuff. The concentration of each compound is measured periodically to determine changes that occur with time. High performance liquid chromatography (HPLC) is used to separate each of the compounds within the mixture, and an ultraviolet (UV) or fluorescence detector is used for detection and quantitation.

The results for each class of compounds tested are as follows.

Fluorinated Benzoic Acids

All commercially available fluorinated benzoic acids have been batch tested over sixty days. HPLC with UV detection was used for all analyses.

These compounds exhibit excellent stability with changes in concentration of less than 5% in each tuff type for most compounds. The concentrations for each of the compounds in each of the tuff types from day 0 to day 60 are shown in the following tables. These data are also presented in the graphs in Appendix A. These results not only show the high stability of these compounds but also demonstrate the excellent precision available through the HPLC/UV methods.

Table 1 Concentrations of Tracers in the Control Samples

Compound	Concentration (ppm) 0	1	5	10	20	30	60
2,3-Difluorobenzoic Acid	5.15	5.19	5.09	5.11	5.13	5.21	5.12
2,4-Difluorobenzoic Acid	5.33	5.32	5.35	5.38	5.25	5.34	5.37
2,5-Difluorobenzoic Acid	5.14	5.15	5.14	5.18	5.13	5.17	5.15
2,6-Difluorobenzoic Acid	4.99	4.97	5.03	5.01	5.02	5.17	5.06
3,4-Difluorobenzoic Acid	5.05	5.06	5.01	5.13	5.04	5.07	5.01
3,5-Difluorobenzoic Acid	5.06	5.20	5.01	5.15	5.05	5.20	5.03
2,3,4-Trifluorobenzoic Acid	4.95	4.92	4.92	5.06	4.90	5.01	4.98
2,3,6-Trifluorobenzoic Acid	5.10	5.13	5.04	5.07	5.06	5.18	5.13
2,4,5-Trifluorobenzoic Acid	5.92	5.94	5.94	6.03	6.08	6.02	5.90
2,4,6-Trifluorobenzoic Acid	5.74	5.77	5.79	5.78	5.84	5.75	5.72
3,4,5-Trifluorobenzoic Acid	5.14	5.16	5.02	5.06	5.31	5.20	5.06
2,3,4,5-Tetrafluorobenzoic Acid	5.74	5.71	5.66	5.70	5.73	5.65	5.60
2,3,5,6-Tetrafluorobenzoic Acid	6.20	6.22	6.29	6.26	6.21	6.27	6.24
Pentafluorobenzoic Acid	5.62	5.64	5.67	5.71	5.67	5.65	5.59
α,α,α-Trifluoro-o-toluic acid	5.14	5.15	5.00	5.07	4.96	5.09	5.05
α,α,α-Trifluoro-m-toluic acid	5.13	5.12	5.02	5.06	5.18	5.12	5.06
α,α,α-Trifluoro-p-toluic acid	5.28	5.29	5.19	5.22	5.23	5.26	5.14

Table 2 Concentrations of Tracers in the Light Tuff Samples

	Concentration (ppm)						
Compound	0	1	5	10	20	30	60
2,3-Difluorobenzoic Acid	5.15	5.19	5.07	5.02	5.00	5.09	5.09
2,4-Difluorobenzoic Acid	5.43	5.45	5.43	5.35	5.23	5.35	5.49
2,5-Difluorobenzoic Acid	5.19	5.18	5.19	5.18	5.10	5.19	5.28
2,6-Difluorobenzoic Acid	4.77	4.78	*	*	*6.58	4.96	
3,4-Difluorobenzoic Acid	5.07	5.14	5.06	5.10	4.99	5.06	5.18
3,5-Difluorobenzoic Acid	5.07	5.08	5.03	5.04	5.08	5.11	5.10
2,3,4-Trifluorobenzoic Acid	4.98	5.04	5.08	5.11	4.94	5.06	5.11
2,4,5-Trifluorobenzoic Acid	5.97	5.99	5.95	5.97	6.01	6.02	6.08
3,4,5-Trifluorobenzoic Acid	5.05	5.08	5.08	5.13	5.18	5.25	5.35
2,3,4,5-Tetrafluorobenzoic Acid	5.78	5.81	5.75	5.69	5.67	5.65	5.71
Pentafluorobenzoic Acid	5.53	5.58	5.55	5.16	5.27	4.96	5.55
α,α,α-Trifluoro-o-toluic acid	4.97	5.02	4.98	5.03	4.91	5.06	5.29
α,α,α-Trifluoro-m-toluic acid	5.06	5.17	5.14	5.14	5.13	5.26	5.10
α,α,α-Trifluoro-p-toluic acid	5.16	5.28	5.25	5.28	5.23	5.33	5.31

*A large interference was observed in all of the light tuff samples. This interfered with the quantitation of 2,3,5,6-Tetrafluorobenzoic acid, 2,4,6-Trifluorobenzoic acid, 2,3,6-Trifluorobenzoic acid and t5 - t30 for 2,6-Difluorobenzoic acid. These data are therefore not reported.

Table 3 Concentrations of Tracers in the Medium Tuff Samples

Compound	Concentration (ppm)						
	0	1	5	10	20	30	60
2,3-Difluorobenzoic Acid	5.17	5.18	5.11	5.15	5.11	5.14	5.10
2,4-Difluorobenzoic Acid	5.41	5.41	5.37	5.39	5.25	5.36	5.45
2,5-Difluorobenzoic Acid	5.19	5.18	5.20	5.18	5.14	5.21	5.24
2,6-Difluorobenzoic Acid	5.05	5.14	5.28	5.21	5.18	5.17	4.99
3,4-Difluorobenzoic Acid	5.12	5.08	5.06	5.10	5.07	5.03	4.99
3,5-Difluorobenzoic Acid	5.18	5.10	5.08	5.10	5.06	5.13	5.11
2,3,4-Trifluorobenzoic Acid	4.98	5.01	5.02	5.13	4.96	5.10	5.11
2,3,6-Trifluorobenzoic Acid	5.05	5.15	4.97	5.02	4.94	4.99	4.53
2,4,5-Trifluorobenzoic Acid	5.99	5.97	5.96	6.04	6.12	6.11	6.09
2,4,6-Trifluorobenzoic Acid	6.01	6.03	*	6.01	5.68	5.67	5.62
3,4,5-Trifluorobenzoic Acid	5.18	5.14	5.15	5.12	5.10	5.18	5.25
2,3,4,5-Tetrafluorobenzoic Acid	5.74	5.74	5.76	5.71	5.76	5.70	5.68
2,3,5,6-Tetrafluorobenzoic Acid	6.29	6.30	6.40	6.36	6.19	6.26	6.29
Pentafluorobenzoic Acid	5.59	5.64	5.73	5.64	5.68	5.69	5.69
α,α,α-Trifluoro-o-toluic acid	5.04	5.13	5.07	5.17	5.07	5.21	5.04
α,α,α-Trifluoro-m-toluic acid	5.08	5.15	5.13	5.19	5.05	5.22	5.19
α,α,α-Trifluoro-p-toluic acid	5.25	5.30	5.25	5.34	5.19	5.31	5.34

*2,4,6-Trifluorobenzoic acid could not be quantitated at T=5 due to the presence of an interference in the chromatogram.

Table 4 Concentrations of Tracers in the Dark Tuff Samples

Compound	Concentration (ppm)						
	0	1	5	10	20	30	60
2,3-Difluorobenzoic Acid	5.26	5.23	5.10	5.12	5.13	5.10	5.15
2,4-Difluorobenzoic Acid	5.38	5.44	5.35	5.36	5.29	5.41	5.47
2,5-Difluorobenzoic Acid	5.17	5.20	5.16	5.18	5.16	5.25	5.25
2,6-Difluorobenzoic Acid	5.07	5.22	5.40	5.41	5.50	5.73	5.04
3,4-Difluorobenzoic Acid	5.07	5.09	5.09	5.10	5.09	5.06	4.98
3,5-Difluorobenzoic Acid	5.06	5.22	5.01	5.04	5.02	5.13	5.12
2,3,4-Trifluorobenzoic Acid	4.96	5.06	5.05	5.14	5.05	5.18	5.12
2,3,6-Trifluorobenzoic Acid	5.07	5.13	4.93	4.99	4.99	5.03	5.02
2,4,5-Trifluorobenzoic Acid	5.95	5.97	5.96	5.99	6.12	6.14	6.11
2,4,6-Trifluorobenzoic Acid	5.85	5.92	*	*7.00	5.67	5.65	5.70
3,4,5-Trifluorobenzoic Acid	5.07	5.10	5.08	5.16	5.20	5.13	5.39
2,3,4,5-Tetrafluorobenzoic Acid	5.74	5.76	5.80	5.68	5.79	5.72	5.62
2,3,5,6-Tetrafluorobenzoic Acid	6.29	6.33	6.22	6.13	6.18	6.23	6.32
Pentafluorobenzoic Acid	5.58	5.63	5.69	5.60	5.62	5.66	5.62
α,α,α-Trifluoro-o-toluic acid	5.00	5.08	5.04	5.04	5.02	5.04	5.09
α,α,α-Trifluoro-m-toluic acid	5.11	5.14	5.09	5.10	5.04	5.25	5.02
α,α,α-Trifluoro-p-toluic acid	5.24	5.31	5.25	5.27	5.09	5.28	5.25

*2,4,6-Trifluorobenzoic acid could not be quantitated at T=5 due to the presence of an interference in the chromatogram. The high concentration reported on T=10 is also due to an interference.

Pyridones

2-Hydroxynicotinic acid (pyridone) and three of its derivatives were batch tested. The pyridone compounds are of interest as groundwater tracers because of their fluorescence properties. Because these compounds fluoresce, they can be detected at low ppb levels. This becomes necessary when dilution exceeds several orders of magnitude during the tracer test. These compounds were quantified over 118 days using HPLC with fluorescence detection. The compounds tested and the results for each of the tuff types and control are listed in Table 5 - 8.

Table 5 Concentrations of Pyridones in the Light Tuff Samples

Compound	Concentration (ppb)						
	0	1	5	11	18	32	118
2-Oxynicotinamide	49.22	49.56	49.05	49.29	48.36	45.63	20.75
2-Hydroxynicotinic acid	88.94	120.32	138.74	151.72	158.34	149.34	<DL
N-Methyl-2-oxynicotinamide	47.20	46.67	46.51	46.75	45.94	56.13	53.09
Methyl 2-Hydroxynicotinate	93.36	41.26	29.56	14.46	4.99	<DL	<DL

Table 6 Concentrations of Pyridones in the Medium Tuff Samples

Compound	Concentration (ppb)						
	0	1	5	11	18	32	118
2-Oxynicotinamide	48.20	44.49	42.88	40.93	39.27	38.68	42.75
2-Hydroxynicotinic acid	56.37	57.77	56.51	54.14	53.77	61.76	37.25
N-Methyl-2-oxynicotinamide	45.60	38.19	33.96	29.91	26.30	27.16	20.42
Methyl 2-Hydroxynicotinate	127.80	77.13	56.17	38.46	25.24	13.26	<DL

Table 7 Concentrations of Pyridones in the Dark Tuff Samples

Compound	Concentration (ppb)						
	0	1	5	11	18	32	118
2-Oxynicotinamide	49.22	48.88	48.36	47.84	46.70	45.56	45.29
2-Hydroxynicotinic acid	61.71	63.78	65.80	82.65	1.84	ND	-7.60
N-Methyl-2-oxynicotinamide	47.00	46.67	46.40	46.42	44.87	41.92	45.39
Methyl 2-Hydroxynicotinate	131.51	121.07	110.49	81.41	49.88	15.10	0.00

Table 8 Concentrations of Pyridones in the Control

Compound	Concentration (ppb)						
	0	1	5	11	18	32	118
2-oxynicotinamide	49.42	49.22	49.21	49.62	48.97	49.82	58.64
2-Hydroxynicotinic acid	50.70	53.93	49.90	53.08	59.19	80.20	73.34
N-Methyl-2-oxynicotinamide	48.44	48.12	48.14	49.01	47.49	51.60	65.60
Methyl 2-Hydroxynicotinate	193.17	187.57	194.47	187.32	178.12	143.37	-9.14

Cinnamic Acids

Four cinnamic acids (3,5-difluorocinnamic acid, 2,5-Difluorocinnamic acid, 2-fluorocinnamic acid, and α-cinnamic acid) were batch tested. The cinnamic acids were found to be unstable in all three tuffs. These compounds were therefore found to be unsuitable for use as groundwater tracers.

Salicylic Acids

Two salicylic acids, 5-fluorosalicylic acid and 3,5-dichlorosalicylic acid, were tested. 5-fluorosalicylic acid was unstable in all three tuffs. 3,5-Dichlorosalicylic acid was stable for 90 days in the light tuff and to 250 days in the medium and dark tuffs. The 3,5-dichlorosalicylic acid was not chosen as a possible tracer because its fluorescent characteristics were poor and there was no increase in sensitivity over the fluorinated benzoates, and its toxicology properties were unknown.

COLUMN TESTING

Another method used to measure the sorption of the tracer compounds to tuff material is the column test. The tracer is injected into a column containing ground tuff, and the time required for its elution is measured. The elution volume, calculated by multiplying the elution time by the measured flow rate, is compared to that of bromide. Bromide, which is considered to be a conservative tracer, is used as a reference for each compound. All fluorinated benzoates have been tested on columns containing each of the tuffs (see the previous report for column dimensions and detection methods). The mean elution volume, the standard deviation, and the percent relative standard deviation (%RSD) for each compound are listed in Tables 9 - 11. Three injections of potassium bromide were made per day and the ratios of the elution volumes, analyte/bromide, were calculated. This ratio is also listed along with the mean, standard deviation (SD), and percent relative standard deviation (%RSD) for the KBr elution volumes.

The elution volumes for all acids are very similar to bromide and are generally within one standard deviation. The ratios, Tracer/KBr, are also very close to one, and in fact in the light and medium tuff most are less than one. This indicates faster travel through the column than bromide. The Tracer/KBr in the dark tuff are slightly higher than in the light and medium tuff, but the elution volumes for KBr injections are still within one standard deviation of the benzoates. If it is assumed that bromide (potassium bromide) does not sorb to the tuff, then all the benzoic and toluic acids also behave conservatively.

Table 9 Column Test Results for the Medium Tuff

Compound	Mean (mL)	Standard Deviation	Tracer %RSD	Tracer/ KBr	KBr Mean	KBr SD	KBr %RSD
2,3-difluorobenzoic acid	206.6	2.00	0.97	0.99	208.1	0.82	0.39
2,4-difluorobenzoic acid	162.6	4.77	2.93	0.96	169.5	2.52	1.49
2,5-difluorobenzoic acid	158.2	7.74	4.89	0.98	161.5	2.64	1.64
2,6-difluorobenzoic acid	161.0	5.81	3.61	1.00	160.6	2.53	1.58
3,4-difluorobenzoic acid	209.3	5.48	2.62	0.98	212.9	4.05	1.90
2,3,4-trifluorobenzoic acid	156.4	1.65	1.05	0.99	157.5	6.18	3.92
2,3,6-trifluorobenzoic acid	206.6	3.74	1.81	0.99	208.6	3.08	1.48
2,4,5-trifluorobenzoic acid	201.4	1.67	0.83	0.98	205.5	1.60	0.78
2,4,6-trifluorobenzoic acid	158.3	9.81	6.20	0.98	161.5	3.73	2.31
3,4,5-trifluorobenzoic acid	210.8	2.02	0.96	1.00	211.7	2.34	1.11
2,3,4,5-tetrafluorobenzoic acid	191.6	7.83	4.09	0.99	193.7	0.00	0.00
2,3,5,6-tetrafluorobenzoic acid	213.0	1.44	0.68	1.00	212.4	2.38	1.12
pentafluorobenzoic acid	207.4	1.26	0.61	1.00	206.5	1.41	0.68
m-toluic acid	210.4	3.34	1.59	0.97	215.9	4.45	2.06
o-toluic acid	205.7	1.20	0.58	0.98	209.7	0.52	0.25
p-toluic acid	212.5	2.42	1.14	1.01	210.5	0.60	0.29

Table 10 Column Test Results for the Light Tuff

Compound	Mean (mL)	Standard Deviation	Tracer %RSD	Tracer/ KBr	KBr mean	KBr SD	KBr %RSD
2,3-difluorobenzoic acid	301.7	6.16	2.04	0.95	316.4	7.91	2.50
2,4-difluorobenzoic acid	288.4	13.0	4.51	0.92	312.0	21.3	6.84
2,5-difluorobenzoic acid	292.7	5.34	1.82	0.99	296.7	3.30	1.11
2,6-difluorobenzoic acid	287.0	10.2	3.56	0.95	302.3	3.74	1.24
3,4-difluorobenzoic acid	292.6	14.7	5.04	0.98	298.2	12.7	4.26
3,5-difluorobenzoic acid	302.5	5.13	1.70	0.95	317.8	11.4	3.59
2,3,4-trifluorobenzoic acid	292.7	7.31	2.50	0.95	309.5	7.02	2.27
2,3,6-trifluorobenzoic acid	292.9	5.54	1.89	0.94	312.9	14.1	4.51
2,4,5-trifluorobenzoic acid	282.0	9.07	3.21	0.92	305.1	3.65	1.20
2,4,6-trifluorobenzoic acid	287.1	13.9	4.84	0.95	302.8	3.64	1.20
3,4,5-trifluorobenzoic acid	292.8	3.77	1.29	0.95	308.0	3.76	1.22
2,3,4,5-tetrafluorobenzoic acid	292.1	13.9	4.77	0.93	315.2	12.4	3.95
2,3,5,6-tetrafluorobenzoic acid	292.4	10.3	3.51	0.92	316.3	18.0	5.70
pentafluorobenzoic acid	292.6	28.3	9.67	0.98	299.1	19.9	6.66
m-toluic acid	294.3	12.3	4.19	0.96	306.0	25.6	8.36
o-toluic acid	287.4	11.9	4.14	0.93	309.2	3.85	1.25
p-toluic acid	285.5	13.9	4.87	0.90	316.1	16.8	5.30

Table 11 Column Test Results for the Dark Tuff

Compound	Mean (mL)	Standard Deviation	Tracer %RSD	Tracer/ KBr	KBr mean	KBr SD	KBr %RSD
2,3-difluorobenzoic acid	177.4	7.29	4.11	1.03	171.4	2.49	1.46
2,4-difluorobenzoic acid	269.9	6.55	2.43	1.01	266.5	9.96	3.73
2,5-difluorobenzoic acid	237.6	20.2	8.51	0.98	242.1	28.9	11.9
2,6-difluorobenzoic acid	152.8	4.68	3.06	1.00	152.8	3.79	2.48
3,4-difluorobenzoic acid	159.1	0.56	1.61	1.02	155.4	0.85	0.55
3,5-difluorobenzoic acid	245.1	10.3	4.22	1.02	240.2	6.74	2.81
2,3,4-trifluorobenzoic acid	250.2	9.55	3.82	1.04	240.0	14.0	5.82
2,3,6-trifluorobenzoic acid	152.8	4.68	3.06	1.00	152.8	3.79	2.48
2,4,5-trifluorobenzoic acid	163.0	6.05	3.71	1.00	162.2	10.5	6.47
2,4,6-trifluorobenzoic acid	135.2	3.49	2.58	0.96	140.5	4.05	2.88
3,4,5-trifluorobenzoic acid	169.4	1.51	0.89	1.01	168.0	0.21	0.12
2,3,4,5-tetrafluorobenzoic acid	162.2	2.51	1.54	0.99	164.7	3.43	2.08
2,3,5,6-tetrafluorobenzoic acid	170.9	1.07	0.63	1.01	169.7	2.23	1.31
pentafluorobenzoic acid	241.9	10.3	4.22	1.05	230.2	9.72	4.22
m-toluic acid	243.1	2.96	1.22	1.06	230.4	4.65	2.02
o-toluic acid	138.4	3.19	2.31	0.98	141.4	5.96	4.22
p-toluic acid	165.5	9.18	5.55	0.99	167.0	13.1	7.85

SOLUBILITY

pH testing:

Solutions of one, ten, and twenty percent concentrations were tested for solubility. The pH of each solution was recorded. If the acid was not completely dissolved, then small increments of sodium hydroxide were added until it dissolved. The solution pH was recorded when all the tracer was dissolved and is listed below in Table 12.

The one and ten percent solutions consisted of 0.1 and 1 gram, respectively, of acid in ten milliliters of J-13 water. The twenty percent solution was made using 0.5 grams of the tracer in 2.5 milliliters of J-13 water.

Table 12. Solubility and pH

Tracer Compound	pH 1%	pH 10%	pH 20%
2,3-difluorobenzoic acid	14	13	14
2,4-difluorobenzoic acid	14	13	14
2,5-difluorobenzoic acid	4	7	14
2,6-difluorobenzoic acid	14*	5	14
3,4-difluorobenzoic acid	14	13	14
3,5-difluorobenzoic acid	12	13	14
2,3,4-trifluorobenzoic acid	13	12	14
2,3,6-trifluorobenzoic acid	1	3	14
2,4,5-trifluorobenzoic acid	4	9	14
2,4,6-trifluorobenzoic acid	10*	7	14
3,4,5-trifluorobenzoic acid	14*	5	14
2,3,4,5-tetrafluorobenzoic acid	2	3	14
2,3,5,6-tetrafluorobenzoic acid	2	3	14
pentafluorobenzoic acid	2	3	14
m-toluic acid	14	14	14
o-toluic acid	12*	11	14
p-toluic acid	14*	12	14

* the increment of NaOH used was larger than necessary to dissolve the tracer.

TOXICITY

Ames Testing

The compounds listed in Table 13 were tested for mutagenicity using the Ames test. Ames testing uses specific strains of bacterium Salmonella typherium selected for its inability to grow without the addition of a specific amino acid. When exposed to a mutagen, the selected bacterium reverts to wild type and can grow in the absence of the amino acid. Mutagenicity is suspected when the number of revertants enumerated from the test compound plates exceeds the number of spontaneous revertants in the negative control plate by a minimum of two-fold.

Five concentrations levels between 0.5 μg / plate and 500 μg / plate were tested in three bacterial strains, TA 97A, TA 98, and TA 100. No mutagenic activity was observed with any of the 19 tracers with or without S9 amendment. S9 is used for the metabolism of the compound. These results indicate that neither the parent compound or its metabolites are mutagens. A complete listing of the results is shown in Appendix A.

Table 13. Tracers tested for mutagenicity

2,3-Difluorobenzoic acid	2,3,4-Trifluorobenzoic acid	o-Trifluoromethylbenzoic acid
2,4-Difluorobenzoic acid	2,4,5-Trifluorobenzoic acid	m-Trifluoromethylbenzoic acid
2,5-Difluorobenzoic acid	3,4,5-Trifluorobenzoic acid	p-Trifluoromethylbenzoic acid
2,6-Difluorobenzoic acid	2,3,4,5-Tetrafluorobenzoic acid	Trifluoroacetic acid
3,4-Difluorobenzoic acid	2,3,5,6-Tetrafluorobenzoic acid	Pentafluoropropionic acid
3,5-Difluorobenzoic acid	Pentafluorobenzoic acid	Heptafluorobutyric acid

Toxicity Literature Review

A literature review of the toxicity of the fluorobenzoates and the perfluorinated aliphatic acids is presented in Appendix B. A synopsis of the results follows.

Very little information regarding the toxicity of the fluorobenzoates was found. A significant body of data exits on the parent compound, benzoic acid, and it is generally recognized as safe. It is used in numerous pharmaceutical preparations and as a preservative in food stuffs. Some studies exist that indicate that the mono- and di-fluorobenzoates are not significantly more toxic than the parent compound.

Health effects data were found for trifluoroacetic acid, but not for pentafluoropropionic acid and heptafluorobutyric acid. Although TFAA has a low human toxicity, about 1 in 10,000 persons can develop a hepatitis with a 50% mortality. For this reason none of the aliphatic compounds were recommended for use as tracers.

QUALITY ASSURANCE PROGRAM

A Quality Assurance Program was developed for both the laboratory testing of potential tracer compounds and the analysis of the field samples collected during the tracer tests at the C-well complex. QA procedures written by HRC, effective 05/10/95 and approved by the USGS Yucca Mountain QA Branch, include:

1.0 Management QA Requirements
2.0 QA Program
3.0 Procurements
4.0 Instructions, Procedures, Plans, and Drawings
5.0 Document Control
6.0 Identification and Control of Items
7.0 Control of Processes
8.0 Control of Measuring and Test Equipment
9.0 Handling, Storage, and Shipping
10.0 Control of Nonconformance and Corrective Action
11.0 Quality Assurance Records
12.0 Surveillances
13.0 Software Quality Assurance

Standard operating procedures (SOPs) (detailed technical procedures), written and used for the field and laboratory tracer tests, include:

Batch Testing of Organic Tracers, Revision 0, effective 5/10/95.
Batch Testing of Organic Tracers, Revision 1, effective 8/1/95.
Organic Tracer Extraction Procedures, Revision 0, effective 8/1/95.
High Pressure Liquid Chromatograph (HPLC) Operation, Revision 0, effective 4/8/95.

High Pressure Liquid Chromatograph (HPLC) Operation, Revision 1, effective 8/1/95.
High Pressure Liquid Chromatograph (HPLC) Operation, Revision 2, effective 12/26/95.
Purchase Inspection, Revision 0, effective 4/8/95.
Purchase Inspection, Revision 1, effective 7/18/95.
Document Control, Revision 0, effective 4/8/95.
Document Control, Revision 1, effective 8/1/95.
Scientific Notebooks, Revision 1, effective 3/31/93.
Scientific Notebooks, Revision 2, effective 5/3/95.
Organic Tracer Scientific Notebooks and Instrument Logs, Revision 0, effective 8/1/95.
Sartorius 2432 Analytical Balance, Revision 0, effective 4/2/92.
Analytical Balance Use, Revision 1, effective 4/8/95.
Analytical Balance Use for the Tracer Project, Revision 2, effective 5/8/95.
Analytical Balance Use for the Tracer Project, Revision 3, effective 8/1/95.
Top-Loading Balance Use for the Tracer Projects, Revision 0, effective 12/26/95.
Data Verification/Validation, Revision 0, effective 4/8/95.
Data Verification/Validation, Revision 1, effective 8/1/95.
Data Verification/Validation, Revision 2, effective 12/26/95.

Internal Assessments

Scientific notebooks and instrument logs are to be evaluated using the scientific notebook SOP applicable by effective date as listed. These evaluations are documented on the associated forms. Batch test data, field tracer-test data, and laboratory tracer-test data are evaluated using the verification/validation SOP applicable by effective date as listed. These evaluations are documented on the associated verification forms and are included with the data packages. In addition, the field instrument log was surveyed in the field. These evaluations are documented in the form of comments in the notebooks.

External Assessments

On 3/3/95, Mr. David Erdmann of the USGS performed a preliminary evaluation of the HRC laboratory. Suggestions from his report, with the exception of the use of control charts, were utilized by HRC.

On 8/9/95, Mr. Pete Rodriguez of the USGS Yucca Mountain QA Branch audited the HRC for compliance to its QA program. Due to a transition in the qualification of suppliers process, rather than a YMP-USGS surveillance report, an OCRWM supplier evaluation report form was received by HRC on 11/22/95 indicating satisfactory review of the HRC QA program and recommendation of HRC placement on the OCRWM QSL. As a result of the audit, the QA procedure 3.0 Procurements was edited for clarification only.

C-WELL TRACER TEST

A preliminary tracer test was started at the C-wells in February 1996. Iodide was chosen as the tracer because of its solubility and excellent sensitivity. We were able to detect iodide levels as low as 3 parts per billion (ppb) using HPLC with a UV detector. During the course of the test, 3124 samples were collected and over 2,500 analyses were performed by HRC personnel. Some of the analyses were conducted in the field to provide real time information to the hydrologist. However, because of the large number of samples collected, most were analyzed in our laboratory facilities.

From an analytical chemistry standpoint, the tracer test was highly successful. The injectate concentration was 10,000 ppm (a 1% solution) and the breakthrough curve peak concentration was approximately 95 parts per billion (ppb). That is a difference of about 5 orders of magnitude. Even with this reduction in concentration, we were able to successfully pinpoint the arrival of the tracer five days after injection and provide sample concentrations with excellent precision given the low concentrations and less than ideal conditions in the field.

Appendix C lists the results of each sample analyzed as well as the injectate concentration, the standard deviation for the method, and a tracer breakthrough curve.

APPENDIX A

MATERIALS AND METHODS

Mutagenicity assays. Mutagenicity assays were performed on the 19 potential tracers as described by Marion and Ames (1983). The assays consisted of tests conducted with buffer and with a hepatic post-mitochondrial supernatant (S9) metabolizing amendment at 4% and at 9% (final concentration). Each tracer was tested with three bacterial strains of *Salmonella typhimurium* (TA97A, TA98, and TA100). Tracer concentrations tested were dependent on the solubility of the compound. Eighteen of the tracers were tested at five concentrations ranging from 500 µg/plate to 0.5 µg/plate, final concentration depending on the tracer. An exception was *p*-trifluoromethylbenzoic acid which was tested at four concentrations ranging from 0.0625 to 1.25 µg/plate, final concentration. All assays were conducted with positive controls dependent on the bacterial strain and the presence or absence of the S9 amendment (Table 1). Negative controls for all assays consisted of distilled water.

Table 1. Experimental design for the positive control.

Strain	Amendment	Positive Control	Final Concentration
TA 97A	buffer	ICR-191	1.0 µg/plate
	S9	2-aminofluorene	5.0 µg/plate
TA 98	buffer	daunomycin	5.0 µg/plate
	S9	2-aminofluorene	5.0 µug/plate
TA 100	buffer	sodium azide	1.5 µg/plate
	S9	2-aminofluorene	5.0 µg/plate

For each assay, 0.05 ml of tracer solution was mixed with 0.1 ml of an eleven hour culture of one of the *S. typhimurium* strains. The bacterial/tracer suspension was mixed with a 0.5 ml amendment (buffer, 4% S9 or 9%S9) and 2 ml of molten top agar (50μM L-histidine, 50μM biotin, 0.5% NaCl, 0.6% agar). The mixture was then plated to Petri plates containing minimal salts agar with glucose. All assays were performed in duplicate. The plates were incubated inverted in the dark at 37°C for 48 hours and the revertant colonies were enumerated visually and recorded. The mean of the duplicate measurements ± 1 standard deviation of the mean were calculated.

RESULTS

The potential mutagenicity of the 19 tracers were measured with *S. typhimurium* strains TA97A, TA98, and TA100 in the presence of 4% or 9% S9 and in the absence of any post-mitochondrial metabolizing amendment (Tables 2-20). Mutagenicity is suspected when the number of revertants enumerated from test compound plates exceeds the number of spontaneous revertants in the negative control plates by a minimum of two-fold (Cerniglia *et al.*, 1985). At the concentrations tested, no two-fold increase in the number of revertants was detected for any of the 19 tracers for any of the three bacterial strains. Therefore, no mutagenic activity was observed with any of the tester strains with or without S9 amendment.

Cerniglia, C.E., J.P. Freeman, G.L. White, R.H. Heflich, and D.W. Miller. 1985. Fungal metabolism and detoxification of the nitropolycyclic aromatic hydrocarbon 1-nitropyrene. Appl. Environ. Microbiol. **50**:649-655.

Marion, D.M. and B.N. Ames. 1983. Revised methods for the *Salmonella* mutagenicity test. Mutat. Res. **113:**173-215.

Tracer: 2,6-DIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)			
			5	15	50	150
TA97A*	Buffer	176±15	209±21	215±12	200±1	154±30
	4% S9	218±7	223±4	220±1	239±1	221±21
	10% S9	215±18	241±17	234±11	251±35	253±13
TA98	Buffer	31±4	28±1	34±10	24±1	24±2
	4% S9	42±11	49±0	37±13	44±5	42±4
	10% S9	48±7	50±1	51±4	46±7	51±4
TA100	Buffer	280±19	233±17	253±17	227±20	214±23
	4% S9	229±16	260±11	223±6	250±23	210±1
	10% S9	227±19	260±2	236±1	251±4	235±24

* Strain TA97A Tracer Concentration for S-9 trials = 0.5, 1.5, 5, 15, 50

Tracer: ORTHO-TRIFLUOROMETHYLBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			1.5	5	15	50	150	
TA97A	Buffer	176±15	221±8	211±5	186±18	191±4	214±32	>3000
	4% S9	218±7	258±13	238±40	227±11	243±2	253±10	892±72
	10% S9	215±18	268±22	263±0	253±2	224±14	228±3	585
TA98	Buffer	31±4	30±1	26±11	29±2	27±4	20±8	730±147
	4% S9	42±11	36±6	46±1	39±8	38±3	37±2	1448±68
	10% S9	48±7	55±1	45±8	44±6	48±8	46±20	416±71
TA100	Buffer	280±19	265±21	249±9	262±30	254±19	253±13	1145±211
	4% S9	229±16	261±5	265±2	270±18	251±17	242±1	1237±107
	10% S9	227±19	244±6	243±4	276±13	253±14	231±1	630±71

* Strain TA97A Tracer Concentration for S-9 trials = 0.15, 0.5, 1.5, 5.0, 15.0

Tracer: META-TRIFLUOROMETHYLBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			1.5	5	15	50	150	
TA97A	Buffer	176±15	198±25	195±18	200±6	218±16	189±17	>3000
	4% S9	218±7	253±4	227±8	238±1	253±0	231±21	892±72
	10% S9	215±18	270±22	227±6	226±3	247±3	246±4	585
TA98	Buffer	31±4		35±4	28±4	33±4	28±4	730±147
	4% S9	42±11		52±8	55±7	40±9	47±6	1448±68
	10% S9	48±7		48±6	59±8	57±5	58±14	416±71
TA100	Buffer	280±19	268±18	269±11	249±13	250±16	248±27	1145±211
	4% S9	229±16	240±5	255±13	244±5	262±22	246±24	1237±107
	10% S9	227±19	239±4	280±2	256±4	235±32	260±17	630±71

* Strain TA97A Tracer Concentration for S-9 trials = 0.15, 0.5, 1.5, 5.0, 15.0

Tracer: PARA-TRIFLUOROMETHYLBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			.0625	.125	.625	1.25		
TA97A	Buffer	202±8	202±30	165±24	188±5	183±24		>3000
	4% S9	230±23	247±13	229±31	230±9	220±2		821±43
	10% S9	238±10	257±10	235±21	238±35	211±27		642±10
TA98	Buffer	45±3	57±13	39±4	42±1	50±12		960±116
	4% S9	65±10	66±13	72±8	74±17	61±4		1076±47
	10% S9	72±4	63±5	74±12	80±9	67±8		464±78
TA100	Buffer	222±30	225±4	247±30	254±1	236±6		2000±0
	4% S9	231±15	222±35	220±13	233±22	210±13		1150±14
	10% S9	219±7	208±14	218±1	228±18	248±21		508±23

Tracer: 2,3,4-TRIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			1.5	5	15	50	150	
TA97A	Buffer	202±8	189±6	186±23	185±12	169±11	139±6	>3000
	4% S9	230±23	264±6	269±33	207±6	222±1	105±71	821±43
	10% S9	238±10	224±4	265±1	238±4	255±13	265±18	642±10
TA98	Buffer	45±3	51±13	47±11	51±11	45±1	45±4	960±116
	4% S9	65±10	67±11	49±1	71±1	130±98	57±11	1076±47
	10% S9	72±4	77±6	70±11	61±4	78±3	66±9	464±78
TA100	Buffer	222±30	229±10	239±1	231±9	273±8	234±12	2000±0
	4% S9	231±15	220±20	218±22	228±13	205±7	231±0	1150±14
	10% S9	219±7	249±1	228±13	238±4	239±10	224±10	508±23

* Strain TA97A Tracer Concentration for S-9 HIGH trials = 0.15, 0.5, 1.5, 5.0, 15.0

Tracer: 3,4,5-TRIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			5	15	50	150	500	
TA97A	Buffer	202±8	174±26	200±4	152±13	189±20	149±1	>3000
	4% S9	230±23	213±6	261±37	209±13	174±38	189±25	821±43
	10% S9	188±27	195±4	265±1	240±13	151±39	158	446±57
TA98	Buffer	45±3	56±15	52±8	53±4	46±4	34±2	960±116
	4% S9	65±10	58±13	58±11	69±1	59±4	592±7	1076±47
	10% S9	72±4	58±7	59±9	57±3	71±10	62±18	464±78
TA100	Buffer	222±30	247±14	219±11	254±21	217±7	105±28	2000±0
	4% S9	231±15	215±10	224±5	230±28	213±4	50±25	1150±14
	10% S9	219±7	237±4	248±14	252±8	218±1	22±15	508±23

Tracer: 2,3,4,5-TETRAFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			5	15	50	150	500	
TA97A	Buffer	202±8	225±23	198±19	156±11	110±21	180±4	>3000
	4% S9	230±23	261±9	250±7	205±6	177±8	217±0	821±33
	10% S9	238±10	265±1	232±11	268±1	250±13	205±8	642±10
TA98	Buffer	45±3	41±9	48±1	51±5	56±3	38±9	960±116
	4% S9	65±10	51±6	72±2	72±5	55±15	52±24	1076±47
	10% S9	72±4	57±11	64±23	70±8	74±6	59±8	464±78
TA100	Buffer	222±30	227±1	261±23	249±17	240±21	194±8	2000±0
	4% S9	231±15	223±11	222±18	204±16	224±12	177±8	1150±14
	10% S9	219±7	211±30	234±14	217±7	216±27	165±17	508±23

* Strain TA97A Tracer Concentration for S-9 HIGH trials = 0.5, 1.5, 5.0, 15.0, 50.0

Tracer: 2,3-DIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			1.5	5	15	50	150	
TA97A	Buffer	194±9	174±23	227±14	204±3	204±21	197±23	>3000
	4% S9	231±13	254±11	245±12	255±12	230±7	210±41	596±18
	10% S9	237±20	257±47	262±6	258±2	241±11	230±7	403±18
TA98	Buffer	38±2	29±6	35±4	41±13	42±6	44±13	516±76
	4% S9	48±5	58±7	53±10	55±14	57±6	56±8	959±101
	10% S9	46±9	66±5	59±4	52±11	61±1	65±8	325±22
TA100	Buffer	201±19	225±23	237±3	224±25	197±11	208±15	1034±59
	4% S9	207±6	225±9	222±12	218±6	195±21	199±1	1070±11
	10% S9	218±12	186±5	220±11	220±23	217±19	208±5	495±27

Tracer: 2,4-DIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			0.5	2.5	5	25	50	
TA97A	Buffer	194±9	203±12	160±13	135±98	213±5	190±36	>3000
	4% S9	231±13	286±25	245±55	285±10	368±62	280±30	596±18
	10% S9	238±10	211±6	233±28	261±20	235±22	256±39	642±10
TA98	Buffer	38±2	38±8	33±11	25±11	35±5	31±4	516±76
	4% S9	48±5	49±4	61±4	35±9	52±4	53±12	959±101
	10% S9	46±9	63±6	56±11	32±8	62±20	66±5	325±22
TA100	Buffer	201±19	207±19	235±6	217±28	219±7	221±18	1034±59
	4% S9	207±6	229±0	232±18	224±8	205±21	209±4	1070±11
	10% S9	218±12	247±8	218±8	222±14	234±13	195±2	495±27

Tracer: 2,5-DIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			3	15	30	150	300	
TA97A	Buffer	194±9	177±29	199±6	217±23	209±24	218±4	>3000
	4% S9	231±13	229±1	268±13	303±21	252±0	258±8	596±18
	10% S9	237±20	284±0	257±8	290±18	272±4	227±11	403±18
TA98	Buffer	38±2	31±1	36±6	44±4	32±13	27±8	516±76
	4% S9	48±5	55±6	58±6	51±6	47±4	42±1	959±101
	10% S9	46±9	47±7	55±6	62±1	57±1	38±2	325±22
TA100	Buffer	201±19	230±28	225±6	226±2	194±13	188±40	1034±59
	4% S9	207±6	251±3	223±14	213±24	231±2	184±3	1070±11
	10% S9	218±12	223±17	245±14	251±1	218±19	181±30	495±27

Tracer: 3,4-DIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			1.5	5	15	50	150	
TA97A	Buffer	194±9	181±20	183±6	194±15	227±1	203±11	>3000
	4% S9	222±15	169±60	220±19	217±13	217±21	202±0	947±65
	10% S9	237±20	268±25	280±1	282±74	292±47	279±17	403±18
TA98	Buffer	26±4	44±8	50±5	41±0	31±17	39±13	171±50
	4% S9	46±11	45±2	56±23	51±8	52±5	34±3	1107±58
	10% S9	53±7	70±10	59±3	62±16	56±7	49±2	258±33
TA100	Buffer	201±19	244±25	247±16	235±4	228±8	216±14	1034±59
	4% S9	207±6	246±30	229±1	241±6	223±24	239±12	1070±11
	10% S9	218±12	227±33	235±39	234±7	223±27	223±8	495±27

Tracer: 3,5-DIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			3	15	30	150	300	
TA97A	Buffer	187±32	231±5	204±12	229±8	213±8	145±23	>3000
	4% S9	222±15	219±6	216±15	222±1	212±19	175±16	947±65
	10% S9	238±10	251±16	247±5	237±6	266±21	229±1	642±10
TA98	Buffer	26±4	44±8	46±3	49±6	41±8	36±16	171±50
	4% S9	46±11	57±13	54±2	56±6	51±1	46±11	1107±58
	10% S9	53±7	65±13	47±10	62±8	63±7	47±10	258±33
TA100	Buffer	203±9	195±23	213±21	216±16	196±6	185±15	1624±34
	4% S9	204±17	203±13	216±30	197±37	208±8	188±4	1362±6
	10% S9	178±12	222±5	219±4	211±33	210±5	193±16	562±40

Tracer: 2,3,5,6-TETRAFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			5	15	50	150	500	
TA97A	Buffer	187±32	190±33	208±21	206±16	199±26	176±4	>3000
	4% S9	222±15	243±25	223±9	227±9	217±17	193±8	947±65
	10% S9	238±10	269±9	253±11	262±27	269±11	231±4	642±10
TA98	Buffer	26±4	37±12	40±8	49±1	37±2	33±4	171±50
	4% S9	46±11	48±3	54±2	72±25	56±11	47±9	1107±58
	10% S9	53±7	54±1	63±2	63±13	66±8	42±6	258±33
TA100	Buffer	203±9	212±1	214±25	217±20	226±22	194±28	1624±34
	4% S9	204±17	206±2	196±18	227±14	204±17	196±11	1362±6
	10% S9	178±12	217±10	212±5	210±22	223±23	164±0	562±40

Tracer: 2,4,5-TRIFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			5	15	50	150	500	
TA97A	Buffer	187±32	207±13	226±12	224±21	209±6	168±0	>3000
	4% S9	222±15	229±1	213±4	201±1	217±8	171±4	947±65
	10% S9	238±10			236±9	266±17	172±21	642±10
TA98	Buffer	26±4	39±0	43±8	27±4	42±8	24±4	171±50
	4% S9	46±11	39±6	43±16	44±0	40±6	180±146	1107±58
	10% S9	53±7	43±0	42±7	54±0	47±9	39±7	258±33
TA100	Buffer	203±9	223±8	209±47	191±18	204±13	158±3	1624±34
	4% S9	204±17	225±9	203±45	195±28	202±13	147±9	1362±6
	10% S9	178±12	211±18	182±0	205±8	195±20	169±7	562±40

Tracer: TRIFLUOROACETIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			5	15	50	150	500	
TA97A	Buffer	187±32	183±8	204±6	214±15	209±44	201±16	>3000
	4% S9	222±15	255±12	247±13	219±5	234±16	168±59	947±65
	10% S9	182±9	201±8	164±48	180±26	194±6	167±7	432±21
TA98	Buffer	50±4	52±4	44±11	41±2	57±3	43±7	370±59
	4% S9	50±6	70±4	77±1	71±6	56±8	64±4	1150±10
	10% S9	63±2	64±16	69±18	70±18	74±2	74±1	413±16
TA100	Buffer	203±9	197±16	211±36	227±4	198±10	209±5	1624±34
	4% S9	204±17	227±25	208±14	205±18	199±13	178±26	1362±6
	10% S9	178±12	252±4	222±34	216±14	243±7	215±16	562±40

Tracer: PENTAFLUOROPROPIONIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			5	15	50	150	500	
TA97A	Buffer	202±18	190±12	188±18	132±28	136±8	163±23	>3000
	4% S9	232±11	204±9	166±18	175±5	185±4	153±4	902±161
	10% S9	221±24	217±6	200±3	191±7	172±21	171±5	491±51
TA98	Buffer	50±4	43±18	38±7	45±6	52±6	43±2	370±59
	4% S9	50±6	60±4	58±0	57±6	57±11	54±5	1150±10
	10% S9	63±2	69±5	59±6	63±12	69±20	75±6	413±16
TA100	Buffer	204±36	221±18	225±24	202±11	192±33	188±5	898±3
	4% S9	199±3	202±13	194±23	210±16	185±23	178±29	1111±16
	10% S9	215±12	233±21	245±18	223±35	228±5	197±0	515±8

Tracer: HEPTAFLUOROBUTYRIC

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			5	15	50	150	500	
TA97A	Buffer	202±18	147±19	166±35	174±1	193±0	145±10	>3000
	4% S9	232±11	214±4	170±21	222±12	187±16	212±18	902±161
	10% S9	221±24	241±1	239±8	244±1	163±30	233±20	491±51
TA98	Buffer	50±4	48±6	45±8	38±8	41±2	45±4	370±59
	4% S9	50±6	67±11	55±1	61±11	63±10	61±10	1150±10
	10% S9	63±2	65±3	64±2	75±4	54±9	64±12	413±16
TA100	Buffer	204±36	234±8	219±4	218±18	217±23	214±21	898±3
	4% S9	199±3	221±34	192±11	181±23	198±3	206±18	1111±16
	10% S9	215±12	213±22	213±18	225±21	239±15	159±6	515±8

Tracer: 3,5-DICHLOROSALICYLIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
			0.5	2.5	5	25	50	
TA97A	Buffer	202±18	184±1	197±9	168±4	183±21	216±1	>3000
	4% S9	232±11	207±4	240±1	219±22	205±17	215±13	902±161
	10% S9	221±24	215±23	249±8	217±9	239±1	254±11	491±51
TA98	Buffer	50±4	48±4	42±19	41±1	37±1	47±2	370±59
	4% S9	50±6	60±8	72±13	56±1	56±11	68±11	1150±10
	10% S9	63±2	51±0	67±2	75±10	70±14	60±8	413±16
TA100	Buffer	204±36	205±4	199±26	207±8	219±1	232±1	898±3
	4% S9	199±3	211±3	225±8	212±2	207±21	214±8	1111±16
	10% S9	215±12	221±9	217±45	221±14	215±1	225±33	515±8

Tracer: PENTAFLUOROBENZOIC ACID

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control †
			5	15	50	150	500	
TA97A*	Buffer	176±15	185±2	190±6	191±2	184±6	173±6	>3000
	4% S9	218±7	228±6	200±21	213±29	218±5	188±7	892±72
	10% S9	215±18	220±23	211±4	237±18	227±13	217±11	585
TA98	Buffer	31±4	30±1	37±1	31±0	30±1	25±9	730±147
	4% S9	42±11	49±6	37±2	45±2	41±1	37±8	1448±68
	10% S9	48±7	51±6	53±9	58±12	72±4	55±1	416±71
TA100	Buffer	280±19	248±45	226±1	216±32	227±8	201±16	1145±211
	4% S9	229±16	239±35	227±14	207±1	234±22	214±21	1237±107
	10% S9	227±19	229±24	238±25	222±8	247±1	206±5	630±71

* Strain TA97A Tracer Concentration for S-9 trials = 0.5, 1.5, 5, 15, 50

Tracer: _____

Strain	Trial	neg. control	Tracer Concentration (µg/plate)					pos. control
TA97A	Buffer							
	4% S9							
	10% S9							
TA98	Buffer							
	4% S9							
	10% S9							
TA100	Buffer							
	4% S9							
	10% S9							

A Comparison of HPLC/MS Thermospray and Particle Beam Methods of Analysis for TFAA/PFPA/HFBA in Ground Water

by Tonya Dombrowski
and Klaus Stetzenbach
Harry Reid Center for Environmental Studies
Barrick Museum of Natural History
University of Nevada-Las Vegas
Las Vegas, Nevada

ABSTRACT: A method is described for the qualitative and quantitative identification of three perfluorinated aliphatic acids in ground water. Organic acids are being used as ground-water tracers during hydrologic characterization for the proposed high-level nuclear waste repository at Yucca Mountain, Nevada. Trifluoroacetic, pentafluoropropionic, and heptafluorobutyric acids were evaluated using both HPLC and HPLC/MS methods. The sensitivity of conventional HPLC methods, using a UV-Vis detector, was very poor. Detection limits for this method were around 100 ppm using a 10 μL injection volume. Because much greater sensitivity was required for the ground-water tracing project, HPLC/MS methods were evaluated using both particle-beam chemical ionization and thermospray techniques. The results of these two methods were compared for sensitivity and reproducibility, as both are essential for the scope of this project. The thermospray technique showed considerably lower detection limits when compared to the particle beam method of analysis. The detection limit for all three acids using the negative thermospray mode was at about 10 ppb using a 10 μL injection volume. The detection limit for the particle-beam analyses was slightly higher. Instrumental settings, sensitivity, and reproducibility for the two HPLC/MS techniques will be discussed.

INTRODUCTION: Yucca Mountain, Nevada, is being evaluated as a potential high-level nuclear waste repository site. The accurate evaluation of ground-water movement is of major importance to the site characterization process. The use of chemical compounds to trace ground-water movement and determine aquifer characteristics such as effective porosity have been widely applied in a number of various circumstances (1-6). To be considered as viable ground-water tracers, however, all compounds used must exhibit certain characteristics. They should:

1) be water soluble
2) not sorb to aquifer material
3) be chemically and biologically stable for the duration of the test
4) be foreign to the local environment
5) be non-toxic
6) have excellent analytical sensitivity

These attributes represent a general case that applies to all tracers, and, while not all of these criteria may be met fully by each tracer compound, they should all be applicable to the fullest possible extent in the initial selection of potential tracer compounds. Their application to the evaluation of ground-water movement is obvious in most cases. If the compounds are to be injected into an aqueous environment, it is clear that they must be soluble in aqueous solutions. The intent of most tracer tests is to determine the direction and speed of the water movement, so it is not desirable to have the tracer sorb to the aquifer material. Since most aquifer materials have a negative charge, anions such as chloride, bromide and organic acids make the best tracers. For accurate interpretation of the results of a tracing test, it is essential that as much as possible of the compound be recovered, and chemical and biological stability will add to the final recovery of the tracer compounds. Typical tracer tests can last from several hours to several weeks. A background contamination of an area by a potential tracing compound will not only add to the difficulty of analytical measurements and interpretation of results but, for organic compounds, may also lead to a higher possibility of biological degradation. The toxicity of a compound is an important consideration whenever chemical compounds are being placed into the natural environment and is therefore a major factor in the selection of potential tracing compounds.

Since the physical and chemical properties of the aquifer and the tracer cannot be changed, the only variable that the researcher has any control over is the analytical sensitivity. The analytical sensitivity will affect and be affected by several of the other areas considered above, as the total amount of a compound being injected into the water system will, to a large extent, be determined by the analytical detection limits for the compound being used. The solubility of the compound will be tied to the amount injected, and this overall amount will influence the potential toxicity, as a large amount of a compound in the natural environment may well exceed the safe, non-toxic levels that a smaller initial concentration would produce. The difference in

sensitivity from 1 ppm to 1 ppb can be significant. If a tracer test requires 1 ppm sensitivity, and 100 kg of tracer are required to achieve this concentration, the same test with a 1 ppb sensitivity would only require 100 grams of tracer to be put into the environment.

The first tracer tests for the Yucca Mountain Site Characterization Project are planned in an area called the C-well complex. This consists of a hydropad with 3 wells arranged in a triangle approximately 100 to 200 feet apart. The wells are 3,000 feet deep and the static water level is at approximately 1,300 feet. Twenty to thirty tracer tests are planned to characterize this saturated interval. It is estimated that 15 to 20 tracers are necessary to minimize the potential of interference from foregoing tests. There are not enough inorganic compounds that are acceptable tracers, so organic compounds will have to be used. We are testing 18 organic acids as possible tracers for this location.

Chemistry: Numerous organic compounds have been used to trace ground-water movement. Organic dyes such as fluorescein and rhodamine have been the most common, but these compounds generally sorb to aquifer materials and are readily degraded by microbes. They are best used in non-quantitative tests to trace large flows of water such as underground streams in karst. Optical brighteners (additives to laundry detergents) suffer from the same drawbacks.

Fluorinated benzoic acids have been used successfully for a number of tracing tests (1-5). Their anions are water soluble, they are readily detected by HPLC with UV detection at the 0.1 to 1 ppm level, and, because of the fluorine substitution, they are resistant to chemical and biological degradation. Their major drawbacks are availability and cost (7).

Perfluorinated aliphatic acids, such as trifluoroacetic acid (TFAA), pentafluoropropionic acid (PFPA), and heptafluorobutyric acid (HFBA), are more soluble and less expensive than the fluorinated benzoates, but they require more sophisticated instrumentation to be detected at low levels. TFAA, PFPA, and HFBA were used as tracers in trench infiltration studies on Mt. Lemmon, Arizona, at an elevation of 9,000 feet with 40 inches of annual precipitation (6). While these studies cannot be used to obtain quantitative information about degradation of the tracers, they do show that they were still present in detectable amounts more than two years after being placed in the trenches in a moist but unsaturated environment.

Toxicity. TFAA is found in fairly high concentration levels in the blood serum ($\approx$150 ppm) and urine ($\approx$300 ppm) of patients who have been anesthetized with halothane anesthetics. No negative effects have been attributed to its presence in the body, and therefore it is assumed to be relatively non-toxic at or below these concentration levels. It is expected that typical concentrations in the recovered water will be in the 1 to 10 ppm range, well below the levels found in anesthetized patients. No toxicity data are available for PFPA and HFBA. These compounds have shown very good long-term stability in the environment and, in most cases, appear to be excreted rather than metabolized (8).

Tracers: The tracer compounds chosen for evaluation for this project can be broken down into two major groups: aromatic acids and aliphatic acids. The aromatic acids, because of the ring structure, can be easily and sensitively evaluated using HPLC techniques and a UV detector. The aliphatic acids do not possess a good chromophore and therefore do not lend themselves to routine analytical methods of analysis. Because of the promise shown by these compounds in previous tracer tests, however, it was decided that an HPLC/MS method would be developed to evaluate them for the purpose of this project. It was further hoped that such a method could also be applied to the aromatic acids in the later stages of the project, to provide a means of positive identification in the event that two or more tracers were present in the same aquifer area.

The high sensitivity of environmental HPLC/MS analysis techniques (9,10), and other work done using TFAA as a potential tuning and calibration compound for thermospray HPLC/MS (11-13) showed that these compounds were potentially well suited for HPLC/MS analysis.

EXPERIMENTAL: An HPLC/MS method for analysis was needed for the aliphatic acid group of the tracer compounds (currently consisting of TFAA, PFPA and HFBA). The bulk of the following discussion will concern this method development and its subsequent evaluation.

Instrumentation: This work was performed with an Extrel Benchmark quadrupole HPLC/MS system (Extrel Corporation, Pittsburgh, PA, USA) configured for both particle-beam and thermospray modes of operation. The MS system was controlled through a Sun Station Sparc I data system which utilized Open Windows ver. 2 and Extrel IONStation software packages. Solvent delivery was performed with a ternary solvent HPLC pump with a flow feedback system to maintain constant flow rate (Spectra-Physics, San Jose, California USA; Model #SP8800). Reagent gases available included both ammonia and methane.

Operating parameters specific to the particle-beam interface included: pressure: $\approx 3.0 \times 10^{-4}$ torr, source temperature 220°C (227-237°C), nebulizer temperature 110°C (110-120°C), expansion region temperature 55 °C. The solvent, 100% methanol, was pumped through a reverse-phase C-18 column, 4.6 mm x 15 cm (Varian/Analytichem International, Harbor City, California USA, P/N 12157017), at 1.00 ml/min which gave a back-pressure of ≈2500 psi.

Operating parameters specific to the thermospray interface included: pressure: $\approx 3.0 \times 10^{-5}$ torr, source temperature 255°C (257-268°C), nebulizer temperature 178°C (173-180°C), repeller -21 V. The solvent, 94.5% H_2O with 0.1M ammonium acetate, 1.0% acetic acid, 4.5% methanol with 0.1M ammonium acetate, was pumped through a reverse-phase C-18 column, 4.6 mm x 15 cm (Varian/Analytichem International, Harbor City, California USA, P/N 12157017), at 1.00 ml/min which gave a back-pressure of ≈2500 psi.

The temperature settings shown in the parentheses are the actual values reported by the status screen; those not in parentheses are the set values entered at the start of the analysis.

Reagents: TFAA and HFBA were obtained from Aldrich, 99% purity. PFPA was obtained from Aldrich, 97% purity.

RESULTS AND DISCUSSION:

Particle-beam Evaluation: Initial method development was started using the particle-beam mode of operation. Electron ionization (EI) and both positive and negative chemical ionization (CI) were evaluated. Negative CI was found to be the most sensitive particle-beam mode for these compounds. Ammonia and methane were used initially as reagent gases, and methane was selected for this work. Sensitivity was about the same with both reagent gases, and methane was both less corrosive and much more readily available. Calibration was accomplished using perfluorotributyl-amine (PTA) as a calibration compound. (See figure #1 for specific operating parameters). On-column injections of the tracer compounds were made over the working range (1.0 to 100 ppm for TFAA, PFPA, HFBA) using a 10 μL injection loop. Direct flow (column bypass) injections were made in the working range (1.0 to 100.0 ppm for TFAA, PFPA, HFBA) using a 0.5 μL injection valve.

The ion spectra for these analyses were fairly simple, usually containing only one or two major ions. The parent peak was not observed for any of the acids when evaluated with the particle-beam technique. For all three acids, the major ion was at a mass showing a consistent loss of 20 from the molecular ion mass. This may be the result of a direct loss of HF from the molecular ion; however, such a loss may also be due to a more complicated mechanism which includes the formation of adduct ions, and the subsequent fragmentation of these larger ions into smaller pieces. A further loss of 44 (64 total from parent ion) was also noted under certain conditions, which could be attributed to the loss of CO_2. The TFAA signal was very unpredictable, and sensitivity was extremely poor. It is felt that this acid may be too volatile to be accurately analyzed using this technique. The PFPA and HFBA, however, gave good signals with fair sensitivity and good reproducibility throughout the working range of 1.0 to 100.0 ppm. Detection limits on column (10 μL loop injection) were at 0.1 ppm for both acids. The methods developed for the evaluation of these acids using negative CI particle-beam MS can most likely be applied to the aromatic acids discussed earlier in this report,

as the aromatic acids should be good electron capture agents. The sensitivities achieved using negative CI for the evaluation of the aliphatic acids, however, fell short of the desired detection limits for this project. The goals set for this research required greater sensitivity than that obtained for these acids from the particle-beam evaluations. Thermospray was therefore examined as a means of improving the sensitivity for these specific compounds.

Thermospray Evaluation: Both positive and negative modes of thermospray were evaluated. Initially the signal was very unstable, and both sensitivity and reproducibility were very poor due to an unusual pulsing of the signal which occurred at elevated temperatures (above 200°C). This problem was almost completely corrected by the exchange of the fused silica capillary tubing for stainless steel hypodermic tubing in the Extrel Benchmark nebulizer assembly. However, the placement of the end of the tubing within the source (see figure #2) was found to have a tremendous influence on the sensitivity of this method. A movement of the end of the tubing by less than 1 mm was significant in most cases and, at distances very near the optimal placement, could effectively cut off the signal completely. The tubing placement was optimized by watching the height and shape of ammonium adduct ions on the scope screen while making fine adjustments in position. Once the optimal placement was located, the ferrules were tightened to hold the tubing securely in position, and no further placement adjustments were made during the course of the analysis. It is unclear at this time whether this placement sensitivity is a distinct characteristic of the stainless steel tubing, or if its effect can be seen in the fused silica capillary tubing as well. Signal reproducibility with the fused silica tubing was so poor that such adjustments were impossible to evaluate.

Thermospray calibration was done using ammonium adduct ions and a series of PEG injections through the flow injection valve. (See figure #1 for specific operating parameters.) On- column injections of the tracer compounds were made over the working range (0.05 to 1.0 ppm for TFAA, PFPA; 0.1 to 1.0 ppm for HFBA) using a 10 μL injection loop. Direct flow injections were made in the working range (1.0 to 10.0 ppm for TFAA, PFPA, HFBA) using a 0.5 μL injection valve.

Negative thermospray ion spectra yielded one major peak for all three acids. Major ions monitored for all three acids were the molecular ion minus one mass unit (TFAA 113, PFPA 163, HFBA 213). Several adduct ions were visible in all three acids' spectra, but the majority of the ion current was concentrated in those ions listed above. The detection limit was at 0.01 ppm for an on- column injection (10 μL) for the TFAA and PFP. This is an order of magnitude better than the results from the negative CI evaluation. For HFBA the detection limit was slightly higher, at 0.05 ppm. The HFBA appears to be more affected by the elevated temperatures in the thermospray source, and the signal is slightly unsteady at the temperatures being applied. With further method optimization, the sensitivity of this technique for the HFBA should be comparable to that for the other two acids. Lower source temperatures seem to improve sensitivity and reproducibility for this acid.

Column vs flow injection: On-column injection reproducibility was compared to flow injection reproducibility and detection limits. It was felt that the use of the flow injection valve could greatly reduce the time involved in method development and, later, in initial sample screening and evaluation, if it could be determined that the flow injection results were reproducible to the degree required. The flow injection valve contained a fixed 0.5 μL injection loop. This small volume greatly reduced the amount of sample being injected and therefore made detection limits for the valve slightly higher than those for on-column injection.

A comparison is shown below of the reproducibility of the two techniques (negative CI particle-beam and negative ion thermospray) with both on-column injection and flow injection data. The percentages given are percent relative standard deviation (%rsd) for area counts only, and do not take into account intensity or peak height. They can be useful, however, for identifying trends and relative values.

PARTICLE BEAM:

Trifluoroacetic acid

on column: N\A Highly unstable

flow injection: N\A

Pentafluoropropionic acid

At Working concentration: (1.0 to 100 ppm)

on column: ≈14.5%

flow injection: ≈14.1%

At Detection Limits: (0.1 ppm)

on column: ≈50.2%

flow injection: ≈33.5%

Heptafluorobutyric acid

At Working concentration: (1.0 to 100 ppm)

on column: ≈13.3%

flow injection: ≈10.8%

At Detection Limits: (0.1 ppm)

on column: ≈46.1%

flow injection: ≈42.8%

THERMOSPRAY:

Trifluoroacetic acid

At Working concentration:

on column: ≈10.1% (0.05 to 1.0 ppm)

flow injection: ≈11.0% (1.0 to 10.0 ppm)

At Detection Limits:

on column: ≈22.4% (0.01 ppm)

flow injection: ≈42.5% (0.1 ppm)

Pentafluoropropionic acid

At Working concentration:

on column: ≈8.1% (0.05 to 1.0 ppm)

flow injection: ≈11.3% (1.0 to 10.0 ppm)

At Detection Limits:

on column: ≈16.8% (0.01 ppm)

flow injection: ≈27.0% (0.1 ppm)

Heptafluorobutyric acid

At Working concentration:

on column: ≈21.1% (0.1 to 1.0 ppm)

flow injection: ≈15.8% (1.0 to 10.0 ppm)

At Detection Limits:

on column: ≈23.3% (0.05 ppm)

flow injection: ≈16.6% (0.1 ppm)

The HFBA values for thermospray show basically the same %rsd for both the working conditions and the detection limit concentrations. This is felt to be due to the temperature problems discussed earlier.

CONCLUSIONS: Several trends in reproducibility and sensitivity for the negative CI particle-beam compared to the negative ion thermospray technique have been identified by this work to date.

The thermospray mode of analysis has been found to give extremely clean and reproducible ion spectra for all three aliphatic compounds (spectra usually contain only the molecular ion minus one as a major peak). The reproducibility of area counts for thermospray is good for the concentration ranges being used.

The thermospray method is affected to a much greater extent by temperature fluctuations, however, which have a large effect on both the sensitivity and reproducibility of the method, especially in the case of HFBA.

Negative CI particle-beam yields fairly good reproducibility for PFPA and HFBA and is much more resistant to the effects of temperature fluctuations than the thermospray technique. The reproducibility using negative CI is better for HFBA, and approximately the same for PFPA, as that obtained with the thermospray technique. However, negative CI particle-beam is not nearly as sensitive overall as thermospray and is not a viable method for the evaluation of TFAA at this time. The thermospray technique is much more sensitive than negative CI for all three acids (TFAA, PFPA, and HFBA). TFAA is easily seen at very low concentrations; sensitivity for PFPA is at least one order of magnitude better with thermospray than with negative CI, and HFBA sensitivity is at least twice as good with thermospray.

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FIGURE #1

Parameter	Particle-beam setting	Thermospray setting
Filament	300eV	70 eV
Emmission	6 mA	6 mA
Extractor	53 V	41 V
Entrance	43 V	8 V
Ion Energy	20 V	10 V
Exit	41 V	70 V
Dynode	5000 V	5000 V
Multiplier	1800 V	1800 V
Repeller	N/A	-21 V
Source Temperature	220°C (227-237°C)	255°C (257-268°C)
Nebulizer Temperature	110°C (110-120°C)	178°C (173-180°C)
Expansion Region	55°C	N/A
Ion polarity	Negative	Negative
Quadrupole DC	Normal	Normal
Pressure	$\approx 3.0 \times 10^{-4}$ torr	$\approx 3.0 \times 10^{-5}$ torr

(Note: voltages may differ from day to day by a few settings for maximum sensitivity, but the overall trends stayed the same as those illustrated below.)

The temperature settings shown in parentheses are the actual values reported by the status screen; those not in parentheses are the set values entered at the start of the analysis. The fluctuations may be either the result of the actual instrumental conditions or an artifact of the status update software interfacing with the thermostat electronics.

APPENDIX B

ORGANIC TRACER TOXICITY REPORT
FLUORINATED BENZOIC ACIDS

DOE Cooperative Agreement

No. DE-FC 08-90NV10972

Tonya Dombrowski
Klaus J. Stetzenbach PhD.

Harry Reid Center For Environmental Studies
University of Nevada - Las Vegas

INTRODUCTION

Ground water tracers are solutes dissolved in or carried by ground water to delineate flow pathways. Tracers provide information on direction and speed of water movement and that of contaminants which might be conveyed by the water. Tracers can also be used to measure effective porosity, hydraulic conductivity, dispersivity and solute distribution coefficients. They can be naturally occurring compounds or elements, or they can be completely foreign to the environment. The latter is generally preferred. For most applications tracers should be conservative, that is, move at the same rate as the water and not adsorb to aquifer materials. Aquifer materials are generally negatively charged, so anionic tracers will not adsorb and will move with the water.

A tracer should behave as follows:

1) Be water soluble.
2) Not adsorb on the aquifer material (i.e., be conservative).
3) Be chemically and biologically stable for the duration of the test.
4) Be foreign to the environment.
5) Have excellent analytical sensitivity.
6) Have a low toxicity.

Fifteen fluorinated organic acids (table 1) are presently being studied as possible tracers for the Yucca Mountain Site Characterization Project. There are two additional isomers of trifluorobenzoic acid, 2,3,6-trifluorobenzoic acid and 2,4,6-trifluorobenzoic acid, that are not presently being studied, but were included in this review of currently available toxicological information. Since these compounds are not used in large quantities in industrial or other processes, only limited data are available, especially human toxicology information.

It should be pointed out here that analytical sensitivity and stability are important adjuncts to the issue of toxicity. Virtually any element or compound that is introduced into an aquifer will cause some degradation of the water quality if the concentration is high enough. Tracers with high analytical sensitivity will permit lower input concentrations and therefore reduce the potential for degradation of the water quality. For example, a difference in sensitivity between 100 ppm and 100 ppb may mean introducing only 1 kg of tracer into the aquifer instead of 1,000 kg.

All organic chemicals dissolved in water, given enough time, will be degraded to carbon dioxide and inorganic ions (if any are contained in the parent compound) by bacterial action. The time required for this to occur depends on many factors, including lethality to indigenous flora, initial concentration, the capability of the microorganisms to utilize the compound and the probability of contact between a molecule and a degrading organism. Since the majority of microorganisms in the subsurface are associated with the host rock and not the water, strong anions will have limited contact with them, thus increasing their longevity in the environment. The fluorinated organic acids, suggested here as potential tracers, are generally quite resistant to chemical and biological activity.

Although not totally unreactive, as anions they will have reduced probability of interaction with bacteria.

POTENTIAL for EXPOSURE to TRACER-CONTAINING WATER

Concerns regarding exposure to pure tracer and the various tracer solutions will depend on the procedures used for transportation, injection and recovery during the tracer tests. For the tracer tests at the c-wells, we anticipate that laboratory space will be available at the site. Therefore, we intend to transport pure tracer to the site and prepare highly concentrated, almost saturated, injection solutions at the site. These highly concentrated solutions will be diluted to approximately 0.1% to 2% solutions for injection in the tracer injection apparatus. The concentration of the injection solution will depend upon the analytical sensitivity of the tracer and the estimated dilution that will take place on its migration to and into the recovery well, which will be from 100 to 200 feet away. The actual dilution will depend on several aquifer parameters, which will be measured by the tracing test. Estimated peak tracer recovery concentrations are expected to range from 1 to 20 ppm.

Location	Physical Form	Amount	Volume	Concentration
Laboratory	Solid	1 kg	_	_
Lab & Test Well	Liquid	1 kg	200 L	5,000 ppm (0.5%)
Groundwater	Liquid	1 kg	10^6 L	1.0 ppm average 10. ppm peak

There are three exposure scenarios for humans and the environment which may result from the use of these tracer compounds. The first is direct contact with or accidental loss of the pure liquid or solid tracer compound. This would happen if the workers spilled the solid (or pure liquid) material or used poor safety practices in the laboratory. The second scenario would occur if the 200 liters of 0.5% solution were spilled in the laboratory or on the ground before the solution was introduced into the injection wells. In both of these cases steps can be taken immediately to rectify or remediate the occurrence. The third scenario of contact is the long-term exposure to very low concentrations of the tracer which are not recovered during the study and which migrate out of the study area. In this case, exposed persons may not be aware of their contact with these compounds.

In this report we will address all three scenarios, provide as much toxicity information as is available and give realistic estimates of the probability of contact with the proposed tracers. In the first two scenarios, the exposure will be acute and the actions will be supervised by technical personnel. In the third scenario, the exposure will be sub-chronic and will involve the greatest risk to the general population.

PURE TRACER

Current estimates are that 100 g to 3 kg of tracer will be used per test. Injection solutions will be prepared on site to minimize possibilities of accidental spills during transport. Handling of the pure tracer to prepare the concentrated injection solution will be limited to trained chemistry personnel. Standard laboratory precautions will be used when these materials are handled. This includes wearing appropriate apparel, safety glasses and respirators if necessary. All warnings noted in the material safety data sheets (MSDS) will be observed.

If the pure tracer is accidentally released into the environment, remediation will depend upon the physical state of the tracer chemical. If the tracer is a solid, remediation will entail removal of the chemical from the ground and any soil that was in contact with the tracer. Since the solid chemical will not react with or penetrate the soil, this should entail only small amounts of soil which may have to be removed. This will be done primarily to prevent contamination so that the tracer can be used without background interference. Liquid tracers may react with and penetrate the soil; this will require more extensive clean-up to prevent contamination.

Potential health effects will be limited to acute toxicity resulting from a single exposure. Since the personnel will be wearing protective clothing and the compounds under consideration have a low volatility, exposure via the normal pathways (ingestion, inhalation or dermal absorption) is expected to be very small.

CONCENTRATED INJECTION SOLUTIONS

The concentrated tracer solutions which will be injected into the wells will vary between 0.1% and 2%. Even though the tracers are acids, the injection solution will be basic to increase the solubility of the tracer and to be closer to the ground water pH. Accidental spills of the injection solution will present problems similar to those described above for the liquid tracers, except there will be larger volumes. The larger volumes, 50 to 200 liters, will prevent complete removal of the material if all or a large portion is spilled. The use of that tracer may then be lost to the project, especially if the spill occurs in the immediate area surrounding one of the wells. Over time, bacterial degradation in the root zone will degrade the tracer to fluoride and carbon dioxide and rainwater will eventually carry some of the compound to groundwater.

Accidental ingestion of the tracer injection solutions by humans or animals are highly unlikely due to the limited access to the area and because the tracer injection apparatus will be a closed system. Exposure from other routes is expected to be very small because of the use of protective clothing. Potential health effects will be limited to acute toxicity resulting from a single exposure.

LOW CONCENTRATION SOLUTIONS

During the tracing test, the tracer will migrate from the injection well to the pumping well, a distance of approximately 100 to 200 feet. It is anticipated that the tracer injection solution will be reduced in concentration by three to six orders of magnitude during its migration. This will result in estimated peak concentrations of 20 ppb to 20 ppm at the pumping well. The amount of tracer recovered will depend upon the length of the tracing test, as well as specific aquifer conditions. Tracer recoveries can be as high as 70 to 80 percent, but typically average 50% or less. Recoveries of two fluorinated benzoic acids that were used as ground water tracers at the Waste Isolation Pilot Project (WIPP) site in New Mexico ranged from 15 to 53 percent (Kelly and Pickens, 1986), and when thiocyanate was used as a tracer in Hanford Washington the recovery was 60% (Thompson, 1982).

If the minimum percent recovery value (15%), and the maximum injection mass (3.0 kg) are used, then 2.55 kg of tracer will remain in the aquifer per test. The concentration of the tracer, which will have been diluted 3 to 6 orders of magnitude during the tracer test, will be further reduced as the tracer is dispersed as a result of the natural ground water movement. By the time it migrates off-site, or reaches a Nevada Test Site well that is being used to supply drinking water, the tracer concentrations will be at extremely low levels if it has not already been degraded by bacteria.

Potential human health effects would be limited to acute or chronic effects resulting from sub-chronic exposure. The worst case exposure would probably result from the use of the recovery well water for drinking water. Because of the limited access to this site, it is not possible that persons living nearby could use well water for domestic drinking water but we will determine the risk from such a scenario in case other test sites are chosen in the future. The exposure would be sub-chronic because there is a single injection of the tracer which then moves with the groundwater flow (50 - 150 L/min). For persons using water from a well (which is fixed in space), exposure to the tracer would exist during the few weeks required for the tracer plume to pass the well.

CHEMISTRY

Fluorinated organic compounds were selected as potential tracers because of their long term environmental stability and low reactivity. The carbon-fluorine bonds are the shortest of the carbon-halide bonds and are therefore expected to be the strongest and least reactive. Low reactivity and low toxicity are characteristics of numerous carbon-fluorine compounds. For example, Teflon (polytetrafluoroethylene) is extremely inert and is used in a variety of products that humans are in contact with every day, from containers to Gore-Tex. Halothane (2-bromo-2-chloro-1,1,1-trifluoroethane) and isofluorane (1-chloro-2,2,2-trifluoroethyl difluoromethyl ether) are anesthetics that are used throughout the world. Halons are used as fire extinguishers and freons have been used for many years as refrigerants and propellants because of their stability in the lower atmosphere and low human toxicity.

As a general rule, it can be stated that the greater the number of halogen atoms on a molecule, especially fluorine, the greater its stability. Perfluorinated acids such as pentafluoro-benzoic acid (PFBA) and trifluoroacetic acid (TFAA) are therefore extremely resistant to chemical attack. Because fluorine is a strong electron withdrawing atom, it also follows that the more fluorine atoms on an organic acid molecule, the stronger that acid becomes.

The acid functional group (carboxyl group), is completely oxidized, difficult to reduce and does not undergo other reactions in aqueous (ground water) solutions. Essentially all of these acids are ionized at typical ground water pH values. The weakest acids being evaluated have dissociation constants (pK_a) values of approximately 4.5, which means they will all be completely ionized and in their anionic form at water pH values of six or higher (Freiser and Fernando, 1963). The increasing number of halogens on a compound increase the ionizability, and consequently, the water solubility.

Ionized compounds are generally not able to pass through the microbial cell membranes and therefore are not readily utilized by these systems. However, when they are utilized, the reactions are almost identical to the non-fluorinated parent compound.

In addition to the chemical and microbial stability, the carbon-fluorine bond is also difficult for mammalian enzyme systems to break down, and compounds that contain these bonds are generally excreted without loss of fluoride rather than metabolized. This tends to make such compounds less toxic. These fluorinated acids are among the most polar of the halogenated organic compounds. They contain a polar functional group, the acid or carboxyl group, and the presence of that group facilitates their excretion as the parent compound directly, or as conjugates of the parent compound.

ENVIRONMENTAL BIODEGRADATION of CONTAMINANTS

Microorganisms are capable of degrading aromatic hydrocarbons and the aromatic fraction can be used to sustain bacterial growth. Utilization of organic compounds occurs via catabolic pathways catalyzed by a series of enzymes. The product formed may then be utilized by another population of bacteria or the resulting compounds may be resistant to further degradation.

Environmental factors that affect the rate and extent of biodegradation of a chemical tracer are its concentration, the population of microorganisms, presence of other nutrients (including trace metals), dissolved oxygen, pH, temperature salinity and contact time. Another factor which may affect degradation is prior exposure of the microbial population to the tracer or to a similar compound. One must be careful about assumptions made because of similarities between two chemicals or environmental conditions. Differences such as positional isomers, type of halogen or activity of the microbial population may alter the expected results.

The fluorinated aromatic acid tracers have pK_a values of 4.5 or less, making them anions at normal ground water pH. Ionized compounds are not able to pass through the microbial cell membrane and therefore are not generally utilized. Some bacteria however have acquired or can acquire the ability to transport such compounds as the result of muta-

tions. It is possible then, during extended tracer tests of 7 to 30 days to lose a small percentage of tracer as the result of bacterial activity. During long tracer tests (1 to 1.5 years) all of the tracer may be degraded.

The success of microbial degradation is also related to previous and/or low level chronic exposure to the compound. Chronic sublethal exposure may increase the tolerance of microorganisms and allow for adaptation of the biological community. The microbial population would then more rapidly respond to the presence of that and/or similar compounds, produce the necessary enzymes, and degradation rates would increase. If the compound is chemically analogous to a natural substrate a similar situation may occur with the microbial population readily producing enzymes necessary for degradation. Some chemicals can also act as initiators. These compounds may or may not be degraded in the process, but their presence gives bacteria the ability to degrade compounds of similar chemical structure. Without the presence of the initiator degradation may not take place.

The concentration of the organic compound is also important in determining the rate of biodegradation. Mineralization rates have been shown to be directly proportional to the concentration of the compound over a wide concentration range. The compound may also be in a concentration too low for degradation to occur. The lowest concentration of a compound that will support microbial growth is termed the threshold. At concentrations too low, degradation produces only enough energy for maintenance of the microbial population and growth is absent. Under these conditions degradation rates are retarded due to lack of an actively growing population. At higher concentrations, diffusion provides molecules to the cell surfaces at a rate sufficient to meet the needs of energy of maintenance and cell growth. The microbial population is stimulated and the number of microbes increase with time and degradation rates are enhanced. Thresholds vary with the microbial population involved. If the population is oligotrophic in nature (grows and survives in an environment with a low concentration of available carbon) a lower threshold may exist.

It is not practical to perform field experiments to attempt to estimate the stability of these tracers in the environment. Laboratory stability tests show the mono-fluorinated benzoic acids are not stable for more than 30 days, while some di- and poly-fluorinated benzoates were stable for more than one year (Thompson and Stetzenbach, 1980). Actual field use has also shown that some isomers are more stable than others (Bowman, 1984) and that some are stable for more than one year under saturated (Jones et al, 1992) and unsaturated (McCray et al, 1983) conditions. However, prolonged use of numerous isomers in an area may enhance degradation (Barackman, 1986), presumably by bacteria.

MICROBIAL STUDIES OF FLUOROBENZOIC ACIDS

All the information related to the microbial degradation of fluorinated benzoic acid is for the mono- and di-fluorobenzoic acid isomers.

A comparison was made of the breakdown of fluorobenzoic acid by *Pseudomonas sp. B13*, and a similar degradation of benzoic acid. Only ordinary enzymes of the benzoate pathway were detected in 2-fluorobenzoate, 3-fluorobenzoate, and 4-fluorobenzoate-grown cells. The production of these enzymes indicates that the compounds were not treated any

differently than the non-substituted acid. These compounds were recognized by the bacteria as benzoic acid (Schreiber, 1980). These studies demonstrate that the substitution of a fluorine for a hydrogen atom can create relatively innocuous analogues that proceed along normal metabolic pathways (Goldman, 1967). More recent research using a difluorobenzoic acid yielded similar results. In one study, the biological degradation of both the fluoro-, and chloro-substituted acids was followed using the release of labeled carbon-dioxide as a marker of bacterial degradation activity. In soil containing bacteria known to utilize benzoic acid as a food source, the chlorinated compounds were degraded much more slowly than the fluorinated compounds (Nimmo, 1990). This difference in rate was most likely due to the fact that the much larger chlorine atoms created some stearic hindrance to breakdown, while the smaller fluorine atoms more closely resembled the hydrogens present in the unsubstituted benzoic acid.

Research conducted on the degradation of 2-fluorobenzoic acid by *Pseudomonas species* isolated from Potomac River mud, showed that over 80% of the fluorine in the 2-fluorobenzoic acid was released as fluoride during the growth of the organism (Goldman, 1967). Similar research using 4-fluorobenzoic acid indicated that nearly 100% of the organic fluorine was released into the culture medium as fluoride (Harper, 1971), indicating that the fluorobenzoate was utilized by the bacteria the same as benzoic acid.

Similar studies have also been done using *Pseudomonas putida* bacteria to monitor the degradation of difluoro compounds. Monofluorobenzoates release fluoride when they are degraded by *P. putida*, and although the reactions involved are considerably more complex for difluorobenzoates, about 85% of the fluorine was mineralized. The degradation potential of *P. putida* was evaluated for six different isomers of difluorobenzoate, and most of the fluorine was eliminated from both positions as F^-, leaving a catechol and a hydrodiol as major products (Cass, 1987; Milne, 1968).

LITERATURE REVIEW OF TRACER TOXICITY

No detailed information on the toxicity of the fluorinated benzoic acids was found. Most of the references to toxicology of these compounds were to the mono-fluorinated benzoic acids, which are not being considered as tracers, and some difluorinated benzoates which are being considered. Many references exist for the parent compound, benzoic acid, since it is used extensively as a preservative and antifungal compound. This information, as well as some studies that show similarities in toxicity between fluorinated and non-fluorinated benzoates, are presented as possible evidence of the relatively low toxicity of the fluorinated benzoates.

In the absence of specific toxicology information about fluorinated benzoic acids, some health effects information will be presented for chlorinated benzoic acids even though they are much more toxic compounds. This will permit us to examine a range of potential toxic effects and the dose-response relationships for worst case scenarios. If there is a low risk for the exposure conditions expected from the tracer experiments for the more toxic compounds, then we will have confidence that there will be a low risk from the less toxic compounds.

BENZOIC ACID

Benzoic acid is a compound of relatively low toxicity and is used in numerous food (Casarett and Doull, 1980) and pharmaceutical (Tester-Daldrup, 1982) products. It is also found naturally in most berries in concentrations as high as 0.05% (Merck, 1989). It has an LDLO of 500 mg/kg (Sigma-Aldrich MSDS) and doses as high as 20 g have been given to human subjects in toxicological studies (Stewart 1960). A case has been reported of a 67 kg man ingesting 50 g doses without ill effects (Gosselin et al. 1984). The lethal dose to 50% of the test population (LD_{50}) in rats has been reported as 1.7 g/kg (Merck, 1989). If a "standard adult human" (SAH) weighing 70 kg (or about 155 pounds) were used, this would amount to a dosage of 119 grams.

Benzoic acid is used as a preservative and an antifungal compound. The acid is used in antifungal preparations, while the sodium or potassium salt, the benzoate ion, is used as a preservative. Benzoic acid is a broad spectrum microbial inhibitor, and is used as a food preservative in a great variety of products ranging from baked goods to jellies to soft drinks. Acid or benzoate concentrations in these products do not exceed one tenth of one per cent or 1,000 ppm (Cassarett and Doull, 1980). The daily acceptable intake is up to 5 mg/kg of body weight of either the acid (Remington, 1985) or the anion (Casarett and Doull, 1980). Benzoic acid is also used as a preservative in many cosmetics, where concentrations range from 0.1 to 0.5% (Remington, 1985). The Food and Drug Administration has classified benzoic acid as GRAS (Generally Recognized as Safe) as an antimicrobial (21CFR 181.23) and as a food additive (21CFR 184.1733) with appropriate levels given in 170.3 subparagraph O subparagraphs 2 and 12.

The effectiveness of benzoic acid as an antifungal and antimicrobial agent is due to the undissociated form. It is therefore effective at a pH of 4.0 or lower, but relatively inactive above a pH of 5.0 (Remington, 1985; Krebs, 1983). Benzoic acid is an active ingredient in topical ointments used for the treatment of fungal infections of the skin such as ringworm and athlete's foot. The concentrations of the acid in these ointments can range from 0.5% to 6.0% (Martindale, 1989).

Benzoic acid is not significantly oxidized in vertebrates. Depending on the species, it conjugated with glycine or glucuronic acid to form hippuric acid or benzoylglucuronic acid which is then excreted in the urine (Neal, 1980). This conjugation with amino acids (Caldwell, 1978) makes the new compound a stronger acid and it is more readily cleared by the kidneys (Jenner, 1980). In humans, benzoic acid taken by mouth is absorbed from the gastro-intestinal tract. It is conjugated with glycine in the liver to form hippuric acid which is rapidly excreted in the urine. Humans can also eliminate benzoic acid as benzoylglucuronic acid (Remington, 1985). In a study, with humans, 96% of a 20 g dose was eliminated as hippuric acid within 12 hours (Stewart, 1960). In a study with rabbits, 83% of the ingested benzoic acid was excreted as the glycine conjugate, 15% as the glucuronide and only 1% as the free acid (Caldwell, 1978).

The finding that benzoic acid is excreted as a conjugate is confirmation that benzoic acid can enter cells in the body, presumably by anion transport mechanisms. Thus, benzoic acid and its derivatives have the potential for further metabolism. It also confirms the finding that benzoic acid itself is a poor substrate for the anion secretion pathway in the

kidney (Ullrich et al., 1988) and must be conjugated to the hippurate before being significantly excreted from the body.

Benzoic acid is readily degraded by microorganisms into CO_2. In stability studies, where benzoate solutions are equilibrated with soil, the compound rapidly disappears from solution (Thompson and Stetzenbach, 1980), and when used as a ground water tracer, it was found to readily be degraded by microorganisms (Barackman, 1986).

METABOLIC PRODUCTION OF BENZOIC AND METHYL-BENZOIC ACIDS

Several chemical compounds are oxidized by the normal metabolic processes to benzoic or toluic acid. By examining their toxicity, additional information can be inferred for the toxicity of benzoic acid. In man, the chief metabolite of inhaled toluene is benzoic acid. Several studies have been done which list the efficiency of this oxidization process at from 62% (Piotrowski, 1967) to 72% (Sbrova, 1952) to 80% (Baselt, third ed.) of the total toluene inhaled. Of the urinary benzoic acid measured, 10 to 20% is conjugated with glucuronic acid, and the remainder is eliminated in the form of hippurate. The excretion of conjugated benzoic acid is rapid, with an excretion half-time of between 2 and 3 hours. The urinary concentration, which is dependant on initial exposure levels, has been measured as 8650 mg/L (Baselt, third ed.) with no reported ill effects. At approximately 24 hours after exposure the levels of the metabolite decline to pre-exposure values (Piotrowski, 1977).

Xylene in the human body undergoes oxidation, which leads to the formation of toluic acids. Three isomers are formed, 2-, 3-, and 4-toluic acid. Two of these compounds, 3- and 4-toluic acid are conjugated almost exclusively with glycine to form 3- and 4-methyl hippuric acids. The 2-toluic acid undergoes preferential conjugation with glucuronic acid. These processes are highly efficient, and in the case of the 3- and 4-toluic acids, oxidation is on the order of 90%, with all the toluic acid bound to glycine (Piotrowski, 1977).

Toluene and xylene have a very low order of toxicity in humans or in animals. The most common finding is central nervous system (CNS) toxicity after inhalation of high concentrations (Casarett and Doull, 1991), a biological effect shared by all volatile organic solvents. It is not possible for benzoic acid or its congeners to demonstrate this type of toxicity because of their low volatility. In vitro tests with these compounds do not show any potential genotoxic effects.

HALOGENATED BENZOIC ACIDS

Research done on the relative lethalities of halogenated compounds was conducted using benzoic acid and halogenated benzoic acids. It was shown that the toxicities of benzoic acid and its 4-fluoro substituted derivative are not significantly different. The chloro-, bromo-, and iodo-substituted acids all exhibit similar toxicities, which are greater than those of the unsubstituted or fluoro-substituted acids. This research also demonstrated that a fluorine atom located in the para (4) position on a benzoic acid molecule had no significant effect on its acute lethality in white rats, but a chlorine, bromine, or iodine atom

in the para position, almost doubled the toxicity of the original benzoic acid compound (Hager and Starkey, 1943). The substitution of a fluorine atom for a hydrogen atom on the compounds evaluated is therefore shown to be the least toxic of all possible halogen substitutions.

Benzoic acids which have a halogen atom in the ortho (2) position on the ring often exhibit herbicidal and/or fungicidal properties (Engesser, 1980). The insecticide 'Dimilin' contains diflubenzuron, which is degraded readily in various agricultural soils and hydro-soils to 2,6-difluorobenzoic acid (Nimmo, 1984). Trichlorobenzoic acid is also used to some extent as an herbicide (Martindale, 1989).

Substantial toxicity data exists for the chlorinated benzoic acids which have found use as herbicides: 2-methoxy-3,6-dichlorobenzoic acid (Dicamba) and 3-amino-2,5-dichlorobenzoic acid (Chloramben). Reference doses (RfD) for a lifetime exposure are 3E-2 mg/kg/day
(2.1 mg/SAH/day for Dicamba (IRIS, 1993) and 1.5E-2 mg/kg/day (1.05 mg/SAH/day for Chloramben (IRIS, 1993). Unfortunately, these values are used to compute a recommended lifetime dose limit for exposure to these compounds. A more realistic exposure parameter would be a 10-day or longer term Health Advisory (HA) value but neither of these two compounds have such a recommended value. The critical effect used for Dicamba was maternal and fetal toxicity in a rabbit developmental study and a No Observed Adverse Effect Level (NOAEL) of 3 mg/kg/day (210 mg/SAH/day) was used. A 90 day feeding study in the rat showed a NOAEL of 250 mg/kg/day and a critical effect of a slight decrease in body weight and food consumption. The critical effect for Chloramben was hepatocyte degeneration in an 18 month mouse feeding study and a Lowest Observed Adverse Effect Level was 15 mg/kg/day (1050 mg/SAH/day). No shorter term studies were reported.

FLUORINATED BENZOIC ACIDS

The fluorinated benzoic acids that are being considered as tracers for the C-well complex fall into two categories. The poly-fluorobenzoates (table 1) have 2,3,4 or 5 fluorine atoms that replace an equivalent number of ring hydrogens. There are sixteen possible isomers of these compounds, fourteen of which are commercially available. (Twelve of these are currently being evaluated, but this report covers all fourteen acids available commercially). The other group is the trifluoromethyl substituted benzoates or trifluorotoluic acids (table 1). These compounds substitute a CF_3 group for a ring hydrogen. There are only three isomers of trifluorotoluic acid.

The number of compounds that have fluorine substituted rings have been increasing rapidly over the last ten to fifteen years, primarily due to their use as precursors in antibiotics and pesticides. (Schreiber, 1980; O'Reilly, 1990; Domagala, 1991). The metabolic breakdown products from these compounds quite often include some of the acids shown on table 1. This has generated some interest in the biodegradation of these compounds. Very little information exists on the fate of these compounds in man. Some

work with animals has been done, but most of the research has been with microbial degradation of the fluorobenzoates.

ANIMAL STUDIES

Studies with rabbits (Caldwell, 1978) exposed to benzoic acid and 2- and 4-fluorobenzoic acids show that the fluorinated analogs are excreted as free acids at significantly higher rates than benzoic acid. This is probably due to their somewhat lower pKa values (Benson; Bowman, 1992; Walter, 1982) and their being better substrates for the anion secretion pathway in the kidney (Ullrich et al., 1988). In the study described by Caldwell (1978), 99% of the benzoic acid dose was recovered; 83% as the glycine conjugate and 15% as the glucuronide. The 2-fluorobenzoic acid (o-FBA) and 4-fluorobenzoic acid (p-FBA) were excreted with almost identical ratios: 43% as the glycine conjugate, 9% as the glucuronide, and 34% as the free acid for o-FBA and 35% for p-FBA. The fate of the other 13 or 14% is unknown. It could have lost F^-, and become benzoic acid as was described for mixed function oxidase enzymes in Pseudomonas bacteria (Goldman, 1967). In another study, rats that were dosed with 100 mg/kg (intraperitoneal) of 4-trifluoromethylbenzoic acid (p-TFMBA) produced the glucuronide as the main urinary metabolite (Ghauri, 1990).

In a comparative toxicity study by Harger and Starkey using white rats, benzoic acid and para substituted fluoro-, chloro-, bromo- and iodo-benzoic acids, it was shown that the toxicities of benzoic acid and its p-fluoro substituted derivative were not significantly different. In this study solutions of the benzoic acids were injected intravenously and the acute lethality was determined. The LD_{50} value for benzoic acid was 1.714 +/- 0.037 g/kg, while that for p-fluorobenzoic acid was 1.542+/-0.107 g/kg. The LD_{50} values for the chloro-, bromo-, and iodo-substituted acids were 0.838+/-0.033, 0.812+/-0.042 and 0.786+/-0.037 g/kg respectively. The values for the latter three halogenated acids are essentially the same, but they are twice as toxic as benzoic acid or the fluoro-substituted acid. Generally, acute toxicity determined after intravenous injection shows compounds to be more toxic than would be determined after oral administration because the blood levels reach higher values after injection. Oral LD_{50} values would be expected to require more compound to cause death than those shown above.

ESTIMATED RISK ASSOCIATED WITH FLUOROBENZOIC ACID EXPOSURE

A risk analysis is composed of three elements; **Exposure** to a **Hazard** results in a **Risk.** In this project, it has been difficult to construct exposure scenarios. **Exposure** to the pure tracer and concentrated injection solutions will be minimized by good industrial hygiene practices and by the fact that the proposed tracer chemicals are not volatile or present in water or food consumed by the workers. Any exposure will be from accidents which might result in acute exposure episodes and will occur to trained personnel who are being supervised by knowledgeable persons.

Likewise, exposure to the tracer chemicals in the groundwater is unlikely because that water will reach the surface at the pumping well. This water will also be handled by the trained personnel. We will assume that this water might be consumed and the potential risk estimated. Also, we will postulate that another well 100 - 200 feet down gradient from the pumping well might be drilled and water used from that well for drinking water purposes.

The **hazard** has been difficult to determine because health effects of these proposed tracer chemicals have not been studied. The fact that these are uncommon chemicals makes them desirable as tracers because there will be no background levels to interfere with the interpretation of the experimental results. We have attempted to bracket the toxicity of the tracer chemicals by choosing similar compounds which are expected to be less toxic and others which are expected to be more toxic.

Risk from Acute Exposure

Exposure due to accidents could result in acute effects if the chemical spills on the skin or is accidently ingested. Exposure via skin absorption cannot be estimated for these compounds but their ionic nature makes it unlikely that much will be absorbed. As mentioned earlier, the LDLo of benzoic acid is 500 mg/kg (35.0 grams per SAH), doses as high as 20 grams have been given to adults without ill effects (300 mg/kg) and the LD_{50} in rats is 1.7 g/kg (120 grams per SAH). The fluorinated benzoic acid analog was shown to have the same LD_{50} as benzoic acid itself after intravenous injection. The daily dose of benzoic acid allowed for adults is 5 mg/kg (350 mg per SAH).

Based on the evidence presented, a single dose of tracer of 5 mg/kg (350 mg per SAH) should present a minimal risk. To derive that the LDLo of 500 mg/kg was adjusted by a factor of 10 for sensitive human populations and another factor of 10 to adjust for the extrapolation of animals to humans. This is the equivalent of ingesting 70 mL of the concentrated injection solution. The chances of someone ingesting concentrated tracer solution are extremely small, as all personnel present would be trained in the proper handling and disposal precautions for these compounds, and the injection apparatus is a closed system. However, this evidence seems to indicate a very low toxicity level for these compounds, even at extremely high concentrations.

Risk from Sub-chronic Exposure

If the pumping well water was used for drinking water, the exposure would not be for an entire lifetime. Exposure to groundwater would occur only as long as the time it would take for the tracer plume to pass the well. Groundwater moves at the rate of 0.14 to 3.4 m/day (Claassen and Cordes 1975) and it is expected that persons would be exposed for less than 6 months if they drank from a well which had been used for a tracer test. The average tracer concentration would be 1 ppm based on a conservative dilution factor of 5,000.

If another well was drilled in the pathway of the tracer gradient (approximately 100 - 200 feet from the pumping well), then another dilution factor of 1,000 should be applied. In this case, groundwater from the well would contain 1 ppb tracer concentration. The

maximum daily dose for a lifetime exposure to benzoic acid is 5 mg/kg/day (350 mg/SAH/day); this equates to a drinking water level of 175 ppm for a water consumption of 2 liters per day. For the chlorinated benzoic acid herbicides, the maximum daily dose for a lifetime exposure is
2.1 mg/SAH/day for Dicamba and 1.05 mg/SAH/day for Chloramben. These equate to drinking water levels of 1 ppm for Dicamba and 0.5 ppm for Chloramben.

The concentration of fluorinated benzoic acids in drinking water that would result in minimal risk lies between 0.5 - 175 ppm based on the probable toxicity of the compounds. This level has been computed for a lifetime (70 years) exposure to these compounds. To adjust this level for a six month exposure, the upper concentration would be increased by 140 times, resulting in a possible highest range concentration of 24500 ppm. It is concluded that the ingestion of water from the pumping well (expected concentration $\approx$1 ppm) or from another well 100 - 200 feet away (expected concentration $\approx$1 ppb) would not result in a significant risk for any adverse health effects.

CONCLUSIONS

Several other conclusions can be drawn from the body of literature cited above:

(I) Benzoic and methyl-benzoic acids are widely used in many pharmaceutical preparations and as preservatives in many food products and cosmetics, often at concentrations which exceed those predicted to occur during tracer testing by several orders of magnitude. With such wide spread use and application, especially by the medical industry, any problems associated with exposure to these compounds should be well documented. To date, no serious health problems have been associated with exposure to benzoic and methyl-benzoic acids.

(II) The fluorinated benzoic and methyl-benzoic acids appear to be fairly non-toxic compounds at low to moderate concentrations. Studies have shown that the mono- and di-fluorinated derivatives of benzoic acid are not significantly more toxic to living systems than the original parent compounds.

(III) Benzoic and methyl-benzoic acids are natural metabolites of toluene and xylene exposure, and even at extremely high concentrations, they have caused no known health problems. Mammalian systems have a well-established pathway using glycine and glucuronic acid conjugation to form hippuric and benzoylglucuronic acids, which are rapidly excreted in the urine. No known health problems have been associated with high concentrations of these acid conjugates.

(IV) Studies of the degradation of fluorinated benzoic acids in soil have shown that defluorination occurs, and nearly all of the organic fluorine is eliminated as fluoride, leaving degradation products which are then broken down further to CO_2. 2,6-Difluorobenzoic acid

has been proven to be stable in a number of tracing experiments, yet it can also be degraded by soil bacteria. This indicates that even highly stable tracers will eventually be degraded.

The above mentioned conclusions, coupled with the fact that potential exposure to these compounds from tracer tests would occur at ultra trace levels, lead to the conclusion that the fluorinated benzoic and methyl-benzoic acids would be relatively safe for use as ground water tracers.

RECOMMENDATIONS

These conclusions and recommendations were made using a "worst case scenario" exposure assessment of a tracing test conducted in a *densely* populated area. The application of this point of view to the actual conditions existing in the proposed tracer testing area should be duly noted when any review of this evaluation is performed.

Before any of these compounds are used in populated areas where sub-chronic exposure is likely, further toxicity studies should be done. These studies should be of 90 day duration as a minimum or of 6 months duration. They should involve two animal species with one species being the rat so the results can be compared with similar compounds. They should be done at three dose levels with one level being low enough to insure that a no effect level would be found.

The existing toxicity data for the proposed compounds are so sketchy that there is a low level of confidence in the levels proposed if repeated human exposure is likely.

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TABLE 1

LIST OF POTENTIAL TRACERS COMPOUNDS for the C-WELL TESTS

FLUORINATED BENZOIC ACIDS

2,3-Difluorobenzoic acid
2,4-Difluorobenzoic acid
2,5-Difluorobenzoic acid
2,6-Difluorobenzoic acid
3,4-Difluorobenzoic acid
3,5-Difluorobenzoic acid

2,3,4-Trifluorobenzoic acid
2,4,5-Trifluorobenzoic acid
3,4,5-Trifluorobenzoic acid

2,3,4,5-Tetrafluorobenzoic acid
2,3,5,6-Tetrafluorobenzoic acid

Pentafluorobenzoic acid

ortho-Trifluoromethylbenzoic acid (2-trifluoromethyltoluic acid)
meta-Trifluoromethylbenzoic acid (3-trifluoromethyltoluic acid)
para-Trifluoromethylbenzoic acid (4-trifluoromethyltoluic acid)

ORGANIC TRACER TOXICITY REPORT
PERFLUORINATED ALIPHATIC ACIDS

DOE Cooperative Agreement

No. DE-FC 08-90NV10972

Tonya Dombrowski
Klaus J. Stetzenbach PhD.

Harry Reid Center For Environmental Studies
University of Nevada - Las Vegas

Eighteen fluorinated organic acids (table 1) are presently being studied as possible tracers for the Yucca Mountain Site Characterization Project. These have been divided into two separate categories: fluorinated aromatic compounds (poly-fluorinated benzoic acids), and fluorinated aliphatic compounds. Fluorinated organic compounds were selected as potential tracers because of their long term environmental stability and low reactivity. Low reactivity and low toxicity are characteristics of numerous carbon-fluorine compounds. As a general rule, it can be stated that the greater the number of halogen atoms on a molecule, especially fluorine, the greater its stability. Perfluorinated acids such as pentafluoro-benzoic acid (PFBA) and trifluoroacetic acid (TFAA) are therefore extremely resistant to chemical attack.

A complete report detailing the available literature references of the stability and toxicity of the fluorinated aromatic acids, as well as an exposure risk assessment for all tracing compounds during, and immediately prior to the actual tracing tests has been submitted separately. Please refer to this report for further information on these topics.

ALIPHATIC ACIDS

In addition to the fluorinated aromatic acids mentioned previously, several fluorinated aliphatic acids are being evaluated for use as ground water tracers. These compounds are: trifluoroacetic acid (TFAA), pentafluoropropionic acid (PFPA) and heptafluorobutyric acid (HFBA).

The parent compounds of these acids occur naturally in, or are present as an additive in many food products. Aliphatic acids such as acetic acid (vinegar) and propionic acid are present in many areas of the food industry. The calcium and sodium salts of propionic acid are used effectively against filamentous fungi in breads, cakes and some cheeses. They are also used to inhibit rope formation in bread dough and milk products. Propionates are formed naturally during the production of Swiss cheese, and act as a natural preservative.

Acetic acid is commonly used as an inhibitor of fungal and bacterial growth to preserve meat products, mayonnaise, and catsup. It is also a main ingredient in many salad dressings, tomato sauces, salsas, and relishes.

Butyric acid occurs naturally in butter as an ester at concentrations of up to 4 or 5%. Magnesium butyrate is used in the manufacture of esters which are used in artificial flavorings (Merck, 1989).

FLUORINATED ALIPHATIC ACIDS

For the three perfluorinated aliphatic acids being considered, toxicity data is available for TFAA only. TFAA is the perfluorinated derivative of acetic acid. It is also a metabolite of anesthetics such as halothane and fluoroxene in both animal and human systems.

ANIMAL STUDIES WITH TFAA

Studies have been done in which TFAA was administered to animals directly, either with an injection into the blood stream or muscle tissue, or in their diet. TFAA at 2.1 mmol concentrations (neutralized pH) was diluted to 5% in water and administered intravenously through the tail vein to 10 rats. Serum concentrations of TFAA after 24 hours were found to be 1.71 mmol. The intestinal mucosa was analyzed after 24 hours, and TFAA was found to be present at 1.02 micromol/gram. The intestinal mucosa was selected because it is an area where rapid proliferation and cell growth occurs, and therefore would show the effects of toxicity sooner than less rapidly growing tissues. No toxic effects were observed in any of the rats studied when compared to control groups (Fraser, 1988). TFAA (neutralized to pH 7.0) at concentrations of up to 25mg/kg of body weight, was given to male rats in their water. These rats were followed over a course of 3 days, for morphological changes in testicular tissues (an area of rapid cell proliferation). No biologically significant changes were seen in the tissue samples at the dosage concentrations studied, compared to control groups (Lloyd, 1988).

Studies done on mice and guinea pigs show the LD_{50} for TFAA to be greater than 2000 mg/kg (intraperitoneal injection) and 1200 mg/kg intravenous administration (table 2). This same research reports that the TFAA does not appear to block the Krebs cycle like the more toxic monofluoroacetic acid (Airaksinen, 1968). Research to date seems to confirm that TFAA is less harmful when taken orally than intravenously because, at physiological pH, it is ionized and therefore unlikely to penetrate the cellular membranes (Cohen, 1978; Cohen, 1975). Mice were not killed by intraperitoneal doses of 5,000 mg/kg of sodium fluoroacetate (Blake, et al., 1969) and no effects were seen after 100 mg/kg of trifluoroethanol ip daily for 18 days except for a failure to gain weight. Histopathological examination did not show any differences between test and control groups in this 18 day study. Trifluoroethanol is more acutely toxic than TFAA (LD_{50} = 350 mg/kg by oral and intraperitoneal routes) and is partially converted to TFAA (about 15%) using the same enzymes which metabolize ethanol (Blake et al., 1969).

CELLULAR EFFECTS OF TFAA

Research has also been done on the effect of TFAA on cellular systems. Studies were done using C6-murine glioma cells (in vitro) where the TFAA concentrations in the cell media exceeded that of the rodent research listed above. The results indicated that the TFAA had a relatively mild impact on the C6 cells, and only minimally affected the cell's

energy metabolism (Ma, 1990). Similar studies performed with the anti-influenza virus showed that the virus activity was not affected by TFAA (Harada, 1991).

METABOLIC TFAA IN ANIMALS

A large body of work has also been done on TFAA as a metabolite in the body. Such a catabolic pathway is known to occur with exposure to certain anesthetics, the ingestion of trifluoroethanol, and the inhalation of certain chlorofluorocarbons.

The anesthetic compounds studied for eventual breakdown to TFAA include halothane, fluoroxene, and desflurane, and isoflurane. Until recently, Halothane was the most widely used anesthetic in the world with the possible exception of nitrous oxide (Greene, 1968). It has been replaced by isoflurane, desflurane, and fluoroxene. All of these anesthetics are commonly referred to as halothane anesthetics, or halothanes. TFAA is the principle oxidative metabolite of halothane anesthesia, and is very stable. As the metabolism of halothane occurs mainly in the liver, concentrations of TFAA in the blood, renal, and hepatic systems reach their peak from 5 to 16 hours after exposure, and then gradually taper off (Ma, 1990).

Recent research on beagle dogs exposed to halothane anesthetics showed that over 80% of all fluoride inhaled was excreted in the urine as organic fluoride, of which TFAA was a major constituent. As a major metabolite, TFAA is distributed from the liver into either the blood or the bile. TFAA in the blood serum is filtered by the kidneys, and subsequently concentrated in the urine. TFAA which enters the bile can be secreted into the duodenum and be reabsorbed. The TFAA which was in the bile and subsequently reabsorbed would also enter the liver, and, since it is not metabolized further, would go into the kidneys, and then be excreted in the urine. The major percentage of the TFAA produced through the metabolism of halothane anesthetics is therefore eventually excreted in the urine (Sakai, 1991).

Similar research done on guinea pigs (Nakao, 1991), rats (vanDyke, 1965), and rabbits (Steir, 1964; Steir, 1968) also show the major metabolite of halothane anesthetics to be TFAA. Analyses done on mice and dogs (Blake, 1967) exposed to fluoroxene anesthetics show the major metabolite to be TFAA also.

TFAA has also been studied as a metabolite of 2,2,2-Trifluoroethanol (TFE) in rats. TFE is the initial metabolite of the anesthetic agent fluoroxene, which is then further broken down into TFAA. TFE and trifluoroacetaldehyde (TFAld) were administered to rats intravenously, and the blood serum, and intestinal mucosa were monitored for TFAA. TFAA was detected at approximately 1 hour after initial exposure, and levels continued to increase over the next 16 hours, and remained at their peak concentration for another 8 hours. It was noted that within the metabolic pathway from fluoroxene to TFAA, there is a toxic compound formed. However, specific research on this problem has demonstrated that the toxic moiety is a metabolic intermediate and not TFAA. Thus, the toxicity of TFE is mediated by its ultimate metabolism to TFAA (Fraser, 1988, 1987), which is then excreted to a large degree in the urine (Blake, 1969). Administration of TFAA directly did not produce any evidence of toxicity in the bone marrow or small intestine, even though it was

shown to be distributed to both the blood serum and small intestine mucosa in similar concentrations to those occurring from administration of TFE and TFAld. This result precludes TFAA or any TFAA conjugate from being the toxic metabolite (Fraser, 1988).

Several of the studies cited above (Fraser, 1988; Lloyd, 1988; Airaksinen, 1968; and Blake, 1987) explored the effects of TFAA as a directly introduced compound, and as a metabolite of TFE. These studies showed that TFAA produced no toxic effects when given in a single dose, and no histological or morphological changes in the analyzed tissues compared with control groups at the concentrations studied (Fraser, 1988; Lloyd, 1988; Airaksinen, 1968). However, there have been no long term toxicity studies performed and the hazard of TFAA cannot be assessed from this data.

METABOLIC TFAA IN HUMANS

Studies of exposure to halothane anesthetics in humans has shown TFAA to be the major metabolic product (Rehder, 1967; Blake, 1972; Cohen, 1975; Witte, 1977). The fact that operating room personnel are continuously exposed to low level concentrations of halothane anesthetics, coupled with the much higher doses received by patients undergoing anesthesia, suggest that the halothane anesthetics are relatively safe at the dosages applied. However, in a small number of cases (1:10,000) a condition called "halothane hepatitis" occurs and 50% of those people die from the disease (Goodman and Gilman, 1990). This response may be related to an immune reaction after a protein adduct has formed with some component of the halothane. Possibilities for this component could be the trifluoroacetaldehyde or the trifluoroacetic acid metabolites formed from halothane. In several preliminary studies, most notably Fraser, 1988; TFAA was shown to have no toxic effects in this metabolic pathway. An oxidative intermediate on the pathway between TFAA and trifluoroacetaldehyde is suspected as the toxic moiety; because this intermediate precedes TFAA in the metabolic process, TFAA is not expected to have a toxic capacity in this hepatic condition according to this research.

Initial research using the body fluids of people exposed to halothane anesthesia show a sharp increase in blood and urine TFAA concentrations over a period of about 8 hours, then a gradual increase over 48 hours, where maximum concentration levels are attained at roughly 48 hours after exposure, and then decline slowly over 11 to 14 days. Maximum concentration values ranged from 130 to 300 ug/ml of TFAA in urine, and 75 to 150 ug/ml of TFAA in blood serum samples (Witte, 1977). Earlier research shows this same pattern of excretion, with roughly the same concentrations and time frame (Rehder, 1967).

The biliary excretion of TFAA in infants was studied using two babies, one 5 months old, and one two months old. Anesthesia was administered prior to performing a surgical procedure; bile, urine, and faeces samples were collected continuously for five days following surgery and TFAA concentrations were measured. The concentrations monitored in these samples showed that all of the TFAA was excreted in the bile and urine. No TFAA was measured in the faecal samples, which shows an enterohepatic circulation for this metabolite (Wark, 1991).

Desflurane and isoflurane anesthetics also produce TFAA as the primary metabolite. The major difference between these anesthetics and Halothane is the extent to which they are metabolized. Halothane is metabolized to between 20 and 30%, while desflurane and isofluorane are metabolized to between 1 and 2%, with the bulk of the administered anesthetic being exhaled unmetabolized.

Thirteen volunteers, used as a healthy metabolism control group, and twenty six patients, that did not necessarily have healthy metabolism, were exposed to desflurane anesthesia. The blood serum showed TFAA concentrations around 40 mg/L, and a urinary excretion rate of about 20 ug per hour TFAA, 24 hours after exposure. The levels of TFAA in the blood serum and urine, after similar exposure to isoflurane are approximately 10 times higher than the desflurane results above (Sutton, 1991). It is apparent from the research cited that TFAA is a metabolic byproduct of these anesthetics that is excreted normally by the body without any further metabolism. Metabolism of these anesthetics leads to significant concentrations of TFAA in the body but little is known about the toxic effects of the anesthetics in humans.

The structural similarity of certain chlorofluorocarbons to halothane anesthetics lead to a study of the metabolic products of HCFC-124, a refrigerant substitute. Results indicate that in human subjects, the major metabolites are TFAA and F^- (Olsen, 1991). This same pathway is thought to extend to other, structurally similar refrigerant compounds currently in use.

CHLORINATED ACETIC ACIDS

The chlorinated analog of TFAA, trichloroacetic acid, has been studied because it is a metabolite of two carcinogenic solvents, trichloroethylene and tetrachloroethylene. Although it might be expected to be more extensively metabolized than the fluoroacetic acids, it provides a reference for comparison.

Trichloroacetate was administered to B6C3F1 mice at concentrations of 1 or 2 g/L for up to 52 weeks (Bull et al., 1990). Trichloroacetate induced hepatoproliferative lesions in male mice, including hepatocellular nodules, adenomas and hepatocellular carcinomas within 12 months. The induction of these lesions was linear with respect to dose. Trichloroacetate did not cause cellular necrosis but rather appeared to increase lipid peroxidation. This suggests that the production of radicals may cause its effects.

ESTIMATED RISK ASSOCIATED WITH TRIFLUOROACETIC ACID EXPOSURE

Risk from Acute Exposure

Exposure due to accidents could result in acute effects if the chemical spills on the skin or is accidently ingested. Exposure via skin absorption cannot be estimated for these compounds but their ionic nature makes it unlikely that much will be absorbed. Oral doses

of trifluoroacetic acid have an LD_{50} in excess of 5,000 mg/kg in mice and have LD_{50}'s in the range of 1,000 - 2,000 mg/kg after systemic administration.

Based on the evidence presented, a single dose of tracer of 5 mg/kg (350 mg/Standard Adult Human (SAH)) should present a minimal risk. To derive that the LD_{50} of 5,000 mg/kg was adjusted by a factor of 10 for sensitive human populations, a factor of 10 to adjust for the extrapolation of animals to humans and another factor of 10 to adjust for using an LD_{50} value instead of an LDL_0. This is the equivalent of ingesting 70 mL of the concentrated injection solution. The chances of someone ingesting concentrated tracer solution are extremely small, as all personnel present would be trained in the proper handling and disposal precautions for these compounds, and the injection apparatus is a closed system. However, this evidence seems to indicate a very low toxicity level for these compounds, even at extremely high concentrations.

Risk from Sub-chronic Exposure

If the pumping well water was used for drinking water, the exposure would not be for an entire lifetime. Exposure to groundwater would occur only as long as the time it would take for the tracer plume to pass the well. Groundwater moves at the rate of 0.14 to 3.4 m/day (Claassen and Cordes 1975) and it is expected that persons would be exposed for less than 6 months if they drank from a well which had been used for a tracer test. The average tracer concentration would be 1 ppm based on a conservative dilution factor of 5,000. If another well was drilled in the pathway of the tracer gradient (approximately 100 - 200 feet from the pumping well), then another dilution factor of 1,000 should be applied. In this case, groundwater from the well would contain 1 ppb tracer concentration. The closest value to a repeated dose toxicity study was the 100 mg/kg/day (700 mg/SAH/day) of trifluoroethanol that was administered to mice for 18 days. That was partially converted (20%) to TFAA; this would be equivalent to 20 mg/kg/day (140 mg/SAH/day) of TFAA. The daily dose for 6 months would have to be adjusted by a factor of 10,000 to provide any confidence in the number. This would result in a 0.070 ppm drinking water level.

The experience in humans with halothane was extensive and involved people who were not healthy but anesthesia is not given on a repeated dose basis. Operating room personnel would be exposed on a daily basis but the dose would be low. The possibility of an immune response is of concern with the halothane data.

The use of the trichloroacetic acid data involves a carcinogenic endpoint. If other compounds were available for use, as is the case with tracer molecules, they would be chosen instead of one which has the potential to be carcinogenic.

CONCLUSIONS

Several conclusions can be drawn from the body of research cited above:

(I) TFAA appears to be a fairly non-toxic compound at low to moderate concentrations, with an LD_{50} several orders of magnitude above the concentrations expected at the downstream end of the tracing tests.

(II) Ionized compounds do not penetrate cell membranes easily, and at groundwater pH values, TFAA will be highly ionized. This will make the compound more water soluble, and therefore more easily excreted by mammalian systems. If TFAA in the water was ingested by people or animals down gradient of the test injection area, it would most likely be excreted in the urine, rather than being metabolized.

(III) Significant concentrations of TFAA are present in patients who have undergone halothane anesthesia, or have been exposed to a number of fluorinated hydrocarbon compounds. There was a low incidence of toxicity (1:10,000) for halothane hepatitis but there was a 50% likelihood of death in those who developed the illness. On that basis, halothane is no longer generally used as an anesthetic agent.

(IV) Parallels can be drawn from the TFAA to the PFPA and HFBA because of the similar structural properties and ionic character of these compounds.

(V) Trifluoroacetic acid and its congeners may not be the compounds of choice for organic tracer use in cases where sub-chronic or chronic exposure may occur unless further toxicity work is done. Its use in situations which may result in single dose exposures is acceptable.

RECOMMENDATIONS

These conclusions and recommendations were made using a "worst case scenario" exposure assessment of a tracing test conducted in a *densely* populated area. The application of this point of view to the actual conditions existing in the proposed tracer testing area should be duly noted when any review of this evaluation is performed.

Before any of these compounds are used in populated areas where sub-chronic exposure is likely, further toxicity studies should be done. These studies should be of 90 day duration as a minimum or of 6 months duration. They should involve two animal species with one species being the rat so the results can be compared with similar compounds. They should be done at three dose levels with one level being low enough to insure that a no effect level would be found.

The existing toxicity data for the proposed compounds are so sketchy that there is a low level of confidence in the levels proposed if repeated human exposure is likely.

TOXICITY REPORT
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TABLE 1

LIST OF POTENTIAL TRACERS COMPOUNDS for the C-WELL TESTS

FLUORINATED BENZOIC ACIDS

2,3-Difluorobenzoic acid
2,4-Difluorobenzoic acid
2,5-Difluorobenzoic acid
2,6-Difluorobenzoic acid
3,4-Difluorobenzoic acid
3,5-Difluorobenzoic acid

2,3,4-Trifluorobenzoic acid
2,4,5-Trifluorobenzoic acid
3,4,5-Trifluorobenzoic acid

2,3,4,5-Tetrafluorobenzoic acid
2,3,5,6-Tetrafluorobenzoic acid

Pentafluorobenzoic acid

ortho-Trifluoromethylbenzoic acid (2-trifluoromethyltoluic acid)
meta-Trifluoromethylbenzoic acid (3-trifluoromethyltoluic acid)
para-Trifluoromethylbenzoic acid (4-trifluoromethyltoluic acid)

PERFLUORINATED ALIPHATIC ACIDS

Trifluoroacetic acid
Pentafluoropropionic acid
Heptafluorobutyric acid

APPENDIX C

C-Well Iodide method variability analysis.

This analysis is performed on duplicate data. We divided data into following three catagory:

Lab duplicates
Field duplicates
Lab & field duplicates

On the basis of concentration, each of the above category is divided into following 3 group

Group1 0-33 ppb
Group1 34-66 ppb
Group1 67-100 ppb

Analysis results

Lab duplicates:

	# of samples	# occurrences		# of samples	# occurrences		# of samples	# occurrences
Group 1	12	30	**Group 2**	18	38	**Group 3**	82	168
	variance=	4.953876		variance=	0.599266		variance=	2.839628
	SD =	2.22573		SD =	0.774123		SD =	1.68512

Conclusion: Data suggest that there is no significance difference in the duplicate values.

Field duplicates:

	# of samples	# occurrences		# of samples	# occurrences		# of samples	# occurrences
Group 1	none	none	**Group 2**	40	86	**Group 3**	8	17
				variance=	1.176028		variance=	5.845658
				SD =	1.084448		SD =	2.417779

Conclusion: Data suggest that there is no significance difference in the duplicate values.

Lab-field duplicates:

Group1	sig. prob=	0.488679	> .05
Group2	sig. prob=	0.31547	> .05
Group3	sig. prob=	0.743794	> .05

Conclusion: Data suggest that there is no significance difference in the duplicate values.

C-well Iodide injectate concentrations

1:20 dil of dil #1		
	mean(ppm)	9932
	sd =	282
1:10 dil of dil #2		
	mean(ppm)	10164
	sd =	158
1:5 dil of dil #3		
	mean(ppm)	10383
	sd =	162
Injectate concentration		
	mean(ppm)	10160
	sd =	272

Yucca Mountain tracer test; 1

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/18/96	10:04:37 AM	893		0.00	02/18	analyzed in field
2/18/96	10:14:49 AM	894		2.65	02/18	analyzed in field
2/18/96	10:25:02 AM	895		0.00	02/18	analyzed in field
2/18/96	10:35:23 AM	896		2.28	02/18	analyzed in field
2/18/96	10:45:36 AM	897		0.00	02/18	analyzed in field
2/18/96	10:55:49 AM	898		2.53	02/18	analyzed in field
2/18/96	11:06:02 AM	899		4.40	02/18	analyzed in field
2/18/96	11:16:15 AM	900		2.55	02/18	analyzed in field
2/18/96	11:26:29 AM	901		3.05	02/18	analyzed in field
2/18/96	11:36:41 AM	902	L/F-D*	3.32		
2/18/96	11:46:54 AM	903		3.33	02/18	analyzed in field
2/18/96	11:57:07 AM	904	L/F-D*	2.79		
2/18/96	12:07:28 PM	905		2.93	02/18	analyzed in field
2/18/96	12:17:40 PM	906	L/F-D*	2.74		
2/18/96	12:27:53 PM	907		3.04	02/18	analyzed in field
2/18/96	12:38:06 PM	908	L/F-D*	3.37		
2/18/96	12:48:18 PM	909		0.00	02/18	analyzed in field
2/18/96	12:58:31 PM	910	L/F-D*	0.00		
2/18/96	1:08:44 PM	911		3.63	02/18	analyzed in field
2/18/96	1:18:56 PM	912	L/F-D	4.13		
2/18/96	1:29:09 PM	913		2.31	02/18	analyzed in field
2/18/96	1:39:30 PM	914	L/F-D*	3.03		
2/18/96	1:50:09 PM	915		3.58	02/18	analyzed in field
2/18/96	2:00:28 PM	916	L/F-D*	4.15		
2/18/96	2:10:42 PM	917		3.39	02/18	analyzed in field
2/18/96	2:20:55 PM	918	L/F-D	4.05		
2/18/96	2:31:09 PM	919		0.00	02/18	analyzed in field
2/18/96	2:41:22 PM	920	L/F-D*	4.69		
2/18/96	2:51:35 PM	921	L/F-D*	2.97		
2/18/96	3:01:48 PM	922		6.12	03/20	analyzed in lab
2/18/96	3:12:10 PM	923				
2/18/96	3:22:22 PM	924		6.06	03/20	analyzed in lab
2/18/96	3:32:35 PM	925				
2/18/96	3:42:48 PM	926		4.99	03/20	analyzed in lab
2/18/96	3:53:00 PM	927				
2/18/96	4:03:13 PM	928		5.98	03/20	analyzed in lab
2/18/96	4:13:26 PM	929				
2/18/96	4:23:39 PM	930				
2/18/96	4:33:52 PM	931				
2/18/96	4:44:13 PM	932				
2/18/96	4:54:26 PM	933		6.46	03/20	analyzed in lab
2/18/96	5:04:44 PM	934				
2/18/96	5:14:57 PM	935				
2/18/96	5:25:10 PM	936				
2/18/96	5:35:23 PM	937				
2/18/96	5:45:36 PM	938				
2/18/96	5:55:49 PM	939		5.62	03/20	analyzed in lab
2/18/96	6:06:01 PM	940				
2/18/96	6:16:22 PM	941				
2/18/96	6:26:34 PM	942		6.39	03/20	analyzed in lab
2/18/96	6:36:47 PM	943				
2/18/96	6:47:00 PM	944				
2/18/96	6:57:14 PM	945		6.79	03/20	analyzed in lab
2/18/96	7:07:29 PM	946				
2/18/96	7:17:41 PM	947				
2/18/96	7:27:54 PM	948		7.18	03/20	analyzed in lab
2/18/96	7:38:07 PM	949				
2/18/96	7:48:28 PM	950		4.33	02/19	analyzed in field
2/18/96	7:58:41 PM	951		7.57	03/20	analyzed in lab
2/18/96	8:08:55 PM	952				
2/18/96	8:19:09 PM	953				
2/18/96	8:29:21 PM	954		7.39	03/20	analyzed in lab
2/18/96	8:39:33 PM	955				
2/18/96	8:49:47 PM	956				
2/18/96	9:00:01 PM	957		7.85	03/20	analyzed in lab
2/18/96	9:10:13 PM	958				
2/18/96	9:20:34 PM	959				
2/18/96	9:31:17 PM	960				
2/18/96	9:41:33 PM	961		5.71	02/19	analyzed in field
2/18/96	9:51:46 PM	962				

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 2

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/18/96	10:01:59 PM	963		7.55	03/20	analyzed in lab
2/18/96	10:12:11 PM	964				
2/18/96	10:22:23 PM	965				
2/18/96	10:32:37 PM	966				
2/18/96	10:42:50 PM	967				
2/18/96	10:53:14 PM	968				
2/18/96	11:03:27 PM	969		7.95	03/20	analyzed in lab
2/18/96	11:13:40 PM	970				
2/18/96	11:23:53 PM	971				
2/18/96	11:34:06 PM	972				
2/18/96	11:44:19 PM	973				
2/18/96	11:54:32 PM	974				
2/19/96	12:04:45 AM	975		7.52	03/20	analyzed in lab
2/19/96	12:14:58 AM	976				
2/19/96	12:25:19 AM	977		6.27	02/19	analyzed in field
2/19/96	12:35:32 AM	978				
2/19/96	12:45:45 AM	979				
2/19/96	12:55:58 AM	980				
2/19/96	1:06:10 AM	981		7.29	03/20	analyzed in lab
2/19/96	1:16:23 AM	982				
2/19/96	1:26:36 AM	983				
2/19/96	1:36:49 AM	984				
2/19/96	1:47:02 AM	985				
2/19/96	1:57:23 AM	986				
2/19/96	2:07:36 AM	987		7.90	03/20	analyzed in lab
2/19/96	2:17:49 AM	988				
2/19/96	2:28:02 AM	989				
2/19/96	2:38:15 AM	990		8.59	03/20	analyzed in lab
2/19/96	2:48:29 AM	991				
2/19/96	2:58:42 AM	992				
2/19/96	3:08:55 AM	993		8.52	03/20	analyzed in lab
2/19/96	3:19:09 AM	994				
2/19/96	3:29:29 AM	995				
2/19/96	3:40:08 AM	996		8.63	03/20	analyzed in lab
2/19/96	3:50:29 AM	997				
2/19/96	4:00:41 AM	998				
2/19/96	4:10:54 AM	999		8.10	03/20	analyzed in lab
2/19/96	4:21:07 AM	1000				
2/19/96	4:31:20 AM	1001				
2/19/96	4:41:33 AM	1002		9.11	03/20	analyzed in lab
2/19/96	4:51:49 AM	1003				
2/19/96	5:02:11 AM	1004				
2/19/96	5:12:24 AM	1005	L/D	9.03		
2/19/96	5:22:38 AM	1006				
2/19/96	5:32:51 AM	1007				
2/19/96	5:43:04 AM	1008		8.77	03/20	analyzed in lab
2/19/96	5:53:17 AM	1009				
2/19/96	6:03:31 AM	1010				
2/19/96	6:13:46 AM	1011		9.42	03/20	analyzed in lab
2/19/96	6:23:59 AM	1012				
2/19/96	6:34:22 AM	1013				
2/19/96	6:44:35 AM	1014		8.79	03/20	analyzed in lab
2/19/96	6:54:48 AM	1015				
2/19/96	7:05:01 AM	1016		8.85	03/20	analyzed in lab
2/19/96	7:15:14 AM	1017				
2/19/96	7:25:27 AM	1018				
2/19/96	7:35:40 AM	1019				
2/19/96	7:45:53 AM	1020				
2/19/96	7:56:06 AM	1021				
2/19/96	8:06:27 AM	1022		9.60	03/20	analyzed in lab
2/19/96	8:16:39 AM	1023		6.44	02/19	analyzed in field
2/19/96	8:26:52 AM	1024		8.12	02/19	analyzed in field
2/19/96	8:37:04 AM	1025		8.01	02/19	analyzed in field
2/19/96	8:47:16 AM	1026		6.46	02/19	analyzed in field
2/19/96	8:57:29 AM	1027		6.95	02/19	analyzed in field
2/19/96	9:07:42 AM	1028		7.07	02/19	analyzed in field
2/19/96	9:17:55 AM	1029		8.52	02/19	analyzed in field
2/19/96	9:28:08 AM	1030		7.34	02/19	analyzed in field
2/19/96	9:38:29 AM	1031		9.16	02/19	analyzed in field
2/19/96	9:48:42 AM	1032	L/F-D*	6.84		

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 3

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/19/96	9:58:55 AM	1033		7.84	02/19	analyzed in field
2/19/96	10:09:09 AM	1034		7.54	02/19	analyzed in field
2/19/96	10:19:22 AM	1035		8.47	02/19	analyzed in field
2/19/96	10:29:34 AM	1036		9.46	02/19	analyzed in field
2/19/96	10:39:47 AM	1037		8.36	02/19	analyzed in field
2/19/96	10:50:00 AM	1038		8.46	02/19	analyzed in field
2/19/96	11:00:13 AM	1039		8.25	02/19	analyzed in field
2/19/96	11:10:45 AM	1040		7.93	02/19	analyzed in field
2/19/96	11:21:29 AM	1041		8.14	02/19	analyzed in field
2/19/96	11:31:43 AM	1042		8.04	02/19	analyzed in field
2/19/96	11:41:58 AM	1043		8.56	02/19	analyzed in field
2/19/96	11:52:12 AM	1044		8.12	02/19	analyzed in field
2/19/96	12:02:25 PM	1045		8.16	02/19	analyzed in field
2/19/96	12:12:38 PM	1046		8.41	02/19	analyzed in field
2/19/96	12:22:51 PM	1047		8.75	02/19	analyzed in field
2/19/96	12:33:03 PM	1048	L/F-D	8.79		
2/19/96	12:43:24 PM	1049		8.64	02/19	analyzed in field
2/19/96	12:53:38 PM	1050	L/F-D	9.33		
2/19/96	1:03:50 PM	1051		9.02	02/19	analyzed in field
2/19/96	1:14:03 PM	1052	L/F-D	9.8		
2/19/96	1:24:17 PM	1053				
2/19/96	1:34:30 PM	1054		10.85	03/20	analyzed in lab
2/19/96	1:44:43 PM	1055				
2/19/96	1:54:56 PM	1056	L/D	10.93		
2/19/96	2:05:09 PM	1057				
2/19/96	2:15:29 PM	1058		11.4	03/19	analyzed in lab
2/19/96	2:25:42 PM	1059				
2/19/96	2:35:55 PM	1060		11.05	03/20	analyzed in lab
2/19/96	2:46:08 PM	1061		9.06	02/19	analyzed in field
2/19/96	2:56:21 PM	1062		12.07	03/20	analyzed in lab
2/19/96	3:06:35 PM	1063				
2/19/96	3:16:48 PM	1064		11.7	03/19	analyzed in lab
2/19/96	3:27:01 PM	1065				
2/19/96	3:37:14 PM	1066		11.32	03/20	analyzed in lab
2/19/96	3:47:35 PM	1067				
2/19/96	3:57:48 PM	1068		11.35	03/20	analyzed in lab
2/19/96	4:08:01 PM	1069				
2/19/96	4:18:14 PM	1070		12.3	03/19	analyzed in lab
2/19/96	4:28:27 PM	1071				
2/19/96	4:38:39 PM	1072		11.51	03/20	analyzed in lab
2/19/96	4:48:52 PM	1073				
2/19/96	4:59:05 PM	1074	L/F-D*	12.37	03/20	analyzed in lab
2/19/96	5:09:18 PM	1075				
2/19/96	5:19:39 PM	1076		11.5	03/19	analyzed in lab
2/19/96	5:29:52 PM	1077				
2/19/96	5:40:04 PM	1078		11.97	03/20	analyzed in lab
2/19/96	5:50:17 PM	1079				
2/19/96	6:00:29 PM	1080		12.57	03/20	analyzed in lab
2/19/96	6:10:42 PM	1081		10.06	02/20	analyzed in field
2/19/96	6:20:55 PM	1082		12.0	03/19	analyzed in lab
2/19/96	6:31:08 PM	1083				
2/19/96	6:41:22 PM	1084		13.26	03/20	analyzed in lab
2/19/96	6:51:43 PM	1085				
2/19/96	7:01:56 PM	1086		13.21	03/20	analyzed in lab
2/19/96	7:12:09 PM	1087				
2/19/96	7:22:22 PM	1088		13.5	03/19	analyzed in lab
2/19/96	7:32:35 PM	1089		9.97	02/20	analyzed in field
2/19/96	7:42:48 PM	1090		13.06	03/20	analyzed in lab
2/19/96	7:53:01 PM	1091				
2/19/96	8:03:14 PM	1092	L/D	12.45		
2/19/96	8:14:02 PM	1093				
2/19/96	8:24:48 PM	1094		13.7	03/19	analyzed in lab
2/19/96	8:35:00 PM	1095				
2/19/96	8:45:13 PM	1096	L/F-D*	14.09	03/20	analyzed in lab
2/19/96	8:55:26 PM	1097				
2/19/96	9:05:39 PM	1098		13.86	03/20	analyzed in lab
2/19/96	9:15:52 PM	1099				
2/19/96	9:26:05 PM	1100		13.4	03/19	analyzed in lab
2/19/96	9:36:18 PM	1101				
2/19/96	9:46:30 PM	1102		12.99	03/20	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 4

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/19/96	9:56:52 PM	1103		11.22	02/20	analyzed in field
2/19/96	10:07:05 PM	1104		13.64	03/20	analyzed in lab
2/19/96	10:17:17 PM	1105				
2/19/96	10:27:30 PM	1106		14.0	03/19	analyzed in lab
2/19/96	10:37:44 PM	1107				
2/19/96	10:47:56 PM	1108		13.60	03/20	analyzed in lab
2/19/96	10:58:09 PM	1109				
2/19/96	11:08:22 PM	1110		14.38	03/20	analyzed in lab
2/19/96	11:18:35 PM	1111				
2/19/96	11:28:56 PM	1112		13.7	03/19	analyzed in lab
2/19/96	11:39:39 PM	1113				
2/19/96	11:49:52 PM	1114		16.02	03/20	analyzed in lab
2/20/96	12:00:05 AM	1115				
2/20/96	12:10:18 AM	1116	L/F-D*	13.59	03/20	analyzed in lab
2/20/96	12:20:31 AM	1117		12.29	02/20	analyzed in field
2/20/96	12:30:45 AM	1118		15.1	03/19	analyzed in lab
2/20/96	12:40:58 AM	1119				
2/20/96	12:51:16 AM	1120		14.96	03/20	analyzed in lab
2/20/96	1:01:38 AM	1121				
2/20/96	1:11:51 AM	1122		13.55	03/20	analyzed in lab
2/20/96	1:22:04 AM	1123				
2/20/96	1:32:25 AM	1124		15.5	03/19	analyzed in lab
2/20/96	1:42:38 AM	1125				
2/20/96	1:52:51 AM	1126		14.44	03/20	analyzed in lab
2/20/96	2:03:04 AM	1127				
2/20/96	2:13:17 AM	1128		15.44	03/20	analyzed in lab
2/20/96	2:23:29 AM	1129				
2/20/96	2:33:49 AM	1130	L/D	14.9		
2/20/96	2:44:02 AM	1131		13.30	02/20	analyzed in field
2/20/96	2:54:15 AM	1132		14.6	03/19	analyzed in lab
2/20/96	3:04:28 AM	1133				
2/20/96	3:14:41 AM	1134		14.7	03/19	analyzed in lab
2/20/96	3:24:54 AM	1135				
2/20/96	3:35:06 AM	1136		16.2	03/19	analyzed in lab
2/20/96	3:45:19 AM	1137				
2/20/96	3:55:32 AM	1138		15.2	03/19	analyzed in lab
2/20/96	4:05:53 AM	1139		13.87	02/20	analyzed in field
2/20/96	4:16:31 AM	1140		15.8	03/19	analyzed in lab
2/20/96	4:27:11 AM	1141				
2/20/96	4:37:24 AM	1142		14.4	03/19	analyzed in lab
2/20/96	4:47:37 AM	1143				
2/20/96	4:57:50 AM	1144		16.2	03/19	analyzed in lab
2/20/96	5:08:03 AM	1145				
2/20/96	5:18:16 AM	1146				
2/20/96	5:28:29 AM	1147		15.9	03/19	analyzed in lab
2/20/96	5:38:50 AM	1148				
2/20/96	5:49:03 AM	1149				
2/20/96	5:59:16 AM	1150		15.0	03/19	analyzed in lab
2/20/96	6:09:29 AM	1151				
2/20/96	6:19:42 AM	1152		15.07	02/20	analyzed in field
2/20/96	6:30:03 AM	1153		16.3	03/19	analyzed in lab
2/20/96	6:40:17 AM	1154		14.76	02/20	analyzed in field
2/20/96	6:50:30 AM	1155				
2/20/96	7:00:42 AM	1156		17.2	03/19	analyzed in lab
2/20/96	7:11:04 AM	1157				
2/20/96	7:21:17 AM	1158				
2/20/96	7:31:30 AM	1159		15.7	03/19	analyzed in lab
2/20/96	7:41:43 AM	1160				
2/20/96	7:51:56 AM	1161				
2/20/96	8:02:08 AM	1162		16.9	03/19	analyzed in lab
2/20/96	8:12:21 AM	1163				
2/20/96	8:22:34 AM	1164				
2/20/96	8:32:47 AM	1165		16.1	03/19	analyzed in lab
2/20/96	8:43:08 AM	1166		15.11	02/20	analyzed in field
2/20/96	8:53:21 AM	1167				
2/20/96	9:03:34 AM	1168		15.20	02/20	analyzed in field
2/20/96	9:13:47 AM	1169				
2/20/96	9:24:26 AM	1170		15.55	02/20	analyzed in field
2/20/96	9:34:47 AM	1171		15.8	03/19	analyzed in lab
2/20/96	9:45:00 AM	1172		15.23	02/20	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 5

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/20/96	9:55:14 AM	1173				
2/20/96	10:05:30 AM	1174		16.36	02/20	analyzed in field
2/20/96	10:15:52 AM	1175		15.85	02/20	analyzed in field
2/20/96	10:26:05 AM	1176		16.82	02/20	analyzed in field
2/20/96	10:36:18 AM	1177		16.22	02/20	analyzed in field
2/20/96	10:46:31 AM	1178		16.37	02/20	analyzed in field
2/20/96	10:56:43 AM	1179		15.82	02/20	analyzed in field
2/20/96	11:06:56 AM	1180		16.11	02/20	analyzed in field
2/20/96	11:17:09 AM	1181		16.71	02/20	analyzed in field
2/20/96	11:27:22 AM	1182		16.62	02/20	analyzed in field
2/20/96	11:37:51 AM	1183		16.69	02/20	analyzed in field
2/20/96	11:48:11 AM	1184		15.65	02/20	analyzed in field
2/20/96	11:58:24 AM	1185		17.07	02/20	analyzed in field
2/20/96	12:08:37 PM	1186		17.11	02/20	analyzed in field
2/20/96	12:19:15 PM	1187		17.79	02/20	analyzed in field
2/20/96	12:29:56 PM	1188		16.29	02/20	analyzed in field
2/20/96	12:40:09 PM	1189		16.45	02/20	analyzed in field
2/20/96	12:50:22 PM	1190		17.29	02/20	analyzed in field
2/20/96	1:00:35 PM	1191		16.91	02/20	analyzed in field
2/20/96	1:10:48 PM	1192		17.05	02/20	analyzed in field
2/20/96	1:21:07 PM	1193		17.32	02/20	analyzed in field
2/20/96	1:31:18 PM	1194		16.58	02/20	analyzed in field
2/20/96	1:41:56 PM	1195		17.09	02/20	analyzed in field
2/20/96	1:52:06 PM	1196		18.12	02/20	analyzed in field
2/20/96	2:02:18 PM	1197		17.92	02/20	analyzed in field
2/20/96	2:12:31 PM	1198		16.99	02/20	analyzed in field
2/20/96	2:27:44 PM	1199		17.55	02/20	analyzed in field
2/20/96	2:42:56 PM	1200		17.53	02/20	analyzed in field
2/20/96	2:58:10 PM	1201		17.82	02/20	analyzed in field
2/20/96	3:13:35 PM	1202		17.56	02/20	analyzed in field
2/20/96	3:28:47 PM	1203		15.90	02/20	analyzed in field
2/20/96	3:44:01 PM	1204		17.17	02/20	analyzed in field
2/20/96	3:59:19 PM	1205		18.37	02/20	analyzed in field
2/20/96	4:14:37 PM	1206		18.47	02/20	analyzed in field
2/20/96	4:29:58 PM	1207		17.63	02/20	analyzed in field
2/20/96	4:45:23 PM	1208		18.10	02/20	analyzed in field
2/20/96	5:00:41 PM	1209				
2/20/96	5:16:01 PM	1210		19.9	03/19	analyzed in lab
2/20/96	5:31:27 PM	1211				
2/20/96	5:47:02 PM	1212		20.0	03/19	analyzed in lab
2/20/96	6:02:21 PM	1213				
2/20/96	6:17:38 PM	1214	L/D	19.6		
2/20/96	6:32:55 PM	1215				
2/20/96	6:48:14 PM	1216		19.4	03/19	analyzed in lab
2/20/96	7:03:32 PM	1217				
2/20/96	7:18:50 PM	1218		20.4	03/19	analyzed in lab
2/20/96	7:34:12 PM	1219				
2/20/96	7:49:44 PM	1220		19.3	03/19	analyzed in lab
2/20/96	8:04:58 PM	1221				
2/20/96	8:20:11 PM	1222		20.4	03/19	analyzed in lab
2/20/96	8:35:32 PM	1223				
2/20/96	8:45:59 PM	1224		19.7	03/19	analyzed in lab
2/20/96	8:56:12 PM	1225				
2/20/96	9:06:25 PM	1226	L/D	20.9		
2/20/96	9:16:37 PM	1227				
2/20/96	9:26:50 PM	1228		17.4	03/18	analyzed in lab
2/20/96	9:37:12 PM	1229				
2/20/96	9:47:24 PM	1230		17.9	03/18	analyzed in lab
2/20/96	9:57:37 PM	1231				
2/20/96	10:07:50 PM	1232		17.8	03/18	analyzed in lab
2/20/96	10:18:02 PM	1233				
2/20/96	10:28:15 PM	1234		17.5	03/18	analyzed in lab
2/20/96	10:38:52 PM	1235				
2/20/96	10:49:17 PM	1236		18.1	03/18	analyzed in lab
2/20/96	10:59:31 PM	1237				
2/20/96	11:09:54 PM	1238		18.6	03/18	analyzed in lab
2/20/96	11:20:07 PM	1239				
2/20/96	11:30:20 PM	1240		18.4	03/18	analyzed in lab
2/20/96	11:40:33 PM	1241				
2/20/96	11:50:46 PM	1242		19.3	03/18	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 6

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/21/96	12:00:59 AM	1243				
2/21/96	12:11:12 AM	1244		18.2	03/18	analyzed in lab
2/21/96	12:21:25 AM	1245				
2/21/96	12:31:37 AM	1246		19.7	03/18	analyzed in lab
2/21/96	12:41:58 AM	1247				
2/21/96	12:52:12 AM	1248		17.9	03/18	analyzed in lab
2/21/96	1:02:24 AM	1249				
2/21/96	1:12:37 AM	1250		20.6	03/18	analyzed in lab
2/21/96	1:22:49 AM	1251				
2/21/96	1:33:02 AM	1252		19.6	03/18	analyzed in lab
2/21/96	1:43:15 AM	1253				
2/21/96	1:53:28 AM	1254		20.0	03/18	analyzed in lab
2/21/96	2:03:42 AM	1255				
2/21/96	2:14:04 AM	1256		20.1	03/18	analyzed in lab
2/21/96	2:24:50 AM	1257				
2/21/96	2:35:28 AM	1258		18.6	03/18	analyzed in lab
2/21/96	2:45:41 AM	1259				
2/21/96	2:55:57 AM	1260	L/D*	19.6	03/18	analyzed in lab
2/21/96	3:06:12 AM	1261				
2/21/96	3:16:24 AM	1262		21.4	03/18	analyzed in lab
2/21/96	3:26:38 AM	1263				
2/21/96	3:37:14 AM	1264		20.7	03/18	analyzed in lab
2/21/96	3:47:45 AM	1265				
2/21/96	3:57:57 AM	1266		20.4	03/18	analyzed in lab
2/21/96	4:08:10 AM	1267				
2/21/96	4:18:23 AM	1268		20.6	03/18	analyzed in lab
2/21/96	4:28:36 AM	1269				
2/21/96	4:38:50 AM	1270		21.4	03/18	analyzed in lab
2/21/96	4:49:04 AM	1271				
2/21/96	4:59:17 AM	1272		20.8	03/18	analyzed in lab
2/21/96	5:09:30 AM	1273				
2/21/96	5:19:52 AM	1274		21.5	03/18	analyzed in lab
2/21/96	5:30:05 AM	1275				
2/21/96	5:40:18 AM	1276		19.6	03/18	analyzed in lab
2/21/96	5:50:31 AM	1277				
2/21/96	6:00:45 AM	1278		21.6	03/18	analyzed in lab
2/21/96	6:10:58 AM	1279				
2/21/96	6:21:11 AM	1280		21.8	03/18	analyzed in lab
2/21/96	6:31:25 AM	1281				
2/21/96	6:41:49 AM	1282		21.5	03/18	analyzed in lab
2/21/96	6:52:10 AM	1283		20.6	03/18	analyzed in lab
2/21/96	7:02:23 AM	1284		21.7	03/18	analyzed in lab
2/21/96	7:12:36 AM	1285				
2/21/96	7:22:49 AM	1286	L/D	23.1		
2/21/96	7:33:02 AM	1287				
2/21/96	7:43:21 AM	1288		21.2	03/18	analyzed in lab
2/21/96	7:53:35 AM	1289		22.0	03/18	analyzed in lab
2/21/96	8:03:51 AM	1290				
2/21/96	8:14:04 AM	1291				
2/21/96	8:24:28 AM	1292	L/D*	21.8	03/18	analyzed in lab
2/21/96	8:34:41 AM	1293				
2/21/96	8:45:18 AM	1294		22.3	03/18	analyzed in lab
2/21/96	8:55:31 AM	1295		22.3	03/18	analyzed in lab
2/21/96	9:05:46 AM	1296	L/F-D*	22.4	03/18	analyzed in lab
2/21/96	9:16:01 AM	1297	L/F-D	22.9		
2/21/96	9:26:14 AM	1298		27.2	02/21	analyzed in field
2/21/96	9:36:27 AM	1299		25.8	02/21	analyzed in field
2/21/96	9:46:39 AM	1300		25.1	02/21	analyzed in field
2/21/96	9:57:00 AM	1301		26.0	02/21	analyzed in field
2/21/96	10:07:13 AM	1302		26.7	02/21	analyzed in field
2/21/96	10:17:26 AM	1303		27.2	02/21	analyzed in field
2/21/96	10:27:38 AM	1304		26.9	02/21	analyzed in field
2/21/96	10:37:50 AM	1305		27.4	02/21	analyzed in field
2/21/96	10:48:03 AM	1306		27.4	02/21	analyzed in field
2/21/96	10:58:17 AM	1307		25.5	02/21	analyzed in field
2/21/96	11:08:30 AM	1308		27.8	02/21	analyzed in field
2/21/96	11:18:43 AM	1309		25.8	02/21	analyzed in field
2/21/96	11:30:04 AM	1310		26.6	02/21	analyzed in field
2/21/96	11:40:17 AM	1311		29.0	02/21	analyzed in field
2/21/96	11:50:29 AM	1312		29.8	02/21	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 7

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/21/96	12:00:42 PM	1313		24.6	02/21	analyzed in field
2/21/96	12:10:55 PM	1314		27.8	02/21	analyzed in field
2/21/96	12:21:08 PM	1315		28.5	02/21	analyzed in field
2/21/96	12:36:21 PM	1316		27.4	02/21	analyzed in field
2/21/96	12:51:41 PM	1317		27.5	02/21	analyzed in field
2/21/96	1:07:03 PM	1318		26.1	02/21	analyzed in field
2/21/96	1:22:38 PM	1319		27.5	02/21	analyzed in field
2/21/96	1:37:52 PM	1320		29.3	02/21	analyzed in field
2/21/96	1:53:27 PM	1321		28.4	02/21	analyzed in field
2/21/96	2:08:45 PM	1322		28.5	02/21	analyzed in field
2/21/96	2:24:05 PM	1323		26.8	02/21	analyzed in field
2/21/96	2:39:23 PM	1324		27.7	02/21	analyzed in field
2/21/96	2:54:46 PM	1325		30.6	02/21	analyzed in field
2/21/96	3:10:04 PM	1326		28.1	02/21	analyzed in field
2/21/96	3:25:22 PM	1327		27.7	02/21	analyzed in field
2/21/96	3:41:02 PM	1328		28.2	02/21	analyzed in field
2/21/96	3:56:15 PM	1329		27.4	02/21	analyzed in field
2/21/96	4:11:28 PM	1330		28.3	02/21	analyzed in field
2/21/96	4:26:47 PM	1331		29.6	02/21	analyzed in field
2/21/96	4:42:05 PM	1332		29.3	02/21	analyzed in field
2/21/96	4:57:39 PM	1333	L/D*	28.3	03/18	analyzed in lab
2/21/96	5:12:56 PM	1334		25.3	03/18	analyzed in lab
2/21/96	5:28:17 PM	1335		25.3	03/18	analyzed in lab
2/21/96	5:43:38 PM	1336		25.7	03/18	analyzed in lab
2/21/96	5:59:29 PM	1337		27.3	03/18	analyzed in lab
2/21/96	6:14:42 PM	1338		25.3	03/18	analyzed in lab
2/21/96	6:29:55 PM	1339		25.6	03/18	analyzed in lab
2/21/96	6:45:15 PM	1340		27.8	03/18	analyzed in lab
2/21/96	7:00:27 PM	1341		26.6	03/18	analyzed in lab
2/21/96	7:15:40 PM	1342		27.5	03/18	analyzed in lab
2/21/96	7:30:53 PM	1343		27.1	03/18	analyzed in lab
2/21/96	7:46:06 PM	1344		26.3	03/18	analyzed in lab
2/21/96	8:01:29 PM	1345		28.7	03/18	analyzed in lab
2/21/96	8:17:08 PM	1346		29.0	03/18	analyzed in lab
2/21/96	8:32:21 PM	1347		27.8	03/18	analyzed in lab
2/21/96	8:47:34 PM	1348		27.3	03/18	analyzed in lab
2/21/96	9:03:07 PM	1349		31.2	03/18	analyzed in lab
2/21/96	9:18:29 PM	1350	L/D*	30.8	03/18	analyzed in lab
2/21/96	9:34:48 PM	1351		27.5	03/18	analyzed in lab
2/21/96	9:50:26 PM	1352		28.5	03/18	analyzed in lab
2/21/96	10:05:49 PM	1353		28.9	03/18	analyzed in lab
2/21/96	10:21:09 PM	1354		29.6	03/18	analyzed in lab
2/21/96	10:36:58 PM	1355		29.0	03/18	analyzed in lab
2/21/96	10:52:11 PM	1356		28.9	03/18	analyzed in lab
2/21/96	11:07:25 PM	1357		34.5	03/18	analyzed in lab
2/21/96	11:22:43 PM	1358		34.0	03/18	analyzed in lab
2/21/96	11:38:01 PM	1359		32.4	03/18	analyzed in lab
2/21/96	11:53:14 PM	1360		33.1	03/18	analyzed in lab
2/22/96	12:08:27 AM	1361		32.7	03/18	analyzed in lab
2/22/96	12:23:39 AM	1362		33.1	03/18	analyzed in lab
2/22/96	12:38:56 AM	1363		34.1	03/18	analyzed in lab
2/22/96	12:54:48 AM	1364		32.5	03/18	analyzed in lab
2/22/96	1:10:00 AM	1365		32.5	03/18	analyzed in lab
2/22/96	1:25:13 AM	1366		32.1	03/18	analyzed in lab
2/22/96	1:40:32 AM	1367		33.5	03/18	analyzed in lab
2/22/96	1:56:10 AM	1368		32.2	03/18	analyzed in lab
2/22/96	2:11:30 AM	1369		33.3	03/18	analyzed in lab
2/22/96	2:26:51 AM	1370		33.1	03/18	analyzed in lab
2/22/96	2:42:15 AM	1371		33.3	03/18	analyzed in lab
2/22/96	2:57:49 AM	1372		31.7	03/18	analyzed in lab
2/22/96	3:13:21 AM	1373		32.6	03/18	analyzed in lab
2/22/96	3:28:35 AM	1374		37.0	03/18	analyzed in lab
2/22/96	3:43:48 AM	1375		33.8	03/18	analyzed in lab
2/22/96	3:59:26 AM	1376		34.5	03/18	analyzed in lab
2/22/96	4:14:46 AM	1377	L/D*	34.1	03/18	analyzed in lab
2/22/96	4:30:05 AM	1378		32.4	03/18	analyzed in lab
2/22/96	4:45:28 AM	1379		32.2	03/18	analyzed in lab
2/22/96	5:00:41 AM	1380		33.2	03/18	analyzed in lab
2/22/96	5:15:54 AM	1381		35.8	02/22	analyzed in field
2/22/96	5:31:27 AM	1382		36.5	02/22	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 8

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/22/96	5:46:40 AM	1383		34.3	02/22	analyzed in field
2/22/96	6:02:14 AM	1384		37.4	02/22	analyzed in field
2/22/96	6:17:36 AM	1385		34.8	02/22	analyzed in field
2/22/96	6:32:58 AM	1386		36.5	02/22	analyzed in field
2/22/96	6:48:18 AM	1387		36.7	02/22	analyzed in field
2/22/96	7:03:58 AM	1388		34.8	02/22	analyzed in field
2/22/96	7:19:19 AM	1389		35.0	02/22	analyzed in field
2/22/96	7:34:36 AM	1390		37.5	02/22	analyzed in field
2/22/96	7:50:28 AM	1391		39.8	02/22	analyzed in field
2/22/96	8:05:41 AM	1392		35.6	02/22	analyzed in field
2/22/96	8:20:54 AM	1393		35.1	02/22	analyzed in field
2/22/96	8:36:17 AM	1394		35.8	02/22	analyzed in field
2/22/96	8:51:37 AM	1395		35.4	02/22	analyzed in field
2/22/96	9:07:15 AM	1396				
2/22/96	9:22:42 AM	1397		37.7	02/22	analyzed in field
2/22/96	9:38:03 AM	1398		37.9	02/22	analyzed in field
2/22/96	9:53:22 AM	1399		38.7	02/22	analyzed in field
2/22/96	10:09:01 AM	1400		38.0	02/22	analyzed in field
2/22/96	10:24:14 AM	1401		36.7	02/22	analyzed in field
2/22/96	10:39:26 AM	1402		38.6	02/22	analyzed in field
2/22/96	10:54:45 AM	1403		38.1	02/22	analyzed in field
2/22/96	11:10:13 AM	1404		37.5	02/22	analyzed in field
2/22/96	11:25:34 AM	1405		39.3	02/22	analyzed in field
2/22/96	11:40:55 AM	1406		38.9	02/22	analyzed in field
2/22/96	11:56:12 AM	1407		38.9	02/22	analyzed in field
2/22/96	12:11:50 PM	1408		41.6	02/22	analyzed in field
2/22/96	12:27:22 PM	1409		41.6	02/22	analyzed in field
2/22/96	12:43:31 PM	1410		40.0	02/22	analyzed in field
2/22/96	12:59:08 PM	1411		38.9	02/22	analyzed in field
2/22/96	1:14:26 PM	1412		38.0	02/22	analyzed in field
2/22/96	1:29:45 PM	1413		39.8	02/22	analyzed in field
2/22/96	1:45:07 PM	1414		40.0	02/22	analyzed in field
2/22/96	2:00:20 PM	1415		39.6	02/22	analyzed in field
2/22/96	2:15:33 PM	1416		39.1	02/22	analyzed in field
2/22/96	2:30:47 PM	1417		40.1	02/22	analyzed in field
2/22/96	2:46:35 PM	1418		41.0	02/22	analyzed in field
2/22/96	3:01:48 PM	1419		41.0	02/22	analyzed in field
2/22/96	3:17:01 PM	1420		41.0	02/22	analyzed in field
2/22/96	3:32:18 PM	1421		41.3	02/22	analyzed in field
2/22/96	3:47:34 PM	1422		39.4	02/22	analyzed in field
2/22/96	4:03:12 PM	1423		41.4	02/22	analyzed in field
2/22/96	4:18:33 PM	1424		39.7	02/22	analyzed in field
2/22/96	4:33:57 PM	1425		41.9	02/22	analyzed in field
2/22/96	4:49:17 PM	1426		38.7	03/15	analyzed in lab
2/22/96	5:05:10 PM	1427		39.8	03/15	analyzed in lab
2/22/96	5:20:23 PM	1428		39.1	03/15	analyzed in lab
2/22/96	5:35:35 PM	1429		39.5	03/15	analyzed in lab
2/22/96	5:50:58 PM	1430		40.0	03/15	analyzed in lab
2/22/96	6:06:37 PM	1431		39.9	03/15	analyzed in lab
2/22/96	6:22:01 PM	1432		41.2	03/15	analyzed in lab
2/22/96	6:37:21 PM	1433		39.8	03/15	analyzed in lab
2/22/96	6:52:42 PM	1434		40.9	03/15	analyzed in lab
2/22/96	7:07:55 PM	1435		40.5	03/15	analyzed in lab
2/22/96	7:23:16 PM	1436		41.3	03/15	analyzed in lab
2/22/96	7:38:28 PM	1437		41.1	03/15	analyzed in lab
2/22/96	7:53:52 PM	1438		39.6	03/15	analyzed in lab
2/22/96	8:09:16 PM	1439		41.6	03/15	analyzed in lab
2/22/96	8:24:35 PM	1440	L/D	40.8		
2/22/96	8:39:56 PM	1441		40.9	03/15	analyzed in lab
2/22/96	8:55:24 PM	1442		41.7	03/15	analyzed in lab
2/22/96	9:10:45 PM	1443		42.5	03/15	analyzed in lab
2/22/96	9:26:02 PM	1444		41.5	03/15	analyzed in lab
2/22/96	9:41:29 PM	1445		41.7	03/15	analyzed in lab
2/22/96	9:57:04 PM	1446		41.4	03/15	analyzed in lab
2/22/96	10:12:23 PM	1447		42.7	03/15	analyzed in lab
2/22/96	10:27:46 PM	1448		41.2	03/15	analyzed in lab
2/22/96	10:43:03 PM	1449		42.4	03/15	analyzed in lab
2/22/96	10:58:16 PM	1450		41.3	03/15	analyzed in lab
2/22/96	11:14:00 PM	1451		42.5	03/15	analyzed in lab
2/22/96	11:29:26 PM	1452		43.1	03/15	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 9

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/22/96	11:44:49 PM	1453		41.6	03/15	analyzed in lab
2/23/96	12:00:11 AM	1454		42.5	03/15	analyzed in lab
2/23/96	12:15:51 AM	1455		41.5	03/15	analyzed in lab
2/23/96	12:31:10 AM	1456		41.6	03/15	analyzed in lab
2/23/96	12:46:37 AM	1457		42.3	03/15	analyzed in lab
2/23/96	1:01:51 AM	1458		42.6	03/15	analyzed in lab
2/23/96	1:17:40 AM	1459		42.7	03/15	analyzed in lab
2/23/96	1:32:59 AM	1460	L/D	42.7		
2/23/96	1:48:19 AM	1461		42.6	03/15	analyzed in lab
2/23/96	2:03:32 AM	1462		42.4	03/15	analyzed in lab
2/23/96	2:19:29 AM	1463		43.5	03/15	analyzed in lab
2/23/96	2:34:41 AM	1464		42.9	03/15	analyzed in lab
2/23/96	2:49:59 AM	1465		43.7	03/15	analyzed in lab
2/23/96	3:05:12 AM	1466		43.6	03/15	analyzed in lab
2/23/96	3:21:03 AM	1467		44.1	03/15	analyzed in lab
2/23/96	3:36:20 AM	1468		45.5	02/23	analyzed in field
2/23/96	3:51:40 AM	1469		46.5	02/23	analyzed in field
2/23/96	4:06:53 AM	1470		46.4	02/23	analyzed in field
2/23/96	4:22:48 AM	1471		46.2	02/23	analyzed in field
2/23/96	4:38:14 AM	1472		46.2	02/23	analyzed in field
2/23/96	4:54:51 AM	1473		47.0	02/23	analyzed in field
2/23/96	5:10:29 AM	1474		47.3	02/23	analyzed in field
2/23/96	5:25:51 AM	1475		54.6	02/23	analyzed in field
2/23/96	5:41:15 AM	1476		48.4	02/23	analyzed in field
2/23/96	5:56:36 AM	1477		50.1	02/23	analyzed in field
2/23/96	6:12:12 AM	1478		48.6	02/23	analyzed in field
2/23/96	6:27:44 AM	1479		49.9	02/23	analyzed in field
2/23/96	6:43:02 AM	1480		47.6	02/23	analyzed in field
2/23/96	6:58:33 AM	1481		49.1	02/23	analyzed in field
2/23/96	7:14:10 AM	1482		50.2	02/23	analyzed in field
2/23/96	7:29:28 AM	1483		47.9	02/23	analyzed in field
2/23/96	7:44:45 AM	1484		45.0	02/23	analyzed in field
2/23/96	8:00:06 AM	1485		50.9	02/23	analyzed in field
2/23/96	8:15:46 AM	1486		47.9	02/23	analyzed in field
2/23/96	8:31:07 AM	1487		49.2	02/23	analyzed in field
2/23/96	8:46:27 AM	1488		48.7	02/23	analyzed in field
2/23/96	9:01:47 AM	1489		49.4	02/23	analyzed in field
2/23/96	9:17:08 AM	1490		47.8	02/23	analyzed in field
2/23/96	9:32:21 AM	1491		46.6	02/23	analyzed in field
2/23/96	9:47:34 AM	1492		49.7	02/23	analyzed in field
2/23/96	10:02:58 AM	1493		49.3	02/23	analyzed in field
2/23/96	10:18:17 AM	1494		50.2	02/23	analyzed in field
2/23/96	10:33:38 AM	1495		50.7	02/23	analyzed in field
2/23/96	10:48:57 AM	1496		48.7	02/23	analyzed in field
2/23/96	11:04:29 AM	1497		48.8	02/23	analyzed in field
				50.9	02/23	analyzed in field
				51.6	02/23	analyzed in field
				49.4	02/23	analyzed in field
				47.3	02/24	analyzed in field
				53.1	02/24	analyzed in field
2/23/96	12:53:25 PM	1503		47.1	03/15	analyzed in lab
2/23/96	1:08:49 PM	1504		48.7	03/15	analyzed in lab
2/23/96	1:24:10 PM	1505		48.5	03/15	analyzed in lab
2/23/96	1:39:35 PM	1506		48.7	03/15	analyzed in lab
2/23/96	1:54:48 PM	1507		48.5	03/15	analyzed in lab
2/23/96	2:10:09 PM	1508		48.4	03/15	analyzed in lab
2/23/96	2:25:28 PM	1509		54.7	03/15	analyzed in lab
2/23/96	2:40:46 PM	1510		52.8	03/15	analyzed in lab
2/23/96	2:56:05 PM	1511		52.9	03/15	analyzed in lab
2/23/96	3:11:49 PM	1512		54.8	03/15	analyzed in lab
2/23/96	3:27:02 PM	1513		51.2	03/15	analyzed in lab
2/23/96	3:42:15 PM	1514		53.8	03/15	analyzed in lab
2/23/96	3:57:31 PM	1515		53.2	03/15	analyzed in lab
2/23/96	4:12:49 PM	1516		49.1	03/15	analyzed in lab
2/23/96	4:28:10 PM	1517		53.3	03/15	analyzed in lab
2/23/96	4:43:31 PM	1518		55.3	03/15	analyzed in lab
2/23/96	4:58:51 PM	1519		53.1	03/15	analyzed in lab
2/23/96	5:14:13 PM	1520		55.9	03/15	analyzed in lab
2/23/96	5:29:48 PM	1521		55.9	03/15	analyzed in lab
2/23/96	5:45:01 PM	1522		54.2	03/15	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 10

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/23/96	6:00:14 PM	1523		54.7	03/15	analyzed in lab
2/23/96	6:15:28 PM	1524		52.0	03/15	analyzed in lab
2/23/96	6:30:47 PM	1525		55.3	03/15	analyzed in lab
2/23/96	6:46:10 PM	1526	L/D*	54.7	03/15	analyzed in lab
2/23/96	7:01:32 PM	1527		54.2	03/15	analyzed in lab
2/23/96	7:16:52 PM	1528		56.2	03/15	analyzed in lab
2/23/96	7:32:14 PM	1529		54.4	03/15	analyzed in lab
2/23/96	7:47:54 PM	1530		59.7	03/15	analyzed in lab
2/23/96	8:03:07 PM	1531		53.8	03/15	analyzed in lab
2/23/96	8:18:20 PM	1532		55.0	03/15	analyzed in lab
2/23/96	8:33:38 PM	1533		58.7	03/15	analyzed in lab
2/23/96	8:48:57 PM	1534		57.5	03/15	analyzed in lab
2/23/96	9:04:16 PM	1535		58.0	03/15	analyzed in lab
2/23/96	9:19:37 PM	1536		60.3	03/15	analyzed in lab
2/23/96	9:34:58 PM	1537		56.7	03/15	analyzed in lab
2/23/96	9:50:17 PM	1538		62.7	03/15	analyzed in lab
2/23/96	10:05:50 PM	1539		58.4	03/15	analyzed in lab
2/23/96	10:21:04 PM	1540		58.6	03/15	analyzed in lab
2/23/96	10:36:17 PM	1541		58.5	03/15	analyzed in lab
2/23/96	10:51:36 PM	1542		57.0	03/15	analyzed in lab
2/23/96	11:06:54 PM	1543		58.3	03/15	analyzed in lab
2/23/96	11:22:16 PM	1544		59.1	03/15	analyzed in lab
2/23/96	11:37:34 PM	1545		62.1	03/15	analyzed in lab
2/23/96	11:52:57 PM	1546		57.7	03/15	analyzed in lab
2/24/96	12:08:18 AM	1547		59.8	03/15	analyzed in lab
2/24/96	12:23:55 AM	1548		60.9	03/15	analyzed in lab
2/24/96	12:39:08 AM	1549		59.6	03/15	analyzed in lab
2/24/96	12:54:20 AM	1550		59.4	03/15	analyzed in lab
2/24/96	1:09:44 AM	1551		60.1	03/15	analyzed in lab
2/24/96	1:25:05 AM	1552		60.2	03/15	analyzed in lab
2/24/96	1:40:27 AM	1553	L/D	58.8		
2/24/96	1:55:50 AM	1554		60.5	03/15	analyzed in lab
2/24/96	2:11:06 AM	1555		64.4	03/15	analyzed in lab
2/24/96	2:26:28 AM	1556		62.2	03/15	analyzed in lab
2/24/96	2:42:02 AM	1557		64.0	03/14	analyzed in lab
2/24/96	2:57:15 AM	1558		63.9	03/14	analyzed in lab
2/24/96	3:12:28 AM	1559		64.6	03/14	analyzed in lab
2/24/96	3:27:49 AM	1560		64.4	03/14	analyzed in lab
2/24/96	3:43:11 AM	1561		64.4	03/14	analyzed in lab
2/24/96	3:58:34 AM	1562		64.4	03/14	analyzed in lab
2/24/96	4:13:56 AM	1563		63.4	03/14	analyzed in lab
2/24/96	4:29:14 AM	1564		61.1	02/24	analyzed in field
2/24/96	4:44:33 AM	1565		61.5	02/24	analyzed in field
2/24/96	5:00:10 AM	1566		60.8	02/24	analyzed in field
2/24/96	5:15:23 AM	1567				
2/24/96	5:30:37 AM	1568		61.0	02/24	analyzed in field
2/24/96	5:45:55 AM	1569		59.8	02/24	analyzed in field
2/24/96	6:01:15 AM	1570		60.2	02/24	analyzed in field
2/24/96	6:16:36 AM	1571		59.6	02/24	analyzed in field
2/24/96	6:31:59 AM	1572		61.6	02/24	analyzed in field
2/24/96	6:47:19 AM	1573		62.4	02/24	analyzed in field
2/24/96	7:02:37 AM	1574		61.0	02/24	analyzed in field
2/24/96	7:18:13 AM	1575		62.8	02/24	analyzed in field
2/24/96	7:33:26 AM	1576		62.3	02/24	analyzed in field
2/24/96	7:48:39 AM	1577		60.8	02/24	analyzed in field
2/24/96	8:03:58 AM	1578		60.8	02/24	analyzed in field
2/24/96	8:19:16 AM	1579		60.6	02/24	analyzed in field
2/24/96	8:34:39 AM	1580		61.9	02/24	analyzed in field
2/24/96	8:50:01 AM	1581		60.9	02/24	analyzed in field
2/24/96	9:05:21 AM	1582		61.2	02/24	analyzed in field
2/24/96	9:20:40 AM	1583		63.4	02/24	analyzed in field
2/24/96	9:36:15 AM	1584		62.7	02/24	analyzed in field
2/24/96	9:51:28 AM	1585		63.1	02/24	analyzed in field
2/24/96	10:06:41 AM	1586		63.3	02/24	analyzed in field
2/24/96	10:21:57 AM	1587		62.1	02/24	analyzed in field
2/24/96	10:37:16 AM	1588		63.3	02/24	analyzed in field
2/24/96	10:52:38 AM	1589		61.6	02/24	analyzed in field
2/24/96	11:07:58 AM	1590		61.5	02/24	analyzed in field
2/24/96	11:23:16 AM	1591		63.6	02/24	analyzed in field
2/24/96	11:38:38 AM	1592		62.3	02/24	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 11

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/24/96	11:54:17 AM	1593		63.6	02/24	analyzed in field
2/24/96	12:09:31 PM	1594		64.2	02/24	analyzed in field
2/24/96	12:24:43 PM	1595		63.7	02/24	analyzed in field
2/24/96	12:40:03 PM	1596		62.5	02/24	analyzed in field
2/24/96	12:55:26 PM	1597	F/D	62.6		
2/24/96	1:10:43 PM	1598		63.2	02/24	analyzed in field
2/24/96	1:26:02 PM	1599		62.5	02/24	analyzed in field
2/24/96	1:41:22 PM	1600		68.2	03/14	analyzed in lab
2/24/96	1:56:43 PM	1601		68.7	03/14	analyzed in lab
2/24/96	2:12:24 PM	1602		67.9	03/14	analyzed in lab
2/24/96	2:27:37 PM	1603		68.2	03/14	analyzed in lab
2/24/96	2:42:50 PM	1604		69.3	03/14	analyzed in lab
2/24/96	2:58:12 PM	1605		72.1	03/14	analyzed in lab
2/24/96	3:13:34 PM	1606		68.7	03/14	analyzed in lab
2/24/96	3:28:56 PM	1607		67.6	03/14	analyzed in lab
2/24/96	3:44:13 PM	1608		69.7	03/14	analyzed in lab
2/24/96	3:59:32 PM	1609		70.8	03/14	analyzed in lab
2/24/96	4:14:53 PM	1610		69.4	03/14	analyzed in lab
2/24/96	4:30:29 PM	1611		70.6	03/14	analyzed in lab
2/24/96	4:45:42 PM	1612		68.9	03/14	analyzed in lab
2/24/96	5:00:56 PM	1613		68.2	03/14	analyzed in lab
2/24/96	5:16:18 PM	1614		70.0	03/14	analyzed in lab
2/24/96	5:31:37 PM	1615		69.2	03/14	analyzed in lab
2/24/96	5:46:55 PM	1616		69.9	03/14	analyzed in lab
2/24/96	6:02:16 PM	1617	L/D*	72.3	03/14	analyzed in lab
2/24/96	6:17:37 PM	1618	L/D	73.5		
2/24/96	6:32:54 PM	1619	L/D	73.6		
2/24/96	6:48:29 PM	1620	L/D	73.8		
2/24/96	7:03:42 PM	1621	L/D	74.3		
2/24/96	7:18:55 PM	1622		73.1	03/14	analyzed in lab
2/24/96	7:34:16 PM	1623		76.1	03/14	analyzed in lab
2/24/96	7:49:39 PM	1624		73.1	03/14	analyzed in lab
2/24/96	8:05:03 PM	1625		74.5	03/14	analyzed in lab
2/24/96	8:20:25 PM	1626		73.8	03/14	analyzed in lab
2/24/96	8:35:42 PM	1627		75.0	03/14	analyzed in lab
2/24/96	8:51:03 PM	1628		73.1	03/14	analyzed in lab
2/24/96	9:06:39 PM	1629		74.4	03/14	analyzed in lab
2/24/96	9:21:52 PM	1630		74.8	03/14	analyzed in lab
2/24/96	9:37:05 PM	1631		74.1	03/14	analyzed in lab
2/24/96	9:52:25 PM	1632		71.9	03/14	analyzed in lab
2/24/96	10:07:43 PM	1633		74.7	03/14	analyzed in lab
2/24/96	10:23:04 PM	1634		77.8	03/14	analyzed in lab
2/24/96	10:38:23 PM	1635				
2/24/96	10:53:46 PM	1636		74.8	03/14	analyzed in lab
2/24/96	11:09:06 PM	1637		75.3	03/14	analyzed in lab
2/24/96	11:24:37 PM	1638		73.0	03/14	analyzed in lab
2/24/96	11:39:50 PM	1639		75.7	03/14	analyzed in lab
2/24/96	11:55:04 PM	1640		73.3	03/14	analyzed in lab
2/25/96	12:10:26 AM	1641		69.5	03/13	analyzed in lab
2/25/96	12:25:47 AM	1642		69.9	03/13	analyzed in lab
2/25/96	12:41:06 AM	1643		69.7	03/13	analyzed in lab
2/25/96	12:56:24 AM	1644		69.5	03/13	analyzed in lab
2/25/96	1:11:45 AM	1645		70.2	03/13	analyzed in lab
2/25/96	1:27:04 AM	1646		70.9	03/13	analyzed in lab
2/25/96	1:42:35 AM	1647		72.3	03/13	analyzed in lab
2/25/96	1:57:49 AM	1648		71.5	03/13	analyzed in lab
2/25/96	2:13:02 AM	1649		71.4	03/13	analyzed in lab
2/25/96	2:28:15 AM	1650		72.3	03/13	analyzed in lab
2/25/96	2:43:35 AM	1651		72.7	03/13	analyzed in lab
2/25/96	2:58:52 AM	1652		72.7	03/13	analyzed in lab
2/25/96	3:14:15 AM	1653		72.4	03/13	analyzed in lab
2/25/96	3:29:34 AM	1654		70.8	03/13	analyzed in lab
2/25/96	3:44:51 AM	1655		72.1	03/13	analyzed in lab
2/25/96	4:00:24 AM	1656		72.4	03/13	analyzed in lab
2/25/96	4:15:36 AM	1657		71.8	03/13	analyzed in lab
2/25/96	4:30:49 AM	1658		71.3	03/13	analyzed in lab
2/25/96	4:46:07 AM	1659		72.3	03/13	analyzed in lab
2/25/96	5:01:27 AM	1660		72.2	03/13	analyzed in lab
2/25/96	5:16:49 AM	1661		72.9	03/13	analyzed in lab
2/25/96	5:32:09 AM	1662		73.4	03/13	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 12

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/25/96	5:47:26 AM	1663		72.5	03/13	analyzed in lab
2/25/96	6:02:44 AM	1664		72.6	03/13	analyzed in lab
2/25/96	6:18:17 AM	1665	L/D*	72.8	03/27	analyzed in lab
2/25/96	6:33:30 AM	1666	L/D	72.7		
2/25/96	6:48:43 AM	1667	L/D	75.6		
2/25/96	7:04:01 AM	1668	L/D	73.7		
2/25/96	7:19:23 AM	1669	L/D	73.9		
2/25/96	7:34:43 AM	1670	L/D*	73.3		
2/25/96	7:50:00 AM	1671	L/D*	74.6		
2/25/96	8:05:20 AM	1672	L/D	71.8		
2/25/96	8:20:41 AM	1673	L/D*	74.4		
2/25/96	8:36:13 AM	1674	L/D*	74.6		
2/25/96	8:51:27 AM	1675	L/D	74.8		
2/25/96	9:06:39 AM	1676	L/D	75.1		
2/25/96	9:21:59 AM	1677	L/D*	75.4		
2/25/96	9:37:19 AM	1678	L/D*	75.6		
2/25/96	9:52:40 AM	1679	L/D*	76.0		
2/25/96	10:08:01 AM	1680	L/D	81.5		
2/25/96	10:23:23 AM	1681	L/D	75.3		
2/25/96	10:38:42 AM	1682	L/D	76.6		
2/25/96	10:54:18 AM	1683	L/D	80.1		
2/25/96	11:09:32 AM	1684	L/D	80.1		
2/25/96	11:24:45 AM	1685	L/D	79.5		
2/25/96	11:40:03 AM	1686	L/D	81.3		
2/25/96	11:55:22 AM	1687	L/D	80.5		
2/25/96	12:10:41 PM	1688	L/D	80.7		
2/25/96	12:26:02 PM	1689	L/D	72.3	03/13	analyzed in lab
2/25/96	12:41:22 PM	1690		74.4	03/13	analyzed in lab
2/25/96	12:56:40 PM	1691		74.2	03/13	analyzed in lab
2/25/96	1:12:16 PM	1692		73.7	03/13	analyzed in lab
2/25/96	1:27:30 PM	1693		74.3	03/13	analyzed in lab
2/25/96	1:42:43 PM	1694		75.4	03/13	analyzed in lab
2/25/96	1:57:58 PM	1695		73.5	03/13	analyzed in lab
2/25/96	2:13:20 PM	1696		73.9	03/13	analyzed in lab
2/25/96	2:28:39 PM	1697		74.8	03/13	analyzed in lab
2/25/96	2:43:59 PM	1698		75.8	03/13	analyzed in lab
2/25/96	2:59:17 PM	1699		75.0	03/13	analyzed in lab
2/25/96	3:14:37 PM	1700		75.1	03/13	analyzed in lab
2/25/96	3:30:11 PM	1701		74.5	03/13	analyzed in lab
2/25/96	3:45:24 PM	1702		75.6	03/13	analyzed in lab
2/25/96	4:00:37 PM	1703		77.5	03/13	analyzed in lab
2/25/96	4:15:53 PM	1704		77.0	03/13	analyzed in lab
2/25/96	4:31:11 PM	1705		78.6	03/13	analyzed in lab
2/25/96	4:46:30 PM	1706		77.4	03/13	analyzed in lab
2/25/96	5:01:49 PM	1707		76.4	03/13	analyzed in lab
2/25/96	5:17:08 PM	1708		76.2	03/13	analyzed in lab
2/25/96	5:32:25 PM	1709		76.5	03/13	analyzed in lab
2/25/96	5:47:59 PM	1710		75.7	02/27	analyzed in field
2/25/96	6:03:12 PM	1711		75.3	03/13	analyzed in lab
2/25/96	6:18:26 PM	1712		79.0	03/13	analyzed in lab
2/25/96	6:33:43 PM	1713		80.3	03/12	analyzed in lab
2/25/96	6:49:04 PM	1714		82.2	03/12	analyzed in lab
2/25/96	7:04:22 PM	1715		81.8	03/12	analyzed in lab
2/25/96	7:19:42 PM	1716		82.8	03/12	analyzed in lab
2/25/96	7:35:01 PM	1717		81.8	03/12	analyzed in lab
2/25/96	7:50:21 PM	1718		81.6	03/12	analyzed in lab
2/25/96	8:06:00 PM	1719		80.6	03/12	analyzed in lab
2/25/96	8:21:13 PM	1720		81.1	03/12	analyzed in lab
2/25/96	8:36:29 PM	1721		80.9	03/12	analyzed in lab
2/25/96	8:51:51 PM	1722		80.2	03/12	analyzed in lab
2/25/96	9:07:11 PM	1723		80.4	03/12	analyzed in lab
2/25/96	9:22:30 PM	1724		80.1	03/12	analyzed in lab
2/25/96	9:37:47 PM	1725		78.8	03/13	analyzed in lab
2/25/96	9:53:07 PM	1726		80.2	03/13	analyzed in lab
2/25/96	10:08:28 PM	1727		73.9	03/13	analyzed in lab
2/25/96	10:24:05 PM	1728		78.1	03/13	analyzed in lab
2/25/96	10:39:18 PM	1729		78.7	03/13	analyzed in lab
2/25/96	10:54:31 PM	1730	L/D*	77.7	03/13	analyzed in lab
2/25/96	11:09:47 PM	1731		79.9	03/13	analyzed in lab
2/25/96	11:25:07 PM	1732		79.8	03/13	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/25/96	11:40:27 PM	1733		80.8	03/13	analyzed in lab
2/25/96	11:55:46 PM	1734		80.7	03/13	analyzed in lab
2/26/96	12:11:07 AM	1735		82.0	03/13	analyzed in lab
2/26/96	12:26:28 AM	1736		77.0	03/13	analyzed in lab
2/26/96	12:42:01 AM	1737		80.8	03/13	analyzed in lab
2/26/96	12:57:14 AM	1738		80.5	03/13	analyzed in lab
2/26/96	1:12:27 AM	1739		79.6	03/13	analyzed in lab
2/26/96	1:27:44 AM	1740		79.4	03/13	analyzed in lab
2/26/96	1:43:04 AM	1741		79.4	03/13	analyzed in lab
2/26/96	1:58:26 AM	1742		79.6	03/13	analyzed in lab
2/26/96	2:13:47 AM	1743		80.9	03/13	analyzed in lab
2/26/96	2:29:07 AM	1744		79.5	03/13	analyzed in lab
2/26/96	2:44:26 AM	1745		78.9	03/13	analyzed in lab
2/26/96	3:00:02 AM	1746		80.6	03/13	analyzed in lab
2/26/96	3:15:14 AM	1747		80.5	03/13	analyzed in lab
2/26/96	3:30:27 AM	1748		80.8	03/13	analyzed in lab
2/26/96	3:45:47 AM	1749		79.7	03/13	analyzed in lab
2/26/96	4:01:07 AM	1750	L/D*	80.3	03/13	analyzed in lab
2/26/96	4:16:23 AM	1751		80.6	03/13	analyzed in lab
2/26/96	4:31:43 AM	1752	L/D*	80.9	03/13	analyzed in lab
2/26/96	4:47:01 AM	1753		80.4	03/13	analyzed in lab
2/26/96	5:02:18 AM	1754		79.6	03/13	analyzed in lab
2/26/96	5:17:55 AM	1755		81.9	03/13	analyzed in lab
2/26/96	5:33:08 AM	1756		80.5	03/13	analyzed in lab
2/26/96	5:48:22 AM	1757		81.1	03/13	analyzed in lab
2/26/96	6:03:37 AM	1758		81.6	03/13	analyzed in lab
2/26/96	6:18:56 AM	1759		81.1	03/13	analyzed in lab
2/26/96	6:34:17 AM	1760		81.8	03/13	analyzed in lab
2/26/96	6:49:35 AM	1761		85.2	03/12	analyzed in lab
2/26/96	7:04:54 AM	1762		85.6	03/12	analyzed in lab
2/26/96	7:20:12 AM	1763		85.1	03/12	analyzed in lab
2/26/96	7:35:48 AM	1764		84.0	03/12	analyzed in lab
2/26/96	7:51:00 AM	1765		85.4	03/12	analyzed in lab
2/26/96	8:06:13 AM	1766		85.4	03/12	analyzed in lab
2/26/96	8:21:34 AM	1767		84.4	03/12	analyzed in lab
2/26/96	8:36:57 AM	1768		84.8	03/12	analyzed in lab
2/26/96	8:52:17 AM	1769		85.3	03/12	analyzed in lab
2/26/96	9:07:34 AM	1770		83.9	03/12	analyzed in lab
2/26/96	9:22:53 AM	1771		85.0	03/12	analyzed in lab
2/26/96	9:38:14 AM	1772		85.0	03/12	analyzed in lab
2/26/96	9:53:48 AM	1773		86.1	03/12	analyzed in lab
2/26/96	10:09:02 AM	1774		85.4	03/12	analyzed in lab
2/26/96	10:24:15 AM	1775		87.6	03/12	analyzed in lab
2/26/96	10:39:31 AM	1776		86.4	03/12	analyzed in lab
2/26/96	10:54:50 AM	1777		84.4	03/12	analyzed in lab
2/26/96	11:10:12 AM	1778		85.0	03/12	analyzed in lab
2/26/96	11:25:30 AM	1779		86.7	03/12	analyzed in lab
2/26/96	11:40:51 AM	1780		84.8	03/12	analyzed in lab
2/26/96	11:56:10 AM	1781		85.8	03/12	analyzed in lab
2/26/96	12:11:46 PM	1782		80.1	02/27	analyzed in field
2/26/96	12:26:59 PM	1783		86.3	03/12	analyzed in lab
2/26/96	12:42:13 PM	1784		85.5	03/12	analyzed in lab
2/26/96	12:57:33 PM	1785	L/D	86.6		
2/26/96	1:12:54 PM	1786		86.6	03/12	analyzed in lab
2/26/96	1:28:16 PM	1787		87.0	03/12	analyzed in lab
2/26/96	1:43:36 PM	1788		87.1	03/12	analyzed in lab
2/26/96	1:58:55 PM	1789		87.4	03/12	analyzed in lab
2/26/96	2:14:20 PM	1790		87.2	03/12	analyzed in lab
2/26/96	2:30:03 PM	1791		85.1	03/12	analyzed in lab
2/26/96	2:45:17 PM	1792		86.8	03/12	analyzed in lab
2/26/96	3:00:30 PM	1793		86.4	03/12	analyzed in lab
2/26/96	3:15:52 PM	1794		87.0	03/12	analyzed in lab
2/26/96	3:31:12 PM	1795		88.2	03/12	analyzed in lab
2/26/96	3:46:34 PM	1796		85.3	03/12	analyzed in lab
2/26/96	4:02:00 PM	1797	L/D	88.0		
2/26/96	4:17:21 PM	1798		85.8	03/12	analyzed in lab
2/26/96	4:32:41 PM	1799				
2/26/96	4:48:14 PM	1800		87.9	03/12	analyzed in lab
2/26/96	5:03:28 PM	1801		88.5	03/12	analyzed in lab
2/26/96	5:18:41 PM	1802		87.5	03/12	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/26/96	5:33:58 PM	1803		87.2	03/12	analyzed in lab
2/26/96	5:49:18 PM	1804		89.4	03/12	analyzed in lab
2/26/96	6:04:38 PM	1805		88.1	03/12	analyzed in lab
2/26/96	6:20:00 PM	1806		84.2	02/27	analyzed in field
2/26/96	6:35:21 PM	1807		88.4	03/12	analyzed in lab
2/26/96	6:50:41 PM	1808		89.0	03/12	analyzed in lab
2/26/96	7:06:15 PM	1809		92.5	03/12	analyzed in lab
2/26/96	7:21:28 PM	1810		90.9	03/12	analyzed in lab
2/26/96	7:36:41 PM	1811		92.4	03/12	analyzed in lab
2/26/96	7:51:56 PM	1812		90.1	03/12	analyzed in lab
2/26/96	8:07:17 PM	1813		91.6	03/12	analyzed in lab
2/26/96	8:22:36 PM	1814		91.4	03/12	analyzed in lab
2/26/96	8:37:52 PM	1815		89.8	03/12	analyzed in lab
2/26/96	8:53:11 PM	1816		91.2	03/12	analyzed in lab
2/26/96	9:08:38 PM	1817		91.3	03/12	analyzed in lab
2/26/96	9:24:09 PM	1818		91.2	03/12	analyzed in lab
2/26/96	9:39:23 PM	1819	L/D*	90.0	03/12	analyzed in lab
2/26/96	9:54:36 PM	1820		90.7	03/12	analyzed in lab
2/26/96	10:09:56 PM	1821		91.0	03/12	analyzed in lab
2/26/96	10:25:18 PM	1822		92.1	03/12	analyzed in lab
2/26/96	10:40:37 PM	1823		90.6	03/12	analyzed in lab
2/26/96	10:55:57 PM	1824		91.4	03/12	analyzed in lab
2/26/96	11:11:15 PM	1825		90.8	03/12	analyzed in lab
2/26/96	11:26:40 PM	1826		90.3	03/12	analyzed in lab
2/26/96	11:42:20 PM	1827		92.0	03/12	analyzed in lab
2/26/96	11:57:32 PM	1828		90.9	03/12	analyzed in lab
2/27/96	12:12:45 AM	1829		91.8	03/12	analyzed in lab
2/27/96	12:28:01 AM	1830		90.6	03/12	analyzed in lab
2/27/96	12:43:20 AM	1831		90.8	03/12	analyzed in lab
2/27/96	12:58:41 AM	1832		91.0	03/12	analyzed in lab
2/27/96	1:14:00 AM	1833		91.6	03/12	analyzed in lab
2/27/96	1:29:19 AM	1834		91.9	03/12	analyzed in lab
2/27/96	1:44:40 AM	1835		90.1	03/12	analyzed in lab
2/27/96	2:00:16 AM	1836		90.8	03/12	analyzed in lab
2/27/96	2:15:29 AM	1837		90.6	03/12	analyzed in lab
2/27/96	2:30:43 AM	1838		89.5	03/12	analyzed in lab
2/27/96	2:45:59 AM	1839		90.2	03/12	analyzed in lab
2/27/96	3:01:16 AM	1840		88.7	03/12	analyzed in lab
2/27/96	3:16:34 AM	1841		91.9	03/12	analyzed in lab
2/27/96	3:31:53 AM	1842		90.3	03/12	analyzed in lab
2/27/96	3:47:13 AM	1843		81.8	03/12	analyzed in lab
2/27/96	4:02:33 AM	1844		88.9	03/12	analyzed in lab
2/27/96	4:18:09 AM	1845		91.7	03/12	analyzed in lab
2/27/96	4:33:22 AM	1846		91.5	03/12	analyzed in lab
2/27/96	4:48:35 AM	1847		91.9	03/12	analyzed in lab
2/27/96	5:03:55 AM	1848		91.1	03/12	analyzed in lab
2/27/96	5:19:16 AM	1849		93.0	03/12	analyzed in lab
2/27/96	5:34:35 AM	1850		91.8	03/12	analyzed in lab
2/27/96	5:49:54 AM	1851		90.8	03/12	analyzed in lab
2/27/96	6:05:16 AM	1852		90.6	03/12	analyzed in lab
2/27/96	6:20:36 AM	1853		88.7	02/27	analyzed in field
2/27/96	6:36:11 AM	1854		86.3	02/27	analyzed in field
2/27/96	6:51:24 AM	1855		85.2	02/27	analyzed in field
2/27/96	7:06:38 AM	1856		86.3	02/27	analyzed in field
2/27/96	7:21:53 AM	1857		88.8	02/27	analyzed in field
2/27/96	7:37:12 AM	1858		85.2	02/27	analyzed in field
2/27/96	7:52:32 AM	1859		87.7	02/27	analyzed in field
2/27/96	8:07:50 AM	1860		87.1	02/27	analyzed in field
2/27/96	8:23:09 AM	1861		85.5	02/27	analyzed in field
2/27/96	8:38:29 AM	1862		87.4	02/27	analyzed in field
2/27/96	8:54:03 AM	1863		86.4	02/27	analyzed in field
2/27/96	9:09:16 AM	1864		85.7	02/27	analyzed in field
2/27/96	9:24:29 AM	1865		85.1	02/27	analyzed in field
2/27/96	9:39:53 AM	1866		83.9	02/27	analyzed in field
2/27/96	9:55:11 AM	1867		86.6	02/27	analyzed in field
2/27/96	10:10:31 AM	1868		85.6	02/27	analyzed in field
2/27/96	10:25:53 AM	1869		84.8	02/27	analyzed in field
2/27/96	10:41:12 AM	1870		84.6	02/27	analyzed in field
2/27/96	10:56:32 AM	1871		84.8	02/27	analyzed in field
2/27/96	11:12:08 AM	1872		86.3	02/27	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/27/96	11:27:21 AM	1873		84.3	02/27	analyzed in field
2/27/96	11:47:34 AM	1874		84.6	02/27	analyzed in field
2/27/96	12:08:00 PM	1875		86.7	02/27	analyzed in field
2/27/96	12:28:27 PM	1876		86.6	02/27	analyzed in field
2/27/96	12:48:58 PM	1877		86.5	02/27	analyzed in field
2/27/96	1:09:25 PM	1878		87.4	02/27	analyzed in field
2/27/96	1:29:52 PM	1879		86.9	02/27	analyzed in field
2/27/96	1:50:21 PM	1880		92.2	03/12	analyzed in lab
2/27/96	2:11:08 PM	1881		92.5	03/12	analyzed in lab
2/27/96	2:31:20 PM	1882		92.9	03/12	analyzed in lab
2/27/96	2:51:36 PM	1883		92.0	03/12	analyzed in lab
2/27/96	3:12:01 PM	1884		90.4	03/13	analyzed in lab
2/27/96	3:32:28 PM	1885		89.3	03/13	analyzed in lab
2/27/96	3:52:55 PM	1886		90.6	03/13	analyzed in lab
2/27/96	4:13:21 PM	1887		89.9	03/13	analyzed in lab
2/27/96	4:33:47 PM	1888		91.0	03/13	analyzed in lab
2/27/96	4:54:11 PM	1889		92.6	03/13	analyzed in lab
2/27/96	5:14:57 PM	1890		89.9	03/13	analyzed in lab
2/27/96	5:35:10 PM	1891		93.1	03/13	analyzed in lab
2/27/96	5:55:26 PM	1892		89.8	03/13	analyzed in lab
2/27/96	6:15:54 PM	1893		90.3	03/13	analyzed in lab
2/27/96	6:36:26 PM	1894		90.1	03/13	analyzed in lab
2/27/96	6:56:53 PM	1895		86.8	03/13	analyzed in lab
2/27/96	7:17:21 PM	1896		89.5	03/07	analyzed in lab
2/27/96	7:37:47 PM	1897		89.1	03/07	analyzed in lab
2/27/96	7:58:14 PM	1898		91.4	03/07	analyzed in lab
2/27/96	8:19:04 PM	1899		89.9	03/07	analyzed in lab
2/27/96	8:39:17 PM	1900		89.4	03/07	analyzed in lab
2/27/96	8:59:34 PM	1901		88.5	03/07	analyzed in lab
2/27/96	9:20:04 PM	1902		89.5	03/07	analyzed in lab
2/27/96	9:40:28 PM	1903		90.4	03/07	analyzed in lab
2/27/96	10:00:59 PM	1904		89.8	03/07	analyzed in lab
2/27/96	10:21:31 PM	1905		90.6	03/07	analyzed in lab
2/27/96	10:42:00 PM	1906		90.5	03/07	analyzed in lab
2/27/96	11:02:27 PM	1907		91.8	03/07	analyzed in lab
2/27/96	11:23:19 PM	1908		90.2	03/13	analyzed in lab
2/27/96	11:43:32 PM	1909		90.9	03/13	analyzed in lab
2/28/96	12:03:54 AM	1910		92.0	03/13	analyzed in lab
2/28/96	12:24:20 AM	1911		87.7	03/13	analyzed in lab
2/28/96	12:44:49 AM	1912		93.2	03/13	analyzed in lab
2/28/96	1:05:15 AM	1913		90.4	03/13	analyzed in lab
2/28/96	1:25:42 AM	1914		90.6	03/13	analyzed in lab
2/28/96	1:46:09 AM	1915		92.9	03/13	analyzed in lab
2/28/96	2:06:36 AM	1916	L/D	91.4		
2/28/96	2:27:24 AM	1917		90.7	03/13	analyzed in lab
2/28/96	2:47:36 AM	1918		89.8	03/13	analyzed in lab
2/28/96	3:07:53 AM	1919		90.7	03/13	analyzed in lab
2/28/96	3:28:20 AM	1920		92.6	03/11	analyzed in lab
2/28/96	3:48:47 AM	1921		92.8	03/11	analyzed in lab
2/28/96	4:09:15 AM	1922		92.2	03/11	analyzed in lab
2/28/96	4:29:43 AM	1923		92.8	03/11	analyzed in lab
2/28/96	4:50:12 AM	1924		93.4	03/11	analyzed in lab
2/28/96	5:10:40 AM	1925		91.8	03/11	analyzed in lab
2/28/96	5:31:32 AM	1926		93.1	03/11	analyzed in lab
2/28/96	5:51:46 AM	1927		92.8	03/11	analyzed in lab
2/28/96	6:12:02 AM	1928		92.8	03/11	analyzed in lab
2/28/96	6:32:28 AM	1929		93.8	03/11	analyzed in lab
2/28/96	6:52:52 AM	1930		92.6	03/11	analyzed in lab
2/28/96	7:13:23 AM	1931		92.6	03/11	analyzed in lab
2/28/96	7:33:51 AM	1932				
2/28/96	7:54:17 AM	1933		95.1	03/06	analyzed in lab
2/28/96	8:14:40 AM	1934		95.1	03/06	analyzed in lab
2/28/96	8:35:22 AM	1935		96.1	03/06	analyzed in lab
2/28/96	8:55:35 AM	1936		93.5	03/06	analyzed in lab
2/28/96	9:15:58 AM	1937		97.5	03/06	analyzed in lab
2/28/96	9:36:27 AM	1938		96.5	03/06	analyzed in lab
2/28/96	9:56:54 AM	1939		93.7	03/06	analyzed in lab
2/28/96	10:17:23 AM	1940		95.5	03/06	analyzed in lab
2/28/96	10:37:47 AM	1941		94.2	03/06	analyzed in lab
2/28/96	10:58:15 AM	1942		95.5	03/06	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/28/96	11:18:42 AM	1943		95.7	03/06	analyzed in lab
2/28/96	11:39:28 AM	1944		91.1	03/13	analyzed in lab
2/28/96	11:59:41 AM	1945		91.2	03/13	analyzed in lab
2/28/96	12:19:58 PM	1946		91.8	03/13	analyzed in lab
2/28/96	12:40:23 PM	1947		90.7	03/13	analyzed in lab
2/28/96	1:00:50 PM	1948		91.7	03/13	analyzed in lab
2/28/96	1:21:29 PM	1949		91.8	03/13	analyzed in lab
2/28/96	1:41:40 PM	1950		90.5	03/13	analyzed in lab
2/28/96	2:02:09 PM	1951		92.0	03/13	analyzed in lab
2/28/96	2:22:35 PM	1952		92.4	03/13	analyzed in lab
2/28/96	2:43:18 PM	1953		91.3	03/13	analyzed in lab
2/28/96	3:03:32 PM	1954		92.3	03/13	analyzed in lab
2/28/96	3:23:52 PM	1955		91.1	03/13	analyzed in lab
2/28/96	3:44:18 PM	1956		97.4	03/12	analyzed in lab
2/28/96	4:04:44 PM	1957		95.8	03/12	analyzed in lab
2/28/96	4:25:09 PM	1958		96.9	03/12	analyzed in lab
2/28/96	4:45:35 PM	1959		93.3	03/12	analyzed in lab
2/28/96	5:06:02 PM	1960		96.3	03/12	analyzed in lab
2/28/96	5:26:26 PM	1961		95.7	03/12	analyzed in lab
2/28/96	5:47:18 PM	1962		96.9	03/12	analyzed in lab
2/28/96	6:07:31 PM	1963		95.3	03/12	analyzed in lab
2/28/96	6:27:49 PM	1964		95.4	03/12	analyzed in lab
2/28/96	6:48:12 PM	1965		97.1	03/12	analyzed in lab
2/28/96	7:08:35 PM	1966		97.2	03/12	analyzed in lab
2/28/96	7:29:01 PM	1967		97.0	03/12	analyzed in lab
2/28/96	7:49:28 PM	1968		93.4	03/06	analyzed in lab
2/28/96	8:09:55 PM	1969		93.7	03/06	analyzed in lab
2/28/96	8:30:21 PM	1970		92.9	03/06	analyzed in lab
2/28/96	8:51:11 PM	1971		92.6	03/06	analyzed in lab
2/28/96	9:11:24 PM	1972		92.6	03/06	analyzed in lab
2/28/96	9:31:44 PM	1973		93.8	03/06	analyzed in lab
2/28/96	9:52:13 PM	1974		94.3	03/06	analyzed in lab
2/28/96	10:12:40 PM	1975	L/D	97.1		
2/28/96	10:33:08 PM	1976		95.4	03/06	analyzed in lab
2/28/96	10:53:34 PM	1977		95.6	03/06	analyzed in lab
2/28/96	11:14:03 PM	1978		96.3	03/06	analyzed in lab
2/28/96	11:34:26 PM	1979		99.7	03/06	analyzed in lab
2/28/96	11:55:14 PM	1980		97.8	03/06	analyzed in lab
2/29/96	12:15:27 AM	1981	L/D*	100.4	03/06	analyzed in lab
2/29/96	12:35:46 AM	1982		99.7	03/06	analyzed in lab
2/29/96	12:56:12 AM	1983		102.2	03/06	analyzed in lab
2/29/96	1:16:42 AM	1984		100.8	03/06	analyzed in lab
2/29/96	1:37:09 AM	1985		98.0	03/06	analyzed in lab
2/29/96	1:57:30 AM	1986		99.7	03/06	analyzed in lab
2/29/96	2:17:56 AM	1987		99.3	03/06	analyzed in lab
2/29/96	2:38:25 AM	1988	L/D	98.2		
2/29/96	2:59:15 AM	1989		97.8	03/06	analyzed in lab
2/29/96	3:19:28 AM	1990		103.8	03/06	analyzed in lab
2/29/96	3:39:46 AM	1991		100.1	03/06	analyzed in lab
2/29/96	4:00:15 AM	1992		103.3	03/06	analyzed in lab
2/29/96	4:20:42 AM	1993		100.6	03/06	analyzed in lab
2/29/96	4:41:08 AM	1994		99.5	03/06	analyzed in lab
2/29/96	5:01:34 AM	1995		98.9	03/06	analyzed in lab
2/29/96	5:22:06 AM	1996		98.0	03/06	analyzed in lab
2/29/96	5:42:32 AM	1997		98.8	03/06	analyzed in lab
2/29/96	6:03:20 AM	1998	L/D*	98.5	03/06	analyzed in lab
2/29/96	6:23:34 AM	1999		91.2	03/07	analyzed in lab
2/29/96	6:43:51 AM	2000		92.0	03/07	analyzed in lab
2/29/96	7:04:17 AM	2001		92.5	03/07	analyzed in lab
2/29/96	7:24:41 AM	2002		91.3	03/07	analyzed in lab
2/29/96	7:45:06 AM	2003		92.0	03/07	analyzed in lab
2/29/96	8:05:31 AM	2004		100.1	03/04	analyzed in lab
2/29/96	8:25:54 AM	2005		98.6	03/04	analyzed in lab
2/29/96	8:46:17 AM	2006		96.9	03/04	analyzed in lab
2/29/96	9:07:02 AM	2007		99.2	03/04	analyzed in lab
2/29/96	9:27:24 AM	2008		96.4	03/05	analyzed in lab
				94.6	03/05	analyzed in lab
2/29/96	10:40:39 AM	2010		95.8	03/05	analyzed in lab
2/29/96	11:01:08 AM	2011		97.2	03/04	analyzed in lab
2/29/96	11:21:33 AM	2012		96.4	03/05	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
2/29/96	11:41:55 AM	2013		94.6	03/05	analyzed in lab
2/29/96	12:02:23 PM	2014		96.9	03/05	analyzed in lab
2/29/96	12:22:47 PM	2015		96.4	03/05	analyzed in lab
2/29/96	12:43:16 PM	2016		92.7	03/19	analyzed in lab
2/29/96	1:03:42 PM	2017	L/D	95.8		
2/29/96	1:24:11 PM	2018		98.2	03/04	analyzed in lab
2/29/96	1:44:56 PM	2019		95.0	03/04	analyzed in lab
2/29/96	2:05:10 PM	2020		98.3	03/04	analyzed in lab
2/29/96	2:25:28 PM	2021		99.2	03/04	analyzed in lab
2/29/96	2:45:53 PM	2022		95.0	03/04	analyzed in lab
2/29/96	3:06:17 PM	2023		97.7	03/04	analyzed in lab
2/29/96	3:26:40 PM	2024		96.3	03/04	analyzed in lab
2/29/96	3:47:06 PM	2025		97.0	03/04	analyzed in lab
2/29/96	4:07:34 PM	2026		95.8	03/04	analyzed in lab
2/29/96	4:27:58 PM	2027		97.7	03/04	analyzed in lab
2/29/96	4:48:51 PM	2028		98.1	03/04	analyzed in lab
2/29/96	5:09:04 PM	2029		97.0	03/04	analyzed in lab
2/29/96	5:29:22 PM	2030		98.5	03/04	analyzed in lab
2/29/96	5:49:50 PM	2031		99.4	03/04	analyzed in lab
2/29/96	6:10:14 PM	2032		98.3	03/04	analyzed in lab
2/29/96	6:30:37 PM	2033		99.0	03/04	analyzed in lab
2/29/96	6:51:00 PM	2034		97.2	03/04	analyzed in lab
2/29/96	7:11:31 PM	2035		94.8	03/04	analyzed in lab
2/29/96	7:31:59 PM	2036		98.4	03/04	analyzed in lab
2/29/96	7:52:45 PM	2037		97.6	03/04	analyzed in lab
2/29/96	8:12:58 PM	2038		94.2	03/04	analyzed in lab
2/29/96	8:33:18 PM	2039		100.3	03/04	analyzed in lab
2/29/96	8:53:40 PM	2040		97.3	03/04	analyzed in lab
2/29/96	9:14:09 PM	2041		100.6	03/04	analyzed in lab
2/29/96	9:34:38 PM	2042		98.9	03/04	analyzed in lab
2/29/96	9:55:06 PM	2043		98.4	03/04	analyzed in lab
2/29/96	10:15:33 PM	2044		97.2	03/04	analyzed in lab
2/29/96	10:35:59 PM	2045				
2/29/96	10:56:49 PM	2046		93.1	03/26	analyzed in lab
2/29/96	11:17:02 PM	2047				
2/29/96	11:37:20 PM	2048				
2/29/96	11:57:46 PM	2049		93.5	03/19	analyzed in lab
3/1/96	12:18:13 AM	2050				
3/1/96	12:38:40 AM	2051				
3/1/96	12:59:07 AM	2052	L/D	95.2		
3/1/96	1:19:35 AM	2053				
3/1/96	1:40:03 AM	2054				
3/1/96	2:00:50 AM	2055		97.0	03/19	analyzed in lab
3/1/96	2:21:03 AM	2056				
3/1/96	2:41:23 AM	2057				
3/1/96	3:01:52 AM	2058	L/D	96.7		
3/1/96	3:22:19 AM	2059				
3/1/96	3:42:49 AM	2060				
3/1/96	4:03:19 AM	2061		95.1	03/19	analyzed in lab
3/1/96	4:23:44 AM	2062				
3/1/96	4:44:14 AM	2063				
3/1/96	5:05:02 AM	2064	L/D*	94.1	03/19	analyzed in lab
3/1/96	5:25:15 AM	2065				
3/1/96	5:45:33 AM	2066				
3/1/96	6:05:58 AM	2067		94.8	03/19	analyzed in lab
3/1/96	6:26:25 AM	2068				
3/1/96	6:46:52 AM	2069				
3/1/96	7:07:15 AM	2070	L/D*	94.7	03/19	analyzed in lab
3/1/96	7:27:39 AM	2071				
3/1/96	7:48:07 AM	2072				
3/1/96	8:08:57 AM	2073		93.1	03/19	analyzed in lab
3/1/96	8:29:11 AM	2074				
3/1/96	8:49:30 AM	2075				
3/1/96	9:09:57 AM	2076	L/D	98.7		
3/1/96	9:30:23 AM	2077				
3/1/96	9:50:49 AM	2078				
3/1/96	10:11:14 AM	2079	L/D	95.3		
3/1/96	10:31:35 AM	2080				
3/1/96	10:51:59 AM	2081				
3/1/96	11:12:43 AM	2082	L/D	99.3		

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/1/96	11:32:55 AM	2083				
3/1/96	11:53:16 AM	2084				
3/1/96	12:13:42 PM	2085		96.0	03/19	analyzed in lab
3/1/96	12:34:06 PM	2086				
3/1/96	12:54:29 PM	2087				
3/1/96	1:14:54 PM	2088	L/D	97.9		
3/1/96	1:35:27 PM	2089				
3/1/96	1:55:46 PM	2090				
3/1/96	2:16:35 PM	2091		95.8	03/19	analyzed in lab
3/1/96	2:36:48 PM	2092				
3/1/96	2:57:05 PM	2093				
3/1/96	3:17:33 PM	2094	L/D	96.9		
3/1/96	3:37:59 PM	2095				
3/1/96	3:58:30 PM	2096		97.4	03/19	analyzed in lab
3/1/96	4:18:58 PM	2097		95.3	03/04	analyzed in lab
3/1/96	4:39:24 PM	2098		98.9	03/04	analyzed in lab
3/1/96	4:59:50 PM	2099		94.8	03/04	analyzed in lab
3/1/96	5:20:47 PM	2100		98.0	03/04	analyzed in lab
3/1/96	5:41:00 PM	2101		99.1	03/04	analyzed in lab
3/1/96	6:01:21 PM	2102		95.2	03/04	analyzed in lab
3/1/96	6:21:47 PM	2103		98.8	03/04	analyzed in lab
3/1/96	6:42:13 PM	2104		98.2	03/04	analyzed in lab
3/1/96	7:02:40 PM	2105		99.4	03/04	analyzed in lab
3/1/96	7:23:11 PM	2106		99.7	03/04	analyzed in lab
3/1/96	7:43:42 PM	2107		99.8	03/04	analyzed in lab
3/1/96	8:04:10 PM	2108		99.0	03/04	analyzed in lab
3/1/96	8:24:57 PM	2109				
3/1/96	8:45:11 PM	2110	L/D	97.4		
3/1/96	9:05:30 PM	2111		97.0	03/04	analyzed in lab
3/1/96	9:25:56 PM	2112		99.9	03/04	analyzed in lab
3/1/96	9:46:22 PM	2113		95.8	03/04	analyzed in lab
3/1/96	10:06:51 PM	2114		96.1	03/04	analyzed in lab
3/1/96	10:27:20 PM	2115		98.2	03/04	analyzed in lab
3/1/96	10:47:46 PM	2116		98.2	03/04	analyzed in lab
3/1/96	11:08:15 PM	2117		96.9	03/04	analyzed in lab
3/1/96	11:29:06 PM	2118		96.6	03/04	analyzed in lab
3/1/96	11:49:19 PM	2119		96.9	03/04	analyzed in lab
3/2/96	12:09:39 AM	2120		97.2	03/04	analyzed in lab
3/2/96	12:30:09 AM	2121		98.4	03/04	analyzed in lab
3/2/96	12:50:36 AM	2122		98.2	03/04	analyzed in lab
3/2/96	1:11:02 AM	2123		98.4	03/04	analyzed in lab
3/2/96	1:31:29 AM	2124		100.0	03/04	analyzed in lab
3/2/96	1:51:56 AM	2125		99.7	03/04	analyzed in lab
3/2/96	2:12:22 AM	2126		99.2	03/04	analyzed in lab
3/2/96	2:33:08 AM	2127		91.9	03/04	analyzed in lab
3/2/96	2:53:21 AM	2128		97.3	03/04	analyzed in lab
3/2/96	3:13:38 AM	2129		99.2	03/08	analyzed in lab
3/2/96	3:34:06 AM	2130		96.0	03/08	analyzed in lab
3/2/96	3:54:33 AM	2131		97.4	03/08	analyzed in lab
3/2/96	4:14:58 AM	2132		96.9	03/08	analyzed in lab
3/2/96	4:35:22 AM	2133		98.1	03/08	analyzed in lab
3/2/96	4:55:50 AM	2134		95.8	03/08	analyzed in lab
3/2/96	5:16:17 AM	2135		94.4	03/08	analyzed in lab
3/2/96	5:37:06 AM	2136		97.7	03/05	analyzed in lab
3/2/96	5:57:18 AM	2137		98.1	03/05	analyzed in lab
3/2/96	6:17:39 AM	2138		98.2	03/05	analyzed in lab
3/2/96	6:38:05 AM	2139		96.8	03/05	analyzed in lab
3/2/96	6:58:32 AM	2140	L/D	98.3		
3/2/96	7:18:58 AM	2141		97.1	03/05	analyzed in lab
3/2/96	7:39:26 AM	2142		98.5	03/19	analyzed in lab
3/2/96	7:59:52 AM	2143				
3/2/96	8:20:21 AM	2144				
3/2/96	8:41:06 AM	2145		98.6	03/19	analyzed in lab
3/2/96	9:01:19 AM	2146	L/D	95.3		
3/2/96	9:21:38 AM	2147	L/D	95.9		
3/2/96	9:42:16 AM	2148		95.9	03/19	analyzed in lab
3/2/96	10:02:33 AM	2149		94.4	03/19	analyzed in lab
3/2/96	10:22:56 AM	2150		95.5	03/19	analyzed in lab
3/2/96	10:43:20 AM	2151		95.3	03/19	analyzed in lab
3/2/96	11:03:48 AM	2152		98.2	03/19	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 19

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/2/96	11:24:17 AM	2153		94.5	03/19	analyzed in lab
3/2/96	11:45:08 AM	2154		94.8	03/19	analyzed in lab
3/2/96	12:05:21 PM	2155		97.8	03/05	analyzed in lab
3/2/96	12:25:38 PM	2156		98.2	03/05	analyzed in lab
3/2/96	12:46:01 PM	2157		98.2	03/05	analyzed in lab
3/2/96	1:06:31 PM	2158		98.3	03/05	analyzed in lab
3/2/96	1:27:00 PM	2159		97.3	03/05	analyzed in lab
3/2/96	1:47:27 PM	2160		99.7	03/05	analyzed in lab
3/2/96	2:07:56 PM	2161		98.9	03/05	analyzed in lab
3/2/96	2:28:24 PM	2162		98.2	03/05	analyzed in lab
3/2/96	2:49:11 PM	2163		98.4	03/05	analyzed in lab
3/2/96	3:09:24 PM	2164		99.8	03/05	analyzed in lab
3/2/96	3:29:42 PM	2165		101.4	03/05	analyzed in lab
3/2/96	3:50:12 PM	2166		100.3	03/05	analyzed in lab
3/2/96	4:10:40 PM	2167		99.0	03/05	analyzed in lab
3/2/96	4:31:08 PM	2168		99.8	03/05	analyzed in lab
3/2/96	4:51:35 PM	2169		99.9	03/05	analyzed in lab
3/2/96	5:12:02 PM	2170		98.8	03/05	analyzed in lab
3/2/96	5:32:26 PM	2171		98.5	03/05	analyzed in lab
3/2/96	5:53:12 PM	2172		101.2	03/05	analyzed in lab
3/2/96	6:13:25 PM	2173		98.3	03/05	analyzed in lab
3/2/96	6:33:44 PM	2174		97.3	03/05	analyzed in lab
3/2/96	6:54:15 PM	2175		97.9	03/05	analyzed in lab
3/2/96	7:14:41 PM	2176		99.1	03/05	analyzed in lab
3/2/96	7:35:09 PM	2177		96.8	03/05	analyzed in lab
3/2/96	7:55:36 PM	2178		98.7	03/05	analyzed in lab
3/2/96	8:16:04 PM	2179		99.2	03/05	analyzed in lab
3/2/96	8:36:30 PM	2180		98.5	03/05	analyzed in lab
3/2/96	8:57:21 PM	2181	L/D	98.3		
3/2/96	9:17:34 PM	2182		97.3	03/05	analyzed in lab
3/2/96	9:37:52 PM	2183		98.3	03/05	analyzed in lab
3/2/96	9:58:18 PM	2184		98.3	03/05	analyzed in lab
3/2/96	10:18:43 PM	2185		97.9	03/05	analyzed in lab
3/2/96	10:39:10 PM	2186		98.4	03/05	analyzed in lab
3/2/96	10:59:35 PM	2187		98.1	03/05	analyzed in lab
3/2/96	11:19:57 PM	2188		97.9	03/05	analyzed in lab
3/2/96	11:40:23 PM	2189		98.3	03/05	analyzed in lab
3/3/96	12:01:10 AM	2190		98.6	03/05	analyzed in lab
3/3/96	12:21:23 AM	2191		97.6	03/05	analyzed in lab
3/3/96	12:41:41 AM	2192		99.4	03/05	analyzed in lab
3/3/96	1:02:08 AM	2193		97.8	03/05	analyzed in lab
3/3/96	1:22:34 AM	2194		98.2	03/05	analyzed in lab
3/3/96	1:43:01 AM	2195		97.8	03/05	analyzed in lab
3/3/96	2:03:29 AM	2196		97.5	03/05	analyzed in lab
3/3/96	2:23:55 AM	2197	L/D*	98.3	03/05	analyzed in lab
3/3/96	2:44:22 AM	2198		97.2	03/05	analyzed in lab
3/3/96	3:05:13 AM	2199		98.6	03/05	analyzed in lab
3/3/96	3:25:26 AM	2200		98.8	03/05	analyzed in lab
3/3/96	3:45:43 AM	2201		98.5	03/05	analyzed in lab
3/3/96	4:06:10 AM	2202		99.4	03/05	analyzed in lab
3/3/96	4:26:36 AM	2203		96.5	03/05	analyzed in lab
3/3/96	4:47:02 AM	2204		96.5	03/05	analyzed in lab
3/3/96	5:07:28 AM	2205		98.0	03/05	analyzed in lab
3/3/96	5:27:59 AM	2206		95.2	03/05	analyzed in lab
3/3/96	5:48:43 AM	2207		97.0	03/05	analyzed in lab
3/3/96	6:09:21 AM	2208		98.1	03/05	analyzed in lab
3/3/96	6:29:34 AM	2209	L/D*	96.4	03/05	analyzed in lab
3/3/96	6:49:52 AM	2210		97.3	03/05	analyzed in lab
3/3/96	7:10:17 AM	2211		95.8	03/05	analyzed in lab
3/3/96	7:30:42 AM	2212		96.8	03/05	analyzed in lab
3/3/96	7:51:12 AM	2213		97.0	03/05	analyzed in lab
3/3/96	8:11:36 AM	2214		94.5	03/05	analyzed in lab
3/3/96	8:31:59 AM	2215		95.1	03/05	analyzed in lab
3/3/96	8:52:28 AM	2216		96.8	03/05	analyzed in lab
3/3/96	9:13:14 AM	2217		97.4	03/05	analyzed in lab
3/3/96	9:33:27 AM	2218		96.6	03/05	analyzed in lab
3/3/96	9:53:46 AM	2219		96.2	03/05	analyzed in lab
3/3/96	10:14:10 AM	2220		95.8	03/05	analyzed in lab
3/3/96	10:34:33 AM	2221		95.1	03/05	analyzed in lab
3/3/96	10:54:59 AM	2222		92.5	03/05	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/3/96	11:15:24 AM	2223		95.6	03/05	analyzed in lab
3/3/96	11:35:47 AM	2224		95.5	03/05	analyzed in lab
3/3/96	11:56:15 AM	2225		95.7	03/05	analyzed in lab
3/3/96	12:17:12 PM	2226		95.6	03/05	analyzed in lab
3/3/96	12:37:25 PM	2227		95.5	03/05	analyzed in lab
3/3/96	12:57:42 PM	2228		94.4	03/05	analyzed in lab
3/3/96	1:18:04 PM	2229		95.9	03/05	analyzed in lab
3/3/96	1:38:31 PM	2230		96.3	03/05	analyzed in lab
3/3/96	1:58:57 PM	2231		95.1	03/05	analyzed in lab
3/3/96	2:19:23 PM	2232		94.6	03/05	analyzed in lab
3/3/96	2:39:51 PM	2233		94.5	03/05	analyzed in lab
3/3/96	3:00:16 PM	2234	L/D*	95.7	03/05	analyzed in lab
3/3/96	3:21:06 PM	2235		97.3	03/05	analyzed in lab
3/3/96	3:41:19 PM	2236		99.5	03/05	analyzed in lab
3/3/96	4:01:38 PM	2237		97.7	03/05	analyzed in lab
3/3/96	4:22:06 PM	2238		97.2	03/05	analyzed in lab
3/3/96	4:42:36 PM	2239		96.6	03/05	analyzed in lab
3/3/96	5:03:02 PM	2240		98.1	03/05	analyzed in lab
3/3/96	5:23:29 PM	2241		96.0	03/05	analyzed in lab
3/3/96	5:43:56 PM	2242		97.0	03/05	analyzed in lab
3/3/96	6:04:22 PM	2243		96.2	03/05	analyzed in lab
3/3/96	6:25:09 PM	2244		96.2	03/05	analyzed in lab
3/3/96	6:45:22 PM	2245		96.0	03/06	analyzed in lab
3/3/96	7:05:43 PM	2246		99.6	03/06	analyzed in lab
3/3/96	7:26:07 PM	2247		96.8	03/06	analyzed in lab
3/3/96	7:46:35 PM	2248		97.7	03/06	analyzed in lab
3/3/96	8:07:00 PM	2249	L/D*	97.0	03/06	analyzed in lab
3/3/96	8:27:31 PM	2250		99.5	03/06	analyzed in lab
3/3/96	8:47:55 PM	2251		97.2	03/06	analyzed in lab
3/3/96	9:08:22 PM	2252		99.4	03/06	analyzed in lab
3/3/96	9:29:07 PM	2253		97.6	03/06	analyzed in lab
3/3/96	9:49:20 PM	2254		98.3	03/06	analyzed in lab
3/3/96	10:09:36 PM	2255		97.9	03/06	analyzed in lab
3/3/96	10:30:05 PM	2256		97.9	03/06	analyzed in lab
3/3/96	10:50:30 PM	2257		96.5	03/06	analyzed in lab
3/3/96	11:10:55 PM	2258		98.3	03/06	analyzed in lab
3/3/96	11:31:23 PM	2259		97.8	03/06	analyzed in lab
3/3/96	11:51:47 PM	2260		99.2	03/06	analyzed in lab
3/4/96	12:12:10 AM	2261		97.6	03/06	analyzed in lab
3/4/96	12:32:55 AM	2262		100.0	03/06	analyzed in lab
3/4/96	12:53:08 AM	2263		97.6	03/06	analyzed in lab
3/4/96	1:13:28 AM	2264		101.2	03/06	analyzed in lab
3/4/96	1:33:56 AM	2265		96.5	03/06	analyzed in lab
3/4/96	1:54:43 AM	2266		99.4	03/06	analyzed in lab
3/4/96	2:14:56 AM	2267		97.4	03/06	analyzed in lab
3/4/96	2:35:18 AM	2268		98.8	03/06	analyzed in lab
3/4/96	2:55:47 AM	2269	L/D	93.6		
3/4/96	3:16:15 AM	2270		95.1	03/08	analyzed in lab
3/4/96	3:37:02 AM	2271		94.8	03/08	analyzed in lab
3/4/96	3:57:15 AM	2272		95.6	03/08	analyzed in lab
3/4/96	4:17:35 AM	2273		94.4	03/08	analyzed in lab
3/4/96	4:38:02 AM	2274		91.9	03/11	analyzed in lab
3/4/96	4:58:32 AM	2275		92.6	03/11	analyzed in lab
3/4/96	5:19:01 AM	2276		94.9	03/08	analyzed in lab
3/4/96	5:39:28 AM	2277		101.4	03/08	analyzed in lab
3/4/96	5:59:54 AM	2278		93.9	03/08	analyzed in lab
3/4/96	6:20:20 AM	2279		94.8	03/08	analyzed in lab
3/4/96	6:41:08 AM	2280		94.4	03/08	analyzed in lab
3/4/96	7:01:21 AM	2281		95.0	03/08	analyzed in lab
3/4/96	7:21:39 AM	2282		95.2	03/08	analyzed in lab
3/4/96	7:42:06 AM	2283		94.5	03/08	analyzed in lab
3/4/96	8:02:35 AM	2284		95.7	03/08	analyzed in lab
3/4/96	8:22:58 AM	2285		93.6	03/08	analyzed in lab
3/4/96	8:43:24 AM	2286		92.3	03/08	analyzed in lab
3/4/96	9:03:51 AM	2287		94.1	03/08	analyzed in lab
3/4/96	9:24:16 AM	2288		91.5	03/08	analyzed in lab
3/4/96	9:45:01 AM	2289	L/F-D*	91.5	03/19	analyzed in lab
3/4/96	10:05:14 AM	2290	L/F-D*	94.0	03/19	analyzed in lab
3/4/96	10:25:30 AM	2291	L/F-D*	93.3	03/19	analyzed in lab
3/4/96	10:45:54 AM	2292		98.5	03/04	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/4/96	11:06:22 AM	2293	L/F-D*	93.6	03/19	analyzed in lab
3/4/96	11:26:49 AM	2294	L/F-D*	92.2	03/19	analyzed in lab
3/4/96	11:47:11 AM	2295		89.0	03/04	analyzed in field
3/4/96	12:07:39 PM	2296	L/F-D*	91.5	03/19	analyzed in lab
3/4/96	12:28:04 PM	2297	L/F-D*	91.0	03/19	analyzed in lab
3/4/96	12:48:50 PM	2298		90.1	03/04	analyzed in field
3/4/96	1:09:03 PM	2299	L/F-D*	93.5	03/19	analyzed in lab
3/4/96	1:29:20 PM	2300		92.7	03/08	analyzed in lab
3/4/96	1:49:44 PM	2301		93.7	03/08	analyzed in lab
3/4/96	2:10:09 PM	2302		91.9	03/08	analyzed in lab
3/4/96	2:30:34 PM	2303		90.9	03/08	analyzed in lab
3/4/96	2:50:59 PM	2304		91.8	03/08	analyzed in lab
3/4/96	3:11:21 PM	2305		93.2	03/08	analyzed in lab
3/4/96	3:31:47 PM	2306		93.7	03/08	analyzed in lab
3/4/96	3:52:35 PM	2307		92.6	03/08	analyzed in lab
3/4/96	4:12:48 PM	2308		94.7	03/08	analyzed in lab
3/4/96	4:33:04 PM	2309		92.3	03/08	analyzed in lab
3/4/96	4:53:31 PM	2310		91.9	03/08	analyzed in lab
3/4/96	5:13:57 PM	2311		92.0	03/08	analyzed in lab
3/4/96	5:34:20 PM	2312		92.2	03/08	analyzed in lab
3/4/96	5:54:44 PM	2313		87.4	03/08	analyzed in lab
3/4/96	6:15:11 PM	2314		91.6	03/08	analyzed in lab
3/4/96	6:35:39 PM	2315		93.2	03/08	analyzed in lab
3/4/96	6:56:31 PM	2316		91.8	03/08	analyzed in lab
3/4/96	7:16:43 PM	2317		91.8	03/08	analyzed in lab
3/4/96	7:37:05 PM	2318		91.9	03/08	analyzed in lab
3/4/96	7:57:32 PM	2319	L/D	91.4		
3/4/96	8:18:01 PM	2320		91.3	03/08	analyzed in lab
3/4/96	8:38:31 PM	2321		90.9	03/07	analyzed in lab
3/4/96	8:58:57 PM	2322		90.0	03/07	analyzed in lab
3/4/96	9:19:23 PM	2323		90.8	03/07	analyzed in lab
3/4/96	9:39:50 PM	2324		90.8	03/07	analyzed in lab
3/4/96	10:00:50 PM	2325		90.5	03/07	analyzed in lab
3/4/96	10:21:03 PM	2326		91.0	03/07	analyzed in lab
3/4/96	10:41:16 PM	2327		91.8	03/07	analyzed in lab
3/4/96	11:01:45 PM	2328		91.0	03/07	analyzed in lab
3/4/96	11:22:14 PM	2329		91.2	03/07	analyzed in lab
3/4/96	11:42:41 PM	2330		89.8	03/07	analyzed in lab
3/5/96	12:03:06 AM	2331	L/D*	91.7	03/07	analyzed in lab
3/5/96	12:23:35 AM	2332		90.5	03/07	analyzed in lab
3/5/96	12:44:01 AM	2333		91.6	03/07	analyzed in lab
3/5/96	1:04:53 AM	2334		90.9	03/07	analyzed in lab
3/5/96	1:25:06 AM	2335		91.4	03/07	analyzed in lab
3/5/96	1:45:23 AM	2336		90.9	03/07	analyzed in lab
3/5/96	2:05:51 AM	2337		90.9	03/07	analyzed in lab
3/5/96	2:26:16 AM	2338		90.0	03/07	analyzed in lab
3/5/96	2:46:43 AM	2339		90.7	03/07	analyzed in lab
3/5/96	3:07:08 AM	2340		90.6	03/07	analyzed in lab
3/5/96	3:27:31 AM	2341		91.8	03/07	analyzed in lab
3/5/96	3:48:00 AM	2342		90.7	03/07	analyzed in lab
3/5/96	4:08:50 AM	2343		91.9	03/07	analyzed in lab
3/5/96	4:29:03 AM	2344		90.9	03/07	analyzed in lab
3/5/96	4:49:19 AM	2345		89.5	03/08	analyzed in lab
3/5/96	5:09:45 AM	2346		87.5	03/08	analyzed in lab
3/5/96	5:30:12 AM	2347		88.3	03/08	analyzed in lab
3/5/96	5:50:38 AM	2348		88.4	03/08	analyzed in lab
3/5/96	6:10:59 AM	2349		89.1	03/08	analyzed in lab
3/5/96	6:31:25 AM	2350		89.5	03/08	analyzed in lab
3/5/96	6:51:55 AM	2351		91.2	03/08	analyzed in lab
3/5/96	7:12:49 AM	2352		89.2	03/08	analyzed in lab
3/5/96	7:33:02 AM	2353		88.9	03/08	analyzed in lab
3/5/96	7:53:22 AM	2354		88.2	03/08	analyzed in lab
3/5/96	8:13:49 AM	2355		88.7	03/08	analyzed in lab
3/5/96	8:34:15 AM	2356		88.2	03/08	analyzed in lab
3/5/96	8:54:42 AM	2357		88.9	03/08	analyzed in lab
3/5/96	9:15:08 AM	2358		89.5	03/08	analyzed in lab
3/5/96	9:35:32 AM	2359	L/D	89.7		
3/5/96	9:55:58 AM	2360		90.8	03/08	analyzed in lab
3/5/96	10:16:42 AM	2361		88.9	03/08	analyzed in lab
3/5/96	10:36:55 AM	2362		90.7	03/08	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/5/96	10:57:10 AM	2363		90.9	03/08	analyzed in lab
3/5/96	11:17:38 AM	2364		89.4	03/08	analyzed in lab
3/5/96	11:38:02 AM	2365		90.0	03/08	analyzed in lab
3/5/96	11:58:31 AM	2366		88.7	03/08	analyzed in lab
3/5/96	12:19:01 PM	2367		88.7	03/08	analyzed in lab
3/5/96	12:39:26 PM	2368		90.2	03/08	analyzed in lab
3/5/96	12:59:52 PM	2369		90.4	03/07	analyzed in lab
3/5/96	1:20:41 PM	2370		90.6	03/07	analyzed in lab
3/5/96	1:40:54 PM	2371		88.8	03/07	analyzed in lab
3/5/96	2:01:12 PM	2372		89.8	03/07	analyzed in lab
3/5/96	2:21:43 PM	2373		89.7	03/07	analyzed in lab
3/5/96	2:42:09 PM	2374		88.2	03/07	analyzed in lab
3/5/96	3:02:36 PM	2375		89.8	03/07	analyzed in lab
3/5/96	3:23:00 PM	2376		89.9	03/07	analyzed in lab
3/5/96	3:43:24 PM	2377		87.1	03/07	analyzed in lab
3/5/96	4:03:55 PM	2378		87.2	03/07	analyzed in lab
3/5/96	4:24:41 PM	2379		86.3	03/07	analyzed in lab
3/5/96	4:44:53 PM	2380	L/D	85.1		
3/5/96	5:05:14 PM	2381		88.0	03/07	analyzed in lab
3/5/96	5:25:41 PM	2382		85.0	03/07	analyzed in lab
3/5/96	5:46:06 PM	2383		86.6	03/07	analyzed in lab
3/5/96	6:06:57 PM	2384		86.9	03/07	analyzed in lab
3/5/96	6:27:10 PM	2385		89.9	03/07	analyzed in lab
3/5/96	6:47:30 PM	2386		85.8	03/07	analyzed in lab
3/5/96	7:07:59 PM	2387		87.3	03/07	analyzed in lab
3/5/96	7:28:53 PM	2388		85.0	03/08	analyzed in lab
3/5/96	7:49:06 PM	2389		84.0	03/08	analyzed in lab
3/5/96	8:09:23 PM	2390		84.8	03/08	analyzed in lab
3/5/96	8:29:48 PM	2391		85.0	03/08	analyzed in lab
3/5/96	8:50:13 PM	2392		81.1	03/08	analyzed in lab
3/5/96	9:10:43 PM	2393		85.5	03/07	analyzed in lab
3/5/96	9:31:08 PM	2394		85.7	03/07	analyzed in lab
3/5/96	9:51:33 PM	2395		86.0	03/07	analyzed in lab
3/5/96	10:11:58 PM	2396		85.3	03/07	analyzed in lab
3/5/96	10:32:50 PM	2397		85.7	03/07	analyzed in lab
3/5/96	10:53:03 PM	2398		85.9	03/07	analyzed in lab
3/5/96	11:13:23 PM	2399		87.4	03/07	analyzed in lab
3/5/96	11:33:47 PM	2400		86.4	03/07	analyzed in lab
3/5/96	11:54:15 PM	2401		87.9	03/07	analyzed in lab
3/6/96	12:14:41 AM	2402		88.7	03/07	analyzed in lab
3/6/96	12:35:08 AM	2403		86.8	03/07	analyzed in lab
3/6/96	12:55:36 AM	2404		88.1	03/07	analyzed in lab
3/6/96	1:16:04 AM	2405	L/F-D	88.1		
3/6/96	1:36:57 AM	2406		86.5	03/06	analyzed in field
3/6/96	1:57:09 AM	2407	L/F-D	88.5		
3/6/96	2:17:30 AM	2408	L/F-D	88.7		
3/6/96	2:37:59 AM	2409		82.3	03/06	analyzed in field
3/6/96	2:58:26 AM	2410		87.7	03/11	analyzed in lab
3/6/96	3:18:53 AM	2411		87.6	03/11	analyzed in lab
3/6/96	3:39:19 AM	2412		87.9	03/11	analyzed in lab
3/6/96	3:59:52 AM	2413		86.8	03/11	analyzed in lab
3/6/96	4:20:19 AM	2414		86.7	03/11	analyzed in lab
3/6/96	4:41:11 AM	2415		85.1	03/06	analyzed in field
3/6/96	5:01:25 AM	2416	L/F-D	85.0		
3/6/96	5:21:43 AM	2417	L/F-D*	87.1	03/06	analyzed in field
3/6/96	5:42:15 AM	2418		86.0	03/06	analyzed in field
3/6/96	6:02:46 AM	2419	L/F-D	87.2		
3/6/96	6:23:14 AM	2420	L/F-D*	85.3	04/19	analyzed in lab
3/6/96	6:43:43 AM	2421		85.8	03/06	analyzed in field
3/6/96	7:04:10 AM	2422	L/F-D*	86.7	03/19	analyzed in lab
3/6/96	7:24:36 AM	2423	L/F-D	87.4		
3/6/96	7:45:28 AM	2424		89.4	03/06	analyzed in field
3/6/96	8:05:41 AM	2425	L/F-D	86.6		
3/6/96	8:26:01 AM	2426		86.5	03/06	analyzed in field
3/6/96	8:46:28 AM	2427		87.0	03/06	analyzed in field
3/6/96	9:06:56 AM	2428		83.3	03/06	analyzed in field
3/6/96	9:27:17 AM	2429		84.6	03/06	analyzed in field
3/6/96	9:47:45 AM	2430		85.6	03/06	analyzed in field
3/6/96	10:08:12 AM	2431		87.8	03/06	analyzed in field
3/6/96	10:28:37 AM	2432		84.1	03/06	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/6/96	10:49:29 AM	2433		85.8	03/06	analyzed in field
3/6/96	11:09:42 AM	2434		83.9	03/06	analyzed in field
3/6/96	11:30:02 AM	2435		84.7	03/06	analyzed in field
3/6/96	11:50:28 AM	2436		84.0	03/06	analyzed in field
3/6/96	12:10:57 PM	2437		87.0	03/06	analyzed in field
3/6/96	12:31:24 PM	2438		85.6	03/06	analyzed in field
3/6/96	12:51:50 PM	2439		84.3	03/06	analyzed in field
3/6/96	1:12:17 PM	2440		83.9	03/06	analyzed in field
3/6/96	1:32:47 PM	2441		86.0	03/06	analyzed in field
3/6/96	1:53:37 PM	2442		85.8	03/11	analyzed in lab
3/6/96	2:14:15 PM	2443		85.5	03/11	analyzed in lab
3/6/96	2:34:28 PM	2444		85.4	03/11	analyzed in lab
3/6/96	2:54:40 PM	2445		85.9	03/11	analyzed in lab
3/6/96	3:15:08 PM	2446		84.8	03/11	analyzed in lab
3/6/96	3:35:36 PM	2447		87.1	03/11	analyzed in lab
3/6/96	3:56:01 PM	2448		87.6	03/11	analyzed in lab
3/6/96	4:16:31 PM	2449		87.1	03/11	analyzed in lab
3/6/96	4:36:57 PM	2450		87.7	03/11	analyzed in lab
3/6/96	4:57:39 PM	2451		87.8	03/11	analyzed in lab
3/6/96	5:17:52 PM	2452		87.7	03/11	analyzed in lab
3/6/96	5:38:09 PM	2453		86.3	03/11	analyzed in lab
3/6/96	5:58:35 PM	2454		86.7	03/11	analyzed in lab
3/6/96	6:19:02 PM	2455	L/D	87.6		
3/6/96	6:39:26 PM	2456		87.1	03/11	analyzed in lab
3/6/96	6:59:56 PM	2457		86.7	03/11	analyzed in lab
3/6/96	7:20:21 PM	2458		86.8	03/11	analyzed in lab
3/6/96	7:40:50 PM	2459		86.7	03/11	analyzed in lab
3/6/96	8:01:42 PM	2460		86.4	03/11	analyzed in lab
3/6/96	8:21:54 PM	2461		88.0	03/20	analyzed in lab
3/6/96	8:42:14 PM	2462		83.8	03/20	analyzed in lab
3/6/96	9:02:41 PM	2463		86.3	03/20	analyzed in lab
3/6/96	9:23:08 PM	2464		85.6	03/20	analyzed in lab
3/6/96	9:43:35 PM	2465		86.9	03/20	analyzed in lab
3/6/96	10:03:59 PM	2466		86.3	03/20	analyzed in lab
3/6/96	10:24:28 PM	2467		82.5	03/20	analyzed in lab
3/6/96	10:44:56 PM	2468		85.4	03/20	analyzed in lab
3/6/96	11:05:48 PM	2469		87.2	03/20	analyzed in lab
3/6/96	11:26:02 PM	2470		84.7	03/20	analyzed in lab
3/6/96	11:46:21 PM	2471		85.2	03/20	analyzed in lab
3/7/96	12:06:48 AM	2472		84.1	03/20	analyzed in lab
3/7/96	12:27:18 AM	2473		83.8	03/20	analyzed in lab
3/7/96	12:47:44 AM	2474		85.0	03/20	analyzed in lab
3/7/96	1:08:14 AM	2475		84.9	03/20	analyzed in lab
3/7/96	1:28:38 AM	2476		84.3	03/20	analyzed in lab
3/7/96	1:49:15 AM	2477		83.1	03/20	analyzed in lab
3/7/96	2:10:01 AM	2478	L/D	81.0		
3/7/96	2:30:14 AM	2479		82.1	03/20	analyzed in lab
3/7/96	2:50:34 AM	2480		81.5	03/20	analyzed in lab
3/7/96	3:10:59 AM	2481		81.0	03/20	analyzed in lab
3/7/96	3:31:24 AM	2482		81.0	03/20	analyzed in lab
3/7/96	3:51:52 AM	2483		82.4	03/20	analyzed in lab
3/7/96	4:12:18 AM	2484		82.8	03/20	analyzed in lab
3/7/96	4:32:41 AM	2485		80.4	03/20	analyzed in lab
3/7/96	4:53:12 AM	2486		82.4	03/20	analyzed in lab
3/7/96	5:14:02 AM	2487	L/D	79.8		
3/7/96	5:34:15 AM	2488		79.9	03/20	analyzed in lab
3/7/96	5:54:37 AM	2489		83.8	03/20	analyzed in lab
3/7/96	6:15:01 AM	2490		82.0	03/20	analyzed in lab
3/7/96	6:35:28 AM	2491		81.1	03/20	analyzed in lab
3/7/96	6:56:00 AM	2492		79.8	03/20	analyzed in lab
3/7/96	7:16:28 AM	2493		79.1	03/20	analyzed in lab
3/7/96	7:36:55 AM	2494		81.4	03/20	analyzed in lab
3/7/96	7:57:22 AM	2495		79.0	03/20	analyzed in lab
3/7/96	8:18:12 AM	2496		80.1	03/20	analyzed in lab
3/7/96	8:38:25 AM	2497	L/D	83.7		
3/7/96	8:58:42 AM	2498		80.3	03/20	analyzed in lab
3/7/96	9:19:07 AM	2499		82.0	03/20	analyzed in lab
3/7/96	9:39:32 AM	2500		83.0	03/20	analyzed in lab
3/7/96	9:59:58 AM	2501		81.0	03/20	analyzed in lab
				82.4	03/20	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
				80.6	03/20	analyzed in lab
3/7/96	1:02:28 PM	2504		83.6	03/20	analyzed in lab
3/7/96	1:09:47 PM	2504				
3/7/96	1:15:27 PM	2505		81.5	03/20	analyzed in lab
3/7/96	1:35:40 PM	2506		85.0	03/20	analyzed in lab
3/7/96	1:55:58 PM	2507		82.6	03/20	analyzed in lab
3/7/96	2:16:24 PM	2508		84.9	03/20	analyzed in lab
3/7/96	2:36:48 PM	2509		84.1	03/11	analyzed in lab
3/7/96	2:57:12 PM	2510		85.3	03/11	analyzed in lab
3/7/96	3:17:37 PM	2511		83.8	03/11	analyzed in lab
3/7/96	3:38:04 PM	2512		83.5	03/11	analyzed in lab
3/7/96	3:58:51 PM	2513		84.5	03/11	analyzed in lab
3/7/96	4:19:03 PM	2514		85.5	03/11	analyzed in lab
3/7/96	4:39:22 PM	2515		84.9	03/11	analyzed in lab
3/7/96	4:59:54 PM	2516		84.7	03/11	analyzed in lab
3/7/96	5:20:22 PM	2517		85.2	03/11	analyzed in lab
3/7/96	5:40:53 PM	2518		85.4	03/11	analyzed in lab
3/7/96	6:01:16 PM	2519		85.6	03/11	analyzed in lab
3/7/96	6:21:39 PM	2520		85.5	03/11	analyzed in lab
3/7/96	6:42:07 PM	2521		86.0	03/11	analyzed in lab
3/7/96	7:02:58 PM	2522		85.1	03/11	analyzed in lab
3/7/96	7:23:11 PM	2523		85.4	03/11	analyzed in lab
3/7/96	7:43:29 PM	2524		86.0	03/11	analyzed in lab
3/7/96	8:04:00 PM	2525		84.7	03/11	analyzed in lab
3/7/96	8:24:26 PM	2526		84.9	03/11	analyzed in lab
3/7/96	8:44:54 PM	2527		85.0	03/11	analyzed in lab
3/7/96	9:05:21 PM	2528		85.4	03/11	analyzed in lab
3/7/96	9:25:47 PM	2529	L/D	84.6		
3/7/96	9:46:15 PM	2530		83.1	03/11	analyzed in lab
3/7/96	10:07:12 PM	2531		85.3	03/11	analyzed in lab
3/7/96	10:27:25 PM	2532		84.2	03/11	analyzed in lab
3/7/96	10:47:42 PM	2533		83.2	03/11	analyzed in lab
3/7/96	11:08:07 PM	2534		82.9	03/11	analyzed in lab
3/7/96	11:28:33 PM	2535		83.0	03/11	analyzed in lab
3/7/96	11:49:00 PM	2536		83.0	03/11	analyzed in lab
3/8/96	12:09:30 AM	2537		82.6	03/11	analyzed in lab
3/8/96	12:29:57 AM	2538		84.0	03/11	analyzed in lab
3/8/96	12:50:23 AM	2539		82.9	03/11	analyzed in lab
3/8/96	1:11:13 AM	2540		82.5	03/11	analyzed in lab
3/8/96	1:31:26 AM	2541		78.7	03/11	analyzed in lab
3/8/96	1:51:44 AM	2542		82.9	03/11	analyzed in lab
3/8/96	2:12:11 AM	2543		83.1	03/11	analyzed in lab
3/8/96	2:32:40 AM	2544		82.1	03/11	analyzed in lab
3/8/96	2:53:05 AM	2545		83.5	03/11	analyzed in lab
3/8/96	3:13:32 AM	2546		87.2	03/11	analyzed in lab
3/8/96	3:34:07 AM	2547		82.0	03/11	analyzed in lab
3/8/96	3:54:37 AM	2548	L/D	83.7		
3/8/96	4:15:26 AM	2549		82.1	03/11	analyzed in lab
3/8/96	4:35:38 AM	2550		79.9	03/11	analyzed in lab
3/8/96	4:55:55 AM	2551		80.7	03/11	analyzed in lab
3/8/96	5:16:20 AM	2552		84.1	03/11	analyzed in lab
3/8/96	5:36:47 AM	2553		81.8	03/11	analyzed in lab
3/8/96	5:57:13 AM	2554		80.8	03/11	analyzed in lab
3/8/96	6:17:43 AM	2555		83.1	03/11	analyzed in lab
3/8/96	6:38:10 AM	2556		82.7	03/11	analyzed in lab
3/8/96	6:58:33 AM	2557		77.7	03/20	analyzed in lab
3/8/96	7:19:24 AM	2558		78.9	03/20	analyzed in lab
3/8/96	7:39:37 AM	2559		78.9	03/20	analyzed in lab
3/8/96	7:59:56 AM	2560		80.1	03/08	analyzed in field
3/8/96	8:20:27 AM	2561	F/D	78.6		
3/8/96	8:41:03 AM	2562		78.9	03/08	analyzed in field
3/8/96	9:02:06 AM	2563		79.0	03/08	analyzed in field
3/8/96	9:22:19 AM	2564		80.1	03/08	analyzed in field
3/8/96	9:42:31 AM	2565		78.7	03/08	analyzed in field
3/8/96	10:02:53 AM	2566		80.6	03/08	analyzed in field
3/8/96	10:23:45 AM	2567		80.5	03/08	analyzed in field
3/8/96	10:43:58 AM	2568		78.1	03/08	analyzed in field
3/8/96	11:04:16 AM	2569		76.8	03/08	analyzed in field
3/8/96	11:24:46 AM	2570		80.0	03/08	analyzed in field
3/8/96	11:45:14 AM	2571		79.9	03/08	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/8/96	12:05:37 PM	2572		78.4	03/08	analyzed in field
3/8/96	12:26:03 PM	2573		74.4	03/08	analyzed in field
3/8/96	12:46:29 PM	2574		78.9	03/08	analyzed in field
3/8/96	1:06:55 PM	2575		78.5	03/08	analyzed in field
3/8/96	1:27:51 PM	2576		78.0	03/08	analyzed in field
3/8/96	1:48:04 PM	2577		76.7	03/20	analyzed in lab
3/8/96	2:08:20 PM	2578		76.0	03/20	analyzed in lab
3/8/96	2:38:47 PM	2579		78.4	03/20	analyzed in lab
3/8/96	3:09:27 PM	2580		77.3	03/20	analyzed in lab
3/8/96	3:40:09 PM	2581		76.9	03/20	analyzed in lab
3/8/96	4:10:46 PM	2582		78.4	03/20	analyzed in lab
3/8/96	4:41:24 PM	2583	L/D	78.0		
3/8/96	5:12:02 PM	2584		75.2	03/20	analyzed in lab
3/8/96	5:43:18 PM	2585		77.8	03/20	analyzed in lab
3/8/96	6:13:31 PM	2586		79.2	03/20	analyzed in lab
3/8/96	6:44:08 PM	2587		78.8	03/20	analyzed in lab
3/8/96	7:14:48 PM	2588		77.1	03/20	analyzed in lab
3/8/96	7:45:30 PM	2589		77.7	03/20	analyzed in lab
3/8/96	8:16:09 PM	2590		77.6	03/20	analyzed in lab
3/8/96	8:46:48 PM	2591		77.4	03/20	analyzed in lab
3/8/96	9:17:26 PM	2592		77.3	03/20	analyzed in lab
3/8/96	9:48:10 PM	2593		76.6	03/20	analyzed in lab
3/8/96	10:18:58 PM	2594		75.9	03/20	analyzed in lab
3/8/96	10:49:35 PM	2595		78.0	03/20	analyzed in lab
3/8/96	11:20:18 PM	2596		75.0	03/20	analyzed in lab
3/8/96	11:50:30 PM	2597		76.6	03/20	analyzed in lab
3/9/96	12:20:56 AM	2598		81.4	03/12	analyzed in lab
3/9/96	12:51:36 AM	2599		80.1	03/12	analyzed in lab
3/9/96	1:22:19 AM	2600		82.9	03/12	analyzed in lab
3/9/96	1:53:00 AM	2601		83.2	03/12	analyzed in lab
3/9/96	2:23:41 AM	2602		82.0	03/12	analyzed in lab
3/9/96	2:54:27 AM	2603		83.3	03/12	analyzed in lab
3/9/96	3:25:01 AM	2604		82.0	03/12	analyzed in lab
3/9/96	3:55:42 AM	2605		81.0	03/12	analyzed in lab
3/9/96	4:26:21 AM	2606		81.2	03/12	analyzed in lab
3/9/96	4:56:34 AM	2607		80.8	03/12	analyzed in lab
3/9/96	5:26:58 AM	2608		80.7	03/12	analyzed in lab
3/9/96	5:57:41 AM	2609		82.3	03/12	analyzed in lab
3/9/96	6:28:23 AM	2610		77.0	04/02	analyzed in field
3/9/96	6:59:01 AM	2611		76.8	04/02	analyzed in field
3/9/96	7:30:18 AM	2612		76.8	04/02	analyzed in field
3/9/96	8:00:31 AM	2613		76.1	04/02	analyzed in field
3/9/96	8:31:06 AM	2614		76.7	04/02	analyzed in field
3/9/96	9:01:44 AM	2615		76.6	04/02	analyzed in field
3/9/96	9:32:23 AM	2616		75.7	04/02	analyzed in field
3/9/96	10:03:01 AM	2617		75.8	04/02	analyzed in field
3/9/96	10:33:44 AM	2618	F/D	76.5		
3/9/96	11:04:20 AM	2619		75.6	04/02	analyzed in field
3/9/96	11:34:59 AM	2620		76.2	04/02	analyzed in field
3/9/96	12:05:25 PM	2621		76.8	04/02	analyzed in field
3/9/96	12:35:38 PM	2622		80.1	03/12	analyzed in lab
3/9/96	1:06:12 PM	2623		79.2	03/12	analyzed in lab
3/9/96	1:36:55 PM	2624		79.6	03/12	analyzed in lab
3/9/96	2:07:32 PM	2625		80.6	03/12	analyzed in lab
3/9/96	2:38:12 PM	2626		78.9	03/12	analyzed in lab
3/9/96	3:08:50 PM	2627		82.9	03/12	analyzed in lab
3/9/96	3:39:03 PM	2628		79.7	03/12	analyzed in lab
3/9/96	4:09:39 PM	2629		79.3	03/12	analyzed in lab
3/9/96	4:40:07 PM	2630		80.6	03/12	analyzed in lab
3/9/96	5:10:34 PM	2631		80.0	03/12	analyzed in lab
3/9/96	5:41:13 PM	2632		80.7	03/12	analyzed in lab
3/9/96	6:11:53 PM	2633		81.0	03/12	analyzed in lab
3/9/96	6:42:32 PM	2634		76.1	03/12	analyzed in lab
3/9/96	7:13:16 PM	2635		81.5	03/12	analyzed in lab
3/9/96	7:45:08 PM	2636		79.8	03/12	analyzed in lab
3/9/96	8:15:45 PM	2637		79.8	03/12	analyzed in lab
3/9/96	8:46:24 PM	2638		79.5	03/12	analyzed in lab
3/9/96	9:17:12 PM	2639		80.4	03/12	analyzed in lab
3/9/96	9:47:54 PM	2640		79.6	03/12	analyzed in lab
3/9/96	10:18:35 PM	2641		80.5	03/12	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/9/96	10:49:12 PM	2642	L/D	79.9		analyzed in lab
3/9/96	11:19:26 PM	2643		79.1	03/12	analyzed in lab
3/9/96	11:49:58 PM	2644		75.0	03/12	analyzed in lab
3/10/96	12:20:16 AM	2645		76.6	03/12	analyzed in lab
3/10/96	12:50:30 AM	2646		71.9	03/20	analyzed in lab
3/10/96	1:21:05 AM	2647	L/D	72.7		
3/10/96	1:51:50 AM	2648		72.2	03/20	analyzed in lab
3/10/96	2:22:21 AM	2649		73.1	03/20	analyzed in lab
3/10/96	2:53:00 AM	2650		70.0	03/20	analyzed in lab
3/10/96	3:23:40 AM	2651		72.4	03/20	analyzed in lab
3/10/96	3:54:18 AM	2652		71.5	03/20	analyzed in lab
3/10/96	4:25:00 AM	2653		72.1	03/20	analyzed in lab
3/10/96	4:55:40 AM	2654		74.7	03/20	analyzed in lab
3/10/96	5:26:24 AM	2655		71.0	03/20	analyzed in lab
3/10/96	5:56:37 AM	2656		74.1	03/20	analyzed in lab
3/10/96	6:27:43 AM	2657		68.8	03/20	analyzed in lab
3/10/96	6:57:57 AM	2658		72.3	03/20	analyzed in lab
3/10/96	7:28:30 AM	2659		71.8	03/20	analyzed in lab
3/10/96	7:59:11 AM	2660		71.1	03/20	analyzed in lab
3/10/96	8:29:52 AM	2661		72.4	03/20	analyzed in lab
3/10/96	9:00:36 AM	2662		72.0	03/20	analyzed in lab
3/10/96	9:31:12 AM	2663		73.2	03/20	analyzed in lab
3/10/96	10:01:52 AM	2664		72.5	03/20	analyzed in lab
3/10/96	10:32:29 AM	2665		70.0	03/20	analyzed in lab
3/10/96	11:03:16 AM	2666		71.9	03/20	analyzed in lab
3/10/96	11:33:56 AM	2667		69.6	03/20	analyzed in lab
3/10/96	12:04:38 PM	2668		72.0	03/20	analyzed in lab
3/10/96	12:35:16 PM	2669		71.0	03/20	analyzed in lab
3/10/96	1:05:56 PM	2670		72.2	04/02	analyzed in field
3/10/96	1:36:35 PM	2671		71.6	04/02	analyzed in field
3/10/96	2:07:14 PM	2672		73.6	04/02	analyzed in field
3/10/96	2:37:53 PM	2673		72.9	04/02	analyzed in field
3/10/96	3:08:35 PM	2674		73.2	04/02	analyzed in field
3/10/96	3:39:26 PM	2675		73.3	04/02	analyzed in field
3/10/96	4:09:39 PM	2676		72.8	04/02	analyzed in field
3/10/96	4:39:59 PM	2677		72.2	04/02	analyzed in field
3/10/96	5:10:39 PM	2678		72.7	04/02	analyzed in field
3/10/96	5:41:16 PM	2679		72.7	04/02	analyzed in field
3/10/96	6:11:56 PM	2680		72.8	04/02	analyzed in field
3/10/96	6:42:36 PM	2681		72.6	04/02	analyzed in field
3/10/96	7:13:17 PM	2682		71.9	03/11	analyzed in field
3/10/96	7:43:57 PM	2683		71.7	03/11	analyzed in field
3/10/96	8:15:10 PM	2684		72.7	03/11	analyzed in field
3/10/96	8:45:23 PM	2685	F/D	72.4		
3/10/96	9:15:36 PM	2686		71.6	03/11	analyzed in field
3/10/96	9:46:01 PM	2687		70.6	03/11	analyzed in field
3/10/96	10:16:41 PM	2688		71.9	03/11	analyzed in field
3/10/96	10:47:18 PM	2689		68.3	03/11	analyzed in field
3/10/96	11:17:55 PM	2690		71.6	03/11	analyzed in field
3/10/96	11:48:15 PM	2691		71.0	03/11	analyzed in field
3/11/96	12:18:28 AM	2692		68.8	03/11	analyzed in field
3/11/96	12:49:44 AM	2693		71.1	03/11	analyzed in field
3/11/96	1:20:16 AM	2694		72.4	03/11	analyzed in field
3/11/96	1:50:29 AM	2695		70.8	03/11	analyzed in field
3/11/96	2:20:43 AM	2696		70.5	03/11	analyzed in field
3/11/96	2:51:19 AM	2697		71.8	03/11	analyzed in field
3/11/96	3:22:01 AM	2698		68.1	03/11	analyzed in field
3/11/96	3:52:44 AM	2699		71.4	03/11	analyzed in field
3/11/96	4:23:22 AM	2700		69.0	03/11	analyzed in field
3/11/96	4:53:58 AM	2701		69.3	03/11	analyzed in field
3/11/96	5:24:42 AM	2702		69.8	03/11	analyzed in field
3/11/96	5:55:24 AM	2703	F/D	67.7		
3/11/96	6:26:05 AM	2704		68.8	03/11	analyzed in field
3/11/96	6:56:45 AM	2705		67.0	03/11	analyzed in field
3/11/96	7:26:58 AM	2706		72.0	03/11	analyzed in field
3/11/96	7:57:28 AM	2707		69.2	03/11	analyzed in field
3/11/96	8:28:09 AM	2708		69.7	03/11	analyzed in field
3/11/96	8:59:53 AM	2709		70.0	03/11	analyzed in field
3/11/96	9:30:33 AM	2710		67.5	03/11	analyzed in field
3/11/96	10:01:18 AM	2711		69.8	03/11	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain tracer test; 27

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/11/96	10:31:49 AM	2712		69.7	03/11	analyzed in field
3/11/96	11:02:31 AM	2713		70.0	03/11	analyzed in field
3/11/96	11:33:13 AM	2714		69.5	03/11	analyzed in field
3/11/96	12:03:54 PM	2715		70.4	03/11	analyzed in field
3/11/96	12:34:34 PM	2716		68.6	03/11	analyzed in field
3/11/96	1:05:14 PM	2717		66.8	03/11	analyzed in field
3/11/96	1:35:51 PM	2718		69.2	03/11	analyzed in field
3/11/96	2:06:30 PM	2719		65.8	03/11	analyzed in field
3/11/96	2:36:55 PM	2720		69.1	03/11	analyzed in field
3/11/96	3:07:07 PM	2721		67.6	03/14	analyzed in lab
3/11/96	3:37:38 PM	2722		72.2	03/14	analyzed in lab
3/11/96	4:08:20 PM	2723		72.0	03/14	analyzed in lab
3/11/96	4:39:00 PM	2724		70.4	03/14	analyzed in lab
3/11/96	5:09:13 PM	2725		70.0	03/14	analyzed in lab
3/11/96	5:39:40 PM	2726		69.4	03/14	analyzed in lab
3/11/96	6:10:19 PM	2727		75.3	03/14	analyzed in lab
3/11/96	6:41:00 PM	2728		71.8	03/14	analyzed in lab
3/11/96	7:11:53 PM	2729		68.9	03/14	analyzed in lab
3/11/96	7:42:25 PM	2730		70.1	03/14	analyzed in lab
3/11/96	8:13:07 PM	2731		70.5	03/14	analyzed in lab
3/11/96	8:43:47 PM	2732		68.8	03/14	analyzed in lab
3/11/96	9:14:26 PM	2733		69.2	03/14	analyzed in lab
3/11/96	9:45:06 PM	2734		70.5	03/14	analyzed in lab
3/11/96	10:15:19 PM	2735	L/D	70.0		
3/11/96	10:45:51 PM	2736		68.8	03/14	analyzed in lab
3/11/96	11:16:07 PM	2737		68.2	03/14	analyzed in lab
3/11/96	11:46:33 PM	2738		68.0	03/14	analyzed in lab
3/12/96	12:17:01 AM	2739		64.4	03/14	analyzed in lab
3/12/96	12:47:43 AM	2740		67.2	03/14	analyzed in lab
3/12/96	1:18:19 AM	2741		69.2	03/14	analyzed in lab
3/12/96	1:49:03 AM	2742		65.4	03/14	analyzed in lab
3/12/96	2:19:46 AM	2743		69.6	03/14	analyzed in lab
3/12/96	2:50:24 AM	2744		68.5	03/14	analyzed in lab
3/12/96	3:20:37 AM	2745		65.1	03/13	analyzed in lab
3/12/96	3:51:11 AM	2746		66.2	03/13	analyzed in lab
3/12/96	4:21:34 AM	2747		63.2	03/13	analyzed in lab
3/12/96	4:51:46 AM	2748		64.6	03/13	analyzed in lab
3/12/96	5:22:24 AM	2749		66.2	03/13	analyzed in lab
3/12/96	5:52:59 AM	2750		65.0	03/13	analyzed in lab
3/12/96	6:23:11 AM	2751		65.4	03/13	analyzed in lab
3/12/96	6:53:27 AM	2752		65.5	03/13	analyzed in lab
3/12/96	7:24:06 AM	2753		66.0	03/13	analyzed in lab
3/12/96	7:54:42 AM	2754		64.4	03/13	analyzed in lab
3/12/96	8:24:58 AM	2755		68.2	03/13	analyzed in lab
3/12/96	8:56:11 AM	2756		64.5	03/13	analyzed in lab
3/12/96	9:26:24 AM	2757		63.7	03/13	analyzed in lab
3/12/96	9:56:56 AM	2758		64.1	03/13	analyzed in lab
3/12/96	10:27:35 AM	2759		64.0	03/13	analyzed in lab
3/12/96	10:58:17 AM	2760		65.2	03/13	analyzed in lab
3/12/96	11:28:54 AM	2761		63.8	03/13	analyzed in lab
3/12/96	11:59:31 AM	2762	L/D	64.8		
3/12/96	12:30:10 PM	2763		63.1	03/13	analyzed in lab
3/12/96	1:00:53 PM	2764		65.4	03/13	analyzed in lab
3/12/96	1:31:23 PM	2765		64.0	03/13	analyzed in lab
3/12/96	2:01:55 PM	2766		64.8	03/13	analyzed in lab
3/12/96	2:32:08 PM	2767		65.4	03/13	analyzed in lab
3/12/96	3:02:49 PM	2768		65.0	03/13	analyzed in lab
3/12/96	3:33:03 PM	2769		66.5	03/13	analyzed in lab
3/12/96	4:03:23 PM	2770		65.1	03/13	analyzed in lab
3/12/96	4:34:02 PM	2771		64.9	03/13	analyzed in lab
3/12/96	5:04:39 PM	2772		64.5	03/13	analyzed in lab
3/12/96	5:34:52 PM	2773		66.5	03/13	analyzed in lab
3/12/96	6:05:24 PM	2774		65.6	03/13	analyzed in lab
3/12/96	6:35:37 PM	2775		63.2	03/13	analyzed in lab
3/12/96	7:05:57 PM	2776		63.9	03/13	analyzed in lab
3/12/96	7:36:36 PM	2777		64.1	03/13	analyzed in lab
3/12/96	8:07:15 PM	2778		64.8	03/13	analyzed in lab
3/12/96	8:37:28 PM	2779		66.4	03/13	analyzed in field
3/12/96	9:07:49 PM	2780		67.3	03/13	analyzed in field
3/12/96	9:38:27 PM	2781		65.5	03/13	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/12/96	10:09:08 PM	2782		66.4	03/13	analyzed in field
3/12/96	10:39:35 PM	2783		64.6	03/13	analyzed in field
3/12/96	11:09:48 PM	2784		67.3	03/13	analyzed in field
3/12/96	11:40:01 PM	2785		64.6	03/13	analyzed in field
3/13/96	12:10:19 AM	2786		65.1	03/13	analyzed in field
3/13/96	12:40:58 AM	2787		66.6	03/13	analyzed in field
3/13/96	1:11:11 AM	2788		69.5	03/13	analyzed in field
3/13/96	1:41:34 AM	2789		64.7	03/13	analyzed in field
3/13/96	2:12:13 AM	2790		67.9	03/13	analyzed in field
3/13/96	2:42:51 AM	2791		68.8	03/13	analyzed in field
3/13/96	3:13:37 AM	2792		65.2	03/13	analyzed in field
3/13/96	3:43:49 AM	2793		64.8	03/13	analyzed in field
3/13/96	4:14:05 AM	2794		65.4	03/13	analyzed in field
3/13/96	4:44:18 AM	2795		64.0	03/13	analyzed in field
3/13/96	5:14:56 AM	2796		65.1	03/13	analyzed in field
3/13/96	5:45:09 AM	2797		61.6	03/13	analyzed in field
3/13/96	6:15:22 AM	2798	F/D	66.7		
3/13/96	6:46:01 AM	2799		62.2	03/13	analyzed in field
3/13/96	7:16:14 AM	2800		67.3	03/13	analyzed in field
3/13/96	7:46:45 AM	2801		65.7	03/13	analyzed in field
3/13/96	8:17:18 AM	2802		62.4	03/13	analyzed in field
3/13/96	8:47:31 AM	2803		66.0	03/13	analyzed in field
3/13/96	9:17:47 AM	2804		64.2	03/13	analyzed in field
3/13/96	9:48:00 AM	2805		63.0	03/13	analyzed in field
3/13/96	10:18:20 AM	2806		63.7	03/13	analyzed in field
3/13/96	10:49:02 AM	2807		63.0	03/13	analyzed in field
3/13/96	11:19:41 AM	2808		63.1	03/13	analyzed in field
3/13/96	11:50:21 AM	2809		64.7	03/13	analyzed in field
3/13/96	12:22:11 PM	2810		64.0	03/13	analyzed in field
3/13/96	12:52:51 PM	2811		62.3	03/13	analyzed in field
3/13/96	1:23:31 PM	2812		63.4	03/13	analyzed in field
3/13/96	1:54:10 PM	2813		60.8	03/13	analyzed in field
3/13/96	2:24:23 PM	2814		62.8	03/27	analyzed in lab
3/13/96	2:55:01 PM	2815		63.1	03/27	analyzed in lab
3/13/96	3:25:14 PM	2816		64.6	03/27	analyzed in lab
3/13/96	3:55:30 PM	2817	L/D	63.8		
3/13/96	4:26:09 PM	2818		64.8	03/27	analyzed in field
3/13/96	4:56:56 PM	2819		65.1	03/27	analyzed in field
3/13/96	5:27:28 PM	2820		64.8	03/27	analyzed in field
3/13/96	5:58:09 PM	2821		64.9	03/27	analyzed in field
3/13/96	6:28:30 PM	2822		64.7	03/27	analyzed in field
3/13/96	6:58:43 PM	2823		64.8	03/27	analyzed in field
3/13/96	7:28:56 PM	2824		65.0	03/27	analyzed in field
3/13/96	7:59:35 PM	2825		64.5	03/27	analyzed in field
3/13/96	8:29:48 PM	2826		64.1	03/27	analyzed in field
3/13/96	9:00:03 PM	2827		65.0	03/28	analyzed in field
3/13/96	9:30:38 PM	2828	F/D	64.5		
3/13/96	10:00:50 PM	2829		64.9	03/28	analyzed in field
3/13/96	10:31:27 PM	2830		63.7	03/28	analyzed in field
3/13/96	11:01:40 PM	2831		64.4	03/28	analyzed in field
3/13/96	11:32:09 PM	2832		64.0	03/28	analyzed in field
3/14/96	12:02:49 AM	2833		64.5	03/28	analyzed in field
3/14/96	12:33:03 AM	2834		64.2	03/28	analyzed in field
3/14/96	1:03:42 AM	2835		64.0	03/28	analyzed in field
3/14/96	1:33:55 AM	2836		65.2	03/28	analyzed in field
3/14/96	2:04:18 AM	2837		64.0	03/28	analyzed in field
3/14/96	2:34:54 AM	2838		64.3	03/29	analyzed in field
3/14/96	3:05:07 AM	2839		64.6	03/29	analyzed in field
3/14/96	3:35:34 AM	2840		63.0	04/01	analyzed in field
3/14/96	4:06:16 AM	2841		63.7	04/01	analyzed in field
3/14/96	4:36:29 AM	2842		64.0	04/01	analyzed in field
3/14/96	5:06:45 AM	2843		63.3	04/01	analyzed in field
3/14/96	5:37:02 AM	2844		63.7	04/01	analyzed in field
3/14/96	6:07:35 AM	2845		62.8	04/01	analyzed in field
3/14/96	6:38:07 AM	2846		64.2	04/01	analyzed in field
3/14/96	7:08:20 AM	2847	F/D	63.4		
3/14/96	7:38:59 AM	2848	L/F-D*	63.3	04/01	analyzed in field
3/14/96	8:09:37 AM	2849		62.8	04/01	analyzed in field
3/14/96	8:39:50 AM	2850	L/F-D	61.9		
3/14/96	9:10:18 AM	2851		62.8	04/01	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/14/96	9:41:02 AM	2852		62.1	04/01	analyzed in field
3/14/96	10:11:44 AM	2853		62.4	04/01	analyzed in field
3/14/96	10:41:57 AM	2854		60.9	04/01	analyzed in lab
3/14/96	11:12:42 AM	2855		60.6	04/01	analyzed in lab
3/14/96	11:42:54 AM	2856		58.5	04/01	analyzed in lab
3/14/96	12:13:16 PM	2857		56.2	04/01	analyzed in lab
3/14/96	12:43:29 PM	2858	L/F-D	60.6		
3/14/96	1:13:53 PM	2859		59.1	03/29	analyzed in lab
3/14/96	1:44:18 PM	2860		59.8	03/29	analyzed in lab
3/14/96	2:14:32 PM	2861		59.5	03/29	analyzed in lab
3/14/96	2:44:45 PM	2862		59.8	03/29	analyzed in lab
3/14/96	3:45:11 PM	2863		58.8	03/29	analyzed in lab
3/14/96	4:46:05 PM	2864		60.5	04/19	analyzed in lab
3/14/96	5:46:18 PM	2865		55.4	03/29	analyzed in lab
3/14/96	6:46:59 PM	2866		55.5	03/29	analyzed in lab
3/14/96	7:47:13 PM	2867		55.1	03/29	analyzed in lab
3/14/96	8:47:51 PM	2868		58.0	03/29	analyzed in lab
3/14/96	9:48:05 PM	2869		55.9	03/29	analyzed in lab
3/14/96	10:48:32 PM	2870		58.6	03/29	analyzed in lab
3/14/96	11:49:11 PM	2871		54.5	03/29	analyzed in lab
3/15/96	12:49:48 AM	2872		54.0	03/29	analyzed in lab
3/15/96	1:50:29 AM	2873		54.0	03/29	analyzed in lab
3/15/96	2:51:08 AM	2874		55.0	03/29	analyzed in lab
3/15/96	3:51:47 AM	2875		54.1	03/29	analyzed in lab
3/15/96	4:52:23 AM	2876		55.4	03/29	analyzed in lab
3/15/96	5:53:04 AM	2877		58.4	03/29	analyzed in lab
3/15/96	6:53:41 AM	2878		58.2	03/29	analyzed in lab
3/15/96	7:54:06 AM	2879		56.7	03/29	analyzed in lab
3/15/96	8:54:19 AM	2880		59.2	03/29	analyzed in lab
3/15/96	9:54:43 AM	2881	L/D*	57.8	03/29	analyzed in lab
3/15/96	10:55:21 AM	2882		58.9	03/29	analyzed in lab
3/15/96	11:55:43 AM	2883		58.0	03/29	analyzed in lab
3/15/96	12:55:57 PM	2884		61.1	04/01	analyzed in field
3/15/96	1:56:35 PM	2885		59.6	04/01	analyzed in field
3/15/96	2:57:04 PM	2886		59.5	04/01	analyzed in field
3/15/96	3:57:17 PM	2887		60.1	04/01	analyzed in field
3/15/96	4:57:30 PM	2888		59.5	04/01	analyzed in field
3/15/96	5:57:49 PM	2889		60.0	04/01	analyzed in field
3/15/96	6:58:30 PM	2890		59.5	04/01	analyzed in field
3/15/96	7:59:20 PM	2891		59.7	04/01	analyzed in field
3/15/96	8:59:32 PM	2892		59.5	04/01	analyzed in field
3/15/96	9:59:46 PM	2893		59.2	04/01	analyzed in field
3/15/96	11:00:18 PM	2894		59.4	04/01	analyzed in field
3/16/96	12:01:01 AM	2895	F/D	59.4		
3/16/96	1:01:44 AM	2896		58.8	04/01	analyzed in field
3/16/96	2:01:57 AM	2897		58.4	04/01	analyzed in field
3/16/96	3:02:28 AM	2898		57.9	04/01	analyzed in field
3/16/96	4:03:05 AM	2899		58.0	04/01	analyzed in field
3/16/96	5:03:52 AM	2900		58.2	04/01	analyzed in field
3/16/96	6:04:05 AM	2901		58.3	04/01	analyzed in field
3/16/96	7:04:28 AM	2902		57.9	04/01	analyzed in field
3/16/96	8:04:48 AM	2903		57.5	04/01	analyzed in field
3/16/96	9:05:01 AM	2904		58.1	04/01	analyzed in field
3/16/96	10:05:13 AM	2905		57.8	04/01	analyzed in field
3/16/96	11:05:45 AM	2906		57.5	04/01	analyzed in field
3/16/96	12:06:23 PM	2907	F/D	58.0		
3/16/96	1:06:37 PM	2908		57.0	03/28	analyzed in field
3/16/96	2:07:12 PM	2909		56.3	03/28	analyzed in field
3/16/96	3:07:25 PM	2910		58.0	03/28	analyzed in field
3/16/96	4:07:55 PM	2911		56.6	03/28	analyzed in field
3/16/96	5:08:33 PM	2912		56.8	03/28	analyzed in field
3/16/96	6:08:51 PM	2913	F/D	57.2		
3/16/96	7:09:33 PM	2914		56.0	03/28	analyzed in field
3/16/96	8:09:46 PM	2915		56.4	03/29	analyzed in field
3/16/96	9:10:03 PM	2916		56.1	03/29	analyzed in field
3/16/96	10:10:16 PM	2917		57.4	03/29	analyzed in field
3/16/96	11:11:07 PM	2918	F/D*	57.1	03/29	analyzed in field
3/17/96	12:11:35 AM	2919		58.8	03/29	analyzed in field
3/17/96	1:12:11 AM	2920		48.9	03/29	analyzed in lab
3/17/96	2:12:26 AM	2921		53.1	03/29	analyzed in lab

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/17/96	3:12:39 AM	2922		48.4	03/29	analyzed in lab
3/17/96	4:13:05 AM	2923	L/D	49.2		
3/17/96	5:13:18 AM	2924		49.4	03/29	analyzed in lab
3/17/96	6:13:58 AM	2925		49.7	03/29	analyzed in lab
3/17/96	7:14:35 AM	2926		47.5	03/29	analyzed in lab
3/17/96	8:15:20 AM	2927		47.2	03/29	analyzed in lab
3/17/96	9:15:32 AM	2928		48.2	03/29	analyzed in lab
3/17/96	10:15:45 AM	2929	L/D	51.5		
3/17/96	11:16:01 AM	2930	L/D	52.4		
3/17/96	12:16:39 PM	2931	L/D	51.9		
3/17/96	1:17:21 PM	2932	F/D*	52.6	04/02	
3/17/96	2:17:35 PM	2933		55.2	03/18	analyzed in field
3/17/96	3:18:12 PM	2934	F/D*	55.7	03/18	
3/17/96	4:18:26 PM	2935		55.8	03/18	analyzed in field
3/17/96	5:19:08 PM	2936	F/D*	56.8	03/18	
3/17/96	6:19:21 PM	2937		56.1	03/18	analyzed in field
3/17/96	7:20:04 PM	2938	F/D	52.9		
3/17/96	8:20:34 PM	2939		52.4	03/18	analyzed in field
3/17/96	9:20:47 PM	2940	F/D*	52.2	04/02	
3/17/96	10:21:00 PM	2941		53.9	03/18	analyzed in field
3/17/96	11:21:40 PM	2942	F/D*	53.8	03/18	
3/18/96	12:22:19 AM	2943		54.2	03/18	analyzed in field
3/18/96	1:22:31 AM	2944	F/D*	54.0	03/18	
3/18/96	2:23:07 AM	2945		54.0	03/18	analyzed in field
3/18/96	3:23:20 AM	2946	F/D	52.4		
3/18/96	4:23:58 AM	2947		53.0	03/18	analyzed in field
3/18/96	5:24:11 AM	2948	F/D	51.5		
3/18/96	6:24:40 AM	2949		51.5	03/18	analyzed in field
3/18/96	7:24:54 AM	2950	F/D	51.0		
3/18/96	8:25:07 AM	2951		52.5	03/18	analyzed in field
3/18/96	9:49:40 AM	2952	F/D	51.6		
3/18/96	10:49:56 AM	2953		52.9	03/18	analyzed in field
3/18/96	11:31:53 AM	2954	F/D	51.1		
3/18/96	12:32:07 PM	2955		52.4	03/18	analyzed in field
3/18/96	1:32:19 PM	2956	L/F-D	50.5		
3/18/96	2:32:50 PM	2957	L/F-D	50.1		
3/18/96	3:33:03 PM	2958		49.2	04/01	analyzed in lab
3/18/96	4:33:15 PM	2959		48.4	04/01	analyzed in lab
3/18/96	5:33:29 PM	2960		51.5	04/01	analyzed in lab
3/18/96	6:33:42 PM	2961		50.8	04/01	analyzed in lab
3/18/96	7:33:55 PM	2962		48.4	04/01	analyzed in lab
3/18/96	8:34:23 PM	2963		50.7	04/01	analyzed in lab
3/18/96	9:34:37 PM	2964	L/D	49.5		
3/18/96	10:34:51 PM	2965		54.0	04/01	analyzed in field
3/18/96	11:35:06 PM	2966		51.8	04/01	analyzed in field
3/19/96	12:35:29 AM	2967		54.1	04/01	analyzed in field
3/19/96	1:35:47 AM	2968		52.1	04/01	analyzed in field
3/19/96	2:36:23 AM	2969		52.4	04/01	analyzed in field
3/19/96	3:36:36 AM	2970		51.5	04/01	analyzed in field
3/19/96	4:36:57 AM	2971		52.4	04/01	analyzed in field
3/19/96	5:37:34 AM	2972		53.0	04/01	analyzed in field
3/19/96	6:37:47 AM	2973		52.6	04/01	analyzed in field
3/19/96	7:38:12 AM	2974		54.0	04/01	analyzed in field
3/19/96	8:38:26 AM	2975		50.4	04/01	analyzed in field
3/19/96	9:38:43 AM	2976		54.4	04/01	analyzed in field
3/19/96	10:39:07 AM	2977		51.6	04/01	analyzed in field
3/19/96	11:39:20 AM	2978	F/D*	50.6	04/01	analyzed in field
3/19/96	12:39:41 PM	2979		50.2	04/19	analyzed in lab
3/19/96	1:39:55 PM	2980		48.9	04/02	analyzed in field
3/19/96	2:40:25 PM	2981		48.4	04/02	analyzed in field
3/19/96	3:40:38 PM	2982		48.8	04/02	analyzed in field
3/19/96	4:40:51 PM	2983		48.6	04/02	analyzed in field
3/19/96	5:41:12 PM	2984		48.4	04/02	analyzed in field
3/19/96	6:41:25 PM	2985	F/D	48.0		
3/19/96	7:41:43 PM	2986		48.3	04/02	analyzed in field
3/19/96	8:42:01 PM	2987	F/D	48.3		
3/19/96	9:42:25 PM	2988	F/D	47.5		
3/19/96	10:42:56 PM	2989	F/D*	47.5		
3/19/96	11:43:24 PM	2990	F/D	46.9		
3/20/96	12:43:37 AM	2991	F/D*	46.8		

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/20/96	1:43:55 AM	2992	L/F-D*	48.0	04/02	analyzed in field
3/20/96	2:44:17 AM	2993	F/D*	47.7	04/02	analyzed in field
3/20/96	3:44:48 AM	2994	F/D*	47.5	04/02	analyzed in field
3/20/96	4:45:02 AM	2995	F/D*	47.4	04/02	analyzed in field
3/20/96	5:45:22 AM	2996	F/D*	47.2	04/02	analyzed in field
3/20/96	6:45:41 AM	2997	F/D*	47.0	03/20	analyzed in field
3/20/96	7:46:02 AM	2998	F/D*	47.1	04/02	analyzed in field
3/20/96	8:46:42 AM	2999	F/D*	46.6	04/02	analyzed in field
3/20/96	9:46:55 AM	3000	F/D*	46.2	04/02	analyzed in field
3/20/96	10:47:09 AM	3001	F/D*	46.1	04/02	analyzed in field
3/20/96	11:47:31 AM	3002	F/D*	46.6	04/02	analyzed in field
3/20/96	12:47:51 PM	3003	F/D*	45.9	04/02	analyzed in field
3/20/96	1:48:04 PM	3004	L/F-D*	45.8	03/20	analyzed in field
3/20/96	2:48:17 PM	3005		45.5	03/26	analyzed in lab
3/20/96	3:48:33 PM	3006		48.5	03/26	analyzed in lab
3/20/96	4:48:54 PM	3007		45.0	03/26	analyzed in lab
3/20/96	5:49:30 PM	3008		49.4	03/26	analyzed in lab
3/20/96	6:49:44 PM	3009		51.0	03/26	analyzed in lab
3/20/96	7:49:59 PM	3010		50.9	03/26	analyzed in lab
3/20/96	8:50:18 PM	3011		50.7	03/26	analyzed in lab
3/20/96	9:50:39 PM	3012		50.2	03/26	analyzed in lab
3/20/96	10:51:03 PM	3013		50.3	03/26	analyzed in lab
3/20/96	11:51:34 PM	3014	L/D*	50.7		
3/21/96	12:51:47 AM	3015		50.1	03/26	analyzed in lab
3/21/96	1:52:04 AM	3016		49.1	03/26	analyzed in lab
3/21/96	2:52:34 AM	3017		49.8	03/26	analyzed in lab
3/21/96	3:52:47 AM	3018		49.0	03/26	analyzed in lab
3/21/96	4:53:05 AM	3019		48.7	03/26	analyzed in lab
3/21/96	5:53:18 AM	3020		49.9	03/26	analyzed in lab
3/21/96	6:53:34 AM	3021		48.9	03/26	analyzed in lab
3/21/96	7:53:55 AM	3022		49.3	03/26	analyzed in lab
3/21/96	8:54:22 AM	3023	L/D	50.3		
3/21/96	9:54:44 AM	3024		51.6	03/26	analyzed in lab
3/21/96	10:54:59 AM	3025		50.1	03/26	analyzed in lab
3/21/96	11:55:37 AM	3026		49.0	03/26	analyzed in lab
3/21/96	12:55:51 PM	3027		49.4	03/26	analyzed in lab
3/21/96	1:56:04 PM	3028		48.7	03/26	analyzed in lab
3/21/96	2:56:17 PM	3029		50.3	03/26	analyzed in lab
3/21/96	3:56:29 PM	3030		49.1	03/26	analyzed in lab
3/21/96	4:56:42 PM	3031		48.5	03/26	analyzed in lab
3/21/96	5:56:58 PM	3032		50.6	03/26	analyzed in lab
3/21/96	6:57:14 PM	3033		48.9	03/26	analyzed in lab
3/21/96	7:57:34 PM	3034	L/D*	48.1		
3/21/96	8:58:03 PM	3035		45.0	04/19	analyzed in lab
3/21/96	9:58:15 PM	3036		43.3	03/27	analyzed in lab
3/21/96	10:58:28 PM	3037		44.0	03/27	analyzed in lab
3/21/96	11:58:41 PM	3038		44.7	03/27	analyzed in lab
3/22/96	12:58:58 AM	3039		44.9	03/27	analyzed in lab
3/22/96	1:59:11 AM	3040		46.1	03/27	analyzed in lab
3/22/96	2:59:27 AM	3041		44.3	03/27	analyzed in lab
3/22/96	3:59:42 AM	3042	L/F-D	44.0		
3/22/96	4:59:59 AM	3043	L/F-D	44.5		
3/22/96	6:00:29 AM	3044	L/F-D*	43.5		
3/22/96	7:00:42 AM	3045	L/F-D*	43.7		
3/22/96	8:00:55 AM	3046	L/F-D*	45.0		
3/22/96	9:01:08 AM	3047	L/F-D*	45.1		
3/22/96	10:01:28 AM	3048	L/F-D*	43.6		
3/22/96	11:01:58 AM	3049		44.3	03/27	analyzed in lab
3/22/96	1:02:12 PM	3050		42.5	03/27	analyzed in lab
3/22/96	3:02:54 PM	3051		42.8	03/27	analyzed in lab
3/22/96	5:03:31 PM	3052		43.1	03/27	analyzed in field
3/22/96	7:04:22 PM	3053		40.6	03/27	analyzed in field
3/22/96	9:05:15 PM	3054		41.3	03/27	analyzed in field
3/22/96	11:05:29 PM	3055		41.2	03/27	analyzed in field
3/23/96	1:06:12 AM	3056		41.9	03/27	analyzed in field
3/23/96	3:06:55 AM	3057		42.2	03/27	analyzed in field
3/23/96	5:07:33 AM	3058		41.7	03/27	analyzed in field
3/23/96	7:08:09 AM	3059		41.8	03/27	analyzed in field
3/23/96	9:08:51 AM	3060		41.8	03/27	analyzed in field
3/23/96	11:09:22 AM	3061		42.0	03/27	analyzed in field

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/23/96	1:10:34 PM	3062		40.0	03/27	analyzed in field
3/23/96	3:10:47 PM	3063	F/D	40.5		
3/23/96	5:11:16 PM	3064		40.5	03/27	analyzed in field
3/23/96	7:11:53 PM	3065		40.0	03/27	analyzed in field
3/23/96	9:12:29 PM	3066		40.4	03/27	analyzed in field
3/23/96	11:12:43 PM	3067		40.7	03/27	analyzed in field
3/24/96	1:12:57 AM	3068		40.3	03/27	analyzed in field
3/24/96	3:13:23 AM	3069		40.1	03/27	analyzed in field
3/24/96	5:13:55 AM	3070		40.3	03/27	analyzed in field
3/24/96	7:14:59 AM	3071		41.7	03/27	analyzed in field
3/24/96	9:15:12 AM	3072		40.3	03/27	analyzed in field
3/24/96	11:15:45 AM	3073		40.0	03/27	analyzed in field
3/24/96	1:16:19 PM	3074		39.2	03/27	analyzed in field
3/24/96	3:17:00 PM	3075	F/D*	39.9		
3/24/96	5:17:38 PM	3076		39.0	03/25	analyzed in lab
3/24/96	7:18:14 PM	3077		38.6	03/25	analyzed in lab
3/24/96	9:18:54 PM	3078		38.1	03/25	analyzed in lab
3/24/96	11:19:07 PM	3079		37.6	03/25	analyzed in lab
3/25/96	1:19:35 AM	3080		37.9	03/25	analyzed in lab
3/25/96	3:20:12 AM	3081		36.9	03/25	analyzed in lab
3/25/96	5:20:54 AM	3082		37.8	03/25	analyzed in lab
3/25/96	7:21:52 AM	3083		37.8	03/25	analyzed in lab
3/25/96	9:22:06 AM	3084		37.8	03/25	analyzed in lab
3/25/96	11:22:47 AM	3085	L/D*	37.1		
3/25/96	1:23:27 PM	3086	L/F-D*	40.6		
3/25/96	3:24:11 PM	3087	L/F-D*	37.2		
3/25/96	5:25:04 PM	3088	L/F-D*	36.1		
3/25/96	7:25:29 PM	3089	L/F-D*	37.4		
3/25/96	9:26:02 PM	3090	L/F-D*	39.0		
3/25/96	11:26:43 PM	3091		38.8	03/29	analyzed in field
3/26/96	1:27:24 AM	3092		39.0	03/29	analyzed in field
3/26/96	3:28:06 AM	3093		39.7	03/29	analyzed in field
3/26/96	5:28:47 AM	3094		37.2	03/29	analyzed in field
3/26/96	7:29:23 AM	3095		39.1	03/29	analyzed in field
3/26/96	9:30:03 AM	3096		39.2	03/29	analyzed in field
3/26/96	11:30:38 AM	3097		38.3	03/29	analyzed in field
3/26/96	1:31:43 PM	3098		38.2	03/28	analyzed in field
3/26/96	3:32:01 PM	3099		36.3	03/28	analyzed in field
3/26/96	5:32:41 PM	3100		37.1	03/28	analyzed in field
3/26/96	7:33:06 PM	3101		37.0	03/28	analyzed in field
3/26/96	9:33:50 PM	3102		37.6	03/28	analyzed in field
3/26/96	11:34:50 PM	3103		37.9	03/28	analyzed in field
3/27/96	1:35:04 AM	3104		37.2	03/28	analyzed in field
3/27/96	3:35:41 AM	3105		37.5	03/28	analyzed in field
3/27/96	5:35:54 AM	3106		37.7	03/28	analyzed in field
3/27/96	7:36:18 AM	3107	F/D*	37.6		
3/27/96	9:36:50 AM	3108	F/D*	37.1	03/28	analyzed in field
				37.2	03/29	analyzed in field
				35.5	03/29	analyzed in field
3/27/96	2:43:19 PM	3111		36.1	03/29	analyzed in field
3/27/96	4:43:56 PM	3112		36.8	03/29	analyzed in field
3/27/96	6:44:32 PM	3113		36.2	03/29	analyzed in field
3/27/96	8:44:45 PM	3114		35.2	03/29	analyzed in field
3/27/96	10:44:58 PM	3115		36.5	03/29	analyzed in field
3/28/96	12:45:37 AM	3116		35.4	03/29	analyzed in field
3/28/96	2:45:50 AM	3117		36.0	03/29	analyzed in field
3/28/96	4:46:03 AM	3118		36.0	03/29	analyzed in field
3/28/96	6:46:40 AM	3119		35.0	03/29	analyzed in field
3/28/96	8:47:50 AM	3120		36.3	03/29	analyzed in field
3/28/96	10:48:04 AM	3121		35.9	03/29	analyzed in lab
3/28/96	12:48:37 PM	3122		33.7	03/29	analyzed in lab
3/28/96	2:49:17 PM	3123		35.5	03/29	analyzed in lab
3/28/96	4:49:55 PM	3124		34.0	03/29	analyzed in lab
3/28/96	6:50:27 PM	3125		32.9	03/29	analyzed in lab
3/28/96	8:51:05 PM	3126		34.3	03/29	analyzed in lab
3/28/96	10:51:43 PM	3127		33.9	03/29	analyzed in lab
3/29/96	12:51:56 AM	3128		33.0	03/29	analyzed in lab
3/29/96	2:52:27 AM	3129	L/F-D*	34.0	03/29	analyzed in field

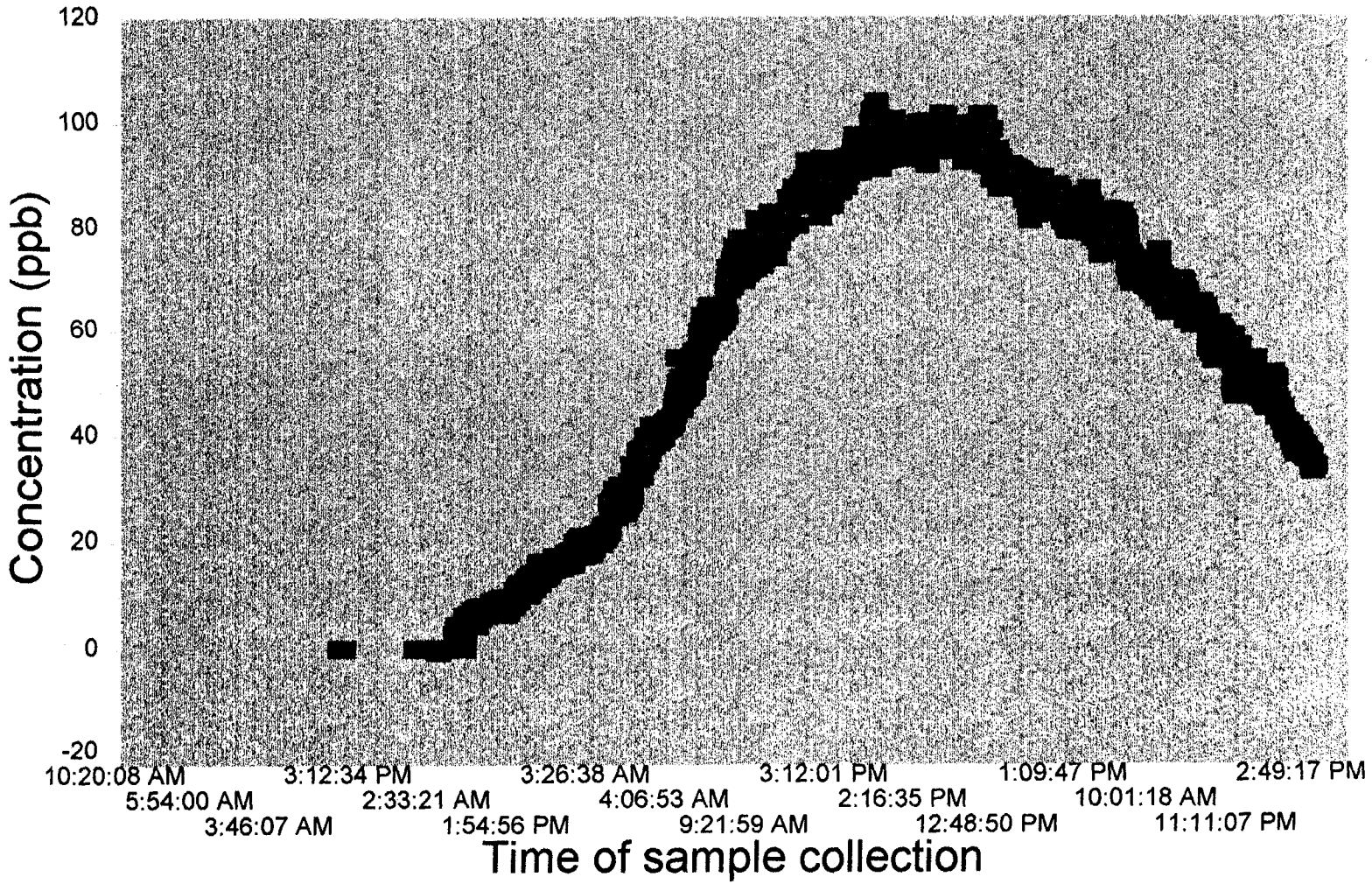
F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Date	Time of Sample	Sample #	Dup. code	Conc (ppb)	Analysis date	place
3/29/96	4:53:09 AM	3130		34.3	04/02	analyzed in field
3/29/96	6:53:39 AM	3131		33.9	04/02	analyzed in field
3/29/96	8:54:15 AM	3132		33.7	04/02	analyzed in field
3/29/96	10:54:51 AM	3133		33.9	04/02	analyzed in field
3/29/96	12:55:27 PM	3134		33.9	04/02	analyzed in field

L/D= analyzed in duplicate in lab;
F/D=analyzed in duplicate in field;
L/F-D= analyzed in duplicate in lab and fiel
*= only one of the values is used.

F/D:mean of field duplicate; L/D:mean of lab duplicates; L/F-D:mean of field & lab duplicates; *: one of the two values

Yucca Mountain Tracer pattern



Data analysis books entitled, Chemical Analysis of Water from Ash Meadows Springs and Chemical Analysis of Water from Death Valley Springs can be issued upon request. Please call 895-1357 and ask for Sally Hamilton.