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Toxicity Study of Selected Military Batteries

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13. ABSTRACT *(Maximum 200 words)*

Alkaline (Alk), Leclanche (LCE) (i.e., C-Zn), lithium-manganese dioxide ($Li-MnO_2$), lithium-sulfur dioxide ($Li-SO_2$), lithium-thionyl chloride ($Li-SOCl_2$), and magnesium (MG) batteries were analyzed under federal Resource Conservation and Recovery Act (RCRA) and state bioassay requirements in order to determine their hazardous waste (HW) characterization. MG and $Li-SOCl_2$ batteries were found to be HW under RCRA for chromium (D007). $Li-MnO_2$, Alk, LCE, and $Li-SOCl_2$ batteries were found to be HW under bioassay requirements. Only completely discharged $Li-SO_2$ batteries were found to be non-hazardous solid waste under both HW identification criteria.

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EXECUTIVE SUMMARY

This document has been prepared to provide information to the U.S. Army regarding the hazard classification under the Resource Conservation and Recovery Act (RCRA) and State of California aquatic bioassay procedures for six types of military batteries. The results of this study will be used in conjunction with that of previous studies to determine the appropriate disposal requirements for discarded batteries.

The study used three standard Environmental Protection Agency (EPA) certified laboratory procedures: Total Constituent Analyses (TCA) protocol, Toxicity Characteristic Leaching Procedure (TCLP), and the Clean Closure Leaching Procedure (CCLT) to determine the chemical characteristics of the batteries and the mobility potential of the parameters, respectively. The results of these analyses were used in conjunction with the aquatic bioassay results to determine (1) whether or not the batteries should be classified as hazardous under RCRA TCLP criteria and (2) the potential aquatic toxicity of leachates which passed the TCLP criteria.

From the findings of this report we conclude that two types of batteries should be classified as hazardous because they failed the TCLP criteria. In addition, three types of batteries should be considered hazardous because of their aquatic toxicity. Lithium thionyl chloride (Li-$SOCl_2$) and Magnesium (MG), were identified by TCLP as characteristically hazardous under RCRA regulations. Lithium-Manganese dioxide (Li-MnO_2), Alkaline (ALK), and Leclanch (LCE) were found to be toxic in the aquatic bioassays.

1. INTRODUCTION

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) has been designated as the Army point of contact for a military battery toxicity study for the U.S. Army Communications-Electronics Command (CECOM)/U.S. Army Laboratory Command (LABCOM). CECOM procures and manages many classes of military batteries and, as one of its responsibilities, provides its customers with current information regarding battery disposal requirements.

New toxicity characteristic (TC) regulations promulgated by the EPA under Title 40 Code of Federal Regulations (CFR) , Part 261.24 have redefined the guidelines that establish solid waste as hazardous waste. This new regulation went into effect on September 25, 1990. As a result, the Extraction Procedure Toxicity Test (EP-Tox) used to establish in part the hazardous nature of solid waste, is no longer appropriate for evaluating battery disposal. The new requirements outline the procedures and guidelines for designating solid waste as hazardous waste and establish, as one of the new requirements, that the TCLP replace the EP-Tox.

1.1. PURPOSE

The purpose of this toxicity study is to chemically and toxicologically characterize six types of military batteries procured by CECOM/LABCOM to ensure that the Army disposes of them in compliance with applicable laws and regulations. In addition, this determination will aid in evaluating available methods for disposal of discarded batteries.

Several objectives have been outlined to achieve the purpose of this study:

- Conduct a TCLP for each battery type, as required by the Resource Conservation and Recovery Act (RCRA), to determine what types of discarded batteries should be classified as hazardous waste under federal criteria.

- Conduct a total chemical analysis (TCA) to identify the contaminants that may be of concern relative to battery disposal.

- Conduct aquatic bioassays of battery leachate.

- Compare the results of the TCLP and bioassay with regulatory requirements in order to provide recommendations for battery disposal.

This report presents background information, analytical methods, analytical findings, quality control measures, and the conclusions and recommendations of the study.

1.2. BACKGROUND

On March 29, 1990, the EPA announced amendments to the hazardous waste regulations in 40 CFR parts 261 et al. These amendments revised the TC regulations and replaced the EP-Tox with the TCLP. The revised TC regulations add 25 organic constituents to the list of contaminants that are evaluated in the leachate test and establish the regulatory levels for these organic constituents.

Previous studies conducted by various Army laboratories evaluated the Li-SO_2, MG, ALK, and Li-$SOCl_2$, batteries to determine if the batteries should be classified as hazardous under RCRA. These studies used the RCRA criteria (reactivity, corrosivity, ignitability, and EP-Toxicity) for categorizing these batteries as hazardous. Table 1 summarizes the findings which concluded that:

- Fully charged or duty-cycle discharged Li-SO_2 and Li-$SOCl_2$ batteries were RCRA hazardous waste because they exhibited the characteristic of reactivity. In addition, the Li component was both reactive and ignitable.
- Fully discharged Li-SO_2 batteries and Li$SOCl_2$ batteries were characterized as non-hazardous waste under RCRA criteria.
- ALK and MG batteries were characterized as non-hazardous under RCRA criteria.

The batteries being evaluated in this toxicity study include those batteries that either have not been evaluated with regard to their hazardous waste status or were not designated as hazardous waste under the now obsolete EP-Tox criteria. These batteries include: three classes of Lithium (Li) batteries, Lithium-Sulfur dioxide (Li-SO_2), Lithium-Thionyl chloride (Li-$SOCl_2$), and Lithium-Manganese dioxide (Li-MnO_2); Alkaline (ALK); Magnesium (MG); and Leclanch (LCE) batteries. Thus, there are six battery types to be tested in this study.

Table 1. Summary of Previous Findings
RCRA Characteristics for Selected Military Batteries

Battery Type	Not Evaluated	RCRA Reactive	RCRA Ignitable	Non-RCRA Waste
Li-SO_2		X(1)	X(1)	X(2)
Li-$SOCl_2$		X(1)	X(1)	X(2)
Li-MnO_2	X			
MG				X
ALK				X(3)
LCE	X			

Notes: (1) Fully charged and duty-cycle discharged.
(2) Fully discharged.
(3) Evaluated but not analytically tested.

2. METHODS

Fig. 1 illustrates the evaluation process used to implement the objectives of this study. CECOM initiated the process by providing a subset of battery samples suitable for the TCLP, TCA, and bioassay. These analyses were performed and the results compared with the data quality objectives (DQOs) listed in *Quality Assurance Plan (QAP) for the Analytical Chemistry Department, QAP: 04-90-0001*, (Kirkpatrick, 1990). Batteries that passed the TCLP were classified as nonhazardous waste and were subjected to the bioassay analysis for further evaluation. Batteries that failed the TCLP are considered hazardous waste and require no additional evaluation, however, the bioassay was also conducted on these batteries to further assess their hazardous properties.

The procedures used and parameters evaluated in the toxicity study analyses are shown in Table 2. Standard methods for analyzing waste and waste water were used for determination of chromates in leachate. In addition, EPA approved procedures (i.e., SW-846 and EPA-600 series) and contract laboratory procedures were used in analyzing the samples. All data generated from the program were verified to ensure that no known errors in the data are being reported and that the DQOs were met. All data verification conforms to Analytical Chemistry Department standard operating procedures (Kirkpatrick 1990).

Table 2. Procedures and parameters included in the toxicity study analyses.

Analysis	Analytical Method	Reference Method
1. Size Reduction	ACD-1769	ACD Methods
2. TCLP Extraction	EPA-1311	SW-846*, CFR-55 (29-6-90)
A. Mercury	EPA-7470	SW-846
B. Arsenic	EPA-7060	SW-846
C. Lead	EPA-7421	SW-846
D. Other Required Metals (Ba, Cd, Cu, Be, Zn, Ni, Sn)	EPA-6010	SW-846
E. Chromates	SM-312	Standard Methods for Water and Wastewater
3. Zero Headspace Extraction (ZHE)	EPA-1311	SW-846 & CFR-55 (29-6-90)
A. Volatile Organics (Acetonitrile, Thionyl Chloride and Vinyl Chloride)	EPA-8240	SW-846
4. TCLP Cyanide Extraction	EPA-1311 (modified)	SW-846
A. Cyanide	EPA-9010	SW-846
5. Total Constituents Analyses		
A. Mercury	EPA-7471	SW-846
B. AA Metals (As, Pb)	EPA-7060/7421	SW-846
C. ICP Metals (Ba, Ni, Cd, Sn, Be, Zn, and Cu)	EPA-6010	SW-846
D. Cyanide	EPA-9010	SW-846
E. Chromates	SM-312	Standard Methods of Water and Wastewater
F. Volatile Organics (Acetonitrile, Thionyl Chloride and Vinyl Chloride)	EPA-8240	SW-846

* The Third Edition of reference method SW-846 was used throughout the project.

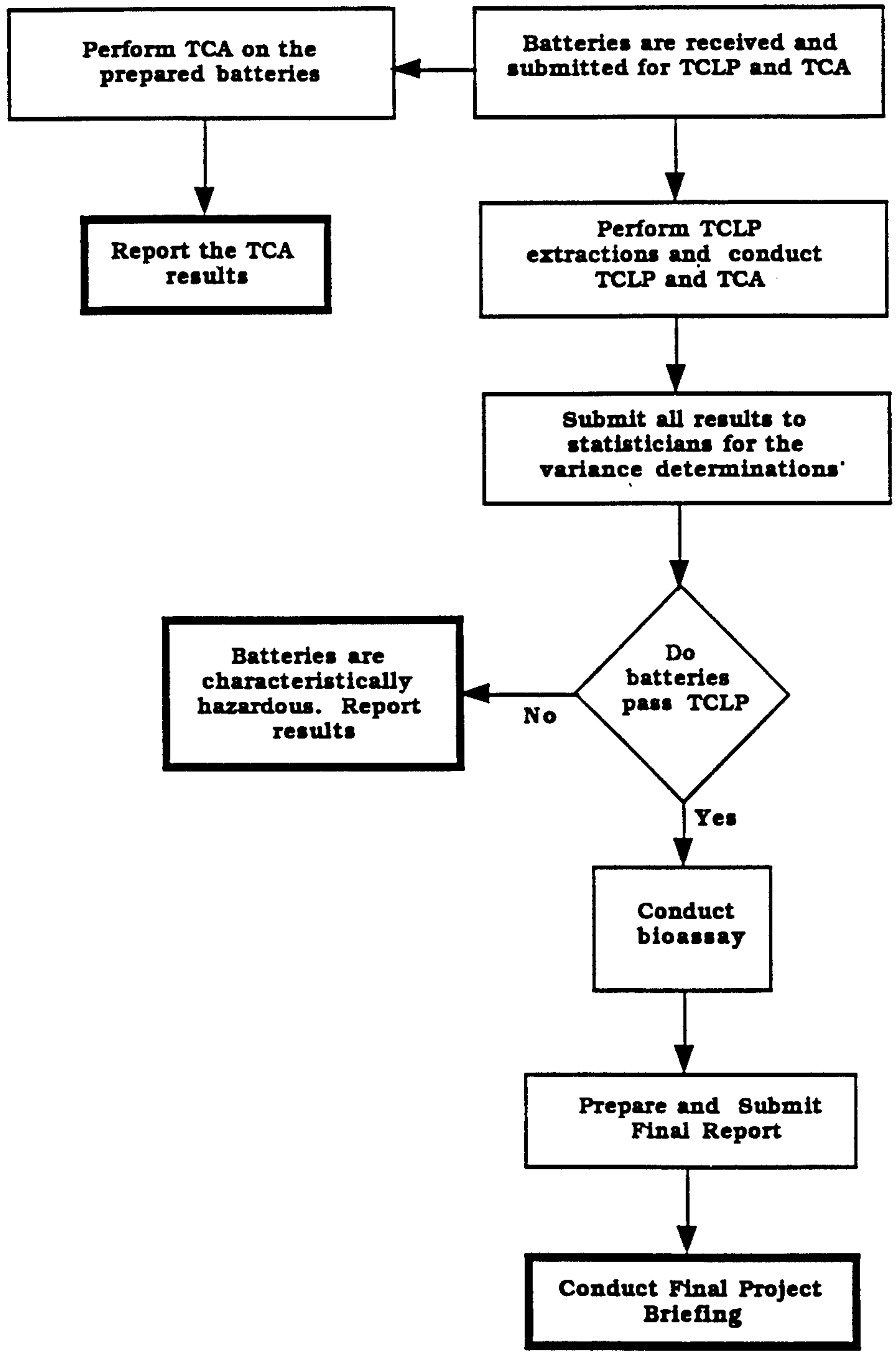
Unlike the EP-toxicity test, which allowed the use of a structure integrity test for solid material, the TCLP requires that the material be reduced to 9.5 mm in size. This requirement is also stated in the CCLT procedure and is necessary to obtain a good sample for TCA analyses. Even through it is required, there are no approved methods for size reduction of battery material. Therefore, the following method was used to size reduce the batteries in this study for TCLP and CCLT extractions and TCA analyses: (1) Using a volt meter, each of the batteries were checked to ascertain whether or not they were discharged. If the batteries read less than 1.5 ohm volts it was considered discharged. This was important because it was ascertained that some of the batteries did not meet the criteria for complete discharge. When a charged battery was found, it was discharged in accordance with the method acquired during a visit to US Army Electronic Technology and Device Laboratory at Fort Monmouth, New Jersey. (2) Once the batteries were considered discharged the entire battery was weighed and the weight recorded. (3) The outer cover of the batteries were next removed and their weight recorded. (4) Any switch components were then removed and weighed and their weight recorded. (5) The internal cells were disassembled and the cell casings and cell contents were separated, weighed and their weights recorded. (6) Using the weights of a total battery and the weights of each separate component the percentage composition for each component was calculated. These percentages were used after size reduction to build a representative sample for each of the batteries. (7) Each component of the battery was size reduced to less than 9.5 mm using sheet metal snips, knife, and a saw. Blanks were analyzed with the samples to assess whether or not the materials used for this operation contaminated the samples. The blank results indicated no contamination from the source material for any parameters analyzed. (8) Using the percentage compositions of the components calculated earlier, representative samples for each battery were built and submitted for extractions and or analysis.

2.1. THE TOXICITY CHARACTERISTIC LEACHING PROCEDURE ANALYSIS

The TCLP analysis measures the potential for mobility of both organic and inorganic contaminants in liquid, solid, and multiphasic wastes. The criteria for deciding mobility potential is a comparison of the contaminant concentration in the leachate with stipulated chemical-specific regulatory criteria. The procedure, outlined in Fig. 2, involves obtaining the TCLP extract and analyzing that extract for the constituents that are regulated by the TC regulation. Batteries with leachate concentrations exceeding the TCLP limit are classified as RCRA hazardous waste.

2.2. THE BIOASSAY

Aquatic bioassays were conducted to further characterize the toxicity of the battery leachates. Such tests may be required by states before the batteries can be disposed of. For example, California Department of Health Services requires that aquatic tests be conducted to "gauge the hazardous potential of a waste" (Polisini and Miller, 1988). Because the TCLP uses an acetate buffer, which is toxic to some aquatic biota, it was necessary to use an alternate method of extraction for conducting the bioassays. The EPA Synthetic Precipitation Leach Test ("Clean Closure Leach Test" or CCLT, SW-846 method 1312) was chosen because it does not require the use of acetate buffers and is not toxic to *Ceriodaphnia*.



TCA = Total Chemical Analysis
TCLP = Toxicity Characteristic Leachate Procedure

Figure 1. Project Flow Chart.

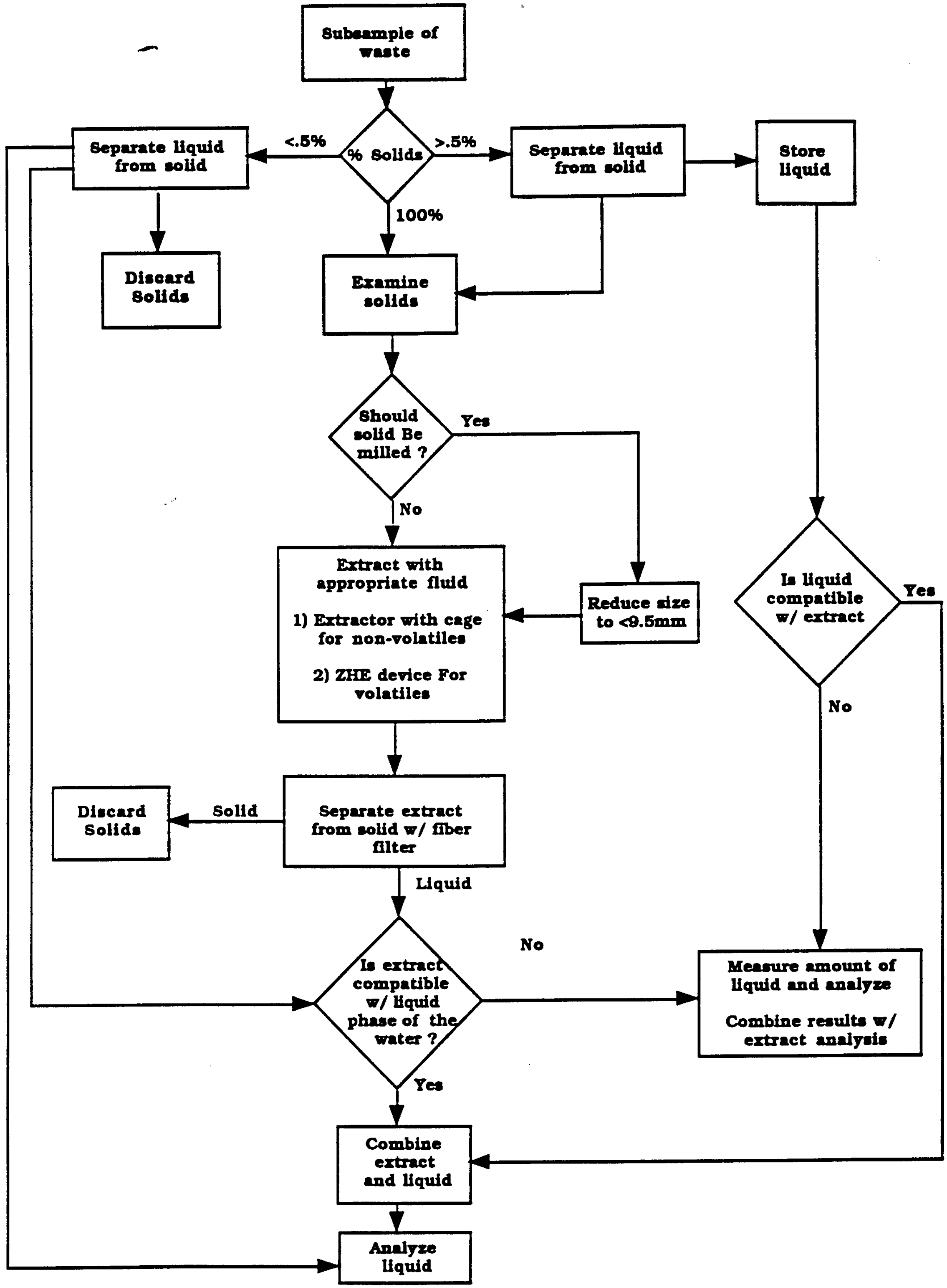


Figure 2. TCLP Procedure.

Leachates of the LCE, $Li\text{-}SO_2$, $Li\text{-}SOCl_2$, $Li\text{-}MnO_2$, MG, and ALK batteries prepared in February 1991 were used for *Ceriodaphnia* 48-h acute toxicity tests. Leachates of the $Li\text{-}SO_2$, $Li\text{-}MnO_2$, MG, and ALK batteries prepared in August 1991 were used for the *Ceriodaphnia* and fathead minnow 96-h toxicity tests. The $Li\text{-}SOCl_2$ battery leachate was not evaluated in August because it was found to be extremely toxic during the 48-h test in February. LCE batteries were not available for further bioassay in August 1991. Two types of controls were used: a blank containing only the leaching solution (no battery) and the water used to dilute the leachates, (2:8(v:v) ratio of degassed mineral water to deionized distilled water). The leachates and blank were neutralized with small amounts of 1N HCl or 1N NaOH and held in refrigeration at 4°C until used.

Procedures for the acute toxicity tests with Ceriodaphnia and fathead minnows followed those outlined in the EPA document, *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms* (Peltier and Weber, 1985) and/or *Standard Methods for the Examination of Waste and Wastewater* (APHA, 1990). The *Ceriodaphnia* acute tests lasted for 48-h or 96-h respectively and the fathead minnow test lasted for 96 h. In the Ceriodaphnia test, five animals that were less than 24 h old (and born within 6 h of each other) were placed in a minimum of 15 mL of test solution. Four replicates of five animals each (total of 20 animals) were used for each test concentration. The Ceriodaphnia were not fed during the 48 h test, but were fed during the 96 h test. In the fathead minnow test, 10 fathead minnows that were 24 to 48 h old were placed in 250 mL for the $Li\text{-}SO_2$, $Li\text{-}MnO_2$, and ALK leachates batteries and in 20 mL for the MG battery leachate, and the blank. A small sample volume was used for the MG battery leachate and the blank because of the small volume available for testing. In all cases, however, the loading factor (g of fish/L) was within the limits specified by the references given above. Two replicates were used for each concentration (total of 20 animals). Standard operating procedures detailing many aspects of the tests (i.e., dilution water, sample preparation, Ceriodaphnia culture methods) are available upon request (Kszos et al., 1989).

Data analyses were completed using EPA software (LC50.BAS obtained from the Environmental Monitoring Support Laboratory, Cincinnati, OH.) on a personal computer. The 48-h LC_{50} (the concentration that kills 50% of the *Ceriodaphnia* in 48 h) was calculated for each battery aliquot using either the probit, moving average, or binomial method. The EPA program chooses the most appropriate test for the data. A copy of the program can be found in Appendix A.

2.3. THE TOTAL CONSTITUENT ANALYSIS

The TCA was performed in accordance with EPA-3050/6010 procedures, SW-846 Third Edition. The analytical protocol for this analysis is discussed in the QAP (Kirkpatrick, 1990). A wet ashing and leaching technique was used to obtain the samples. A large sample size was required to obtain a representative sample for all parts of the batteries.

3. QUALITY ASSURANCE AND QUALITY CONTROL

The TCLP and TCA for the battery toxicity study was used to provide chemical characterization of the different battery types so that appropriate disposal methods can be selected. To carry out this objective a QAP was prepared to accompany the final data package. The plan is outlined in *Quality Assurance Plan for the Analytical Chemistry Department, QAP: 04-90-0001* (Kirkpatrick 1990). The Quality Assurance/Quality Control (QA/QC) procedures outlined in the QAP are coordinated through the QA/QC program manager and incorporate individual standard operating procedures that are specific to this project. The QAP addresses only the analysis that is conducted once the samples are received into the laboratory (Kirkpatrick, 1990).

The analyses were controlled by regulatory QC protocol, as specified by applicable regulations and procedures. These procedures specify the protocol for grouping samples into analytical batches with appropriate calibration standards, blanks, laboratory controls, spikes, and replicate analysis of analytes from a single sample container (duplicate samples originate in the field). In the absence of regulatory QC protocol, the analyses are controlled through the use of bench controls, replicates, spikes, duplicates, and other checks (Kirkpatrick 1990).

The TCA metal analyses were conducted using approved EPA-3050 methodology which may or may not produce the best TCA results. The batteries were prepared for analysis using the wet ashing technique followed by the EPA-3050 procedure. The ashing technique requires several sequential digestions with nitric, hydrochloric, and hydrofluoric acids. The final digestion is in 10% nitric acid. The purpose of this technique is to achieve as close to total dissolution as possible by completely destroying the structure of the matrix and exposing more surface area to the digestion solutions. Theoretically, one should be able to dissolve everything in the matrix with the exception of the refractory materials and one can assume that no metals of concern are still in the refractory materials. However, upon completion of the ashing and dissolution steps, black, carbon-like material were still present in the solution. It was assumed that this material was refractory material and was not considered part of the analyses. However, due to the fact that we do not have a standard battery material with known concentrations of metals and could not spike the battery matrix to ascertain the recovery data we cannot verify and validate the assumption made. Therefore, it is recommended in the QAP that these results be accepted with reservations and that the accuracy of the analyses be confirmed with vendor data.

The volatile organic analyses (VOAs) were not conducted on the battery matrix for TCA. The material of interest could not be introduced to the Gas Chromatograph/Mass Spectrometer (GC/MS) instrumentation in a way that meaningful and defensible results could be obtained. Due to the fact that the laboratory could not meet the data quality objectives of the project for this analysis and obtain data that it could defend, the decision was made to not conduct this analysis.

Data QA Plans for sampling, shipment, preparation, and analysis of the battery samples have been documented in the QAP. All DQOs were met on the TCLP analyses and all QC criteria were met for both the metal and organic TCLP analyses. Procedures for the acute toxicity tests with *Ceriodaphnia* and fathead minnows followed those outlined in the EPA document, *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine*

Organisms (Peltier and Weber 1985) and/or Standard Methods for the Examination of Waste and Wastewaters (APHA, 1990). Standard operating procedures and a quality assurance plan are documented in the ORNL Environmental Sciences Division Toxicology Laboratory Quality Assurance Program (Kszos et al., 1989).

4. ANALYTICAL FINDINGS

4.1. THE TCLP

The summary data in Tables 3 and 4 indicate that all batteries, with the exception of Li-$SOCl_2$ and MG, passed the TCLP test for metals. In both cases the element that failed the test was chromium. Although the average value for chromium in the leachate for the Li-$SOCl_2$ batteries was 4.2 mg/L, which is below the regulatory limit of 5 mg/L, the 95% upper confidence limit about the average exceeds the regulatory limit. However, the maximum detected value in the samples was greater than the TCLP limit, thus classifying the Li-$SOCl_2$ batteries as hazardous due to the chromium concentrations. The average value for chromium in the leachate of the MG batteries was 9.1 mg/L, which is above the TCLP limit of 5 mg/L also classifying the MG batteries as hazardous due to chromium concentrations. The Li-$SOCl_2$ also showed a high leachability for nickel, a constituent of concern in this study, but at present is not a TCLP metal. TCLP data in Table 4 indicate that the volatile organic constituents of concern are well below the TCLP limits. The data in Table 4 are reported with the **U** and **J** qualifiers. The U qualifier indicates that the compound was analyzed for but not detected. The number is the attainable detection limit for the sample. The J qualifier is used when the mass spectral data indicate the presence of a compound that meets the identification criteria but the result is less than the sample quantitation limit but greater than zero. This is flagged as an estimated value. For example, if the sample quantitation limit is 10ug/L, but a concentration of 3 ug/L is calculated, it is reported as 3J. The details of the sampling and analytical protocol are further discussed in the QAP (Kirkpatrick 1990). A copy of all analytical data is contained within Appendix B.

Table 3. Summary Table of TCLP Metals Results (mg/L) per Battery Type.

Constituent	$Li-SO_2$ (range)	$Li-SOCl_2$ (range)	$Li-MnO_2$ (range)	MG (range)	ALK (range)	LCE (range)	TCLP Limits (mg/L)
Arsenic							5.0
range	<0.050 - <0.050	<0.050 - 0.18	<0.050 - 0.080	0.11 - 0.19	<0.050 - 0.067	<0.050 - <1.0	
average	<0.050	0.10	0.062	0.15	0.053	0.190	
std dev	0	0.06	0.012	0.03	0.006	0.357	
Barium							100
range	<0.10 - <0.10	<0.10 - 0.34	<0.10 - <0.10	0.73 - 1.30	<0.10 - <0.10	<0.10 - 0.61	
average	<0.10	0.15	<0.10	0.88	<0.10	0.18	
std dev	0	0.08	0	0.19	0	0.19	
Cadmium							1.0
range	0.015 - 0.020	<0.0030 - <0.0030	<0.0030 - <0.0030	<0.0030 - 0.0039	<0.0030 - <0.0030	<0.0030 - 0.34	
average	0.017	<0.0030	<0.0030	0.0033	<0.0030	0.052	
std dev	0.002	0	0	0.0004	0	0.127	
Chromium							5.0
range	<0.010 - <0.010	3.3 - 5.9	<0.010-0.017	6.4 - 11.0	<0.010 - <0.010	<0.010 - 0.010	
average	<0.010	4.2	0.012	9.1	<0.010	0.010	
std dev	0	1.1	0.004	1.5	0	0	
Lead	<						5.0
range	0.050 - <0.050	<0.050 - <0.050	<0.050 - <0.050	<0.050-<0.050	<0.050-<0.050	<0.050 - <1.0	
average	<0.050	<0.050	<0.050	<0.050	<0.050	0.186	
std dev	0	0	0	0	0	0.359	
Mercury	NA*	NA	NA	NA			0.20
range					0.022-0.042	0.009 - 0.082	
average					0.033	0.040	
std dev					0.007	0.026	
Selenium							1.0
range	<0.050 - <0.050	0.062 - 0.110	<0.050 - <0.050	0.059 - 0.120	<0.050-<0.050	<0.050 - 0.098	
average	<0.050	0.082	<0.050	0.088	<0.050	0.058	
std dev	0	0.018	0	0.02	0	0.018	
Silver							5.0
range	<0.010 - <0.010	<0.010 - <0.010	<0.010 - <0.010	<0.010 - <0.010	<0.010-0.011	<0.010 - 0.11	
average	<0.010	<0.010	<0.010	<0.010	<0.010	0.036	
std dev	0	0	0	0	0.0004	0.037	

* Constituent was not analyzed for in this battery type.

Table 4. Summary Table of TCLP Volatile Organic Results (mg/L) per Battery Type.

Constituent	Li-SO_2 (mg/L)	Li-$SOCl_2$ (mg/L)	Li-MnO_2 (mg/L)	MG (mg/L)	ALK (mg/L)	LCE (mg/L)	TCLP Limits (mg/L)
Benzene							0.5
range	<0.005U - <0.005U	0.001JB - <0.005U	0.001JB - 0.005U	<0.005U - <0.005U	<0.005U - <0.005U	<0.005U - <0.005U	
average	<0.005U	0.003JB	0.003JB	<0.005U	<0.005U	<0.005U	
std dev	0	0.002	0.002	0	0	0	
Carbon Tetrachloride							0.5
range	<0.005U - <0.005U	<0.005U - <0.005U	<0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	<0.005U - <0.005U	
average	0.005U	<0.005U	<0.005U	<0.005U	<0.005U	<0.005U	
std dev	0	0	0	0	0	0	
Chlorobenzene							100.0
range	<0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	0.005U - <0.005U	
average	0.005U	<0.005U	<0.005U	<0.005U	<0.005U	<0.005U	
std dev	0	0	0	0	0	0	
Chloroform							6.0
range	0.001J - <0.005U	0.002J - 0.003J	0.002J - 0.003J	0.002J - <0.005U	0.002J - 0.003J	0.001J - <0.005U	
average	0.004J	0.003J	0.003J	0.002J	0.002J	0.002J	
std dev	0.002	0.0004	0.0004	0.001	0.0004	0.001	
1,2-Dichloroethane							0.5
range	<0.005U - <0.005U	<0.005U - 0.070	<0.005U - <0.005U	0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	
average	<0.005U	0.029	<0.005U	<0.005U	<0.005U	<0.005U	
std dev	0	0.024	0	0	0	0	
1,1-Dichloroethylene							0.7
range	<0.005U - <0.005U	<0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	
average	<0.005U	<0.005U	<0.005U	<0.005U	<0.005U	<0.005U	
std dev	0	0	0	0	0	0	

continued

Constituent	Li-SO_2 (mg/L)	Li-$SOCl_2$ (mg/L)	Li-MnO_2 (mg/L)	MG (mg/L)	ALK (mg/L)	LCE (mg/L)	TCLP Limits (mg/L)
Methyl-ethyl-ketone							200.0
range	<0.005U - 0.016	<0.005U - <0.005U	<0.005U - 0.037	0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	
average	0.006	<0.005U	0.024	<0.005U	<0.005U	<0.005U	
std dev	0.004	0	0.010	0	0	0	
Tetrachloroethylene							0.7
range	0.005U	0.003J - 0.005	0.001J - <0.005U	0.005U - <0.005U	0.003J - <0.005U	0.005U - <0.005U	
average	0.005U	0.005	<0.005U	<0.005U	0.005	<0.005U	
std dev	0	0.0008	0.0008	0	0.0008	0	
Trichloroethylene							0.5
range	0.005U	0.001J - 0.005U	<0.005U - <0.005U	0.002J - <0.005U	<0.005U - <0.005U	<0.005U - 0.033	
average	0.005U	0.005U	<0.005U	0.003J	<0.005U	0.012	
std dev	0	0	0	0.002	0	0.01	
Vinyl Chloride							0.2
range	0.005U	<0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	<0.005U - <0.005U	0.005U - <0.005U	
average	0.005U	<0.005U	<0.005U	<0.005U	<0.005U	<0.005U	
std dev	0	0	0	0	0	0	

U - Compound was analyzed for but not detected. The number is the attainable detection limit for the sample.
B - Parameter was found in the reagent blank as well as the sample.
J - Indicates an estimated value.

4.2. THE TCA

As previously stated, the TCA analyses were performed in October of 1990 and in August 1991 due to the need for additional leachate for the 96-hr bioassay. Table 5 is a summary of the TCA analysis. This analysis showed significant levels of copper, nickel, tin, zinc, lead, and barium. Cadmium was present ranging from <6.0 ug/g in the Li-$SOCl_2$ battery to 42.0 ug/g in the LCE battery. Arsenic, however, was not found in the analysis (detection limits on these samples ranged from <46 ug/g to <100 ug/g).

Table 5. Summary Table of TCA Analyses from October 1990 per each battery type. All values are in ug/g.

Constituent	Li-SO_2	Li-$SOCl_2$	Li-MnO_2	MG	ALK	ALK	LCE
Arsenic	<100	<100	<46	<50	<100	<100	<50
Barium	NA	NA	NA	2,100	NA	NA	NA
Beryllium	NA	NA	NA	<0.30	NA	NA	NA
Cadmium	6.5	<6.0	7.9	3.2	9.2	7.8	42
Copper	5,600	19,000	25	6.5	2,800	3,300	250
Lead	<100	<100	<46	<50	100	<100	<50
Nickel	3,200	170,000	20,000	NA	3,400	3,300	17
Tin	200	219	200	500	180	170	170
Zinc	NA	NA	NA	500	NA	NA	NA

4.3. THE CLEAN CLOSURE LEACHING PROCEDURE EXTRACT

Table 6 is a summary of the analyses conducted on the CCLT extract in August 1991. The CCLT was used to collect leachate for the 96-hr aquatic bioassay. No comparisons can be made in the constituent concentrations in the CCLT extract and the TCA analyses because different solutions were used to perform each of the analyses extractions. The TCA analyses uses either an acetate buffer or acetic acid solution to extract metals for analyses. This extraction results in a much greater dissolution of metals. The CCLT uses deionized water only during extraction, thus, resulting in a lesser degree of dissolution.

Table 6. Summary Table of CCLT Extract-deionized water Analysis from August 1991 per each battery type. All values are in ug/g.

Constituent	Li-SO_2	Li-MnO_2	MG	ALK
Arsenic	<0.050	<0.050	<0.050	<0.050
Barium	0.24	0.045	0.11	0.0047
Cadmium	<0.0030	<0.0030	<0.0030	<0.0030
Chromium	<0.010	<0.010	0.60	<0.010
Copper	0.036	0.0055	<0.004	0.0045
Lead	<0.050	<0.050	<0.050	<0.050
Nickel	<0.010	<0.010	<0.010	<0.010
Selenium	<0.050	<0.050	<0.050	1.1
Silver	<0.0060	<0.0060	<0.0060	<0.0060

4.4. BIOASSAYS

4.4.1. *Ceriodaphnia* 96-h Acute Tests

Results of the 96-h acute toxicity tests with *Ceriodaphnia* are summarized in table 7. Mortality in each concentration of battery leachate tested is presented in Appendix D, Tables D1-D4. Leachates were prepared in August 1991. The mean 96-h LC50s ranged from 51 mg/L for ALK to 18,067 mg/L for MG. The toxicity of the battery leachates from least toxic to most toxic was MG <<< Li-SO_2 << Li-MnO2 < ALK. Full-strength blank caused nearly 100% mortality of *Ceriodaphnia* in 96-h, but all the animals survived in the 50% concentration (Table D5). Mortality in the dilution water was 15%.

Table 7. *Ceriodaphnia* 96-h LC50 values for each battery aliquot. All values are in mg/L.

Battery	Aliquot	LC50	95% Confidence Limits	Method	Mean
MG	1	18,607	15,000-30,000	Binomial	
	2	17,527	0.0-30,000	Binomial	18,0
Li-SO_2	1	866	500-1,500	Binomial	
	2	538	250-1,500	Binomial	702
Li-MnO_2	1	73	60-125	Binomial	
	2	72	58-90	Moving Average	73
ALK	1	49	32-65	Probit	
	2	54	45-65	Probit	51

4.4.2. Fathead minnow 96-h Acute Tests

Results of the 96-h acute toxicity tests with fathead minnows are summarized in Table 8. Mortality in each concentration of battery leachate tested is presented in Appendix E, Tables E1-E4. Leachates were prepared in August 1991. The mean 96-h LC50s ranged from 246 mg/L for ALK to 22,928 for MG. The toxicity of the battery leachates from least toxic to most toxic was MG <<< Li-SO_2 << Li-MnO_2 < ALK. Mortality in the blank was 17.5%. In test containers containing either 250 mL or 20 mL of dilution water, mortality was 0% and 4%, respectively.

Table 8. Fathead minnow 96-h LC50 values for each battery aliquot. All values are in mg/L.

Battery	Aliquot	LC50	95% Confidence Limits	Method	Mean
MG	1	22,928	12,500-infinity	Binomial	
	2	>25,000	NA[a]	NA[a]	22,928[b]
Li-SO_2	1	676	500-1,000	Binomial	
	2	707	500-1,000	Binomial	691
Li-MnO_2	1	320	250-500	Binomial	
	2	257	207-320	Moving Average	288
ALK	1	262	125-500	Binomial	
	2	229	125-500	Binomial	246

[a]NA = not applicable. [b]Value based on one aliquot.

4.4.3. Summary

Table 9 summarizes the results of all acute toxicity test results for all of the battery types. The LC50 is that concentration (mg of battery/L) killing 50% of the test animals in the specified time period.

Table 9. Summary of acute toxicity test results for all battery types. All values are in mg/L.

	Test Results	
	Fathead minnow[1]	*Ceriodaphnia*[1]
Battery	96-h LC50 (mg/L)	96-h LC50 (mg/L)
MG	22,928	18,067
Li-SO_2	691	702
Li-MnO_2	288	73
ALK	246	51
LCE	See Below[2]	See Below[2]
Li-$SOCl_2$	See Below[3]	See Below[3]

[1]Fathead minnow and *Ceriodaphnia* tests were conducted using battery leachates prepared in August.

[2]Battery was discontinued. Preliminary *Ceriodaphnia* 48-h test results indicate that battery would be classified as toxic (LC50 = 289 mg/L) using California regulations (LC50 < 500 mg/L; Polisini and Miller, 1988).

[3]Battery not available in August. Preliminary *Ceriodaphnia* 48-h test results indicate that leachate is highly toxic (LC50 < 2.5 mg/L) and would be classified as hazardous using California regulations.

5. CONCLUSIONS AND RECOMMENDATIONS

The TCLP, TCA, and bioassay analyses were successfully conducted on the samples from the six batteries provided by CECOM/LABCOM. Two battery types, Li-$SOCl_2$ and MG, were identified by the TCLP analysis as characteristically hazardous under RCRA regulations. Based on this analysis alone, these two classes of batteries should be characterized under RCRA regulations with a hazardous waste number of D007 for chromium.

It is important to understand that the TCLP results are useful only when compared to the specific TCLP guidelines, because these guidelines were developed for the evaluation of concentrated TCLP leachate. Other guidelines and regulatory limits, such as drinking water quality standards, are not applicable to the TCLP results. These standards apply to concentrations at drinking water sources etc., not the concentrated leachate from a TCLP analysis.

Bioassay results indicate that the toxicity of the battery leachates ranked from least to most toxic was MG < Li-SO_2 < Li-MnO_2 < ALK < LCE < Li-$SOCl_2$. California Department of Health Services regulations (Polisini and Miller 1988) state that "the waste generator shall demonstrate that the waste does not have an LC50 less than 500 mg/L in order to qualify for a nonhazardous designation on the basis of aquatic toxicity". Thus Li-MnO_2 and ALK batteries tested in August and LCE and Li-$SOCl_2$ preliminary bioassay results indicate that those classes of batteries should be classified as hazardous waste in states which use a bioassay to characterize the solid waste stream. Although the California regulations do not call for *Ceriodaphnia* bioassays, the results clearly demonstrate that battery leachates pose a threat to aquatic life.

Toxicity of the leaching solution did not affect the bioassay results. The LC50 for the MG leachate represents a 46% dilution, which was below the concentration of leaching solution that was toxic to fathead minnows or *Ceriodaphnia*.

Toxicity of the Li-$SOCl_2$ battery leachate may have been high due to concentrations of nickel. According to the TCLP results, this leachate may contain up to 640 mg/L Ni. Tests conducted in the laboratory have shown that Ni may be acutely toxic (48 h) to *Ceriodaphnia* at a concentration as low as 30 μg/L (Kszos et al. 1991). Thus, Ni is probably a major contributor to the toxicity of the leachate from this battery.

Based on the results of this study, it is clear that all six of the batteries that were tested present a disposal problem for the Army. As a result, it may be necessary to evaluate possible disposal methods available for these types of solid wastes and to select an appropriate disposal method that minimizes cost and maximizes disposal efficiency. Models may be available to evaluate such conditions using the leachate data presented here. If possible, a variety of disposal options should be assessed to determine the optimal location and method of battery disposal.

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APPENDIX A
EPA LC_{50} SOFTWARE CODE (BASIC)

LC50.BAS

```
1                     0   D                              I                          M
A(10),B(10),C(10),D(10),E(10),F(10),G(18,18),H(10),I(10),J(10),K(10),L(10),M(10),N(10),
P(10),T(10),V(10),X(10),Y(10),Z(10)
30 INPUT "NUMBER OF CONCENTRATIONS =";M
40 FOR J=1 TO M
50 PRINT "CONCENTRATION NUMBER";J;"= "
51 INPUT C3
52 C(J)=C3
60 NEXT J
70 FOR J=1  TO M
80 PRINT "NUMBER OF FISH AT START OF TEST IN CONCENTRATION ";C(J);" =
"
81 INPUT E(J)
90 NEXT J
100 FOR J=1 TO M
110 PRINT "NUMBER OF FISH DEAD IN CONCENTRATION ";C(J);" = "
111 INPUT D(J)
120 NEXT J
130 LPRINT "CONC.","NUMBER","NUMBER","PERCENT","BINOMIAL"
140 LPRINT "  ","EXPOSED","DEAD","DEAD","PROB.(%)"
150 K0=0
160 FOR J=1 TO M
170 L(J)=LOG(C(J))/LOG(10)
180 P(J)=D(J)/E(J)
190 I(J)=1
240 B1=0
250 N1=E(J)
260 IF P(J)>.5 THEN 290
270 N2=D(J)
280 GOTO 300
290 N2=E(J)-D(J)
300 FOR N=0 TO N2
310 B2=1
311 B3=1
320 FOR I=(N1-N+1) TO N1
330 B2=B2*I
340 NEXT I
350 FOR I = 2 TO N
360 B3=B3*I
370 NEXT I
380 B1=B1+(B2/B3)
390 NEXT N
400 B(J)=100*B1*(.5^N1)
```

```
410 LPRINT C(J),E(J),D(J),100*P(J),B(J)
450 A1=SQR(D(J)/(E(J)+1))
460 A2=ATN(A1/(SQR(1-A1*A1)))
470 IF D(J)=E(J) THEN 510
480 A3=SQR((D(J)+1)/(E(J)+1))
490 A4=ATN(A3/(SQR(1-A3*A3)))
500 GOTO 520
510 A4=1.57079633#
520 A(J)=180*(A2+A4)/(2*3.14159)
530 NEXT J
540 FOR J=1 TO M
550 IF P(J)>0 THEN 610
560 IF J>1 THEN 590
570 Y(J)=-2.67*(1-P(J+1)/2)
580 GOTO 810
590 Y(J)=-2.67*(1-P(J-1)/2)
600 GOTO 810
610 IF P(J)<1 THEN 665
620 IF J<M THEN 650
630 Y(J)=2.67*(1-(1-P(J-1))/2)
640 GOTO 810
650 Y(J)=2.67*(1-(1-P(J+1))/2)
660 GOTO 810
665 P1=P(J)
670 I1=0
680 IF P1<=.5 THEN 710
690 P1=1-P1
700 I1=1
710 P2=SQR(LOG(1/P1/P1))
720 P3=((.010328*P2+.802853)*P2+2.515517)
730 Y(J)=P3/(((.001308*P2+.189269)*P2+1.432788)*P2+1)-P2
740 IF I1=1 THEN 750
745 GOTO 760
750 Y(J)=-Y(J)
760 IF K0>0 THEN 790
770 X3=C(J)
780 GOTO 800
790 IF X3=C(J) THEN 810
800 K0=K0+1
810 NEXT J
1000 B4=0
1001 B5=0
1002 B6=0
1003 B7=0
1010 FOR J=1 TO M
1020 IF B(J)<1776 THEN 1040
```

```
1030 GOTO 1230
1040 IF P(J)<.5 THEN 1090
1050 IF B(J)>2.5 THEN 1090
1060 B4=C(J)
1070 B5=B(J)
1080 NEXT J
1090 FOR J=M TO 1 STEP -1
1100 IF P(J)>.5 THEN 1150
1110 IF B(J)>2.5 THEN 1150
1120 B6=C(J)
1130 B7=B(J)
1140 NEXT J
1150 B8=100-B5-B7
1160 IF B4>0 THEN 1190
1170 LPRINT "THE BINOMIAL TEST SHOWS THAT ";B6;"AND + INFINITY CAN BE"
1180 GOTO 1200
1190 LPRINT "THE BINOMIAL TEST SHOWS THAT ";B6;"AND ";B4;" CAN BE"
1200 LPRINT "USED AS STATISTICALLY SOUND CONSERVATIVE 95 PERCENT"
1210 LPRINT "CONFIDENCE LIMITS SINCE THE ACTUAL CONFIDENCE LEVEL"
1220 LPRINT "ASSOCIATED WITH THESE LIMITS IS ";B8;" PERCENT."
1230 FOR J=1 TO M
1240 IF P(J)<.5 THEN 1270
1250 G1=J
1260 NEXT J
1270 FOR J=M TO 1 STEP -1
1280 IF P(J)>.5 THEN 1310
1290 G2=J
1300 NEXT J
1310 IF P(G2)<P(G1) THEN 1340
1320 M1=((C(G1))*(C(G2)))^.5
1330 GOTO 1370
1340 G3=(45-A(G2))/(A(G1)-A(G2))
1350 G4=L(G2)+(L(G1)-L(G2))*G3
1360 M1=10^G4
1370 LPRINT "AN APPROXIMATE LC50 FOR THIS SET OF DATA IS ";M1
1380 LPRINT
1390 IF K0>1 THEN 1440
1400 LPRINT "WHEN THERE ARE LESS THAN TWO CONCENTRATIONS AT
WHICH THE PERCENT"
1410 LPRINT "DEAD IS BETWEEN 0 AND 100, NEITHER THE MOVING AVERAGE
NOR THE"
1420 LPRINT "PROBIT METHOD CAN GIVE ANY STATISTICALLY SOUND
RESULTS."
1430 GOTO 3850
1440 I4=0
1450 FOR S=M-1 TO 1 STEP -1
```

```
1460 FOR N=1 TO M-S+1
1470 IF S<3 THEN 1580
1480 FOR J=1 TO S-2
1490 J(J+2)=((L(N+J+1)-L(N+1))/(L(N+1)-L(N)))-J
1500 NEXT J
1510 FOR J=1 TO S
1520 T(J)=-.5*(S-1)+(J-1)+J(J)
1530 NEXT J
1540 W1=0
1541 W2=0
1550 FOR K=1 TO S
1560 W1=W1+T(K)*(.5+E(N+K-1))
1565 W2=W2+T(K)*T(K)*(.5+E(N+K-1))
1570 NEXT K
1580 K1=1
1590 V(N)=0
1600 FOR J=N TO N+S-1
1610 IF S>2 THEN 1640
1620 M(J)=1
1630 GOTO 1650
1640 M(J)=W2-T(K1)*W1
1650 G(J,N)=M(J)*(.5+E(J))
1660 V(N)=V(N)+G(J,N)
1670 K1=K1+1
1680 NEXT J
1690 K(N)=0
1700 F(N)=0
1710 FOR J=N TO N+S-1
1720 K(N)=K(N)+G(J,N)*L(J)/V(N)
1730 F(N)=F(N)+G(J,N)*A(J)/V(N)
1740 NEXT J
1750 F(N)=(INT((1000000!)*F(N)+.5))/(1000000!)
1760 NEXT N
1770 K2=1
1780 FOR J=1 TO M-S
1790 X(K2)=0
1800 K4=0
1810 FOR N=J TO J+S
1820 IF P(N)=0 THEN 1850
1830 IF P(N)=1 THEN 1850
1840 K4=K4+1
1850 NEXT N
1860 IF K4<2 THEN 1920
1870 IF F(J)=F(J+1) THEN 1920
1880 IF F(J)<45 THEN 1920
1890 IF F(J+1)>45 THEN 1920
```

```
1900 X(K2)=J
1910 K2=K2+1
1920 NEXT J
1930 IF X(1)=0 THEN 2360
1940 IF I4=1 THEN 1980
1950 LPRINT ">>>>>>>>>RESULTS CALCULATED USING THE MOVING
AVERAGE METHOD"
1960 LPRINT "SPAN","G","LC50","95 PERCENT CONFIDENCE LIMITS"
1970 I4=1
1980 FOR N=1 TO K2-1
1990 P=X(N)
2000 Q=X(N)+1
2010 Y=F(Q)-F(P)
2020 A=(45-F(P))/Y
2030 M2=K(P)+(K(Q)-K(P))*A
2040 M3=10^M2
2050 V1=0
2051 V2=0
2053 V3=0
2060 FOR J=1 TO S
2070 V1=V1+((3282.81*(G(P+J-1,P)^2))/((4*E(P+J-1)+2)*(V(P))^2))
2080 V2=V2+((3282.81*(G(Q+J-1,Q)^2))/((4*E(Q+J-1)+2)*(V(Q))^2))
2090 IF J=1 THEN 2110
2100 V3=V3+((3282.81*G(P+J-1,P)*G(Q+J-2,Q))/((4*E(P+J-1)+2)*V(P)*V(Q)))
2110 NEXT J
2120 V4=V1+V2-2*V3
2130 V5=V1-V3
2140 Z=1.96
2150 G=Z*Z*V4/(Y^2)
2160 IF G=1 THEN 2330
2170 R=V1-2*A*V5+(A^2)*V4-G*(V1-((V5^2)/V4))
2180 IF R<0 THEN 2330
2190 V6=Z*SQR(R)/(Y*(1-G))
2200 V7=(A-G*V5/V4)/(1-G)
2210 L2=K(P)+(K(Q)-K(P))*(V7-V6)
2220 U2=K(P)+(K(Q)-K(P))*(V7+V6)
2230 L3=10^L2
2240 U3=10^U2
2250 IF G<1 THEN 2310
2260 IF A<(V5/V4) THEN 2290
2270 LPRINT S,G,M3,"0",U3
2280 GOTO 2340
2290 LPRINT S,G,M3,L3,"+ INFINITY"
2300 GOTO 2340
2310 LPRINT S,G,M3,L3,U3
2320 GOTO 2340
```

```
2330 LPRINT S,G,M3,"     0","+ INFINITY"
2340 NEXT N
2350 GOTO 2420
2360 NEXT S
2370 IF I4=1 THEN 2420
2380 LPRINT "THE MOVING AVERAGE METHOD CANNOT BE USED WITH THIS SET OF DATA"
2390 LPRINT "BECAUSE NO SPAN WHICH PRODUCES MOVING AVERAGE ANGLES THAT BRACKET"
2400 LPRINT "45 DEGREES ALSO USES TWO PERCENT DEAD BETWEEN 0 AND 100 PERCENT."
2410 LPRINT
2420 IF K0>1 THEN 2470
2430 LPRINT "WHEN THERE ARE LESS THAN TWO CONCENTRATIONS AT WHICH THE PERCENT"
2440 LPRINT "DEAD IS BETWEEN 0 AND 100, THE PROBIT METHOD CANNOT GIVE ANY"
2450 LPRINT"STATISTICALLY SOUND RESULTS."
2460 GOTO 3850
2470 S1=0
2471 S2=0
2472 S3=0
2473 S4=0
2475 K3=0
2476 I3=0
2480 FOR J=1 TO M
2485 S1=S1+L(J)
2490 S2=S2+Y(J)
2500 S3=S3+L(J)*L(J)
2510 S4=S4+L(J)*Y(J)
2520 NEXT J
2530 B=(S4-S1*S2/M)/(S3-S1*S1/M)
2540 A=(S2-B*S1)/M
2550 F1=0
2551 F2=0
2552 F3=0
2553 F4=0
2554 F5=0
2556 F6=0
2560 FOR J=1 TO M
2570 Z(J)=A+B*L(J)
2580 Z1=ABS(Z(J))
2590 IF Z1>8 THEN 2700
2600 Z2=.39894228#*EXP(-.5*Z1*Z1)
2610 Z3=1/(1+.2316419*Z1)
2620 Z4=((1.330274*Z3-1.821256)*Z3+1.781478)*Z3
```

```
2630 P=Z2*Z3*((Z4-.356563782#)*Z3+.31938153#)
2640 IF Z(J)<0 THEN 2680
2650 Q=P
2660 P=1-P
2670 GOTO 2730
2680 Q=1-P
2690 GOTO 2730
2700 P=1E-16
2710 Z2=1E-15
2720 GOTO 2640
2730 W3=E(J)*(Z2/P)*(Z2/Q)
2740 W4=Z(J)+(P(J)-P)/Z2
2750 F1=F1+L(J)*W3
2760 F2=F2+W3*W4
2770 F3=F3+L(J)*L(J)*W3
2780 F4=F4+W3*W4*W4
2790 F5=F5+L(J)*W3*W4
2800 F6=F6+W3
2810 NEXT J
2820 F7=F5-F1*F2/F6
2830 F8=F3-F1^2/F6
2840 B=F7/F8
2850 A=(F2-B*F1)/F6
2860 K3=K3+1
2870 D1=0
2880 FOR J=1 TO N
2890 D1=(A+B*L(J)-Z(J))^2+D1
2900 NEXT J
2910 IF D1<1E-11 THEN 2960
2920 IF K3<25 THEN 2550
2930 LPRINT "NO CONVERGENCE IN 25 ITERATIONS. THE PROBIT METHOD
PROBABLY"
2940 LPRINT "CANNOT BE USED WITH THIS SET OF DATA."
2950 GOTO 3860
2960 F9=F1/F6
2970 F0=F4-F2^2/F6
2980 C1=F0-F7^2/F8
2990 V=M-2
3000 IF V=0 THEN 3430
3010 IF C1/V>20 THEN 3220
3020 J=1
3030 FOR I=V TO 2 STEP -2
3040 J=J*I
3050 NEXT I
3060 C2=C1^(INT((V+1)/2))*EXP(-C1/2)/J
3070 IF INT (V/2)=V/2 THEN 3100
```

```
3080 C3=SQR(2/C1/3.14159)
3090 GOTO 3110
3100 C3=1
3110 C4=1
3111 C5=1
3120 V=V+2
3130 C5=C5*C1/V
3140 IF C5<1E-10 THEN 3170
3150 C4=C4+C5
3160 GOTO 3120
3170 C6=1-C2*C3*C4
3180 IF C6>=.001 THEN 3200
3190 C6=0
3200 V=M-2
3210 GOTO 3250
3220 C6=0
3230 GOTO 3250
3240 C6=1492
3250 IF C6<=.05 THEN 3290
3260 T5=1.96
3270 H=1
3280 GOTO 3370
3290 IF V=1 THEN 3330
3300 IF V=2 THEN 3350
3310 T5=1.95996+1/(.413*V-.423)
3320 GOTO 3360
3330 T5=12.706
3340 GOTO 3360
3350 T5=4.303
3360 H=C1/V
3370 G=H*T5^2/B^2/F8
3380 E1=SQR(H/F8)
3390 E2=B-T5*E1
3400 E3=B+T5*E1
3410 LPRINT">>>>>>>RESULTS CALCULATED USING THE PROBIT METHOD"
3415 LPRINT
3420 LPRINT"ITERATIONS","G","H","GOODNESS OF FIT PROBABILITY"
3430 IF C6=1492 THEN 3460
3440 LPRINT K3,G,H,C6
3450 GOTO 3470
3460 LPRINT K3,G,H," (CANNOT BE CALCULATED)"
3470 LPRINT
3480 IF C6>0 THEN 3510
3490 LPRINT "A PROBABILITY OF 0 MEANS THAT IT IS LESS THAN 0.001"
3500 LPRINT
3510 IF C6>.05 THEN 3550
```

```
3520 LPRINT "SINCE THE PROBABILITY IS LESS THAN 0.05, RESULTS CALCULATED"
3530 LPRINT "USING THE PROBIT METHOD PROBABLY SHOULD NOT BE USED."
3540 LPRINT
3550 LPRINT"SLOPE  =",B
3560 LPRINT "95 PERCENT CONFIDENCE LIMITS =";E2; "   AND   ";E3
3570 LPRINT
3580 M4=-A/B
3590 M5=10^(M4)
3600 LPRINT "LC50  =  ",M5
3610 IF G=1 THEN 3770
3620 H1=H*((1-G)/F6+(M4-F9)^2/F8)
3630 IF H1<0 THEN 3770
3640 H2=SQR(H1)
3650 L4=M4+G*(M4-F9)/(1-G)-H2*T5/((ABS(B))*(1-G))
3660 U4=M4+G*(M4-F9)/(1-G)+H2*T5/((ABS(B))*(1-G))
3670 L5=10^L4
3680 U5=10^U4
3690 IF G<1 THEN 3750
3700 IF M4>F9 THEN 3730
3710 LPRINT "95 PERCENT CONFIDENCE LIMITS  =  0  AND  " ;U5
3720 GOTO 3790
3730 LPRINT "95 PERCENT CONFIDENCE LIMITS  =  ";L5; " AND  + INFINITY"
3740 GOTO 3790
3750 LPRINT "95 PERCENT CONFIDENCE LIMITS  =  " ;L5; "   AND   " ;U5
3760 GOTO 3790
3770 LPRINT "95 PERCENT CONFIDENCE LIMITS  =  0   AND   + INFINITY"
3790 IF I3=1 THEN 3860
3800 M4=(-2.32679-A)/B
3810 M5=10^M4
3820 LPRINT "LC1   =  ",M5
3830 I3=1
3840 GOTO 3610
3860 END
```

APPENDIX B
ANALYTICAL DATA FOR TCLP AND TCA ANALYSES

October 1990

Table 2. Total Constituents Analysis Metal Results of Selected Batteries For the US Army Toxicity Study

Customer Number	Lab Id Number	Battery Type	Arsenic ug/g	Cadmium ug/g	Copper ug/g	Lead ug/g	Nickel ug/g
BA-5598-26	901018-192	Li-SO2	<100	6.5	5,600	<100	3,200
BA-6598-1	901018-200	Li-SOCl2	<100	<6.0	19,000	<100	170,000
BA-5372-1	901018-208	Li-MnO3	<46	7.9	25	<46	20,000
BA-4386-1	901018-216	Mg	<50	3.2	6.5	<50	NA
BA-3517-1	901018-224	ALK	<100	9.2	2,800	100	3,400
BA-3517-2	901018-225	ALK	<100	7.8	3,300	<100	3,300
BA-2-11	901112-004	LCE	<50	42.0	250	<50	17

Table 2. Total Constituents Analysis Metal Results of Selected Batteries For the US Army Toxicity Study -Continued

Customer Number	Lab Id Number	Battery Type	Tin ug/g	Beryllium ug/g	Zinc ug/g	Barium ug/g
BA-5598-26	901018-192	Li-SO2	200	NA	NA	NA
BA-6598-1	901018-200	Li-SOCl2	219	NA	NA	NA
BA-5372-1	901018-208	Li-MnO3	200	NA	NA	NA
BA-4386-1	901018-216	Mg	500	<0.30	500	2,100
BA-3517-1	901018-224	ALK	180	NA	NA	NA
BA-3517-2	901018-225	ALK	170	NA	NA	NA
BA-2-11	901112-004	LCE	170	NA	NA	NA

Note: The total Constituents Analyses were conducted using approved EPA Methodology. However, the SW-846 Method 3050 ma produce the best TCA results. It is recommended that the results be accepted with reservations and confirmed usin vendor data.

Table 3. TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Li-SO2

Customer Number	Lab Id Number	Arsenic mg/L	Cadmium mg/L	Barium mg/L	Lead mg/L	Chromium mg/L	Selenium mg/L	Silver mg/L
BA-5598-26	901018-192	<0.050	0.016	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5598-27	901018-193	<0.050	0.019	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5598-6	901018-194	<0.050	0.020	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5598-15	901018-195	<0.050	0.017	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5598-12	901018-196	<0.050	0.016	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5598-19	901018-197	<0.050	0.018	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5598-7	901018-198	<0.050	0.015	<0.10	<0.050	<0.010	<0.050	<0.010
	Average	<0.050	0.017	<0.10	<0.050	<0.010	<0.050	<0.010
	Std Dev	0	0.002	0	0	0	0	0
	Variance	0	0.000004	0	0	0	0	0
	TCLP Limits	5.0	1.0	100(1)	5.0	5.0	1.0	5.0

Table 4. Non-TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Li-SO2

Customer Number	Lab Id Number	Copper mg/L	Nickel mg/L	Tin mg/L	Cyanide mg/L
BA-5598-26	901018-192	0.045	<0.050	0.16	<0.1
BA-5598-27	901018-193	0.042	<0.050	0.19	<0.1
BA-5598-6	901018-194	0.042	<0.050	0.20	<0.1
BA-5598-15	901018-195	0.042	<0.050	0.17	<0.1
BA-5598-12	901018-196	0.043	<0.050	0.17	<0.1
BA-5598-19	901018-197	0.041	<0.050	0.38	<0.1
BA-5598-7	901018-198	0.044	<0.050	0.31	<0.1
	Average	0.043	<0.050	0.22	<0.1
	Std Dev	0.001	0	0.08	0
	Variance	0.000002	0	0.0064	0

Table 5. TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Li-SOCl2

Customer Number	Lab Id Number	Arsenic mg/L	Cadmium mg/L	Barium mg/L	Lead mg/L	Chromium mg/L	Selenium mg/L	Silver mg/L
BA-6598-1	901018-200	<0.050	<0.0030	0.11	<0.050	3.3	0.062	<0.010
BA-6598-2	901018-201	0.15	<0.0030	0.34	<0.050	5.9	0.096	<0.010
BA-6598-3	901018-202	0.051	<0.0030	0.15	<0.050	5.1	0.063	<0.010
BA-6598-4	901018-203	0.070	<0.0030	0.15	<0.050	3.9	0.091	<0.010
BA-6598-5	901018-204	0.17	<0.0030	0.13	<0.050	3.0	0.067	<0.010
BA-6598-6	901018-205	<0.050	<0.0030	<0.10	<0.050	4.8	0.110	<0.010
BA-6598-7	901018-206	0.18	<0.0030	0.11	<0.050	3.3	0.087	<0.010
	Average	0.10	<0.0030	0.15	<0.050	4.2	0.082	<0.010
	Std Dev	0.06	0	0.08	0	1.1	0.018	0
	Variance	0.0036	0	0.0064	0	1.2	0.00032	0
	TCLP Limits	5.0	1.0	100	5.0	5.0	1.0	5.0

Table 6. Non-TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Li-SOCl2

Customer Number	Lab Id Number	Cpper mg/L	Nickel mg/L	Tin mg/L	Cyanide mg/L
BA-6598-1	901018-200	0.055	320	0.56	NA
BA-6598-2	901018-201	0.076	480	0.60	NA
BA-6598-3	901018-202	0.064	530	0.90	NA
BA-6598-4	901018-203	0.065	530	0.81	NA
BA-6598-5	901018-204	0.065	660	0.63	NA
BA-6598-6	901018-205	0.062	450	0.74	NA
BA-6598-7	901018-206	0.064	640	0.51	NA
	Average	0.064	516	0.68	NA
	Std Dev	0.006	116	0.14	
	Variance	0.000036	13,456	0.020	

Table 7. TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Li-MnO2

Customer Number	Lab Id Number	Arsenic mg/L	Cadmium mg/L	Barium mg/L	Lead mg/L	Chromium mg/L	Selenium mg/L	Silver mg/L
BA-5372-1	901018-208	<0.050	<0.0030	<0.10	<0.050	0.017	<0.050	<0.010
BA-5372-2	901018-209	0.073	<0.0030		<0.050			
BA-5372-3	901018-210	0.080	<0.0030		<0.050			
BA-5372-4	901018-211	0.066	<0.0030	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5372-5	901018-212	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	<0.010
BA-5372-6	901018-213	0.065	<0.0030		<0.050			
BA-5372-7	901018-214	0.052	<0.0030		<0.050			
	Average	0.062	<0.0030	<0.10	<0.050	0.012	<0.050	<0.010
	Std Dev	0.012	0	0	0	0.004	0	0
	Variance	0.00014	0	0	0	0.000016	0	0
	TCLP Limits	5.0	1.0	100 (1)	5.0	5.0	1.0	5.0

Table 8. Non-TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Li-MnO2

Customer Number	Lab Id Number	Copper mg/L	Nickel mg/L	Tin mg/L	Cyanide mg/L
BA-5372-1	901018-208	<0.0040	<0.050	<0.030	NA
BA-5372-2	901018-209	<0.0040	<0.050	<0.030	NA
BA-5372-3	901018-210	<0.0040	<0.050	0.042	NA
BA-5372-4	901018-211	<0.0040	0.20	<0.030	NA
BA-5372-5	901018-212	<0.0040	<0.050	<0.030	NA
BA-5372-6	901018-213	<0.0040	<0.050	0.039	NA
BA-5372-7	901018-214	<0.0040	0.18	<0.030	NA
	Average	<0.0040	0.090	0.033	NA
	Std Dev	0	0.069	0.005	
	Variance	0	0.0048	0.000025	

Table 9. TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Mg

Customer Number	Lab Id Number	Arsenic mg/L	Cadmium mg/L	Chromium mg/L	Lead mg/L	Barium mg/L	Selenium mg/L	Silver mg/L
BA-4386-1	901018-216	0.11	0.0039	10.0	<0.050	0.85	0.100	<0.010
BA-4386-4	901018-217	0.17	0.0035	8.8	<0.050	0.85	0.059	<0.010
BA-4386-6	901018-218	0.16	<0.0030	9.1	<0.050	0.73	0.088	<0.010
BA-4386-7	901018-219	0.11	<0.0030	6.4	<0.050	1.30	0.097	<0.010
BA-4386-8	901018-220	0.18	<0.0030	11.0	<0.050	0.80	0.086	<0.010
BA-4386-9	901018-221	0.19	0.0035	10.0	<0.050	0.84	0.120	<0.010
BA-4386-10	901018-222	0.14	<0.0030	8.7	<0.050	0.81	0.064	<0.010
	Average	0.15	0.0033	9.1	<0.050	0.88	0.088	<0.010
	Std Dev	0.03	0.0004	1.5	0	0.19	0.02	0
	Variance	0.0009	0.00000016	2.2	0	0.036	0.0004	0
	TCLP Limits	5.0	1.0	5.0	5.0	100	1.0	5.0

Table 10. Non-TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type Mg

Customer Number	Lab Id Number	Copper mg/L	Tin mg/L	Berylium mg/L	Zinc mg/L	Chromates mg/L
BA-4386-1	901018-216	0.042	0.58	<0.0010	<0.020	25.9
BA-4386-4	901018-217	0.039	0.52	<0.0010	<0.020	22.3
BA-4386-6	901018-218	0.029	0.47	<0.0010	<0.020	23.4
BA-4386-7	901018-219	0.037	0.53	<0.0010	<0.020	16.7
BA-4386-8	901018-220	0.038	0.56	<0.0010	<0.020	26.5
BA-4386-9	901018-221	0.040	0.55	<0.0010	<0.020	25.0
BA-4386-10	901018-222	0.028	0.47	<0.0010	<0.020	22.0
	Average	0.036	0.53	<0.0010	<0.020	23.1
	Std Dev	0.005	0.04	0	0	3.3
	Variance	0.000025	0.0016	0	0	10.9

Table 11. TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type ALK

Customer Number	Lab Id Number	Arsenic mg/L	Cadmium mg/L	Barium mg/L	Lead mg/L	Chromium mg/L	Selenium mg/L	Mercury mg/L	Silver mg/L
BA-3517-1	901018-224	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	0.037	<0.010
BA-3517-2	901018-225	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	0.026	<0.010
BA-3517-3	901018-226	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	0.030	0.011
BA-3517-4	901018-227	0.067	<0.0030	<0.10	<0.050	<0.010	<0.050	0.036	0.010
BA-3517-5	901018-228	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	0.042	<0.010
BA-3517-6	901018-229	0.052	<0.0030	<0.10	<0.050	<0.010	<0.050	0.036	<0.010
BA-3517-7	901018-230	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	0.022	<0.010
	Average	0.053	<0.0030	<0.10	<0.050	<0.010	<0.050	0.033	<0.010
	Std Dev	0.006	0	0	0	0	0	0.007	0.0004
	Variance	0.000036	0	0	0	0	0	0.000049	0.00000016
	TCLP Limits	5.0	1.0	100	5.0	5.0	1.0	0.20	5.0

Table 12. Non-TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type ALK

Customer Number	Lab Id Number	Copper mg/L	Nickel mg/L	Tin mg/L	Chromates mg/L
BA-3517-1	901018-224	<0.0040	<0.050	0.035	<0.02
BA-3517-2	901018-225	<0.0040	<0.050	0.041	<0.02
BA-3517-3	901018-226	<0.0040	0.10	<0.030	<0.02
BA-3517-4	901018-227	<0.0040	0.11	<0.030	<0.02
BA-3517-5	901018-228	<0.0040	0.10	0.032	<0.02
BA-3517-6	901018-229	<0.0040	<0.050	0.036	<0.02
BA-3517-7	901018-230	<0.0040	0.13	0.043	<0.02
	Average	<0.0040	0.084	0.035	<0.02
	Std Dev	0	0.034	0.005	0
	Variance	0	0.0012	0.000025	0

Table 13. TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type LCE

Customer Number	Lab Id Number	Arsenic mg/L	Cadmium mg/L	Barium mg/L	Lead mg/L	Chromium mg/L	Selenium mg/L	Mercury mg/L	Silver mg/L
BA-2-11	901112-004	<1.0	0.34	0.16	<1.0	<0.010	<0.050	0.082	0.11
BA-2-13	901112-005	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	0.021	0.014
BA-2-14	901112-006	<0.050	<0.0030	<0.10	<0.050	<0.010	0.061	0.065	<0.010
BA-2-16	901112-007	<0.050	<0.0030	<0.10	<0.050	<0.010	0.098	0.045	<0.010
BA-2-18	901112-008	<0.050	<0.0030	<0.10	<0.050	<0.010	<0.050	0.027	0.043
BA-2-61	901112-009	0.052	<0.0030	<0.10	<0.050	0.010	<0.050	0.032	0.054
BA-2-NJ	901112-044	0.081	0.013	0.61	<0.050	<0.010	<0.050	0.009	<0.010
	Average	0.190	0.052	0.18	0.186	0.010	0.058	0.040	0.036
	Std Dev	0.357	0.127	0.19	0.359	0	0.018	0.026	0.037
	Variance	0.127	0.016	0.036	0.129	0	0.00032	0.00068	0.0014
	TCLP Limits	5.0	1.0	100	5.0	5.0	1.0	0.200	5.0

Table 14. Non-TCLP Metal Results of Selected Batteries For the US Army Toxicity Study -Type LCE

Customer Number	Lab Id Number	Copper mg/L	Nickel mg/L	Tin mg/L	Chromates mg/L
BA-2-11	901112-004	2.8	<1.0	0.65	<0.02
BA-2-13	901112-005	<0.0040	0.12	<0.030	<0.02
BA-2-14	901112-006	0.039	<0.050	0.038	<0.02
BA-2-16	901112-007	0.041	<0.050	0.042	<0.02
BA-2-18	901112-008	<0.0040	0.10	<0.030	<0.02
BA-2-61	901112-009	<0.0040	0.14	<0.030	<0.02
BA-2-NJ	901112-044	<0.0040	<0.050	<0.030	<0.02
	Average	0.414	0.186	0.121	<0.02
	Std Dev	1.052	0.359	0.233	0
	Variance	1.107	0.129	0.054	0

Table 15. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Li-SC

Customer Number	BA-5598 -26	BA-5598 -27	BA-5598 -6	BA-5598 -15	BA-5598 -12	BA-5598 -19	BA- -.
Lab Id Number	901018 -192	901018 -193	901018 -194	901018 -195	901018 -196	901018 -197	901018 -198
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Carbon Tetra-Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chlorobenzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chloroform	0.005U	0.005U	0.002J	0.001J	0.002J	0.005U	0.005U
1,2 Dichlor-ethane	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
1-1 Dichlor-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Methyl ethyl ketone	0.005U	0.005U	0.005U	0.016	0.005U	0.005U	0.005U
Tetrachloro-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Trichloro-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Vnyl Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U

Table 15. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Li-SO2-C ed

Parameters	AVE	STD	VAR	TCLP Limits
Benzene	0.005U	0	0	0.5
Carbon TetraChloride	0.005U	0	0	0.5
Chlorobenzene	0.005U	0	0	100.0
Chloroform	0.004J	0.002	0.004	6.0
1,2 Dichlorethane	0.005U	0	0	0.5
1,1 Dichlorethylene	0.005U	0	0	0.7
Methyl ethyl ketone	0.006	0.004	0.008	200.0
Tetrachloroethylene	0.005U	0	0	0.7
Trichloroethylene	0.005U	0	0	0.5
Vnyl Chloride	0.005U	0	0	0.2

Note: The Toxicity Characteristic Constituents were taken from the March 29 CFR, Vol. 55 No. 61, pages 11845, 11846, Ta

Table 16. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Li-SOC

Customer Number	BA-6598 -1	BA-6598 -2	BA-6598 -3	BA-6598 -4	BA-6598 -5	BA-6598 -6	BA-659 -7
Lab Id Number	901018 -200	901018 -201	901018 -202	901018 -203	901018 -204	901018 -205	90101 -206
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benzene	0.005U	0.005U	0.005U	0.001JB	0.001JB	0.001JB	0.001JE
Carbon Tetra-Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005L
Chlorobenzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chloroform	0.003J	0.003J	0.002J	0.003J	0.003J	0.003J	0.003J
1,2 Dichlor-ethane	0.005U	0.036	0.012	0.031	0.006	0.046	0.070
1,1 Dichlor-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005L
Methyl ethyl ketone	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005L
Tetrachloro-ethylene	0.003J	0.005	0.005U	0.005U	0.005U	0.005U	0.005L
Trichloro-ethylene	0.005U	0.005U	0.005U	0.001J	0.005U	0.005U	0.005L
Vnyl Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005L

Table 16. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Li-SOCl2-Continue

Parameters	AVE	STD	VAR	TCLP Limits
Benzene	0.003JB	0.002	0.004	0.5
Carbon Tetrachloride	0.005U	0	0	0.5
Chlorobenzene	0.005U	0	0	100.0
Chloroform	0.003J	0.0004	0.0008	6.0
1,2 Dichlorethane	0.029	0.024	0.048	0.5
1,1 Dichlorethylene	0.005U	0	0	0.7
Methyl ethyl ketone	0.005U	0	0	200.0
Tetrachloroethylene	0.005	0.0008	0.002	0.7
Trichloroethylene	0.005U	0	0	0.5
Vnyl Chloride	0.005U	0	0	0.2

Note: The Toxicity Characteristic Constituents were taken from the March 29 CFR, Vol. 55 No. 61, pages 11845, 11846, Ta

Table 17. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Li-MnO.

Customer Number	BA-5372 -1	BA-5372 -2	BA-5372 -3	BA-5372 -4	BA-5372 -5	BA-5372 -6	BA -7
Lab Id Number	901018 -208	901018 -209	901018 -210	901018 -211	901018 -212	901018 -213	901018 -214
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benzene	0.001JB	0.001JB	0.001JB	0.005U	0.005U	0.005U	0.005U
Carbon Tetra-Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chlorobenzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chloroform	0.003J	0.003J	0.003J	0.003J	0.002J	0.002J	0.003J
1,2 Dichlor-ethane	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
1,1 Dichlor-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Methyl ethyl ketone	0.037	0.026	0.034	0.021	0.022	0.022	0.005U
Tetrachloro-ethylene	0.005U	0.005	0.005U	0.005U	0.001J	0.005U	0.005U
Trichloro-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Vnyl Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U

Table 17. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Li-MnO2-Co. ..ue

Parameters	AVE	STD	VAR	TCLP Limits
Benzene	0.003JB	0.002	0.004	0.5
Carbon Tetrachloride	0.005U	0	0	0.5
Chlorobenzene	0.005U	0	0	100.0
Chloroform	0.003J	0.0004	0.0008	6.0
1,2 Dichlorethane	0.005U	0	0	0.5
1,1 Dichlorethylene	0.005U	0	0	0.7
Methyl ethyl ketone	0.024	0.010	0.020	200.0
Tetrachloroethylene	0.005	0.0008	0.002	0.7
Trichloroethylene	0.005U	0	0	0.5
Vnyl Chloride	0.005U	0	0	0.2

Note: The Toxicity Characteristic Constituents were taken from the March 29 CFR, Vol. 55 No. 61, pages 11845, 11846, Tab

Table 18. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Mg

Customer Number	BA-4386 -1	BA-4386 -4	BA-4386 -6	BA-4386 -7	BA-4386 -8	BA-4386 -9	BA-4386 -10
Lab Id Number	901018 -216	901018 -217	901018 -218	901018 -219	901018 -220	901018 -221	901018 -222
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Carbon Tetra-Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chlorobenzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chloroform	0.002J	0.002J	0.002J	0.005U	0.002J	0.003J	0.002J
1,2 Dichlor-ethane	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
1,1 Dichlor-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Methyl ethyl ketone	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Tetrachloro-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Trichloro-ethylene	0.005U	0.002J	0.002J	0.005U	0.003J	0.001J	0.002J
Vnyl Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U

Table 18. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type Mg-Continued

Parameters	AVE	STD	VAR	TCLP Limits
Benzene	0.005U	0	0	0.5
Carbon Tetrachloride	0.005U	0	0	0.5
Chlorobenzene	0.005U	0	0	100.0
Chloroform	0.002J	0.001	0.002	6.0
1,2 Dichlorethane	0.005U	0	0	0.5
1,1 Dichlorethylene	0.005U	0	0	0.7
Methyl ethyl ketone	0.005U	0	0	200.0
Tetrachloroethylene	0.005U	0	0	0.7
Trichloroethylene	0.003J	0.002	0.004	0.5
Vnyl Chloride	0.005U	0	0	0.2

Note: The Toxicity Characteristic Constituents were taken from the March 29 CFR, Vol. 55 No. 61, pages 11845, 11846, Ta

Table 19. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type

Customer Number	BA-3517 -1	BA-3517 -2	BA-3517 -3	BA-3517 -4	BA-3517 -5	BA-3517 -6	BA-3... -7
Lab Id Number	901018 -224	901018 -225	901018 -226	901018 -227	901018 -228	901018 -229	901018 -230
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Carbon Tetra-Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chlorobenzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chloroform	0.002J	0.002J	0.002J	0.002J	0.002J	0.002J	0.003J
1,2 Dichlor-ethane	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
1,1 Dichlor-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Methyl ethyl ketone	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Tetrachloro-ethylene	0.004J	0.005	0.005U	0.005U	0.005U	0.005U	0.003J
Trichloro-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Vnyl Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U

Table 19. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type ALK-Continued

Parameters	AVE	STD	VAR	TCLP Limits
Benzene	0.005U	0	0	0.5
Carbon Tetrachloride	0.005U	0	0	0.5
Chlorobenzene	0.005U	0	0	100.0
Chloroform	0.002J	0.0004	0.0008	6.0
1,2 Dichlorethane	0.005U	0	0	0.5
1,1 Dichlorethylene	0.005U	0	0	0.7
Methyl ethyl ketone	0.005U	0	0	200.0
Tetrachloroethylene	0.005	0.0008	0.002	0.7
Trichloroethylene	0.005U	0	0	0.5
Vnyl Chloride	0.005U	0	0	0.2

Note: The Toxicity Characteristic Constituents were taken from the March 29 CFR, Vol. 55 No. 61, pages 11845, 11846, Tab

Table 20. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type LCE

Customer Number	BA-2-11	BA-2-13	BA-2-14	BA-2-16	BA-2-18	BA-2-61	BA-2-NJ
Lab Id Number	901112 -004	901112 -005	901112 -006	901112 -007	901112 -008	901112 -009	901112 -044
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Carbon Tetra-Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chlorobenzene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Chloroform	0.002J	0.005U	0.002J	0.001J	0.002J	0.001J	0.003J
1,2 Dichlor-ethane	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
1,1 Dichlor-ethylene	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Methyl ethyl ketone	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Tetrachloro-ethylene	0.003J	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U
Trichloro-ethylene	0.015	0.005U	0.033	0.004J	0.014	0.009	0.005U
Vnyl Chloride	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U	0.005U

Table 20. TCLP Volatile Organic Results of Selected Batteries For the US Army Toxicity Study -Type LCE-Continued

Parameters	AVE	STD	VAR	TCLP Limits
Benzene	0.005U	0	0	0.5
Carbon Tetrachloride	0.005U	0	0	0.5
Chlorobenzene	0.005U	0	0	100.0
Chloroform	0.002J	0.001	0.002	6.0
1,2 Dichlorethane	0.005U	0	0	0.5
1,1 Dichlorethylene	0.005U	0	0	0.7
Methyl ethyl ketone	0.005U	0	0	200.0
Tetrachloroethylene	0.005U	0	0	0.7
Trichloroethylene	0.012	0.01	0.02	0.5
Vnyl Chloride	0.005U	0	0	0.2

Note: The Toxicity Characteristic Constituents were taken from the March 29 CFR, Vol. 55 No. 61, pages 11845, 11846, T.

August 1991

Oak Ridge K-25 Site
Analytical Chemistry Department
Results of Analyses

Date Printed:
30-SEP-1991 09:07

AnaLIS ID: 910822-220   Project: G134 WAT   Customer Sample ID: LIS02
Customer: J. JONES   Requisition Number:
Date Sampled: 20-AUG-1991   Date Sample Received: 20-AUG-1991
Sampled By: WICKER   Date Sample Completed: 26-AUG-1991
Material Description: WATER   Date Sample Approved: 26-AUG-1991
Current Program Manager: C. R. Kirkpatrick   [] : Result has been Corrected for Spike

Procedure No.	Analysis	Result	Q Qual	Units	Analyst	QA File Number	Date Completed
***** Inductively Coupled Plasma Laboratory *****							
EPA-3010 EPA-6010	Arsenic	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Barium	0.24		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Cadmium	<0.0030		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Chromium	<0.010		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Copper	0.036		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Lead	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010)10	Nickel	<0.010		mg/L	MJ SCHEUER	10823X	23-AUG-1991
,010 EPA-6010	Selenium	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Silver	<0.0060		mg/L	MJ SCHEUER	10823X	23-AUG-1991

***** Comments from the Plasma Emission Laboratory *****

****

Plasma Emission Laboratory Comments :

The pH of this sample was found to be 7 prior to sample preparation.
A pH greater than two indicates that the sample was not preserved during the sampling process.
Since the sample was not preserved the results should be considered as estimated values.
A pH greater than two violates the requirements of the EPA
Statement of Work SW-846.
The method blank associated with this sample was logged into the K25
Analytical Chemistry Department Computer system(ANALIS) using sample
number 910823-014.
This sample was found to have the following
clarity/color/artifacts: COLORLESS/CLEAR/NO ARTIFACTS

****

Date Printed:
30-SEP-1991 C

Oak Ridge K-25 Site
Analytical Chemistry Department
Results of Analyses

AnaLIS ID: 910822-219 Project: G134 WAT
Customer: J. JONES
Date Sampled: 20-AUG-1991
Sampled By: WICKER
Material Description: WATER
Current Program Manager: C. R. Kirkpatrick

Customer Sample ID: LIMNO2
Requisition Number:
Date Sample Received: 20-AUG-1991
Date Sample Completed: 26-AUG-1991
Date Sample Approved: 26-AUG-1991
[] : Result has been Corrected for Spike

Procedure No.	Analysis	Result	Q Qual	Units	Analyst	QA File Number	Date Complet
***** Inductively Coupled Plasma Laboratory *****							
EPA-3010 EPA-6010	Arsenic	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-
EPA-3010 EPA-6010	Barium	0.045		mg/L	MJ SCHEUER	10823X	23-AUG-
EPA-3010 EPA-6010	Cadmium	<0.0030		mg/L	MJ SCHEUER	10823X	23-AUG-
EPA-3010 EPA-6010	Chromium	<0.010		mg/L	MJ SCHEUER	10823X	23-AUG-
EPA-3010 EPA-6010	Copper	0.0055		mg/L	MJ SCHEUER	10823X	23-AUG-
EPA-3010 EPA-6010	Lead	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-
EPA-3010 EPA-6010	Nickel	<0.010		mg/L	MJ SCHEUER	10823X	23-AUG-
EPA-3010 EPA-6010	Selenium	<0.050		mg/L	MJ SCHEUER	10823X	3-
EPA-3010 EPA-6010	Silver	<0.0060		mg/L	MJ SCHEUER	10823X	23-AUG

***** Comments from the Plasma Emission Laboratory *****

****

Plasma Emission Laboratory Comments :

The pH of this sample was found to be 6 prior to sample preparation.
A pH greater than two indicates that the sample was not preserved during the sampling process.
Since the sample was not preserved the results should be considered as estimated values.
A pH greater than two violates the requirements of the EPA
Statement of Work SW-846.
The method blank associated with this sample was logged into the K25
Analytical Chemistry Department Computer system(ANALIS) using sample
number 910823-014.
This sample was found to have the following
clarity/color/artifacts: COLORLESS/CLEAR/NO ARTIFACTS

****

Oak Ridge K-25 Site
Analytical Chemistry Department
Results of Analyses

Date Printed:
30-SEP-1991 09:C

AnaLIS ID: 910822-221   Project: G134 WAT   Customer Sample ID: MG
Customer: J. JONES   Requisition Number:
Date Sampled: 20-AUG-1991   Date Sample Received: 20-AUG-1991
Sampled By: WICKER   Date Sample Completed: 26-AUG-1991
Material Description: WATER   Date Sample Approved: 26-AUG-1991
Current Program Manager: C. R. Kirkpatrick   [] : Result has been Corrected for Spike

Procedure No.	Analysis	Result	Q Qual	Units	Analyst	QA File Number	Date Completed
***** Inductively Coupled Plasma Laboratory *****							
EPA-3010 EPA-6010	Arsenic	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Barium	0.11		mg/L	MJ SCHEUER	10823X	23-AUG-199'
EPA-3010 EPA-6010	Cadmium	<0.0030		mg/L	MJ SCHEUER	10823X	23-AUG-199
EPA-3010 EPA-6010	Chromium	0.60		mg/L	MJ SCHEUER	10823X	23-AUG-199
EPA-3010 EPA-6010	Copper	<0.004		mg/L	MJ SCHEUER	10823X	23-AUG-199
EPA-3010 EPA-6010	Lead	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-199
EPA-3010 -6010	Nickel	<0.010		mg/L	MJ SCHEUER	10823X	23-AUG-199
-3010 EPA-6010	Selenium	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-199
EPA-3010 EPA-6010	Silver	<0.0060		mg/L	MJ SCHEUER	10823X	23-AUG-199

***** Comments from the Plasma Emission Laboratory *****

****

Plasma Emission Laboratory Comments :

The pH of this sample was found to be 6 prior to sample preparation.
A pH greater than two indicates that the sample was not preserved during the sampling process.
Since the sample was not preserved the results should be considered as estimated values.
A pH greater than two violates the requirements of the EPA
Statement of Work SW-846.
The method blank associated with this sample was logged into the K25
Analytical Chemistry Department Computer system(ANALIS) using sample
number 910823-014.
This sample was found to have the following
clarity/color/artifacts: COLORLESS/CLEAR/NO ARTIFACTS

****

Date Printed:
30-SEP-1991 09:07

Oak Ridge K-25 Site
Analytical Chemistry Department
Results of Analyses

AnaLIS ID: 910822-218 Project: G134 WAT
Customer: J. JONES
Date Sampled: 20-AUG-1991
Sampled By: WICKER
Material Description: WATER
Current Program Manager: C. R. Kirkpatrick

Customer Sample ID: ALK
Requisition Number:
Date Sample Received: 20-AUG-1991
Date Sample Completed: 26-AUG-1991
Date Sample Approved: 26-AUG-1991
[] : Result has been Corrected for Spike

Procedure No.	Analysis	Result	Q Qual	Units	Analyst	QA File Number	Date Completed
***** Inductively Coupled Plasma Laboratory *****							
EPA-3010 EPA-6010	Arsenic	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Barium	0.0047		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Cadmium	<0.0030		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Chromium	<0.010		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Copper	0.0045		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Lead	<0.050		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Nickel	<0.010		mg/L	MJ SCHEUER	10823X	23-AUG-1991
EPA-3010 EPA-6010	Selenium	1.1		mg/L	MJ SCHEUER	10823X	23-. /91
EPA-3010 EPA-6010	Silver	<0.0060		mg/L	MJ SCHEUER	10823X	23-AUG-1991

***** Comments from the Plasma Emission Laboratory *****

****

Plasma Emission Laboratory Comments :

The pH of this sample was found to be 6 prior to sample preparation.
A pH greater than two indicates that the sample was not preserved during the sampling process.
Since the sample was not preserved the results should be considered as estimated values.
A pH greater than two violates the requirements of the EPA
Statement of Work SW-846.
The method blank associated with this sample was logged into the K25
Analytical Chemistry Department Computer system(ANALIS) using sample
number 910823-014.
This sample was found to have the following
clarity/color/artifacts: COLORLESS/CLEAR/NO ARTIFACTS

****

APPENDIX C

CERIODAPHNIA 48-H ACUTE TESTS

Results of the 48-h acute toxicity tests with *Ceriodaphnia* are summarized in Table C1. Mortality in each concentration of battery leachate tested is presented in Tables C2-C8. The 48-h *Ceriodaphnia* toxicity tests were preliminary and used to determine the appropriate concentrations for the 96-h bioassays. Leachates were prepared in February 1991. The mean 48-h LC50s ranged from <2.5 mg/L for Li-$SOCl_2$ to 6,743 mg/L for MG. The toxicity of the battery leachates from least toxic to most toxic was MG << ALK = LCE < Li-MnO_2 < Li-SO_2 << Li-$SOCl_2$. Mortality in the blank was 10% (Table C8) and in the dilution water was 0%.

Table C1. Summary of 48-h LC50 values for all battery types. All values are in mg/L.

	Test Results
	Ceriodaphnia[1]
Battery	48-h LC50 (mg/L)
MG	6,743
Li-SO_2	51
Li-MnO_2	179
ALK	422
LCE	289
Li-$SOCl_2$	<2.5

[1]*Ceriodaphnia* 48-h test was conducted with batteries prepared in February.

Table C1. *Ceriodaphnia* 48-h LC50 values for each battery aliquot. All values are in mg/L.

Battery	Aliquot	LC50	95% Confidence Limits	Method	Mean
MG	1	8,096	6,696-9,918	Probit	
	2	5,391	4,502-6,627	Moving Average	6,743
ALK	1	310	237-398	Moving Average	
	2	533	412-686	Moving Average	422
LCE	1	277	209-355	Moving Average	
	2	301	250-500	Binomial	289
Li-MnO_2	1	149	111-204	Probit	
	2	209	157-276	Moving Average	179
Li-SO_2	1	62	50-78	Probit	
	2	40	30-52	Probit	51
Li-$SOCl_2$	1	<2.5	------------	------------	
	2	<2.5	------------	------------	------

Table C2. Mortality results of *Ceriodaphnia* 48-h acute toxicity test with leachate from MG battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 48 h
1	12,000	20	17
	6,000	20	5
	3,000	20	0
	1,500	20	0
	500	20	0
2	12,500	20	20
	6,000	20	6
	3,000	20	5
	1,500	20	0
	500	20	0

Table C3. Mortality results of *Ceriodaphnia* 48-h acute toxicity test with leachate from ALK battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 48 h
1	1,500	20	20
	500	20	19
	250	20	4
	125	20	1
	60	20	0
	30	20	0
2	1,500	20	20
	500	20	20
	250	20	7
	125	20	4
	60	20	8
	30	20	0
	15	20	0

Table C4. Mortality results of *Ceriodaphnia* 48-h acute toxicity test with leachate from LCE battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 48 h
1	1,500	20	20
	500	20	20
	250	20	4
	125	20	1
	60	20	0
	30	20	0
2	1,500	20	20
	500	20	20
	250	20	5
	125	20	0
	60	20	0
	30	20	0

Table C5. Mortality results of *Ceriodaphnia* 48-h acute toxicity test with leachate from Li-MnO_2 battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 48 h
1	1,500	20	20
	500	20	17
	250	20	13
	125	20	10
	60	20	4
	30	20	0
	15	20	1
2	1,500	20	20
	500	20	20
	250	20	13
	125	20	2
	60	20	0
	30	20	2
	15	20	0

Table C6. Mortality results of *Ceriodaphnia* 48-h acute toxicity test with leachate from Li-SO_2 battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 48 h
1	500	20	20
	250	20	20
	125	20	18
	60	20	8
	30	20	3
	15	20	0
2	500	20	20
	250	20	20
	125	20	19
	60	20	12
	30	20	7
	15	20	3

Table C7. Mortality results of *Ceriodaphnia* 48-h acute toxicity test with leachate from Li-$SOCl_2$ battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 48 h
1	30.0	20	20
	22.5	20	20
	15.0	20	20
	5.0	20	20
	2.5	20	20
2	30.0	20	20
	22.5	20	20
	15.0	20	20
	5.0	20	20
	2.5	20	20

Table C8. Mortality results of *Ceriodaphnia* 48-h acute toxicity test with blank sample containing no battery contamination.

Concentration (%)	Number at start of test	Number dead in 48 h
100	20	2
50	20	0
25	20	0

Appendix D
Results of *Ceriodaphnia* 96-h Acute Tests

Table D1. Mortality results of *Ceriodaphnia* 96-h acute toxicity test with leachate from MG battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	50,000	20	20
	30,000	20	20
	15,000	20	4
2	50,000	20	20
	30,000	20	20
	15,000	20	6

Table D2. Mortality results of *Ceriodaphnia* 96-h acute toxicity test with leachate from Li-MnO_2 battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	250	20	20
	125	20	20
	60	20	5
	30	20	0
	15	20	0
2	250	20	20
	125	20	16
	60	20	11
	30	20	0
	15	20	0

Table D3. Mortality results of *Ceriodaphnia* 96-h acute toxicity test with leachate from Li-SO_2 battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	3,000	20	20
	1,500	20	20
	500	20	0
	250	20	0
2	3,000	20	20
	1,500	20	20
	500	20	9
	250	20	0

Table D4. Mortality results of *Ceriodaphnia* 96-h acute toxicity test with leachate from ALK battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	500	20	20
	250	20	20
	125	20	15
	60	20	13
	30	20	6
2	500	20	20
	250	20	20
	125	20	20
	60	20	12
	30	20	1

Table D5. Mortality results of *Ceriodaphnia* 96-h acute toxicity test with blank.

Aliquot	Concentration (%)	Number at start of test	Number dead in 96 h
1	100	20	18
	50	20	1
	25	20	0
2	100	20	20
	50	20	0
	25	20	3

Appendix E
Results of Fathead Minnow 96-h Acute Tests

Table E1. Mortality results of fathead minnow 96-h acute toxicity test with leachate from MG battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	25,000	20	12
	12,000	20	0
2	25,000	20	7
	12,500	20	2

Table E2. Mortality results of fathead minnow 96-h acute toxicity test with leachate from Li-SO_2 battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	1,000	20	20
	500	20	0
	250	20	1
	125	20	0
2	1,000	20	20
	500	20	0
	250	20	1
	125	20	0

Table E3. Mortality results of fathead minnow 96-h acute toxicity test with leachate from Li-MnO_2 battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	1,000	20	20
	500	20	20
	250	20	3
	125	20	0
	60	20	0
2	1,000	20	20
	500	20	20
	250	20	4
	125	20	2
	60	20	0

Table E4. Mortality results of fathead minnow 96-h acute toxicity test with leachate from ALK battery.

Aliquot	Concentration (mg/L)	Number at start of test	Number dead in 96 h
1	500	20	20
	250	20	9
	125	20	0
	60	20	0
	30	20	0
2	500	20	20
	250	20	12
	125	20	0
	60	20	0
	30	20	0

Table E5. Mortality results of fathead minnow 96-h acute toxicity test with blank.

Aliquot	Concentration (%)	Number at start of test	Number dead in 96 h
1	100	20	3
	50	20	0
2	100	20	4
	50	20	0