TECHNICAL REPORTS ON CHAFF AND FLARES
TECHNICAL REPORT NO. 5
LABORATORY ANALYSIS OF CHAFF AND FLARE MATERIALS

NOVEMBER 1994

Prepared for:
U.S. Air Force
Headquarters Air Combat Command
Langley Air Force Base, Virginia

EXECUTIVE SUMMARY

This report summarizes the results of laboratory testing performed as one component of a study being conducted by the U.S. Air Force, Headquarters Air Combat Command (ACC) on the environmental effects of using self-protection chaff and flares in military aircraft training. The objective of the laboratory testing component of this study was to identify the types and quantities of chemicals that could leach from chaff, flares, and flare ash under various conditions.

The tests were conducted by applying a series of surrogate environment treatments to samples of aluminum coated glass fiber chaff, M-206 flare pellet material, and an uncontrolled sample of flare ash recovered from a chamber in which flares had be previously burned. A controlled burn sample was not generated for this study. Each of the samples was reacted with four extracting solutions designed to simulate acidic (pH 4), neutral (pH 7), alkaline (pH 10), and marine (pH 7.8 synthetic seawater) conditions. A modified toxicity characteristic leaching procedure (TCLP) was used for the extractions. Chaff extracts were analyzed for presence of aluminum, magnesium, copper, manganese, titanium, vanadium, zinc, boron, and silicon. Flare pellet and flare ash extracts were analyzed for magnesium, aluminum, boron, barium, and chromium. These elements were selected for analysis based on the known composition of chaff and flares. The flare ash extracts were also examined for ammonia, nitrate, and nitrite, and hydrogen gas formation was measured from the flare pellet samples.

The results of the laboratory tests were evaluated for potential chemical effects from chaff and flare use on terrestrial, freshwater aquatic, and marine environments. The following paragraphs summarize the findings.

Chaff

Only four of the nine elements analyzed were detected in the chaff samples: aluminum, magnesium, zinc, and boron. The levels were strongly correlated to pH, with the highest concentrations occurring in the pH 4 solution. None of the quantities were high enough to generate concern for terrestrial environments. Although no copper was detected in any of the chaff samples, the low threshold for toxicity in some aquatic organisms render the findings inconclusive with respect to copper in freshwater aquatic environments and confined marine environments. However, considering the maximum amount of chaff that could be deposited in any given area, the quantity of copper involved is minute.

Flares

Of the five elements analyzed, three--magnesium, barium, and chromium--were detected in the flare pellet extracts, and four--magnesium, barium, chromium, and boron--were detected in the flare ash extracts. No aluminum was detected in any of the flare extracts. Ammonia and nitrate were detected in all the flare ash extracts, and nitrite was detected in the pH 10 treatment. A substantial quantity of hydrogen gas was produced by the flare pellet sample.

None of the chemicals detected were in quantities sufficient to raise concern about effects on terrestrial environments. However, the results were inconclusive with respect to potential effects from boron in marine environments and from magnesium, barium, and boron, as well as ammonia, in freshwater aquatic environments. The flare pellet and ash samples also substantially raised the pH of the extracting solutions.

Conclusions and Recommendations

While uncertainties continue to exist concerning potential effects from flare use on sensitive, confined aquatic environments, the likelihood of impacts is low and directly related to the quantity of flare ash deposited in a location. Further analysis is only warranted in areas of high flare use with small confined water bodies that support organisms sensitive to the elements produced by flare ash. Although dud flares have a potential for affecting certain highly sensitive environments, incidents of dud flares are very rare, the probability of impacts is remote, and any impacts that could occur would be localized. Therefore, no further analysis of chemical effects from dud flares is necessary. Consideration could be given to conducting a series of bioassay tests of chaff and flare ash to determine their toxicity to aquatic organisms at various concentrations and identify a threshold level of concern.

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ACRONYMS AND ABBREVIATIONS

ACC	Air Combat Command
AFC	aluminum foil chaff
Al	aluminum
Al_2O_3	alumina
AQUIRE	Aquatic Information Retrieval
B	boron
$BaCrO_4$	barium chromate
B_2O_3	boron oxide
CaO	calcium oxide
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
Cu	copper
ECM	electronic countermeasures
EPA	Environmental Protection Agency
Fe	iron
Fe_2O_3	iron oxide
GCF	glass fiber chaff
$KClO_4$	potassium perchlorate
kg	kilogram
K_2O	potassium oxide
L	liter
Mg	magnesium
mg	milligram
MgO	magnesium oxide
Mn	manganese
NaOAC	sodium acetate
Na_2O	sodium oxide
NH_3	ammonia

NO_2	nitrite
NO_3	nitrate
pH	relative acidity or alkalinity
ppm	parts per million
QC	quality control
RCRA	Resource Conservation and Recovery Act
Si	silicon
SiO_2	silicon dioxide
SSW	synthetic seawater
TCLP	toxicity characteristic leaching procedure
Ti	titanium
*u*g	microgram
USAF	United States Air Force
USFWS	United States Fish and Wildlife Service
V	vanadium
Zn	zinc

1.0 INTRODUCTION

This report presents the results of laboratory research conducted to determine the potential chemical impacts to the environment from self-protection military chaff and flares used by U.S. Air Force Air Combat Command (ACC) units in training. The purpose of the research summarized in this document was to develop baseline data reflecting possible environmental effects of using self-protection chaff and flares in training areas. These data were collected to provide information on possible environmental consequences of the deposition of chaff, dud flares, and residual flare ash in areas underlying special-use airspace.

The laboratory research was designed to subject chaff and flare materials and flare ash to a range of surrogate environments to assess their relative stability and identify types and quantities of contaminants of concern (COC) that might leach into soil and water under varying conditions. Laboratory results were subject to quality assurance review and data validation, in accordance with U.S. Environmental Protection Agency (EPA) guidelines. This report describes the laboratory procedures used, presents the data validation findings, summarizes conclusions that may be reached based on the laboratory results, and makes recommendations for further analysis.

2.0 APPROACH TO ANALYSIS

2.1 COMPONENT CHEMISTRY

Self-protection chaff and flares are used at military ranges and in special-use airspace across the United States. The use of chaff and flares offers three distinct classes of solid materials capable of releasing toxic or hazardous chemicals into the environment: (1) dispersed chaff, (2) dud flares, and (3) flare ash.

Multiple environmental conditions were created in the laboratory to simulate the varied environments across the U.S. in which these components might be deposited. Although individual conditions could vary, a limited number of specific environments were simulated to represent a range of conditions, and a generic set of chaff and flare constituents was assumed for this study, due to the varied nature of different chaff and flare models.

Chaff

The two major types of military chaff in use are aluminum foil and aluminum-coated glass fibers. The aluminum foil-type is no longer manufactured, although it may still be in use. This study focused on the more widely used aluminum-coated glass fiber chaff. The major components of the glass fibers and the aluminum coating in fiber-type chaff are listed in Table 2-1 (USAF 1993). Samples of military chaff extract were analyzed for magnesium, aluminum, copper, manganese, silicon, titanium, vanadium, zinc, and boron, based upon the composition listed in Table 2-1.

Table 2-1. Components of Glass Fibers and Aluminum Coating

Element	Chemical Symbol	Percent (by weight)
Glass Fiber		
Silicon dioxide	SiO_2	52-56
Alumina	Al_2O_3	12-16
Calcium Oxide and Magnesium Oxide	CaO and MgO	16-25
Boron Oxide	B_2O_3	8-13
Sodium Oxide and Potassium Oxide	Na_2O and K_2O	1-4
Iron Oxide	Fe_2O_3	1 or less
Aluminum Coating*		
Aluminum	Al	99.45 min.
Silicon and Iron	Si and Fe	0.55 max.
Copper	Cu	0.05
Manganese	Mn	0.05
Zinc	Zn	0.05
Vanadium	V	0.05
Titanium	Ti	0.05
Others	---	0.05

* Aluminum is typically alloy 1145.

Flares

Military self-protection flares also vary in composition, with the primary flare body comprised of a molded mixture of magnesium and polytetrafluoroethylene (Teflon). Attached to the primary flare body are additional compounds to aid in proper flare ignition. These include the first fire mixture, the intermediate fire mixture, and the dip coat. These compounds are more sensitive than the main magnesium and Teflon flare body and help to ensure proper ignition. The entire flare is protected in a primarily aluminum casing. The main chemical components of typical military flares and expected debris products are presented in Table 2-2 (USAF 1993).

Table 2-2. Composition and Debris of Typical Flares

Part	Components
Combustible	
Flare Pellet	Polytetrafluoroethylene (Teflon) (-C_2F_4]n- n = 20,000 units) Magnesium (Mg) Fluoroelastomer (Viton, Fluorel, Hytemp)
First Fire Mixture	Boron (B) Magnesium (Mg) Potassium perchlorate ($KClO_4$) Barium chromate ($BaCrO_4$) Fluoroelastomer
Immediate Fire/Dip Coat	Polytetrafluoroethylene (Teflon) (-[C_2F_4]n- n = 20,000 units) Magnesium (Mg) Fluoroelastomer (Viton, Fluorel, Hytemp)
Primer Assembly*	
Assemblage (Debris)	
Aluminum Wrap	Mylar or filament tape bonded to aluminum tape
End Cap	Plastic (nylon) or Aluminum
Felt Spacers	Felt pads (0.25 inches × cross section of flare)
Slider Assembly, Safety and Initiation Device*	

* The primer assembly, slider assembly, and initiation devices were not included for analysis.

Samples of M-206 model flare pellet extracts were analyzed for magnesium, aluminum, boron, barium, and chromium based upon the chemical compositions presented in Table 2-2.

Flare Ash

In order to be effective, the self-protection flare is designed to be ejected from the aircraft and be consumed (burn out) prior to reaching the ground. If the flare performs as designed, it will be completely consumed while still in the air, leaving only reaction gases released to the air and solid by-products to reach the ground. Pure sources of flare ash produced specifically by M-206 flares similar to those used in the flare pellet tests were unavailable, so residual flare ash from previous flare test burns at a U.S. Army test facility was collected and analyzed. No information was available about the specific composition of the flares burned to produce the ash, so certain assumptions of the chemical composition of the ash samples were made. Based upon known composition of typical military flares, the ash was analyzed for magnesium, aluminum, boron, barium, and chromium, similar to the flare pellet samples. In addition, one ash sample was analyzed for organic compounds under the suspicion that organic compound formation might occur during the combustion of the polytetrafluoroethylene binder.

Extraction Leaching Environments

Military self-protection chaff and flares are composed of relatively stable chemicals. Silicon and aluminum in chaff are relatively inert. Flares are composed primarily of magnesium, also relatively inert except in water. It was hypothesized that any major threats to the environment might occur with the deposition of chaff, dud flares, and flare ash in moist, wet areas where the components within the debris products would be subject to leaching by surface or ground water. Due to the widespread use of chaff and flare products in a great number of climatic areas, an approach was taken to attempt to synthesize various pH conditions to which any such debris might be exposed. Modified toxicity characteristic leaching procedure (TCLP) extractions were adopted to provide a reference point to existing leachate data.

Four individual leachate solutions were employed for this study. Chaff, flare pellet, and flare ash samples were prepared and extracted according to TCLP guidelines in sodium acetate buffer solutions of pH 4.0, to simulate harsh acidic conditions, and pH 10.0, to simulate harsh alkaline conditions. A sodium acetate buffer solution of pH 7.0 was used to simulate a neutral aquatic condition, and an imitation seawater solution (pH 7.76) made from a commercially available saltwater aquarium mix was used to simulate the effects of debris materials coming to rest in marine estuarian areas.

In addition, samples of flare material were immersed in water to determine the potential for hydrogen gas evolution caused by the reaction of the magnesium in the flare body with water.

2.2 LABORATORY ANALYSIS

Due to the nature of the samples submitted to the laboratory and the wide variation of environments in which chaff and flares are used, the laboratory analysis techniques were slightly modified to simulate various conditions. In order to obtain precision and accuracy data for these modified procedures, additional quality control (QC) samples were analyzed along with the samples of concern. These included analysis of all samples in duplicate, a matrix spike (inorganics) or a matrix spike and matrix spike duplicate (organics), a blank, a blank spike, and a laboratory QC spike for samples in each extraction medium.

TCLP solution extracts were selected as a method for sample analysis for multiple reasons. The compositions of the stock chaff and flare samples used in this analytical study are known. Therefore, the value of a direct analysis of either chaff or flare samples would be minimal in that it would not provide any additional information. Due to the relatively inert nature of the materials composing both chaff and flares, it is unlikely that any immediate environmental impacts would occur, except for the reaction of the magnesium flare body should it land in an aqueous environment. This incident would precipitate the evolution of substantial amounts of hydrogen gas. Consequently, TCLP extraction techniques were selected to simulate weathering and leaching of materials contained in chaff and flare samples into ground and surface water samples.

Sodium acetate buffered solutions at pH levels more extreme (pH 4.0 and pH 10.0) than those likely to be encountered in nature were selected to rigorously subject the chaff, flare, and ash samples to harsh conditions while maintaining a relatively stable pH. The amounts of aqueous solution used in the tests to act upon the samples was substantially less than would be expected when similar debris of chaff and flare usage settle to earth; thus the ratio of sample to aqueous solution was much greater in the TCLP extraction than would occur in the environment. The TCLP extraction procedure and the extreme pH levels allowed the material to be subjected to simulated long-term weathering in a relatively short (18 hours) time period. In order to maintain as constant a pH as possible, buffered solutions were employed. In nature, the larger volumes of water encountered by the debris and the mitigating effects of the soil and salts in the water would perform this buffering process.

Analytes were selected for analysis based on their existence in the compositional makeup of the samples, not on their toxicity. Whereas the chemicals in the chaff and flares are well documented, the composition of the flare ash was speculative. It was reasoned that only inorganic materials present in the parent product might be contained in the ash by-product, thus only a limited number of inorganic elements were analyzed for. It was also reasoned that the carbon-fluoride-based polymer used to bind the magnesium in the flare body might produce organic compounds during the combustion process. The high heat of combustion (approximately 2,000 degrees Fahrenheit) of the flare would most certainly destroy or volatilize any lightweight organic compounds formed, although it was considered possible that heavier organic compounds might be produced.

2.3 DATA VALIDATION

The reports of laboratory data are contained in Appendix A. All laboratory data were reviewed and validated to EPA Level III standards. The samples were reported along with all applicable laboratory blanks, spikes, and duplicates. Because the samples were not environmental samples, but rather pure product, there were no associated field blanks or equipment rinseate samples. The received data were manually entered into a database for data qualification, data management, and report generation. A summary from this database is provided in Appendix B. The data were reviewed and qualified according to guidelines derived from the following documents:

- *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses*, EPA Contract Laboratory Program, February, 1988.

- *National Functional Guidelines for Organic Data Review, Multi-Media, Multi-Concentration and Low Concentration Water,* EPA Contract Laboratory Program, June, 1991.

These guidelines effectively provide standard operating procedures for specific areas of data validation, while other areas are more subjective. Each criterion was evaluated with respect to each sample and to each compound where applicable. Where a criterion was not met for a specific sample or compound, the database was accessed and qualified for that criterion. The data qualifying procedure applied individual qualifiers to the database for each of the validation criteria. The two qualifiers used in qualifying data validity for this data were:

U	Not Detected
J	An estimated or uncertain value

The laboratory data were reviewed for completeness, comparing the laboratory QC results with the required control limits or using professional judgment where control limits were not specified, qualifying affected data points according to the proper procedure, and preparing a technical justification for the validation action taken. The validation process included the following elements where applicable:

- Contract-required holding times
- GC/MS mass calibration and tuning results (i.e., frequency verification and QC limit evaluation - organics only)
- Initial and continuing calibration results (i.e., frequency verification and control limit evaluation)
- Blank results, including method blanks, initial and continuing calibration blanks, and preparation blanks (i.e., frequency verification and comparison with sample concentrations)
- System monitoring compound results (i.e., control limit evaluation - organics only)
- Matrix spike and matrix spike duplicate analysis (i.e., frequency verification and control limit evaluation - organics only)
- Matrix spike samples and duplicate sample analysis (i.e., frequency verification and control limit evaluation - inorganics only)
- System performance and overall data quality - professional judgment

Inorganic Data Validation

This section presents a discussion of the validation results for the trace metals analysis.

Holding Times. The samples analyzed in this particular case were product samples as opposed to environmental samples. The samples were supplied rather than collected and, as a result, holding times were not applicable.

Initial Calibration Verification. All initial calibration requirements were met for all samples analyzed in this case.

Continuing Calibration Verification. All continuing calibration acceptance criteria were met for all samples except the following: vanadium associated with the chaff sample in the pH 10 buffered extraction solution and in the simulated marine water extraction solution had a percent recovery of 88 percent. All positive results for vanadium for chaff in the pH 10 and marine solutions are estimated ('UJ').

Blank Contamination. Boron and magnesium contamination was found to varying degrees in most of the laboratory blanks associated with the samples in this case. In accordance with standard protocol, concentrations of elements occurring in samples associated with contaminated blanks were qualified as non-detects ('U') if the sample concentration was less than five times the blank concentration. Affected blanks are as follows:

Blank Solution	Element	Concentration	Affected Samples
pH 4 blank	Magnesium	1.14 mg/L	chaff, flare, ash
pH 7 blank	Magnesium	0.05 mg/L	chaff, flare
	Boron	0.1 mg/L	chaff, flare
pH 10 blank	Magnesium	1.14 mg/L	chaff, flare, ash
Marine blank	Magnesium	867 mg/L	chaff, flare, ash

mg/L = milligrams per liter

Matrix Spike Recovery. Matrix spike recoveries were measured in each extract solution as a measure of overall accuracy of the extraction and analysis technique. Matrix spike recoveries were generally low, and the data were qualified as estimated ('UJ' or 'J') in all associated samples, due to the following matrix spike recovery percentages:

Extract Solution	Element	Percent Recovery	Affected Samples
pH 4	Boron	35	ash
pH 7	Boron	64	chaff
pH 7	Barium	72	flare
pH 7	Boron	42	ash
pH 10	Boron	64	chaff
Marine	Aluminum	64	chaff
Marine	Aluminum	66	ash
Marine	Aluminum	69	flare

Duplicate Sample Analysis. Duplicate samples were analyzed in each of the TCLP extract solutions as a measure of the overall precision of the extraction and analysis procedures. Duplicate sample analysis resulted in consistently high relative percent differences, and the data were qualified as estimated ('UJ' or 'J') in all associated samples, due to the following differences in results:

Extract Solution	Element	Percent Difference	Affected Samples
pH 4.0	Boron	40.0	chaff
pH 4.0	Magnesium	21.3	chaff
pH 4.0	Barium	66.7	flare
pH 4.0	Chromium	62.1	flare
pH 7.0	Aluminum	40.0	chaff
pH 7.0	Boron	85.7	chaff
pH 7.0	Magnesium	30.3	chaff
pH 7.0	Barium	26.4	flare
pH 7.0	Barium	28.6	ash
pH 10.0	Aluminum	40.0	chaff
pH 10.0	Zinc	40.0	chaff
pH 10.0	Barium	46.2	flare
Marine	Boron	50.0	chaff
Marine	Barium	46.2	flare
Marine	Nitrate	66.7	ash
Marine	Nitrite	22.5	ash

System Performance. The exceedances in laboratory quality control samples indicate substantial variances may exist with regards to the actual analyzed quantities reported by the laboratory. The low matrix spike recoveries indicate that reported quantities of boron in the buffered extract solutions and the aluminum results reported in the marine extracts may be biased low. The high percent differences in the duplicate analyses indicate difficulties in obtaining consistent analytical values. These difficulties may be the result of the extract solutions used in the modified procedures. In light of the differences encountered, statistically significant distributions could not be derived from the number of samples tested. Therefore, because of the limited testing with the modified extract procedures used, findings should be considered approximate in the case of aluminum, boron, and barium.

Organic Data Validation

This section presents a discussion of the validation results for the semi-volatile organics. A pH 7.0 buffer solution extraction on a sample of flare ash was analyzed for semi-volatile organics to determine if the combustion of a flare might produce organic by-products.

Holding Times. The samples analyzed in this particular case were product samples as opposed to environmental samples. The samples were supplied rather than collected and as a result holding times were not applicable.

Initial Calibration Verification. All initial calibration requirements were met for all samples analyzed in this case.

Continuing Calibration Verification. All continuing calibration acceptance criteria were met for all samples except for pentachlorophenol. Pentachlorophenol in the continuing calibration standard analyzed with the samples had a difference of -38.7 percent. As a result, the pentachlorophenol results in the associated sample were estimated ('UJ').

Blank Contamination. The blank associated with the samples in this case exhibited no signs of contamination other than a small amount of 4,6-dinitro-2-methylphenol. This compound was detected in the blank sample at a concentration of 1 microgram per liter (*u*g/L). The compound was also detected in the ash sample at the same concentration. According to data validation guidelines, this concentration was raised to the quantification limit and qualified as not detected ('24 U').

Matrix Spike Recoveries. All matrix spike and matrix spike duplicate compound recoveries were within established quality control limits for the samples analyzed in this case.

System Monitoring Compounds. Surrogate spike compounds were monitored as an indicator of system performance. All surrogate recoveries were within established limits and, as a result, all requirements for system monitoring compounds were met for the samples in this case. Internal standard area counts are also examined as an indicator of system performance. The level of laboratory analysis required for these samples did not require the reporting of internal standards data, so they were not considered in this data validation. Due to the consistently acceptable recoveries of the surrogate and matrix spike compounds, the lack of this raw data is not considered to affect the quality of the analytic data.

System Performance. All quality control checks performed by the laboratory as a measure of overall system efficiency were consistently within established control limits. The data should be considered accurate and precise for the compound analysis presented herein. Additionally, no organic contaminants were detected except for minor amounts of common laboratory contaminants.

3.0 DATA SUMMARY AND EVALUATION

3.1 RESULTS OF LABORATORY ANALYSIS

Table 3-1 presents average concentrations of elements found in the chaff, flare pellet, and flare ash tests. Detailed results of the laboratory sample tests are provided in Appendix A and summarized in Appendix B. Appendix C presents an interpretation of the data by the laboratory's project scientist.

Table 3-1. Average Element Concentrations from Surrogate Environment Solutions

Treatment	Concentration (mg/L)										
	Mg	Al	Cu	Mn	Si	Ti	V	Zn	B	Ba	Cr
					Glass Fiber Chaff						
pH 4	0.24	170	<0.02	<0.02	<1.0	<0.05	<0.02	0.40	1.5	NA	NA
pH 7	0.17	0.3	<0.02	<0.02	<1.0	<0.05	<0.02	0.06	1.4	NA	NA
pH 10	0.18	3.0	<0.02	<0.02	<1.0	<0.05	<0.02	0.03	0.9	NA	NA
SSW	871	0.3	<0.02	<0.02	<1.0	<0.05	<0.02	0.04	0.8	NA	NA
					Flare Pellet						
pH 4	2945	<0.1	NA	NA	NA	NA	NA	NA	<0.1	3.0	0.29
pH 7	4.4	<0.1	NA	NA	NA	NA	NA	NA	<0.1	2.7	<0.02
pH 10	2.4	<0.1	NA	NA	NA	NA	NA	NA	<0.1	2.6	<0.02
SSW	640	<0.1	NA	NA	NA	NA	NA	NA	<0.1	2.6	<0.02
					Flare Ash						
pH 4	857	<0.1	NA	NA	NA	NA	NA	NA	17.9	185	<0.02
pH 7	186	<0.1	NA	NA	NA	NA	NA	NA	18.0	1.4	<0.02
pH 10	202	<0.1	NA	NA	NA	NA	NA	NA	89.0	1.0	0.03
SSW	948	<0.1	NA	NA	NA	NA	NA	NA	68.0	<0.5	0.03

NA = Not analyzed; SSW - synthetic seawater; less than (<) values indicate the element was not present or occurred below the method detection limit.

Chaff

Chaff tests detected four of the nine elements analyzed: magnesium, aluminum, zinc, and boron. Aluminum was the dominant element at pH 4 and pH 10. The highest quantity was at pH 4, with an average of 170 mg/L. In contrast, the average at pH 10 was 3 mg/L, and findings in the pH 7 and synthetic seawater (pH 7.8) solutions averaged 0.3 mg/L. In both of the neutral solutions, boron was the dominant element found. The high quantities of magnesium detected in the synthetic seawater treatment are attributable to the composition of the extracting solution.

Flares

Only two of the elements analyzed in the flare pellet extracts were detected in all treatments: magnesium and barium. Chromium was detected only in the pH 4 treatment. The magnesium concentration was strongly affected by the solution pH. The flare pellet and flare ash extraction also affected the pH of the leaching solutions. All of the post extraction solutions for flare duds had pH levels close to 10, including the pH 4 solution (see Appendix C).

Three samples of flare material were reacted with the pH 4 solution for a 72-hour period to assess production of hydrogen gas. All three samples resulted in comparable quantities of gas (522-539 liters per kilogram). The gas was colorless and highly flammable and presumed to be primarily hydrogen. However, it was not odorless and may have contained some other volatile contaminant.

Flare Ash

Analysis of the flare ash extracts resulted in detection of magnesium and boron in all treatments, and barium and chromium in some of the treatments (see Table 3-1). Magnesium was the dominant element in all samples. Boron occurred at much higher concentrations in the flare ash than in the flare pellet extracts, particularly in the pH 10 and synthetic seawater solutions. Barium was detected in all but the synthetic seawater treatment, and was very high (average of 185 mg/L) in the pH 4 solution. Low levels of chromium were detected in the pH 10 and synthetic seawater treatments.

In addition to the metals detected, all flare ash extracts contained measurable levels of ammonia (NH_3) and nitrate (NO_3), and nitrite (NO_2) was detected in the pH 10 treatment.

The flare ash samples were uncontrolled recoveries of previous burns, and the potential for contamination is high. Debris, including paper clips, wire, and plant tissue, were removed from the samples prior to analysis.

3.2 FINDINGS

The effects of releases of chaff, dud flares, and flare ash on the environmental depend on a variety of factors, including the quantity of material released, the propensity of these materials to leach toxic chemicals under given conditions, and the sensitivity of receiving environments to contaminants of concern. In that vein, the material likely to generate the highest volume of debris is chaff, which eventually precipitates totally to the surface. Dud flares are rare and incidental events, so it is extremely unlikely that any location would experience a "build-up" of dud flare material in the environment. Flare ash is a by-product of combustion and is widely dispersed by winds. The likelihood that a sufficient quantity of chaff or flare ash would fall into a particular pond, stream, or estuary, to measurably affect its chemical make-up is remote.

The stability of these materials in soils and sediments is important because it determines the rate of release of chemical constituents. The major factors influencing stability include the size of the particle (exposed surface area), chemical environment, and availability of water. The glass fiber and flare ash are predicted to be more susceptible to weathering effects than flare duds on the basis of particle size alone. The aluminum coating on glass fiber chaff is the least stable under acidic and extremely alkaline conditions. The highest solubility occurs under acidic conditions. The magnesium in flare material and flare ash is less stable in acidic environments than in neutral or alkaline conditions. The dissolution of either chaff or flare material will be greatest where water content is high. Thus, weathering will be more rapid in wet, acidic environments than in dry, neutral and alkaline environments.

The following sections summarize potential effects of chemicals leaching from chaff and flare materials on terrestrial, freshwater aquatic, and marine environments, based on the findings of the laboratory analysis.

Terrestrial Environment

The evaluation of potential chemical effects from chaff and flare use on terrestrial environments considered the following issues:

- Direct toxicity to plants
- Uptake and accumulation of toxic constituents in plants that might be consumed by domestic livestock or wildlife
- Contamination of ground water

Chaff

Elements of concern for chaff include aluminum, magnesium, copper, manganese, titanium, vanadium, zinc, boron, and silicon. Of these, only aluminum, magnesium, zinc, and boron were detected in the laboratory analysis. The absence of copper, manganese, titanium, and vanadium in the laboratory extracts may indicate that the chaff samples used did not contain these elements, but they may still occur and are therefore included in the analysis.

Aluminum, magnesium, and silicon occur naturally in relatively high concentrations in soils, and the probability of significant toxic effects are slight. The national average for natural aluminum concentration in soils is 72,000 milligrams per kilogram (mg/kg). Aluminum restricts root growth in some plants at soil solution concentrations as low as 1 mg/L. However, soil solution aluminum concentrations are reduced by ion exchange reactions, solid phase precipitation, and ligand exchange processes. Consequently, soil solution concentrations of aluminum in the toxic range are only likely to occur in extremely acid and very sandy soils. Potential plant toxicity would likely be limited to sensitive crops, since native vegetation will have adapted to local conditions, and liming, a common practice on acid agricultural soils, would reduce the potential for aluminum toxicity (Munk 1994).

There are no reportable spill quantities for aluminum under the Resource Conservation and Recovery Act (RCRA) or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). One test used in evaluating action levels for hazardous materials is the occurrence of analytes of concern at a concentration equivalent to three times the background level (40 Code of Federal Regulations [CFR] Part 300, App. A, Sec. 2.3). Based on the results of the pH 4 surrogate environment laboratory treatment, which produced the highest concentration of aluminum, an estimated 325,000 kilograms of chaff would have to be deposited on an acre of land to triple the aluminum concentration in the upper inch of soil, assuming a mean soil content of 72,000 mg/kg (Munk 1994). This is equivalent to over 3 million chaff bundles and exceeds the total annual use by ACC units nationwide.

Magnesium also occurs naturally in large concentrations in soil (mean content of 9,000 mg/kg). Magnesium deficiencies may occur in humid acidic soils, and toxicity occurs rarely in alkaline soils formed from ultra-mafic rocks. Correcting deficiencies or inducing plant toxicity would require the addition of readily available magnesium at the rate of several tons per acre (Munk 1994).

Silicon is not known to be toxic to plants, and elevated uptake by plants has not been documented. The surrogate environmental laboratory tests did not detect dissolution of silicon in even the most acidic solution (pH 4).

Small quantities of copper, manganese, titanium, vanadium, and zinc may occur in the aluminum coating of chaff. Only zinc was detected in the laboratory tests. It is likely that the other trace metals were not present in the particular lot of chaff analyzed (Munk 1994). Except for titanium, these trace elements are considered essential nutrients for either plant or animal growth. Toxic effects may occur at elevated concentrations in soil or plant tissue. Copper, manganese, titanium, and zinc have strong affinities to precipitate as hydroxy oxides with oxygen and hydroxyl ligands under oxidized neutral and alkaline conditions. Under anaerobic conditions, they tend to precipitate as sulfides and carbonates, depending on pH. In addition, a number of other mechanisms may reduce the activity of these elements in solution, including ion exchange coprecipitation and chelation with natural organic compounds. In general, the mobility and availability of these metals increase with increasing acidity, which also tends to coincide with soil conditions likely to be deficient in these elements. In contrast, vanadium occurs as anions, and its mobility and availability may decrease with increasing acidity in some soils (Munk 1994).

Of the five transition metals that may occur in chaff, only copper, vanadium, and zinc have RCRA reportable quantities, and none have critical TCLP limits under 40 CFR Part 261.24. The RCRA reportable quantities are 2,273 kg for copper and 454 kg for vanadium or zinc. This would represent nearly 1 million kg of chaff for the more restrictive metals.

Boron is both an essential and toxic element for plants. Boron deficiencies are most likely to occur in humid, acid soils, and toxicity occurs in alkaline environments. Sensitive plants are affected by concentrations as low as 0.3 mg/L. In general, the availability of boron to plants decreases with increasing soil pH and under arid conditions. Increased availability corresponds with conditions most likely to be deficient in boron. Boron detection in the surrogate environment laboratory tests of chaff corresponded with pH. There is no RCRA reportable quantity or critical TCLP limit for boron. However, natural soil content is low (mean of 33 mg/kg), and the amount of chaff deposition required to raise soil concentration to triple background level is less than for any other element (estimated 571 kg/acre) (Munk 1994). Nevertheless, this represents about 5,700 bundles of chaff.

In summary, the exposure of organisms to elements in chaff depends on the rate of release of these materials in the environment. The availability and mobility of metals in the soil will be reduced by a number of attenuation factors, including solid phase precipitation, ion exchange, coprecipitation, and complexation with iron and aluminum oxyhydroxides and organic matter. Retention of elements in soil will reduce their availability to organisms and the potential for ground water contamination. The results of the laboratory tests indicate that chaff is more susceptible to dissolution in wet, acid environments than under arid, alkaline or neutral conditions. Based on available data, broad-scale, significant accumulations of metals in soil would require extremely large releases of chaff (Munk 1994).

Flares

Elements of concern for flares include magnesium, boron, barium, and chromium. The laboratory test results indicate that the potential for release of these elements is strongly related to pH, the highly acidic media producing higher concentrations (with the exception of barium in the flare pellet samples, which did not vary appreciably with pH). Impacts from dud flares are not considered of significant concern because the incidence of duds is rare, and the number that would have to land in a single location to have an effect is on the order of tens of thousands. Therefore, the analysis that follows concentrates on chemicals released by flare ash.

The principal element in flares and in flare ash is magnesium. As noted above for chaff, magnesium occurs naturally in soil at a mean concentration of 9,000 mg/kg. The highest concentrations produced by the surrogate environment laboratory tests were 3,050 mg/L for a dud flare and 861 mg/L for flare ash at pH 4. At higher pH, the concentrations dropped off dramatically, to an average of 186 mg/kg at pH 7 and 202 mg/kg at pH 10 for the flare ash (the reductions were even more dramatic with the flare pellet samples).

Flare ash samples also produced detectable quantities of boron, barium, and, in some samples, chromium. Boron and chromium concentrations were higher in the pH 10 and synthetic seawater treatments. Barium was detected in the pH 4, 7, and 10 treatments, with the highest levels found in the most acidic solution. The unexpectedly high quantities of barium detected in the flare ash samples raise questions about potential contamination of the ash used, which was not produced in a controlled environment.

Barium mobility and uptake by plants is not well studied, since barium generally occurs sparingly in solutable forms and at low concentrations in most soils. Test results indicate it will become more mobile in low pH environments. Barium can be toxic to animals when ingested in forms other than the insoluble barium sulfate. The elevated barium concentration in the pH 4 extracts of the flare ash suggest that barium may present a localized hazard for sensitive organisms. There are no RCRA reportable quantities for barium, but the critical TCLP limit in 40 CFR Part 261.24 is 100 mg/L. This level was exceeded in only one of the laboratory findings, in the pH 4 extract of flare ash (the next highest finding was less than 2 mg/L) (Munk 1994).

As noted above for chaff, boron toxicity can occur in alkaline environments, and the laboratory tests of flare ash produced the highest concentrations in the alkaline (pH 10) solution. There are no RCRA reportable quantities or critical TCLP limits for boron. Based on a mean background soil content of 33 mg/kg, the amount of flare ash that would be required to raise the boron concentration to triple the background level in the upper inch of soil was estimated at over 1,500 kg/acre (Munk 1994). This represents about 4,000 flares.

Chromium was detected in low concentrations in the pH 10 treatment of flare ash. The low quantities detected indicate that chromium is not a significant issue. The RCRA reportable quantity for chromium is 2,273 kg, and the critical TCLP limit is 5 mg/L. In contrast, the highest detected concentration in the laboratory test of flare ash was 0.03 mg/L (Munk 1994).

Three replicate samples of flare pellet material were analyzed to measure production of hydrogen gas. An average sample of 1.1 gram of flare produced an average of 580 milliliters of hydrogen gas. Assuming an average flare weight of 370 grams, a complete flare falling into water could produce 195 liters of hydrogen gas. Hydrogen gas is highly explosive if in a confined area, although it would dissipate rapidly in an open environment. Hydrogen gas production from dud flares would not pose an environmental threat, but it could be a safety hazard if a wet flare were placed in an enclosed container.

Freshwater Aquatic Environment

Freshwater aquatic environments are potentially more sensitive to chemicals released from chaff and flares than terrestrial environments for the following reasons: (1) dissolution of materials will be faster in water than on land, (2) chemicals are more mobile and more available to organisms, and (3) the thresholds of toxicity tend to be lower for sensitive aquatic species. The extreme pH levels used in the laboratory analysis are not directly applicable to aquatic environments because pH 4 is too acidic and pH 10 too basic for most aquatic organisms. These data, along with the more normal pH 7 test results, can, however, be used in a qualified fashion to indicate trends in solubility and toxicity.

Chaff

Among the elements examined in chaff, only aluminum and copper have the potential for sufficiently high concentrations to be of concern in aquatic environments. Magnesium, boron, manganese, titanium, vanadium, and silicon concentrations are less than values known to cause toxicity to aquatic organisms.

Aluminum solubility and toxicity are highly pH dependent. The highest concentrations in the laboratory tests occurred at pH 4 (170 ppm) and the lowest at pH 7 (0.3 ppm). The freshwater acute value for aluminum is 1.496 ppm, and the chronic value is reported as 0.742 ppm for a pH range of 6.9 to 8.2. There are no data available on acute or chronic levels at the extreme pH levels of 4 and 10 used in the laboratory analysis. The extracts from the pH 7 samples, which lie within the 6.9-8.2 range, were approximately one-sixth the freshwater acute value for aluminum. These extract values represent a very high chaff-to-water ratio (1:20) which could not occur in the environment. Therefore, aluminum toxicity due to chaff is not likely to be a concern in aquatic environments.

Copper was not detected in the laboratory tests, which had a detection limit of 0.02 mg/L, but the freshwater acute value is 0.018 parts per million (ppm), which is below the detection limit. While the findings of the laboratory research are inconclusive with respect to copper, it is unlikely that chaff would be deposited in a body of water in sufficient quantity to cause harm to aquatic life.

Chaff disperses widely when employed from military aircraft. Depending on the altitude of release and wind speed and direction, the chaff from a single bundle can be spread over distances ranging from less than a quarter mile to over 100 miles (USAF 1994). The most confined distribution would be from a low-altitude release in calm conditions. The chaff from one bundle could be expected to distribute over about a quarter mile area (160 acres). The average distribution for a bundle of RR-112A chaff (the largest model) would be about 69,000 chaff dipoles per acre. Each dipole could contain a maximum of 1.8×10^{-9} gram of copper (at 0.05 percent of the aluminum coating). An entire bundle of 11 million dipoles could contain approximately 0.02 gram of copper (the quantity would be proportionally less for the smaller bundles, such as RR-170A which contains approximately 3 million dipoles). Thus, the worst case condition would be clump of undispersed RR-112A chaff falling in total in a small, confined body of water. Even in this worst case situation, the amount of copper introduced would be equivalent to the copper in one penny.[*]

Flares

Of the five metals measured in the flare pellet material, only magnesium showed sufficiently high levels to warrant consideration. Aluminum, boron, barium, and chromium did not extract in sufficient quantities to be of concern to aquatic organisms. Magnesium was measured at almost 3,000 ppm at pH 4, dropping to 4.4 ppm at pH 7, which more closely approximates typical aquatic environments. There are no aquatic criteria for magnesium, but a review of the on-line Aquatic Information Retrieval (AQUIRE) data service showed a 50 percent lethal concentration (LC50) response in water fleas (*Daphnia magna*) at 140 to 160 ppm. It is not possible to extrapolate precisely the level of magnesium that would be extracted over a pH range of 5 to 9, which would cover most aquatic environments, however, it appears that effects would only occur in the more acidic environments. Even then, the occurrence of dud flares is so rare as to be highly unlikely to have an impact.

The elements of concern in the flare ash extracts are magnesium, barium, and boron. Aluminum and chromium were either undetected or in insufficient quantities to threaten aquatic life. Magnesium extracts ranged from an average of 186 ppm at pH 7 to an average of 857 ppm at pH 4. Barium showed as high as 191 ppm at pH 4, but lower levels at pH 7 (1.4 ppm) and pH 10 (1.0 ppm). There are no established water quality criteria for barium, but the

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[*] Pennies manufactured since 1982 have a total weight of 2.5 grams and are 0.8 percent copper.

AQUIRE database showed that values as low as 14.5 ppm were toxic to water fleas, while higher values (690 ppm) were necessary to cause 50 percent mortality in mosquito fish (*Gambusia affinis*). Both species live in environments that generally have a pH of over 6.9, and would not be affected at the levels found in the pH 7 laboratory test. No data are available concerning toxicity of barium for aquatic life that live in lower pH environments.

There are no water quality criteria established for boron. However, in a comparison of the TCLP laboratory data against a U.S. Fish and Wildlife Service publication on toxicity effects of boron (USFWS 1985), the levels of boron extracted in the pH 10 samples of flare ash would be sufficient to cause lethal or chronic effects in several aquatic species.

Flare ash extracts also contained measurable levels of ammonia. The values ranged from 2.8 to 3.2 ppm and are at or above levels reported by EPA as toxic to aquatic life (EPA 1985). In addition, both the flare dud and the flare ash samples had a significant effect on the pH of the solutions with which they reacted. The 1.1 gram samples of flare ash raised the pH of 225 milliliters of buffered sodium acetate solution from pH 4 to pH 9.6. While flare ash quantities likely to settle in a body of water are very small, a dud flare falling into a small, confined pond could raise the pH and adversely affect aquatic life in the water. This is an extremely unlikely event, however.

In summary, the TCLP test results are inconclusive with respect to potential effects from flare ash on sensitive aquatic habitats, primarily because the toxicity levels to some aquatic organisms are so low. However, the potential for impact is highly dependent on the quantity of material deposited in a given body of water. After burning, the ash produced by a flare would be widely dispersed by wind, and the quantity settling in a single location would be minute. Conditions warranting further consideration might include small water bodies containing organisms that are highly sensitive to magnesium, barium, boron, ammonia, or pH changes in areas that receive a high amount of flare use.

Marine Environment

A significant amount of training with chaff and flares occurs over the open ocean. Although the vastness of the receiving waters and the resulting dilution of any materials or chemicals deposited make the potential for impact extremely remote, laboratory extraction tests were conducted using synthetic seawater to identify chemicals that could be released into the ocean. The results could be of interest in a more confined estuarine environment.

Chaff

The concentrations detected for all elements of concern were low in the synthetic seawater solution. The high levels of magnesium detected are attributable to the magnesium in the extracting solution. As with freshwater aquatic environments, the only chemical of potential concern is copper. The marine chronic value for copper is 0.003 ppm, which is well below the laboratory detection limit of 0.02 mg/L. However, as discussed above for freshwater environments, the quantity of copper involved, if any, is minute.

Flares

Incidental flare duds falling into marine environments would not be expected to generate adverse effects due to the small amount of chemicals released. The only chemicals detected in the flare ash samples were magnesium, boron, and chromium. Unlike the freshwater extracts, no barium was detected. Magnesium levels were as high as 86 ppm, after correction for the high background level of magnesium in seawater (about 867 ppm). No magnesium toxicity data are available for seawater. The boron extract had a value of 68 ppm, which could be sufficient to cause effects in some aquatic species (USFWS 1985). Chromium was not detected in sufficient quantities for concern.

3.3 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the surrogate environment laboratory tests conducted on aluminum-coated glass fiber chaff, flare pellet material, and flare ash, and considering the quantities of chaff and flares used in military training, no acute or cumulative chemical effects are anticipated on terrestrial environments. There are no significant unresolved issues related to chemical effects of these materials on soils or, consequently, on plants, animals, or ground water.

The potential for effects to freshwater aquatic environments is directly related to the quantity of material deposited in a water body and the sensitivity of aquatic organisms that live in the affected area. With respect to chaff, the only element of concern is copper. No copper was detected in any of the chaff samples subject to laboratory analysis, but, based on information about the composition of the aluminum coating, it could occur. The maximum quantity of copper that could be released in a body of water is so minute that no further analysis is considered necessary. Any unusual site-specific concerns (e.g., highly sensitive environment subject to repeated chaff releases) could be addressed through a monitoring program.

With respect to flare use, the study was inconclusive concerning potential for impacts from barium, boron, and ammonia produced by flare ash, as well as effects on pH. These would only be of potential concern in small water bodies subject to substantial, repeated flare use, and which support organisms sensitive to these chemicals. Deposition of flare ash in the concentrations used for the laboratory analysis could be toxic to aquatic organisms. However, these concentrations (material to solution ratio of 1:20) were far higher than could occur as a result of military training. More precise studies could be conducted using more appropriate concentrations of flare ash and pH ranges more accurately reflecting actual aquatic environments (5-9.2). If such tests are conducted, flare ash samples should be recovered under more controlled conditions to reduce the likelihood of contamination. Any site-specific issues in areas proposed for flare employment could be addressed with an ecological risk assessment, based on anticipated levels of flare use, or a water body of concern could be monitored for chemical effects. Two approaches could be taken:

(1) The quantity of flare ash deposition could be projected based on anticipated number of flares and resulting copper concentration could be estimated and

compared to acute or chronic values or to toxicological data for the organisms of concern.

(2) The sensitive water body of concern could be subject to a long-term monitoring program to determine whether flare use is affecting its chemical composition.

While the potential for adverse effects is considered low, consideration could be given to conducting bioassay tests of chaff and flare ash to further assess their toxicity to aquatic organisms. A tiered approach would be appropriate, starting with a toxicity test involving a range of conditions (freshwater, estuarine, marine) and concentrations. A range of organisms should also be considered, including invertebrate (*Ceriodaphnia* and *Mulinia*), fish (*Pimephales* and *Cyprinodon*), water plant (*Champia*), and amphipod (*Hyalella* and *Leptocheirus*). The objective of the tests would be to determine the concentrations at which 50 percent mortality occurred. If a marginal response were observed, a long-term exposure (28 days) in a chronic amphipod benthic test could be performed.

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5.0 LIST OF PREPARERS

Robin Brandin, Project Manager, SAIC
B.A., History of Art, Bryn Mawr College, 1971
M.C.R.P., City and Regional Planning, Rutgers University, 1974
Environmental Planning, Air Force Institute of Technology, 1979
Architectural Planning, Air Force Institute of Technology, 1980
Certified Planner, American Institute of Certified Planners, 1984
Years of Experience: 20

Thomas Belnek, Senior Environmental Scientist, SAIC
B.S., Environmental Science, University of New Hampshire, 1979
M.S., Environmental Science, Washington State University, 1985
Years of Experience: 11

Lewis Munk, Project Scientist, Soil and Water West, Inc.
B.S., Soil Sciences, University of Arizona, 1980
M.S., Soils and Biometeorology, Utah State University, 1988
Ph.D., Soils and Biometeorological Chemistry, University of California at Davis, 1993
Years of Experience: 15

Robert Rea, Senior Engineer, SAIC
B.S., Civil Engineering, Texas A&M College, 1956
M.S., Aeronautical Engineering, Air Force Institute of Technology, 1960
C.E., Civil Engineer (Guggenheim Scholarship), Columbia University, 1962
M.B.A., Business Administration, University of Phoenix, 1987
Registered Professional Engineer (Ohio, Arizona, New Mexico)
Years of Experience: 32

Timothy Thompson, Environmental Toxicologist, SAIC
M.S., Ocean Sciences, University of British Columbia, 1982
Years of Experience: 13

Richard Tremaglio, Staff Chemist, SAIC
B.S., Chemistry, Muskingum College, 1989
Years of Experience: 5

APPENDIX A

LABORATORY DATA

Soil and Water West, Inc. Natural Resource Consultants and Testing Laboratories

Custom Analytical Services

Project: Chaff, Flare Dud, and Flare Ash Analyses
Work order: 1368
Date Received: 3/30/95-6/7/94
Date Reported: 8/17/94

Laboratory Director
Russell H. Zittlosen

Project Scientist
Lewis Munk

1700 Southern Blvd., Rio Rancho, New Mexico 87124 (505) 891-9472 FAX (505) 892-6607 Incorporated 1988

Soil and Water West, Inc. **Natural Resource Consultants/Testing Laboratories**
1700 Southern Blvd. Rio Rancho, New Mexico Phone (505) 891-9472 FAX (505) 892-6607

Client: SAIC R. Rea
Work Order No.: 1368
Received: 3/30/94
Reported: 8/17/94
Page 1 of 16

Results/QA-QC

Initial pH: 4.00 **Matrix:** Chaff **Extractant:** 0.1 N NaOAC (pH 4.0); 18 h contact time

Extraction Date: 7/14/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	0.26	0.21	21.3	2.20	0.26	2.00	97	1.14	0.01
Al	182	158	14.1	193	182	10.0	110	0	0.1
Cu	0	0	0.0	0.19	0	0.20	95	0	0.02
Mn	0	0	0.0	0.20	0	0.20	100	0	0.02
Si	0	0	0.0	9.5	0	10.0	95	0	1.0
Ti	0	0	0.0	0.27	0	0.25	108	0	0.05
V	0	0	0.0	0.21	0	0.20	105	0	0.02
Zn	0.39	0.40	2.5	0.59	0.39	0.20	100	0	0.01
B	1.2	1.8	40.0	2.1	1.2	0.63	144	0	0.1
Ba									0.5
Cr									0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	25.00	25.00							NA
Final pH	4.52	4.45						3.97	NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	2.18	1.00	104	5.00	4.92	16.0	16.1	99	8/2/94
Al	1.0	1.0	100	100	94.5	4.1	4.0	102	8/4/94
Cu	0.20	0.20	100	2.00	1.98	0.40	0.41	98	8/1/94
Mn	0.15	0.20	75	1.00	1.00	0.21	0.22	95	8/1/94
Si	9.0	10.0	90	100	93.1	2.0	2.0	100	8/4/94
Ti	0.19	0.20	95	0.25	0.27	0.12	0.13	92	8/2/94
V	0.17	0.20	85	0.25	0.23	0.15	0.17	88	8/2/94
Zn	0.19	0.20	95	1.00	1.02	1.03	1.10	94	8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba									8/4/94
Cr									8/2/94
NH3-N									
NO3/NO2									
Final pH									7/15/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 4.00 **Matrix:** Flare Dud **Extractant:** 0.1 N NaOAC (pH 4.0); 18 h contact time

Extraction Date: 7/25/94 **Extract Dilution Ratio:** 1:20

	Sample Results			**Matrix Spike Recovery**					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	3050	2840	7.1	3570	3050	500	104	1.14	0.01
Al	0	0	0.0	9.0	0.0	10.0	90	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	0.0	0.0	0.0	0.7	0.0	0.63	112	0	0.1
Ba	2.0	4.0	66.7	9.5	2.0	10.0	75	0	0.5
Cr	0.20	0.38	62.1	2.30	0.20	2.00	105	0	0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	52.52	51.00							NA
Final pH	10.52	10.53							NA

	Blank Spike Recovery			**Continuing Calib.**		**QC Sample**			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	2.18	1.00	104	5.00	4.92	16.0	16.1	99	8/2/94
Al	1.0	1.0	100	100	94.5	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba	5.0	5.0	100	50.0	50.5	5.2	5.0	104	8/4/94
Cr	0.20	0.20	100	2.00	2.08	0.45	0.46	98	8/2/94
NH3-N									
NO3/NO2									8/8/94
Final pH									7/15/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 6/7/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 4.00 **Matrix:** Flare Ash **Extractant:** 0.1 N NaOAC (pH 4.0); 18 h contact time

Extraction Date: 7/14/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	861	852	1.1	863	861	2.00	100	1.14	0.01
Al	0	0	0.0	8.9	0.0	10.0	89	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	17.7	18.0	1.7	18.8	17.7	3.13	35	0	0.1
Ba	178	191	7.0	196	178	20.0	90	0	0.5
Cr	0	0	0.0	2.18	0.0	2.00	109	0	0.02
NH3-N	see NH3-N Result								0.1
NO2-N	see NO2 results								
NO3-N	see NO3 results								0.1
Weight (g)	30.00	30.00							NA
Final pH	9.59	9.52							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	2.18	1.00	104	5.00	4.92	16.0	16.1	99	8/2/94
Al	1.0	1.0	100	100	94.5	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba	5.0	5.0	100	50.0	50.5	5.2	5.0	104	8/4/94
Cr	0.20	0.20	100	2.00	2.08	0.45	0.46	98	8/2/94
NH3-N	see NH3 results sheet								
NO3/NO2	see NO3, NO2 results								8/8/94
Final pH									7/15/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 7.00 **Matrix:** Chaff **Extractant:** 0.1 N NaOAC (pH 7.0); 18 h contact time

Extraction Date: 7/12/94 **Extract Dilution Ratio:** 1:20

	Sample Results			**Matrix Spike Recovery**					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	0.14	0.19	30.3	2.06	0.14	2.00	96	0.05	0.01
Al	0.3	0.2	40.0	9.2	0	10.0	89	0	0.1
Cu	0	0	0.0	0.20	0	0.20	100	0	0.02
Mn	0	0	0.0	0.20	0	0.20	100	0	0.02
Si	0	0	0.0	8.9	0	10.0	89	0	1.0
Ti	0	0	0.0	0.25	0	0.25	100	0	0.05
V	0	0	0.0	0.21	0	0.20	105	0	0.02
Zn	0.05	0.06	18.2	0.27	0.05	0.20	110	0	0.01
B	2.0	0.8	85.7	2.4	2.0	0.63	64	0.1	0.1
Ba									0.5
Cr									0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	25.00	25.00							NA
Final pH	7.22	7.14							NA

	Blank Spike Recovery			**Continuing Calib.**		**QC Sample**			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	1.00	1.00	95	5.00	5.14	16.0	16.1	99	8/2/94
Al	1.0	1.0	100	100	100	4.1	4.0	102	8/4/94
Cu	0.19	0.20	95	2.00	1.98	0.40	0.41	98	8/1/94
Mn	0.20	0.20	100	1.00	1.00	0.21	0.22	95	8/1/94
Si	8.6	10.0	86	100	93.1	2.0	2.0	100	8/4/94
Ti	0.21	0.20	105	0.25	0.27	0.12	0.13	92	8/2/94
V	0.18	0.20	90	0.25	0.23	0.15	0.17	88	8/2/94
Zn	0.20	0.20	100	1.00	1.02	1.03	1.10	94	8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba									8/4/94
Cr									8/2/94
NH3-N									
NO3/NO2									
Final pH									7/13/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 7.00 **Matrix:** Flare Dud **Extractant:** 0.1 N NaOAC (pH 7.0); 18 h contact time

Extraction Date: 7/12/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	4.52	4.36	3.6	6.43	4.52	2.00	96	0.05	0.01
Al	0	0	0.0	9.2	0.0	10.0	92	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	0.0	0.0	0.0	0.6	0.0	0.63	96	0	0.1
Ba	2.3	3.0	26.4	9.5	2.3	10.0	72	0	0.5
Cr	0	0	0.0	2.20	0.00	2.00	110	0	0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	128.00	124.70							NA
Final pH	10.67	10.69							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	1.00	1.00	95	5.00	5.14	16.0	16.1	99	8/2/94
Al	1.0	1.0	100	100	100	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba	5.1	5.0	102	50.0	52.4	5.2	5.0	104	8/4/94
Cr	0.22	0.20	110	2.00	1.98	0.45	0.46	98	8/2/94
NH3-N									
NO3/NO2									
Final pH									7/13/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 6/7/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 7.00 **Matrix:** Flare Ash **Extractant:** 0.1 N NaOAC (pH 7.0); 18 h contact time

Extraction Date: 7/12/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	184	187	1.6	264	184	100	80	1.14	0.01
Al	0	0	0.0	8.7	0.0	10.0	87	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	17.6	18.4	4.4	18.9	17.7	3.13	42	0.1	0.1
Ba	1.2	1.6	28.6	10.1	1.2	10.0	89	0	0.5
Cr	0	0	0.0	2.21	0.0	2.00	110	0	0.02
NH3-N	see NH3-N results								0.1
NO3/NO2	see NO3, NO2 results								0.1
Weight (g)	30.00	30.00							NA
Final pH	10.31	10.28							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	2.18	1.00	104	5.00	4.92	16.0	16.1	99	8/2/94
Al	1.0	1.0	100	100	94.5	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.7	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba	5.1	5.0	102	50.0	52.4	5.2	5.0	104	8/4/94
Cr	0.22	0.20	110	2.00	1.98	0.45	0.46	98	8/2/94
NH3-N									
NO3/NO2									
Final pH									7/13/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 10.00 **Matrix:** Chaff **Extractant:** 0.1 N NaOAC (pH 10.0); 18 h contact time

Extraction Date: 7/19/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	0.18	0.17	5.7	2.12	0.18	2.00	97	0.02	0.01
Al	2.4	3.6	40.0	11.6	2	10.0	92	0	0.1
Cu	0	0	0.0	0.19	0	0.20	95	0	0.02
Mn	0	0	0.0	0.21	0	0.20	105	0	0.02
Si	0	0	0.0	10.4	0	10.0	104	0	1.0
Ti	0	0	0.0	0.24	0	0.25	96	0	0.05
V	0	0	0.0	0.24	0	0.20	120	0	0.02
Zn	0.03	0.02	40.0	0.28	0.03	0.20	125	0	0.01
B	0.9	0.9	0.0	1.3	0.9	0.63	64	0	0.1
Ba									0.5
Cr									0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	25.00	25.00							NA
Final pH	7.98	8.48							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	1.00	1.00	98	5.00	5.17	16.0	16.1	99	8/2/94
Al	0.9	1.0	90	100	100	4.1	4.0	102	8/4/94
Cu	0.20	0.20	100	2.00	1.98	0.40	0.41	98	8/1/94
Mn	0.20	0.20	100	1.00	1.00	0.21	0.22	95	8/1/94
Si	10.3	10.0	103	100	98.1	2.0	2.0	100	8/4/94
Ti	0.23	0.20	115	0.25	0.27	0.12	0.13	92	8/2/94
V	0.19	0.20	95	0.25	0.22	0.15	0.17	88	8/2/94
Zn	0.20	0.20	100	1.00	1.02	1.03	1.10	94	8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba									8/4/94
Cr									8/2/94
NH3-N									
NO3/NO2									
Final pH									7/20/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 10.00 **Matrix:** Flare Dud **Extractant:** 0.1 N NaOAC (pH 10.0); 18 h contact time

Extraction Date: 7/19/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	2.43	2.44	0.4	4.35	2.43	2.00	96	0.02	0.01
Al	0	0	0.0	9.2	0.0	10.0	92	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	0.0	0.0	0.0	0.6	0.0	0.63	96	0	0.1
Ba	2.0	3.2	46.2	11.8	2.0	10.0	98	0	0.5
Cr	0	0	0.0	2.27	0.00	2.00	113	0	0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	125.80	122.20							NA
Final pH	10.88	10.90							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	1.00	1.00	98	5.00	5.17	16.0	16.1	99	8/2/94
Al	0.9	1.0	90	100	100	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba	5.1	5.0	102	50.0	51.0	5.2	5.0	104	8/4/94
Cr	0.21	0.20	105	2.00	2.02	0.45	0.46	98	8/2/94
NH3-N									
NO3/NO2									
Final pH									7/20/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 6/7/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 10.00 **Matrix:** Flare Ash **Extractant:** 0.1 N NaOAC (pH 10.0); 18 h contact time

Extraction Date: 7/19/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	197	206	4.5	282	197	100	85	0.02	0.01
Al	0	0	0.0	9.4	0.0	10.0	94	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	88	90	0.0	130	88.0	12.5	336	0	0.1
Ba	0.9	1.0	10.5	12.2	0.9	10.0	113	0	0.5
Cr	0.03	0.02	0.0	2.28	0.0	2.00	112	0	0.02
NH3-N	see NH3 results								0.1
NO3/NO2	see NO3, NO2 results								0.1
Weight (g)	30.00	30.00							NA
Final pH	10.33	10.32							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std (mg/L)	Ending Cal (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	1.00	1.00	98	5.00	5.17	16.0	16.1	99	8/2/94
Al	0.9	1.0	90	100	100	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.6	0.63	96	2.0	2.0	0.92	0.86	107	8/4-5/94
Ba	5.1	5.0	102	50.0	51.0	5.2	5.0	104	8/4/94
Cr	0.21	0.20	105	2.00	2.02	0.45	0.46	98	8/2/94
NH3-N									
NO3/NO2									
Final pH									7/20/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 7.76 **Matrix:** Chaff **Extractant:** Synthetic seawater; 18 h contact time

Extraction Date: 7/21/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	873	868	0.6	968	873	100	95	867	0.01
Al	0.3	0.3	0.0	6.7	0	10.0	64	0	0.1
Cu	0	0	0.0	0.20	0	0.20	100	0	0.02
Mn	0	0	0.0	0.20	0	0.20	100	0	0.02
Si	0	0	0.0	8.5	0	10.0	85	0	1.0
Ti	0	0	0.0	0.32	0	0.25	128	0	0.05
V	0	0	0.0	0.24	0	0.20	120	0	0.02
Zn	0.04	0.04	0.0	0.25	0.04	0.20	105	0	0.01
B	1.0	0.6	50.0	1.5	1.0	0.63	79	0	0.1
Ba									0.5
Cr									0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	25.00	25.00							NA
Final pH	7.64	7.76							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	NA	NA	NA	500	503	16.0	16.1	99	8/2/94
Al	0.8	1.0	80	100	100	4.1	4.0	102	8/4/94
Cu	0.19	0.20	95	2.00	1.98	0.40	0.41	98	8/1/94
Mn	0.19	0.20	95	1.00	1.00	0.21	0.22	95	8/1/94
Si	9.3	10.0	93	100	98.1	2.0	2.0	100	8/4/94
Ti	0.30	0.20	150	0.25	0.24	0.12	0.13	92	8/2/94
V	0.22	0.20	110	0.25	0.22	0.15	0.17	88	8/2/94
Zn	0.20	0.20	100	1.00	1.02	1.03	1.10	94	8/1/94
B	0.6	0.63	96	2.0	1.9	0.92	0.86	107	8/4-5/94
Ba									8/4/94
Cr									8/2/94
NH3-N									
NO3/NO2									
Final pH									7/22/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 7.76 **Matrix:** Flare Dud **Extractant:** Synthetic seawater; 18 h contact time

Extraction Date: 7/21/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	635	645	1.6	710	635	100	75	867	0.01
Al	0	0	0.0	6.6	0.0	10.0	66	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	0.0	0.0	0.0	0.5	0.0	0.63	80	0	0.1
Ba	2.0	3.2	46.2	11.8	2.0	10.0	98	0	0.5
Cr	0	0	0.0	2.27	0.00	2.00	113	0	0.02
NH3-N									0.1
NO3-N									0.1
NO2-N									0.01
Weight (g)	53.94	55.20							NA
Final pH	10.69	10.68							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	NA	NA	NA	500	503	16.0	16.1	99	8/2/94
Al	0.8	1.0	80	100	100	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.6	0.63	96	2.0	1.9	0.92	0.86	107	8/4-5/94
Ba	10.1	10.0	101	50.0	46.4	5.2	5.0	104	8/4/94
Cr	0.21	0.20	105	2.00	1.94	0.45	0.46	98	8/2/94
NH3-N									
NO3/NO2									8/8/94
Final pH									7/26/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 6/7/94
Reported: 8/17/94

Results/QA-QC

Initial pH: 7.76 **Matrix:** Flare Ash **Extractant:** Synthetic seawater; 18 h contact time

Extraction Date: 7/21/94 **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Analyte	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spiked Result (mg/L)	Sample Result* (mg/L)	Spike Added (mg/L)	Recovery (%)	Blank (mg/L)	MDL (mg/L)
Mg	942	953	1.2	1038	942	100	96	867	0.01
Al	0	0	0.0	6.9	0.0	10.0	69	0	0.1
Cu									0.02
Mn									0.02
Si									1.0
Ti									0.05
V									0.02
Zn									0.01
B	68	68	0.0	94.0	68.0	12.5	208	0	0.1
Ba	0	0	0.0	8.1	0.0	10.0	81	0	0.5
Cr	0.03	0.03	0.0	1.89	0.0	2.00	93	0	0.02
NH3-N	see NH3 results								0.1
NO3-N	see NO3 results								
NO2-N	see NO2 results								0.1
Weight (g)	30.00	30.00							NA
Final pH	10.20	9.98							NA

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Analyte	Blank Spike (mg/L)	Spike Added (mg/L)	Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
Mg	NA**	NA**	NA**	500	503	16.0	16.1	99	8/2/94
Al	0.8	1.0	80	100	100	4.1	4.0	102	8/4/94
Cu									8/1/94
Mn									8/1/94
Si									8/4/94
Ti									8/2/94
V									8/2/94
Zn									8/1/94
B	0.6	0.63	96	2.0	1.9	0.92	0.86	107	8/4-5/94
Ba	10.1	10.0	101	50.0	46.4	5.2	5.0	104	8/4/94
Cr	0.21	0.20	105	2.00	1.94	0.45	0.46	98	8/2/94
NH3-N									
NO3/NO2									
Final pH									7/22/94

* Zero denotes less than method detection limit.
MDL = Method Detection Limit

Client: SAIC/R. Rea
Work Order No.: 1368
Received: see data sheets
Reported: 8/17/94

NH3-N Results and QA-QC

Initial pH: NA **Matrix:** Flare Ash **Extractant:** Varied

Extraction Date: See data sheets **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Environment	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spike Added (mg/L)	Spiked Result (mg/L)	MS Recovery (%)	Duplicate Spike Result (mg/L)	MSD Recovery (%)	Matrix Spike RPD
pH 4.0	3.4	2.8	19.4	5.0	8.6	104	7.3	90	14.4
pH 7.0	3.1	3.3	6.3	5.0	7.4	86.0	7.8	90	4.5
pH 10.0	2.6	2.9	10.9	5.0	7.4	96.0	7.4	90	6.5
Marine	3.5	3.4	2.9	5.0	8.0	90.0	8.7	106	16.3

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Environment	Blank (mg/L)	Blank Spike (mg/L)	BS Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
pH 4.0	0.4	4.8	88	Drift Corrected		5.1	5.5	93	8/9/94
pH 7.0	0.6	7.8	144	Drift Corrected		5.1	5.5	93	8/9/94
pH 10.0	0.6	4.7	82	Drift Corrected		5.1	5.5	93	8/9/94
Marine	0.5	5.0	90	Drift Corrected		5.1	5.5	93	8/9/94

* Zero denotes less than detection limit.

Client: SAIC/R. Rea
Work Order No.: 1368

Received: see data sheets
Reported: 8/17/94

NO3-N Results and QA-QC

Initial pH: NA **Matrix:** Flare Ash **Extractant:** Varied

Extraction Date: See data sheets **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Environment	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spike Added (mg/L)	Spiked Result (mg/L)	MS Recovery (%)	Duplicate Spike Result (mg/L)	MSD Recovery (%)	Matrix Spike RPD
pH 4.0	30	30	0.0	1330	1290	95	1310	96	1.6
pH 7.0	30	30	0.0	1330	1370	101	1320	97	3.8
pH 10.0	30	30	0.0	1330	1350	99	1330	98	1.5
Marine	20	10	66.7	1330	750	55	620	46	17.9

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Environment	Blank (mg/L)	Blank Spike (mg/L)	BS Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
pH 4.0	0.3	12.2	89	Drift Corrected		4.1	3.60	114	8/1/94
pH 7.0	0.4	9.5	68	Drift Corrected		4.1	3.60	114	8/1/94
pH 10.0	0.8	9.9	68	Drift Corrected		4.1	3.60	114	8/1/94
Marine	17.7	20.1	18	Drift Corrected		4.1	3.60	114	8/1/94

* Zero denotes less than detection limit.

NO2-N Results and QA-QC

Initial pH: NA **Matrix:** Flare Ash **Extractant:** Varied

Extraction Date: See data sheets **Extract Dilution Ratio:** 1:20

	Sample Results			Matrix Spike Recovery					
Environment	Sample Result* (mg/L)	Duplicate Result* (mg/L)	RPD	Spike Added (mg/L)	Spiked Result (mg/L)	MS Recovery (%)	Duplicate Spike Result (mg/L)	MSD Recovery (%)	Matrix Spike RPD
pH 4.0	0	0	0.0	0.05	0.02	40.0	0.02	40.0	0.0
pH 7.0	0	0	0.0	0.05	0.02	40.0	0.01	20.0	66.7
pH 10.0	0.79	0.63	22.5	0.25	1.02	92.0	0.88	100	8.3
Marine	0	0	0.0	0.05	0.01	20.0	0.02	40.0	66.7

	Blank Spike Recovery			Continuing Calib.		QC Sample			
Environment	Blank (mg/L)	Blank Spike (mg/L)	BS Recovery (%)	Initial Std. (mg/L)	Ending Cal. (mg/L)	Found (mg/L)	True (mg/L)	Recovery (%)	Date Analyzed
pH 4.0	0.00	0.05	100	0.20	0.20	2.34	2.30	102	8/8/94
pH 7.0	0.00	0.01	20	0.20	0.21	2.34	2.30	102	8/8/94
pH 10.0	0.00	0.04	16	0.20	0.21	2.34	2.30	102	8/8/94
Marine	0.00	0.02	40	0.20	0.21	2.34	2.30	102	8/8/94

* Zero denotes less than detection limit.

Client: SAIC/R. Rea
Work Order No.: 1368

Received: 3/30/94
Reported: 8/17/94

Flare Dud Gas Production

Results/QA-QC

Initial pH: 4.0 **Matrix:** Flare Dud **Extractant:** 0.1 N NaOAC (pH 4.0); 72 h contact time

Treatment Date: 7/29/94 - 8/1/94 **Extract Dilution Ratio:** 1:200

	Gas	Experimental parameters							
Replicate	Production (L/kg)	Measured Gas (ml)	Flare Mass (g)	Solution Volume (ml)	Initial pH	Final pH	Initial Temp. (C)	Final Temp. (C)	Reaction Time (h)
1	522	605	1.16	225.0	4.00	9.57	20.0	19.8	72
2	522	585	1.13	225.0	4.00	9.55	20.0	19.8	72
3	539	550	1.02	225.0	4.00	9.55	20.0	19.9	72

Water displacement method, constant temperature

Soil and Water West, Inc. **Natural Resource Consultants/Testing Laboratories**

1700 Southern Blvd. Rio Rancho, New Mexico Phone (505) 891-9472 FAX (505) 892-6607

Client: SAIC/R. Rea
Work Order No.: 1368

Received: NA
Reported: 8/17/94

Methods addendum

Methods

Analyte	EPA	Standard Methods	MDL (mg/L)
Mg	846-7450		0.01
Al	846-7020		0.1
Cu	846-7210		0.02
Mn	846-7560		0.02
Si		4500-Si,B	1.0
Ti	600-283.2		0.05
V	846-7911		0.02
Zn	846-7950		0.01
B		4500-B, C	0.1
Ba	846-7080		0.5
Cr	846-7190		0.02
NH3	600-350.3		0.1
NO3		4500-NO3,D	0.1
NO2	600-354.1		0.01

International
Lubrication and
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Creating the standards for industry.

P.O. Box 15212
Rio Rancho, NM 87174
(505) 892-1666 (800) 237-4532
Fax (505) 892-9601

ILFC Laboratory Report

for

Soil and Water West Inc.
1700 Southern Blvd.
Rio Rancho NM
(505) 891-9472

Project No:
Project Location:

Sampler: (505) 891-9472
Date Sampled: Not Given
Date Received: 7/14/94
Date Reported: 08/03/1994
Report #: 94589

Laboratory Manager Dean Dupree

DATA QUALIFIERS

Q	**Qualifying Code**
U	Indicates that the sample was analyzed for but not detected.
J	Indicates an estimated value.
B	Used when the analyte is found in the blank as well as the sample.
E	The concentration of the analyte exceeds the calibration range.
D	Indicates that the sample has a dilution factor greater than 1.0.

1B

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.

BLANK

Lab Name: ILFC

Contract:

Batch No.:

Project:

Location:

Matrix: (soil/water) WATER

Lab Sample ID: SBLK01

Sample wt/vol: 700.0 (g/mL) ML

Lab File ID: AUG02A06.D

Level: (low/med)

Date Received:

% Moisture: 100

decanted: (Y/N): N

Date Extracted:

Concentrated Extract Volume: 1000 (uL)

Date Analyzed: 8/2/94

Injection Volume: 1.0 (uL)

Dilution Factor: 1.0

GPC Cleanup: (Y/N) N

pH:

Concentration Units: (ug/L or ug/Kg) ug/L

CAS No.	Compound	Concentration Units: (ug/L or ug/Kg) ug/L	Q
110-86-1	Pyridine	29	U
106-46-7	1,4-Dichlorobenzene	14	U
95-48-7	o-Cresol	29	U
106-44-5	m,p-Cresol	29	U
67-72-1	Hexachloroethane	14	U
98-95-3	Nitrobenzene	14	U
87-68-3	Hexachlorobutadiene	14	U
88-06-2	2,4,6-Trichlorophenol	29	U
95-95-4	2,4,5-Trichlorophenol	29	U
121-14-2	2,4-Dinitrotoluene	14	U
118-74-1	Hexachlorobenzene	14	U
87-86-5	Pentachlorophenol	29	U

1B
SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.

BLANK

Lab Name: ILFC
Contract:

Batch No.: 94589
Project:
Location:

Matrix: (soil/water) WATER
Lab Sample ID: 13068

Sample wt/vol: 700.0 (g/mL) ML
Lab File ID: AUG02A06.D

Level: (low/med)
Date Received:

% Moisture: 100
decanted: (Y/N): N
Date Extracted:

Concentrated Extract Volume: 1000 (uL)
Date Analyzed: 8/2/94

Injection Volume: 1.0 (uL)
Dilution Factor: 1.0

GPC Cleanup: (Y/N) N
pH:

Concentration Units: (ug/L or ug/Kg) ug/L

CAS No.	Compound	Concentration (ug/L)	Q
62-75-9	N-Nitrosodimethylamine	14	U
111-44-4	bis(2-Chloroethyl)ether	14	U
108-95-2	Phenol	14	U
95-57-8	2-Chlorophenol	14	U
541-73-1	1,3-Dichlorobenzene	14	U
106-46-7	1,4-Dichlorobenzene	14	U
95-50-1	1,2-Dichlorobenzene	14	U
108-60-1	bis(2-chloroisopropyl)ether	14	U
67-72-1	Hexachloroethane	14	U
621-64-7	N-Nitroso-di-n-propylamine	14	U
98-95-3	Nitrobenzene	14	U
78-59-1	Isophorone	14	U
88-75-5	2-Nitrophenol	14	U
105-67-9	2,4-Dimethylphenol	14	U
111-91-1	bis(2-Chloroethoxy)methane	14	U
120-83-2	2,4-Dichlorophenol	14	U
120-82-1	1,2,4-Trichlorobenzene	14	U
91-20-3	Naphthalene	14	U
87-68-3	Hexachlorobutadiene	14	U
59-50-7	4-Chloro-3-methylphenol	29	U
77-47-4	Hexachlorocyclopentadiene	14	U
88-06-2	2,4,6-Trichlorophenol	14	U
91-58-7	2-Chloronaphthalene	14	U
208-96-8	Acenaphthylene	14	U
131-11-3	Dimethylphthalate	14	U
606-20-2	2,6-Dinitrotoluene	14	U
83-32-9	Acenaphthene	14	U
51-28-5	2,4-Dinitrophenol	71	U
121-14-2	2,4-Dinitrotoluene	14	U
100-02-7	4-Nitrophenol	71	U
86-73-7	Fluorene	14	U
7005-72-3	4-Chlorophenyl-phenylether	14	U
84-66-2	Diethylphthalate	14	U

1B

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.
BLANK

Lab Name: ILFC
Contract:
Batch No.: 94589
Project:
Location:
Matrix: (soil/water) WATER
Lab Sample ID: 13068
Sample wt/vol: 700.0 (g/mL) ML
Lab File ID: AUG02A06.D
Level: (low/med)
Date Received:
% Moisture: 100
decanted: (Y/N): N
Date Extracted:
Concentrated Extract Volume: 1000 (uL)
Date Analyzed: 8/2/94
Injection Volume: 1.0 (uL)
Dilution Factor: 1.0
GPC Cleanup: (Y/N) N
pH:

CAS No.	Compound	Concentration Units: (ug/L or ug/Kg) ug/L	Q
534-52-1	4,6-Dinitro-2-methylphenol	1	J
86-30-6	n-Nitrosodiphenylamine	14	U
103-33-3	Azobenzene	14	U
101-55-3	4-Bromophenyl-phenylether	14	U
118-74-1	Hexachlorobenzene	14	U
87-86-5	Pentachlorophenol	71	U
85-01-8	Phenanthrene	14	U
120-12-7	Anthracene	14	U
84-74-2	Di-n-butylphthalate	14	U
206-44-0	Fluoranthene	14	U
92-87-5	Benzidine	29	U
129-00-0	Pyrene	14	U
85-68-7	Butylbenzylphthalate	14	U
91-94-1	3,3'-Dichlorobenzidine	29	U
56-55-3	Benzo[a]anthracene	14	U
218-01-9	Chrysene	14	U
117-81-7	bis(2-Ethylhexyl)phthalate	14	U
117-84-0	Di-n-octylphthalate	14	U
205-99-2	Benzo[b]fluoranthene	14	U
207-08-9	Benzo[k]fluoranthene	14	U
50-32-8	Benzo[a]pyrene	14	U
193-39-5	Indeno[1,2,3-cd]pyrene	14	U
53-70-3	Dibenz[a,h]anthracene	14	U
191-24-2	Benzo[g,h,i]perylene	14	U

1F

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

SAMPLE NO.

BLANK

Lab Name: ILFC

Contract:

Batch No.: 94589

Project:

Location:

Matrix: (soil/water) WATER

Lab Sample ID: 13068

Sample wt/vol: 700.0 (g/mL) ML

Lab File ID: AUG02A06.D

Level: (low/med)

Date Received:

% Moisture: 100

decanted: (Y/N) N

Date Extracted:

Concentrated Extract Volume: 1000 (uL)

Date Analyzed: 8/2/94

Injection Volume: 1.0 (uL)

Dilution Factor: 1.0

GPC Cleanup: (Y/N) N

pH:

Number TICs found: 10

Concentration Units: (ug/L or ug/Kg) ug/L

CAS Number	Compound Name	RT	Est. Conc.	Q
1.	Acetic Acid	4.03	510	J
2. 1569-50-2	3-Penten-2-ol	4.18	61	J
3. 96-22-0	3-Pentanone	4.29	6	J
4. 109-60-4	n-Propyl acetate	4.61	36	J
5. 623-42-7	Butanoic acid, methyl ester	4.79	7	J
6. 637-78-5	Propanoic acid, 1-methylethy	5.53	170	J
7. 105-54-4	Butanoic acid, ethyl ester	6.67	14	J
8. 106-36-5	Propanoic acid, propyl ester	6.89	18	J
9. 123-86-4	Acetic acid, butyl ester	7.01	8	J
10. 638-11-9	Butanoic acid, 1-methylethyl	7.71	130	J
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
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30.				

1B

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.

ASH A

Lab Name: ILFC

Contract:

Batch No.:

Project:

Location:

Matrix: (soil/water) WATER

Lab Sample ID: 13066

Sample wt/vol: 418.0 (g/mL) ML

Lab File ID: AUG02A07.D

Level: (low/med)

Date Received:

% Moisture: 100

decanted: (Y/N): N

Date Extracted:

Concentrated Extract Volume: 1000 (uL)

Date Analyzed: 8/2/94

Injection Volume: 1.0 (uL)

Dilution Factor: 1.0

GPC Cleanup: (Y/N) N

pH:

Concentration Units: (ug/L or ug/Kg) ug/L

CAS No.	Compound	(ug/L or ug/Kg) ug/L	Q
110-86-1	Pyridine	48	U
106-46-7	1,4-Dichlorobenzene	24	U
95-48-7	o-Cresol	48	U
106-44-5	m,p-Cresol	48	U
67-72-1	Hexachloroethane	24	U
98-95-3	Nitrobenzene	24	U
87-68-3	Hexachlorobutadiene	24	U
88-06-2	2,4,6-Trichlorophenol	48	U
95-95-4	2,4,5-Trichlorophenol	48	U
121-14-2	2,4-Dinitrotoluene	24	U
118-74-1	Hexachlorobenzene	24	U
87-86-5	Pentachlorophenol	48	U

1B

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.
ASH A

Lab Name: ILFC
Contract:
Batch No.: 94589
Project:
Location:
Matrix: (soil/water) WATER
Lab Sample ID: 13066
Sample wt/vol: 418.0 (g/mL) ML
Lab File ID: AUG02A07.D
Level: (low/med)
Date Received:
% Moisture: 100
decanted: (Y/N): N
Date Extracted:
Concentrated Extract Volume: 1000 (uL)
Date Analyzed: 8/2/94
Injection Volume: 1.0 (uL)
Dilution Factor: 1.0
GPC Cleanup: (Y/N) N
pH:

CAS No.	Compound	Concentration Units: (ug/L or ug/Kg) ug/L	Q
62-75-9	N-Nitrosodimethylamine	24	U
111-44-4	bis(2-Chloroethyl)ether	24	U
108-95-2	Phenol	24	U
95-57-8	2-Chlorophenol	24	U
541-73-1	1,3-Dichlorobenzene	24	U
106-46-7	1,4-Dichlorobenzene	24	U
95-50-1	1,2-Dichlorobenzene	24	U
108-60-1	bis(2-chloroisopropyl)ether	24	U
67-72-1	Hexachloroethane	24	U
621-64-7	N-Nitroso-di-n-propylamine	24	U
98-95-3	Nitrobenzene	24	U
78-59-1	Isophorone	2	J
88-75-5	2-Nitrophenol	24	U
105-67-9	2,4-Dimethylphenol	24	U
111-91-1	bis(2-Chloroethoxy)methane	24	U
120-83-2	2,4-Dichlorophenol	24	U
120-82-1	1,2,4-Trichlorobenzene	24	U
91-20-3	Naphthalene	24	U
87-68-3	Hexachlorobutadiene	24	U
59-50-7	4-Chloro-3-methylphenol	48	U
77-47-4	Hexachlorocyclopentadiene	24	U
88-06-2	2,4,6-Trichlorophenol	24	U
91-58-7	2-Chloronaphthalene	24	U
208-96-8	Acenaphthylene	24	U
131-11-3	Dimethylphthalate	24	U
606-20-2	2,6-Dinitrotoluene	24	U
83-32-9	Acenaphthene	24	U
51-28-5	2,4-Dinitrophenol	120	U
121-14-2	2,4-Dinitrotoluene	24	U
100-02-7	4-Nitrophenol	120	U
86-73-7	Fluorene	24	U
7005-72-3	4-Chlorophenyl-phenylether	24	U
84-66-2	Diethylphthalate	24	U

SAMPLE NO.

ASH A

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

Lab Name: ILFC
Contract:
Batch No.: 94589
Project:
Location:
Matrix: (soil/water) WATER
Lab Sample ID: 13066
Sample wt/vol: 418.0 (g/mL) ML
Lab File ID: AUG02A07.D
Level: (low/med)
Date Received:
% Moisture: 100
decanted: (Y/N): N
Date Extracted:
Concentrated Extract Volume: 1000 (uL)
Date Analyzed: 8/2/94
Injection Volume: 1.0 (uL)
Dilution Factor: 1.0
GPC Cleanup: (Y/N) N
pH:

CAS No.	Compound	Concentration Units: (ug/L or ug/Kg) ug/L	Q
534-52-1	4,6-Dinitro-2-methylphenol	1	J
86-30-6	n-Nitrosodiphenylamine	24	U
103-33-3	Azobenzene	24	U
101-55-3	4-Bromophenyl-phenylether	24	U
118-74-1	Hexachlorobenzene	24	U
87-86-5	Pentachlorophenol	120	U
85-01-8	Phenanthrene	24	U
120-12-7	Anthracene	24	U
84-74-2	Di-n-butylphthalate	6	J
206-44-0	Fluoranthene	24	U
92-87-5	Benzidine	48	U
129-00-0	Pyrene	24	U
85-68-7	Butylbenzylphthalate	24	U
91-94-1	3,3'-Dichlorobenzidine	48	U
56-55-3	Benzo[a]anthracene	24	U
218-01-9	Chrysene	24	U
117-81-7	bis(2-Ethylhexyl)phthalate	79	
117-84-0	Di-n-octylphthalate	24	U
205-99-2	Benzo[b]fluoranthene	24	U
207-08-9	Benzo[k]fluoranthene	24	U
50-32-8	Benzo[a]pyrene	24	U
193-39-5	Indeno[1,2,3-cd]pyrene	24	U
53-70-3	Dibenz[a,h]anthracene	24	U
191-24-2	Benzo[g,h,i]perylene	24	U

1F

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

SAMPLE NO.

ASH A

Lab Name: ILFC Contract:

Batch No.: 94589 Project: Location:

Matrix: (soil/water) WATER Lab Sample ID: 13066

Sample wt/vol: 418.0 (g/mL) ML Lab File ID: AUG02A07.D

Level: (low/med) Date Received:

% Moisture: 100 decanted: (Y/N) N Date Extracted:

Concentrated Extract Volume: 1000 (uL) Date Analyzed: 8/2/94

Injection Volume: 1.0 (uL) Dilution Factor: 1.0

GPC Cleanup: (Y/N) N pH:

Concentration Units:
(ug/L or ug/Kg) ug/L

Number TICs found: 21

CAS Number	Compound Name	RT	Est. Conc.	Q
1.	Acetic Acid	3.98	660	J
2. 115-18-4	3-Buten-2-ol, 2-methyl-	4.22	130	J
3. 637-78-5	Propanoic acid, 1-methylethy	5.52	40	J
4. 922-65-6	1,4-Pentadien-3-ol	5.79	7	J
5. 928-97-2	3-Hexen-1-ol, (E)-	6.66	11	J
6. 584-02-1	3-Pentanol	6.82	13	J
7. 626-93-7	2-Hexanol	6.90	36	J
8. 638-11-9	Butanoic acid, 1-methylethyl	7.71	37	J
9. 109-52-4	Pentanoic acid	8.87	7	J
10. 111-76-2	Ethanol, 2-butoxy-	9.20	7	J
11. 615-29-2	3-Hexanol, 4-methyl-	9.84	34	J
12. 624-96-4	Butane, 1,3-dichloro-3-methy	10.49	19	J
13. 124-07-2	Octanoic Acid	10.93	12	J
14. 53907-95-2	2-Propanol, 1-(1-methylpropo	11.04	16	J
15. 104-76-7	1-Hexanol, 2-ethyl-	11.83	12	J
16. 111-14-8	Heptanoic acid	12.77	7	J
17. 1526-17-6	2-Fluoro-6-nitrophenol	14.15	9	J
18. 112-05-0	Nonanoic acid	16.05	10	J
19. 99-94-5	Benzoic acid, 4-methyl-	16.23	5	J
20.	Phenol, 2-fluoro-4-nitro-	17.03	12	J
21. 398-23-2	1,1'-Biphenyl, 4,4'-difluoro	17.42	6	J
22.				
23.				
24.				
25.				
26.				
27.				
28.				
29.				
30.				

1B
SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.

ASH B

Lab Name: ILFC

Contract:

Batch No.:

Project:

Location:

Matrix: (soil/water) WATER

Lab Sample ID: 13067

Sample wt/vol: 180.0 (g/mL) ML

Lab File ID: AUG02A08.D

Level: (low/med)

Date Received:

% Moisture: 100

decanted: (Y/N): N

Date Extracted:

Concentrated Extract Volume: 1000 (uL)

Date Analyzed: 8/2/94

Injection Volume: 1.0 (uL)

Dilution Factor: 1.0

GPC Cleanup: (Y/N) N

pH:

CAS No.	Compound	Concentration Units: (ug/L or ug/Kg) ug/L	Q
110-86-1	Pyridine	110	U
106-46-7	1,4-Dichlorobenzene	56	U
95-48-7	o-Cresol	110	U
106-44-5	m,p-Cresol	110	U
67-72-1	Hexachloroethane	56	U
98-95-3	Nitrobenzene	56	U
87-68-3	Hexachlorobutadiene	56	U
88-06-2	2,4,6-Trichlorophenol	110	U
95-95-4	2,4,5-Trichlorophenol	110	U
121-14-2	2,4-Dinitrotoluene	56	U
118-74-1	Hexachlorobenzene	56	U
87-86-5	Pentachlorophenol	110	U

1B

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.
ASH B

Lab Name: ILFC
Contract:
Batch No.: 94589
Project:
Location:
Matrix: (soil/water) WATER
Lab Sample ID: 13067
Sample wt/vol: 180.0 (g/mL) ML
Lab File ID: AUG02A08.D
Level: (low/med)
Date Received:
% Moisture: 100
decanted: (Y/N): N
Date Extracted: -
Concentrated Extract Volume: 1000 (uL)
Date Analyzed: 8/2/94
Injection Volume: 1.0 (uL)
Dilution Factor: 1.0
GPC Cleanup: (Y/N) N
pH:

CAS No.	Compound	Concentration Units: (ug/L or ug/Kg) ug/L	Q
62-75-9	N-Nitrosodimethylamine	56	U
111-44-4	bis(2-Chloroethyl)ether	56	U
108-95-2	Phenol	56	U
95-57-8	2-Chlorophenol	56	U
541-73-1	1,3-Dichlorobenzene	56	U
106-46-7	1,4-Dichlorobenzene	56	U
95-50-1	1,2-Dichlorobenzene	56	U
108-60-1	bis(2-chloroisopropyl)ether	56	U
67-72-1	Hexachloroethane	56	U
621-64-7	N-Nitroso-di-n-propylamine	56	U
98-95-3	Nitrobenzene	56	U
78-59-1	Isophorone	4	J
88-75-5	2-Nitrophenol	56	U
105-67-9	2,4-Dimethylphenol	56	U
111-91-1	bis(2-Chloroethoxy)methane	56	U
120-83-2	2,4-Dichlorophenol	56	U
120-82-1	1,2,4-Trichlorobenzene	56	U
91-20-3	Naphthalene	56	U
87-68-3	Hexachlorobutadiene	56	U
59-50-7	4-Chloro-3-methylphenol	110	U
77-47-4	Hexachlorocyclopentadiene	56	U
88-06-2	2,4,6-Trichlorophenol	56	U
91-58-7	2-Chloronaphthalene	56	U
208-96-8	Acenaphthylene	56	U
131-11-3	Dimethylphthalate	56	U
606-20-2	2,6-Dinitrotoluene	56	U
83-32-9	Acenaphthene	56	U
51-28-5	2,4-Dinitrophenol	280	U
121-14-2	2,4-Dinitrotoluene	56	U
100-02-7	4-Nitrophenol	280	U
86-73-7	Fluorene	56	U
7005-72-3	4-Chlorophenyl-phenylether	56	U
84-66-2	Diethylphthalate	56	U

1B

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET

SAMPLE NO.

ASH B

Lab Name: ILFC Contract:

Batch No.: 94589 Project: Location:

Matrix: (soil/water) WATER Lab Sample ID: 13067

Sample wt/vol: 180.0 (g/mL) ML Lab File ID: AUG02A08.D

Level: (low/med) Date Received:

% Moisture: 100 decanted: (Y/N): N Date Extracted:

Concentrated Extract Volume: 1000 (uL) Date Analyzed: 8/2/94

Injection Volume: 1.0 (uL) Dilution Factor: 1.0

GPC Cleanup: (Y/N) N pH:

CAS No.	Compound	Concentration Units: (ug/L or ug/Kg) ug/L	Q
534-52-1	4,6-Dinitro-2-methylphenol	280	U
86-30-6	n-Nitrosodiphenylamine	56	U
103-33-3	Azobenzene	56	U
101-55-3	4-Bromophenyl-phenylether	56	U
118-74-1	Hexachlorobenzene	56	U
87-86-5	Pentachlorophenol	280	U
85-01-8	Phenanthrene	56	U
120-12-7	Anthracene	56	U
84-74-2	Di-n-butylphthalate	6	J
206-44-0	Fluoranthene	56	U
92-87-5	Benzidine	110	U
129-00-0	Pyrene	56	U
85-68-7	Butylbenzylphthalate	56	U
91-94-1	3,3'-Dichlorobenzidine	110	U
56-55-3	Benzo[a]anthracene	56	U
218-01-9	Chrysene	56	U
117-81-7	bis(2-Ethylhexyl)phthalate	120	
117-84-0	Di-n-octylphthalate	56	U
205-99-2	Benzo[b]fluoranthene	56	U
207-08-9	Benzo[k]fluoranthene	56	U
50-32-8	Benzo[a]pyrene	56	U
193-39-5	Indeno[1,2,3-cd]pyrene	56	U
53-70-3	Dibenz[a,h]anthracene	56	U
191-24-2	Benzo[g,h,i]perylene	56	U

1F
SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET
TENTATIVELY IDENTIFIED COMPOUNDS

SAMPLE NO.
ASH B

Lab Name: ILFC
Contract:
Batch No.: 94589
Project:
Location:
Matrix: (soil/water) WATER
Lab Sample ID: 13067
Sample wt/vol: 180.0 (g/mL) ML
Lab File ID: AUG02A08.D
Level: (low/med)
Date Received:
% Moisture: 100
decanted: (Y/N) N
Date Extracted:
Concentrated Extract Volume: 1000 (uL)
Date Analyzed: 8/2/94
Injection Volume: 1.0 (uL)
Dilution Factor: 1.0
GPC Cleanup: (Y/N) N
pH:
Number TICs found: 12
Concentration Units: (ug/L or ug/Kg) ug/L

CAS Number	Compound Name	RT	Est. Conc.	Q
1.	Acetic Acid	4.02	2000	J
2. 115-18-4	3-Buten-2-ol, 2-methyl-	4.21	330	J
3. 637-78-5	Propanoic acid, 1-methylethy	5.52	47	J
4. 544-12-7	3-Hexen-1-ol	6.66	23	J
5. 75-65-0	2-Propanol, 2-methyl-	6.82	32	J
6. 565-60-6	2-Pentanol, 3-methyl-	6.90	75	J
7. 638-11-9	Butanoic acid, 1-methylethyl	7.71	33	J
8. 615-29-2	3-Hexanol, 4-methyl-	9.85	91	J
9. 1526-17-6	2-Fluoro-6-nitrophenol	14.15	71	J
10. 65-85-0	Benzoic Acid	14.67	240	J
11. 112-05-0	Nonanoic acid	16.02	30	J
12.	Phenol, 2-fluoro-4-nitro-	17.03	63	J
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2C
WATER SEMIVOLATILE SURROGATE RECOVERY

Lab Name: ILFC **Contract:** ____________

Batch No.: ________ **Project:** ________ **Location:** ____________

	SAMPLE NO.	S1 #	S2 #	S3 #	S4 #	S5 #	S6 #	TOT OUT
01	SBLK01	61	42	76	77	101	93	
02	ASH A	42	38	74	72	98	103	
03	ASH B	52	51	85	76	95	94	
04	BLANKMS	86	78	86	67	82	81	
05	ASH BMS	74	77	73	60	81	76	
06	ASH BMSD	75	79	74	56	77	75	
07								
08								
09								
10								
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	QC LIMITS
S1 = 2-Fluorophenol (S)	(10-120)
S2 = Phenol-d6 (S)	(10-120)
S3 = Nitrobenzene-d5 (S)	(10-120)
S4 = 2-Fluorobiphenyl (S)	(10-120)
S5 = 2,4,6-Tribromophenol (S)	(10-120)
S6 = Terphenyl-d14 (S)	(10-120)

\# Column to be used to flag recovery values
* Values outside of contract required QC limits
D Surrogate diluted out

3C
WATER SEMIVOLATILE MATRIX SPIKE/MATRIX SPIKE DUPLICATE RECOVERY

Lab Name: ILFC Contract: ____________

Batch No.: ____________ Project: ________ Location: ____________

Matrix Spike - Sample No.: ASH B

COMPOUND	SPIKE ADDED (ug/L)	SAMPLE CONCENTRATION (ug/L)	MS CONCENTRATION (ug/L)	MS % REC	#	QC. LIMITS REC.
Pyridine	1700	0	1600	94		(50-300)
1,4-Dichlorobenzene	1700	0	1200	71		(50-300)
o-Cresol	1700	0	1600	94		(50-300)
m,p-Cresol	1700	0	1400	82		(50-300)
Hexachloroethane	1700	0	680	40		(30-300)
Nitrobenzene	1700	0	2300	135		(50-300)
Hexachlorobutadiene	1700	0	1000	59		(50-300)
2,4,6-Trichlorophenol	1700	0	2000	118		(50-300)
2,4,5-Trichlorophenol	1700	0	1400	82		(50-300)
2,4-Dinitrotoluene	1700	0	3000	176		(50-300)
Hexachlorobenzene	1700	0	1500	88		(50-300)

COMPOUND	SPIKE ADDED (ug/L)	MSD CONCENTRATION (ug/L)	MSD % REC	#	% RPD	#	QC LIMITS RPD	QC LIMITS REC.
Pyridine	1700	1600	94		0		30	(50-300)
1,4-Dichlorobenzene	1700	1200	71		0		30	(50-300)
o-Cresol	1700	1600	94		0		30	(50-300)
m,p-Cresol	1700	1400	82		0		30	(50-300)
Hexachloroethane	1700	680	40		0		30	(30-300)
Nitrobenzene	1700	2300	135		0		30	(50-300)
Hexachlorobutadiene	1700	970	57		3		30	(50-300)
2,4,6-Trichlorophenol	1700	1900	112		5		30	(50-300)
2,4,5-Trichlorophenol	1700	1200	71		15		30	(50-300)
2,4-Dinitrotoluene	1700	3000	176		0		30	(50-300)
Hexachlorobenzene	1700	1400	82		7		30	(50-300)

(1) N-Nitroso-di-n-propylamine

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits

Comments: ____________

3C

WATER SEMIVOLATILE MATRIX SPIKE/MATRIX SPIKE DUPLICATE RECOVERY

Lab Name: ILFC Contract: ______

Batch No.: ______ Project: ______ Location: ______

Matrix Spike - Sample No.: ASH B

COMPOUND	SPIKE ADDED (ug/L)	SAMPLE CONCENTRATION (ug/L)	MS CONCENTRATION (ug/L)	MS % REC	#	QC. LIMITS REC.
Pentachlorophenol	1700	0	2000	118		(50-300)

COMPOUND	SPIKE ADDED (ug/L)	MSD CONCENTRATION (ug/L)	MSD % REC	#	% RPD	#	QC LIMITS RPD	QC LIMITS REC.
Pentachlorophenol	1700	2000	118		0		30	(50-300)
RPD: 0 out of 12 outside limits								
Spike Recovery: 0 out of 24 outside limits								

(1) N-Nitroso-di-n-propylamine

Column to be used to flag recovery and RPD values with an asterisk
* Values outside of QC limits

Comments: ______

3C

WATER SEMIVOLATILE MATRIX SPIKE/MATRIX SPIKE DUPLICATE RECOVERY

Lab Name: ILFC Contract:

Batch No.: Project: Location:

Matrix Spike - Sample No.: BLANK

COMPOUND	SPIKE ADDED (ug/L)	SAMPLE CONCENTRATION (ug/L)	MS CONCENTRATION (ug/L)	MS % REC	#	QC. LIMITS REC.
Pyridine	286	0	240	84		(50-300)
1,4-Dichlorobenzene	286	0	243	85		(50-300)
o-Cresol	286	0	449	157		(50-300)
m,p-Cresol	286	0	144	50		(50-300)
Hexachloroethane	286	0	146	51		(30-300)
Nitrobenzene	286	0	487	170		(50-300)
Hexachlorobutadiene	286	0	180	63		(50-300)
2,4,6-Trichlorophenol	286	0	341	119		(50-300)
2,4,5-Trichlorophenol	286	0	244	85		(50-300)
2,4-Dinitrotoluene	286	0	568	199		(50-300)
Hexachlorobenzene	286	0	271	95		(50-300)

COMPOUND	SPIKE ADDED (ug/L)	MSD CONCENTRATION (ug/L)	MSD % REC	#	% RPD	#	QC LIMITS RPD	QC LIMITS REC.
Pyridine	286					*	30	(50-300)
1,4-Dichlorobenzene	286					*	30	(50-300)
o-Cresol	286					*	30	(50-300)
m,p-Cresol	286					*	30	(50-300)
Hexachloroethane	286					*	30	(30-300)
Nitrobenzene	286					*	30	(50-300)
Hexachlorobutadiene	286					*	30	(50-300)
2,4,6-Trichlorophenol	286					*	30	(50-300)
2,4,5-Trichlorophenol	286					*	30	(50-300)
2,4-Dinitrotoluene	286					*	30	(50-300)
Hexachlorobenzene	286					*	30	(50-300)

(1) N-Nitroso-di-n-propylamine

Column to be used to flag recovery and RPD values with an asterisk

* Values outside of QC limits

Comments:

3C

WATER SEMIVOLATILE MATRIX SPIKE/MATRIX SPIKE DUPLICATE RECOVERY

Lab Name: ILFC Contract:

Batch No.: Project: Location:

Matrix Spike - Sample No.: ASH B

COMPOUND	SPIKE ADDED (ug/L)	SAMPLE CONCENTRATION (ug/L)	MS CONCENTRATION (ug/L)	MS % REC #	QC. LIMITS REC.
Pentachlorophenol	240	0	350	146	(50-300)

COMPOUND	SPIKE ADDED (ug/L)	MSD CONCENTRATION (ug/L)	MSD % REC #	% RPD #	QC LIMITS RPD	QC LIMITS REC.
Pentachlorophenol	240			*	30	(50-300)
RPD: 0 out of 12 outside limits						
Spike Recovery: 0 out of 24 outside limits						

(1) N-Nitroso-di-n-propylamine

Column to be used to flag recovery and RPD values with an asterisk

* Values outside of QC limits

Comments:

4B

SEMIVOLATILE METHOD BLANK SUMMARY

SAMPLE NO.

SBLK01

Lab Name: ILFC Contract: ______

Batch No.: ______ Project: ______ Location: ______

Lab File ID: AUG02A06.D Lab Sample ID: SBLK01

Instrument ID: GC/MS-1 Date Extracted: ______

Matrix: (soil/water) WATER Date Analyzed: 8/2/94

Level: (low/med) ______ Time Analyzed: 1421

THIS METHOD BLANK APPLIES TO THE FOLLOWING SAMPLES, MS AND MSD:

	SAMPLE NO.	LAB SAMPLE ID	LAB FILE ID	DATE ANALYZED
01	ASH A	13066	AUG02A07.D	08/02/94
02	ASH B	13067	AUG02A08.D	08/02/94
03	BLANKMS	13068S	AUG02A09.D	08/02/94
04	ASH BMS	13067S	AUG02A10.D	08/02/94
05	ASH BMSD	13067SD	AUG02A11.D	08/02/94
06				
07				
08				
09				
10				
11				
12				
13				
14				
15				
16				
17				
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COMMENTS:

Page 1 of 1

5B

SEMIVOLATILE ORGANIC INSTRUMENT PERFORMANCE CHECK
DECAFLUOROTRIPHENYLPHOSPHINE (DFTPP)

Lab Name : ILFC Contract:

Batch No.: Project: Location:

Lab File ID: DFT0802.D DFTPP Injection Date: 8/2/94

Instrument ID: GC/MS-1 DFTPP Injection Time: 0858

m/e	ION ABUNDANCE CRITERIA	%RELATIVE ABUNDANCE
51	30.0 - 60.0% of mass 198	56.7
68	Less than 2.0% of mass 69	0.4 (0.5)1
69	Mass 69 relative abundance	75.5
70	Less than 2.0% of mass 69	0.4 (0.6)1
127	40.0 - 60.0% of mass 198	48.0
197	Less than 1.0% of mass 198	0.0
198	Base Peak, 100 % relative abundance	100.0
199	5.0 - 9.0% of mass 198	7.2
275	10.0 - 30.0% of mass 198	19.8
365	Greater than 1% of mass 198	2.0
441	Present, but less than mass 443	0.0
442	Greater than 40% of mass 198	69.1
443	17.0 - 23.0% of mass 442	13.6 (19.7)2

1-Value is % mass 69 2-Value is % mass 442

This check applies to the following SAMPLES, MS, MSD, BLANKS and STANDARDS:

	SAMPLE NO.	LAB SAMPLE ID	LAB FILE ID	DATE ANALYZED	TIME ANALYZED
01	SSTD050	CCAL50	AUG02A02.D	8/2/94	1025
02	SBLK01	SBLK01	AUG02A06.D	8/2/94	1421
03	ASH A	##	AUG02A07.D	8/2/94	1519
04	ASH B	##	AUG02A08.D	8/2/94	1617
05	BLANKMS	13068S	AUG02A09.D	8/2/94	1715
06	ASH BMS	13067S	AUG02A10.D	8/2/94	1813
07	ASH BMSD	13067SD	AUG02A11.D	8/2/94	1911
08					
09					
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20					
21					
22					

6B

SEMIVOLATILE ORGANICS INITIAL CALIBRATION DATA

Lab Name: ILFC
Contract:
Batch No.:
Project:
Location:
Instrument ID: GC/MS-1
Calibration Date(s): 8/2/94 8/2/94
Calibration Times: 0927 1319

Lab File ID:
RRF20 = AUG02A01.D
RRF50 = AUG02A02.D
RRF80 = JUN23A10.D
RRF120 = JUN23A11.D
RRF160 = JUN23A12.D

COMPOUND	RRF20	RRF50	RRF80	RRF120	RRF160	$\overline{RRF}$	% RSD
Pyridine	1.437	1.806	1.742	1.678	1.694	1.671	8.4
1,4-Dichlorobenzene *	1.402	1.382	1.427	1.344	1.210	1.353	6.3 *
o-Cresol	1.325	1.406	1.404	1.271	1.452	1.371	5.3
m,p-Cresol	2.606	2.767	2.775	2.507	2.707	2.672	4.3
Hexachloroethane	0.583	0.656	0.631	0.623	0.580	0.615	5.3
Nitrobenzene	1.778	2.006	2.096	2.053	2.099	2.006	6.6
Hexachlorobutadiene	0.143	0.136	0.128	0.122	0.108	0.128	10.4
2,4,6-Trichlorophenol	0.133	0.143	0.127	0.120	0.142	0.133	7.2
2,4,5-Trichlorophenol	0.162	0.183	0.163	0.154	0.152	0.163	7.5
2,4-Dinitrotoluene	0.222	0.376	0.387	0.388	0.390	0.352	20.8
Hexachlorobenzene	0.288	0.274	0.267	0.265	0.224	0.263	9.1
Pentachlorophenol	0.051	0.090	0.062	0.068	0.104	0.075	28.9
2-Fluorophenol (S)	1.238	1.291	1.355	1.376	1.381	1.328	4.7
Phenol-d6 (S)	1.643	1.828	1.924	1.918	2.055	1.874	8.1
Nitrobenzene-d5 (S)	1.770	2.001	1.944	1.930	1.988	1.927	4.8
2-Fluorobiphenyl (S)	1.074	1.018	1.141	1.190	1.099	1.104	5.9
2,4,6-Tribromophenol (S)	0.099	0.103	0.119	0.129	0.125	0.115	11.7
Terphenyl-d14 (S)	0.487	0.477	0.475	0.468	0.471	0.476	1.6

* Compounds with required minimum RRF and maximum %RSD values.
All other compounds must meet a minimum RRF of 0.010.

7B
SEMIVOLATILE CONTINUING CALIBRATION CHECK

Lab Name: ILFC
Contract:
Batch No.:
Project:
Location:
Instrument ID: GC/MS-1
Calibration Date: 8/2/94
Time: 1025
Lab File ID: AUG02A02.D
Init. Calib. Date(s): 8/2/94 1/0/00
Init. Calib. Times: 1025 0000

COMPOUND	$\overline{\text{RRF}}$	RRF50	MIN RRF	%D	MAX %D
Pyridine	1.671	1.694		-1.4	25.0
1,4-Dichlorobenzene	1.353	1.210	0.050	10.6	25.0
o-Cresol	1.371	1.452		-5.9	25.0
m,p-Cresol	2.672	2.706		-1.3	25.0
Hexachloroethane	0.615	0.580		5.7	25.0
Nitrobenzene	2.006	2.099		-4.6	25.0
Hexachlorobutadiene	0.128	0.108		15.6	25.0
2,4,6-Trichlorophenol	0.133	0.142		-6.8	25.0
2,4,5-Trichlorophenol	0.163	0.152		6.7	25.0
2,4-Dinitrotoluene	0.352	0.390		-10.8	25.0
Hexachlorobenzene	0.263	0.224		14.8	25.0
Pentachlorophenol	0.075	0.104		-38.7	25.0
2-Fluorophenol (S)	1.328	1.381	0.010	-4.0	25.0
Phenol-d6 (S)	1.874	2.055	0.010	-9.7	25.0
Nitrobenzene-d5 (S)	1.927	1.988	0.010	-3.2	25.0
2-Fluorobiphenyl (S)	1.104	1.099	0.010	0.5	25.0
2,4,6-Tribromophenol (S)	0.115	0.125	0.010	-8.7	25.0
Terphenyl-d14 (S)	0.476	0.471	0.010	1.1	25.0

All other compounds must meet a minimum RRF of 0.010.

APPENDIX B

SUMMARY OF LABORATORY RESULTS

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data
Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Chaff	0.1 N NaOAC	4.0	Initial	Magnesium	0.26	UJ	mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Aluminum	182		mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Copper	0.02	U	mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Manganese	0.02	U	mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Silicon	1.0	U	mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Titanium	0.05	UJ	mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Vanadium	0.02	U	mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Zinc	0.39		mg/L
Chaff	0.1 N NaOAC	4.0	Initial	Boron	1.2	J	mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Magnesium	0.21	UJ	mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Aluminum	158		mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Copper	0.02	U	mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Manganese	0.02	U	mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Silicon	1.0	U	mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Titanium	0.05	UJ	mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Vanadium	0.02	U	mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Zinc	0.40		mg/L
Chaff	0.1 N NaOAC	4.0	Duplicate	Boron	1.8	J	mg/L
Dud Flare	0.1 N NaOAC	4.0	Initial	Magnesium	3050		mg/L
Dud Flare	0.1 N NaOAC	4.0	Initial	Aluminum	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	4.0	Initial	Boron	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	4.0	Initial	Barium	2.0	J	mg/L
Dud Flare	0.1 N NaOAC	4.0	Initial	Chromium	0.20	J	mg/L
Dud Flare	0.1 N NaOAC	4.0	Duplicate	Magnesium	2840		mg/L
Dud Flare	0.1 N NaOAC	4.0	Duplicate	Aluminum	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	4.0	Duplicate	Boron	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	4.0	Duplicate	Barium	4.0	J	mg/L
Dud Flare	0.1 N NaOAC	4.0	Duplicate	Chromium	0.38	J	mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Magnesium	861		mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Aluminum	0.1	U	mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Boron	17.7	J	mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Barium	178		mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Chromium	0.20	U	mg/L
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Magnesium	852		mg/L
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Aluminum	0.1	U	mg/L
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Boron	18.0	J	mg/L

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data

Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Barium	191		mg/L
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Chromium	0.20	U	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Magnesium	0.14	UJ	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Aluminum	0.3	J	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Copper	0.02	U	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Manganese	0.02	U	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Silicon	1.0	U	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Titanium	0.05	UJ	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Vanadium	0.02	U	mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Zinc	0.05		mg/L
Chaff	0.1 N NaOAC	7.0	Initial	Boron	2.0	J	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Magnesium	0.19	UJ	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Aluminum	0.2	J	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Copper	0.02	U	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Manganese	0.02	U	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Silicon	1.0	U	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Titanium	0.05	UJ	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Vanadium	0.02	U	mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Zinc	0.06		mg/L
Chaff	0.1 N NaOAC	7.0	Duplicate	Boron	0.8	J	mg/L
Dud Flare	0.1 N NaOAC	7.0	Initial	Magnesium	4.52		mg/L
Dud Flare	0.1 N NaOAC	7.0	Initial	Aluminum	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	7.0	Initial	Boron	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	7.0	Initial	Barium	2.3	J	mg/L
Dud Flare	0.1 N NaOAC	7.0	Initial	Chromium	0.20	U	mg/L
Dud Flare	0.1 N NaOAC	7.0	Duplicate	Magnesium	4.36		mg/L
Dud Flare	0.1 N NaOAC	7.0	Duplicate	Aluminum	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	7.0	Duplicate	Boron	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	7.0	Duplicate	Barium	3.0	J	mg/L
Dud Flare	0.1 N NaOAC	7.0	Duplicate	Chromium	0.20	U	mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Magnesium	184		mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Aluminum	0.1	U	mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Boron	17.6	J	mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Barium	1.2	J	mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Chromium	0.20	U	mg/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Magnesium	187		mg/L

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data

Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Aluminum	0.1	U	mg/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Boron	18.4	J	mg/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Barium	1.6	J	mg/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Chromium	0.20	U	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Magnesium	0.18		mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Aluminum	2.4	J	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Copper	0.02	U	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Manganese	0.02	U	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Silicon	1.0	U	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Titanium	0.05	UJ	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Vanadium	0.02	U	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Zinc	0.03	J	mg/L
Chaff	0.1 N NaOAC	10.0	Initial	Boron	0.9	J	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Magnesium	0.17		mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Aluminum	3.6	J	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Copper	0.02	U	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Manganese	0.02	U	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Silicon	1.0	U	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Titanium	0.05	UJ	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Vanadium	0.02	U	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Zinc	0.02	J	mg/L
Chaff	0.1 N NaOAC	10.0	Duplicate	Boron	0.9	J	mg/L
Dud Flare	0.1 N NaOAC	10.0	Initial	Magnesium	2.43		mg/L
Dud Flare	0.1 N NaOAC	10.0	Initial	Aluminum	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	10.0	Initial	Boron	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	10.0	Initial	Barium	2.0	J	mg/L
Dud Flare	0.1 N NaOAC	10.0	Initial	Chromium	0.20	U	mg/L
Dud Flare	0.1 N NaOAC	10.0	Duplicate	Magnesium	2.44		mg/L
Dud Flare	0.1 N NaOAC	10.0	Duplicate	Aluminum	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	10.0	Duplicate	Boron	0.1	U	mg/L
Dud Flare	0.1 N NaOAC	10.0	Duplicate	Barium	3.2	J	mg/L
Dud Flare	0.1 N NaOAC	10.0	Duplicate	Chromium	0.20	U	mg/L
Flare Ash	0.1 N NaOAC	10.0	Initial	Magnesium	197		mg/L
Flare Ash	0.1 N NaOAC	10.0	Initial	Aluminum	0.1	U	mg/L
Flare Ash	0.1 N NaOAC	10.0	Initial	Boron	88		mg/L
re Ash	0.1 N NaOAC	10.0	Initial	Barium	0.9		mg/L

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data

Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	0.1 N NaOAC	10.0	Initial	Chromium	0.03		mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Magnesium	206		mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Aluminum	0.1	U	mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Boron	90		mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Barium	1.0		mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Chromium	0.02		mg/L
Chaff	Synthetic Seawater	7.76	Initial	Magnesium	873	U	mg/L
Chaff	Synthetic Seawater	7.76	Initial	Aluminum	0.3	J	mg/L
Chaff	Synthetic Seawater	7.76	Initial	Copper	0.02	U	mg/L
Chaff	Synthetic Seawater	7.76	Initial	Manganese	0.02	U	mg/L
Chaff	Synthetic Seawater	7.76	Initial	Silicon	1.0	U	mg/L
Chaff	Synthetic Seawater	7.76	Initial	Titanium	0.05	UJ	mg/L
Chaff	Synthetic Seawater	7.76	Initial	Vanadium	0.02	U	mg/L
Chaff	Synthetic Seawater	7.76	Initial	Zinc	0.04		mg/L
Chaff	Synthetic Seawater	7.76	Initial	Boron	1.0	J	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Magnesium	868	U	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Aluminum	0.3	J	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Copper	0.02	U	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Manganese	0.02	U	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Silicon	1.0	U	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Titanium	0.05	UJ	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Vanadium	0.02	U	mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Zinc	0.04		mg/L
Chaff	Synthetic Seawater	7.76	Duplicate	Boron	0.6	J	mg/L
Dud Flare	Synthetic Seawater	7.76	Initial	Magnesium	635	U	mg/L
Dud Flare	Synthetic Seawater	7.76	Initial	Aluminum	0.1	UJ	mg/L
Dud Flare	Synthetic Seawater	7.76	Initial	Boron	0.1	U	mg/L
Dud Flare	Synthetic Seawater	7.76	Initial	Barium	2.0	J	mg/L
Dud Flare	Synthetic Seawater	7.76	Initial	Chromium	0.20	U	mg/L
Dud Flare	Synthetic Seawater	7.76	Duplicate	Magnesium	645	U	mg/L
Dud Flare	Synthetic Seawater	7.76	Duplicate	Aluminum	0.1	UJ	mg/L
Dud Flare	Synthetic Seawater	7.76	Duplicate	Boron	0.1	U	mg/L
Dud Flare	Synthetic Seawater	7.76	Duplicate	Barium	3.2	J	mg/L
Dud Flare	Synthetic Seawater	7.76	Duplicate	Chromium	0.20	U	mg/L
Flare Ash	Synthetic Seawater	7.76	Initial	Magnesium	942	U	mg/L
re Ash	Synthetic Seawater	7.76	Initial	Aluminum	0.1	UJ	mg/L

SUMMARY OF LABORATORY RESULTS
Chaff and Flare Analytical Data
Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	Synthetic Seawater	7.76	Initial	Boron	68		mg/L
Flare Ash	Synthetic Seawater	7.76	Initial	Barium	0.5	U	mg/L
Flare Ash	Synthetic Seawater	7.76	Initial	Chromium	0.03		mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Magnesium	953	U	mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Aluminum	0.1	UJ	mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Boron	68		mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Barium	0.5	U	mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Chromium	0.03		mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Ammonia (NH3-N)	3.4		mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Ammonia (NH3-N)	3.1		mg/L
Flare Ash	0.1 N NaOAC	10.0	Initial	Ammonia (NH3-N)	2.6	U	mg/L
Flare Ash	Synthetic Seawater	7.76	Initial	Ammonia (NH3-N)	3.5		mg/L
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Ammonia (NH3-N)	2.8		mg/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Ammonia (NH3-N)	3.3		mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Ammonia (NH3-N)	2.9	U	mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Ammonia (NH3-N)	3.4		mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Nitrate (NO3-N)	30		mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Nitrate (NO3-N)	30		mg/L
Flare Ash	0.1 N NaOAC	10.0	Initial	Nitrate (NO3-N)	30		mg/L
Flare Ash	Synthetic Seawater	7.76	Initial	Nitrate (NO3-N)	20	UJ	mg/L
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Nitrate (NO3-N)	30		mg/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Nitrate (NO3-N)	30		mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Nitrate (NO3-N)	30		mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Nitrate (NO3-N)	10	UJ	mg/L
Flare Ash	0.1 N NaOAC	4.0	Initial	Nitrite (NO2-N)	0.01	UJ	mg/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Nitrite (NO2-N)	0.01	UJ	mg/L
Flare Ash	0.1 N NaOAC	10.0	Initial	Nitrite (NO2-N)	0.79	J	mg/L
Flare Ash	Synthetic Seawater	7.76	Initial	Nitrite (NO2-N)	0.01	UJ	mg/L
Flare Ash	0.1 N NaOAC	4.0	Duplicate	Nitrite (NO2-N)	0.01	UJ	mg/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Nitrite (NO2-N)	0.01	UJ	mg/L
Flare Ash	0.1 N NaOAC	10.0	Duplicate	Nitrite (NO2-N)	0.63	J	mg/L
Flare Ash	Synthetic Seawater	7.76	Duplicate	Nitrite (NO2-N)	0.01	UJ	mg/L
Dud Flare	0.1 N NaOAC	4.0	Initial	Hydrogen Gas	522		L/kg
Dud Flare	0.1 N NaOAC	4.0	Duplicate	Hydrogen Gas	522		L/kg
Dud Flare	0.1 N NaOAC	4.0	TRP	Hydrogen Gas	539		L/kg
Flare Ash	0.1 N NaOAC	7.0	Initial	n-Nitrosodimethylamine	24	U	ug/L

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data

Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	0.1 N NaOAC	7.0	Initial	bis(2-Chloroethyl)ether	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Phenol	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2-Chlorophenol	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	1,3-Dichlorobenzene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	1,4-Dichlorobenzene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	1,2-Dichlorobenzene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	bis(2-Chloroisopropyl)ether	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Hexachloroethane	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	n-Nitroso-di-n-propylamine	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Nitrobenzene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Isophorone	2	J	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2-Nitrophenol	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2,4-Dimethylphenol	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	bis(2-Chloroethoxy)methane	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2,4-Dichlorophenol	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	1,2,4-Trichlorobenzene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Naphthalene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Hexachlorobutadiene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	4-Chloro-3-methylphenol	48	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Hexachlorocyclopentadiene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2,4,6-Trichlorophenol	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2-Chloronaphthalene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Acenaphthylene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Dimethylphthalate	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2,6-Dinitrotoluene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Acenaphthene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2,4-Dinitrophenol	120	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	2,4-Dinitrotoluene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	4-Nitrophenol	120	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Fluorene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	4-Chlorophenyl-phenylether	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Diethylphthalate	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	4,6-Dinitro-2-methylphenol	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	n-Nitrosodiphenylamine	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Azobenzene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	4-Bromophenyl-phenylether	24	U	ug/L

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data

Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	0.1 N NaOAC	7.0	Initial	Hexachlorobenzene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Pentachlorophenol	120	UJ	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Phenanthrene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Anthracene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Di-n-butylphthalate	6	J	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Fluoranthene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Benzidine	48	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Pyrene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Butylbenzylphthalate	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	3,3'-Dichlorobenzidine	48	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Benzo[a]anthracene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Chrysene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	bis(2-Ethylhexyl)phthalate	79		ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Di-n-octylphthalate	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Benzo[b]fluoranthene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Benzo[k]fluoranthene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Benzo[a]pyrene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Indeno[1,2,3-cd]pyrene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Dibenz[a,h]anthracene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Initial	Benzo[g,h,i]perylene	24	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	n-Nitrosodimethylamine	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	bis(2-Chloroethyl)ether	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Phenol	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2-Chlorophenol	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	1,3-Dichlorobenzene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	1,4-Dichlorobenzene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	1,2-Dichlorobenzene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	bis(2-Chloroisopropyl)ether	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Hexachloroethane	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	n-Nitroso-di-n-propylamine	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Nitrobenzene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Isophorone	4	J	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2-Nitrophenol	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2,4-Dimethylphenol	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	bis(2-Chloroethoxy)methane	56	U	ug/L
re Ash	0.1 N NaOAC	7.0	Duplicate	2,4-Dichlorophenol	56	U	ug/L

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data

Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	0.1 N NaOAC	7.0	Duplicate	1,2,4-Trichlorobenzene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Naphthalene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Hexachlorobutadiene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	4-Chloro-3-methylphenol	110	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Hexachlorocyclopentadiene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2,4,6-Trichlorophenol	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2-Chloronaphthalene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Acenaphthylene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Dimethylphthalate	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2,6-Dinitrotoluene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Acenaphthene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2,4-Dinitrophenol	280	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	2,4-Dinitrotoluene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	4-Nitrophenol	280	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Fluorene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	4-Chlorophenyl-phenylether	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Diethylphthalate	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	4,6-Dinitro-2-methylphenol	280	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	n-Nitrosodiphenylamine	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Azobenzene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	4-Bromophenyl-phenylether	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Hexachlorobenzene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Pentachlorophenol	280	UJ	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Phenanthrene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Anthracene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Di-n-butylphthalate	6	J	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Fluoranthene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Benzidine	110	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Pyrene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Butylbenzylphthalate	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	3,3'-Dichlorobenzidine	110	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Benzo[a]anthracene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Chrysene	56	U	ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	bis(2-Ethylhexyl)phthalate	120		ug/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Di-n-octylphthalate	56	U	ug/L
lare Ash	0.1 N NaOAC	7.0	Duplicate	Benzo[b]fluoranthene	56	U	ug/L

SUMMARY OF LABORATORY RESULTS

Chaff and Flare Analytical Data
Initial Leaching Tests

Sample Matrix	Extraction Environment	Ph	Sample Analysis	Parameter	Results	Qualifier	Units
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Benzo[k]fluoranthene	56	U	*u*g/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Benzo[a]pyrene	56	U	*u*g/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Indeno[1,2,3-cd]pyrene	56	U	*u*g/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Dibenz[a,h]anthracene	56	U	*u*g/L
Flare Ash	0.1 N NaOAC	7.0	Duplicate	Benzo[g,h,i]perylene	56	U	*u*g/L

0.1 N NaOAC = sodium acetate buffer solution
U = undetected
J = estimated or uncertain
mg/L = milligram per liter
*u*g/L = microgram per liter

APPENDIX C

LABORATORY STUDY AND INTERPRETATION OF ECM CHAFF, FLARES, AND FLARE ASH IN VARIOUS ENVIRONMENTS

Soil and Water West, Inc. Natural Resource Consultants and Testing Laboratories

Laboratory Study and Interpretation of ECM Chaff, Flares, and Flare Ash in Various Environments

3 October 1994

Prepared by: Dr. Lewis Munk, CPSS
Soil and Water West, Inc.
1700 Southern Boulevard
Rio Rancho, NM 87124

1700 Southern Blvd., Rio Rancho, New Mexico 87124 (505) 891-9472 FAX (505) 892-6607 Incorporated 1988

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Laboratory Study and Interpretation of ECM Chaff, Flares, and Flare Ash in Various Environments

1.0 Introduction

The U.S. Air Force deploys electronic counter measure (ECM) chaff and flares as part of its research, development, and training programs. Chaff and flares are released in special-use airspace throughout the United States that overlie a wide range of terrestrial, freshwater, and marine environments. Little is known about the effects of ECM releases in the environment, although, both the chaff and flares may contain potentially toxic trace elements. In Technical Reports on Chaff and Flares, Technical Report No. 1, the Air Force recognized the need to study chaff and flares in various soil and water environments (USAF, 1993). Thus, short-term laboratory investigations of the chemical behavior of these materials in various chemical environments were initiated and are reported here. The primary purpose of this study is to determine the relative stability of the chaff, flares, and flare ash subjected to different reaction conditions (e.g., pH) that might be encountered in natural systems. Secondarily, the probable fate and reaction of selected elements in soil systems is discussed. Finally, releases of chaff and flares are compared with soil background levels and regulatory standards for selected elements.

2.0 Methods and Materials

2.1 Chaff and Flares

Glass fiber chaff (GFC) and aluminum foil chaff (AFC) are the two general types of chaff deployed by the Air Force. This investigation focused on the glass fiber chaff and no data were obtained for the AFC. The GFC is slightly smaller than a human hair ($\simeq 25\ \mu m$ in diameter) and ranges in length from about 7.5 to more than 50 mm. The GFC consists of a glass core encased in an aluminum coating. The glass core is composed primarily of Si, Al, Ca, Mg and B, with minor amounts of Na, K, and Fe. The aluminum coating may contain minor amounts of Si, Fe, Cu, Mn, Mg, Zn, V, and Ti. (USAF, 1993).

Flares (type M-206) and flare combustion residues (ash) were evaluated in this study. The flare components that were tested include the flare pellet, first fire mix, intermediate fire mix, dip coat, and aluminum filament-reinforced-tape wrapping. The flare pellets are primarily composed of magnesium and Teflon that is coated with $KClO_4$, $BaCrO_4$, B, Mg, fluoroelastomers, and Al (USAF, 1993). The primer assembly, end cap, felt spacers, piston, and case were not analyzed. The exact components collected for the flare ash analysis are unknown since the flares were not burned at this facility.

2.2 Surrogate Environment Treatments

Samples of test-fired chaff, flare pellets, and flare ash were reacted with four surrogate environment extracting solutions to evaluate the release of selected elemental components under controlled conditions. The extracting solutions were meant to simulate pH conditions that might be encountered in soil, vadose zone, and marine systems. The soil-vadose zone surrogates include strongly acid (pH 4.0), neutral (pH 7.0), and extremely alkaline (pH 10.0) conditions prepared using buffered 0.1 N sodium acetate (NaOAC) solutions. The marine conditions (pH 7.8) were simulated using a synthetic seawater solution (40CFR part 300, App. C). With the exception of the synthetic seawater (SSW), these solutions are considered approximations since the composition and concentration of the extractant may differ from soil solutions.

The protocol for the EPA Toxicity Characteristic Leaching Procedure (TCLP) was employed for the extraction of the samples except the pH 7.0, 10.0, and SSW extracting solutions deviate from the standard method. A solid to solution ratio of about 1:20 was used and the samples were tumbled end-over-end for 18 hours. Because of extensive gas production in the pH 4.0 treatment, the flare dud samples were mixed in a reciprocating shaker, rather than tumbled. After tumbling, the extract was filtered through a 0.7 μm filter and separate aliquots were preserved with HNO_3 and H_2SO_4. The metals (Al, Cu, Mg, Mn, Si, Ti, V, Zn) were analyzed using a Perkin Elmer 603 atomic absorption spectrophotometer (AAS) and Hitachi Z-8200 AAS-graphite furnace. Boron was determined colorimetrically. Orion ion selective electrodes (model 290A) were used to analyze ammonia (NH_3), nitrate (NO_3), and nitrite (NO_2). Duplicate samples of the chaff, flare, and flare ash were extracted and analyzed.

2.3 Sample Size and Preparation

The size and quantity of material extracted is important since it affects the amount of surface area exposed to the solution and the ability of the solution to effect a complete reaction. A sample weight to solution ratio of 1:20 was used in all the treatments. The flare pellets with the aluminum tape attached were cut into pieces ($\simeq$ 1 cm^3). Whole flares were used in the pH 7.0 and 10.0 treatments, however, because of sample limitations only portions of flares were used in the pH 4.0 and SSW treatments. These flares were cut to include approximately equal amounts of the first fire, intermediate fire, and dip coat components. The glass fiber chaff was homogenized, but otherwise unaltered prior to extraction. The chaff samples were discharged from active cartridges (test-fired) at Hill Air Force Base, Utah prior to delivery to this laboratory. The flare ash sample contained foreign debris (e.g., paper clips, wire, plant tissue) that were removed by hand prior to homogenizing the sample for analysis.

The flare duds are expected to release elements at a higher rate than they would under field conditions since the size of the flare pellets was reduced exposing more surface area. In contrast, the chaff dissolution may have been retarded since the chaff formed tightly bound clumps (1-3 cm in diameter) during the tumbling process restricting the solution contact with the fibers. No particle size or solution contact interferences are expected for the flare ash based on the physical appearance of the flare ash after extraction.

2.4 Flare Gas Production

Three samples of the flare dud were reacted with the pH 4.0 surrogate environment solution to determine gas production under these acidic conditions. Gas production was determined at a constant temperature (20°C) using the water displacement method. Flare pellet fragments about three mm in diameter were reacted with the 0.1 N NaOAC (pH 4.0) solution (1:200 solid to liquid ratio) for 72 hours. The test was terminated at 72 hours since the initially high rate of gas production had decreased to a negligible level.

3.0 Results

3.1 Surrogate Environment Extractions

3.3.1 Glass Fiber Chaff

The analytical data for the glass fiber chaff are listed in Table 1. Four of the nine elements analyzed were detected in the surrogate environment treatments. The elements Mg, Al, Zn, and B were detected in all the treatments. Alternatively, Cu, Mn, Si, Ti, and V were not detected in any of the extracts, though they may occur in concentrations below the method detection limit. Magnesium occurred at consistently low concentrations in the pH 4.0, 7.0, and 10.0 treatments. The high magnesium concentration in the SSW treatment is a treatment artifact associated with the magnesium matrix of the extracting solution. Aluminum in solution displays amphoterism, that is its solubility is highest in acidic (pH < 5.0) and alkaline solutions (pH > 8.5-9.0), and lowest near neutrality (pH 7.0-8.0). The effects of pH on aluminum solubility are clearly illustrated by the data in table 1, where the pH 4.0 treatment had the highest concentrations of dissolved aluminum, and the pH 7.0 and SSW (pH 7.8) treatments had the lowest aluminum concentrations. The aluminum concentration in the pH 10.0 treatment was probably controlled by solid phase equilibrium processes with the aluminum oxyhydroxide precipitates (e.g., synthetic gibbsite or bayerite) that were observed on the treated chaff fibers (Munk, 1994). Zinc and boron were measured in all the treatment extracts with the highest values measured in the most acidic treatment.

The absence of Cu, Mn, Ti, and V in the extracts should not be interpreted to indicate that these elements would not be released in any of the treatments, since it is not known whether they were present in the glass fiber chaff samples. The assumption that these metals occur in the glass fiber chaff aluminum coating was based on industry standards for typical trace metal contaminants in processed aluminum metal, rather than analytical data (Pers. Comm. Robert Rea, SAIC). Zinc, Cu, Mn, Ti, and V were all reported to occur at similar concentrations (3000-5000 ppm) in the aluminum coating (USAF, 1993). Given that Zn was detected, and the similarities in analytical detection limits and the chemistry of Zn, Cu, Mn, Ti, and V it is likely that these metals did not occur in the fibers analyzed at this laboratory. The release of Zn is interpreted to indicate that the other heavy metals would probably be released if they were present in the aluminum coating and that the effect would be greatest under acidic conditions.

3.3.1 Flare Dud

Of the five elements analyzed in the flare dud extracts magnesium, barium and chromium were detected. The magnesium concentration was strongly effected by the solution pH (Table 1). The depressed magnesium concentration in the SSW extract was probably controlled by solid phase equilibrium with $MgCO_3$ and $MgSO_4$ prior to filtering. Barium occurs as $BaCrO_4$ on the magnesium flare pellets and was detected in most of the surrogate environment extracts. The barium concentration was slightly higher in the acidic environment, but there was little difference between the treatments. Chromium was detected only in the pH 4.0 extracts.

3.3.3 Flare Ash

Analysis of the flare ash extracts resulted in the detection of magnesium and boron in all the treatments, and barium and chromium in some of the treatments (Table 1.). The boron concentrations were highest in the pH 10.0 and SSW treatments and nearly equivalent in the pH 4.0 and 7.0 surrogate environments. Boron occurred at much higher concentrations in the flare ash than in the flare dud extracts. Barium was detected in the pH 4.0, 7.0, and 10.0 treatments with highest values measured in the most acidic solution. The variable and in some cases elevated concentrations of barium in the flare ash extracts suggests that the barium occurs as some species other than $BaCrO_4$, that is significantly influenced by pH and solid phase precipitation. Alternatively, the reduced particle size of the flare ash may account for the increased solubility compared to the flare duds. The extremely low concentrations in the SSW treatment probably result from the precipitation of insoluble $BaSO_4$. Low levels of chromium were detected in the pH 10.0 and SSW treatments. In addition to these metals, all the flare ash extracts contained measurable levels of ammonia (NH_3) and nitrate (NO_3) (Table 2.). Nitrite (NO_2) was detected only in the pH 10.0 treatment extract.

Table 1. Average (n=2) elemental concentrations of the surrogate environment solutions after reaction with the glass fiber chaff, flare dud, and flare ash. †

Treatment	Mg	Al	Cu	Mn	Si	Ti	V	Zn	B	Ba	Cr
	mg l^{-1}										
					Glass Fiber Chaff						
pH 4	0.24	170	<0.02	<0.02	<1.0	<0.05	<0.02	0.40	1.5	NA	NA
pH 7	0.17	0.3	<0.02	<0.02	<1.0	<0.05	<0.02	0.06	1.4	NA	NA
pH 10	0.18	3.0	<0.02	<0.02	<1.0	<0.05	<0.02	0.03	0.9	NA	NA
SSW	871	0.3	<0.02	<0.02	<1.0	<0.05	<0.02	0.04	0.8	NA	NA
					Flare Dud						
pH 4	2945	<0.1	NA	NA	NA	NA	NA	NA	<0.1	3.0	0.29
pH 7	4.4	<0.1	NA	NA	NA	NA	NA	NA	<0.1	2.7	<0.02
pH 10	2.4	<0.1	NA	NA	NA	NA	NA	NA	<0.1	2.6	<0.02
SSW	640	<0.1	NA	NA	NA	NA	NA	NA	<0.1	2.6	<0.02
					Flare Ash						
pH 4	857	<0.1	NA	NA	NA	NA	NA	NA	17.9	185	<0.02
pH 7	186	<0.1	NA	NA	NA	NA	NA	NA	18.0	1.4	<0.02
pH 10	202	<0.1	NA	NA	NA	NA	NA	NA	89.0	1.0	0.03
SSW	948	<0.1	NA	NA	NA	NA	NA	NA	68.0	<0.5	0.03

† NA = Not analyzed; SSW = synthetic seawater; less than (<) values indicate the element was not present or occurred below the method detection limit.

3.3.4 Flare Gas Production

The reaction of the flare pellets with the surrogate environment solutions resulted in the generation of gas. The gas production was positively correlated with solution pH, thus, the highest gas production resulted from reaction with the pH 4.0 environment. Gas generation in the pH 4.0 solution was quantified and this treatment resulted in an average gas production of 528 l/kg. The gas was colorless and highly flammable and is presumed to be composed primarily of hydrogen (H_2). However, unlike hydrogen gas, it was not odorless and may contain some other volatile contaminant.

Table 2. Average nitrogen concentrations (n=2) in flare ash extracts, post-extraction pH, and flare dud gas production.

	Flare Ash			Post Extraction pH[†]			Flare Dud[‡]
	NH_3-N	NO_3-N	NO_2-N	GFC	FD	FA	Gas Production
	mg l^{-1}						l kg^{-1}
pH 4	3.1	30	<0.01	4.49	10.53	9.56	528
pH 7	3.2	30	<0.01	7.18	10.68	10.30	NA
pH 10	2.8	30	0.71	8.23	10.89	10.33	NA
SSW	3.5	15	<0.01	7.70	10.69	10.09	NA

[†] GFC = glass fiber chaff; FD = flare dud; FA = flare ash. [‡] Average of 3 replicates; NA = not analyzed.

4.0 Discussion

4.1 Relative Stability of the Chaff, Flare Duds, and Flare Ash in Different Environments

The stability of solid phase components in soils and sediments is important since it determines the rate of release of potentially toxic constituents. The major factors that influence the stability (rate of dissolution) of solid phase constituents in soils include the size of the particle (exposed surface area), chemical environment, and availability of water. The glass fiber chaff and flare ash are predicted to be more susceptible to weathering effects than flare duds on the basis of particle size alone. The aluminum coating on the glass fiber chaff is the least stable under acidic and extremely alkaline conditions based on the chemical extraction data (Table 1) and the evaluation of the scanning electron micrographs of treated fibers (Munk, 1994). The highest solubility is expected under acidic conditions. The magnesium matrix of the flare duds and flare ash is less stable in acid environments than in near neutral or alkaline conditions. Furthermore, the dissolution of the chaff and flares will be greatest were the soil water content is high and the dissolution products are consistently moved away from the solid phase surface (e.g., leaching regime). Thus, the glass fiber chaff, flare duds, and flare ash will probably weather more rapidly in wet, acid environments than in arid, circum-neutral and alkaline environments.

4.2 Occurrence, Fate, and Reaction of Selected Elements in Different Environments

The toxicity of elements in soil and water systems depends on the amount and form of the element in the soil, the soil attenuation capacity, and the tolerance and exposure modes of the target organisms. Broad-scale evaluations of elemental toxicity are confounded by the large number of conditions that exist in nature. Consequently, a conclusive assessment of the toxicity of the chaff, flare dud, and flare ash components in particular environments is beyond the scope of this report. However, generalization about the probable reaction of these materials under different conditions can be made. Thus, the intent of this section is to provide information concerning the likely fate, and potential for toxic effects of selected elements in different soil systems. For this evaluation three pathways are considered including, 1) direct toxicity to plants resulting in the reduction or cessation of plant growth, 2) uptake and accumulation of toxic constituents in plants that might consumed by domestic or wild grazing animals, and 3) movement of the elements from the soil (vadose zone) to groundwater systems. Direct ingestion or inhalation of soils are additional possible pathways, but are not addressed here.

The elements selected for discussion are those that are likely to result from the weathering of the chaff, flare duds, and flare ash. They include aluminum, silicon, magnesium, barium, copper, manganese, titanium, vanadium, chromium, and boron. These elements are discussed in groups based on their probable fate in soils.

4.2.1 Aluminum, Silicon, and Magnesium

Aluminum, silicon, and magnesium occur in relatively high concentrations in soils. They are discussed together since the probability of significant toxic effects are slight. Silicon is not known to be toxic to plants and elevated uptake by plants has not been documented, thus, it is unlikely that grazing animals would ingest sufficient quantities to develop toxicity symptoms. Plant magnesium deficiencies and toxicities have been reported (Tisdale and Nelson, 1975). Magnesium deficiencies may occur on humid region acid soils and toxicity effects occur rarely on alkaline soils formed from ultra-mafic rocks (e.g., serpentinites). Correcting deficiencies or inducing plant toxicities would require the addition of readily available magnesium at rates in the range of several tons per acre. This rate would be equivalent to burning about 15,000 flares per acre in a relatively short amount of time. A larger number of flare duds would be needed to produce the same effect because of the reduced magnesium release rate associated with the low surface area of the duds.

Aluminum restricts root growth in some plants at soil solution concentrations as low as 1 mg L^{-1}. However, soil solution Al concentrations are strongly influenced (depressed) by ion exchange reactions, solid phase precipitation, and ligand exchange processes (Bohn et al., 1985; Sposito, 1989; Hsu, 1989). Consequently, soil solution concentrations of aluminum in the toxic range are only likely to occur in extremely acid and very sandy soils. Potential plant toxicity effects would probably only occur in sensitive crops, rather than adapted, native vegetation, and would be localized in the immediate vicinity of extremely high concentrations of glass fiber chaff. Liming, a common practice on acid agricultural soils, would reduce the potential for aluminum toxicity.

The chromatographic removal of aluminum, magnesium, and silicon that is translocated through the soil profile should alleviate the potential for groundwater contamination. No effects are expected under arid, alkaline soil conditions or in marine environments since the dissolution rates are low and the chemical environment is conducive to the formation of slightly soluble oxyhydroxides, and carbonates. Furthermore, it is speculated that the formation of aluminum oxyhydroxides on the surface of the chaff fibers will armor the fibers, thus, reducing the weathering rate and consequent release of aluminum.

4.2.2 Transition Metals

Chromium, copper, manganese, titanium, vanadium and zinc are transition metals that are reported to occur at relatively low concentration in the glass fiber chaff (Cu, Mn, Ti, V, Zn) and flare duds (Cr) (USAF, 1993). With the exception of zinc and chromium, none of these metals were detected in any of the surrogate environment extractions and, thus, may not be a real concern. Nonetheless, the potential fate of these constituents will be discussed since they may occur in some types or lots of the glass fiber chaff. These trace elements are considered essential nutrients for either plant or animal growth, except for titanium. Similarly, they may be toxic when they occur at elevated concentrations in the soil or plant tissue. Copper, Mn, Ti, and Zn have strong affinities to precipitate as hydroxyoxides with oxygen (O^{2-}) and hydroxyl (OH^-) ligands under oxidized, circum-neutral and alkaline conditions. Under anaerobic conditions they tend to precipitate as sulfides and carbonates depending on the pH of the system. In addition, a number of other mechanisms besides direct solid phase precipitation operate to reduce the activity of these elements in solution, including ion exchange, coprecipitation, and chelation with natural organic compounds. In general, the mobility and availability of these metals increase with increasing acidity. The increased availability of these metals in acid soils coincides with the soil conditions likely to promote deficiencies of these essential elements. Thus, minor additions of the essential elements would function as micronutrient fertilizers. Some aquatic organisms are sensitive to copper and zinc, and localized adverse effects may occur if the chaff is concentrated in relatively closed-system acidic environments.

In contrast to the other transition metals discussed here, chromium and vanadium occur as anions and their mobility and availability may decrease with increasing acidity in some soils. This decrease in solution activity results from the increased anion retention capacity of iron and aluminum hydroxyoxides as the pH decreases. Chromium is mobile in the Cr(VI) form and immobile in the Cr(III) valence state (Bartlett and Kimble, 1976a and 1976b). Well aerated neutral to alkaline soil conditions tend to promote the mobility of Cr(VI), whereas, acid soils and those with relatively high organic matter contents tend to reduce the Cr(VI) to Cr(III) and limit its mobility (Bartlett and Kimble, 1976a). The relative concentrations of Cr(III) and Cr(VI) were not determined as part of this investigation.

Chromatographic attenuation of the transition metals as they move through the vadose zone is speculated to negate adverse effects on groundwaters. Soils with relatively high clay, iron and aluminum hydroxides, and organic matter contents will be most effective in retaining these metals. The concentration of metals in sandy, acid soils with shallow water tables increases the risk of groundwater contamination.

4.2.3 Barium and Boron

Barium mobility and uptake by plants is not well studied since barium generally occurs in sparingly soluble forms and at low concentrations in most soil systems. However, it will react much like the other alkaline earth metals (e.g., Ca, Mg, Na, and K) in soils and will become more mobile in low pH environments. Barium is toxic to animals when ingested in forms other than the insoluble barium sulfate. The elevated barium concentration in the pH 4.0 extracts of the flare ash indicate that barium may present a localized hazard for sensitive organisms.

Boron is both an essential and toxic element for plants. Boron deficiencies are most likely to occur in humid, acid soils whereas, toxicities are not uncommon in alkaline environments (Bohn et al., 1985). Sensitive plants are affected by concentrations as low as 0.3 mg L^{-1}, while tolerant species can withstand boron soil solution levels of up to 4.0 mg L^{-1}. In general, the availability of boron to plants decreases with increasing soil pH and under low available soil water conditions (e.g., arid region soils) (Tisdale and Nelson, 1975). Increased availability under humid, acid conditions corresponds to the those areas most likely to be deficient in boron. The relatively slow release of boron from the glass matrix of the glass fiber chaff probably negates any potential adverse effects. Thus, only the flare ash seems to present a potential hazard with respect to boron if it is concentrated in both time and space in sensitive environments.

5.0 Regulatory Comparisons

This section provides a comparison of background soil metal concentrations with established regulatory levels and the estimated total concentration of metals in the chaff and flares (Table 3). No single value exists for acceptable metal levels in soils since the environmental risks depend on a large number of site and organism specific factors. The elemental composition of the chaff and flares were based on available data derived from Technical Reports on Chaff and Flares, Technical Report No. 1 (USAF, 1993) and from records provided by Mr. Robert Rea (SAIC). In some cases, analytical data on the composition of the chaff and flares were not available and the values in Table 3 represent calculated estimates.

The applicability of the Resource Recovery and Conservation Act (RCRA) and TCLP regulatory standards to the release of chaff and flare is equivocal, nonetheless, they are presented for comparison. Many of the elements listed here are not included in the RCRA List of Hazardous Substances and Reportable Quantities (40CFR 302.4). The RCRA limits in table 3, specify the quantity of materials that require notification of release in the environment. Comparison of the TCLP values with data for the pH 4.0 surrogate environment treatments indicates that only the flare ash would be considered a substance of concern since it exceeds the acceptable level for barium. The TCLP test is used to determine whether wastes can be disposed of in standard landfills or if a hazardous waste landfill must be used. Exclusion of a substance from these lists does not mean that the substance is not hazardous by some other criteria or that releases would not result in adverse environmental impacts.

One test used in evaluating action levels for hazardous materials in soils is the analytical requirement that the analyte occurs at a concentration equivalent to three times the background level (40 CFR Part 300, App. A, Sect. 2.3). The last two columns in Table 3 show the estimated amount of glass fiber chaff and M-206 flares that would have to be released to triple the concentration of metals in an acre-inch of an arbitrary soil (upper inch of soil on one acre of land). This analysis assumes an equal distribution of material over the landscape, that the estimated concentration of elements in the chaff and flares is correct, and that extraction of the metals would be complete. The mean soil contents were chosen to represent background levels (Table 3). Soils with higher or lower metal concentrations would result in higher or lower loading rates for the chaff and flares. The limiting element in this analysis for both the chaff (571 kg chaff/acre) and flares (1521 kg chaff/acre) is boron.

Table 3. Estimated elemental concentrations of soils, glass fiber chaff, and M-206 flares. Regulatory limits for selected elements and estimated amount of materials needed to significantly exceed background levels.

Element	Total[1] Soil Content	Mean[2] Soil Content	Critical[3] RCRA Limits	Critical[4] TCLP Limits	Estimated[5] Concentration GFC	Estimated[5] Concentration Flare	Amount Needed to Exceed[6] 3 Times Background Level GFC	Amount Needed to Exceed[6] 3 Times Background Level Flare
	mg kg^{-1}	mg kg^{-1}	kg	mg L^{-1}	mg kg^{-1}	mg kg^{-1}	kg acre^{-1}	kg acre^{-1}
Aluminum	10,000-200,000	72,000	none	none	99,450	5,200	325,792	—
Barium	100-3,000	580	none	100	NA	9,766	—	50,192
Boron	2-100	33	none	none	26,000	2,000	571	1,521
Chromium	5-3000	54	2273	5.0	NA	NA	—	12,150
Copper	2-100	25	2273	none	50	NA	225,000	—
Magnesium	9,000	9,000	none	none	NA	NA	—	—
Manganese	200-3,000	550	none	none	50	NA	4,950,000	—
Titanium	1,000-10,000	2,900	none	none	30	NA	43,500,000	—
Vanadium	20-500	80	454	none	50	NA	720,000	—
Zinc	10-300	60	454	none	50	NA	540,000	—

1) From Bohn et al., 1985; 2) From Sposito, 1989; 3) RCRA reportable quantities from 40CFR part 302.4. 4) Maximum concentration of Contaminants for the Toxicity Characteristic, Regulatory Level-40 CFR part 261.24. These values should be compared to the pH 4.0 surrogate environment treatment. Other characteristics, such as, reactivity, ignitability, and corrosivity may be considered to assess substance hazards; 5) Estimated concentration of elements in glass fiber chaff (GFC) and M-206 flares pellets. Estimates derived from data obtained from USAF (1993) or Mr. Robert Rea (Science Applications International Corporation); 6) Estimated amount of glass fiber chaff and M-206 flares released per acre to achieve a 3X increase in metal background levels in the upper inch of an arbitrary soil. Background levels are based on mean soil contents in column 2. NA = not applicable, unknown, or classified information.

6.0 Conclusion

The rate of release of the elements contained in these materials controls the ultimate exposure to organisms. Secondarily, the availability and mobility of metals in the soils will be reduced by a number of attenuation factors including, solid phase precipitation, ion exchange, coprecipitation, complexation with iron and aluminum oxyhydroxides and organic matter. Retention of the elements in the soils will reduce the availability to organisms and the potential for groundwater contamination. The results of the laboratory studies indicate that the chaff, flare duds, and flare ash are more susceptible to dissolution in wet, acid environments than under arid, alkaline conditions. The potential for adverse environmental effects associated with chaff and flare releases is predicted to be minor and localized. Based on available data, broad-scale, significant accumulations of metals in the soil would require extremely large releases of the chaff and flares to be concentrated in time and space.

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