DISTRIBUTION SHEET

To Distribution	From 7FD60	Page 1 of 1 Date 9/23/94
Project Title/Work Order WRAP Module 1 Sampling Strategy and Waste Characterization Alternatives Study/W451A		EDT No. 607369 ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
D. E. Ball	G6-46	X			
M. L. Bedick	H6-30	X			
C. L. Bergeson	G6-46	3			
R. J. Bottenus	N3-13	X			
J. R. Cooper	H4-19	X			
B. A. Crawford	T6-09	X			
D. R. Duncan	H5-33	X			
R. A. Hyre	LATA	X			
M. D. LeClair	G6-47	X			
B. A. Mayancsik	L4-92	X			
C. A. Petersen	G6-47	X			
J. A. Pottmeyer	LATA	X			
C. M. Seidel	B2-23	X			
J. A. Swenson	G6-45	X			
K. B. Wehner	T6-50	X			
J. R. Weidert	G3-15	X			
J. J. Wong	B2-24	X			
Central Files	L8-04	X			
WRAP/DMC	G3-15	X			
<i>OSTI</i>	<i>L8-07</i>	<i>X</i>			

RECEIVED
NOV 21 1994
OSTI

SEP 30 1994

35 Station 21

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 607369

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) 7FD60	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: W-026	6. Cog. Engr.: C. L. Bergeson	7. Purchase Order No.: N/A
8. Originator Remarks: For release.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: 9/30/94

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-W026-ES-013		0	WRAP Module 1 Sampling Strategy and Waste Characterization Alternatives Study	NA	I		

16. KEY			
Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)										(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp.
1	1	Cog. Eng. CL Bergeson	<i>[Signature]</i>	9/23/94	G6-46	BA Mayancsik	<i>[Signature]</i>	9-23-94	L4-92	1	1
1	1	Cog. Mgr. DE Ball	<i>[Signature]</i>	9/23/94	G6-46						
		QA									
		Safety									
		Env.									
1	1	RJ Bottenus	<i>[Signature]</i>	9/26/94	N3-13						
1	1	MD LeClair	<i>[Signature]</i>	9/23/94	G6-47						

18. C. L. Bergeson Signature of EDT Originator 9/23/94 Date	19. BA Mayancsik Authorized Representative for Receiving Organization 9-23-94 Date	20. D. E. Ball Cognizant Manager 9/23/94 Date	21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments
---	--	--	---

INSTRUCTIONS FOR COMPLETION OF THE ENGINEERING DATA TRANSMITTAL

(USE BLACK INK OR TYPE)

BLOCK	TITLE	
(1)*	EDT	● Pre-assigned EDT number.
(2)	To: (Receiving Organization)	● Enter the individual's name, title of the organization, or entity (e.g., Distribution) that the EDT is being transmitted to.
(3)	From: (Originating Organization)	● Enter the title of the organization originating and transmitting the EDT.
(4)	Related EDT No.	● Enter EDT numbers which relate to the data being transmitted.
(5)*	Proj./Prog./Dept./Div.	● Enter the Project/Program/Department/Division title or Project/Program acronym or Project Number, Work Order Number or Organization Code.
(6)*	Cognizant Engineer	● Enter the name of the individual identified as being responsible for coordinating disposition of the EDT.
(7)	Purchase Order No.	● Enter related Purchase Order (P.O.) Number, if available.
(8)*	Originator Remarks	● Enter special or additional comments concerning transmittal, or "Key" retrieval words may be entered.
(9)	Equipment/Component No.	● Enter equipment/component number of affected item, if appropriate.
(10)	System/Bldg./Facility	● Enter appropriate system, building or facility number, if appropriate.
(11)	Receiver Remarks	● Enter special or additional comments concerning transmittal.
(12)	Major Asm. Dwg. No.	● Enter applicable drawing number of major assembly, if appropriate.
(13)	Permit/Permit Application No.	● Enter applicable permit or permit application number, if appropriate.
(14)	Required Response Date	● Enter the date a response is required from individuals identified in Block 17 (Signature/Distribution).
(15)*	Data Transmitted	
	(A)* Item Number	● Enter sequential number, beginning with 1, of the information listed on EDT.
	(B)* Document/Drawing No.	● Enter the unique identification number assigned to the document or drawing being transmitted.
	(C)* Sheet No.	● Enter the sheet number of the information being transmitted. If no sheet number, leave blank.
	(D)* Rev. No.	● Enter the revision number of the information being transmitted. If no revision number, leave blank.
	(E) Title or Description of Data Transmitted	● Enter the title of the document or drawing or a brief description of the subject if no title is identified.
	(F)* Impact Level	● Enter the appropriate Impact Level (Block 15). Also, indicate the appropriate approvals for each item listed, i.e., SQ, ESQ, etc. Use NA for non-engineering documents.
	(G) Reason for Transmittal	● Enter the appropriate code to identify the purpose of the data transmittal (see Block 16).
	(H) Originator Disposition	● Enter the appropriate disposition code (see Block 16).
	(I) Receiver Disposition	● Enter the appropriate disposition code (see Block 16).
(16)	Key	● Number codes used in completion of Blocks 15 (G), (H), and (I), and 17 (G), (H) (Signature/Distribution).
(17)	Signature/Distribution	
	(G) Reason	● Enter the code of the reason for transmittal (Block 16).
	(H) Disposition	● Enter the code for the disposition (Block 16).
	(J) Name	● Enter the signature of the individual completing the Disposition 17 (H) and the Transmittal.
	(K)* Signature	● Obtain appropriate signature(s).
	(L)* Date	● Enter date signature is obtained.
	(M)* MSIN	● Enter MSIN. Note: If Distribution Sheet is used, show entire distribution (including that indicated on Page 1 of the EDT) on the Distribution Sheet.
(18)	Signature of EDT Originator	● Enter the signature and date of the individual originating the EDT (entered prior to transmittal to Receiving Organization). If the EDT originator is the cognizant engineer, sign both Blocks 17 and 18.
(19)	Authorized Representative for Receiving Organization	● Enter the signature and date of the individual identified by the Receiving Organization as authorized to approve disposition of the EDT and acceptance of the data transmitted, as applicable.
(20)*	Cognizant Manager	● Enter the signature and date of the cognizant manager. (This signature is authorization for release.)
(21)*	DOE Approval	● Enter DOE approval (if required) by letter number and indicate DOE action.

*Asterisk denote the required minimum items check by Configuration Documentation prior to release; these are the minimum release requirements.

RELEASE AUTHORIZATION

Document Number: WHC-SD-W026-ES-013, Revision 0

Document Title: WRAP Module 1 Sampling Strategy and Waste Characterization Alternatives Study

Release Date: 9/29/94

* * * * *

This document was reviewed following the
procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

* * * * *

WHC Information Release Administration Specialist:

Christine Willingham

C. Willingham
(Signature)

9/29/94
(Date)

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

SUPPORTING DOCUMENT		1. Total Pages ¹⁹⁹ 202
2. Title WRAP Module 1 Sampling Strategy and Waste Characterization Alternatives Study		3. Number WHC-SD-W026-ES-013
		4. Rev No. 0
5. Key Words WRAP 1, sampling, sampling strategy, characterization, field screening technologies, sample analysis methods		6. Author Name: C. L. Bergeson <i>C. L. Bergeson</i> Signature Organization/Charge Code 7FD60/A451A
7. Abstract <p>The Waste Receiving and Processing Module 1 Facility is designed to examine, process, certify, and ship drums and boxes of solid wastes that have a surface dose equivalent of less than 200 mrem/h. These wastes will include low-level and transuranic wastes that are retrievably stored in the 200 Area burial grounds and facilities in addition to newly generated wastes.</p> <p>Certification of retrievably stored wastes processing in WRAP 1 is required to meet the waste acceptance criteria for onsite treatment and disposal of low-level waste and mixed low-level waste and the Waste Isolation Pilot Plant Waste Acceptance Criteria for the disposal of TRU waste. In addition, these wastes will need to be certified for packaging in TRUPACT-II shipping containers.</p> <p>Characterization of the retrievably stored waste is needed to support the certification process. Characterization data will be obtained from historical records, process knowledge, nondestructive examination, nondestructive assay, visual inspection of the waste, head-gas sampling, and analysis of samples taken from the waste containers.</p> <p>Sample characterization refers to the method or methods that are used to test waste samples for specific analytes. The focus of this study is the sample characterization needed to accurately identify the hazardous and radioactive constituents present in the retrieved wastes that will be processed in WRAP 1. In addition, some sampling and characterization will be required to support NDA calculations and to provide an over-check for the characterization of newly generated wastes.</p> <p>This study results in the baseline definition of WRAP 1 sampling and analysis requirements and identifies alternative methods to meet these requirements in an efficient and economical manner.</p>		
8. PURPOSE AND USE OF DOCUMENT - This document was prepared for use within the U.S. Department of Energy and its contractors. It is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. This document is not approved for public release or review. APPROVED FOR PUBLIC RELEASE cw 9-29-94 PATENT STATUS - This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Patent Counsel, U.S. Department of Energy Field Office, Richland, WA. DISCLAIMER - This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.		10. RELEASE STAMP <div style="border: 1px solid black; padding: 10px; text-align: center;"> OFFICIAL RELEASE BY WHC DATE SEP 30 1994 35 Station 21 </div>
9. Impact Level NA		

**WRAP Module 1 Sampling Strategy
and Waste Characterization
Alternatives Study**

September 1994

Primary Author:

C. L. Bergeson - Westinghouse Hanford Company

Supporting Authors:

R. A. Hyre - Los Alamos Technical Associates
M. D. LeClair - Westinghouse Hanford Company
J. A. Pottmeyer - Los Alamos Technical Associates

Westinghouse Hanford Company
Richland, Washington

MASTER

EXECUTIVE SUMMARY

Waste certification in the Waste Receiving and Processing Facility Module 1 (WRAP 1) is needed to meet the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria, TRUPACT II packaging criteria, Hanford Site solid waste acceptance criteria for low-level waste, and acceptance criteria for planned mixed low level waste treatment and disposal facilities. The waste certification process for WRAP 1 employs nondestructive examination (NDE), nondestructive assay (NDA), visual inspection of the waste, and waste sample analysis. Data to support waste certification acquired prior to processing in WRAP 1, including NDE, NDA, analysis of historical records, process knowledge, and head-gas sampling, is also used. This information includes the dangerous, hazardous, and radioisotopic constituents potentially present and their quantities. As a permitted treatment, storage, and disposal facility, WRAP 1 will receive, characterize, treat, and repackage 55-gal waste drums. Additionally, WRAP 1 will assume the role of generator for the incompletely characterized wastes generated and buried prior to 1987.

Currently, the WRAP 1 facility is in construction, with completion planned for February 1996. The baseline waste sample analysis provisions are:

- No analytical capability in the main process (MP) gloveboxes;
- Field screening in restricted waste management (RWM) gloveboxes, limited to pH analysis and the capability to add more field screening; and
- All other analysis done in a laboratory external to WRAP 1.

The WRAP 1 baseline average annual sampling number and outyear sampling cost were approximated at 2,065 and \$1.1M/year, respectively, for the retrieved, suspect transuranic (TRU) 55-gal waste drums only.

The focus of this study was to define the WRAP 1 characterization strategy that included:

- Identification of data required to support characterization;
- Identification of characterization methods within and prior to WRAP 1;
- Identification of data obtained from different characterization methods;
- Definition of the sampling analysis methods required to support operations; and
- Evaluation of alternate means of acquiring the needed characterization data using field screening techniques, that include existing and emerging analysis methods, as well as laboratory analysis.

The chemical and physical information for this study has been obtained by reviewing characterization reports for the seven largest generators (55-gal drums): Plutonium Finishing Plant (21,196); 325 Building (4,131), Plutonium-Uranium Extraction Plant (4,012); Babcock & Wilcox (1,451); 231-Z Building (1,360); Westinghouse Advanced Reactor & Nuclear Fuels Divisions (910); and General Electric's Vallencitos Nuclear Center (150).

The seven major generators account for approximately 86% of the retrieved, suspect TRU 55-gal waste drums. A table was generated to provide a summary of the 172 different analytes, 14 different radionuclides, and physical contents, that are potentially present in the wastes generated by these seven facilities.

The method to determine the presence or absence of an analyte was identified for each analyte using NDE, NDA, head gas sampling, and/or visual inspection. These characterization methods identified 6 different analytes distinguishable using this information. The remaining 166 different analytes, not identified using these methods, would require sample analysis. The regulatory status of these analytes, potentially present in the waste, was determined based upon applicable regulations (e.g., Resource Conservation and Recovery Act, Department of Transportation, and WIPP). Non-regulated analytes accounted for 22%, leaving 136 regulated analytes. Further evaluation of the regulatory detection limits noted only 16 of the 136 regulated analytes were regulated below 1wt% (~1.5 lbs/drum), establishing a quantity based analyte list of concern. Reduction of the original 176 analyte list down to 16 analytes, for quantities below 1wt%, reduces the analytical effort/cost required for a large portion of the waste.

Sampling strategy alternatives were developed utilizing combinations of field screening technologies and full laboratory analysis, both within and external to WRAP 1, that could characterize the retrieved, suspect TRU 55-gal waste drums. Field screening technologies ranged from fiber-optic chemical sensors, to pH meters, to x-ray fluorescence spectrometry. The evaluation criteria included project impact, compatibility with facility operations, equipment maturity, and secondary waste generation. The preferred waste characterization/sampling strategy alternative, that accommodates characterization of the retrieved, suspect TRU 55-gal waste drums, and best satisfies the criteria is as follows:

WRAP 1 facility performs:

- Field screening in the RWM glovebox to assure chemical compatibility;
- Customized spot tests specific to a batch(es) in RWM; and
- Customized spot tests for MP gloveboxes performed in RWM.

External laboratory performs:

- Field screening and full analysis, as needed.

Also, the need to add a weigh scale inside the MP gloveboxes was identified to correlate the sample and waste drum. Implementation of the preferred sampling strategy is expected to reduce the average outyear sampling cost for the retrieved, suspect TRU 55-gal waste drums.

In conclusion, it is the recommendation of this study team that, follow-on activities to develop (e.g., batching study, characterization documents, etc.), demonstrate, and qualify (e.g., Data Quality Objective Process), the customized spot tests be pursued.

TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	PURPOSE AND NEED	1
1.2	BACKGROUND	2
	1.2.1 Historical Background	2
	1.2.2 WRAP 1 Process	4
	1.2.3 Waste Characterization and Certification Requirements	6
1.3	SCOPE	9
2.0	CONCLUSIONS AND RECOMMENDATIONS	11
2.1	CONCLUSIONS	11
2.2	RECOMMENDATIONS	12
3.0	UNCERTAINTIES AND ASSUMPTIONS	15
4.0	WASTE CHARACTERIZATION METHODS	19
4.1	HISTORICAL RECORDS AND PROCESS KNOWLEDGE	19
4.2	NONDESTRUCTIVE EXAMINATION	19
4.3	NONDESTRUCTIVE ASSAY	20
4.4	FIELD SCREENING AND HEAD-GAS SAMPLING	20
4.5	SAMPLING AND ANALYSIS REQUIREMENTS	21
5.0	WRAP 1 CHARACTERIZATION BASELINE	35
5.1	AVERAGE OUTYEAR SAMPLING REQUIREMENTS	35
5.2	CHARACTERIZATION FLOW DIAGRAM	36
5.3	BASELINE SAMPLING COSTS	36
6.0	FIELD SCREENING METHODS CONSIDERED	57
6.1	STRIPPING VOLTAMMETRY	59
6.2	FIBER-OPTIC CHEMICAL SENSORS	59
6.3	NEUTRON ACTIVATION ANALYSIS	60
6.4	X-RAY FLUORESCENCE SPECTROMETRY	61
6.5	FIELD PORTABLE AND HAND-HELD GAS CHROMATOGRAPHS	61
6.6	pH PROBE	62
6.7	PHOTOIONIZATION AND FLAME IONIZATION DETECTORS FOR GAS DETECTION	62
6.8	COLORIMETRIC AND TITRIMETRIC METHODS	63
6.9	IMMUNOASSAY FIELD TEST KITS	64
6.10	FIELD PORTABLE FOURIER TRANSFORM RAMAN SPECTROMETER	65
6.11	FIELD GAS CHROMATOGRAPH/MASS SPECTROMETER	65
6.12	LASER ABLATION-INDUCTIVELY COUPLED PLASMA-ATOMIC EMISSION SPECTROMETRY (LA-ICP-AES) AND OTHER LASER ABLATION METHODS	66
6.13	BIOSENSORS	67
6.14	ION MOBILITY SPECTROMETER AND GC/IMS	68
6.15	FOURIER TRANSFORM INFRARED SPECTROMETERS	68
6.16	OTHER FIELD PORTABLE OPTICAL/SPECTROSCOPIC METHODS	69
6.17	ION-SELECTIVE ELECTRODES	70
6.18	CHEMICAL IDENTIFICATION FIELD TEST KITS	71
6.19	POLARIZED LIGHT MICROSCOPY	71
7.0	DESCRIPTION OF ALTERNATIVES TO THE WRAP 1 CHARACTERIZATION BASELINE	73
7.1	ALTERNATIVES CONSIDERED	73

8.0	COMPARISON AND ASSESSMENT OF ALTERNATIVES	77
8.1	CRITERIA FOR THE EVALUATION OF ALTERNATIVES	77
8.2	EVALUATION OF ALTERNATIVES	78
9.0	DISCUSSION OF THE PREFERRED ALTERNATIVE	81
10.0	REFERENCES	83
APPENDIX A:	FACT SHEETS FOR MAJOR GENERATORS OF SOLID TRANSURANIC WASTES RETRIEVABLY STORED AT THE HANFORD SITE.	A-1
APPENDIX B:	CHARACTERIZATION REQUIREMENTS IMPOSED BY ALL APPLICABLE REGULATIONS	B-1
APPENDIX C:	FIELD SCREENING DATA SHEETS	C-1

LIST OF FIGURES

Figure 1.	WRAP Module 1 Top Level Flowsheet	5
Figure 2.	WRAP Module 1 Pictorial Flow Diagram.	7
Figure 3.	Characterization Flow Diagram.	38

LIST OF TABLES

Table 1.	Regulated Chemicals and Radionuclides Suspected to be Present in Retrievably Stored Waste	23
Table 2.	Volatile Organic Compounds	28
Table 3.	Characterization Methods to be Used for Analytes Suspected in Retrievably Stored Waste	29
Table 4.	Average Outyear Sampling Requirements	39
Table 5.	Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste	40
Table 6.	Average Outyear Sampling Cost For Retrievably Stored, Suspect TRU, 55-gal Drums in WRAP 1 Main Processing Gloveboxes and Restricted Waste Management.	54
Table 7.	Laboratory Analyses Cost Estimate	55
Table 8.	Field Screening Technology Capabilities.	58
Table 9.	Evaluation Matrix.	79

LIST OF ACRONYMS

AEC	Atomic Energy Commission
AES	Atomic emission spectrometry
CFR	Code of Federal Regulations
CVS	Container Venting System
D	diameter
DOE	Department of Energy
DOT	U.S. Department of Transportation
DQO	Data Quality Objective
DR	digital radiography
EPA	Environmental Protection Agency
ERT	Environmental Response Team
FID	Flame ionization detector
FOCS	Fiber-optic chemical sensors
FP	Function Parameters
FTIR	Fourier Transform Infrared
GC	Gas chromatography
H	height
Hg	mercury
IAD	Immediate Action Directive
ICP	inductively-coupled plasma
INEL	Idaho National Engineering Laboratory
ISE	ion-selective electrodes
L	length
LA	laser ablation
LEL	lower explosive limit
LIBS	laser-induced breakdown spectroscopy
LLW	low-level waste
MLLW	mixed low-level waste
MPG	Main Processing Glovebox
MS	Mass Spectrometers
NDA	nondestructive assay
NDE	nondestructive examination
OD	outer diameter
PAHs	Polycyclic aromatic hydrocarbons
Pb	lead
PCBs	Polychlorinated biphenyls
PFP	Plutonium Finishing Plant
PGNAA	Prompt Gamma Neutron Activity Analysis
PID	Photoionization detector
PINS	Portable Isotopic Neutron Spectroscopy
PNA	Prompt Neutron Activity Analysis
PNL	Pacific Northwest Laboratories
PPM	parts per million
PUREX	Plutonium-Uranium Extraction
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RTR	real time radiography
RWM	Restricted Waste Management
SAR	Safety Analysis Report
SDRD	Supplemental Design Requirements Document
STC	Science and Technology Center
SWITS	Solid Waste Information and Tracking System
SWOC	Solid Waste Operations Complex

LIST OF ACRONYMS (cont.)

TRU	Transuranic Waste
TRUPACT II	Transuranic Package Transporter Two
TSD	Treatment, Storage, and Disposal
VNC	Vallecitos Nuclear Center (General Electric)
VOC	Volatile Organic Compounds
W	width
WAC	Waste Acceptance Criteria
WARD	Westinghouse Advanced Reactor Division
WEC	Westinghouse Electric Corporation
WHC	Westinghouse Hanford Company
WIPP	Waste Isolation Pilot Plant
WIPP-WAC	Waste Isolation Pilot Plant Waste Acceptance Criteria
WNFD	Westinghouse Nuclear Fuels Division
WRAP	Waste Receiving and Processing
XRF	X-Ray Fluorescence Spectrometry

UNITS OF MEASURE

Amp	ampere
cm	centimeter
°C	degrees celsius
°F	degrees fahrenheit
ft	feet
g	gram
gal	gallon
Hz	hertz
K	thousand
kg	kilogram
L	liter
lb	pound
M	million
μm	micrometer
mg	milligram
mil	millimeter
ml	milliliter
mrem/h	millirem per hour
mV	millivolt
nm	nanometer
nCi/g	nanocurie/gram
ppm	parts per million
ppb	parts per billion
V	volt
W	watt

WRAP Module 1 Sampling Strategy and Waste Characterization Alternatives Study

1.0 INTRODUCTION

The Waste Receiving and Processing Module 1 (WRAP 1) Facility is designed to examine, process, certify, and ship drums and boxes of solid wastes that have a surface dose equivalent of less than 200 mrem/h (Mayancsik 1993). These wastes will include low level and transuranic (TRU) wastes that are retrievably stored in the 200 Area burial grounds and facilities in addition to newly generated wastes (waste generated post 1987).

Certification of retrievably stored wastes processing in WRAP 1 is required to meet the waste acceptance criteria for onsite treatment and disposal of low level waste (LLW) and mixed low level waste (MLLW) and the Waste Isolation Pilot Plant Waste Acceptance Criteria (WIPP-WAC) for the disposal of TRU waste. In addition, these wastes will need to be certified for packaging in TRUPACT-II shipping containers.

Characterization of the retrievably stored waste is needed to support the certification process. Characterization data will be obtained from historical records, process knowledge, nondestructive examination (NDE), nondestructive assay (NDA), visual inspection of the waste, head-gas sampling, and analysis of samples taken from the waste containers.

Sample characterization refers to the method or methods that are used to test waste samples for specific analytes. The focus of this study is the sample characterization needed to accurately identify the hazardous and radioactive constituents present in the retrieved wastes that will be processed in WRAP 1. In addition, some sampling and characterization will be required to support NDA calculations and to provide an over-check for the characterization of newly generated wastes (Sexton 1992).

This study results in the baseline definition of WRAP 1 sampling and analysis requirements and identifies alternative methods to meet these requirements in an efficient and economical manner.

1.1 PURPOSE AND NEED

The purpose of sampling is to identify hazardous and radionuclide materials in the waste that are not identifiable through other characterization methods. Some hazardous materials, such as lead, will be identified through NDE. Others, such as carbon tetrachloride, may be identified through head-gas sampling completed during retrieval operations. However, there are some chemical constituents that are only identifiable through sampling and chemical analysis of the waste (Sexton 1993).

The primary objectives of the Sampling Strategy and Waste Characterization Alternatives Study include the following:

- Identify the data required to support characterization.
- Identify characterization methods that will be used prior to processing in WRAP 1.
- Identify the data to be obtained from the different characterization methods.
- Define the sampling and analytical methods required to support operations.
- Evaluate characterization and sampling strategies, including existing and emerging analysis methods as well as laboratory analysis.

1.2 BACKGROUND

1.2.1 Historical Background

Since 1944, the production of defense related materials at the Hanford Site has generated radioactive wastes. The bulk of these wastes have been disposed of or stored in the 200 East and 200 West Area burial grounds and waste storage facilities.

In 1970, the Atomic Energy Commission (AEC, now the U.S. Department of Energy [DOE]) directed that AEC sites segregate "waste with known or detectable contamination of transuranium nuclides" from other waste types (*Immediate Action Directive 0511-21* [AEC 1970]). Transuranium nuclides are those with an atomic number greater than that of uranium (92). The AEC further directed that these wastes be packaged and stored as contamination-free packages for at least 20 years. The 20-year interim storage was to allow time to study permanent disposal options for TRU contaminated wastes.

The *Immediate Action Directive* did not provide a detailed definition for TRU waste in 1970, and AEC contractors implemented the directive to the best of their ability with the instrumentation then available. In 1973, the AEC further defined TRU waste as material contaminated with certain alpha-emitting radionuclides with half-lives greater than 20 years and activity greater than 10 nCi/g. The radionuclides included were ²³³U and its daughter products, as well as plutonium and transplutonium nuclides with the exception of ²³⁸Pu and ²⁴¹Pu (AEC 1973). In 1982, the TRU waste segregation limits were raised to 100 nCi/g and included ²³⁸Pu and ²⁴¹Pu as stated in DOE Order 5820.1, *Management of Transuranic Material* (DOE 1982).

The current DOE definition of TRU waste follows:

"Without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g at the time of assay. Heads of Field Elements can determine that other alpha contaminated wastes, peculiar to a specific site, must be managed as transuranic waste."

In RLID 5820.2A, the Richland Operations Office (RL) head further specifies that *"In addition to TRU radionuclides, radium sources and ²³³U in concentrations greater than 100 nCi/g at the time of assay are considered TRU waste."*

In addition to radioactive materials, Hanford production plants and support operations used a wide variety of chemicals. Many of these chemicals are now classified as hazardous by the U.S. Environmental Protection Agency (EPA) or dangerous by the Washington State Department of Ecology (Ecology). When dangerous and/or hazardous constituents are found in radioactive wastes they are termed "mixed" wastes.

During the time when much of the mixed waste currently stored at the Hanford Site was generated, there were no definitions or regulations governing the storage, disposal, or documentation of mixed wastes. In 1987, the DOE issued a mixed by-product ruling stating that the hazardous and dangerous components of mixed waste are regulated by the *Resource Conservation and Recovery Act of 1976 (RCRA)* (DOE 1987). In November 1987, the EPA authorized Ecology to regulate the hazardous and dangerous constituents of mixed wastes at Hanford.

During the next two decades, the TRU waste that was stored in the 200 Area burial trenches and storage facilities beginning in 1970 is to be retrieved for characterization and processing at the WRAP facilities. The wastes that are currently defined as TRU will be repackaged in WRAP 1 and shipped to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico for final disposal. Other wastes, stored as suspect TRU prior to the 1982 concentration limit change from 10 nCi/g to 100 nCi/g, may be redesignated as LLW or MLLW. The LLW wastes will be sent to land disposal, and the MLLW will be processed either in WRAP 2A or the Thermal Treatment Facility.

In addition to the processing of suspect TRU wastes currently in retrievable storage, the WRAP 1 facility will also process newly generated wastes. (In this document, "newly generated waste" refers to waste generated after 1987, which is required to be fully characterized by the generator. It does not reflect the RCRA definition.) As these wastes will be fully characterized at the generating facility, WRAP 1 will verify the waste constituents and certify the wastes for shipment to WIPP. Verification will occur by overchecking approximately 10% of the newly generated waste using NDE and NDA. Ten percent of the verification samples are projected to require sample analysis.

1.2.2 WRAP 1 Process

WRAP 1 will process suspect TRU waste that can be handled without radiation shielding (contact handled wastes with radioactive dose rates less than 200 mrem/hr at any point on the waste container). It will be able to process a total of 6,825 drums per year, with an anticipated split of 2,625 drums of retrieved wastes and 4,200 drums of newly generated waste (and a 50% split on LLW and TRU), and 70 boxes per year. The process flow for retrieved wastes and newly generated waste within WRAP Module 1 is shown in Figure 1.

Nominally, 40 waste drums and 2 waste boxes are received on a daily and weekly basis, respectively. Newly generated drums (208-L) and retrieved drums in 322-L overpacks are received 4 to a pallet. Before entering the NDA/NDE area, waste drums are removed from the pallets, each waste drum is weighted, and its bar code is read. A weight label is attached to each waste drum.

Applicable information pertaining to the received waste containers is entered into the WRAP 1 data management system. Weight information is used to calculate specific TRU activity and also is used to identify containers that exceed weight limits established in the waste acceptance criteria.

All waste drums and boxes received at WRAP Module 1 are subjected to NDA/NDE as part of verifying compliance with waste certification requirements and to determinate appropriate method for processing noncompliant waste present in the received waste drums. Waste processed in WRAP Module 1 will meet the following four requirements of the WIPP-WAC:

- (1) no free liquids are allowed;
- (2) pyrophorics must be stabilized;
- (3) explosives or compressed gases are not allowed; and
- (4) corrosives must be neutralized.

If an incoming waste container has completed NDA/NDE assessment and has been found to contain certified waste, it can be returned to the shipping and receiving areas, and prepared for shipment. All incoming waste drums found from the NDA/NDE operation to contain noncompliant (restricted) waste are sent to the waste processing area. In addition, those waste drums which contain certified waste that are to be characterized and supercompacted are sent to waste processing.

In waste processing, incoming waste drums which do not meet the appropriate disposal criteria are opened and sorted in two process glovebox lines to remove the noncompliant (restricted) waste and are then supercompacted and repackaged. Waste drums that meet the appropriate disposal criteria can be directly supercompacted to reduce the waste volume. Two glovebox lines (with associated heating, ventilating, and air conditioning systems) are provided to perform waste processing operations, one dedicated to TRU waste and the other to LLW. The two glovebox lines and their associated equipment are segregated to prevent cross-contamination of LLW with TRU waste material.

Figure 1. WRAP Module 1 Top Level Flowsheet.

	RECEIVING	SHIPPING
LLW	3413	2550
TRU	3412	3037
TOTALS	6825	5587

Items that are not certifiable in WRAP 1, such as LLMW, LLW Class III, and other regulated waste in drums (e.g., lead bricks, polychlorinated biphenyls [PCBs]), that cannot be processed to a certifiable form are either left in the drum or are removed from the drum in the appropriate waste process line and repackaged in the restricted waste management (RWM) glovebox. In either case, the drums containing the noncertifiable material are then palletized and sent to continued storage pending treatment at another facility.

Noncompliant (restricted) waste items that are segregated, containerized, and transferred from the two waste process gloveboxes are received at the two RWM gloveboxes. One RWM glovebox is dedicated to LLW and the other to TRU waste material to avoid the possibility of cross contamination. Samples of restricted waste items are obtained for analysis in each RWM glovebox. The RWM gloveboxes also provide limited restricted waste treatment capabilities.

After processing, all outgoing waste drums are subjected to NDA (and some to NDE) necessary for certification before shipment. The WRAP 1 overall process is pictorially depicted in Figure 2.

1.2.3 Waste Characterization and Certification Requirements

The WRAP 1 facility is being designated to receive, characterize, treat and repackage suspect TRU waste retrieved from the burial grounds. Limited information is available on the chemical contents of this retrieved waste because the waste was generated prior to full institution of WAC 173-303 standards at Hanford. This study addresses the waste sample characterization needed to support certification and designation of retrievably stored solid wastes in the WRAP 1 facility. A brief discussion of the characterization and certification requirements imposed by State and Federal regulations and the DOE Orders as well as onsite and offsite waste acceptance criteria for various TSD facilities follows.

1.2.3.1 Characterization Requirements. As a permitted TSD facility, WRAP 1 will receive, characterize, treat, and repackage suspect TRU waste retrieved from the burial grounds. All Hanford TSD facilities are subject to the characterization requirements of WAC 173-303-300 and waste manifesting requirements as outlined in RCRA (40 CFR 264.70).

Additionally, WRAP 1 will also assume the role of generator for the incompletely characterized wastes generated and buried prior to 1987. As a generator, WRAP 1 will be required to manifest the shipment of hazardous wastes using a Uniform Hazardous Waste Manifest (40 CFR 263.20). One key element of the Uniform Hazardous Waste Manifest includes the assignment of applicable hazardous wastes codes. To validate these waste codes, generators are required to characterize the waste and certify that the hazardous characteristics of the manifested waste are correctly identified.

WRAP Module 1 Pictorial Flow Diagram

Figure 2.

1.2.3.2 Certification Requirements. Depending on their radioactive and hazardous content, waste processed in WRAP 1 may be disposed at WIPP (TRU) or onsite (for LLW and MLLW). All final waste forms will require certification according to the requirements of the DOE Orders as well as the Federal and State regulations. *Certified waste*, as defined in DOE Order 5820.2A, is "waste that has been confirmed to comply with disposal site waste acceptance criteria (e.g., the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria for transuranic waste) under an approved certification program." DOE Order 5820.2A, *Radioactive Waste Management*, and Richland Operations Office Implementing Document RLID 5820.2A provide the guidelines, policies, and minimum requirements by which the DOE manages radioactive wastes and contaminated facilities. These orders define the performance objectives for DOE disposal sites and dictate the certification requirements associated with wastes destined for disposal.

As defined in DOE Order 5820.2A, generators of waste are required to implement a waste certification program to provide assurance that the waste acceptance criteria for any TSD facility used by the generator are met. For waste processed in WRAP 1, these TSD facilities might include WIPP, WRAP 2A, Thermal Treatment Facility, Low Level Burial Grounds, etc. The certification program is to describe methods used to determine radioactive material content of the waste (e.g., assay, material balance, etc.) and to ensure compliance with the applicable disposal criteria.

Some of the wastes to be processed in WRAP 1 fall into the land disposal restricted (LDR) category. The requirement to certify LDR waste was promulgated in 40 Code of Federal Regulations (CFR) 268, and an LDR certification statement is required to accompany all LDR waste to land disposal.

1.2.3.3 Waste Acceptance Criteria. Waste acceptance criteria for DOE facilities are based on the disposal site performance objectives defined in DOE Order 5820.2A. The acceptance criteria for the Hanford Site TSD facilities are delineated in EP-0063-4 (Willis 1994). Since WRAP 1 is a TSD facility, newly generated wastes entering WRAP 1 must also meet the criteria specified in EP-0063-4. Specifically, mixed wastes must be characterized and repackaged at WRAP 1 for storage and treatment at other facilities prior to disposal on-site.

Repackaged TRU wastes exiting WRAP 1 are to be sent to WIPP, located in Carlsbad, New Mexico, for final disposal. The current draft of the WIPP waste acceptance criteria impose several restrictions on the TRU waste that it will receive. Characterization of the wastes is needed to assure that noncompliant TRU waste from WRAP 1 is not received at WIPP. Specific restrictions include, but are not limited to, the following:

- radionuclide pyrophorics;
- explosives;
- RCRA characteristic ignitable (D001), corrosive (D002), and reactive (D003) waste;
- sludges that are not analyzed for total volatile organic compounds (VOCs) and toxic metals; and

- non-immobilized wastes with >1% by weight of particulate material <10 μ m in diameter or >15% by weight of particulate material <200 μ m in diameter.

1.2.3.4 Restricted Waste Management Process Parameters. The RWM gloveboxes will perform limited processing of wastes that do not meet the criteria for disposal at WIPP (for TRU waste) or onsite (for LLW). The processing needed to meet waste acceptance criteria may require some additional characterization of the waste to assess treatability. The additional characterization is not envisioned as altering the number of samples that will be analyzed, only the number and types of analytical determinations that will be performed on a given sample.

Process parameters for RWM are not currently identified. The processes to be used are expected to be similar to those being developed for use in WRAP 2A. Primary parameters identified for WRAP 2A processing include the following:

- Hazard Class (ignitable, reactive, etc.)
- pH
- Total alkalinity/acidity
- Metals
 - DOOx metals (total and leachable): As, Ba, Cd, Cr, Pb, Hg, Se, Ag
 - FO39 metals (total and leachable): Sb, Be, Cu, Ni, Tl, V, Zn
 - Others (total): Ca, Fe, Mg, K, Na, Sn
- Soluble Salts
 - NH_4^+ , NO_3^- , PO_4^{3-} , SO_4^{2-} , Cl^- , F^- , S^{2-} , CN^-
- Radiological Characteristics
 - Gross Alpha
 - Gross Beta/Gamma
 - Contact dose rate
- Organics
 - Total Organic Carbon (TOC)
 - Volatile Organic Compounds (VOC)

1.3 SCOPE

This study identifies the sampling needs and alternative sampling and analytical methods/strategies to support characterization of the retrieved solid waste that will be processed in WRAP 1. This document provides the background, logic, methods and results of this study in the following sections.

- Section 1.0 introduces the purpose and need for performing this study as well as the background necessary for placing this study in perspective.
- Section 2.0 provides the recommendations and conclusions reached by the study team.

- Section 3.0 documents the uncertainties and assumptions that were developed for use in this study.
- Section 4.0 discusses the methods to be used to characterize the wastes entering WRAP 1 and the data that will be supplied through each of the methods. Characterization methods discussed include historical records, process knowledge, NDE, NDA, field screening and head-gas sampling, and laboratory analysis.
- Section 5.0 describes the characterization design basis for WRAP 1. Average outyear sampling requirements as well as the laboratory characterization strategy and costs are in Section 7.0
- Section 6.0 provides a summary of both existing and emerging technologies that may be applied to meet the analytical needs for waste sample characterization data that is not supplied by another characterization method (i.e., NDA, NDE, process knowledge). Information about the maturity, use, limitations, advantages, and operational costs of each technology is given.
- Section 7.0 describes the functional alternatives that were reviewed to meet characterization needs. These alternatives may consist of one or may of the technologies described in the previous section.
- Section 8.0 develops the criteria to compare and assess the functional alternatives developed in Section 7.0. Each alternative is then evaluated against the criteria. Issues and uncertainties associated with each alternative are identified and documented.
- Section 9.0 provides a more detailed discussion of the preferred alternative (or alternatives) chosen.
- Section 10.0 lists the references used in this study.

2.0 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations discussed below are based on the uncertainties and assumptions developed during the study, the regulatory drivers for waste characterization, the selected characterization methods, available field screening technologies, the criteria identified to evaluate alternatives, and the assessment and comparison of alternatives.

2.1 CONCLUSIONS

The design for WRAP 1 is based on sending all samples of incompletely characterized waste to an external laboratory facility for full characterization. The only field screening technology included in the baseline design is pH analysis. This study identified alternate means of acquiring needed characterization data using other field screening techniques.

Field screening technologies identified in this document include remote (in situ) analysis as well as field portable instrumentation. The following field screening technologies were evaluated: stripping voltammetry; fiber-optic chemical sensors; neutron activation analysis; X-ray fluorescence spectrometry; field portable and hand-held gas chromatographs; pH probe; photoionization and flame ionization detectors for gas detection; colorimetric and titrimetric methods; immunoassay field test kits; remote fourier transform raman spectrometers; field portable gas chromatograph/mass spectrometers; laser ablation-inductively coupled plasma atomic emission spectrometry and other laser ablation methods; biosensors; ion mobility spectrometer; fourier transform infrared spectrometers; other field portable optical/spectroscopic methods; ion-selective electrodes; chemical identification field test kits; and polarized light microscopy.

The field screening technologies above were used to generate alternatives which were then evaluated by the study team. Eight alternatives were developed. Each combined analytical equipment in WRAP 1 with an external laboratory facility capable of obtaining all needed characterization data. Evaluation criteria included the following elements: cost; equipment size; training and expertise to operate; handling; sample turnaround; secondary waste generation; compatibility with facility operations; project impact; maturity; total analysis done in WRAP 1; and cost per sample.

The preferred waste characterization/sampling strategy alternative was selected based on above criteria and is summarized below.

In the main process gloveboxes, wastes are visually inspected and noncompliant items removed. Any suspect materials present in the drum contents that remain will be sampled and sent to the laboratory for identification. Of the 126 analytes identified as potentially present in the retrievably stored waste, only 19 are regulated in quantities <1 wt%. If it can be determined that the suspect substance does not constitute 1 wt% or greater of the drum's weight and is not one of these 19 analytes, further analysis may not be required.

Noncompliant items from the main process gloveboxes are sent to the RWM gloveboxes. Field screening will be performed in the RWM glovebox to assure chemical compatibility to support safe storage of the waste and safe transport of samples to the laboratory. This compatibility testing may include pH testing, flammability testing with a Flame Ionization Detector (FID) or hot platinum wire sensor, reactivity testing with universal reagent, specific to a given analysis, in small quantities (colorimetric method), and explosivity determination to be handled administratively.

Customized spot tests (e.g., thin layer chromatography, colorimetrics) specific to a given batch(es) will also be performed in the RWM gloveboxes. These spot tests will be used to identify the most common analytes present in a specific batch. The selection of test type for a given batch is based on generator information, information gained from previous processing steps (e.g., trench-side testing), and WRAP 1 operating experience with the batch. No capital costs are associated with customized spot tests.

A laboratory external to the WRAP 1 facility then performs additional analysis to complete waste characterization. This includes preliminary screening, which serves as a quick indicator as to whether a particular constituent is present in the sample, and full analysis as needed.

Including external laboratory analysis as part of the sampling strategy offers several advantages to the WRAP 1 project. First, no design changes are required (e.g., floor plan, glovebox configuration, operator space, traffic patterns, etc.). Second, the cost per sample remains constant as the number of samples decrease, ultimately reducing the overall sample cost. Third, WRAP 1 personnel can remain focused on operations and will not need to become laboratory experts, and expertise remains localized within an external laboratory. Fourth, projected laboratory capabilities can handle the sample load projections for WRAP 1, can reduce turn around time for field screening results, and will manage all waste generated as a result of the analysis work they conduct.

2.2 RECOMMENDATIONS

The study team recommends that the preferred waste characterization/sampling strategy alternative be implemented. Under this scenario, WRAP 1 will perform the following activities:

- visual inspection of the waste for suspicious items requiring characterization,
- cursory field screening in the RWM gloveboxes to assure chemical compatibility in the final waste drums, and
- customized spot tests for chemicals specific to a given waste batch.

The external laboratory will perform field screening and full analysis as needed.

Several activities will need to be completed before the alternative above can be implemented. First, the design of the main process gloveboxes will need to be revised to accommodate scales. These scales will be needed to calculate the weight percentage for suspect materials.

Second, the chemicals associated with potential WRAP 1 batches will need to be reviewed in order to determine the analytes for which spot tests are available or could be developed. In addition, the chemicals in each batch should be reviewed in order to determine which spot tests will provide the greatest cost savings to the project. For those chemicals selected as a result of this process that do not have spot tests available commercially, customized spot tests will need to be developed and demonstrated.

Finally, it is recommended that the Data Quality Objective (DQO) process for WRAP 1 characterization sampling and analysis activities be completed as soon as possible. The DQO process focuses on establishing the quality and quantity of data required for decision making by linking the data collection with problem resolution. The DQO process is mandated by the Hanford Federal Facility Agreement and Consent Order.

This page intentionally left blank.

3.0 UNCERTAINTIES AND ASSUMPTIONS

A list of the assumptions and uncertainties developed for use in this study are presented below.

- WRAP 1 feed is composed of retrievably stored, 55-gal, suspect TRU waste drums; newly generated, 55-gal, TRU waste drums; and 8'X5'X5' waste boxes. However, only 55-gal drums will be opened and characterized in WRAP 1.
- WRAP 1 will perform characterization of the retrieved waste destined for other Solid Waste Operations Complex (SWOC) facilities (e.g., WRAP 2A, LLW disposal, WIPP, thermal treatment, etc.).
- The chemical and physical items that are used as a basis for the study have been obtained by looking at characterization reports for the largest nine generators - Plutonium Finishing Plant (PFP); Plutonium-Uranium Extraction (PUREX) Plant (including Laboratory operations); 231-Z; General Electric's Vallecitos Nuclear Center (VNC); Westinghouse Advanced Reactor Division (WARD) and Westinghouse Nuclear Fuels Division (WNFD); Babcock and Wilcox; and the 325 Building (Westinghouse Hanford Company [WHC] and Pacific Northwest Laboratories [PNL] operations).
- The sources identified above generated approximately 86% of the retrievably stored 55-gal waste drums of suspect TRU waste. This will be the study basis for evaluation of characterization in the WRAP 1 facility. The remaining 14% of the waste was generated by an additional 45 generators. A review of the Solid Waste Information and Tracking System (SWITS) database for the hazardous chemicals records from these additional generators was used to augment the list discussed above.
- The Data Quality Objective (DQO) process was not included in this study effort; however, it is expected that the DQO process will be a follow-on to this study and will use information contained herein. It is assumed that the results of this study will be consistent with the results of the DQO effort.
- WRAP 1 will utilize analytical capabilities internal and external to the facility to perform characterization of waste destined for treatment or disposal at other facilities.
- On-site and/or off-site laboratories will have the capacity to handle all WRAP 1 samples.
- With respect to retrieved waste, WRAP 1 will serve in the capacity of both a generator and a treatment, storage, and/or disposal (TSD) facility. Since the retrieved waste is incompletely characterized, WRAP 1 will perform generator designation as defined in Washington Administrative Code (WAC) 173-303-070. The waste code assignment that results from generator designation will dictate future treatment, storage and disposal requirements.

WRAP 1 is also a TSD facility and will conduct general waste analysis to support TSD activities it will perform for the waste. This general waste analysis is conducted per requirements outline in WAC 173-303-300.

- It is assumed that in certain instances, the use of alternate test methods (other than those standard methods specified in WAC 173-303-110) will be acceptable to designate waste in WRAP 1. This assumption is based primarily on the position the Washington State Department of Ecology has taken with the Backlog Waste program (DOE-RL 1993). It should be noted that WAC 173-303-300 does not mandate the use of standard test methods such as EPA's SW-846, *Test Methods for Evaluating Solid Waste* (EPA 1986); consequently, there is no restriction on the use of alternate test methods to conduct general waste analysis.
- The regulations that apply to waste characterization and designation will not change appreciably over the life of the plant.
- Random representative samples from the main process gloveboxes will be analyzed as discrete samples of suspicious materials based upon visual inspection. Samples from a given drum will be barcoded.
- Sampling is also required to support the selections of NDA algorithms. Since very similar radioisotope distributions are expected among waste drums processed in the same batch, it is assumed that one sample per 20 containers will be required to support NDA algorithm selection.
- As an integration function, the designation activities of WRAP 1 also may support the process characterization required for wastes that will be processed subsequently in the WRAP 1 RWM and WRAP 2A. Process characterization is not envisioned as altering the *number of samples* that are required for analysis, only the *number and types of determinations (tests/analytical results per sample)* that may be performed on a given sample to facilitate treatment. It is believed this additional analysis would have minimal impact on the number of determinations per sample. Any of these additional determinations that are required to support process characterization will be based on the WRAP 2A information currently available from process engineers.
- The RWM sample design basis in the Supplemental Design Requirements Document (SDRD) is 32 samples/day assuming one sample per noncompliant item (Weidert 1993). The assumption of one sample per noncompliant item and one noncompliant item per drum will be used for the purposes of this study.
- The RWM samples will be considered in the evaluation of alternatives. However, sampling of any treated product leaving RWM will not be considered in this study.

- The analyte list required for RWM samples is assumed to be no more extensive than that identified for the drum from which the sample was taken.
- All noncompliant items sent to RWM on a single transfer stand are from the same generator batch of waste.
- The turnaround time for samples sent to an external laboratory for analysis will be 14 calendar days.
- The external laboratory will be responsible for all wastes generated as a result of sample analysis.
- All samples will be returned to WRAP 1 upon completion of their analysis in an external laboratory.
- If laboratories not located on the Hanford Site are used, WRAP 1 samples can be packaged and transported in accordance with all applicable regulations.
- Field screening techniques can be performed at an analytical laboratory which is not located in WRAP 1.
- If field screening is to be performed in WRAP 1, it must be done within a glovebox. Some equipment could be located external to the glovebox, but probes would have to extend into the glovebox.

This page intentionally left blank.

4.0 WASTE CHARACTERIZATION METHODS

Data to support the characterization of solid wastes entering WRAP 1 will be acquired from NDE, NDA, visual inspection, historical records, head-gas sampling, and sample analysis. This section discusses the technical basis for each of these methods as well as the data elements each method will generate. The data to be supplied by each method are then compared with the list of analytes expected to be present in the retrievably stored waste to determine which analytes can only be determined through sample analysis.

4.1 HISTORICAL RECORDS AND PROCESS KNOWLEDGE

Knowledge of waste handling and processing practices, in addition to an understanding of the processes that generated the retrievably stored waste, provides a strong basis for the definition of sampling requirements for the retrieved waste to be handled in WRAP 1. Characterization reports have been completed for the largest generators of historical waste: PFP (Duncan et al. 1993), PUREX (Pottmeyer et al. 1993a), 231-Z (Pottmeyer et al. 1993b), the 325 Laboratory (shared by WHC and PNL) (Pottmeyer et al. 1993c), VNC (Vejvoda et al. 1993), Babcock and Wilcox's Leechburg, PA facility (Duncan 1994a), and WARD/WNFD (Duncan 1994b). These reports were compiled using historical documents, the SWITS database, and interviews with knowledgeable individuals.

The major generators listed above produced approximately 86% of the retrievably stored waste that will be sent to WRAP 1. Table 1 provides a summary, in matrix form, of the regulated chemicals, radionuclides, and physical contents of concern that are potentially present in the wastes generated by these seven facilities. More details about these wastes and the facilities that generated them can be found in the facility fact sheets in .

All of the analytes listed in Table 1 were reviewed to determine their status under the WAC, RCRA, and U.S. Department of Transportation (DOT) regulations. These chemicals also were reviewed against the requirements of DOE Order 5820.2A and the WIPP-WAC. Appendix B contains the list of regulated analytes, the statute, DOE order, or waste acceptance document under which they are regulated, and the reportable quantity for each.

4.2 NONDESTRUCTIVE EXAMINATION

The two primary functions of the WRAP 1 NDE System are (1) to identify the presence, or verify the absence, of noncompliant materials in the unmanifested, retrieved drums in order to direct their removal (and avoid operational surprises) in repackaging operations and (2) to certify that outgoing drums of all TRU waste (newly generated and processed) and a portion of LLW are free of liquids and other noncompliant items.

Nondestructive examination in this application refers to the use of various X-ray techniques to examine the contents of a container without opening it. The purpose of NDE is to minimize the chances that a drum contains undetected free liquids, powders, potentially explosive pressurized gas cylinders or other noncompliant items (Gilles 1993).

Real time radiography (RTR) applies X-ray fluoroscopy to the imaging of waste drums. The output of an X-ray source is passed through a drum and onto a fluoroscopic screen. The resulting image is observed in real time as the drum is rotated and incremented vertically past the source. An image intensifier is used to provide better contrast and brightness. The operator is able to "jog" the drum by starting and stopping the rotation. This permits the dramatic viewing of free liquids as they slosh about. The RTR images recorded on super video helical scan tape media are provided along with voice annotation as an information record. The image intensifier based fluoroscopy RTR systems provide high resolution and penetration capability. Selected regions of interest can be captured and transferred to the optical storage media.

Linear-array digital radiography (DR) augments the RTR system. A linear array of solid state detectors provides a digital x-ray image of the drum "slice". In this case, a drum is rotationally fixed and scanned vertically with the linear digital images being stored. After scanning is finished, a complete view of the drum is assembled and displayed. Two DR views, 90 degrees apart, with suspect areas annotated, serve as a "road-map" for more extensive examination using the RTR capability. These images are stored on bi-metallic optical disc storage media (century media) (Gilles 1993).

4.3 NONDESTRUCTIVE ASSAY

Nondestructive assay (NDA) refers to the measurement of fission and activation products as well as the actinide contents of solid radioactive waste (Gilles 1993). Nondestructive means that the waste is not altered as it would be if a physical sample were to be taken for chemical or other analysis. For NDA to be successful, the types of radionuclides present in the waste must be characterized to establish the algorithm that should be used.

Characterization of radionuclides involves the determination of the quantity of each radionuclide present in a particular waste stream and the development of ratios of the values obtained (for both alpha and beta emitters) to the one or two radionuclides that NDA actually measures (Gilles 1994). NDA cannot perform this characterization. Instead, the NDA method measures the radiation from a few key radionuclides in the waste. Then NDA calculates the quantities of all other radionuclides present from previously developed characterization information using an algorithm. Radioactive materials emit alpha and beta particles as well as gamma rays and neutrons. It is not practical, however, to measure alpha or beta emissions since they do not penetrate the walls of a typical steel waste container. Therefore, NDA must rely on gamma and neutron measurements.

4.4 FIELD SCREENING AND HEAD-GAS SAMPLING

Prior to the placement of retrieved waste drums in storage to await further processing, field screening will be performed to determine the hydrogen, methane, butane, and total volatile organic compounds (VOC) concentrations. If the flammable gas concentrations are less than 25% of the lower explosive limit (LEL) (1% hydrogen, 1.25% methane, or 0.5% butane) and the VOC concentration is less than 500 ppm, no further gas testing nor purging will be done (Johnson 1992). If the VOC concentration equals or

exceeds 500 ppm, a flammability test will be performed; if the gases are then determined to be flammable, the head-gas samples will be analyzed to determine the constituents and their relative concentrations. If the VOC concentration equals or exceeds 600 ppm both the flame test and head-gas analysis will be required. It is projected that approximately 10% of the waste received will exceed the 25% LEL and will require head-gas sampling. Table 2 is a listing of VOCs that the head-gas samples will be analyzed for.

All drums will be processed through a container venting system (CVS). This system provides the capabilities to vent the drums, collect discrete samples for archiving and quality control purposes, screen and analyze the gas samples on a real time basis, control air emissions for dangerous, hazardous, and radionuclide constituents while venting or sampling, and mitigate the adverse effects on personnel from an explosion during the venting procedure. After gas sampling, the system will install a filter in the drum head. The filter will provide absorption of volatile organic compounds but permit the passage of hydrogen and other inorganic gases. For gas mixtures that are in the flammable or explosive range, the drum will be purged with an inert gas until the head gas is no longer flammable.

4.5 SAMPLING AND ANALYSIS REQUIREMENTS

The list of chemicals, radionuclides, and physical contents suspected to be present in the mixed wastes that will be retrieved and processed in WRAP 1 was presented in Table 1. Each analyte on this list was reviewed in order to determine whether that analyte could be accurately determined visually or with one of the characterization methods discussed above (NDE, NDA, Field Screening and Head Gas Sampling). The results of this review are shown in Table 3.

In Table 3 all analytes are classified with the following codes:

- A indicates the radionuclide will be measured during the NDA operation.
- BS indicates that basis sampling is required to determine the algorithm to be applied to the NDA requirements.
- E indicates the analyte will be identified during the NDE operation.
- H indicates the analyte may be determined by head-gas sampling.
- S indicates the analyte can be determined through additional sampling and analysis
- V indicates the analyte can be determined with a visual inspection.
- - indicates the analyte is not present in the specified generator waste.

The information not directly supplied by NDE, NDA, head-gas sampling, or historical records will require additional sampling and analysis of the waste. Currently, plans call for sending waste samples to the laboratory for analysis. This baseline assumption is discussed further in Section 6.0.

The primary purpose for this engineering study is to identify and evaluate alternative methods to accomplish this sampling and analysis. Section 7.0 presents other characterization technologies and methods that will be considered. These technologies and methods will be used to construct the functional alternatives to laboratory analysis which are discussed in Section 8.0.

Table 1. Regulated Chemicals and Radionuclides Suspected to be Present in Retrievably Stored Waste (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Number of Drums ==>	21196	2506	1506	2414	1717	1451	1360	910	150
CHEMICAL * Found in TRU waste but not in the nine generators listed.									
Acetic Acid [64-19-7]	X	X	-	X	-	-	-	-	-
Acetone [67-64-1]	X	-	X	X	X	-	X	-	-
Aluminum (metal) [7429-90-5]	X	X	-	X	-	-	-	-	X
Aluminum Nitrate [13473-90-0]	X	X	-	-	-	-	-	-	-
Ammonia (Anhydrous) [7664-41-7]	-	-	-	X	X	-	-	-	-
Ammonium Ceri Nitrate [16774-21-3]	X	-	-	-	-	-	-	-	-
Ammonium Chloride [12125-02-9]	X	-	-	-	-	-	-	-	-
Ammonium Fluoride [12125-01-8]	-	X	-	-	-	-	-	-	-
Ammonium Hydroxide [1336-21-6]	X	-	-	X	X	-	-	-	-
Ammonium Nitrate [6484-52-2]	-	X	-	-	-	-	-	-	-
Ammonium Sulfate [10043-01-3]	X	-	-	-	-	-	-	-	-
Arsenic (metal) [7440-38-2]	X	-	-	-	-	-	-	-	-
Asbestos [1332-21-4]	X	X	X	X	-	-	X	X	X
Barium (metal) [7440-39-3]	-	X	X	-	-	-	-	-	-
Barium Nitrate [10022-31-8]	X	-	-	X	-	-	-	-	-
Benzene [71-43-2]	X	-	-	-	-	-	X	-	-
Beryllium [7440-41-7]	X	X	-	X	-	X	X	-	-
Boric Acid [10043-35-3]	X	-	-	X	-	-	-	-	-
Butanol [71-36-3]	-	-	-	-	X	-	-	-	-
Cadmium (dust) [7440-43-9]	X	X	X	-	-	-	X	-	-
Cadmium Nitrate [10325-94-7]	-	X	X	-	-	-	-	-	-
Calcium Chloride [10043-52-4]	-	-	-	X	X	-	-	-	-
Calcium Nitrate [10124-37-5]	-	-	-	X	-	-	-	-	-
Carbon Tetrachloride [56-23-5]	X	X	X	X	X	-	X	-	-
Ceric Sulfate [13590-82-4]	-	-	X	X	X	-	-	-	-
Cerous Nitrate [10108-73-3]	-	-	-	X	-	-	-	-	-
Chloroform [67-66-3]	-	X	X	-	-	-	-	-	-
Chlorosulfonic Acid [7790-94-5]	X	-	-	-	-	-	-	-	-
Chromic Acid [7738-94-5]	-	-	-	X	-	-	-	-	-
* Chromium (metal) [7440-47-3]	-	-	-	-	-	-	-	-	-

Table 1. Regulated Chemicals and Radionuclides Suspected to be Present in Retrievably Stored Waste (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Citric Acid [77-92-9]	-	-	-	X	-	-	-	-	-
* Cresylic Acid [1319-77-3]	-	-	-	-	-	-	-	-	-
Cyclohexane [110-82-7]	-	X	X	-	-	-	-	-	-
Decane [124-18-5]	-	X	-	-	-	-	-	-	-
* Diesel [68476-34-6/68334-30-5]	-	-	-	-	-	-	-	-	-
* Dioctyl Phthalate (DOP) [117-84-0]	-	-	-	-	-	-	-	-	-
Ethanol [64-17-5]	-	-	-	X	X	-	-	-	-
* Ethylbenzene [100-41-4]	-	-	-	-	-	-	-	-	-
Ethylene Glycol [107-21-1]	-	-	-	-	-	-	-	-	X
Ferric Nitrate [10421-48-4]	X	X	-	X	-	-	-	-	-
Ferric Sulfate [10028-22-5]	-	-	-	X	-	-	-	-	-
Formaldehyde [50-00-0]	-	X	-	-	-	-	-	-	-
Freon-113 [76-13-1]	-	-	-	-	-	-	X	-	-
* Hexachlorobenzene [118-74-1]	-	-	-	-	-	-	-	-	-
Hexone [108-10-1]	-	X	X	X	X	-	-	-	-
Hydrazine [302-01-2]	X	X	-	X	X	-	-	-	-
Hydriodic Acid [10034-85-2]	X	-	-	X	X	-	-	-	-
Hydrobromic Acid [10035-10-6]	X	-	X	-	-	-	-	-	-
Hydrochloric Acid [7647-01-0]	X	-	X	X	X	-	X	-	-
Hydrofluoric Acid [7664-39-3]	X	-	-	X	X	X	-	-	-
Hydrogen Peroxide [7722-84-1]	X	X	X	X	X	-	X	-	-
* Isobutanol [78-83-1]	-	-	-	-	-	-	-	-	-
Isopropyl Alcohol [67-63-0]	-	-	X	X	X	-	-	-	-
Kerosene [8008-20-6]	-	X	X	X	X	-	-	-	-
Lead [7439-92-1]	X	X	X	X	-	-	X	X	X
Lead Chromate [7758-97-6]	X	-	-	-	-	-	-	-	-
Magnesium [7439-95-4]	-	-	X	-	-	-	-	-	-
Mercuric Thiocyanate [592-85-8]	X	-	-	-	-	-	-	-	-
Mercury [7439-97-6]	X	X	X	X	X	X	X	X	-
Methanol [67-56-1]	X	-	-	X	X	-	-	-	-
Methylene Chloride [75-09-2]	-	-	-	X	-	-	X	-	-
Methyl Ethyl Ketone [78-93-3]	-	-	-	X	X	-	-	-	-

Table 1. Regulated Chemicals and Radionuclides Suspected to be Present in Retrievably Stored Waste (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Methyl Lactic Acid [80--7]	-	-	-	X	X	-	-	-	-
Naphthalene [91-20-3]	-	X	-	-	-	-	-	-	-
Naphthylamine [134-32-7/91-59-8]	X	-	-	-	-	-	-	-	-
Nitric Acid [7697-37-2]	X	X	X	X	X	X	X	X	-
Nitrilotriacetic Acid [139-13-9]	-	-	-	-	X	-	-	-	-
Oxalic Acid [144-62-7]	X	X	-	X	X	-	-	X	-
Pentasodium DTPA [140-01-2]	-	-	-	-	X	-	-	-	-
Perchloric Acid [7601-90-3]	-	-	-	X	X	-	-	-	-
Phosphoric Acid [7664-38-2]	X	X	-	X	X	X	X	-	-
Polychlorinated Biphenyl [1336-36-3]	X	-	-	-	-	-	X	-	-
Potassium Acetate [127-08-2]	X	-	-	-	-	-	-	-	-
Potassium Carbonate [584-08-7]	X	-	-	X	-	-	-	-	-
Potassium Chromate [7789-00-6]	-	-	-	X	-	-	-	-	-
* Potassium Cyanide [151-50-8]	-	-	-	-	-	-	-	-	-
Potassium Fluoride [7789-23-3]	-	X	-	-	-	-	-	-	-
Potassium Hydroxide [1310-58-3]	X	X	X	X	X	-	-	-	-
Propane [74-98-6]	X	-	-	-	-	-	X	-	-
* Pyridine [110-86-1]	-	-	-	-	-	-	-	-	-
Silicon [7440-21-3]	-	X	-	-	-	-	-	-	-
* Silver (metal) [7440-22-4]	-	-	-	-	-	-	-	-	-
Silver Chloride [7783-90-6]	X	-	-	-	-	-	-	-	-
Silver Nitrate [7761-88-8]	X	X	X	X	X	-	-	-	-
Silver Oxide [20667-12-3]	X	-	-	-	-	-	-	-	-
Silver Sulfate [10294-26-5]	X	-	-	-	-	-	-	-	-
Sodium [7440-23-5]	-	-	-	X	-	-	X	-	-
Sodium Bicarbonate [144--8]	-	-	-	X	-	-	-	-	-
Sodium Bisulfite [7631-90-5]	X	-	X	X	-	-	-	-	-
Sodium Bromate [7789-38-0]	-	-	X	-	-	-	-	-	-
Sodium Carbonate [197-19-8]	X	X	X	X	X	-	-	-	-
* Sodium Chromate [7775-11-3]	-	-	-	-	-	-	-	-	-
Sodium Dichromate [10588-01-9]	-	-	-	X	X	-	-	-	-
Sodium Fluoride [7681-49-4]	X	X	X	-	X	-	-	-	-

Table 1. Regulated Chemicals and Radionuclides Suspected to be Present in Retrievably Stored Waste (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Sodium Hydroxide [1310-73-2]	X	X	X	X	X	-	X	-	-
Sodium Hypochlorite [7681-52-9]	-	-	-	X	-	-	-	-	-
Sodium Nitrate [7631-99-4]	X	X	X	X	X	-	-	-	-
Sodium Nitrite [7632-00-0]	X	X	-	X	-	X	-	-	-
Sodium Oxalate [62-76-0]	X	-	-	X	-	-	-	-	-
Sodium Phosphate [76-54-9]	-	-	-	X	X	-	X	-	-
Sodium Silicate [1344-09-8]	-	-	-	X	X	-	-	-	-
Strontium Nitrate [10042-76-9]	-	-	-	X	X	-	-	-	-
Sulfamic Acid [5329-14-6]	X	X	-	-	-	-	X	-	-
Sulfuric Acid [7664-93-9]	X	X	X	X	X	X	-	-	-
Tartaric Acid [87-69-4]	-	X	-	-	-	-	-	-	-
Teflon [9002-84-0]	-	-	-	-	-	-	X	-	-
* Tetrachloroethylene [127-18-4]	-	-	-	-	-	-	-	-	-
Tetrasodium EDTA [62-02-8]	-	-	-	X	X	-	-	-	-
Toluene [108-88-3]	X	-	-	X	X	-	-	-	-
Tributyl Phosphate [126-73-8]	X	X	X	X	X	-	-	-	-
Trichloroethane [79-00-5/71-6]	-	X	-	X	X	-	X	-	-
Trichloroethylene [79-01-6]	-	-	-	-	-	-	X	-	-
Tungsten (powder) [7440-33-7]	X	-	-	-	-	-	X	-	-
Undecane [1120-21-4]	-	X	-	-	-	-	-	-	-
Uranyl Nitrate Hexahydrate [13520-83-7]	-	-	-	-	-	-	X	-	-
Vanadium Pentoxide [1314-62-1]	-	-	-	X	X	-	-	-	-
Xylene [1330-20-7]	X	X	X	X	X	-	-	-	-
Zirconium [7440-67-7]	-	X	-	X	-	-	X	-	-

Table 1. Regulated Chemicals and Radionuclides Suspected to be Present in Retrievably Stored Waste (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PPF Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
RADIOISOTOPES									
Americium-241	X	X	X	X	X	X	-	-	-
Cesium-137	-	X	X	X	X	X	-	-	-
Cobalt-60	-	X	X	X	X	X	-	-	-
Curium-245	-	-	-	X	-	-	-	-	-
Neptunium-237	X	X	X	X	-	-	X	-	-
Plutonium	X	X	X	X	X	X	X	X	X
Plutonium-238	X	X	X	X	-	-	X	X	-
Plutonium-239	X	X	X	-	-	-	X	X	X
Plutonium-240	X	X	X	-	-	X	X	X	X
Plutonium-241	X	X	X	-	-	-	X	X	-
Plutonium-242	X	X	X	-	-	-	X	X	X
Thorium-232	X	X	X	X	-	-	X	X	-
Uranium-233	X	X	X	-	X	-	X	-	X
Uranium-235	X	X	X	X	X	-	X	-	X
Uranium-238	X	X	X	X	X	-	X	-	X

Table 2. Volatile Organic Compounds (Ocampo 1993).

Acetone	1,2-Dichloroethane	Toluene
Benzene	1,1-Dichloroethene	1,1,1-Trichloroethane
Bromoform	cis-1,2-Dichloroethene	Trichloroethylene
Butanol	Ethyl benzene	1,1,2-Trichloroethane
2-Butanone	Ethyl ether	1,2,2-trifluoroethane
Carbon tetrachloride	Methanol	1,3,5-Trimethylbenzene
Chlorobenzene	Methylene chloride	1,2,4-Trimethylbenzene
Chloroform	4-Methyl-2-pentanone	m-Xylene
Cyclohexane	Nitrobenzene	o-Xylene
1,1-Dichloroethane	1,1,2,2-Tetrachloroethane	p-Xylene
	Tetrachloroethene	

Table 3. Characterization Methods to be Used for Analytes
Suspected in Retrievably Stored Waste. (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Number of Drums ==>	21196	2506	1506	2414	1717	1451	1360	910	150
CHEMICAL * Found in TRU waste but not in the 8 generators listed.									
Acetic Acid [64-19-7]	S	S	-	S	-	-	-	-	-
Acetone [67-64-1]	S/H	-	S/H	S/H	S/H	-	S/H	-	-
Aluminum (metal) [7429-90-5]	V/S	V/S	-	V/S	-	-	-	-	V/S
Aluminum Nitrate [13473-90-0]	S	S	-	-	-	-	-	-	-
Ammonia (Anhydrous) [7664-41-7]	-	-	-	S/H	S/H	-	-	-	-
Ammonium Ceric Nitrate [16774-21-3]	S	-	-	-	-	-	-	-	-
Ammonium Chloride[12125-02-9]	S	-	-	-	-	-	-	-	-
Ammonium Fluoride[12125-01-8]	-	S	-	-	-	-	-	-	-
Ammonium Hydroxide[1336-21-6]	S	-	-	S	S	-	-	-	-
Ammonium Nitrate [6484-52-2]	-	S	-	-	-	-	-	-	-
Ammonium Sulfate [10043-01-3]	S	-	-	-	-	-	-	-	-
Arsenic (metal) [7440-38-2]	S	-	-	-	-	-	-	-	-
Asbestos [1332-21-4]	E/V/S	E/V/S	E/V/S	E/V/S	-	-	E/V/S	E/V/S	E/V/S
Barium (metal) [7440-39-3]	-	S	S	-	-	-	-	-	-
Barium Nitrate [10022-31-8]	-	-	-	S	-	-	-	-	-
Benzene [71-43-2]	S/H	-	-	-	-	-	S/H	-	-
Beryllium [7440-41-7]	S	S	-	S	-	S	S	-	-
Boric Acid [10043-35-3]	S	-	-	S	-	-	-	-	-
Butanol [71-36-3]	-	-	-	-	S/H	-	-	-	-
Cadmium (dust) [7440-43-9]	-	S	S	-	-	-	S	-	-
Cadmium Nitrate [10325-94-7]	-	S	S	-	-	-	-	-	-
Calcium Chloride [10043-52-4]	-	-	-	S	S	-	-	-	-
Calcium Nitrate [10124-37-5]	-	-	-	S	-	-	-	-	-
Carbon Tetrachloride[56-23-5]	S/H	S/H	S/H	S/H	S/H	-	S/H	-	-
Ceric Sulfate [13590-82-4]	-	-	S	S	S	-	-	-	-
Cerous Nitrate [10108-73-3]	-	-	-	S	-	-	-	-	-
Chloroform [67-66-3]	-	S/H	S/H	-	-	-	-	-	-
Chlorosulfonic Acid [7790-94-5]	S	-	-	-	-	-	-	-	-
Chromic Acid [7738-94-5]	-	-	-	S	-	-	-	-	-
* Chromium (metal)[7440-47-3] (V/S)	-	-	-	-	-	-	-	-	-

S=Sample Analysis, BS=Basis Sampling, V=Visual Inspection, H=Head-Gas Sampling, E=NDE, A=NDA

Table 3. Characterization Methods to be Used for Analytes
Suspected in Retrievably Stored Waste. (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Citric Acid [77-92-9]	-	-	-	S	-	-	-	-	-
* Cresylic Acid [1319-77-3] (S)	-	-	-	-	-	-	-	-	-
Cyclohexane [110-82-7]	-	S/H	S/H	-	-	-	-	-	-
Decane [124-18-5]	-	S/H	-	-	-	-	-	-	-
* Diesel [68476-34-6/68334-30-5] (S)	-	-	-	-	-	-	-	-	-
* Dioctyl Phthalate (DOP) [117-84-0] (S)	-	-	-	-	-	-	-	-	-
Ethanol [64-17-5]	-	-	-	S/H	S/H	-	-	-	-
* Ethylbenzene [100-41-4] (S/H)	-	-	-	-	-	-	-	-	-
Ethylene Glycol [107-21-1]	-	-	-	-	-	-	-	-	S
Ferric Nitrate [10421-48-4]	S	S	-	S	-	-	-	-	-
Ferric Sulfate [10028-22-5]	-	-	-	S	-	-	-	-	-
Formaldehyde [50-00-0]	-	S/H	-	-	-	-	-	-	-
Freon-113 [76-13-1]	-	-	-	-	-	-	S/H	-	-
* Hexachlorobenzene [118-74-1] (S/H)	-	-	-	-	-	-	-	-	-
Hexone [108-10-1]	-	S/H	S/H	S/H	S/H	-	-	-	-
Hydrazine [302-01-2]	S/H	S/H	-	S/H	S/H	-	-	-	-
Hydriodic Acid [10034-85-2]	S	-	-	S	S	-	-	-	-
Hydrobromic Acid [10035-10-6]	S	-	S	-	-	-	-	-	-
Hydrochloric Acid [7647-01-0]	S	-	S	S	S	-	S	-	-
Hydrofluoric Acid [7664-39-3]	S	-	-	S	S	S	-	-	-
Hydrogen Peroxide [7722-84-1]	S	S	S	S	S	-	S	-	-
* Isobutanol [78-83-1] (S/H)	-	-	-	-	-	-	-	-	-
Isopropyl Alcohol [67-63-0]	-	-	S/H	S/H	S/H	-	-	-	-
Kerosene [8008-20-6]	-	S	S	S	S	-	-	-	-
Lead [7439-92-1]	-	E	E	E	-	-	E	E	E
Lead Chromate [7758-97-6]	S	-	-	-	-	-	-	-	-
Magnesium [7439-95-4]	-	-	V/S	-	-	-	-	-	-
Mercuric Thiocyanate [592-85-8]	S	-	-	-	-	-	-	-	-
Mercury [7439-97-6]	V	V	V	V	V	V	V	V	-
Methanol [67-56-1]	S/H	-	-	S/H	S/H	-	-	-	-
Methylene Chloride [75-09-2]	-	-	-	S/H	-	-	S/H	-	-
Methyl Ethyl Ketone [78-93-3]	-	-	-	S/H	S/H	-	-	-	-
Methyl Lactic Acid [80--7]	-	-	-	S	S	-	-	-	-

S=Sample Analysis, BS=Basis Sampling, V=Visual Inspection, H=Head-Gas Sampling, E=NDE, A=NDA

Table 3. Characterization Methods to be Used for Analytes
Suspected in Retrievably Stored Waste. (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Naphthalene [91-20-3]	-	S	-	-	-	-	-	-	-
Naphthylamine [134-32-7/91-59-8]	S	-	-	-	-	-	-	-	-
Nitric Acid [7697-37-2]	S	S	S	S	S	S	S	S	-
Nitrilotriacetic Acid [139-13-9]	-	-	-	-	S	-	-	-	-
Oxalic Acid [144-62-7]	S	S	-	S	S	-	-	S	-
Pentasodium DTPA [140-01-2]	-	-	-	-	S	-	-	-	-
Perchloric Acid [7601-90-3]	-	-	-	S	S	-	-	-	-
Phosphoric Acid [7664-38-2]	S	S	-	S	S	S	S	-	-
Polychlorinated Biphenyl [1336-36-3]	S	-	-	-	-	-	S	-	-
Potassium Acetate [127-08-2]	S	-	-	-	-	-	-	-	-
Potassium Carbonate [584-08-7]	S	-	-	S	-	-	-	-	-
Potassium Chromate [7789-00-6]	-	-	-	S	-	-	-	-	-
* Potassium Cyanide [151-50-8] (S)	-	-	-	-	-	-	-	-	-
Potassium Fluoride [7789-23-3]	-	S	-	-	-	-	-	-	-
Potassium Hydroxide [1310-58-3]	S	S	S	S	S	-	-	-	-
Propane [74-98-6]	V/H	-	-	-	-	-	V/H	-	-
* Pyridine [110-86-1] (S/H)	-	-	-	-	-	-	-	-	-
Silicon [7440-21-3]	-	S	-	-	-	-	-	-	-
* Silver (metal) [7440-22-4] (V/S)	-	-	-	-	-	-	-	-	-
Silver Chloride [7783-90-6]	S	-	-	-	-	-	-	-	-
Silver Nitrate [7761-88-8]	S	S	S	S	S	-	-	-	-
Silver Oxide [20667-12-3]	S	-	-	-	-	-	-	-	-
Silver Sulfate [10294-26-5]	S	-	-	-	-	-	-	-	-
Sodium [7440-23-5]	-	-	-	S	-	-	S	-	-
Sodium Bicarbonate [144--8]	-	-	-	S	-	-	-	-	-
Sodium Bisulfite [7631-90-5]	S	-	S	S	-	-	-	-	-
Sodium Bromate [7789-38-0]	-	-	S	-	-	-	-	-	-
Sodium Carbonate [197-19-8]	S	S	S	S	S	-	-	-	-
* Sodium Chromate [7775-11-3] (S)	-	-	-	-	-	-	-	-	-
Sodium Dichromate [10588-01-9]	-	-	-	S	S	-	-	-	-
Sodium Fluoride [7681-49-4]	S	S	S	-	S	-	-	-	-
Sodium Hydroxide [1310-73-2]	S	S	S	S	S	-	S	-	-
Sodium Hypochlorite [7681-52-9]	-	-	-	S	-	-	-	-	-

S=Sample Analysis, BS=Basis Sampling, V=Visual Inspection, H=Head-Gas Sampling, E=NDE, A=NDA

Table 3. Characterization Methods to be Used for Analytes
Suspected in Retrievably Stored Waste. (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
Sodium Nitrate [7631-99-4]	S	S	S	S	S	-	-	-	-
Sodium Nitrite [7632-00-0]	S	S	-	S	-	S	-	-	-
Sodium Oxalate [62-76-0]	S	-	-	S	-	-	-	-	-
Sodium Phosphate [76-54-9]	-	-	-	S	S	-	S	-	-
Sodium Silicate [1344-09-8]	-	-	-	S	S	-	-	-	-
Strontium Nitrate[10042-76-9]	-	-	-	S	S	-	-	-	-
Sulfamic Acid [5329-14-6]	S	S	-	-	-	-	S	-	-
Sulfuric Acid [7664-93-9]	S	S	S	S	S	S	-	-	-
Tartaric Acid [87-69-4]	-	S	-	-	-	-	-	-	-
Teflon [9002-84-0]	-	-	-	-	-	-	V/S	-	-
* Tetrachloroethylene [127-18-4] (S/H)	-	-	-	-	-	-	-	-	-
Tetrasodium EDTA [62-02-8]	-	-	-	S	S	-	-	-	-
Toluene [108-88-3]	S/H	-	-	S/H	S/H	-	-	-	-
Tributyl Phosphate [126-73-8]	S	S	S	S	S	-	-	-	-
Trichloroethane [79-00-5/71--6]	-	S/H	-	S/H	S/H	-	S/H	-	-
Trichloroethylene [79-01-6]	-	-	-	-	-	-	S	-	-
Tungsten (powder) [7440-33-7]	S	-	-	-	-	-	S	-	-
Undecane [1120-21-4]	-	S/H	-	-	-	-	-	-	-
Uranyl Nitrate Hexahydrate [13520-83-7]	-	-	-	-	-	-	S	-	-
Vanadium Pentoxide[1314-62-1]	-	-	-	S	S	-	-	-	-
Xylene [1330-20-7]	S/H	S/H	S/H	S/H	S/H	-	-	-	-
Zirconium [7440-67-7]	-	V/S	-	V/S	-	-	V/S	-	-

S=Sample Analysis, BS=Basis Sampling, V=Visual Inspection, H=Head-Gas Sampling, E=NDE, A=NDA

Table 3. Characterization Methods to be Used for Analytes
Suspected in Retrievably Stored Waste. (5 sheets)

BATCH DEFINITION BY GENERATOR ==>									
CHARACTERIZATION ELEMENTS	PFP Proc/ Lab	PUREX Plant	PUREX Lab	WHC 325 Bldg	PNL 325 Bldg	B&W	231-Z Bldg	WARD and WNFD	VNC
RADIOISOTOPES									
Americium-241	BS/A	BS/A	BS/A	BS/A	BS/A	BS/A	-	-	-
Cesium-137	-	A	A	A	A	A	-	-	-
Cobalt-60	-	A	A	A	A	A	-	-	-
Curium-245	-	-	-	BS/A	-	-	-	-	-
Neptunium-237	BS/A	BS/A	BS/A	BS/A	-	-	BS/A	-	-
Plutonium	BS/A	BS/A	BS/A	BS/A	BS/A	BS/A	BS/A	BS/A	BS/A
Plutonium-238	BS/A	BS/A	BS/A	BS/A	-	-	BS/A	BS/A	-
Plutonium-239	A	A	A	-	-	-	A	A	A
Plutonium-240	BS/A	BS/A	BS/A	-	-	BS/A	BS/A	BS/A	BS/A
Plutonium-241	BS/A	BS/A	BS/A	-	-	-	BS/A	BS/A	-
Plutonium-242	BS/A	BS/A	BS/A	-	-	-	BS/A	BS/A	BS/A
Thorium-232	BS/A	BS/A	BS/A	BS/A	-	-	BS/A	BS/A	-
Uranium-233	BS/A	BS/A	BS/A	-	BS/A	-	BS/A	-	BS/A
Uranium-235	A	A	A	A	A	-	A	-	A
Uranium-238	BS/A	BS/A	BS/A	BS/A	BS/A	-	BS/A	-	BS/A

S=Sample Analysis, BS=Basis Sampling, V=Visual Inspection, H=Head-Gas Sampling, E=NDE, A=NDA

This page intentionally left blank.

5.0 WRAP 1 CHARACTERIZATION BASELINE

The WRAP 1 design basis assumes that all waste samples will be sent to a laboratory facility for full characterization. The only field screening capability in the WRAP 1 Facility is pH testing. The baseline alternative discussed in the following section consolidates the current design basis with the assumptions and uncertainties identified in Section 3.0 of this study. Based on this alternative, the average outyear sampling requirements, a characterization flow diagram, and the baseline sampling costs have been identified.

5.1 AVERAGE OUTYEAR SAMPLING REQUIREMENTS

The average outyear sampling requirements for retrievably stored, suspect TRU waste to be processed in WRAP 1 main processing gloveboxes (MPG) and restricted waste management (RWM) are shown in Table 4. The average annual sampling number is estimated at 2,000.

The average outyear sampling requirement calculations are based on the current design basis, the assumptions identified previously in Section 3.0 and the following design criteria and assumptions:

- The major generators considered in this study constitute 86% of retrievably stored 55-gal drums. A linear extrapolation was used to account for the remaining 14%.
- The total number of waste drums by generator considered are as follows:

PFP Process & Lab	=	21,196 (Duncan et al. 1993)
PUREX Plant	=	2,506 (Pottmeyer et al. 1993a)
PUREX Laboratory	=	1,506 (Pottmeyer et al. 1993a)
WHC 325 Building	=	2,414 (Pottmeyer et al. 1993c)
PNL 325 Building	=	1,717 (Pottmeyer et al. 1993c)
Babcock & Wilcox	=	1,451 (Duncan 1994a)
231-Z Building	=	1,360 (Pottmeyer et al. 1993b)
WARD/WNFP	=	910 (Duncan 1994b)
VNC	=	150 (Vejvoda et al. 1993).
- The waste certification and sampling parameters stated in the Supplemental Design Requirements Document (Weidert 1993) considered include the following:
 - Split the retrievably stored suspect TRU drums into 50% TRU and 50% LLW;
 - Sample 50% of the TRU drums; and
 - Sample 50% of the LLW drums.
- The facility operating parameters considered are (Mayancsik 1994):
 - Design life of facility = 30 years; and
 - 175 operating days per year (70% or 35 weeks/year).

- Visual grab sampling is assumed. Samples of material from all waste packages contained in a given drum are not tracked individually.
- The radiological analysis to support NDA algorithms has been assumed at 1 in 20 drums will require sampling. This average is on the premise that not every drum will require sampling.
- LLW operation will begin in March 1997 with the first year throughput assumed to be 50% of the throughput in subsequent years.
- TRU operation will begin in March 1998 with the first year throughput assumed to be at 50% of the throughput in subsequent years.

5.2 CHARACTERIZATION FLOW DIAGRAM

A laboratory characterization flow diagram was developed to analyze solid waste from each of the nine waste generators presented in this study. Assuming analysis will be required for all chemical components at regulatory levels, a full laboratory characterization flow diagram was developed as shown in Figure 3. This characterization flow diagram will determine all chemical components of interest to WRAP 1 including those from the process stream and those that result from chemical reactions.

5.3 BASELINE SAMPLING COSTS

The average outyear sampling costs for the retrievably stored, suspect TRU waste to be processed in WRAP 1 gloveboxes are shown in Table 6. The costs are broken down by sample type and by the glovebox where the samples will be taken. Note that the costs shown do not include transportation, overhead, or documentation costs.

The costs shown in Table 6 were calculated including the following assumptions:

- The cost estimates for laboratory analyses shown in Table 7 are representative of the costs that will be incurred with WRAP 1 samples of retrieved waste.
- The grab samples taken in the main process gloveboxes can be selected based on visual inspection to identify suspicious materials.
- Purge and trap analysis for volatile materials will not be required because initial drum venting will have identified any significant quantities of volatiles or these materials will be present in low, non-regulated concentrations.

- Increased operating experience will result in decreasing costs associated with sampling and analysis. Costs are projected to decrease by 10% in the second year of operations and by 50% in subsequent years. This cost reduction is based primarily on process knowledge that will be gained in the visual inspection of the waste. In addition, many suspected hazardous material present in <1 wt% of the waste are not regulated and will not be sampled.
- The sample costs can be reduced by 15% to reflect that some of the analytical tests shown on the flow chart in Figure 3 are mutually exclusive. For example, soluble analytes will not be subjected to the tests for insoluble analytes.
- The MPG waste is composed of 100% solids, of which 5% are metals.
- The RWM waste is composed of approximately 67% liquids and 33% solids. Five percent of the solids are assumed to be metals.

A characterization table summarizing the laboratory capabilities that discloses possible confirmation analyses for the analyte list is presented in Table 5. The analyte property listed in Table 5 would direct the analysis through the Figure 3 Characterization Flow Diagram to identify what analysis would be required for a specific analyte. The analytical methods listed in Table 5 are the confirmation (or last) analyses. The analyses in Table 5 are one alternative for characterization of each analyte. Other analyses not listed may be equally valid.

The estimated costs for laboratory analyses are summarized in Table 7.

Solid Waste Tot

CINS=Cost Included in Next Step

Figure 3. Char

Characterization Scheme

September 8, 1994

Table 4. Average Outyear Sampling Requirements For Retrievably Stored Suspect TRU 55-gal Drums in WRAP 1 Main Processing Gloveboxes (MPG) and Restricted Waste Management (RWM).

Fiscal Year	Hazardous Chemical				Radiological		Totals
	LLW		TRU		LLW	TRU	
	MPG	RWM	MPG	RWM	MPG & RWM		
1997	95	6	0	0	10	0	296
1998	259	6	99	677	26	10	1109
1999	327	6	268	677	33	27	1846
2000	327	6	339	677	33	34	2065
2001	327	6	339	677	33	34	2065
2002	327	6	339	677	33	34	2065
2003	327	6	339	677	33	34	2065
2004	327	6	339	677	33	34	2065
2005	327	6	339	677	33	34	2065
2006	327	6	339	677	33	34	2065
2007	327	6	339	677	33	34	2065
2008	327	6	339	677	33	34	2065
2009	327	6	339	677	33	34	2065
2010	327	6	339	677	33	34	2065

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste. (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
(2) ACID LOW SOLUBILITY (\$191)			
Boric Acid	>10wt% (WT01/02)	ICP and acid titration	may require fusion
(3) HYDROCARBON MIXTURE (\$3)			
Diesel	(D001)	GC/FID or GC/MS	
Kerosene	(D001)	GC/FID, GC/MS	blend
(4) INORGANIC ACID (\$233)			
Chromic Acid	>0.01wt% or total carcinogen >1wt% (WC02); pH≤2 or pH≥12.5 (D002); Cr>5mg/l (D007)	pH, ICP, & chromate analysis	
Hydriodic Acid	pH≤2 or pH≥12.5 (D002)	titration of acid & IC	
Hydrobromic Acid	pH≤2 or pH≥12.5 (D002)	titration of acid & IC	
Hydrochloric Acid	≥1wt% (WT01/02); pH≤2 or pH≥12.5 (D002)	titration of acid & IC	
Hydrofluoric Acid	≥0.1wt% (WT01/02); pH≤2 or pH≥12.5 (D002); discarded commercial chemical product or container (U134)	titration of acid & IC	
Nitric Acid	(D001); pH≤2 or pH≥12.5 (D002)	titrate acid and IC	liquid
Perchloric Acid	≥10wt% (WT01/02); (D001); pH≤2 or pH≥12.5 (D002); (D003)	titration	highly reactive with organics
Phosphoric acid	≥10wt% (WT01/02); pH≤2 or pH≥12.5 (D002)	titrate acid and IC	liquid in water
Sulfamic Acid	≥0.1wt% (WT01/02); pH≤2 or pH≥12.5 (D002)	titrate acid and	solid
Sulfuric Acid	≥1wt% (WT01/02); pH≤2 or pH≥12.5 (D002)	titrate acid and IC	liquid

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
<u>Notes for specific chemicals:</u> Hydrochloric acid was used as a cleaning solution in 231-Z. Nitric Acid will be found on rags and paper towels from PFP, PUREX, 231-Z and 325. At PUREX rags were packed wet after decontamination. Also expect to see nitric acid in and on equipment from PFP. At 325 nitric acid was neutralized and mixed with Portland cement for disposal. Phosphoric acid from 231-Z is expected to exist on rags. In addition, it is reported that 231-Z generated phosphoric acid contaminated with plutonium. Sulfamic acid was received at 231-Z as a powder and mixed with water for the dissolution of plutonium. PUREX used a 93 percent weight solution of sulfamic acid. Sulfuric acid was also used as a 93 percent weight solution during processing. Sulfuric acid was also used in the PFP process.			
(5) INSOLUBLE SALT (\$151)			
Barium Nitrate	≥1wt% (WT01/02); (D001); >100mg/L Ba (D005)	ICP and IC analysis	
Ceric Sulfate	(D001)	ICP and IC analysis	after fusion
Cerous Nitrate	≥10wt% (WT01/02); (D001)	ICP and IC analysis	after fusion
Lead Chromate	>0.01wt% or total carcinogen >1wt% (WC02); >5mg/l Cr (D007) or Pb (D008)	ICP (chromate analysis)	
Mercuric Thiocyanate	≥0.1wt% (WT01/02); >0.2mg/l Hg (D009)	ICP and thiocyanate analysis	
Silver Chloride	>5mg/l Ag (D011)	ICP and IC	
Silver Oxide	≥10wt% (WT01/02); >5mg/l Ag (D011)	ICP and IC	
Silver Sulfate	>5mg/l Ag (D011)	ICP and IC	
Vanadium Pentoxide	≥0.1wt% (WT01/02); discarded commercial chemical product or container (P120)	ICP	
<u>Notes for specific chemicals:</u> Mercuric Thiocyanate was used in small quantities in the PFP lab.			

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
(6) METAL OR ALLOY FINES (\$2)			
Aluminum	(D001); (D003)	EDX or ICP	metal fines
Arsenic	$\geq 0.1\text{wt}\%$ (WT01/02); $> 0.01\text{wt}\%$ or total carcinogen $> 1\text{wt}\%$ (WC02); $> 5\text{mg/l}$ As (D004)	EDX or ICP	
Barium	(D001); (D003); $> 100\text{mg/l}$ Ba (D005)	EDX or ICP	
Beryllium	$> 0.01\text{wt}\%$ or total carcinogen $> 1\text{wt}\%$ (WC02)	EDX or ICP	
Cadmium	$\geq 1\text{wt}\%$ (WT01/02); $> 0.01\text{wt}\%$ or total carcinogen $> 1\text{wt}\%$ (WC02); $> 1\text{mg/l}$ Cd (D006)	EDX or ICP	dust
Chromium	$> 5\text{mg/l}$ Cr (D007)	EDX or ICP	
Magnesium	(D001); (D003)	EDX or ICP	
Silicon	$\geq 10\text{wt}\%$ (WT01/02); (D001)	EDX or ICP	
Silver	$> 5\text{mg/l}$ Ag (D011)	EDX or ICP	
Sodium	(D001); (D003); $\text{pH} \leq 2$ or $\text{pH} \geq 12.5$ (D002)	EDX or ICP	reactive
Tungsten	(D001)	EDX or ICP	powder
Zirconium	(D001)	EDX or ICP	
Notes for specific chemicals: Beryllium chips from 231-Z were double bagged and stored in cardboard boxes from 1960 to 1978. Typical amounts of beryllium are reported as 200 to 300 grams per container with a maximum estimated as 1 kilogram per container. Beryllium waste could also be found in 231-Z glovebox waste. PFP used very small quantities of beryllium in neutron multipliers and NDA. Cadmium can be expected in boxes from the 231-Z lab and in sealed cans from PUREX. Magnesium found as magnesium oxide in fire extinguishers could be present in the waste generated by 231-Z. Sodium - Extremely small quantities of sodium packed in boxes are expected from 231-Z. Tungsten was used in the 231-Z process and could be present in the waste. Zirconium chips were packed in boxes in 231-Z but were concreted in the 325 labs.			

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
(7) ORGANIC ACID (\$1058 liquid or \$683 solid)			
Acetic Acid	pH≤2 or pH≥12.5 (D002); chelating agent (DOE Order 5820.2A)	GC/FID; GC/MS; HPLC/MS; or IC	
Citric Acid	pH≤2 or pH≥12.5 (D002); chelating agent (DOE Order 5820.2A)	HPLC/MS or IC	
Cresylic Acid	≥10wt% (WT01/02); pH≤2 or pH≥12.5 (D002); present in non-halogenated solvents (F004); >200mg/l cresol (D026)	EPA method 8270	
Methyl Lactic Acid	chelating agent (DOE Order 5820.2A)	HPLC	
Nitrilotriacetic Acid	≥10wt% (WT01/02); chelating agent (DOE Order 5820.2A)	HPLC	
Oxalic Acid	pH≤2 or pH≥12.5 (D002); chelating agent (DOE Order 5820.2A)	IC; HPLC	
Tartaric Acid	chelating agent (DOE Order 5820.2A)	IC; HPLC	
(9) SEMI-VOLATILE ORGANIC (\$3 liquid or \$4 solid)			
Diethyl Phthalate (DOP)	discarded commercial chemical product or container (U107)	EPA 8270	
Ethylene Glycol	≥10wt% (WT01/02); chelating agent (DOE Order 5820.2A)	GC/FID or GC/MS	
Hexachlorobenzene	≥1wt% (WT01/02); >0.01wt% or total carcinogen >1wt% (WC02); discarded commercial chemical product or container (U127); >0.13mg/l hexachlorobenzene (D032)	EPA 8270	
Hydraulic fluid with PCB's	≥0.001wt% (WT01/02) PCB; >0.01wt% or total carcinogen >1wt% (WC02)	extraction and PCB analysis; EPA 8080	semi-volatile ASTM 6410
Naphthalene	≥1wt% (WT01/02); (D001); discarded commercial chemical product or container (U165)	EPA 8270	paint
Naphthylamine	≥10wt% (WT01/02); discarded commercial chemical product or container (U167)	EPA 8270	
Polychlorinated Biphenyl	≥10wt% (WT01/02); >0.01wt% or total carcinogen >1wt% (WC02)	EPA 8080	
Tributyl Phosphate	≥10wt% (WT01/02)	EPA 8270, GC/FID, or GC/MS	
Undecane	(D001)	GC/FID or GC/MS	

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
<u>Notes for specific chemicals:</u> Hydraulic fluid with PCB's was used in the gloveboxes in 231-Z. Processes using pumps and lathes are identified as possible sources of hydraulic fluid contaminated with PCB's. Tributyl Phosphate - In PUREX a 25 percent volume solution of Tributyl phosphate was mixed in a normal paraffin hydrocarbon diluent. PFP used large quantities of TBP mixed with Carbon tetrachloride. In the event that these two chemicals emulsified at PFP, the entire volume would be replaced with new solution. Emulsified TBP and Carbon tetrachloride was disposed in 4 liter poly bottles that were surrounded by conwed pads and packed in 55-gal drums. Undecane - specifically n-dodecane to n-pentadecane, was used in the PUREX process.			
(10) SOLUBLE BASE (\$45)			
Ammonium Hydroxide	$\geq 1\text{wt}\%$ (WT01/02); $\text{pH} \leq 2$ or $\text{pH} \geq 12.5$ (D002)	NH_4 analysis and OH titration	
Potassium Hydroxide	$> 1\text{wt}\%$ (WT01/02); $\text{pH} \leq 2$ or $\text{pH} \geq 12.5$ (D002)	ICP and titration	
Sodium Hydroxide	$\text{pH} \leq 2$ or $\text{pH} \geq 12.5$ (D002)	ICP and titration	
<u>Notes for specific chemicals:</u> Potassium Hydroxide - PUREX is reported to have used potassium hydroxide in a 45 percent weight solution. Sodium Hydroxide is expected to exist on rags or on process equipment from PUREX. PFP used a 6 percent solution of sodium hydroxide and the expected waste form include contaminated rags. In the 325 labs, sodium hydroxide was neutralized and concreted. A large amount of Sodium hydroxide from 231-Z is expected to exist as a clay-like sludge packed with absorbent in 55-gal drums. Sodium hydroxide solution from 231-Z is also expected to exist in 1-gallon containers.			
(11) SOLUBLE SALT/COMPLEXANT (\$1258 liquid or \$1034 solid)			
Aluminum Nitrate	$\geq 10\text{wt}\%$ (WT01/02); (D001)	ICP and IC analysis	
Aluminum Sulfate	$\geq 10\text{wt}\%$ (WT01/02)	ICP and IC analysis	
Ammonium Ceri Nitrate	(D001)	NH_4 , ICP and IC analysis	
Ammonium Chloride	$\geq 10\text{wt}\%$ (WT01/02)	NH_4 and IC analysis	
Ammonium Fluoride	$\text{pH} \leq 2$ or $\text{pH} \geq 12.5$ (D002)	NH_4 and IC analysis	
Ammonium Nitrate	$\geq 10\text{wt}\%$ (WT01/02); (D001); (D003)	NH_4 and IC analysis	
Ammonium Sulfate	$\geq 10\text{wt}\%$ (WT01/02)	NH_4 and IC analysis	
Cadmium Nitrate	$\geq 1\text{wt}\%$ (WT01/02); $> 0.01\text{wt}\%$ or total carcinogen $> 1\text{wt}\%$ (WC02); $> 1\text{mg/l}$ Cd (D006)	ICP and IC analysis	
Calcium Chloride	$\geq 10\text{wt}\%$ (WT01/02)	ICP and IC analysis	

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
Calcium Nitrate	(D001); (D003)	ICP and IC analysis	
Ferric Nitrate	(D001)	ICP and IC analysis	may require Fe^{+2}/Fe^{+3} ratio
Ferrous Sulfate	>1wt% (WT01/02)	ICP and IC analysis	may require Fe^{+2}/Fe^{+3} ratio
Pentasodium DPTA	chelating agent (DOE Order 5820.2A)	HPLC	complexant
Potassium Acetate	≥ 10 wt% (WT01/02)	ICP and HPLC (IC)	complexant
Potassium Carbonate	≥ 10 wt% (WT01/02)	ICP and carbonate	
Potassium Chromate	>0.01wt% or total carcinogen >1wt% (WC02); (D001); >5mg/l Cr (D007)	ICP	
Potassium Cyanide	≥ 0.1 wt% (WT01/02); (D003); discarded commercial chemical product or container (P098)	ICP and cyanide analysis	
Potassium Fluoride	≥ 1 wt% (WT01/02); pH ≤ 2 or pH ≥ 12.5 (D002)	ICP and IC	
Silver Nitrate	(D001); >5mg/l Ag (D011)	ICP and IC	
Sodium Bicarbonate	≥ 10 wt% (WT01/02)	ICP/titration or carbonate	
Sodium Bisulfite	≥ 10 wt% (WT01/02)	ICP and colorimetric	
Sodium Bromate	(D001)	ICP and IC	
Sodium Carbonate	≥ 10 wt% (WT01/02)	ICP and carbonate analysis	
Sodium Chromate	>0.01wt% or total carcinogen >1wt% (WC02); >5mg/l Cr (D007)	ICP (and chromate)	
Sodium Dichromate	≥ 0.1 wt% (WT01/02); >0.01wt% or total carcinogen >1wt% (WC02); >5mg/l Cr (D007)	ICP and colorimetric	
Sodium Fluoride	≥ 1 wt% (WT01/02); pH ≤ 2 or pH ≥ 12.5 (D002)		
Sodium Nitrate	≥ 10 wt% (WT01/02); (D001)	ICP and IC	
Sodium Nitrite	≥ 1 wt% (WT01/02); (D001)	ICP and IC	
Sodium Oxalate	chelating agent (DOE Order 5820.2A)	HPLC (or ICP and IC)	complexant

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
Sodium Phosphate	pH≤2 or pH≥12.5 (D002)	ICP and IC	
Sodium Silicate	≥10wt% (WT01/02)	ICP	
Strontium Nitrate	≥10wt% (WT01/02); (D001)	ICP and IC	
Tetrasodium EDTA	chelating agent (DOE Order 5820.2A)	HPLC	complexant
Uranyl Nitrate Hexahydrate	(D001)	ICP and IC	
<p><u>Notes on specific chemicals:</u></p> <p>Aluminum Nitrate was used in PUREX as a 1.68 M solution.</p> <p>Ammonium Fluoride - PUREX mixed 11.2 M of ammonium fluoride with 1.1 M of ammonium nitrate.</p> <p>Ammonium Nitrate - PUREX mixed 11.2 M of ammonium fluoride with 1.1 M of ammonium nitrate.</p> <p>Cadmium Nitrate - A 50 percent weight solution of cadmium nitrate was used in PUREX.</p> <p>Ferrous Sulfate - A green viscous, 2.9 M solution of ferrous sulfate was used in PUREX.</p> <p>Potassium Cyanide - Electroplating baths containing potassium cyanide were generated by 231-Z.</p> <p>Silver Nitrate from PUREX was generated in solution form.</p> <p>Sodium Fluoride from PFP and PUREX is expected to exist as a finely pulverized white powder.</p> <p>Sodium Nitrate was generated in the PFP process. PUREX received sodium nitrite in pellet form and dissolved it in solution for use in the process.</p> <p>Sodium Oxalate was generated in the PFP process.</p> <p>Sodium Phosphate was used in 231-Z.</p> <p>Uranium Nitrate Hexahydrate - Small amounts of uranium nitrate hexahydrate in boxes are expected from 231-Z. Additionally, 231-Z waste could include small beakers of Uranyl nitrate solidified in kitty litter. The 325 labs usually grouted waste Uranyl nitrate hexahydrate, but some precipitate could also exist. PUREX has generated process equipment and rags expected to be contaminated with Uranyl nitrate hexahydrate.</p>			
(13) VOLATILE ORGANIC (\$200)			
Acetone	≥10wt% (WT01/02); pH≤2 or pH≥12.5 (D002); discarded commercial chemical product or container (U002); present in spent non-halogenated solvents (F003)	EPA 8240	purge and trap
Benzene	≥10wt% (WT01/02); >0.01wt% or total carcinogen >1wt% (WC02); (D001); discarded commercial chemical product or container (U019); present in spent non-halogenated solvents (F005)	GC/FID or GC/MS	purge and trap
Butanol	≥1wt% (WT01/02); (D001); discarded commercial chemical product or container (U031); present in spent non-halogenated solvents (F003)	EPA 8240	

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
Carbon Tetrachloride	$\geq 10\text{wt}\%$ (WT01/02); $> 0.01\text{wt}\%$ or total carcinogen/halogenated hydrocarbon $> 1\text{wt}\%$ (WC02, WP01/02); discarded commercial chemical product or container (U211); present in spent non-halogenated solvents (F001); $> 0.5\text{mg/l}$ CCl_4 (D019)	EPA 8240	purge and trap
Chloroform	$\geq 0.1\text{wt}\%$ (WT01/02); $> 0.01\text{wt}\%$ or total carcinogen/halogenated hydrocarbon $> 1\text{wt}\%$ (WC02, WP01/02); discarded commercial chemical product or container (U044); $> 6\text{mg/l}$ chloroform (D022)	EPA 8240	purge and trap
Cyclohexane	(D001); discarded commercial chemical product or container (U056)	GC/FID or GC/MS	purge and trap
Decane	(D001)	GC/FID or GC/MS	purge and trap
Ethanol	(D001)	EPA 8240	purge and trap
Ethylbenzene	$\geq 10\text{wt}\%$ (WT01/02); (D001); present in spent non-halogenated solvents (F003)	EPA 8240, 8020, or 8015	
Formaldehyde	$\geq 1\text{wt}\%$ (WT01/02); (D001); discarded commercial chemical product or container (U122)	EPA 8315	gas; purge and trap
Freon-113	$> 0.01\text{wt}\%$ or total halogenated hydrocarbon $> 1\text{wt}\%$ (WP01/02); present in spent non-halogenated solvents (F001/002)	EPA 8240, GC/ECD, GC/FID, or GC/MS	purge and trap
Hexone	$\geq 10\text{wt}\%$ (WT01/02); (D001); discarded commercial chemical product or container (U161); present in spent non-halogenated solvents (F003)	EPA 8240 or 8015	purge and trap
Isobutanol	$\geq 10\text{wt}\%$ (WT01/02); (D001); discarded commercial chemical product or container (U140); present in spent non-halogenated solvents (F005)	EPA 8240	
Isopropyl Ethanol	$\geq 10\text{wt}\%$ (WT01/02); (D001)	GC/FID	
Methanol	$\geq 10\text{wt}\%$ (WT01/02); (D001); discarded commercial chemical product or container (U154); present in spent non-halogenated solvents (F003)	GC/FID, GC/MS	
Methyl Ethyl Ketone	$\geq 10\text{wt}\%$ (WT01/02); (D001); discarded commercial chemical product or container (U159); present in spent non-halogenated solvents (F005); $> 200\text{mg/l}$ methyl ethyl ketone (D035)	EPA 8240 or 8015	

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
Methylene Chloride	≥0.1wt% (WT01/02); >0.01wt% or total carcinogen/ halogenated hydrocarbon >1wt% (WC02, WP01/02); discarded commercial chemical product or container (U080); present in spent non-halogenated solvents (F001/002)	EPA 8240 or 8010	
Pyridine	≥1wt% (WT01/02); discarded commercial chemical product or container (U196); present in spent non-halogenated solvents (F005); >5mg/l pyridine (D038)	EPA 8240 or 8270	
Tetrachloroethylene	≥10wt% (WT01/02); >0.01wt% or total halogenated hydrocarbon >1wt% (WP01/02); discarded commercial chemical product or container (U210); present in spent non-halogenated solvents (F001/002); >0.7mg/l tetrachloroethylene (D039)	EPA 8240 or 8010	
Toluene	≥10wt% (WT01/02); (D001); present in spent non-halogenated solvents (F005)	EPA 8240 or 8020	
Trichloroethane	≥10wt% (WT01/02); >0.01wt% or total carcinogen and halogenated hydrocarbon >1wt% (WC02, WP01/02); discarded commercial chemical product or container (U226/227); present in spent non-halogenated solvents (F001/002)	EPA 8240 or 8010	
Trichloroethylene	>0.01wt% or total halogenated hydrocarbon >1wt% (WP01/02); discarded commercial chemical product or container (U228); present in spent non-halogenated solvents (F001/002)	EPA 8240 or 8010	
Xylene	≥10wt% (WT01/02); (D001); discarded commercial chemical product or container (U239); present in spent non-halogenated solvents (F003)	EPA 8240, 8020	

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets)

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
<p>The chemicals listed could exist various in combinations and forms. For instance, 231-Z indicated that nonpunctured aerosol cans containing a mixture of VOC's were occasionally sent to solid waste. Organic solvents from 231-Z were typically packed in reagent bottles and disposed in 55-gal drums. The 325 labs commonly poured waste scintillation liquids into kitty litter and stored the waste in one quart (sometimes 5 quart) metal cans with slip lids. These cans were packed into double lined bags in 55-gal drums surrounded by more kitty litter. It is estimated that one drum of waste contained 5 to 8 cans of scintillation liquids. The ratio of kitty litter to scintillation liquids was 1:1 in the early 1980's and later was changed to 2:1. In more recent years, conwed* fiber was used as an absorbent.</p> <p>* Conwed is a trademark of Leucadia, Inc.</p> <p><u>Notes on specific chemicals:</u></p> <p>Acetone was used in 231-Z processing and in the PFP laboratory.</p> <p>Benzene was used conservatively in the gloveboxes in 231-Z and was only used in the early 1970's in the PFP laboratory.</p> <p>Carbon Tetrachloride (liquid) is expected to exist in large quantities from 231-Z and the PFP laboratory.</p> <p>Freon-113 was used to clean plutonium parts and to measure density in 231-Z.</p> <p>Methylene Chloride - It was reported that approximately 10 to 20 gallons of paint stripper in the form of methylene chloride was generated by 231-Z and is stored in 55-gal drums.</p> <p>Trichloroethane was generated in 231-Z.</p> <p>Trichloroethylene was generated in 231-Z.</p>			
NO LABORATORY ANALYSIS REQUIRED			
Ammonia (anhydrous)	$\geq 0.1\text{wt}\%$ (WT01/02); (D001); $\text{pH} \leq 2$ or $\text{pH} \geq 12.5$ (D002)	converted to NH_4OH	
(1) Asbestos	$> 0.01\text{wt}\%$ or total carcinogen $> 1\text{wt}\%$ (WC02)	standard method (microscopic analysis)	asbestos fiber
Chlorosulfonic Acid	H_2SO_4 - $> 1\text{wt}\%$ (WT01/02); HCl - $> 10\text{wt}\%$ (WT01/02)	water decomposing analyte	covered elsewhere
Hydrazine	$> 0.01\text{wt}\%$ or total carcinogen $> 1\text{wt}\%$ (WC02); $\text{pH} \leq 2$ or $\text{pH} \geq 12.5$ (D002)	titration with oxidizer (spot check)	highly reactive; may require titration
Hydrogen Peroxide	(D001)	titration (spot check)	30% solutions only
Lead	$> 0.01\text{wt}\%$ or $> 1\text{wt}\%$ total carcinogen (WC02); $> 5\text{mg/l}$ Pb (D008)	EDX or ICP	

Table 5. Characterization for Analytes Expected to be Present in Retrievable Stored Suspect TRU Waste (15 sheets).

ANALYTE	REGULATORY ACTION LIMITS	POSSIBLE ANALYTICAL METHODS	COMMENTS
Mercury	discarded commercial chemical product or container (U151); >0.2mg/l Hg (D009)	ICP or CVAAS	liquid metal
Propane	(D001)	GC/FID or GC/MS	
<p>Notes on specific chemicals:</p> <p>Asbestos is expected to exist in the following forms: floor tiles and insulation from 231-Z, friable and non-friable tiles and insulation (if friable, wetted and wrapped in plastic) from PUREX, and in 3 feet by 5 feet sheets that lined gloveboxes in the 325 labs. It is possible that asbestos from the 325 labs could be contaminated with acid. If the asbestos from the 325 labs were in a friable form, it was wetted and sealed in 5 quart cans.</p> <p>Hydrazine - A 11.3 M solution of hydrazine was used in PUREX in the IX columns.</p> <p>Hydrogen Peroxide was generated from 231-Z in pint size bottles packed in laboratory boxes. PFP used Hydrogen peroxide as a 20 percent solution in the mass spectrometer, and PUREX generated swabs and rags contaminated with Hydrogen peroxide as well as reagent bottles containing liquid Hydrogen peroxide.</p> <p>Lead - Significant quantities of lead sheets and pigs were disposed from 231-Z and the 325 labs disposed lead shielding and bricks.</p> <p>Mercury produced by broken instruments and manometers is expected from several generators. Mercury was also used by 231-Z to test void spaces in castings. Mercury waste packaged at Babcock was solidified with Fisher Scientific's Mercury Absorbent Powder.</p> <p>Propane - One pound cylinders containing propane were discarded from several facilities until about 1973. Some of the propane cylinders were purged and the valves were removed before disposal.</p>			

Physical Waste Form General Notes. (waste forms expected to be contaminated with hazardous/dangerous constituents)

Liquids from laboratory operations, processing, and cleanup operations are most likely to be found in one or more of the following ways:

- containerized liquids in glass- or poly-bottles surrounded by absorbent;
- absorbed liquids on kitty litter/vermiculite, cloth/rags/nylon, conwed pads, dirt/soil/diatomaceous earth, paper/cardboard, and asbestos tiles (glovebox waste especially utilized kotex pads, gloves, etc.);
- on the surface of equipment parts;
- holdup in equipment parts; and
- in a cemented form.

Specific packaging was done for a number of chemicals. Notes on these waste forms can be found at the end of each section.

WT01, Toxicity Category for waste with more than one hazardous constituent:

WT02 The equivalent concentration for the waste must be determined using the following formula

$$\text{Equivalent Concentration (\%)} = \Sigma X\% + \frac{\Sigma A\%}{10} + \frac{\Sigma B\%}{100} + \frac{\Sigma C\%}{1000} + \frac{\Sigma D\%}{10000}$$

where $\Sigma(X, A, B, C, \text{ or } D)\%$ is the sum of all the concentration percentages for a particular toxic category. If the equivalent concentration is greater than 0.001 wt%, regardless of quantity, that waste is regulated. Using the waste graph in WAC 173-303-9906 with the determined equivalent concentration and the total waste quantity, the designation of the waste as DW (WT02) or EHW (WT01) can be determined. The waste graph should not be modified for mixed waste.

WC02 Carcinogen: A waste containing one or more carcinogenic constituent is regulated as carcinogenic (WC02) if either the concentration of any one carcinogenic constituent exceeds 0.01 wt% of the waste quantity or the total concentration summed for all carcinogenic constituents exceeds 1 wt% of the waste quantity.

WP01, Persistence: A waste containing one or more halogenated hydrocarbons (HH) is regulated when the total

WP02, concentration is greater than 0.01 wt%. This waste can be designated as DW (WP02) for total
WP03 concentrations between 0.01 wt% and 1 wt% or EHW (WP01) for total concentrations greater than 1 wt%. A waste containing one or more polycyclic aromatic hydrocarbons with more than 3 rings and less than 7 rings is regulated as EHW (WP03) when the total concentration is greater than 1 wt%.

D001 A waste is regulated with the D001 waste code (ignitability characteristic) if it is either a liquid, other than an aqueous solution containing less than 24% alcohol by volume and has a flash point less than 140 °F or it is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard or it is an ignitable compressed gas as defined in 49 CFR 173.300 or it is an oxidizer as defined in 49 CFR 173.151. NOTE: EPA has not changed its reference to 49 CFR 173.300 and 173.151 to conform to new hazard class definitions under DOT's "HM-181" rules.

D002 A waste is regulated with D002 waste code (corrosivity characteristic) if it is either an aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5 or it is a liquid and corrodes steel (SAE 1020) at a rate greater than .250 inches per year at a test temperature of 130 °F.

D003 A waste is regulated with D003 waste code (reactivity characteristic) if it has any of the following properties: it is normally unstable and readily undergoes violent change without detonating; it reacts violently with water; it forms potentially explosive mixtures with water; it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment when mixed with water; it is a cyanide ore sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present danger to human health or the environment; it is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement; it is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure; it is an forbidden explosive (49 CFR 173.51), a Class A explosive (49 CFR 173.53), or a Class B explosive (49 CFR 173.88).

U & P codes A waste is regulated with the U and P waste codes if it's sole active ingredient is a discarded commercial chemical product or manufacturing chemical intermediate (a product, then a waste), an off-specification commercial chemical product or manufacturing chemical intermediate, a residue remaining in a container or in an inner liner removed from a container that has held any commercial chemical product or manufacturing chemical intermediate, or a residue or contaminated soil, water or other debris resulting from cleanup of a spill into or on any land or water of any commercial chemical product or manufacturing chemical intermediate. The numbers associate the U and P codes to the specific constituent.

F001 A waste is regulated with the F001 waste code if it is listed in the following spent halogenated solvents used in degreasing: Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; and is a sludge from the recovery of these solvents in degreasing operations. These wastes contain or may contain halogenated hydrocarbons. Although WAC 173-303-082 states that these wastes are DW, WAC 173-303-070(5), special knowledge, requires generators who know that their waste contains greater than one percent of these listed halogenated hydrocarbons to designate their waste EHW.

F002 A waste is regulated with the F002 waste code if it is listed in the following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro- 1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane and 1,1,2 trichloroethane; and is the still bottoms from the recovery of these solvents. These wastes contain or may contain halogenated hydrocarbons. Although WAC 173-303-082 states that these wastes are DW, WAC 173-303-070(5), special knowledge, requires generators who know that their waste contains greater than one percent of these listed halogenated hydrocarbons to designate their waste EHW.

- F003 A waste is regulated with the F003 waste code if it is listed in the following spent non-halogenated solvents: Xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; and is the still bottoms from the recovery of these solvents.
- F004 A waste is regulated with the F004 waste code if it is listed in the following spent non-halogenated solvents: Cresols and cresylic acid, nitrobenzene; and is the still bottoms from the recovery of these solvents.
- F005 A waste is regulated with the F005 waste code if it is listed in the following spent non-halogenated solvents: Toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, 2-nitropropane; and is the still bottoms from the recovery of these solvents.

DOE Order 5820.2A

The waste acceptance criteria for storage, treatment, or disposal facilities shall address the restrictions for chelating and complexing agents having the potential for mobilizing radionuclides.

Table 6. Average Outyear Sampling Cost For Retrievably Stored, Suspect TRU, 55-gal Drums in WRAP 1 Main Processing Gloveboxes (MPG) and Restricted Waste Management (RWM).

Fiscal Year	Hazardous Chemical				Radiological		Totals
	LLW		TRU		LLW	TRU	
	MPG	RWM	MPG	RWM	MPG & RWM		
1997	\$121,517	\$188,839	\$0	\$0	\$1,143	\$0	\$311,769
1998	\$296,848	\$461,307	\$125,781	\$195,465	\$3,834	\$1,462	\$1,084,698
1999	\$333,303	\$517,959	\$307,264	\$477,494	\$4,843	\$5,013	\$1,644,833
2000	\$291,641	\$453,214	\$344,998	\$536,133	\$4,843	\$5,013	\$1,635,843
2001	\$294,978	\$388,469	\$301,874	\$469,116	\$4,843	\$5,013	\$1,419,294
2002	\$208,315	\$323,724	\$258,749	\$402,100	\$4,843	\$5,013	\$1,202,744
2003	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603
2004	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603
2005	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603
2006	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603
2007	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603
2008	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603
2009	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603
2010	\$208,315	\$323,724	\$215,624	\$335,083	\$4,843	\$5,013	\$1,092,603

Table 7. Laboratory Analyses Cost Estimate.

Analysis	Solid	Liquid
Volatile Organics	\$200	\$200
Visual Inspection	\$5	\$5
EDX	\$250	--
Cyanide	\$85	\$70
Acid/base Ph	\$30	\$15
Titration	\$30	\$30
IC for anions	\$40	\$25
Ammonium	\$216	\$200
Chromate	\$26	\$26
ICP/MS & separation	\$110	\$100
GEA analysis	\$38	\$35
TCLP	\$225	\$180
ICP	\$120	\$120
Hg	\$50	\$40
Semi-Volatiles	\$450	\$400
Complexants	\$300	\$280
PCB's		\$200
Organic screening		\$150

EDX energy dispersive x-ray spectroscopy
 GEA gamma energy analysis
 IC ion chromatography
 PCB polychlorinated biphenyl
 TCLP toxicity characteristic leaching procedure

This page intentionally left blank.

6.0 FIELD SCREENING METHODS CONSIDERED

Sampling and analysis will be required to attain the necessary characterization data for WRAP 1 wastes. The previous section describes the use of laboratory analysis to provide these data. This section describes field screening methods and technologies that provide alternatives to various laboratory analysis.

Technologies were identified that could potentially be applied to field screening of hazardous waste, including remote (in situ) analysis as well as field portable instrumentation. This effort involved the development of technology data sheets designed to provide the description, applications, advantages, limitation, specifications, analysis capacities/capabilities, sample preparations/limitations, system operation, and life cycle cost. The general classes of analytes covered in this technology search include organics (both volatile and semi-volatile) and inorganics (mainly metals and dissolved salts). Applicable media include liquid, solid, and gas. Technology data sheets were prepared for the following field screening technologies:

- Stripping voltammetry;
- Fiber-optic chemical sensors;
- Neutron activation analysis;
- X-Ray fluorescence spectrometry;
- Field portable and hand-held gas chromatographs;
- pH probe;
- Photoionization and flame ionization detectors for gas detection;
- Colorimetric and titrimetric methods;
- Immunoassay field test kits;
- Remote fourier transform raman spectrometers;
- Field portable gas chromatograph/mass spectrometers;
- Laser ablation-inductively coupled plasma atomic emission spectrometry and other laser ablation methods;
- Biosensors;
- Ion mobility spectrometer;
- Fourier transform infrared spectrometers;
- Other field portable optical/spectroscopic methods;
- Ion-selective electrodes;
- Chemical identification field test kits; and
- Polarized light microscopy.

A brief description of each field screening technology is presented in this section, and complete technology data sheets are included in Appendix C. Table 8 lists each field screening technology and indicates the detection capability for all selected classes of analytes.

Table 8. Field Screening Technology Capabilities.

Technology	Asbestos	Low Solubility Acids	Hydro-carbon Mixtures	Inorganic Acids	Insoluble Salts	Metals/Alloys	Organic Acids	Semi-Volatile Organics	Soluble Bases	Soluble Salts/Complex-ants	Volatiles Organics
6.1 - Stripping Voltammetry	N	N	N	X	*	N	N	N	*	*	N
6.2 - Fiber-Optic Chemical Sensors	N	N	X	X	N	N	X	N	X	X	X
6.3 - Neutron Activation Analysis	N	X	?	*	X	X	N	N	*	X	N
6.4 - X-Ray Fluorescence Spectroscopy	N	N	N	*	*	X	N	N	*	*	N
6.5 - Gas Chromatography	N	N	X	N	N	N	X	X	N	N	X
6.6 - pH Probes	N	N	N	X	N	N	X	N	X	N	N
6.7 - Photoionization & Flame Ionization Detectors	N	N	X	N	N	N	X	X	N	N	X
6.8 - Colorimetric & Titrimetric Methods	N	N	X	X	N	*	*	N	X	X	N
Key: N = N/A * = Somewhat Applicable X = Applicable ? = Unknown											
6.9 - Immunoassay Field Test Kit	N	X	X	N	X	X	X	X	N	X	X
6.10 - Fourier Transform Raman Spectroscopy	N	X	X	X	X	N	X	X	X	X	X
6.11 - Field GC/MS	N	N	X	N	N	N	X	X	N	N	X
6.12 - Laser Ablation-ICP-AES	N	N	N	N	X	X	N	N	*	X	N
6.13 - Biosensors	N	X	X	N	X	X	X	X	N	X	X
6.14 - Ion Mobility Sensors/Spectroscopy	N	N	X	N	N	N	N	X	N	N	X
6.15 - Fourier Transform Infrared (FTIR) Spectroscopy	N	X	X	X	X	N	X	X	X	X	X
6.16 - VNIR Spectroscopic Methods	N	N	X	*	*	N	N	X	N	X	X
Key: N = N/A * = Somewhat Applicable X = Applicable											
6.17 - Ion Selective Electrodes	N	N	N	X	N	N	N	N	N	X	N
6.18 - "HazCat" Kit	Y	*	*	Y	*	Y	*	Y	Y	*	Y
6.19 - Polarized Light Scope	X	X	N	X	X	N	X	N	*	X	N
Key: N = N/A * = Somewhat Applicable X = Applicable											

6.1 STRIPPING VOLTAMMETRY (Electroanalytical Techniques and Electrochemical Sensors)

An electrochemical cell consists of two or more electrodes that function as transducers between a chemical system and an electrical system in which the electrical parameters of voltage can be measured and controlled. In electroanalytical chemistry, the magnitude of a voltage or current signal from an electrochemical cell is related to the concentration of a particular analyte in the cell. This technology can be used for both qualitative and quantitative analysis.

Electrochemical sensors produce an electric signal in response to a chemical reaction. There are several types of electrochemical devices that have potential as in situ sensors, including stripping voltammetry, a catalytic surface-modified ion electrode employing amperometric titration, and resistance/capacitance sensors. There are even electrochemical immunoassay sensors being developed. However, the maturity of the technology for field and in situ applications is uncertain.

The intended application of stripping voltammetry is field and in situ analysis of metals in aqueous solution. This technology detects metals and anions at very low detection limits (even parts per trillion). For environmental applications, development has focused on heavy metal detection. Samples must be in the liquid phase and the operation is designed for bench-top and in situ use. Since the technology is still relatively new, life cycle cost information is unknown.

6.2 FIBER-OPTIC CHEMICAL SENSORS

Fiber-optic chemical sensors (FOCS), also called chemical optrodes, combine fiber optics, chemistry, immobilization techniques, and spectroscopy to perform highly-sensitive, highly-selective chemical sensing. FOCS generally use a specific chemical coating that reacts chemically or physically in the presence of the target contaminants. This technology is useful for monitoring known (or suspected) chemicals in a waste stream, typically aqueous.

The sensor consists of a reagent (chemically-selective indicating layer) immobilized at the end of a fiber optic distal tip. Light is introduced into the proximal end of the fiber and transmitted via total internal reflection through the fiber to the distal fiber surface. The reagent either reacts with the target contaminant to produce an optical signal or to modify an existing signal. The light that is delivered down the fiber is modified by the reaction of the analyte (target contaminant) with the reagent. The return signal indicates the presence of a specific contaminant or a family of chemicals, and the intensity indicates the concentration. FOCS typically measure fluorescence, colorimetric change, or refractive index change.

Fiber optic chemical sensors (FOCS) have been used to continuously monitor contaminants in water. The typical application is for field/in situ monitoring hydrocarbons and organics in vapor and water. Fiber optic chemical sensing technology is still mostly a laboratory Research and Development activity.

Currently available FOCS are for organics in aqueous solution applications (e.g., aromatics and chlorinated hydrocarbons). There are also alkali and heavy metal ion sensors based on selective ionophores or chromophores. Many of these chemical sensors have been laboratory tested but not field demonstrated. Development and testing will be required to implement the technology for a specific application.

Detection limits for this technology are unquantified, but are expected to be in the ppm range. With unknown samples, the technology is probably more qualitative than quantitative. Response times will vary, but should be fast enough that analysis time will not be a concern.

The FOCS are highly selective, but they are also highly sensitive. The effects of temperature, pH, dissolved solids (especially at higher concentrations), radiation, etc. will be issues that need to be addressed and resolved.

Due to the research and development, demonstration, and validation activities that would need to be performed to implement this technology, the system cost would be medium to high. However, operating cost and maintenance cost are expected to be low. The FOCS are expected to have a long life expectancy since the data handling equipment can be isolated from the harsh environment and only the sensor would require replacement.

6.3 NEUTRON ACTIVATION ANALYSIS

Neutron activation analysis is an established technique for elemental analysis in many fields such as earth science, biology, forensics, the fine arts, and industry. With activation analysis, a sample being studied is bombarded with a flux of neutrons so that the element or elements of interest in the sample are transformed into radioactive elements. The decay activities of these elements are a function of the concentration of the original element in the sample. The measurement is made quantitative either by knowledge of the neutron flux and the activation cross sections, or by the use of pure elemental standards, irradiated under the same conditions as the sample. These methods are known as absolute and comparative neutron activation analysis, respectively.

Most analyses performed are of the comparative type, and slow neutrons from a reactor (source) are usually used. High-resolution gamma spectroscopy with a Ge detector can be used for the analysis of the sample spectrum. Other detector options that provide either higher speed or higher intrinsic efficiency are possible, but are usually lower resolution.

Some elements cannot be analyzed by this method because the activation product is stable or is not easily observed. Also, the activation cross sections for different elements vary greatly.

One notable advantage of this technology is the ability to characterize depth profiles (not just surface characterization like X-ray fluorescence). For example, neutron penetration greater than 40 inches is possible in packed soil. However, moisture, plastics (e.g., polyethylene), organics (e.g., oils), and carbon (e.g., granular activated carbon) may act as neutron

moderators which interfere with the accuracy of results and introduce errors that are difficult to resolve.

The range of detection for neutron activation analysis is variable, but is expected to be ppm to weight percent. The limitation will be on the detector, geometry, and data interpretation software. In general, the technology is expected to be applicable from trace levels to high concentrations. This technology will analyze any sample configuration or phase, although liquids require appropriate calibration. The expected system costs for neutron activation analysis is high, and little is known regarding the other life cycle costs.

6.4 X-RAY FLUORESCENCE SPECTROMETRY

X-ray fluorescence (XRF) spectrometry is an established analytical method for elemental analysis. The basis of the X-ray fluorescence technique is that when an atom is bombarded with high-energy particles (e.g., X-ray photons), an inner orbital electron may be displaced, leaving the atom in an excited state. The atom can regain stability by rearrangement of the atomic electrons, and inner-shell vacancies may be filled with electrons from outer shells, causing emission of characteristic X-ray radiation that is then detected and measured.

X-ray fluorescence spectrometry is used for qualitative and quantitative elemental analysis. Field portable XRF analyzers are generally intended for solids, powders, liquids, and thin films or coatings. Analyses may be performed in situ, in the field, or in a laboratory environment. Some analyzers have sampling capabilities to also analyze liquids as well as particulates in air (by collecting on a filter). Samples may be analyzed with an in situ or on-site using the instrument as a bench-top analyzer.

Detection limits for XRFs vary, ranging from 10 to 100 ppm. Moisture content and particle size variation can interfere with (affect) intensity measurements. 20-30% moisture or more will lighten the mass of the matrix, and affect the detected signal. Particle size variations represents heterogeneity. Since the active area is only a couple of hundred micron or so thick, air gaps will introduce uncertainties in intensity measurements. For specific applications, the data analysis software can be customized to correctly interpret signals from media different than the standard ones developed by the vendor (e.g., soil and paint on walls). A number of well-characterized samples could be required for calibration.

The system cost for XRF spectrometry is expected to be approximately \$60,000. Operating cost is negligible, but sensors must be replaced every year or two, depending on the extent of use and handling. The equipment is expected to have a useful life in terms of years.

6.5 FIELD PORTABLE AND HAND-HELD GAS CHROMATOGRAPHS

Gas chromatography is a separation technique (using column separation) based on the differential interaction of volatilized sample components with a liquid, or sometimes a solid, stationary phase. As sample components are transported through a column containing the stationary phase by an inert carrier gas mobile phase, they distribute themselves between the two phases.

Analytes that are weakly retained by the stationary phase will exit the end of the column at nearly the velocity of the carrier gas. Compounds that interact strongly with the stationary phase will spend relatively more time in it, and emerge later from the column. Ideally, components of mixtures appear in separated bands at the end of the column, and can be detected and measured by a variety of detectors.

A Gas Chromatograph (GC) is the separator, and the accompanying detector determines the utility for chemical species quantification (e.g., mass spectrometer can be used to identify and quantify organics). A portable or hand-held GC could be used to detect, identify, and quantify toxic vapor. The utility for the WRAP application would be to identify volatile species in the vapor space of waste drums.

This technology is most useful for volatile species in the vapor phase. It is expected to be too complicated for unknown liquid or solid analyses, since identification and quantification of unknown matrices would require a mass spectrometer detector, increasing the complexity of the instrument. Detection limits of part per million, billion, and trillion are achievable depending on the injector, detector chosen, and background interference from local contamination. Accuracy depends on the type of injector, type of detector, type of sample, and sample preparation.

The system cost for this technology is expected to range from \$10,000 to \$35,000 depending on the options and accessories. The operating cost is expected to be low, while the maintenance cost is expected to be higher than most field instrumentation.

6.6 pH PROBE

Quick pH measurements of liquid can be made using hand-held pH analyzers. The key parameters are measured with a set of replaceable sensors connected with standard connectors to the hand-held portable meter. These analyzers are typically used for water and aqueous solutions. Hand-held and battery-operated units are available. After immersing the sensor in the liquid of interest, data is obtained almost immediately. Detection limits are in the range of 1-13 pH or ± 500 mV for pH, and the accuracy resolution for pH is 0.01 units with an accuracy of ± 0.02 pH units, or 1 mV $\pm 2\%$ mV.

System, operating, and maintenance are all expected to be low. The pH analyzers can be purchased for less than \$1,000. Additionally, sensors and electrodes are easily replaced, so the life expectancy is high.

6.7 PHOTOIONIZATION AND FLAME IONIZATION DETECTORS FOR GAS DETECTION

A flame ionization detector (FID) is used to detect many organic compounds. The detector measures only C-H containing molecules (oxidizable carbon atoms), and gives no response for water, carbon dioxide, or other organic compounds. The FID contains a small gas burner that produces a hydrogen flame, a polarizing voltage source, and an ion collector. Organic compounds are burned, ionic fragments and free electrons are formed. These fragments are collected, producing an electric current proportional to the rate at which the sample enters the flame. The signal from the mass sensitive

detector is amplified and processed, with the magnitude of the signal being directly proportional to the concentration of organics present. The detector/instrument has a unique response to each organic compound.

A photoionization detector operates in roughly the same manner, but uses an intense lamp instead of a hydrogen flame.

This technology is commonly used to detect flammable or potentially explosive environments to allow for safe operation or entry. The analyzers also are used for organic vapor monitoring/analysis in the laboratory or in the field. The instruments can be coupled with other instruments (e.g., gas chromatograph) for better quantification of mixtures of organic vapors. Speciation of organics is limited without this additional instrumentation. In industry, this technology is used for hazardous waste site investigation, landfill gas monitoring, leak detection of gas/fuel lines and networks, and occupation hygiene monitoring.

Detection limits are below 0.1 ppm, and system response time is between 2 and 3 seconds for the portable field instruments. Samples must be in the vapor/gas phase to be analyzed. System cost for this technology is expected to be approximately \$6,000 with a low operating cost.

6.8 COLORIMETRIC AND TITRIMETRIC METHODS

The basis for the technology is that the addition of a reagent to a sample will cause a color change that can be analyzed by a spectrophotometer (reflectance or transmission). The color change indicates the presence of the target analyte, and the hue and intensity can be compared to color standards to estimate the contaminant type and concentration.

Colorimetric tests are convenient field testing methods for soil and water analysis. The best application is water sampling, because other samples may require extraction. One possible limitation is the lack of developed analyte lists for soil and groundwater applications. The technology applicability to concentrated liquid waste is unknown, because the extractants available must be able to recover all of the target analytes in a sample for accurate analysis. Another significant limitation is the possibility of violent reactions between the test chemicals and expected WRAP 1 wastes (e.g., hydrazine). This would have to be addressed in the DQO Process and subsequent activities.

Detection limits are in the ppb and ppm ranges. When working with an unknown matrix, even thorough laboratory analysis is not extremely accurate. Colorimetric methods would be useful for qualitative analysis of solid and liquid waste samples. As a quantitative tool, this technology could be used to determine the minimum concentration of analyte in a sample matrix.

Colorimetric and titrimetric hardware is available for approximately \$1,000, resulting in a low system cost. Operating cost is also expected to be low. Chemicals within the test kits have a shelf life of approximately two years.

6.9 IMMUNOASSAY FIELD TEST KITS

The immunoassay technique relies on an antibody that is developed to have a high degree of sensitivity to the target compound. This antibody's high specificity is coupled with a sensitive colorimetric reaction that provides visualization of the result.

The immunoassay analysis starts when an enzyme conjugate is added to antibody-coated tubes. The target analyte, which may be present in a sample, competes with the enzyme conjugate for a limited number of antibody binding sites. After a washing step, the enzyme conjugate or target analyte bound to the antibody in the tube remains.

Substrate solution is added to produce a color. The intensity of the color formed is inversely proportional to the concentration of the target analyte in the sample. The Yes/No (presence/absence of target analyte) determination is made by comparing the color developed by an unknown sample to the color formed with the standard.

Immunoassay methods provide timely, cost effective, and accurate information on contamination levels of key pollutants. Applications that have been investigated and demonstrated include:

Soil and groundwater monitoring (for fuels) in the petrochemical industry and underground storage tank removal and remediation.

- PCB monitoring in contaminated soil.
- Polyaromatic hydrocarbon monitoring in the petrochemical, utility, and wood preserving industries.

To date, most of the applications have been field screening of soil and water/groundwater samples for organics (fuels, PCBs, and polyaromatic hydrocarbons [PAHs]). There is limited applicability currently to heavy metals (only a mercury test kit is currently available). Many immunoassay methods have been positively reviewed by the EPA. Detection limits range from ppb to ppm depending on the analyte of interest. The accuracy of this technology is considered qualitative and semi-quantitative. The EPA validation studies indicate that field tests can accurately identify 95% of samples that are contaminated at or above the chosen action level.

Typically solid, though liquid samples can be analyzed, the sample must be in a form that can be easily weighed and that all of the analytes of interest can be easily extracted using the vendor extractants. Four or five separate samples can be analyzed in less than one hour.

A test kit containing four single-use applications per kit is approximately \$500. The operating cost and maintenance cost also are considered low. Since the contents of the kits are disposed after use, new kits must continually be replaced.

6.10 FIELD PORTABLE FOURIER TRANSFORM RAMAN SPECTROMETER

Raman spectroscopy is a characterization method that produces spectral information used to identify molecules in solutions and solid materials. In Raman spectroscopy, light impinges on a sample and is scattered from it. The light which is scattered is dependent on the excitation source used. Therefore, Raman scattering may be observed at any laser frequency. This characteristic makes Raman-based techniques ideally suited for application with fiber optics because the source frequency can be tuned to favorable light transmission ranges for various fiber optic materials.

The basic setup of many Raman systems involves fiber optics to deliver and collect the radiation. A laser provides the light source that bombards the sample. The optical cables then collect both Rayleigh and Raman scattering. A filter rejects the Rayleigh scattering, and allows the Raman scattering to pass into a detector. In many cases, a charged coupled device detector is used to image the light which is dispersed by the monochromator. Fourier Transform Raman (FTR) provides the longest wavelength excitation possible by use of a Nd:YAG laser coupled with a germanium detector. This technique is known to eliminate fluorescence and interference from silica bands which are often observed at lower wavelengths. Raman scattering is used for several analytical techniques, including Resonance Raman Spectroscopy (RRS) and Surface Enhanced Raman Spectroscopy (SERS). Resonance Raman Spectroscopy is used to identify specific chemical species, and SERS is used to screen a wide variety of molecules. Portable SERS units have been reduced to suitcase size, and have ppm range detection capabilities for many compounds.

This technology can provide process monitoring, sample screening, qualitative and quantitative analysis of mixtures of four components or less, and molecular characterization. Solid inorganic salts, pure solvents and reagents, and concentrated solutions are detected by weight percent with a 20% qualitative accuracy. The hardware can be remote or bench top, requires a specialized half-time technician to operate, and analyzes a single sample in approximately two minutes.

The system cost is expected to be less than \$130,000. Operating cost is estimated to require the support of one full time equivalent and \$10,000 annually for fiber replacement. Vendor service contracts to supply maintenance are available for approximately \$4,000 per year.

6.11 FIELD GAS CHROMATOGRAPH/MASS SPECTROMETER

Field Gas Chromatograph/Mass Spectrometer (GC/MS) is typically a laboratory analytical method used for organic analysis, including speciation and quantification. Recent advances in field transportable GC/MS instruments now make it feasible to perform field environmental testing without the need for further laboratory confirmation. The gas chromatograph separates organics so the mass spectrometer can identify and quantify the organics in the sample. Volatile species on solid matrices can be thermally desorbed and injected into the GC/MS. Atmospheric samples can be directly sampled by the mass spectrometer. Liquid samples can be analyzed by direct head-space sample, purge-and-trap, or direct injection of samples prepared by extraction.

The primary application for this technology is quantitative analysis (including speciation) of organics (volatile and semi-volatile) in a variety of matrices (solid, liquid, and gas). Semi-volatiles are more difficult because extraction/sample preparation is required before injection into the GC/MS. This technology is a highly sensitive analytical method to detect organics. It is able to handle a variety of sample matrices and can identify/speciate volatile organics in unknown samples.

Volatile and semi-volatile organics are detected at a range of ppb to weight percent, but the instrument must be configured properly to the range of interest for accurate analysis. Samples can be liquid, solid, gas, or atmospheric samples. Accuracy is excellent, but will depend on the sample matrix and proper sampling and extraction procedures. Capacity depends on the level of sample preparation.

System cost is expected to range between \$150,000 and \$200,000. Operating cost is expected to be low, but maintenance cost is expected to be high. Life expectancy is still relatively unknown.

6.12 LASER ABLATION-INDUCTIVELY COUPLED PLASMA-ATOMIC EMISSION SPECTROMETRY (LA-ICP-AES) AND OTHER LASER ABLATION METHODS

Laser plasmas or optically-induced breakdown plumes are generated by focusing the output of a pulsed laser onto a small spot. The breakdown threshold is the minimum power density necessary for a plasma to form. Breakdown thresholds are generally on the order of several megawatts per square centimeter. The plasma causes breakdown of the target analyte, usually metals, and the sample can either be drawn into an instrument for analysis (e.g., ICP) or the emission from the plasma can be analyzed directly by a detector (monochromator). Direct measurement of a plasma is called Laser-Induced Breakdown Spectroscopy (LIBS). In LA-ICP-AES, a sample is ablated to the breakdown threshold, in the same manner as in LIBS, but the ablated sample is fed using a flow of argon into an ICP which then generates a spectrum based on the plasma. There is also LA-ICP with mass spectroscopy, where the ICP is used as the ion source for mass spectroscopy. Laser ablation-ICP-MS works well for metals analysis.

Field and in situ analysis of metals are the currently demonstrated applications. A majority of development of laser ablation analytical technologies are being developed in the national and federal laboratories. The spectroscopy technology is well developed, but the laser ablation method for sampling is still being developed. Field and portable instrumentation is being assigned at Los Alamos National Laboratories. This unit is suitcase size and is being fitted for fiber optic remote applications.

The intended application of this technology is chemical characterization of solids, typically metals (elemental analysis only). The analytes detected depend on the accompanying instrumentation, but the current applications are for metals analysis. Since the technology is relatively new, detection and accuracy is unknown and variable, but expected to be high. Life cycle costs are undetermined at this time, but are expected to be expensive.

6.13 BIOSENSORS

A biosensor is a biologically-active sensing element connected to a physical transducer of some type. The sensor can be prepared by coating, doping, or some other method, and the biological activity of this sensor is converted by a transducer into a signal which can be amplified and processed. "biologically-active" refers to techniques which use biochemical reactions as an indicator. For instance, the immunoassay field kits described in a separate sheet uses a biochemical reaction to produce a colorimetric change which can be detected and quantified. Other types of sensing elements have been, and are being, developed.

Biosensors can be divided into three categories based on the type of bioactive material employed: cell products, cell parts, and whole cells/organisms. Cell products include biochemicals, enzymes, and antigens/antibodies. Cell parts include cell membranes and receptor sites. And whole cells/organisms include proteins, bacteria, yeast, and other whole organisms. As an example, the enzyme electrode has very good specificity, and a number of researchers have developed it for environmental detection of organic contaminants (e.g., phenol). An enzyme catalyzes reactions in organic solvents to produce observable and quantifiable results.

The physical detection component of the biosensor systems (i.e., to translate the biosensor reaction to a signal that can be interpreted/quantified) can be chosen from electronic, mechanical, and optical systems. For instance, an amperometric biosensor measures the electric current across a membrane or directly at a reference electrode or other transducing surface. Piezoelectric detectors are popular mechanical components, and fiber optics are excellent optical detectors.

There are many types of biosensing systems and accompanying detection systems. The most common method for environmental applications are immunoassay field test kits which are described in a separate sheet. Interest in-situ sensing is increasing, and offers a high cost savings potential for reducing laboratory analysis. For in situ sensing, the sensors directly contact the material under investigation, and the biochemical reaction is detected, and the response signal is transmitted and analyzed.

Many biosensing technologies are used in biological and medical diagnostics applications. For environmental applications, biosensing methods have been developed for measuring organic contamination in water/groundwater; however, this technology is still mostly in the development stage for environmental applications, especially in situ applications.

Technology offers potential for detection of a wide range of contaminants, including metals, but currently detection is primarily for organics. The technology will not discriminate between isotopes. The technology is generally best for liquid applications. Detection is variable, but expected to be high. Accuracy is also expected to be high. Validation, calibration and data interpretation will be important. Life cycle costs are still unknown, but are expected to be low.

6.14 ION MOBILITY SPECTROMETER AND GC/IMS

Ion mobility spectrometry (IMS) is a method for detection of low level concentrations of organic vapors using gas phase ion mobilities in small drift tubes with weak electric fields. There are two steps in IMS, ion creation and ion separation. Molecules undergo ionization through proton or electron transfer in air at ambient pressure. The chemical ionization in air at atmospheric pressure results in robust ions that survive passage through an electric field and collisions with other species with little fragmentation. The ions are separated by differences in mobilities (drift times).

The primary information obtained from an ion mobility spectrometer is the mobility spectrum, which can be compared to reference spectra of known compounds for identification. With the addition of a GC, mixtures of organic vapors can be separated and analyzed.

The main application of IMS and GC/IMS is the detection, identification, and quantification of low concentrations of organic vapors in air. The technology is mostly in the research and development and applications development phase, and commercial off-the-shelf units are not yet available.

Samples need no preparation but must be in the gas phase, and detection limits are in the ppb range. Accuracy and capacity are expected to be excellent. Since the technology is relatively new, little information is available on life cycle costs.

6.15 FOURIER TRANSFORM INFRARED SPECTROMETERS

Fourier Transform Infrared (FTIR) Spectroscopy is an analytical technique sometimes used in conjunction with chromatography. In FTIR spectroscopy an interferometer which splits the light source and reflects it by means of mirrors. An interferogram is generated, representing the signal in the time domain. From the interferogram, a spectrum in the frequency domain is generated by means of a fourier transform algorithm.

Infrared spectroscopy is based on the physics that the vibrations of molecules in lattices result in small displacements of the atoms about their equilibrium positions. The energy levels in a lattice are quantized in each mode of vibration. The number of modes depends on the number of atoms in a molecule. An incoming photon having the correct energy will be absorbed and excite the lattice. The vibrational frequency of this excitation is characteristic of the molecule. In addition to the fundamental vibrational frequencies, combination bands (frequencies) can also be produced by the addition of frequencies from two different vibrational modes.

Fourier Transform Infrared is one of the fastest growing areas of analytical instrumentation development, with industrial applications driving technology development. It has many applications for detecting organics. Infrared (IR) spectroscopy is often not appropriate for analyzing complex matrices because of the elemental interferences with the signal. Fourier Transform Infrared spectrometry is much better in terms of sensitivity than dispersive IR. The technique works best for sampling and analysis of gaseous samples. No sample preparation is required for this application.

Fourier Transform Infrared analysis can be performed in two different ways: sampling with diffuse reflectance, or using attenuated total reflection sampling. Diffuse reflectance generally uses parabolic mirrors, and does not require sample contact.

Spectra-Tech Inc. has developed FTIR fiber optics for remote/field analysis. Applications include liquids and solids, with environments such as hazardous, corrosive, high/low temperature, high/low pressure. The technology can also be used for process and reaction monitoring.

Data is not yet available to estimate life cycle cost; however, system cost is expected to be medium while operation and maintenance cost is expected to be low.

6.16 OTHER FIELD PORTABLE OPTICAL/SPECTROSCOPIC METHODS

A number of optical methods have been, and are being developed for field and in situ use, including IR, FTIR, ultraviolet (UV), near infrared region (NIR), and Raman.

Other field instruments use a fiber-optic cable to sample the light field being measured. Light enters the end of the cable, and is split into three signals, one going to each of three spectrometers. The unit uses a silicon photodiode array overlaid with an order separation filter to measure the Visible/Near Infrared Region (VNIR) from 350 nm to 1000 nm, and two scanning spectrometers are used to measure the near infrared region from 1000 nm to 2500 nm. Measurement modes include reflectance, transmittance, absorbance, and transreflectance; the unit has a number of probes available, including a fiber-optic reflectance probe (for gas and solids analysis) and an immersible transmission probe (for liquid analysis). The data from the unit is downloaded to a portable personal computer for interpretation. Another field instrument utilizes a VNIR spectrometer and fiber-optic reflectance probe, but basically operates the same as the fiber-optic cable.

The following applications are identified for this technology:

- Mineral identification,
- Plant physiology,
- Ocean color,
- Medical diagnosis,
- Process control, and
- Analytical chemistry, and
- Gas/atmosphere analysis.

Detection includes analytes that absorb in the VNIR and NIR, mostly organics, water, and some gases. Solid, liquid, and gas samples can be analyzed, and the optical range covers 350 nm to 2400 nm. Accuracy is variable and will depend on a variety of factors, especially chemometrics software developed for data interpretation. Depending on the measurement mode and the type of probe used, this technology operates as a field sampling/analysis or in situ measurement method. Since no sample needs to be taken or prepared, capacity is rated as high.

The system cost is expected to be between \$50,000 and \$100,000 for hardware, but operating cost and maintenance cost are both expected to be low. Life expectancy is unknown, but expected to be high.

6.17 ION-SELECTIVE ELECTRODES

Determining the concentration of specific inorganic ion species with an electrode involves measuring the flow of ions across a membrane. Ion selective electrodes (ISE) are a type of electrochemical sensor, but is described separately in this section.

Solid-state (sealed) electrodes have a sensing membrane permanently mounted in the electrode tip. An ion potential develops across this membrane. Electrodes are available to measure a variety of ion species. Solid-state electrodes are resistant to most inorganic reagents, and can be used with some organic solvents. They require no filling solution, and can be stored dry, making them virtually maintenance free.

Gas sensing electrodes are used to measure gases dissolved in solution. A gas sensing electrode has a gas permeable/ion impermeable membrane. The dissolve gas diffuses across the membrane into a small volume of filling solution that is specific for each electrode. The gas of interest reacts with the filling solution, causing the pH of the filling solution to change. This change is detected by an internal pH sensing element.

Liquid membrane electrodes have a water-insoluble liquid ion exchanger held in place by an inert porous membrane. The membrane allows contact between the sample and the liquid ion exchanger, but minimizes mixing. There are two types of liquid membrane electrodes:

- Traditional liquid membrane, in which the electrodes contain a porous membrane that is soaked and saturated with the ion exchanger, and
- Plastic liquid ion exchange electrodes (or polyvinyl chloride [PVC] membrane electrodes), similar to the traditional liquid membrane, except that the sensing module is a non-porous PVC gel containing the ion exchanger.

This technology is primarily design to measure/monitor dissolved inorganics and gases in solution. The ISE is much like a pH probe/meter, because it is inserted in a liquid sample (or in situ) and a measurement is taken as soon as the reading stabilizes. Detection of analytes is variable, but generally in the ppb through ppm range, and as high as 0.1%. Accuracy depends on the sample matrix, but it is expected to more than adequate for field screening.

The system cost includes approximately \$1,000 for the pH/mV meter, and less than \$500 per ISE. Operating cost and maintenance cost are both expected to be low. Life expectancy is expected to be high depending on life of the electrodes.

6.18 CHEMICAL IDENTIFICATION FIELD TEST KITS

The HazCat Chemical Identification System is designed for the qualitative identification of unknown materials. HazCat kits are an emergency response tool designed specifically for on-site identification or categorization of virtually any spilled or abandoned material, liquid or solid. HazTech Systems Inc.'s HazCat system consists of 100 field tests which allows a non-chemist, having extensive training, to quickly and precisely identify or categorize chemical substances.

The HazCat system guides the user through a decision-tree process to final identification of the chemical hazard. The user simply follows step-by-step procedures in the manual. Test systems for both liquids and solids are part of the kit, and more than 100 tests can be run with the reagents provided to identify and categorize over 1,000 substances.

This technology will detect a wide range of analytes, including a variety of metals (e.g., Pb, Cr, Hg, Ni), anions (e.g., Cl⁻, F⁻, CN⁻), inorganic/organic acids, asbestos, ammonia, etc. The range of detection is generally about 50 ppm. The accuracy of this method is only qualitative, and will provide no quantitative analysis, except indicating analyte is above detection limit. The typical assay time is less than 20 minutes; thus, capacity is considered high.

The system cost for the HazCat kits is approximately \$3,000. The operating cost includes the replacement of reagents and hardware, but is expected to be low. Maintenance cost is negligible.

6.19 POLARIZED LIGHT MICROSCOPY

Inorganic salts form crystalline structures that are optically active. Because these structures can rotate polarized light they are referred to as intrinsically birefringent. In addition, structures consisting of elongated particles in a parallel array or stacked discs embedded in a medium whose refractive index differs from that of the structure exhibit form birefringence. This means that the structures will pass plane polarized light only if the plane of polarization is parallel to the long axis of the particles. This is true even if the particles are not intrinsically birefringent - that is, if the particles transmit polarized light with equal probability for all angles of incidence.

Substances that exhibit intrinsic or form birefringence are easily observed using a polarized light microscope, and detailed information about molecular architecture can be obtained in a relatively short time. Since various molecules have unique crystalline structures, sizes and internal architecture, this technique can be used analytically to determine the identity of inorganic salts and other molecules. Asbestos is easily viewed under a polarized light microscope. If the quantity and dilution of the sample placed on the microscope slide is known, it is possible to obtain a semi-quantitative estimates of analyte concentration.

The essential components of a polarizing light microscope are a polarizer held between the light source and the condenser; a rotating stage or sample holder; an analyzer, situated between the objective and the eyepiece, which can be set so that its axis is perpendicular to the polarizer axis; and a compensator. Because polarized light is partly depolarized by reflection and refraction, the condenser is adjusted so that the object is illuminated by nearly parallel light.

7.0 DESCRIPTION OF ALTERNATIVES TO THE WRAP 1 CHARACTERIZATION BASELINE

The following section identifies alternatives which include field screening equipment for use in WRAP 1 and serve as an alternate means of acquiring needed characterization data in a more efficient and economic manner than the existing WRAP 1 baseline. The alternatives were designed to provide a wholistic approach to analyzing for all expected analytes and waste matrices. Each alternative includes one or more of the analysis methods described in Appendix C.

These alternatives were generated and evaluated by a team whose members were selected for their knowledge of laboratory capabilities, analytical methods, field screening technologies and the WRAP 1 design. The process followed for this three-day technology evaluation session is documented in Appendix D. The conclusions from the session are summarized below. The baseline alternative, discussed in Section 6.0, was used for comparison and evaluation.

7.1 ALTERNATIVES CONSIDERED

This section describes the eight characterization strategy alternatives generated by the team. For a more detailed description of the field screening technologies included in each alternative, refer the respective part of . Note that relative capital costs were included for all pieces of equipment that would need to be purchased for WRAP 1 under that alternative. Alternative 1 has no additional costs associated with it as this alternative forms the basis for all of the others.

Alternative 1:

- WRAP 1 performs some field screening in the RWM glovebox to assure chemical compatibility to support safe storage. This compatibility testing includes: (1) pH indication with litmus paper or other means; (2) flammability testing with a Flame Ionization Detector (FID) or hot platinum wire sensor; (3) reactivity testing with universal reagent in small quantities (colormetric method); and (4) explosivity determination is dealt with administratively because it must be known prior to the sample analysis stage of the process.
- The laboratory performs field screening which serves as a quick screen as to whether a particular constituent is present in the sample. The laboratory also performs full analysis as needed.

Alternative 2:

- WRAP 1 performs compatibility testing as defined in Alternative 1. In addition, WRAP 1 videotapes the sorting process and performs preliminary screening using the following equipment: (1) FT Raman for detection of volatile/semi-volatile organics, soluble salts and inorganic acids ($\approx$ \$120K); (2) XRF for detection of metals ($\approx$ \$15K); and (3) Polarized Light Microscope (PLM) for detection of asbestos ($\approx$ \$5K). The capital costs total $\approx$ \$140K.

- The laboratory performs full analysis as needed.

Alternative 3:

- WRAP 1 performs compatibility testing as defined in Alternative 1. In addition, WRAP 1 videotapes the sorting process and performs preliminary screening using the following equipment: (1) FT Raman for detection of volatile/semi-volatile organics, soluble salts and inorganic acids ($\approx$ \$120K); (2) XRF for detection of metals ($\approx$ \$15K); and (3) Polarized Light Microscope (PLM) for detection of asbestos ($\approx$ \$5K). The capital costs total $\approx$ \$140K.

To this point, this Alternative is identical to Alternative 2, however, Alternative 3 goes one step further and incorporates customized spot testing (e.g., thin layer chromatography, colormetrics) capabilities in WRAP 1. These tests are specific to a batch(es) and are selected based on information available from the generator, information gathered from previous processing steps (e.g., trench-side testing at the point of retrieval), and knowledge gathered from previous batch processing in WRAP 1. No capital costs are associated with customized spot tests.

- The laboratory performs full analysis as needed.

Alternative 4:

- WRAP 1 performs compatibility testing as defined in Alternative 1. WRAP 1 also performs customized spot tests (e.g., thin layer chromatography, colormetrics) specific to a batch(es) and selected based on information available from the generator, information gathered from previous processing steps (e.g., trench-side testing at the point of retrieval), and knowledge gathered from previous batch processing in WRAP 1. No capital costs are associated with customized spot tests.
- The laboratory performs field screening which serves as a quick screen as to whether a particular constituent is present in the sample. The laboratory also performs full analysis as needed.

Alternative 5:

- WRAP 1 performs compatibility testing as defined in Alternative 1. In addition, WRAP 1 videotapes the sorting process and performs preliminary screening using the following equipment: (1) XRF for detection of metals ($\approx$ \$15K); (2) Polarized Light Microscope (PLM) for detection of asbestos ($\approx$ \$5K); and (3) FTIR Spectroscopy ($\approx$ \$50K). The capital costs total $\approx$ \$70K.
- The laboratory performs full analysis as needed.

Alternative 6:

- WRAP 1 performs compatibility testing as defined in Alternative 1. In addition, WRAP 1 videotapes the sorting process and performs preliminary screening using the following equipment: (1) FT Raman

for detection of volatile/semi-volatile organics, soluble salts and inorganic acids ($\approx$ \$120K); (2) XRF for detection of metals ($\approx$ \$15K); (3) Polarized Light Microscope (PLM) for detection of asbestos ($\approx$ \$5K); and (4) FTIR Spectroscopy ($\approx$ \$50K). The capital costs total $\approx$ \$190K.

- The laboratory performs full analysis as needed.

Alternative 7:

- WRAP 1 performs compatibility testing as defined in Alternative 1. In addition, WRAP 1 videotapes the sorting process and performs preliminary screening using the following equipment: (1) XRF for detection of metals ($\approx$ \$15K); (2) Polarized Light Microscope (PLM) for detection of asbestos ($\approx$ \$5K); and (3) Gas Chromatography Flame Ionization Detector ($\approx$ \$40K). The capital costs total $\approx$ \$190K.
- The laboratory performs full analysis as needed.

Alternative 8:

- WRAP 1 performs compatibility testing as defined in Alternative 1. In addition, WRAP 1 videotapes the sorting process and performs preliminary screening using the following equipment: (1) Ion Chromatography (IC) for anions and organic acids ($\approx$ \$85-95); (2) Inductively Coupled Plasma (ICP) for metals ($\approx$ \$30); (3) Gas Chromatography Flame Ionization Detector ($\approx$ \$40K); and (4) Polarized Light Microscope (PLM) for detection of asbestos ($\approx$ \$5K). The capital costs total $\approx$ \$160-170K.
- The laboratory performs a small amount of analysis as needed.

This page intentionally left blank.

8.0 COMPARISON AND ASSESSMENT OF ALTERNATIVES

This section presents the results alternatives evaluation conducted as part of the three-day technology evaluation session.

8.1 CRITERIA FOR THE EVALUATION OF ALTERNATIVES

Objective criteria were used to assess each of the alternatives identified in Section 8.0. The evaluation team's objective was to reduce analytical cost, improve analytical efficiency and minimize impact to the WRAP 1 design. These objectives are reflected in the following criteria the team selected for the alternatives evaluation effort.

- 1) Cost: Capital Equipment Not Related To Construction costs associated with analytical equipment in WRAP 1.
- 2) Size of Equipment: Physical size of analytical equipment in WRAP 1; Equipment compatibility with existing glovebox arrangement and floor plan.
- 3) Training and Expertise to Operate: Extent to which specialists, certified/qualified operator, procedures, etc. are required to operate the equipment.
- 4) Handling: Required packaging, shipping, transportation and transfers within facility (of sample); sample preparation in WRAP 1 glovebox to allow transfer out of glovebox; ALARA considerations.
- 5) Sample Turnaround: Rate at which WRAP 1 receives analysis results.
- 6) Secondary Waste Generation: Waste generated from analysis activities conducted in WRAP 1.
- 7) Compatibility with Facility Operations: Sensitivity to WRAP 1 environment (e.g., humidity, dirt, vibrations, radiation, etc.)
- 8) Project Impact: Degree to which implementation of alternative impacts project cost and schedule.
- 9) Maturity: Level of equipment development required.
- 10) Total Analysis Done in WRAP 1: Relative amount of characterization performed in WRAP 1 as compared to that conducted in a laboratory.
- 11) Cost Per Sample: Cost incurred by WRAP 1 for analysis of a sample. This includes manhours to perform characterization, and to calibrate and maintain the equipment.

8.2 EVALUATION OF ALTERNATIVES

After criteria were selected, each was assigned a value to reflect its relative importance with respect to the other criteria (referred to as the relative weight). The baseline and each of the eight alternatives were evaluated against each criteria and assigned a ranking for each. This ranking reflected the degree to which a given alternative met the criteria on a scale of 1 to 10 (1 = poor; 10 = excellent). The summation of the ranking multiplied by the respective relative weight resulted in a total score for each alternative. The results of this process are shown in Table 9, Evaluation Matrix.

Table 9. Evaluation Matrix.

FUNCTION FOR STUDY: CHARACTERIZE WASTE IN WRAP 1	ALTERNATIVES									
	Relative Weights	Baseline	Compat. Testing in WRAP 1	Compat. Testing/ Raman/ XRF/PLM in WRAP 1	Compat. Testing/ Raman/XRF/ PLM/Cust. Spot Tests in WRAP 1	Compat. & Cust. Spot Tests in WRAP 1	Compat. Testing/ XRF/ FTIR/PLM in WRAP 1	Compat. Testing/ XRF/FTIR / PLM/FT Raman in WRAP 1	Compat. Testing/ PLM/XRF/ GC FID in WRAP 1	Compat. Testing/ IC/ICP/ GC FID/ PLM in WRAP 1
CRITERIA		0	1	2	3	4	5	6	7	8
1. Cost (Equipment Only)	5	10/50	10/50	6/30	6/30	10/50	8/40	4/20	8/40	4/20
2. Size of Equipment	5	10/50	10/50	6/30	6/30	10/50	8/40	4/20	6/30	2/10
3. Training/Expertise to Operate	10	10/100	8/80	6/60	6/60	7/70	6/60	4/40	6/60	2/20
4. Handling	10	2/20	3/30	7/70	7/70	7/70	7/70	7/70	5/50	4/40
5. Sample Turnaround	10	2/20	2/20	5/50	6/60	3/30	6/60	8/80	7/70	10/100
6. Secondary Waste Generation	5	10/20	9/45	8/40	8/40	8/40	8/40	8/40	5/25	4/20
7. Compatibility with Facility Operations	15	10/150	10/150	5/75	5/75	9/135	5/75	5/75	4/60	2/30
8. Project Impact (Sched/Cost)	10	10/100	10/100	6/60	6/60	10/100	6/60	6/60	4/40	2/20
9. Maturity	15	10/150	9/135	6/90	6/90	7/105	3/45	4/60	7/105	9/135
10. Total Analysis Done in WRAP 1	5	2/10	3/15	5/25	6/30	4/20	6/30	7/35	7/35	9/45
11. Cost per Sample	10	1/10	2/20	7/70	8/80	9/90	7/70	7/70	7/70	3/30
TOTAL		710	695	600	625	760	590	570	585	470
FINAL RANKING		2	3	5	4	1	6	8	7	9

KEY: EXCELLENT = 10, VERY GOOD = 8, GOOD = 6, FAIR = 4, POOR = 1

The rating for each criterion is noted in an x/y format where x refers to the raw score shown in this key and y is the raw score multiplied by the relative weight factor.

This page intentionally left blank.

9.0 DISCUSSION OF THE PREFERRED ALTERNATIVE

Based on the results of the evaluation described in Section 8.2, Alternative 4 is the preferred alternative. It received the highest ranking of 760, followed closely by the Baseline with a ranking of 710 and Alternative 2 with a ranking of 695. Like the baseline, Alternatives 2 and 4 provide very little analytical capability within WRAP 1 and are dependent on external laboratories to conduct a large amount of the analysis supporting WRAP 1 characterization. The remaining alternatives included increased analytical capabilities within WRAP 1 that would require WRAP 1 design modifications and additional staffing to provide the analytical expertise need. In addition, laboratory analysis would still be required should regulated analytes be detected in the waste.

Use of an external laboratory provides the following advantages over a WRAP 1 in-facility laboratory approach.

- The most prominent advantage is that no design changes are required to implement these top three alternatives. Other alternatives which incorporate analysis equipment within WRAP 1 are constrained by the existing design (e.g., floor plan, glovebox configuration, operator space, traffic patterns, etc.).
- In addition cost per sample remains constant as the number of samples decrease, whereas in a WRAP 1 laboratory scenario, the cost per sample will actually increase as the number of samples decrease since the same number of staff and the same amount of maintenance is required regardless of the number of samples to be processed.
- WRAP 1 personnel can remain focused on operations and need not be sidetracked with laboratory issues that may arise.
- Expertise remains localized within an external laboratory. In the WRAP 1 laboratory scenario, there could conceivably be just one chemist working in WRAP 1. This work situation provides minimal opportunity for interaction with others in the same field.
- Since laboratories manage all waste generated from the analysis work they conduct, this reduces the secondary waste burden to WRAP 1.

Like Alternative 1, the preferred alternative (Alternative 4) incorporates compatibility testing into WRAP 1. Although incompatible wastes have always been prohibited in the same waste container, this was viewed as an added assurance that the waste could be safely stored while awaiting full analytical results.

In addition to compatibility testing, the preferred alternative incorporates customized spot testing into WRAP 1. This testing will be performed in the Restricted Waste Management gloveboxes and serves to reduce the number of samples sent to an external laboratory for analysis. This approach takes full advantage of the process knowledge that can be gained through operation of the WRAP 1 facility. Initially, most samples will be

sent to the external laboratory for analysis, but through operational experience, more and more information about the waste will be made available. It will become possible to identify mutually exclusive and mutually inclusive constituents and to make correlations between NDE results and chemical content. All this information provides for a statistical means of eliminating what could be in a given waste, or said another way, it provides a means of defining what will be in a given waste. It is at this point that spot tests can be customized for a given batch as a screening mechanism. This approach to screening is very flexible because as batch characteristics change, the spot tests can be modified accordingly. There is no equipment, and therefore, no capital cost associated with this approach.

As previously indicated, Alternative 4 was intended for application in the RWM gloveboxes. Actually, the team had focused primarily on the RWM gloveboxes when generating and evaluating all eight alternatives. At the conclusion of their evaluation effort, they questioned whether the preferred alternative, or any alternative developed, could be applied to the process gloveboxes. In considering this, it was noted that the process gloveboxes have less space for additional equipment than do the RWM gloveboxes. The physical features of the process gloveboxes (e.g., the slanted sort table designed to collect liquids) also limit the types of analysis that can be conducted within these gloveboxes.

It is in the process gloveboxes that restricted waste items such as containerized liquids or solids, HEPA filters, gas cylinders, and aerosol cans are removed from the waste stream and repackaged for processing in the RWM gloveboxes. The waste that remains is the heterogeneous waste such as debris wastes (rags, plastic, etc.) and some adsorbents and soils. It is this remaining waste that is sampled within the process glovebox.

The samples taken within the process glovebox account for 31% of the samples being addressed by this study or approximately 27% of the samples being taken in WRAP 1. In addition, most contaminants must be present at greater than one weight percent in order for a container contents to be regulated. Using visual inspection to detect obvious heterogeneous waste contamination and incorporating a weigh scale into the process glovebox would allow for a rapid decision as to the regulatory status of many of the debris wastes. It is recognized that soil and absorbent waste would still require sampling.

The team concluded that in addition to the discrete sampling of obviously contaminated area present in regulated quantities, 10% random sampling of a given waste stream should be conducted. The need to add a weigh scale inside the main process gloveboxes was identified. A statistical approach would be used for determining the rate at which random sampling would continue. Over time, incorporation of this strategy would significantly reduce the number of process glovebox samples. It was concluded that the remaining number of process glovebox samples could be repackaged and screened using the customized spot testing in the RWM gloveboxes without impacting RWM glovebox operation.

10.0 REFERENCES

- AEC, 1970, *Immediate Action Directive 0511-21*, U.S. Atomic Energy Commission, Washington, D.C.
- AEC, 1973, *Atomic Energy Commission Manual*, Chapter 0511, "Radioactive Waste Management," U.S. Atomic Energy Commission, Washington, D.C.
- Ball, D. E., J. K. Keve, and J. R. Weber, 1994, *Nondestructive Examination Equipment in the Hanford WRAP 1 and Retrieval Projects*, WHC-SA-2327-S, Westinghouse Hanford Company, Richland, Washington.
- Crawford, B. A., 1994, *Drum Sampling and Analysis Instrumentation for the Field*, WHC-SD-WA-QAPP-022, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- DOE, 1982, *Management of Transuranic Material*, DOE Order 5820.1, U.S. Department of Energy, Washington, D.C.
- DOE, 1987, *Code of Federal Regulations*, Part 962, 52 *Federal Register*, 159397-1592, "Radioactive Waste, By-Products Material Final Rule," Title 10, U.S. Department of Energy, Washington, D.C.
- DOE, 1988, *Radioactive Waste Management*, DOE Order 5920.2A, U.S. Department of Energy, Washington, D.C.
- DOE, 1991, *Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, WIPP-DOE-069, Rev. 4, Washington, D.C.
- DOE-RL, 1993, *Waste Analysis Plan for Confirmation or Completion of Tank Farms Backlog Waste Designation*, DOE/RL-93-70, Revision 1, U.S. Department of Energy, Richland, WA.
- Duncan, D. R., 1990, *Solid Waste Management Program Plan*, WHC-EP-0363, Westinghouse Hanford Company, Richland, Washington.
- Duncan, D.R., et al., 1993, *Characterization of Past and Present Solid Waste Streams from the Plutonium Finishing Plant*, WHC-EP-0621, Westinghouse Hanford Company, Richland, Washington.
- Duncan, D. R., 1994a, *Radioactive Waste Shipments to Hanford Retrievable Storage from Babcock and Wilcox, Leechburg, Pennsylvania*, WHC-EP-0719, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- Duncan, D. R., 1994b, *Radioactive Waste Shipments to Hanford Retrievable Storage from Westinghouse Advanced Reactors and Nuclear Fuels Divisions, Cheswick, Pennsylvania*, WHC-EP-0718, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- Ecology 1991, *Washington Administrative Code*, "Dangerous Waste Regulations," Chapter 173-303, Washington State Department of Ecology, Olympia, Washington.

- EPA, 1986, *Test Methods for Evaluating Solid Waste*, SW-846, Third Edition, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.
- EPA, 1992, *Code of Federal Regulations*, Title 40 Parts 260 to 299, U.S. Environmental Protection Agency, Washington, D.C.
- Gilles, W. P., 1993, *Solid Waste Projects Nondestructive Assay/Nondestructive Examination Review*, Internal Memo #87330-93-WPG-026 REV 2, Westinghouse Hanford Company, Richland, Washington.
- Gilles, W. P., 1994, *Solid Waste Projects Nondestructive Assay/Nondestructive Examination Review*, WHC-SD-WM-ER-285 Rev 0, Westinghouse Hanford Company, Richland, Washington.
- Johnson, D. M., 1992, *Solid Waste Retrieval Facility Phase 1, Project W-113*, WHC-SD-W113-FDC-001 REV 1, Westinghouse Hanford Company, Richland, Washington.
- Joyce, J. P., June 1993, *Radioisotopic Characterization of Retrievably Stored Transuranic Waste Containers at the Hanford Site*, WHC-SD-WM-TI-517, Revision 1, Westinghouse Hanford Company, Richland, Washington.
- Mayancsik, B. A., 1994, *Waste Receiving and Processing Facility Module 1 Functional Design Criteria*, WHC-SD-W026-FDC-001, Revision 2, Westinghouse Hanford Company, Richland, Washington.
- Olson, W. W., 1994, *Waste Receiving and Processing Facility Module 1 Preliminary Safety Analysis Report*, WHC-SD-W026-SAR-001, Revision 1, Westinghouse Hanford Company, Richland, Washington.
- Ocampo, V. P., 1993, *Project W-113 Drum Venting and Head Gas Sampling System*, WHC-SD-W113-ES-003 REV 0, Westinghouse Hanford Company, Richland, Washington.
- Pottmeyer, J. A., et al., 1993a, *Characterization of Past and Present Solid Waste Streams from the Plutonium-Uranium Extraction Plant*, WHC-EP-0646, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- Pottmeyer, J. A., et al., 1993b, *Characterization of Past and Present Solid Waste Streams from 231-Z*, WHC-EP-0659, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- Pottmeyer, J. A., et al., 1993c, *Characterization of Past and Present Solid Waste Streams from the 325 Radiochemistry Building*, WHC-EP-0696, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- Pottmeyer, J. A., NOT RELEASED YET, *A Review of Chemicals for Inclusion in the W-112 Source Term*, WHC-IP- , Westinghouse Hanford Company, Richland, Washington.
- Reddinger, R. W., 1992, *Unstable and Reactive Chemicals in TRU Retrievable Waste*, WHC-IP-0813, Westinghouse Hanford Company, Richland, Washington.

- Sexton, R. A., 1992, *Waste Receiving and Processing Facility, Module 1, Characterization and Process Alternatives Study*, WHC-SD-W026-ES-009, Rev 0, Westinghouse Hanford Company, Richland, Washington.
- Sexton, R. A., 1993, *An Approach for Sampling Solid Heterogeneous Waste at Hanford's WRAP & Solid Waste Projects*, Westinghouse Hanford Company WHC-SA-1789-FP, Westinghouse Hanford Company, Richland, Washington.
- Sexton, R. A., 1993, *Characterization Parameters Requiring Sampling Analysis*, WHC-SD-W026-ES-009, Revision 0, Westinghouse Hanford Company, Richland, Washington.
- Valero, O. J., et al., 1993, *1993 Solid Waste Reference Forecast Summary*, WHC-EP-0567-1, Westinghouse Hanford Company, Richland, Washington.
- Vejvoda, E. et al., 1993, *Radioactive Waste Shipments to Hanford Retrievable Storage from the General Electric Vallecitos Nuclear Center, Pleasanton, California*, WHC-EP-0672, Westinghouse Hanford Company, Richland, Washington.
- Weidert, J. R., 1993, *Supplemental Design Requirements Document - Project W-026*, WHC-SD-W026-SDRD-001, Revision 3, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1992, *Standard Engineering Practices: Engineering Studies*, WHC-CM-6-1, Appendix C, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Willis, N. P., 1993, *Hanford Site Solid Waste Acceptance Criteria*, WHC-EP-0063, Revision 4, Westinghouse Hanford Company, Richland, Washington.
- Wood, M. I., 1992, *Status of Performance Assessment Studies for the Disposal of LLW in the 218W5 Burial Ground, 200W Area*, WHC-SA-1365-FP, Westinghouse Hanford Company, Richland, Washington.

**Appendix A: FACT SHEETS FOR MAJOR GENERATORS OF SOLID TRANSURANIC
WASTES RETRIEVABLY STORED AT THE HANFORD SITE**

Appendix A contains fact sheets for the major generators of solid transuranic (TRU) wastes retrievably stored at the Hanford Site. Fact sheets are designed to provide a quick overview of the types of wastes expected from each of the following facilities:

- Plutonium Finishing Plant (PFP);
- Plutonium-Uranium Extraction (PUREX) Plant;
- Plutonium Metallurgy Building (231-Z);
- 325 Laboratory;
- General Electric Company's Vallecitos Nuclear Center;
- Babcock and Wilcox's Leechburg, PA facility; and
- Westinghouse Electric Corporation's Advanced Reactor and Nuclear Fuels Divisions.

These major generators account for approximately 86% of the retrievably stored waste that will be sent to WRAP-1.

Data contained in Appendix A were provided by characterization documents as referenced at the end of each fact sheet. Information compiled in these documents is derived from historical documents, the Solid Waste Information and Tracking System (SWITS) database, and interviews with knowledgeable individuals.

Data tables in each fact sheet identify physical constituents, hazardous constituents, and radioisotopes present in the retrievably stored solid waste from each of the major generators included in this study. The estimated number of 55-gal drums retrievably between 1970 and 1992 are listed under each constituent category.

The foundation of the data contained in each fact sheet is dependent on the quality of historical records and recordkeeping requirements at the time when the wastes were generated. The year of generation is important because recordkeeping requirements have become significantly more inclusive over time. Some information is lost, such as the exact physical constituents, since recording that information was not required until 1978. This information is reflected in the tables as physical constituents labeled miscellaneous, unknown, or other. In addition, hazardous constituents were not required to be listed until 1986; therefore, the lists provided in Appendix A do not include all currently regulated materials present nor are the number of drums listed the only containers likely to contain a given chemical. The information provided in this table should be used only to indicate the relative likelihood that the listed chemicals also will occur in drums stored prior to 1986.

Plutonium Finishing Plant TRU Solid Waste Fact Sheet

• **General Description of the Waste** - Between 1970 and 1991, 21,296 55-gal drums of transuranic (TRU) solid waste were shipped from the PFP to retrievable storage at Hanford. These wastes were generated primarily as a result of plutonium processing, maintenance, housekeeping, and waste processing.

• **Packaging** - The following containers were used for disposal of TRU waste generated at the PFP: DOT 17C or 17H galvanized 55-gal drums; plywood boxes coated with fiberglass reinforced polyester (FRP); burlap, cloth, paper, or plastic bags; concrete, fiberboard, metal, plastic, or wooden boxes; fiberboard, plastic, wooden, or metal cartons; fiberboard, plastic, wooden, or metal cases; and metal drums, barrels, or kegs.

• **Contents** - The general types of waste generated during processing include dissolver heels; graphite molds; tantalum crucibles and funnels; ceramics; furnace insulation; and spent machine tools, fixturing and gauging. Maintenance activities generated solid waste such as spent and failed processing equipment, piping, tubing, flanges, fitting, valves, traps, vessels, furnaces, hot plates, leaded glove box windows, bolts, nuts, straps, screws, nails, wire, connectors, broken tools, and various sheet metal items. The majority of the solid waste, produced by the PFP, were related to housekeeping. These include rags, paper cartons, high efficiency particulate air (HEPA) filters, gloves and plastic bags. Waste processing activities generated additional mixed wastes including spent tributylphosphate TBP extraction solvent and spent caustic scrubber (potassium hydroxide) solution.

• **Physical Constituents**

Constituent	Number of Drums
Metal/Iron/Galvanized/Sheet	8,160
Misc/Unknown/Other	3,671
Absorbant/Kitty Litter/Vermiculite	298
Aluminum	7
Asbestos	37
Ashes	132
Cement	30
Ceramics	12
Cloth/Rags/Nylon	11,129
Concrete	133

Constituent	Number of Drums
Conwed Pads	121
Copper Metal	15
Cork	230
Dirt/Soil/Diatomaceous Earth	3,780
Fiberglass	19
Filters	26
Floor Sweeps	14
Floor Tile	4
Foam/Styrofoam	4
Glass	4,757
Leather	49
Oils	111
Organics	114
Paints/Lucite	26
Paper/Cardboard	16,181
Plastic/Polyurathane	18,674
Plexiglass	18
Resins	7
Rubber	15,876
Sand	17
Silica Sel	39
Sludges	52
Stainless Steel	209
Teflon	8
Wood/Lumber/Plywood	588
Batteries	5
Brick/Firebrick	1
Carborundum	5
Graphite	1
Grout	2
Insulation Non-Asbestos	6

Constituent	Number of Drums
Lead	193
Lead Shielding	15
Mercury	5
PCB	5
Chemicals	5

Hazardous Constituents

Hazardous constituents were not required to be listed until 1986. The records for these drums are dated 1970-91; therefore, the list below may not include all currently regulated materials present. Of the 21,296 drums of TRU waste from the PFP, 132 drums (0.62%) are listed as containing mixed waste.

Hazardous Constituents	Number of Drums	Notes
Acetone		Used in Analytical Laboratory
Asbestos	31	Insulation
Benzene		Used in early 1970's in Analytical Laboratory
Copper	4	Metals
Corrosive	3	Analytical chemicals
Oil	21	Various types
Organic	5	Absorbed on various media
Acid	1	Analytical chemical
Aluminum Nitrate Monohydrate	1	Analytical chemical
Barium	23	Analytical chemical
Beryllium	10	
2-Butoxyethanol	1	
Cadmium	23	Analytical chemical
Calcium Chlorofluorophosphate	2	Analytical chemical
Carbon tetrachloride	10	Process and Analytical chemicals
Chromium	2	Process chemical

Hazardous Constituents	Number of Drums	Notes
Lead	67	Shielding material
Lead Acid	5	Process chemical
Lead Chromate	24	Process chemical
Lead Chromate Oxide	2	Process chemical
Lead Chromate, Chlorin Paraffin	4	Process chemical
Lead Chromates	1	Process chemical
Mercury	24	Analytical chemical
Phosphoric Acid	1	
Potassium Hydroxide	7	Analytical chemical
Selenium	1	Analytical chemical
Sulfuric Acid	3	Analytical chemical
Tributyl Phosphate	9	Process chemical
Trimethyl-benzene	1	
Zylene	2	
Amercoat 234	1	Process chemical
Hydraulic Fluid	16	
PCB	41	Used in electrical components
Sodium Hydroxide	1	Process and Analytical chemical

• Radioisotopes Present

Isotopes	Number of Drums
Pu	21,047
Uranium-Enriched	7
Am-241	19
Np-237	71
U-233	150
Pu-238	22
Th-232	1

Isotopes	Number of Drums
Uranium-Depleted	32
Uranium-Natural	27
Pu-239	10
Pu-240	10
Pu-241	10
Pu-242	10

For More Information

Pottmeyer, J.A., E.J. Vejvoda, J.A. Reddick, K.M. Sheldon, and M.I. Weyns, and D.R. Duncan, 1993, *Characterization of Past and Present Solid Waste Streams from the Plutonium Finishing Plant*, WHC-EP-0621, Westinghouse Hanford Company, Richland, WA.

Plutonium Uranium Extraction (PUREX) Plant TRU Solid Waste Factsheet

• **General Description of the Waste** - Between 1970 and 1992, 4,005 55-gal drums of TRU solid waste were generated by the PUREX Plant. The PUREX process was designed to separate uranium, plutonium, neptunium, and fission products present in irradiated fuel elements from the Hanford site reactors. The constituents were separated and purified by a solvent extraction process using an organic phase TBP dissolved in a normal paraffin hydrocarbon (NPH) and a nitric acid aqueous phase.

• **Packaging** - The TRU waste generated at the PUREX Plant was packaged in DOT 17C or 17H painted or galvanized 55-gal drums as well as in a number of other container types. Prior to the requirement for galvanized drums (circa 1982), drums were painted for identification using the following color code: low level waste (LLW) drums were indicated with black paint and a black dome, drums containing combustible waste with <0.5 g of TRU nuclide per drum were

indicated with black paint and a silver dome, drums containing combustible waste with >0.5 g of TRU nuclide per drum were indicated with black paint and a yellow dome, and drums containing non combustible TRU waste were indicated with red paint and a red dome.

• **Contents** - The TRU waste generated from the process lines falls into five groups: spent and failed equipment and tools; housekeeping and glovebox maintenance items, such as rags, plastic bottles, wipes, cardboard containers, HEPA prefilters, gloves, and cutout plastic bags; ventilation HEPA filters; demolition and major equipment removal, such as gloveboxes, tanks, and piping; and processing items, such as filters, drum filter cloth, contaminated lubricant, and other miscellaneous items.

Solid waste was also generated by the analytical laboratory in the form of contaminated apparatus, equipment, waste rags, paper, cardboard, rubber gloves, etc.

• **Physical Constituents**

Constituent	Number of Drums
Metal/Iron/Galvanized/Sheet	425
Misc/Unknown/Other	3,215
Absorbant/Kitty Litter/Vermiculite	50
Aluminum	10
Cloth/Rags/Nylon	481
Concrete	1
Conweb Pads	3
Copper Metal	20

Constituent	Number of Drums
Cork	3
Cotton/Kotex	23
Equipment	1
Filters	4
Floor Tile	11
Glass	207
Lead	2
Leather	3
Paper/Cardboard	418
Plastic/Polyurathane	639
Plexiglass	3
Rubber	315
Stainless Steel	157
Teflon	2
Wood/Lumber/Plywood	127
Brick/Firebrick	1
Lead	23
Chemicals	3

• **Hazardous Constituents**

Hazardous constituents were not required to be listed until 1986. The records for these drums are dated 1970-92; therefore, the list below may not include all currently regulated materials present. Of the 4,005 drums of TRU waste from the PUREX plant, 185 drums (4.6%) are listed as containing mixed waste.

Hazardous Constituents	Number of Drums	Notes
Copper	6	Metal
Barium	2	Process by product
Cadmium	3	Process by product and chemical
Calcium Chlorofluorophosphate	1	Process chemical

Hazardous Constituents	Number of Drums	Notes
Carbon tetrachloride		Process and Analytical chemical
Caustic	1	
Chloroform	1	
Cyclohexane	1	
Lexane	1	
Kerosene		Process chemical
Lead	167	Shielding material
Mercury	3	From manometers
Nitric Acid	85	Process and Analytical chemical
Sodium Hydroxide	104	Process chemical
Tributyl Phosphate		Process chemical
Thenoyl Trifouoroacetone		Analytical reagent
Sodium Hydroxide		Process and Analytical chemical
Triisooctylamine		Process chemical
Trioctylphospine		Process chemical
Xylene		Process chemical

• Radioisotopes Present

Isotopes	Number of Drums
Pu	3,968
Am-241	3
Pu-238	3
Uranium-Natural	5
Pu-239	3
Pu-240	3
Pu-241	3
Pu-242	2

Isotopes	Number of Drums
Ce-141	1
Ta-182	1

For More Information

Pottmeyer, J.A., M.I. Weyns, D.S. Delorenzo, E.J. Vejvoda, and D.R. Duncan, 1993, *Characterization of Past and Present Solid Waste Streams from the Plutonium-Uranium Extraction Plant*, WHC-EP-0646, Westinghouse Hanford Company, Richland, WA.

231-Z TRU Solid Waste Fact Sheet

• **General Description of the Waste** - Between 1969 and 1988, 1,360 55-gal drums of TRU solid waste were shipped from the Plutonium Metallurgy Laboratory (231-Z) facility to retrievable storage at Hanford. These wastes were generated primarily as a result of research and development programs utilizing plutonium. Some of the sources of solid waste generation include: general weapons development, process waste from glove boxes, numerous classified research and development programs, advanced decontamination and decommissioning technologies, general laboratory procedures, foundry area, housekeeping activities, and four clean out campaigns.

• **Packaging** - The following containers were used for disposal of TRU waste generated at the 231-Z facility: DOT 17C or 17H galvanized 55-gal drums; plywood boxes coated with FRP; burlap, cloth,

paper, or plastic bags; concrete boxes; metal drums, barrels, or kegs; metal boxes, cartons, and cases; and wooden boxes, cartons and cases. Some items were disposed of or stored without additional packaging, such as trucks, flatbeds, compactors, loadluggers, glove boxes, HEPA filters, self-contained equipment, and miscellaneous scrap.

• **Contents** - The general types of waste generated during routine operations included contaminated materials and equipment (such as tools, glove box sections, ductwork, and refrigeration equipment and reservoirs), housekeeping items (metal cans, glass, paper, aerosol cans, rags, plastic bottles, wipes, and cardboard containers), processing items (polypropylene wound filters and drum filter cloth), and absorbed liquids (acids, bases, process chemicals, oils, and hydraulic fluids).

• **Physical Constituents**

Constituent	Number of Drums
Metal/Iron/Galvanized/Sheet	64
Misc/Unknown/Other	213
Absorbant/Kitty Litter/Vermiculite	14
Cloth/Rags/Nylon	4
Oils	874
Paper/Cardboard	58
Plastic/Polyurathane	66
Rubber	43
Wood/Lumber/Plywood	211
Brick/Firebrick	8
Concrete	2

• **Hazardous Constituents**

Hazardous constituents were not required to be listed until 1986. The records for these drums are dated 1969-88; therefore, the list below may not include all currently regulated materials present. Of the 1,360 drums of TRU waste from the 231-Z facility, 18 drums (1.3%) are listed as containing mixed waste.

Hazardous Constituents	Number of Drums	Notes
Oil	17	1972 to 1976 218-W-4B
Beryllium	1	1 drum in 1972 218-W-4B
Sodium	1	1 drum 1982 218-W-4C

- Radioisotopes Present

Isotopes	Number of Drums
Pu	1,360
Uranium-Enriched	3
Np-237	2
Th-232	1
Uranium-Depleted	10
Uranium-Natural	3

For More Information

Pottmeyer, J.A., D.S. DeLorenzo, M.I. Weyns-Rollosso, D.E. Berkowitz, E.J. Vejvoda, and D.R. Duncan, 1993, *Characterization of Past and Present Solid Waste Streams from 231-Z*, WHC-EP-0659, Westinghouse Hanford Company, Richland, WA.

325 TRU Solid Waste Fact Sheet

- **General Description of the Waste** - The 325 Radiochemistry Building, also called the Applied Chemistry Building, was built to house and handle multi-curie level chemical development work with high activity substance. Tasks performed at the facility have included chemistry and analysis, radioactive materials processing, safeguards and materials management, waste management, technical research and development, and operational health physics. Programs supported by the 325 facility have included, but are not limited to, the following: Reclamation of Uranium and Plutonium by Extraction process, Reduction-Oxidation process, PUREX process, Plutonium Reclamation Facility (PRF), Nuclear Waste Vitrification Project (NWVP), Fast Flux Test Facility (FFTF), and Liquid Metal fast Breeder Reactor (LMFBR) program.

Because the 325 Building is a research facility, the work done in the building has been extremely varied. In addition, between 1970 and 1987, both Westinghouse Hanford Company (WHC) and Pacific Northwest Laboratories (PNL) have jointly occupied the facility. The total number of 55-gal drums of suspect TRU waste generated by these organizations totaled over 4130. Of these, 2,414 drums were designated as coming from WHC, and 1,717 drums were designated as PNL. In the physical contents, hazardous contents, and radionuclides tables found below, the 325 wastes designated as being generated by WHC and PNL are considered separately, as is the waste produced in the 325-A hot cell annex.

- **Packaging** - During the 1970 to 1987 time frame, TRU waste was generated by five to six separate glovebox lines. Wastes were generally put into 5-gal paint cans. For a time, these cans were sometimes packed into a larger "potato chip" can, which were then stacked in 55-gal drums. The potato chip cans were abandoned eventually due to the large bulk of waste overpacking created.

The 55-gal drums used were either DOT 17C or 17H drums. Prior to 1982, most of these drums were painted. After 1982, galvanized drums replaced the painted drums.

Catalyst packs were placed on drums beginning in the mid-1980's. If a drum was vented, it also had a catalyst pack.

Acid solutions containing uranium and plutonium, acid digestion wastes, and uranyl nitrate from the digestion of fuel pins were mixed with Portland cement in a 5-quart paint can to effectively neutralize them. Beginning in the mid-1980's the procedure was changed, and acid solutions had to be neutralized prior to mixing them with the cement.

Also beginning in the mid-1980's time frame, mercury was packaged in culverts about 8 inch in diameter and 2.4 ft long. The culverts were then put into drums with approximately 6 inch of concrete on the top and bottom. It was common to fill the spaces around the culverts with bagged poly-bottles and other items.

- **Contents** - A typical TRU drum would probably be made up of the following items: plastic vials and bottles, broken glass, electrodes (perhaps with mercury), paper towels, neoprene gloves, and old

laboratory equipment (balance, pH meters, etc.).

325 Westinghouse Hanford Company

- Physical Constituents

Constituent	Number of Drums
Metal/Iron/Galvanized/Sheet	120
Misc/Unknown/Other	509
Absorbant/Kitty Litter/Vermiculite	40
Cloth/Rags/Nylon	112
Concrete	79
Conweb Pads	53
Filters	83
Glass	50
Paper/Cardboard	176
Plastic/Polyurathane	175
Rubber	8
Wood/Lumber/Plywood	81

- Radioisotopes Present

Isotopes	Number of Drums
Pu	2368
Uranium-Enriched	227
Am-241	1
Np-237	1
U-233	2
Pu-238	2
Th-232	35
Uranium-Depleted	89
Uranium-Natural	222
Cm-245	1

325 Pacific Northwest Laboratory

• Physical Constituents

Constituent	Number of Drums
Metal/Iron/Galvanized/Sheet	294
Misc/Unknown/Other	1492
Absorbant/Kitty Litter/Vermiculite	46
Asbestos	5
Cement	14
Ceramics	10
Cloth/Rags/Nylon	57
Conweb Pads	1
Dirt/Soil/Diatomaceous Earth	15
Floor Sweeps	5
Foam/Styrofoam	1
Glass	113
Leather	3
Paper/Cardboard	227
Plastic/Polyurathane	302
Cotton/Kotex	8
Animal Waste	15
Equipment	7
Salt Bath	1
Oxides/Powder	1
Liquid	15
Rubber	223
Stainless Steel	5
Wood/Lumber/Plywood	10
Brick/Firebrick	1
Insulation Non-Asbestos	3
Lead	3
Charcoal	4

- Hazardous Constituents**

Hazardous Constituents	Number of Drums	Notes
Asbestos	5	Insulation
Lead	2	Shielding material
Mercury	1	Analytical chemical
Nitric Acid	1	Analytical chemical

- Radioisotopes Present**

Isotopes	Number of Drums
Pu	1648
Uranium-Enriched	30
Am-241	81
Np-237	25
Pu-238	29
Th-232	5
Uranium-Depleted	20
Uranium-Natural	30
Pu-239	28
Pu-240	28
Pu-241	28
Pu-242	27
Cm-245	1
Pm-147	1
Am-243	2
Ce-144 PR144	2
Cm-243	13
Cm 244	7
Co-60	15
Cs-134	15
Cs-137 Ba-137M	47
Ee-152	3
Wu-154	17
Mn-54	1

Isotopes	Number of Drums
Ru-106 Rh-106	2
Sb-125	1
Te-125M	1
Th-228	17
Zr-95 Nb-95	1

325A Hot Cells

• Physical Constituents

Constituent	Number of Drums
Misc/Unknown/Other	15

• Radioisotopes Present

Isotopes	Number of Drums
Pu	15
U-233	1
Th-232	10

For More Information

Pottmeyer, J.A., M.I. Weyns-Rollosso, K.D. Dicenso, D.S. DeLorenzo, and D.R. Duncan, 1993, *Characterization of Past and Present Solid Waste Streams from the 325 Radiochemistry Building*, WHC-EP-0696, Westinghouse Hanford Company, Richland, WA.

General Electric Vallecitos Nuclear Center TRU Solid Waste Fact Sheet

• **General Description of the Waste** - In 1981 and 1982, 150 55-gal drums of TRU solid waste was shipped from the Vallecitos Nuclear Center (VNC) to be retrievably stored at Hanford. These wastes were associated with the Fast Flux Test Reactor (FFTR) program, which involved the fabrication and testing of fuel assemblies that utilized plutonium in an oxide form. The waste was generated primarily as a result of the decontamination and decommissioning of the laboratories at the end of this program. No routine operational radioactive wastes were sent to Hanford from VNC.

• **Packaging** - The plutonium contaminated wastes from the FFTR program were packaged in large plywood boxes coated with fiberglass reinforced polyester or in 17C or 17H 55-gal drums. For some shipments a rigid polyurethane foam (*Instapak*, Sealed Air Corporation) was employed to fill interior voids.

• **Contents** - The general types of waste generated by decontamination and decommissioning (D&D) activities included process and fabrication equipment, gloveboxes, glovebox supporting apparatus, ventilation ducting, and other miscellaneous service items contaminated with plutonium. A partial list of discarded equipment items follows: centerless grinding equipment, sintering furnace, gaging and inspection apparatus, glass tanks, gloveboxes, powder collection assembly, calciner assembly, feed nozzle assembly, scrubber assembly, precipitator assembly, reduction vessel assembly. Intermediate and small size objects in the waste include analytical and sample preparation apparatus; segments of heating/ventilation/air conditioning duct work; fabrication tooling and gaging; inspection apparatus; valving; piping; tubing; flanges; wiring; unistruts; shelving; and broken glass.

• **Physical Constituents**

Physical Description	Number of Drums	Notes
Aluminum	33	
Antifreeze	31	
Carborundum	21	From mixed-oxide pellet grinding
Cement	7	Used to solidify solutions and slurries
Ceramics	5	Used as insulators
Concrete	22	From decontamination and demolition activities
Copper Metal	33	
Cotton/Kotex	113	Cleanup swabs and pads

Physical Description	Number of Drums	Notes
Dirt/Soil/Diatomaceous Earth	31	
Foam/Styrofoam	13	
Glass	34	From spent equipment
Insulation/Non-asbestos	22	
Marble	1	Laboratory bench tops
Molybdenum	29	Used in high temperature sintering
Oil	80	Spent vacuum pump oil
Paint/Lucite	24	
Paper/Cardboard	114	Paperwork, labels, and cartons
Plastic/Polyurethane	114	Cut-out bags and shipping container filler
Rubber	41	
Sand	5	
Stainless Steel	33	
Wood/Lumber/Plywood	114	

• Hazardous Constituents

Hazardous constituents were not required to be listed until 1986. The records for these drums are dated 1981-82; therefore, the list below may not list all currently regulated materials present. Of the 150 drums from VNC, 86 drums (57%) are listed as containing mixed waste.

Hazardous Constituent	Number of Drums	Notes
Antifreeze	30	Coolant
Copper	7	---
Oil	80	Vacuum pump oils
Lead Bricks	---	Lead bricks were noted on burial records.
Hydraulic Fluid	---	Hydraulic Fluid was noted on burial records and may have been translated to "oil" in the SWITS database.

- Radioisotopes Present

The plutonium and uranium present in these drums resulted from the testing and fabrication of mixed oxide fuels. In general, the mixed oxide fuel prepared for the FFTR program had a nominal 1-to-4 ratio of plutonium to uranium. The ^{240}Pu content of the plutonium employed was approximately 10% and 16.5%. The ^{235}U enrichment levels of the uranium employed were 0.7% (normal), 37.5%, 45.5%, 75%, 87.5%, and 93%.

The 150 drums of TRU waste sent to Hanford all contained plutonium contaminated waste for a total of 500.9 g of plutonium. A sum of 159,654.57 g of uranium is listed as present in 116 of the drums (77% of the total). Mixed fission products, with a total activity of 1.29 curies, are noted as being present in all drums.

For More Information

Vejvoda, E.J., J.A. Pottmeyer, D.S. DeLorenzo, M.I. Weyns, and D.R. Duncan, 1993, *Radioactive Shipments to Hanford Retrievable Storage from the General Electric Vallecitos Nuclear Center, Pleasanton, California*, WHC-EP-0672, Westinghouse Hanford Company, Richland, WA.

Westinghouse Advanced Reactor and Nuclear Fuels Divisions TRU Solid Waste Fact Sheet

- **General Description of the Waste** - Between 1980 and 1984, 910 55-gal drums of TRU solid waste were shipped from the Westinghouse Advanced Reactors Division (WARD) and the Westinghouse Nuclear Fuels Division (WNFD) facilities to retrievable storage at Hanford. The WARD and WNFD were collocated at Westinghouse Electric Corporation's Cheswick, PA site and shared portions of the same buildings.

The WARD operated two nuclear fuel laboratories. The Plutonium Laboratory provided process and fabrication development and characterization of mixed uranium-carbide fuel materials and fuel elements. Uranium-plutonium oxide fuel assemblies were fabricated in the Advanced Fuels Laboratory. The Plutonium Fuels Development Laboratory was operated by WNFD for the development and fabrication of Light Water Reactor Recycle Fuel.

The wastes sent from Cheswick to retrievable storage at Hanford were generated primarily as a result of the D&D of these facilities. The D&D process required the removal of all process equipment, the associated glove-box type containment structures, the glovebox ventilation ductwork and filtration systems, and associated service items.

Prior to 1980, radioactive solid waste generated during routine operations, at the WARD and WNFD facilities, and shipped to Hanford appears to have been redesignated as originating from the Hanford facility that received the waste shipment from off-site.

- **Packaging** - Prior to packaging, laboratory and process items were disassembled and categorized as clean, low specific activity (non-TRU) or TRU. TRU wastes were further segregated into combustibles and non-combustibles. Waste items with both components were treated as combustible waste. In addition, the use of the Super Tiger Overpack required that hard and soft wastes be segregated. Hard waste items were defined as those items rigid enough to be forced through the plastic bagging material unless they were suitably blunted or padded. Soft items were defined as items that could be compressed to conform to the package without padding. Items with both hard and soft components that were not easily separable were treated as hard waste.

The following containers were used for disposal of TRU waste generated at the WARD and WNFD facilities: DOT 17C or 17H galvanized 55-gal drums, plywood boxes coated with fiberglass reinforced polyester (FRP), M-III steel storage bins, and corrugated steel boxes. The following discussion refers only to wastes packaged in 55-gal drums.

Combustible (soft) waste items (sheeting, gloves, paper, prefilter media, polyethylene bottles, shoe covers, decontamination wipes, etc.) were double bagged in 12-mil, heat sealed polyvinyl chloride (PVC) plastic and placed in a drum with a 12-mil, heat-sealed PVC liner.

Noncombustible (hard) waste items (tools and equipment, piping and ductwork, unvented aerosol cans, etc.) were wiped or brushed clean. Sharp edges and protrusions were padded with polyethylene foam, taped and double bagged in a 12-mil, heat-sealed poly-vinyl chloride (PVC) bagging material. Piping, tubing and similar objects were bundled into packages 30" long by 8" diameter maximum. These packages were then loaded into a prefoamed drum with a two-inch annular thickness and a three-inch end thickness (top and bottom) of polyurethane foam. The drum was lined with a 12-mil PVC liner prior to foaming.

Organic liquid wastes (lubricant, hydraulic fluids, paints) were absorbed with twice as much absorbant as required to completely absorb the liquid present. The absorbed liquid was then placed in 1-gal polyurethane bottles with screw-top caps. Bottles from WARD were then double bagged in 12-mil, heat-sealed PVC and placed in pre-foamed drums lined with the PVC. Bottles from WNFD were not placed in pre-foamed drums, but were double-bagged, placed in a lined drum and surrounded by more absorbant.

Inorganic aqueous liquid waste was solidified in concrete in a 30-gal plastic fiber pack. The fiber pack was heat-sealed within a 12-mil PVC bag, which in turn was centered within a 55-gal drum lined with a 12-mil, heat-sealed liner and filled with absorbent.

Mercury was mixed with Fisher Scientific's Mercury Absorbant Powder to form an amalgam. The amalgam was double-bagged and surrounded by a minimum of 6" of concrete in a galvanized drum. The drum contained no other waste and liner and drum were sealed.

- *Contents* - The general types of waste generated during routine operations included contaminated materials and equipment such as glove boxes, hoods and ductwork. Decontamination and decommissioning generated other wastes such as filters, residues from air and water purification, ion-exchange beds, rags, gloves, shoe covers and decontamination wipes. Other typical wastes include paper, wood, plastic, metal and floor sweepings.

- Physical Constituents

Constituent	Number of Drums
Metal/Iron/Galvanized/Sheet	658
Misc/Unknown/Other	77
Absorbant/Kitty Litter/Vermiculite	326
Asbestos	69
Cement	253
Ceramics	197
Cloth/Rags/Nylon	499
Concrete	57
Dirt/Soil/Diatomaceous Earth	13
Fiberglass	135
Foam/Styrofoam	15
Glass	438
Leather	187
Oils	74
Organics	63
Paints/Lucite	321
Paper/Cardboard	823
Plastic/Polyurathane	848
Rock/Gravel	48
Rubber	758
Sheetrock	58
Wood/Lumber/Plywood	622
Insulation Non-Asbestos	23
Plaster	22

- Hazardous Constituents**

Hazardous constituents were not required to be listed until 1986. The records for these drums are dated 1980-84; therefore, the list below may not include all currently regulated materials present. Of the 910 drums of TRU waste from the WARD and WNFD facilities, 137 drums (15%) are listed as containing mixed waste.

- Hazardous Constituents**

Hazardous Constituents	Number of Drums	Notes
Asbestos	1	Insulation material
Oil	60	Various types
Organic	76	Absorbed on vermiculite and placed in 1-gal poly bottles

- Radioisotopes Present**

Isotopes	Number of Drums
Pu	851
Uranium-Enriched	217
Uranium-Depleted	58
Uranium-Natural	487

For More Information

WHC, 1993, *Radioactive Waste Shipments to Hanford Retrievable Storage from Westinghouse Advanced Reactors and Nuclear Fuels Division, Cheswick, Pennsylvania*, WHC-EP-0718, Westinghouse Hanford Company, Richland, WA.

Babcock and Wilcox TRU Solid Waste Fact Sheet

- **General Description of the Waste** - Between 1977 and 1983, 1,451 55-gal drums of TRU solid waste were shipped from the Babcock and Wilcox Plutonium Facility to retrievable storage at Hanford. These wastes were associated with the fabrication of $\text{PuO}_2\text{-UO}_2$ fuel rods and pellet stacks for the FFTF cores 1, 2, 3 and 4 and subsequent decontamination and clean out activities.

- **Packaging** - Galvanized 17C or 17H 55-gal drums make up 98% of the total number of containers; other containers used included barrels, kegs, metal boxes, cartons, cases and portable tanks. Due to shipping constraints 55-gal drums contain no more than 15 g of Pu each.

Line and laboratory wastes were bagged out of the gloveboxes into nominal 1-1/2-gal paper cans. After assay, these cans were placed into 55-gal drums. Commonly, all powder was swept from glovebox waste (i.e., gloves, plastic, glass, paper, etc.) before packaging. Fingers were cut off gloves to eliminate air pockets. Glassware was placed in metal containers, crushed and double bagged. Metal cans were cleaned with a wire brush, painted on all surfaces with latex paint, then compacted. Glovebox/hood equipment had any sharp edges removed with a file. If filing was not practical the edges were covered with tape. The entire piece of equipment was then painted, dried, and compacted.

Non-line waste (non-glovebox waste) were routinely compacted to approximately half of their initial bulk volume.

Primary HEPA filters were packaged one per drum.

Jet mill bags were placed in the 1-1/2-gal paper cans prior to placement in the drums.

Liquid wastes were immobilized by absorption on Speedi-Dri (vermiculite). Drums were not provided with vent clips, but were outgassed before being sealed. After about 1980 all liquified waste was solidified in cement.

Hot cell liquid wastes were solidified in concrete mix or Portland cement.

Contaminated hydraulic and vacuum pump oil was mixed with sand and Portland cement. Water was added to the mixture to produce a slurry. The oil did not separate after addition of water or after solidification.

- **Contents** - *Line and laboratory wastes* include miscellaneous small items of equipment, electrodes, rubber gloves, plastics, primary filters, etc. Small packages of laboratory wastes were included with line wastes and were similar in nature. Other wastes identified from laboratory operations include crucibles (used for combustion of mixed oxide powders), discarded glass and metal components, and pellets in mounts.

Non-line wastes, 'non-glovebox waste', included all materials for discard from plant operating and service areas where known or potential radioactive contamination existed. These wastes were commonly packaging materials, housekeeping trash, cloth or plastic sheet materials, used non-radioactive materials containers, maintenance scrap, decontamination wipes, and scrap balances. A large fraction of this waste (>75%) was 'suspect TRU' waste assayed at a nominal zero plutonium content.

High-efficiency particulate air filters and jet mill bags were used in all gas handling lines or ducts. A total of 206 55-gal drums with HEPA filters were shipped, including 99 drums with a nominal zero plutonium content.

Scrap and combined wastes originated in controlled zones as a result of plant maintenance and cleanout operations. Scrap items include spent equipment, broken tools, furnace brick, glovebox windows, and other items within glovebox enclosures that were too large for paper cans. Combined wastes included items originating from more than one source. For example, a non-line waste increment with added line waste packages became combined waste.

Scrap recovery liquids refer to ion exchange raffinates. Sludges include insolubles washed from tanks or filtered from process streams and spent resins from ion exchange columns. Scrap recovery liquids were contained in 299 drums of shipped waste. Sludges, contained in 5 drums, included 45.5% of the total Pu associated with this category of waste.

Analytical laboratory waste contained a variety of solutions arising from chemical analysis of selected fuel samples. Chemicals contained in this waste stream include butanol with methanol, acetone, pentylacetate methanol, titanium, tungsten, chloride, fluoride, sulfate, tri-N-octylamine-xylene mixture, sodium hydroxide, sulfuric acid, silver sulfate, tin and hydroxylamine.

Non-scrap recovery liquids are liquids generated by sources not listed above and include Sump drainage, hydraulic oils, organic solvents, lubricants, and spent solvents or cleaning solutions.

- Physical Constituents**

Constituent	Number of Drums
Metal/Iron/Galvanized/Sheet	7
Misc/Unknown/Other	66
Cement	439
Ceramics	52
Cloth/Rags/Nylon	15
Glass	366
Paper/Cardboard	524
Plastic/Polyurethane	524
Rubber	509
Wood/Lumber/Plywood	498
Plexiglass	191

- Hazardous Constituents**

Hazardous constituents were not required to be listed until 1986. The records for these drums are dated 1977-83; therefore, the list below may not include all currently regulated materials present. Of the 1,451 drums of TRU waste from the Babcock and Wilcox Plutonium Facility, only one (1) drum (0.07%) is listed as containing mixed waste.

Hazardous constituents	Number of Drums	Notes
Beryllium	1	Used to manufacture sources

- Radioisotopes Present**

Isotopes	Number of Drums
Pu	1146
Am-241	149
Uranium-Depleted	902
Uranium-Natural	66

For More Information

Duncan, D.R., 1994, *Radioactive Waste Shipments to Hanford Retrievable Storage from Babcock and Wilcox, Leechburg, Pennsylvania*, WHC-EP-0719, Westinghouse Hanford Company, Richland, WA.

**Appendix B: CHARACTERIZATION REQUIREMENTS IMPOSED BY ALL APPLICABLE
REGULATIONS**

**Westinghouse
Hanford Company****Internal
Memo**

From: RCRA Compliance Support
Phone: 373-6624 H6-30
Date: May 5, 1994
Subject: CHARACTERIZATION REQUIREMENTS IMPOSED BY ALL APPLICABLE
REGULATIONS

88410-94-075

To: C. L. Bergeson H1-60

cc: D. E. Ball	G6-46	J. A. Pottmeyer	LATA
E. M. Greager	H6-30	R. J. Swan	H6-30
M. D. LeClair	H1-60	J. J. Wong	B2-24
B. A. Mayancsik	H5-33	MLB/LB	

Reference: Memo, C. L. Bergeson, to M. L. Bedick "Statement of Work for Regulatory Support for the WRAP-1 Sampling Strategy and Waste Characterization Alternatives Study," dated April 7, 1994.

As you requested in the reference letter, I have determined the potential analytes in the waste that should be characterized based on all applicable regulations. This information is summarized in the two attachments.

The first attachment consists of two tables. The first table is a list of the analytes that could possibly be regulated by RCRA, DOT, and the WIPP. The potentially regulated analytes that are determined to be RCRA regulated will also be regulated by the DOT regulations for the purpose of transportation. The second table is a list of the analytes that are not regulated by RCRA, DOT, or WIPP.

The proposed non-regulated analytes (Table 2) have only been checked for chelating agents and D001, D002, and D003 waste code criteria. Based on discussions with R. M. Lipinski, these are the only items of concern for WIPP acceptance and DOE Order 5820.2A. Currently WIPP will not accept those analytes that are regulated with the D001, D002, and D003 waste codes. The WIPP Quality Assurance Program Plan (QAPP) is in draft form. Analytes in Table 2 should be checked for regulatory status when QAPP is finalized.

The second attachment contains the guidelines that determined what regulatory codes apply to the different constituents and clarifies information symbolically presented in attachment 1.

Please call me on 373-6624 if you have any further questions.

Melanie L. Bedick
Engineer

rlm

Attachments 2

88410-94-075
ATTACHMENT 1
Consisting of 9 Pages

REGULATORY STATUS OF WRA 1 ANALYTE LIST

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Table 1. WRAP-1 List of Potentially Regulated Analytes										
Acetic acid, Glacial (64-19-7)	C	**	-	F	CR	-	-	-	-	2270
Acetone (Isobutyl Alcohol) (67-64-1)	D	-	-	F	-	-	U002 F003	-	-	2270
Alkylbenzene (See alkanes with benzene-- ethylbenzene, toluene)										
Aluminum (metal fines) (7429-90-5)	-	-	-	F	-	R	-	-	-	45.4
Aluminum (III) nitrate (nonhydrate) (13473-90-0)	D	-	-	O	-	-	-	-	-	-
Ammonia (Anhydrous) (7664-41-7)	B	-	-	-	-	-	-	-	-	45.4
Ammonium ceric nitrate (16774-21-3)	-	-	-	O	-	-	-	-	-	-
Ammonium chloride (12125-02-9)	D	-	-	-	-	-	-	-	-	2270
Ammonium fluoride (12125-01-8)	-	-	-	-	CR	-	-	-	-	2270
Ammonium hydroxide (1336-21-6)	C	-	-	-	CR	-	-	-	-	454
Ammonium nitrate (6484-52-2)	D	-	-	O	-	R	-	-	-	45.4
Ammonium sulfate (7783-20-2)	D	-	-	-	-	-	-	-	-	-
Arsenic (7440-38-2) Arsenic trioxide (1327-53-3)	D B	C	-	-	-	-	- P012	D004	-	.454
Asbestos (1332-21-4)	-	C	-	-	-	-	-	-	-	.454
Barium (metal fines) (7440-39-3)	-	-	-	F	-	R	-	D005	-	454
Barium nitrate (10022-31-8)	C	-	-	O	-	-	-	D005	-	45.4
Benzene (71-43-2)	D	C	-	F	-	-	U019 F005	D018	-	4.54
Beryllium (7440-41-7)	-	C	-	-	-	-	P015	-	-	4.54
Boric acid (10043-35-3)	D	-	-	-	-	-	-	-	-	2270

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
1-Butanol (n-Butyl alcohol) (71-36-3)	C	-	-	F	-	-	U031 F003	-	-	2270
Cadmium (metal fines) (7440-43-9)	C	C	-	-	-	-	-	D006	-	4.54
Cadmium nitrate (10325-94-7)	C	C	-	-	-	-	-	D006	-	-
Calcium chloride (10043-52-4)	D	-	-	-	-	-	-	-	-	-
Calcium nitrate (10124-37-5)	-	-	-	O	-	R	-	-	-	45.4
Carbon tetrachloride (56-23-5)	D	C	HH	-	-	-	U211 F001	D019	-	4.54
Ceric sulfate (13590-82-4)	-	-	-	O	-	-	-	-	-	45.4
Cerous nitrate (10108-73-3)	D	-	-	O	-	-	-	-	-	45.4
Chloroform (67-66-3)	B	C	HH	-	-	-	U044	D022	-	4.54
Chromic acid (7738-94-5)	-	C	-	-	CR	-	-	D007	-	-
Chromium (7440-47-3)	-	-	-	-	-	-	-	D007	-	4.54
Citric acid (77-92-9)	-	-	-	-	CR	-	-	-	Chelating agent	45.4
Cresylic acid (1319-77-3)	D	-	-	-	CR	-	U052 F004	D026	-	454
Cupric sulfate (7758-98-7)	C	-	-	-	-	-	-	-	-	4.54
Cuprous cyanide (Cyanide solutions) (544-92-3)	-	-	-	-	-	R	P029	-	-	4.54
Cyclohexane (Hexahydrobenzene) (110-82-7)	-	-	-	F	-	-	U056	-	-	454
Decane (124-18-5)	-	-	-	CO	-	-	-	-	-	-
Diesel fuel (68334-30-5)	-	-	-	CO	-	-	-	-	-	-
Diesel fuel #2 (68476-34-6)	-	-	-	CO	-	-	-	D018	-	-
Di-n-octyl phthalate (DOP) (117-84-0)	-	-	-	-	-	-	U107	-	-	-
Ethanol (Ethyl alcohol) (64-17-5)	-	-	-	F	-	-	-	-	-	-

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Ethylbenene (100-41-4)	D	-	-	F	-	-	F003	-	-	454
Ethylene glycol (107-21-1)	D	-	-	-	-	-	-	-	Chelating agent	-
Ferrous sulfate (7720-78-7)	C	-	-	-	-	-	-	-	-	454
Formaldehyde (50-00-0)	C	-	-	CO	-	-	U122	-	-	45.4
Formic acid (64-18-6)	C	-	-	-	CR	-	U123	-	-	2270
Freon-113 (1,1,2-Trichloro-1,2,2-trifluoroethane) (76-13-1)	-	-	HH	-	-	-	F001 F002	-	-	2270
Halogenated Hydrocarbon (Halogenated Organic Compds)	-	-	-	-	-	-	F001 F002	-	-	-
Hexachlorobenzene (118-74-1)	C	C	HH	-	-	-	U127	D032	-	4.54
Hydrazine (Diamine) (302-01-2)	B	C	-	F	CR	R	U133	-	-	.454
Hydrobromic acid (10035-10-6)	-	-	-	-	CR	-	-	-	-	-
Hydrochloric acid (7647-01-0)	C	-	-	-	CR	-	-	-	-	2270
Hydrofluoric acid (7664-39-3)	B	-	-	-	CR	-	U134	-	-	45.4
Hydrogen peroxide (30% solution) (7722-84-1)	-	-	-	O	-	-	-	-	-	45.4
Hydriodic acid (Hydrogen iodide) (10034-85-2)	-	-	-	-	CR	-	-	-	-	-
Isobutanol (Isobutyl alcohol) (78-83-1)	D	-	-	F	-	-	U140 F005	-	-	2270
Isopropyl ethanol (Isopropyl alcohol) (67-63-0)	D	-	-	F	-	-	-	-	-	45.4
Kerosene (8008-20-6)	-	-	-	CO	-	-	-	-	-	-
Lead (7439-92-1)	-	C	-	-	-	-	-	D008	-	.454
Lead chromate (7758-97-6)	-	C	-	-	-	-	-	D008, D007	-	.454
Magnesium (metal fines) (7439-95-4)	-	-	-	F	-	R	-	-	-	5

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Mercuric thiocyanate (592-85-8)	B	-	-	-	-	-	-	D009	-	4.54
Mercury (7439-97-6)	-	-	-	-	-	-	U151	D009	-	.454
Methanol (67-56-1)	D	-	-	F	-	-	U154 F003	-	-	2270
Methylene chloride (Dichloromethane) (75-09-2)	B	C	HH	-	-	-	U080 F001 F002	-	-	454
Methyl Ethyl Ketone (2-Butanone) (78-93-3)	D	-	-	F	-	-	U159 F005	D035	-	2270
Methyl isobutyl ketone (4-METHYL-2-PENTANONE) (Hexone) (108-10-1)	D	-	-	F	-	-	U161 F003	-	-	-
Methyl lactic acid (methylester) (80-55-7)	-	-	-	-	-	-	-	-	Chelating agent	-
Naphthalene (91-20-3)	C	-	-	F	-	-	U165	-	-	45.4
1-Naphthylamine (1-Naphthylamine) (134-32-7)	D	-	-	-	-	-	U167	-	-	45.4
2-Naphthylamine (2-Naphthylamine) (91-59-8)	D	-	-	-	-	-	U168	-	-	4.54
Nitric acid (7697-37-2)	-	-	-	O	CR	-	-	-	-	454
Nitrilotriacetic acid (139-13-9)	D	-	-	-	-	-	-	-	Chelating agent	-
Normal Paraffin Hydrocarbon (NPH) (See Decane, Undecane, Dodecane, Tridecane, Tetradecane)										
Oxalic acid (144-62-7)	-	-	-	-	CR	-	-	-	Chelating agent	45.4
Pentasodium DTPA (Pentasodium diethylenetriaminepentaacetate) (140-01-2)	-	-	-	-	-	-	-	-	Chelating agent	-
Perchloric acid (7601-90-3)	D	-	-	O	CR	R	-	-	-	45.4
Phenyltrifluoroacetone (326-92-0)	-	-	-	-	-	-	-	-	Chelating agent	-
Phosphoric acid (7664-38-2)	D	-	-	-	CR	-	-	-	-	2270

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Polychlorinated biphenyl (PCB) (1336-36-3)	D	-	HH	-	-	-	-	-	-	.454
Potassium acetate (127-08-2)	D	-	-	-	-	-	-	-	-	-
Potassium carbonate (584-08-7)	D	-	-	-	-	-	-	-	-	-
Potassium chromate (7789-00-6)	-	C	-	F	-	-	-	D007	-	4.54
Potassium cyanide (151-50-8)	B	-	-	-	-	R	P098	-	-	4.54
Potassium fluoride (7789-23-3)	C	-	-	-	CR	-	-	-	-	-
Potassium hydroxide (1310-58-3)	C	-	-	-	CR	-	-	-	-	454
Potassium permanganate (7722-64-7)	D	-	-	O	-	-	-	-	-	45.4
Propane (74-98-6)	-	-	-	F	-	-	-	-	-	-
Pyridine (110-86-1)	C	-	-	-	-	-	U196 F005	D038	-	-
Selenium (7782-49-2)	-	-	-	-	-	-	-	D010	-	4.54
Silicon (fines) (7440-21-3)	D	-	-	F	-	-	-	-	-	-
Silver (7440-22-4)	-	-	-	-	-	-	-	D011	-	.454
Silver chloride (7783-90-6)	-	-	-	-	-	-	-	D011	-	.454
Silver nitrate (7761-88-8)	-	-	-	O	-	-	-	D011	-	.454
Silver oxide (20667-12-3)	D	-	-	-	-	-	-	D011	-	.454
Silver sulfate (10294-26-5)	-	-	-	-	-	-	-	D011	-	-
Sodium (7440-23-5)	-	-	-	F	CR	R	-	-	-	4.54
Sodium bicarbonate (144-55-8)	D	-	-	-	-	-	-	-	-	-
Sodium bisulfite (7631-90-5)	D	-	-	-	-	-	-	-	-	2270
Sodium bromate (7789-38-0)	-	-	-	O	-	-	-	-	-	45.4
Sodium carbonate (497-19-8)	D	-	-	-	-	-	-	-	-	-

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Sodium chromate (7775-11-3)	-	C	-	-	-	-	-	D007	-	4.54
Sodium cyanide (143-33-9)	-	-	-	-	-	-	P106	-	-	4.54
Sodium dichromate (10588-01-9)	B	C	-	-	-	-	-	D007	-	4.54
Sodium fluoride (7681-49-4)	C	-	-	-	CR	-	-	-	-	454
Sodium hydroxide (1310-73-2)	-	-	-	-	CR	-	-	-	-	454
Sodium nitrate (7631-99-4)	D	-	-	0	-	-	-	-	-	-
Sodium nitrite (7632-00-0)	C	-	-	0	-	-	-	-	-	45.4
Sodium oxalate (62-76-0)	-	-	-	-	-	-	-	-	Chelating agent	-
Sodium phosphate, tribasic (7601-54-9)	-	-	-	-	CR	-	-	-	-	2270
Sodium silicate solution (pH = 3, 9 per chem. dict.) (1344-09-8)	D	-	-	-	-	-	-	-	-	-
Strontium nitrate (10042-76-9)	D	-	-	0	-	-	-	-	-	45.4
Sulfamic acid (5329-14-6)	D	-	-	-	CR	-	-	-	-	-
Sulfonic acid (Chloro-) (7790-94-5)	-	-	-	-	CR	-	-	-	-	454
Sulfuric acid (7664-93-9)	B	-	-	-	CR	-	-	-	-	454
D-Tartaric acid (147-71-7)	-	-	-	-	-	-	-	-	Chelating agent	-
DL-Tartaric acid (133-37-9)	-	-	-	-	-	-	-	-	Chelating agent	-
L-Tartaric acid (87-69-4)	-	-	-	-	-	-	-	-	Chelating agent	-
Teflon (9002-84-0)	-	-	HH	-	-	-	-	-	-	-
Tetrachloroethylene (Tetrachloroethene) (127-18-4)	D	-	HH	-	-	-	U210 F001 F002	D039	-	45.4
Tetrasodium EDTA (Edetate sodium) (64-02-8)	-	-	-	-	-	-	-	-	Chelating agent	-
Toluene (108-88-3)	D	-	-	F	-	-	F005	-	-	454

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Tributyl phosphate (Phosphoric acid, tributyl ester) (126-73-8)	D	-	-	-	-	-	-	-	-	-
1,1,1-Trichloroethane (Methylchloroform) (71-55-6)	D	-	HH	-	-	-	U226 F001 F002	-	-	454
1,1,2-Trichloroethane (79-00-5)	D	C	HH	-	-	-	U227 F002	-	-	45.4
Trichloroethylene (79-01-6)	-	-	HH	-	-	-	U228 F001 F002	D040	-	45.4
Tungsten powder (7440-33-7)	-	-	-	F	-	-	-	-	-	45.4
Undecane (1120-21-4)	-	-	-	CO	-	-	-	-	-	-
Uranyl nitrate (solid) (10102-06-4)	D	-	-	-	-	-	-	-	-	45.4
Uranyl nitrate hexahydrate (13520-83-7)	-	-	-	O	-	-	-	-	-	-
Vanadium pentoxide (1314-62-1)	B	-	-	-	-	-	P120	-	-	454
Xylene (Dimethylbenzene) (1330-20-7) (mixed)	D	-	-	F	-	-	U239 F003	-	-	454
Zirconium (metal fines) (7440-67-7)	-	-	-	F	-	-	-	-	-	45.4
Table 2. WRAP-1 List of Proposed Non-Regulated Analytes										
Aluminum sulfate (10043-01-3)	-	-	-	-	-	-	-	-	-	2270
Bromocresol purple (115-40-2)	-	-	-	-	-	-	-	-	-	-
Calcium chlorofluorophosphate (12394-20-6)	-	-	-	-	-	-	-	-	-	-
Carborundum (Silicon carbide) (409-21-2)	-	-	-	-	-	-	-	-	-	-
Ceric nitrate (10108-73-3)	-	-	-	-	-	-	-	-	-	-
Copper (7440-50-8)	-	-	-	-	-	-	-	-	-	2270
Diatomaceous Earth, Natural (61790-53-2)	-	-	-	-	-	-	-	-	-	-

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Dibutyl phosphate (107-66-4)	-	-	-	-	-	-	-	-	-	-
Dodecane (112-40-3)	-	-	-	-	-	-	-	-	-	-
Ferric sulfate (10028-22-5)	-	-	-	-	-	-	-	-	-	454
Ferrous ammonium sulfate (10045-89-3)	-	-	-	-	-	-	-	-	-	454
Graphite (7782-42-5)	-	-	-	-	-	-	-	-	-	-
Hydraulic fluid (no CAS #)	-	-	-	-	-	-	-	-	-	-
Hydroxylamine hydrochloride (5470-11-1)	-	-	-	-	-	-	-	-	-	-
Hydroxylamine nitrate (13465-08-2)	-	-	-	-	-	-	-	-	-	-
Iron (metal) (7439-89-6)	-	-	-	-	-	-	-	-	-	-
Lithium fluoride (7789-24-4)	-	-	-	-	-	-	-	-	-	-
Mineral oil (8012-95-1)	-	-	-	-	-	-	-	-	-	-
Molybdenum (7439-98-7)	-	-	-	-	-	-	-	-	-	-
Phenylxylylene (79535-98-1)	-	-	-	-	-	-	-	-	-	-
Polypropylene (9003-07-0)	-	-	-	-	-	-	-	-	-	-
Polystyrene (Styrene polymer) (9003-53-6)	-	-	-	-	-	-	-	-	-	-
Portland Cement (65997-15-1)	-	-	-	-	-	-	-	-	-	-
Potassium dichromate (778-50-9)	-	-	-	-	-	-	-	-	-	-
Rhodium (7440-16-6)	-	-	-	-	-	-	-	-	-	-
Sodium benzenesulfonate (515-42-4)	-	-	-	-	-	-	-	-	-	-
Sodium diuranate (Sodium uranate(VI)) (13721-34-1)	-	-	-	-	-	-	-	-	-	-
Sodium hypochlorite (Bleach) (7681-52-9)	-	-	-	-	-	-	-	-	-	45.4
Sodium iodide (7681-82-5)	-	-	-	-	-	-	-	-	-	-
Sodium sulfate (7757-82-6)	-	-	-	-	-	-	-	-	-	-

	WA STATE TOXICITY CATEGORY (1)	C (2)	P (3)	D1 (4)	D2 (5)	D3 (6)	LISTED WASTE CODE (7)	FED. TCLP TC (8)	DOE Order 5820.2A (9)	Reportable * Quantity (Kg) (10)
Sulfonate polystyrene divinyl benzene (39389-20-3)	-	-	-	-	-	-	-	-	-	-
Tetradecane (629-59-4)	-	-	-	-	-	-	-	-	-	-
Thymolphthalein (thymol blue) (76-61-9)	-	-	-	-	-	-	-	-	-	-
Tributyl phosphate (126-73-8)	-	-	-	-	-	-	-	-	-	-
Tridecane (629-50-5)	-	-	-	-	-	-	-	-	-	-
Tri-iso-octylamine (68955-06-6)	-	-	-	-	-	-	-	-	-	-
Tri-n-octylamine (Nimetazepam) (2011-67-8) (21 CFR 1308.14)	-	-	-	-	-	-	-	-	-	-
Trioctylphosphine oxide (78-50-2)	-	-	-	-	-	-	-	-	-	-
Yttrium nitrate (10361-93-0)	-	-	-	-	-	-	-	-	-	-

* These reportable quantities are defined at 40 CFR 302.4

** The dash means that the information is not applicable or not available for the analyte

CODE KEY AND GUIDELINES

Code Key and Guidelines

(1) Washington State Toxicity Category

Toxicity Category for waste with one hazardous constituent:

Category X	The constituent is regulated if it is present in the waste at .001 wt% or greater.
Category A	The constituent is regulated if it is present in the waste at .01 wt% or greater.
Category B	The constituent is regulated if it is present in the waste at .1 wt% or greater.
Category C	The constituent is regulated if it is present in the waste at 1 wt% or greater.
Category D	The constituent is regulated if it is present in the waste at 10 wt% or greater.

Toxicity Category for waste with more than one hazardous constituent:

The equivalent concentration for the waste must be determined using the following formula

$$\text{Equivalent Concentration (\%)} = \Sigma X\% + \frac{\Sigma A\%}{10} + \frac{\Sigma B\%}{100} + \frac{\Sigma C\%}{1000} + \frac{\Sigma D\%}{10000}$$

where $\Sigma(X, A, B, C, \text{ or } D)\%$ is the sum of all the concentration percentages for a particular toxic category. If the equivalent concentration is greater than .001%, regardless of quantity, that waste is regulated. Using the waste graph in WAC 173-303-9906 with the determined equivalent concentration and the total waste quantity, the designation of the waste as DW (WT02) or EHW (WT01) can be determined. The waste graph should not be modified for mixed waste.

- (2) Carcinogen (C) A waste containing one or more carcinogenic constituent is regulated as carcinogenic (WC02) if either the concentration of any one carcinogenic constituent exceeds .01% of the waste quantity or the total concentration summed for all carcinogenic constituents exceeds 1% of the waste quantity.

Table Code: C - Potential carcinogen

- (3) Persistence (P) A waste containing one or more halogenated hydrocarbons (HH) is regulated when the total concentration is greater than .01%. This waste can be designated as DW (WP02) for total concentrations between .01% and 1% or EHW (WP01) for total concentrations greater than 1%. A waste containing one or more polycyclic aromatic hydrocarbons with more than 3 rings and less than 7 rings is regulated as EHW (WP03) when the total concentration is greater than 1%.

Table Code: HH - Potential for persistence for halogenated hydrocarbons

- (4) D1 A waste is regulated with the D001 waste code (ignitability characteristic) if it is either a liquid, other than an aqueous solution containing less than 24% alcohol by volume and has a flash point less than 140 °F or it is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard or it is an ignitable compressed gas as defined in 49 CFR 173.300 or it is an oxidizer as defined in 49 CFR 173.151. NOTE: EPA has not changed its reference to 49 CFR 173.300 and 173.151 to conform to new hazard class definitions under DOT's "HM-181" rules.

Table Code: F - Potential flammability
O - Potential oxidizer
CO - Potential combustibility

- (5) D2 A waste is regulated with D002 waste code (corrosivity characteristic) if it is either an aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5 or it is a liquid and corrodes steel (SAE 1020) at a rate greater than .250 inches per year at a test temperature of 130 °F.

Table Code: CR - Potential corrosivity

- (6) D3 A waste is regulated with D003 waste code (reactivity characteristic) if it has any of the following properties: it is normally unstable and readily undergoes violent change without detonating; it reacts violently with water; it forms potentially explosive mixtures with water; it generates toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment when mixed with water; it is a cyanide ore sulfide bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors or fumes in a quantity sufficient to present danger to human health or the environment; it is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement; it is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure; it is an forbidden explosive (49 CFR 173.51), a Class A explosive (49 CFR 173.53), or a Class B explosive (49 CFR 173.88).

Table Code: R - Potentially reactive

(7) Listed Waste Code

U and P codes A waste is regulated with the U and P waste codes if it's sole active ingredient is a discarded commercial chemical product or manufacturing chemical intermediate (a product, then a waste), an off-specification commercial chemical product or manufacturing chemical intermediate, a residue remaining in a container or in an inner liner removed from a

container that has held any commercial chemical product or manufacturing chemical intermediate, or a residue or contaminated soil, water or other debris resulting from cleanup of a spill into or on any land or water of any commercial chemical product or manufacturing chemical intermediate. The numbers associate the U and P codes to the specific constituent.

- F001 A waste is regulated with the F001 waste code if it is listed in the following spent halogenated solvents used in degreasing: Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; and is a sludge from the recovery of these solvents in degreasing operations. These wastes contain or may contain halogenated hydrocarbons. Although WAC 173-303-082 states that these wastes are DW, WAC 173-303-070(5), special knowledge, requires generators who know that their waste contains greater than one percent of these listed halogenated hydrocarbons to designate their waste EHW.
- F002 A waste is regulated with the F002 waste code if it is listed in the following spent halogenated solvents: Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro- 1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane and 1,1,2 trichloroethane; and is the still bottoms from the recovery of these solvents. These wastes contain or may contain halogenated hydrocarbons. Although WAC 173-303-082 states that these wastes are DW, WAC 173-303-070(5), special knowledge, requires generators who know that their waste contains greater than one percent of these listed halogenated hydrocarbons to designate their waste EHW.
- F003 A waste is regulated with the F003 waste code if it is listed in the following spent non-halogenated solvents: Xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; and is the still bottoms from the recovery of these solvents.
- F004 A waste is regulated with the F004 waste code if it is listed in the following spent non-halogenated solvents: Cresols and cresylic acid, nitrobenzene; and is the still bottoms from the recovery of these solvents.
- F005 A waste is regulated with the F005 waste code if it is listed in the following spent non-halogenated solvents: Toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, 2-nitropropane; and is the still bottoms from the recovery of these solvents.

(8) Federal TCLP Toxicity Characteristic (FED. TCLP TC)

- D004 A waste is regulated with D004 waste code if the concentration of Arsenic is 5 mg/L or greater.
- D005 A waste is regulated with D005 waste code if the concentration of Barium is 100 mg/L or greater.
- D006 A waste is regulated with D006 waste code if the concentration of Cadmium is 1 mg/L or greater.
- D007 A waste is regulated with D007 waste code if the concentration of Chromium is 5 mg/L or greater.
- D008 A waste is regulated with D008 waste code if the concentration of Lead is 5 mg/L or greater.
- D009 A waste is regulated with D009 waste code if the concentration of Mercury is 0.2 mg/L or greater.
- D010 A waste is regulated with D010 waste code if the concentration of Selenium is 1 mg/L or greater.

- D011 A waste is regulated with D011 waste code if the concentration of Silver is 5 mg/L or greater.
D018 A waste is regulated with D018 waste code if the concentration of Benzene is 0.5 mg/L or greater.
D019 A waste is regulated with D019 waste code if the concentration of Carbon tetrachloride is 0.5 mg/L or greater.
D022 A waste is regulated with D022 waste code if the concentration of Chloroform is 6 mg/L or greater.
D026 A waste is regulated with D026 waste code if the concentration of Cresol is 200 mg/L or greater.
D032 A waste is regulated with D032 waste code if the concentration of Hexachlorobenzene is 0.13 mg/L or greater.
D035 A waste is regulated with D035 waste code if the concentration of Methyl ethyl ketone is 200 mg/L or greater.
D038 A waste is regulated with D038 waste code if the concentration of Pyridine is 5 mg/L or greater.
D039 A waste is regulated with D039 waste code if the concentration of Tetrachloroethylene is 0.7 mg/L or greater.
D040 A waste is regulated with D040 waste code if the concentration of Trichloroethylene is 0.5 mg/L or greater.

(9) DOE Order 5820.2A (1988):

Chelating agent Not accepted based on DOE Order because it interferes with treatment processes

(10) Reportable Quantity

Identifies the quantity that requires reporting to the National Response Center when such hazardous substance is released into the environment, over a 24-hour period, in quantities that are equal or exceed the associated reportable quantity.

Appendix C: FIELD SCREENING DATA SHEETS

Technologies were identified that could potentially be applied to field screening of hazardous waste, including remote (in situ) analysis as well as field portable instrumentation.

The following technology data sheets identify characterization alternatives for WRAP 1, as well as technologies for WRAP 2A to reduce or replace a "sampling and laboratory analysis" approach. Field/portable instrumentation as well as remote/in situ characterization technologies were identified. The general classes of analytes which were covered in this technology search included organics (both volatile and semi-volatile) and inorganics (mainly metals and dissolved salts.) Applicable media include liquid, solid, and gas. There was no effort made to identify technologies for radionuclide detection, speciation, and quantifiacton.

The criteria and format of the data sheets were developed based on the information requirements to evaluate the capabilities of each field screening technology within the WRAP 1 option. The format for each technology data sheet include the technology title, description, advantages, limitations, applications, specifications, analysis capacities/capabilities, system operation, and life cycle cost. If information for any of the above items was not available, it was so noted or a best subjective estimate/guess was made. Technology data sheets were prepared for the following field screening technologies:

- C-1 STRIPPING VOLTAMMETRY
- C-2 FIBER-OPTIC CHEMICAL SENSORS
- C-3 NEUTRON ACTIVATION ANALYSIS
- C-4 X-RAY FLUORESCENCE SPECTROMETRY
- C-5 FIELD PORTABLE AND HAND-HELD GAS CHROMATOGRAPHS
- C-6 pH/CONDUCTIVITY PROBE
- C-7 PHOTOIONIZATION AND FLAME IONIZATION DETECTORS FOR GAS DETECTION
- C-8 COLORIMETRIC AND TITRIMETRIC METHODS
- C-9 IMMUNOASSAY FIELD TEST KITS
- C-10 FIELD PORTABLE FOURIER TRANSFORM RAMON SPECTROMETER
- C-11 FIELD PORTABLE GC/MS
- C-12 LASER ABLATION METHODS
- C-13 BIOSENSORS
- C-14 ION MOBILITY SENSORS/SPECTROSCOPY
- C-15 FOURIER TRANSFORM INFRARED (FTIR) SPECTROSCOPY
- C-16 OTHER FIELD/PORTABLE OPTICAL/SPECTROSCOPIC TECHNOLOGIES
- C-17 ION SELECTIVE ELECTRODES
- C-18 CHEMICAL IDENTIFICATION FIELD TEST KITS (HAZ CAT)
- C-19 POLARIZED LIGHT MICROSCOPY

C-1 STRIPPING VOLTAMMETRY (Electroanalytical Techniques and Electrochemical Sensors)

C-1.1 Description

An electrochemical cell consists of two or more electrodes which function as transducers between a chemical system and an electrical system in which the electrical parameters of voltage can be measured and controlled. In electroanalytical chemistry, the magnitude of a voltage or current signal from an electrochemical cell is related to the concentration of a particular analyte in the cell. This technology can be used for both qualitative and quantitative analysis.

Electrochemical sensors produce an electric signal in response to a chemical reaction. There are several types of electrochemical devices that have potential as in situ sensors, including stripping voltammetry, a catalytic surface-modified ion electrode employing amperometric titration, and resistance/capacitance sensors. There are even electrochemical immunoassay sensors being developed.

In stripping voltammetry, the target analyte is concentrated at one of the working electrodes. Voltammetry is the measurement of current-potential relationships in an electrochemical cell. The stripping voltammetry consists of two steps: depositing the target analyte at one of the electrodes by controlled-potential electrolysis (which is pre-concentration of the target analyte), and removing/stripping of the analyte that is deposited at the electrode by an appropriate potential scan. The resulting current signal is used to quantify the concentration of analyte. Anodic stripping voltammetry (stripping step gives anodic current) is used primarily for the determination of heavy metals, and cathodic stripping voltammetry (stripping step gives cathodic current) is used for measuring anion concentrations. There is also a stripping voltammetry technique that involves complexing the target metal analyte to a ligand followed by adsorptive accumulation of the complex on an electrode.

With an amperometric sensor, a voltage is applied between the working and reference electrodes. The imposed potential encourages electron transfer (redox) reactions to occur, causing a current flow that is proportional to the concentration of the analyte.

Resistance/capacitance sensors rely on adsorption of target analytes by chemically-specific polymeric coatings. The target molecules that are adsorbed change the resistance or capacitance of the sensing surface which changes an electrical signal, and can be related to contaminant concentration.

C-1.2 Applications

New Mexico State University has developed an electrochemical sensor for detecting chromium (VI), based on adsorptive stripping voltammetry. This type of voltammetry involves concentrating the target analyte on one of the working electrodes. Potentially, this type of electrochemical sensing technology could be used for detecting trace levels of calcium, magnesium, strontium, barium, nickel, cobalt, aluminum, uranium, iron, copper, yttrium, and vanadium.

Metorex sells a field portable (not in situ) anodic stripping voltameter that is used to detect a variety of metals and heavy metals in the ppb to low ppm range. The system comes with a 21 component standards kit for calibration, and can be connected to a PC.

C-1.3 Summary of Advantages

- High selectivity and sensitivity.
- Multi-element capability (heavy metals).
- Applicable to anions (e.g., nitrate, nitrite, chloride).
- Quick turnaround expected.
- Reproducible results
- Independent of waste matrix
- Low cost.

C-1.4 Summary of Limitations

- Maturity of the technology for field and in situ applications is uncertain.
- Some methods require extraction of contaminant from sample matrix into an extractant matrix before electrochemical analysis.
- Inability to work with complex matrix.
- Generate Hg waste.
- Too sensitive.
- Sample must be in solution.

C-1.5 Specifications

Vendor(s): New Mexico State University (R&D)

General Electric Co., Environmental Research Center (R&D)

Metorex (originally Outokumpu Electronics)

Model Number(s): Metorex: TRACE-MET 2000

Weight: unknown, but expected to be low.

Dimensions: unknown, but expected to be small.

Space Requirements: unknown, but expected to be low.

Power Requirements: expected to be low.

Metorex TRACE-MET 2000: 24V battery or external (11 V to 30 V DC).

Description of System Operation: as described in section above.

Intended Application: field and in situ analysis of metals in aqueous solution.

Technology Maturity: high for laboratory instrumentation, but lower for field applications, and even lower for in situ applications.

C-1.6 Analysis Capacities/Capabilities

Analytes Detected: metals and anions. For environmental applications, development has focused on heavy metal detection.

Metorex TRACE-MET 2000: Sb, As, Bi, Cd, Cu, Au, Pb, Hg, Tl, Zn, In, Mn, Ag, Se, Sn, Fe, Ni, Co, and Cr.

Range of Detection: very low detection limits (even parts per trillion).

Metorex TRACE-MET 2000: low ppb to low ppm.

Precision/Accuracy: varies with different technologies.

Capacity/Throughput: unknown, but expected to be high.

C-1.7 Sample Preparation/Limitations

Sample Volume: low, enough to immerse electrodes for in situ.

Metorex TRACE-MET 2000: 10 ml cell.

Sample Conditioning: none.

Sample Configuration/Phase: liquid.

Interferences: unknown.

C-1.8 System Operation

Mode of Operation: bench-top and in situ.

Manpower Requirements: low.

Calibration: unknown, but expected to be important.

Metorex TRACE-MET 2000: standards supplied for calibration.

Environmental Restrictions: For in situ applications, electrodes/sensors will be placed directly in liquid, and current applied.

Safety Considerations: Build-up of hazardous materials on electrodes.

C-1.9 Life Cycle Cost

System Cost: unknown.

Operating Cost: unknown, but expected to be low.

Maintenance Cost: unknown.

Life Expectancy: unknown.

C-2 FIBER-OPTIC CHEMICAL SENSORS

C-2.1 Description

Fiber-optic chemical sensors (FOCS), also called chemical optrodes, combine fiber optics, chemistry, immobilization techniques, and spectroscopy to perform highly-sensitive, highly-selective chemical sensing. FOCS generally use a specific chemical coating that reacts chemically or physically in the presence of the target contaminants. This technology is useful for monitoring known (or suspected) chemicals in a waste stream, typically aqueous.

The sensor consists of a reagent (chemically-selective indicating layer) immobilized at the end of a fiber optic distal tip. Light is introduced into the proximal end of the fiber and transmitted via total internal reflection through the fiber to the distal fiber surface. The reagent either reacts with the target contaminant to produce an optical signal or to modify an existing signal. The light that is delivered down the fiber is modified by the reaction of the analyte (target contaminant) with the reagent. The return signal indicates the presence of a specific contaminant or a family of chemicals, and the intensity indicates the concentration. The FOCS typically measure fluorescence, colormetric change, or refractive index change.

C-2.2 Applications

FOCS have been used to continuously monitor contaminants in water. The typical application is for field/in situ monitoring hydrocarbons and organics in vapor and water. Fiber optic chemical sensing technology is still mostly a laboratory R&D activity.

C-2.3 Summary of Advantages

- Continuous monitoring capability.
- Small size and flexibility.
- Highly sensitive and selective to target analytes.
- Can be used to monitor a threshold level.
- For effluent monitoring

C-2.4 Summary of Limitations

- Smaller dynamic range than competing technologies.
- Its applicability to unknown/uncharacterized samples as a quantitative tool is uncertain.
- Limited analyte list currently.
- Development and testing required for most sensors and applications to advance maturity level of technology to a useable stage.
- Sensor window must be kept clean.
- Sample must be in solution.
- Fiber optics may not be compatible with radionuclides.

C-2.5 Specifications

Vendor(s): FiberChem, Inc.

First Omega Group, Inc.

Geo-Centers, Inc., Sensor Systems Group

Lawrence Livermore National Laboratory (R&D)

Purus, Inc.

Sandia National Laboratories (R&D)

Model Number(s):

Weight: low.

Dimensions: low.

Space Requirements: low.

Power Requirements: low.

Description of System Operation: Same as description in Section 7.2.1 above. The FOCS fiber end can be a distance from the analyzer and data handling equipment. One would envision using an instrument like this in the same manner as a portable pH probe. The distal end must be immersed in the sample media (liquid). The complexity of the data handling and interpretation will depend on the type of spectroscopy and the capabilities of the spectroscopy software.

Intended Application: Current applications are for detecting and monitoring specific organic contaminants in water. Conceivably, this would be applicable to sensing contaminants in liquid media. Analytes of interest would be organics and heavy metals. Development and testing will be required to adapt this technology for this application.

Technology Maturity: Mostly research and development, though there have been some commercial products, mostly for monitoring organics in water.

C-2.6 Analysis Capacities/Capabilities

Analytes Detected: Currently available sensors are for organic in aqueous solution applications (e.g., aromatics and chlorinated hydrocarbons). There are also alkali and heavy metal ion sensors based on selective ionophores or chromophores. Many of these chemical sensors have been laboratory tested but not field demonstrated. Development and testing will be required to implement the technology for a specific application.

Range of Detection: Variable. Detection limits are expected to be in the ppm range. Dynamic range is smaller than other competitive techniques which is a result of the intrinsic equilibrium basis on which the sensors operate.

Precision/Accuracy: Variable. With unknown samples, the technology is probably more qualitative than quantitative.

Capacity/Throughput: This technology detects contaminants in liquid aqueous media, so samples do not need to be obtained. Response times will vary, but should be fast enough that analysis time will not be a concern.

C-2.7 Sample Preparation/Limitations

Sample Volume: low, enough to immerse the tip of the sensor.

Sample Conditioning: none required.

Sample Configuration/Phase: liquid/aqueous. Current demonstrated technology is most applicable to aqueous solution with dilute concentrations of contaminants.

Interferences: area of concern. FOCS are highly selective, but they are also highly sensitive. The effects of temperature, Ph, dissolved solids (especially at higher concentrations), radiation, etc. will be issues that need to be addressed and resolved.

C-2.8 System Operation

Mode of Operation: in situ.

Manpower Requirements: low.

Calibration: area of concern.

Environmental Restrictions: If sample media is radioactively contaminated, sensors will need to be decontaminated before removal.

Safety Considerations: none.

C-2.9 Life Cycle Cost

System Cost: medium to high, mainly because of the R&D, demonstration, and validation activities that would need to be performed to implement this technology.

Operating Cost: low.

Maintenance Cost: low.

Life Expectancy: high. The detector, analyzer, and data handling equipment can be isolated from the FOCS, so only the sensor would experience harsh environment and need to be replaced.

C-3 NEUTRON ACTIVATION ANALYSIS

C-3.1 Description

Prompt neutron activation analysis (PNAA) is an established technique for elemental analysis in many fields such as earth science, biology, forensics, the fine arts, and industry. With activation analysis, a sample being studied is bombarded with a flux of neutrons so that the element or elements of interest in the sample are transformed into radioactive elements. The decay activities of these elements are a function of the concentration of the original element in the sample. The measurement is made quantitative either by knowledge of the neutron flux and the activation cross sections, or by the use of pure elemental standards, irradiated under the same conditions as the sample. These methods are known as absolute and comparative neutron activation analysis, respectively.

Most analyses performed are of the comparative type, and thermal neutrons from a reactor (source) are usually used. High-resolution gamma spectroscopy with a Ge detector can be used for the analysis of the sample spectrum. Other detector options that provide either higher speed or higher intrinsic efficiency are possible, but are usually lower resolution.

Some elements cannot be analyzed by this method because the activation product is stable or is not easily observed. Also, the activation cross sections for different elements vary greatly.

C-3.2 Applications

Idaho National Engineering Laboratory (INEL) has developed a Portable Isotopic Neutron Spectroscopy (PINS) chemical assay system using a ^{252}Cf source. Neutron irradiation of a target produces characteristic gamma rays which signal presence or absence of various chemical elements. The system uses a high-purity germanium gamma-ray detector, an electronics/multi-channel analyzer package, and a notebook PC for control. PINS has been used to detect old munitions in a construction site, and also to detect liquid chlorine, herbicides, and pesticides in an abandoned container. The key elements that the PINS system was set up to detect were chlorine, sulfur, and phosphorus.

Pajarito Scientific Corp. is developing a drum assaying technology using neutron activation combined with passive and active gamma detection to assay radioactive materials in waste drums. Heavy metals are not part of the characterization capabilities of this system.

C-3.3 Summary of Advantages

- High resolution; elements have characteristic emissions when irradiated by a neutron flux.
- Rapid elemental analysis/immediate turnaround (minutes).
- Able to characterize depth profiles (not just surface characterization like XRF). For example, neutron penetration greater than 40 inches is possible in packed soil.
- Applicable to many elements, including most metals/heavy metals.
- Detects low level metals.

C-3.4 Summary of Limitations

- Moisture will affect results; unknown moisture may introduce errors that are difficult to resolve.
- Other interference (neutron moderators) include plastics (e.g., polyethylene), organics (e.g., oils), and carbon (e.g., granular activated carbon).
- Strontium-90 has no gamma but decays to yttrium-90. The gamma emission is weak and is not easily separated and identified.
- The PNAA is not widely accepted; validation and qualification required. A source license is required for acceptable results.

C-3.5 Specifications

- Expensive maintenance.
- Too sensitive (error propagation)

Vendor(s): Westinghouse Electric Corporation (WEC)
(Science & Technology Center)

EG&G ORTEC

Idaho National Engineering Laboratory (INEL) (developer)

Pajarito (drum assaying technology)

Model Number(s): INEL: PINS system

EG&G ORTEC:

Pajarito drum assayer:

WEC: Prompt Gamma Neutron Activation Analysis (PGNAA)

Weight: varies, but high in general compared to most laboratory instrumentation.

Dimensions: varies, but higher than laboratory instrumentation in general.

Space Requirements: varies, but expected to be high.

Power Requirements: varies, but expected to be high.

Description of System Operation: The technology is a method of non-contact (remote) analysis of materials in different geometries. For instance, the PGNAA is engineered for characterizing a flat surface at depth (e.g., soil or floors), while the Pajarito system is engineered for assaying drums. The system uses neutrons to irradiate a material, and the gamma emissions from the activated material are detected, measured, and analyzed. Neutron sources include ^{252}Cf , electronic neutron generator tubes, deuterium/tritium sources (D+T), and deuterium sources (D+D). Detectors that can be used include plastic scintillators, NaI scintillators, and germanium solid state detectors.

Intended Application: Non-destructive, non-invasive characterization (elemental analysis) of soils, surfaces, and packages.

Technology Maturity: Technology is developed and demonstrated for specific applications, but not really commercialized yet. Validation and qualification testing for specific elements and applications will be required.

C-3.6 Analysis Capacities/Capabilities

Analytes Detected: elemental (applicable to most elements though there may be some problems (weak signals and/or interferences) with certain elements (e.g., Sr).

Range of Detection: variable, but is expected to be ppm to weight percent. The limitation will be on the detector, geometry, and data interpretation software. In general, the technology is expected to be applicable from trace levels to high concentrations.

Precision/Accuracy: variable and uncertain. Westinghouse claims 10 ppm sensitivity for uranium in soil up to 24 inches. Accuracy is dependent on calibration to the geometry and matrix being investigated.

Capacity/Throughput: high. Analysis times will depend on source, detector, geometry, and matrix.

C-3.7 Sample Preparation/Limitations

Sample Volume: variable.

Sample Conditioning: none required.

Sample Configuration/Phase: any, though liquids will moderate neutrons, and appropriate calibration will be required.

Interferences: Neutron moderators (e.g., water, plastics, organics) and geometry dependence.

C-3.8 System Operation

Mode of Operation: non-invasive, non-destructive in situ characterization at depth.

Manpower Requirements: unknown.

Calibration: Validation and qualification of the technology will be required for specific applications. Algorithms would need to be developed to resolve uncertainties and errors due to interferences.

Environmental Restrictions: none. There are virtually no residual activated materials with this technology because the neutron bombardment times are short.

Safety Considerations: Radioactive sources must be used to provide the neutron flux.

C-3.9 Life Cycle Cost

System Cost: \$1M.

Operating Cost: unknown.

Maintenance Cost: unknown.

Life Expectancy: ~10 yr.

C-4 X-RAY FLUORESCENCE SPECTROMETRY

C-4.1 Description

X-ray fluorescence (XRF) spectrometry is an established analytical method for elemental analysis. The basis of the X-ray fluorescence technique is that when an atom is bombarded with high-energy particles (e.g., X-ray photons), an inner orbital electron may be displaced, leaving the atom in an excited state. The atom can regain stability by rearrangement of the atomic electrons, and inner-shell vacancies may be filled with electrons from outer shells, causing emission of characteristic X-ray radiation that is then detected and measured.

Conventional X-ray spectrometers have three basic parts: the primary source, the spectrometer, and the measuring electronics. The primary source consists of a stable high-voltage generator and a sealed X-ray tube, which delivers an intense source of continuous radiation. The spectrometer collects and separates (by wavelength or energy) the fluorescence radiation produced by elements bombarded by the source. A photon detector, usually a gas flow or a scintillation counter, converts separated photons into electrical signals which are measured and displayed by the electronics.

X-ray fluorescence spectrometers either isolate narrow wavelength bands (wavelength-dispersive spectrometry) or narrow energy bands (energy-dispersive spectrometry). Emission wavelengths are well characterized for atomic elements, so isolation of individual characteristic lines allows the unique identification of an element. Also, elemental concentrations can be estimated from the intensities of these characteristic lines.

C-4.2 Applications

X-ray fluorescence spectrometry is used for qualitative and quantitative elemental analysis. The technique could potentially reduce the number of atomic absorption/ inductively-coupled plasma (AA/ICP) analyses that would need to be performed in the laboratory.

Outokumpu Electronics, Inc., claims that their portable XRF analyzer with a high-resolution, solid-state detector probe can be successfully used for on-site, hazardous waste screening and analysis at EPA Level I data quality objectives.

TN Technologies claims that using their portable XRF unit is a viable, effective approach to meet the on-site metals analysis needs of many U.S. EPA/ Environmental Response Team hazardous waste site evaluation/removal programs QA2 data objectives have been achieved that provide quick, on-site, multi-element analysis of large numbers of in situ as well as prepared samples. Their statistical evaluations infer that both methods produce identical regression coefficients (i.e., confidence of the analyses is the same for both in situ and prepared sample analysis). Examples of specific applications include: extent of contamination studies, on-site metal analyses to direct removal actions, analysis of paint for Pb content, analysis of air filters for metals, and post-cleanup surveys.

C-4.3 Summary of Advantages

- Portable field or in situ instrument used for metals analysis (qualitative and quantitative).
- Detects metals, pure salts, and powders.
- Quick measurement, requiring little sample preparation.
- Compact size.
- Can handle liquids and solids.
- Rugged, well-proven field instrument.
- Works well in radiological environment.
- Accurate qualitative analysis (metals identification).

C-4.4 Summary of Limitations

- Calibration issues with a heterogeneous matrix.
- Not accurate for heterogeneous materials
- Low depth of penetration.
- Detects only at surface area, so matrix/surface condition may reduce accuracy.
- Requires license to operate X-Ray Source.
- Mercury and Sodium are not detected because they vaporize in the vacuum.
- Requires a vacuum to be maintained.

C-4.5 Specifications

Vendor(s): ASOMA Instruments, Inc. (800-333-6310)
 The Perkin Elmer Company (203-762-4811)
 Fisons Instruments (800-227-0277)
 On-Site Instruments (800-444-1674)
 Scitec Corp. (509-783-9850) (mainly for lead paint)

HNU Systems Inc.
 160 Charlemont St.
 Newton, MA 02161-9987
 (617) 964-6690 (800) 962-6032 FAX: 617-965-5812

TN Technologies Inc.
 Box 800
 Round Rock, TX 78680-0800
 (512) 388-9100 (800) 736-0801 FAX: 388-9200
 Attn: Margo Myers

Metorex Inc.

1900 NE Division St., Suite 204

Bend, OR 97701

(503) 385-6748 (800) 229-9209 FAX: 503-385-6750

HAZ-MET, a field portable XRF analyzer combined with TRACE-MET, a field portable anodic stripping voltameter, provides detection of metal contaminants from ppb or ppm levels up to 100%.

Model Number(s): TN Technologies' Spectrace 9000

Metorex's X-MET series of field portable XRF analyzers (920P and 880)

Weight: TN Technologies' Spectrace 9000: 20 lbs

Metorex's X-MET: 8-9 lb probe and 14 lb analyzer

Dimensions: TN Technologies' Spectrace 9000:

Probe: 5" x 3" x 8.5"

Analyzer: 13" x 12" x 4"

Metorex's X-MET:

Probe: 8"L x 4"W x 10"H

Analyzer: 16" x 16" x 4"

Space Requirements: low in general.

Power Requirements: normal AC power for bench-top applications, rechargeable batter-operated for field applications.

TN Technologies' Spectrace 9000: Battery operated (4 to 5 hours continuous use), rechargeable. Can be operated on AC power (110 or 230 volts).

Metorex's X-MET: Battery operated (10 hour continuous use), rechargeable. Can be operated on AC power (115 or 230 VAC).

Description of System Operation: TN Technologies' Spectrace 9000 is a portable "high performance" XRF elemental analysis system. The unit has a high-resolution HgI_2 X-ray detector, which reduces multi-element spectral interference problems, resulting in claimed excellent accuracy and precision. The unit has three excitation sources, iron-55, cadmium-109, and americium-241, to cover a wide range of elements. The accompanying software can perform a wide range of analysis, including spectra manipulation integration, peak identification, and spectrum smoothing.

Metorex's X-MET analyzers have multiple excitation source capability (normally ^{109}Cd and/or ^{241}Am), and uses a high-resolution $\text{Si}(\text{Li})$ probe (lithium drifted silicon) for surface analysis. The probe has a 30 mm^2 active area, and is cooled by a small built-in liquid nitrogen dewar (8 hour capacity before recharging). The X-MET analyzer also has high-resolution gas-filled proportional counter detectors which can handle bulk analysis as well as surface analysis. The system includes data handling hardware and software.

Intended Application: Field portable XRF analyzers are generally intended for solids, powders, liquids, and thin films or coatings. Analyses may be performed in situ, in the field, or in a laboratory environment. Some analyzers have sampling capabilities to also analyze liquids as well as particulates in air (by collecting on a filter).

Technology Maturity: Commercially available for the most part.

C-4.6 Analysis Capacities/Capabilities

Analytes Detected: Will depend on excitation source(s).

TN Technologies' Spectrace 9000: set up for measuring K, Ca, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Zr, Mo, Hg, Pb, Cd, Sn, Sb, and Ba. Can be set up for analysis of sulfur through uranium (atomic numbers 16-92). Limited to simultaneous analysis of 25 elements.

Metorex's X-MET systems are normally set up for analyzing atomic numbers 13 to 92 (Al to U) using a combination of four sources (^{55}Fe , ^{244}Cm , ^{109}Cd , and ^{241}Am), and is limited to simultaneous analysis of 6 elements.

Range of Detection: TN Technologies' Spectrace 9000: Detection limits vary, ranging from 10 to 100 ppm. Upper end of detection can be as high as the pure substance, but is normally used in the weight percent range.

Metorex's X-MET systems: ppm to 100%.

Precision/Accuracy: In 1987, the U.S. EPA accepted the Energy Dispersive XRF as a Level I analytical method. This means that XRF technology can be used for screening and preliminary on-site evaluation of contaminant levels, with accuracies acceptable if within +/-50%, precision of +/-10%, and an instrument detection limit of 1000 ppm. Users have demonstrated better precision and accuracy than this.

TN Technologies' Spectrace 9000: Normally less than 20 percent relative.

Metorex's X-MET systems: 10-12% resolution for the proportional counter, and 2.5% for the Si(Li) detector (peak discrimination). Precision of 6 to 7 mg/kg.

Capacity/Throughput: TN Technologies' Spectrace 9000: simultaneous analysis of up to 25 elements. Measurement times per sample vary from 30 to 240 seconds. The system has data storage, data processing, and PC interface capabilities that allows 300 sets of analytical results and 120 sets of spectra to be stored and analyzed (e.g., normalizing spectra, peak identification, smoothing, integration).

Metorex's X-MET turnaround times are on the order of 30-100 seconds for initial screening and hot-spot delineations. Longer measurement times (100 to 500 seconds) are typically used for higher precision and accuracy requirements.

C-4.7 Sample Preparation/Limitations

Sample Volume: TN Technologies' Spectrace 9000: For in situ applications, the diameter of the probe window is about 1.5 inches, so the sample surface must be as large. Active measured depth is only around 200 micron. For the bench-top application, the sample cup holds 4 to 5 gram samples.

Metorex's X-MET systems are similar to TN Technologies'.

Sample Conditioning: None usually required. Surface probe devices must be positioned flush against the sample surface. Wet samples (greater than 20 wt% moisture) are normally allowed to air dry before a measurement is made. The ideal situation is a homogeneous sample.

For some applications, samples are placed in a sample cup. The sample must be flattened so the probe can be positioned flush with the sample.

Sample Configuration/Sample Phase: solids, liquids, powders, thin films, coatings.

Interferences: Moisture content and particle size variation can interfere with (affect) intensity measurements. 20-30% moisture or more will lighten the mass of the matrix, and affect the detected signal. Particle size variations represents heterogeneity. Since the active area is only a couple of hundred micron or so thick, air gaps will introduce uncertainties in intensity measurements. For specific applications, the data analysis software can be customized to correctly interpret signals from media different than the standard ones developed by the vendor (e.g., soil and paint on walls).

C-4.8 System Operation

Mode of Operation: In situ (probe) or on-site using the instrument as a bench-top analyzer. Liquid samples may require pre-concentration, and particulate-in-air samples require collection via filtration.

Manpower Requirements: low.

Calibration: As with most analytical methods, it is important to understand the sample matrix. Once the instrument is calibrated for a specific application (e.g., lead paint on walls), no further calibration is usually required. Like all comparative analytical techniques. XRF spectrometry requires a number of well-characterized samples for calibration. Two types of calibration are employed in field portable XRF: empirical parameters and fundamental parameters. In the empirical parameters method, analyzed samples may either be samples collected on the given site and analyzed in the lab, or they may be spiked samples. In the fundamental parameters method, at least one fully characterized calibration sample is required, which is analyzed for every element in the sample. All major, minor, and trace elements must be characterized, even if not being analyzed in the unknown samples. This method is useful in dealing with unanticipated or unexpected elements and out-of-range concentrations.

TN Technologies Spectrace 9000: No calibration is required for site-specific applications that are part of the instrument's library (e.g., soil and paint). A fundamental parameters (FP)-based method is used to calculate elemental concentrations. FP is a mathematical treatment of chemical matrix effects used in conjunction with pure element or known standard element responses to develop an iterative algorithm for analysis of a specific sample type (e.g., soil, oil, thin film, and paint). An energy calibration is performed automatically with each analysis to prevent error due to gain shifts. The vendor has developed an application generator program that can be used to customize the instrument to specific applications that are not part of their library.

Environmental Restrictions: Small, sealed, radioactive sources are used, but should pose no risk to the environment. Portable instruments have been used in the field for a number of years.

Safety Considerations: None.

C-4.9 Life Cycle Cost

System Cost: \$50,000 - \$60,000 for TN Technologies field portable Spectrace 9000. Costs of similar laboratory and field instruments will probably be around this range.

Operating Cost: negligible.

Maintenance Cost: ^{109}Cd and ^{55}Fe sources must be replaced every year or two because of their short half-lives. HgI_2 detectors must be replaced every two to six years, depending on the environment and handling.

Life Expectancy: years.

C-5 FIELD PORTABLE AND HAND-HELD GAS CHROMATOGRAPHS

C-5.1 Description

Gas chromatography is a separation technique (using column separation) based on the differential interaction of volatilized sample components with a liquid, or sometimes a solid, stationary phase. As sample components are transported through a column containing the stationary phase by an inert carrier gas mobile phase, they distribute themselves between the two phases. Analytes that are weakly retained by the stationary phase will exit the end of the column at nearly the velocity of the carrier gas. Compounds that interact strongly with the stationary phase will spend relatively more time in it, and emerge later from the column. Ideally, components of mixtures appear in separated bands at the end of the column, and can be detected and measured by a variety of detectors.

C-5.2 Applications

Typically a laboratory instrument, Gas Chromatographs have been moved to the field. A Gas Chromatograph (GC) is the separator, and the accompanying detector determines the utility for chemical species quantification (e.g., mass spectrometer can be used to identify and quantify organics). This technology sheet will focus on the use of this technology for toxic air/gas monitoring. A portable or hand-held GC could be used to detect, identify, and quantify toxic vapors. The utility for the WRAP application would be to identify volatile species in the vapor space of waste drums.

PHOTOVAC has developed a hand-held GC that utilizes capillary column chromatography with a photoionization detector to detect aromatics, certain chlorinated and non-chlorinated hydrocarbons, solvents (e.g., ketones and toluene). The instrument has individual application modules which are pre-programmed for specific monitoring tasks, mostly volatile organics that are of concern in industrial hygiene and environmental monitoring.

SRI Instruments' 9300 Gas Chromatograph is a small certification-grade gas chromatograph for field or laboratory use. The instrument has seven injector options (maximum of three on one instrument), including a thermal soil desorber for soils and solids and a purge and trap for volatiles in liquids. The system also has seven detector options (maximum of four on one instrument), including a thermal conductivity detector, flame ionization detector, photoionization detector, and electrolytic conductivity detector. The system is connected to a PC and comes with Peaksimple II Data System software for spectra interpretation. The software can also automate and control certain GC functions.

C-5.3 Summary of Advantages

- Near real-time gas analysis.
- Qualitative and quantitative methods can be applied.

C-5.4 Summary of Limitations

- Most useful for volatile species in the vapor phase.
- Probably too complicated for unknown liquid or solid analyses.
- Complexity of instrument and analytical methods increases as data quality objectives become more stringent.
- Identification and quantification of unknown matrices would require mass spectrometer detector, increasing complexity of instrument.
- Set up for only 4 or 5 target chemicals.
- High maintenance cost.

C-5.5 Specifications

Vendor(s): PHOTOVAC INTERNATIONAL INC.
25-B Jefryn Boulevard West
Deer Park, NY 11729
(516) 254-4199 FAX: (516) 254-4284

SRI Instruments
6700-B Paradise Rd.
Las Vegas, NV 89119
(702) 361-2210 FAX: (702) 361-9690

Model Number(s): PHOTOVAC: SnapShot™

SRI Instruments: 9300 GC

Weight: PHOTOVAC SnapShot: 8.3 lbs

SRI Instruments 9300 GC: 30-60 lbs, depending on options.

Dimensions: PHOTOVAC SnapShot: 14"L x 5"W x 9"H

SRI Instruments 9300 GC: 12"W x 15"D x 13"H

Space Requirements: low for hand-held, medium (bench-top space) for portable analyzers.

Power Requirements: low for PHOTOVAC's hand-held SnapShot (battery operated, rechargeable with 4-6 hour operational life), standard 120 VAC or 220 VAC for bench-top systems.

Description of System Operation: Gas sample is drawn through a separator column, partitioning different constituents. Some type of detector analyzes the separated components as they exit the column.

Intended Application: PHOTOVAC SnapShot: analysis of toxic vapors.

SRI Instruments 9300 GC: laboratory or field analysis of volatiles in gas/vapor, liquid, and even solid samples.

Technology Maturity: commercial.

C-5.6 Analysis Capacities/Capabilities

Analytes Detected: PHOTOVAC SnapShot: benzene, toluene, total C8 aromatics, certain chlorinated hydrocarbons, certain ketones, and certain hydrocarbons (propane, butane, and pentane).

SRI Instruments 9300 GC: volatile organic species.

Range of Detection: PHOTOVAC SnapShot: Low ppm (sub ppm for benzene) to as high as 1600 ppm (acetone).

SRI Instruments 9300 GC: Depending on injector and detector options, part per million, billion, and trillion detection limits are achievable. Upper end will vary depending on detector from 2 to 5 orders of magnitude above the detection limit.

Precision/Accuracy: Precision and accuracy will vary depending on a variety of factors, including type of injector, type of detector, type of sample, and sample preparation.

PHOTOVAC SnapShot: Typically +/-15% within 1 decade of calibration point.

Capacity/Throughput: PHOTOVAC SnapShot: Between 4 and 10 minutes per analysis.

SRI Instruments 9300 GC: Longer than hand-held instruments due to longer columns/separation times and more thorough data acquisition and interpretation.

C-5.7 Sample Preparation/Limitations

Sample Volume: Low

Sample Conditioning: PHOTOVAC SnapShot: none.

SRI Instruments 9300 GC: variable, depending on sampling and injection options.

Sample Configuration/Phase: PHOTOVAC SnapShot: vapor/gas.

SRI Instruments 9300 GC: variable (solid, liquid, gas), depending on sampling, preparation, and injection methods.

Interferences: PHOTOVAC SnapShot: volatile organics not in the vendor's library of application modules may give false readings.

SRI Instruments 9300 GC: Since the method is based on retention times, it may be difficult to accurately characterize unknown species. Use of a mass spectrometer for identification is described in a separate technology sheet.

C-5.8 System Operation

Mode of Operation: PHOTOVAC SnapShot: hand-held operation.

SRI Instruments 9300 GC: field portable or bench-top operation.

Manpower Requirements: PHOTOVAC SnapShot: low, just user.

SRI Instruments 9300 GC: medium, requires technician-level expertise for routine operations.

Calibration: PHOTOVAC SnapShot: comes with calibration kit.

SRI Instruments 9300 GC: Calibration facilitated by accompanying software.

Environmental Restrictions: None.

Safety Considerations: PHOTOVAC SnapShot: Since this is a hand-held device, the user must be near the point of measurement. PHOTOVAC has an intrinsically-safe version that is ETC Classified to UL Standard 913 for use in Class I, Division I, Groups A, B, C, and D Hazardous Locations.

SRI Instruments 9300 GC: Column temperatures go as high as 400°C, though external temperature are safe. The carrier gas used for chromatography is typically hydrogen, so compressed hydrogen gas cylinders will be a concern. If a photoionization detector or electrolytic conductivity detector is used, the carrier gas can be air, so only the system's air compressor would be needed.

C-5.9 Life Cycle Cost

System Cost: PHOTOVAC's SnapShot costs between \$10,000 and \$20,000, depending on options and accessories.

SRI Instruments 9300 GC: \$15,000 to \$35,000, depending on options.

Operating Cost: low in general.

PHOTOVAC's SnapShot uses inexpensive, field-replaceable, carrier gas cartridges.

Maintenance Cost: higher maintenance costs than most field instrumentation.

PHOTOVAC's SnapShot has an optional maintenance contract that costs \$1,500 to \$1,625 per year.

Life Expectancy: PHOTOVAC's SnapShot: expected high life, built for rugged field use.

C-6 pH PROBE

C-6.1 Description

Quick pH measurements of liquid can be made using hand-held pH analyzers. For instance, Perstorp's hand-held Triple-Check analyzer is designed for the simultaneous measurements of pH/mV (using a general purpose single-junction pH electrode), conductivity, and temperature of water and aqueous solutions. The key parameters are measured with a set of replaceable sensors connected with standard connectors to the hand-held portable meter. The instrument has automatic temperature compensation. The user can display uncompensated or auto-compensated results, and store up to 250 sets of readings for review and recording at a later time.

C-6.2 Applications

Typically used for water and aqueous solutions. The Triple-Check analyzer is hand-held and batter-operated.

C-6.3 Summary of Advantages

- Simple, quick pH check.
- Sensors can be easily replaced.
- Data can be downloaded to a PC.

C-6.4 Summary of Limitations

- Only data that can be obtained is pH and conductivity.
- Sensor probes must be kept clean.
- Must be periodically calibrated.

C-6.5 Specifications

Vendor(s): Perstorp Analytical Environmental
Box 648
Wilsonville, OR 97070
(503) 682-3848 FAX: (503) 685-9218

Model Number(s): Perstorp Triple Check™ Water Analyzer

Weight: 1 to 10 lbs, depending on cable length.

Dimensions: Analyzer is 7.5"L x 4.15"W x 1.5"D, probe is 12"L x 1.5"OD.

Space Requirements: low.

Power Requirements: 6-volt rechargeable battery or 110 VAC/60Hz (220 VAC/50 Hz optional)

Description of System Operation: pH and conductivity are obtained using standard pH electrodes and conductivity sensors. After immersing the sensor in the liquid of interest, data is obtained almost immediately.

Intended Application: water and aqueous solutions.

Technology Maturity: commercial.

C-6.6 Analysis Capacities/Capabilities

Analytes Detected: pH and conductivity/total dissolved solids (TDS)

Range of Detection: 1-13 pH or +/-500 mV for pH, and 10-99,990 microSiemens or 5-49,990 ppm for conductivity/TDS.

Precision/Accuracy: Resolution for pH is 0.01 pH units with an accuracy of +/-0.02 pH units, or 1 mV +/-2% mV. Resolution for conductivity/total dissolved solids is 0.1% of range, and accuracy is 3% of full scale.

Capacity/Throughput: not a concern.

C-6.7 Sample Preparation/Limitations

Sample Volume: low (in situ: enough to immerse probe).

Sample Conditioning: none.

Sample Configuration/Phase: water and aqueous solutions.

Interferences: Temperature, which is automatically compensated for.

C-6.8 System Operation

Mode of Operation: Field/in situ.

Manpower Requirements: low.

Calibration: Compensation and calibration data are permanently stored in the Triple-Check instrument's microprocessor.

Environmental Restrictions: None.

Safety Considerations: None.

C-6.9 Life Cycle Cost

System Cost: low, less than \$1,000.

Operating Cost: low, essentially labor.

Maintenance Cost: low, less than \$100 to replace a probe/sensor.

Life Expectancy: high. Sensors/electrodes can be easily replaced.

C-7 PHOTOIONIZATION AND FLAME IONIZATION DETECTORS FOR GAS DETECTION

C-7.1 Description

A flame ionization detector (FID) is used to detect many organic compounds. The detector measures only C-H containing molecules (oxidizable carbon atoms), and gives no response for water, carbon dioxide, or other organic compounds. The FID contains a small gas burner that produces a hydrogen flame, a polarizing voltage source, and an ion collector. Organic compounds are burned, ionic fragments and free electrons are formed. These fragments are collected, producing an electric current proportional to the rate at which the sample enters the flame. The signal from the mass sensitive detector is amplified and processed, with the magnitude of the signal being directly proportional to the concentration of organics present. The detector/instrument has a unique response to each organic compound.

A photoionization detector (PID) operates in roughly the same manner, but uses an intense lamp instead of a hydrogen flame.

C-7.2 Applications

Flame ionization detectors and PIDs are used for organic vapor monitoring/analysis in the laboratory or in the field. The instruments can be coupled with other instruments (e.g., gas chromatograph) for better quantification of mixtures of organic vapors. In industry, this technology is used for hazardous waste site investigation, landfill gas monitoring, leak detection of gas/fuel lines and networks, and occupation hygiene monitoring.

C-7.3 Summary of Advantages

- High sensitivity.
- Detects flammability.
- Wide dynamic range.
- Identifies unique chemical compounds when used in combination with a GC.
- Fast response.
- Indicates safe environment before introducing other system with energy (i.e. lasers).

C-7.4 Summary of Limitations

- Speciation of organics is limited without additional instrumentation.
- Does not identify which compounds contribute to flammability.
- Vapor monitoring technology only.
- Sample must be a liquid solution.

C-7.5 Specifications

Vendor(s): Environmental Instruments (EI)
5650 Imhoff Dr., #A
Concord, CA 94520-5350
510-686-4474, 800-648-9355

Sensidyne
800-451-9444

Model Number(s): EI: Determinator 580D portable PID organic vapor meter.

Sensidyne: portable FID organic vapor meter.

Weight: low, under 10 lbs.

Dimensions: small, field portable.

Space Requirements: low.

Power Requirements: usually battery-operated or standard AC.

Description of System Operation: Probe is used to "sniff" the air environment or vapor space of interest. Response is almost immediate (seconds).

Intended Application: field monitoring of organic vapors in air.

EI's PID instrument has a vacuum pump sampler that can be used to obtain soil gas samples.

Technology Maturity: high.

C-7.6 Analysis Capacities/Capabilities

Analytes Detected: organics. Each organic gives a unique detector response. Instrument is usually calibrated to look for specific compounds.

EI's instrument can detect most organic vapors and some inorganic gases.

Sensidyne's FID has an optional GC for better quantification capability.

Range of Detection: Laboratory instruments have dynamic ranges of 10^7 to 10^8 , with detection limits well below 0.1 ppm.

EI's Determinator PID model 580D: 0.1 to 2,000 ppm

Sensidyne's FID: 0 to 1,000 ppm and 0 to 10,000 ppm.

Precision/Accuracy: Very good.

EI's Determinator PID model 580D: 0.1 ppm resolution in the 0-200 ppm range, and 1.0 ppm resolution in the 200-2000 ppm range.

Capacity/Throughput: high, with system response times of 2-3 seconds for the portable field instruments.

C-7.7 Sample Preparation/Limitations

Sample Volume: low.

Sample Conditioning: none.

Sample Configuration/Phase: vapor/gas.

Interferences: unknown. Uncertain how well the technology can handle mixtures of unknown vapors.

C-7.8 System Operation

Mode of Operation: field and in situ (with "sniffing" probes)

Manpower Requirements: low, just user.

Calibration: field instruments mentioned in text comes with calibration kits. Unknown how well the instruments can handle unknown mixtures.

Environmental Restrictions: none.

Safety Considerations: FID uses hydrogen gas for combustion to produce intense ionization flame.

C-7.9 Life Cycle Cost

System Cost: EI's Determinator PID model 580D: around \$5,000.

Sensidyne's FID: \$6,600 for the intrinsically-safe version, \$8,100 with the GC option.

Operating Cost: low, hydrogen gas use with the FID.

Maintenance Cost: unknown.

Life Expectancy: unknown.

C-8 COLORIMETRIC AND TITRIMETRIC METHODS

C-8.1 Description

The basis for the technology is that the addition of a reagent to a sample will cause a color change that can be analyzed by a spectrophotometer (reflectance or transmission). The color change indicates the presence of the target analyte, and the hue and intensity can be compared to color standards to estimate the contaminant type and concentration.

C-8.2 Applications

Colorimetric tests are convenient field testing methods for soil and water analysis.

HNU-Hanby has environmental field test kits for detecting and quantifying contaminants in soil and water such as petroleum products and PCBs. The procedure with HNU's kits is to perform a simple extraction step to separate the analyte of interest from the sample matrix, add a color development catalyst, and compare the color change (hue and intensity) to color standards.

CHEMetrics, Inc. products employ patented **self-filling** reagent ampoules and portable instrumentation. The vacuum-sealed ampoules contain unit doses of pre-formulated reagents, and are used to perform simplified calorimetric and titrimetric tests. CHEMetrics products include tests for 40 analytes, ranging from parts per billion to percent. Analytes detected include alkalinity, ammonia, chloride, chromate, copper, cyanide, nitrate, and nitrite.

C-8.3 Summary of Advantages

Calorimetric and Titrimetric Methods

Summary of Advantages:

- Simple field analysis.
- Sensitive and specific methods of available.

Summary or Limitations

- Limited analyte list.
- More reliable as a qualitative rather than quantitative method.
- Best application is water samples; others may require extraction.
- Indicates existence of single chemical.
- Inexpensive (can make up own reagents).

C-8.4 Summary of Limitations

Calorimetric and Titrimetric Methods

Summary of Advantages:

- Simple field analysis
- Sensitive and specific methods of available.

Summary or Limitations

- limited analyte list.
- More reliable as a qualitative rather than quantitative method.
- Best application is water samples; others may require extraction.
- Indicates existence of single chemical.
- Inexpensive (can make up own reagents).
- Requires large space within the glovebox.
- Labor intensive/operator dependent.
- Not specific to one analyte.
- May result in violent reactions with expected WRAP 1 waste (i.e. hydrazine)
- Like chemicals may result in false positives.
- Generates secondary wastes.
- Accuracy of results are matrix dependent since technology is designed for operation with water.

C-8.5 Specifications

Vendor(s): HNU Systems Inc.
160 Charlemont St.
Newton, MA 02161-9987
(617) 964-6690 (800) 724-5600 FAX: 617-558-0056

CHEMetrics
Route 28
Calverton, VA 22016
(800) 356-3072 FAX: (703) 788-4856

Model Number(s): HNU Systems: Hanby Environmental Field Test Kits

CHEMetrics: CHEMets, ULR CHEMets, VACUettes, Titrets, Vacu-vials

Weight: low.

Dimensions: small.

Space Requirements: low.

Power Requirements: low.

Description of System Operation: With HNU's kits, a waste sample is mixed with a solvent to extract the analyte (contaminant) of interest. The solvent (extractant phase) is separated, a color development reagent is added, the color hue and intensity is measured with a spectrophotometer (reflectance and/or transmittance), and the color is compared to standards.

With CHEMetrics' kits (intended for water samples), the user snaps the ampoule tip in the sample. Vacuum pulls the sample in automatically. The sample mixes with the reagent to form a color. Results are quantified using a color comparator or a spectrophotometer. For samples requiring dilution, VACUettes ampoules (filled by capillary action) are used to obtain a specific volume of sample. The ampoules are immersed in a diluent, and the ampoule is snapped, allowing the reagent to mix with the sample. In a Titret cell, a sample is drawn into the cell until a color change signals that the equivalence point has been reached. Titration is stopped at that point, the ampoule is held in an upright position, and the test result is read directly from a scale printed on the Titret cell.

Intended Application: HNU's kits are designed for field analysis of soil and water samples, mainly looking for petroleum products and PCBs.

CHEMetrics' test kits are for water samples, and there is no extraction procedure.

Technology Maturity: high, but limited analyte list are for environmental (soil and groundwater) applications. The applicability to concentrated liquid waste is unknown; the extractants available must be able to recover all of the target analytes in a sample for accurate analysis.

C-8.6 Analysis Capacities/Capabilities

Analytes Detected: HNU: petroleum products, PCBs

CHEMetrics: alkalinity, ammonia, calcium, chloride, chlorine, chromate, copper, cyanide, detergents, formaldehyde, glycol, hydrazine, hydrogen peroxide, iron, manganese, nitrate, nitrite, Ph, phenol, phosphate, silica, sulfide, sulfite, zinc, and others.

Range of Detection: variable. Detection limits in the ppb and ppm ranges. Upper range varies from ppm to a few weight percent.

Precision/Accuracy: variable. When working with an unknown matrix, even thorough laboratory analysis is not extremely accurate. Colorimetric methods would be useful for qualitative analysis of solid and liquid waste samples. As a quantitative tool, these kits could be used to determine the minimum concentration of analyte in a sample matrix.

Capacity/Throughput: high.

C-8.7 Sample Preparation/Limitations

Sample Volume: low, a few milliliters or grams.

Sample Conditioning: extraction procedure for some tests.

Sample Configuration/Phase: liquid and solid for HNU's kits, and only water samples for the CHEMetrics' kits. The applicability of these kits to concentrated liquids is uncertain.

Interferences: For tests that require extraction, error will be introduced if the extractant does not recover all of the target analyte from the sample. It is unknown whether CHEMetrics' kits can be applied to liquid samples containing a high percentage of dissolved components and/or organics.

C-8.8 System Operation

Mode of Operation: field testing, not in situ. Representative samples must be obtained.

Manpower Requirements: low.

Calibration: none required for intended applications. Sample matrix interferences (e.g., turbid water samples) may result in erroneous readings.

Environmental Restrictions: none.

Safety Considerations: handling of the extractants and color development reagents. Material safety data sheets are provided for the test kits.

C-8.9 Life Cycle Cost

System Cost: low, less than \$1,000 for the hardware.

Operating Cost: low, single-use ampoule kits are around \$20.

Maintenance Cost: none.

Life Expectancy: The ampoules are single use and disposable. Kits have shelf lives of around 2 years.

C-9 IMMUNOASSAY FIELD TEST KITS

C-9.1 Description

The immunoassay technique relies on an antibody that is developed to have a high degree of sensitivity to the target compound. This antibody's high specificity is coupled with a sensitive colorimetric reaction that provides visualization of the result.

The immunoassay analysis starts when an enzyme conjugate is added to antibody-coated tubes. The target analyte, which may be present in a sample, competes with the enzyme conjugate for a limited number of antibody binding sites. After a washing step, the enzyme conjugate or target analyte bound to the antibody in the tube remains. Substrate solution is added to produce a color. The intensity of the color formed is inversely proportional to the concentration of the target analyte in the sample. The Yes/No (presence/absence of target analyte) determination is made by comparing the color developed by an unknown sample to the color formed with the standard.

The basic test consists of four steps:

- 1) Sample extraction is extracting the contaminants from the matrix under investigation. This involves weighing, chemical extraction, and filtering.
- 2) Sample preparation, which is basically dilution of the extracted sample.
- 3) Immunoassay, which is incubation of the sample in the antibody-coated tubes, followed by washing and addition of a color development solution.
- 4) Interpretation of results, by comparing the color developed in a standard to the color in a sample using a photometer.

C-9.2 Applications

The main use of immunoassay is in bioanalytical chemistry, where it is estimated hundreds of millions of immunoassays per year.

This technology has moved into the environmental industry, where immunoassay methods provide timely, cost effective, and accurate information on contamination levels of key pollutants. Applications that have been investigated and demonstrated include:

- Soil and groundwater monitoring (for fuels) in the petrochemical industry and underground storage tank removal and remediation.
- PCB monitoring in contaminated soil.
- Polyaromatic hydrocarbon monitoring in the petrochemical, utility, and wood preserving industries.

C-9.3 Summary of Advantages

- Designed for field use.
- Specificity: technique is sensitive to individual compounds or classes of compounds, and are for the most part unaffected by the composition of the sample or matrix.
- Quick analysis: 30 minute analysis.
- EPA approval: many of the immunoassay methods have been assigned draft methods by the EPA Office of Solid Waste.
- Low cost.
- Able to be customized to specific applications.
- Safe to operate.

C-9.4 Summary of Limitations

- Limited number of compounds can be analyzed currently.
- Not an in situ method; sample extraction is required.
- More qualitative than quantitative.
- Kit must be purchased.
- Labor sensitive.
- Generates secondary wastes.
- Requires some extraction

C-9.5 Specifications

Vendor(s): Millipore Corp.
BioNebraska, Inc.

EnSys Environmental Products, Inc.
P.O. Box 14063
Research Triangle Park, NC 27709
(800) 242-7472 (919) 941-5509 FAX: (919) 941-5519

Model Number(s): EnSys's PETRO RIS^E for petroleum fuels analysis, PCB RIS^E for PCB detection, and PAH RIS^E for polyaromatic hydrocarbon detection.

Weight: small.

Dimensions: small.

Space Requirements: low.

Power Requirements: low (for photometer). 110 V power source or battery sources are typical.

Description of System Operation: Field analysis (not in situ) requires sample extraction and preparation.

Intended Application: To date, most of the applications have been field screening of soil and water/groundwater samples for organics (fuels, PCBs, and PAHs). There is limited applicability currently to heavy metals (only a mercury test kit is currently available).

Technology Maturity: This technology is broadly applied in the medical diagnostics field. Development is being expanded in the environmental monitoring field.

C-9.6 Analysis Capacities/Capabilities

Analytes Detected: Currently, only petroleum compounds, polychlorinated biphenyls (PCBs), PAHs, and mercury. However, the technology is not limited to these analytes; development will be required to adapt the technology for other constituents (e.g., other heavy metals).

Range of Detection: ppb to ppm depending on analyte of interest.

Precision/Accuracy: Qualitative and semi-quantitative method. EnSys claims their field sample extraction method provides 70% to 80% recovery equivalent to that provided by lab-based extraction procedures. The majority of EnSys test kits have been assigned draft methods by the EPA Office of Solid Waste. EPA validation studies indicate that the field tests can accurately identify 95% of samples that are contaminated at or above the chosen action level.

Capacity/Throughput: High. Typically, four or five separate samples can be analyzed in less than one hour.

C-9.7 Sample Preparation/Limitations

Sample Volume: low; gram quantities.

Sample Conditioning: Extraction, filtration, and dilution are required.

Sample Configuration/Phase: Typically solid, though liquid samples can be analyzed, the sample must be in a form that can be easily weighed and that all of the analyte of interest can be easily extracted using the vendor extractants.

Sample Phase: Solid and liquid.

Interferences: Few. For the most part, immunoassay methods are very analyte specific. Specific interferants are provided by the vendor for each method.

C-9.8 System Operation

Mode of Operation: Field screening, but not in situ.

Manpower Requirements: low.

Calibration: none. Colorimetric method needs no calibration because a photometer is used to compare the sample color to a standard.

Environmental Restrictions: none.

Safety Considerations: none.

C-9.9 Life Cycle Cost

System Cost: low. \$200 to \$400 per test kit, with four single-use applications per kit

Operating Cost: low, requiring labor and waste disposal.

Maintenance Cost: low, since these are disposable analyses.

Life Expectancy: low. Single-use antibody tubes are disposed of after each analysis, and must be replaced.

C-10 FIELD PORTABLE FOURIER TRANSFORM RAMON (FTR) SPECTROMETER

C-10.1 Description

Raman spectroscopy is a method which identifies a broad range of materials, and has sensitivity to many materials. In Raman spectroscopy, a sample is irradiated with an intense source of monochromatic radiation, of a frequency higher than vibrational frequencies and lower than electronic frequencies of the sample. Lasers at 514 nm and 830 nm are popular choices. The radiation scattering is then analyzed by a spectrometer. The Raman effect involves monitoring the change in rotational or vibrational energy of a molecule due to an inelastic collision with the incident photon.

The basic setup of many current Raman systems involves fiber optics to deliver and collect the radiation. An argon-ion or diode laser provides the radiation source that bombards the sample. The optical cables then collect both Rayleigh and Raman scattering. A filter rejects the Rayleigh scattering, and allows the Raman scattering to pass into a detector. In many cases, a charged coupled device detector is used to sense the spectrum. Raman scattering is used for several analytical techniques, including Resonance Raman Spectroscopy (RRS) and Surface Enhanced Raman Spectroscopy (SERS). The RRS is used to identify specific chemical species, and SERS is used to screen a wide variety of molecules. Portable SERS units have been reduced to suitcase size, and have ppb range detection capabilities many compounds.

The WHC Process Chemistry laboratories is currently investigating dispersive Raman spectroscopy for hot cell applications. Studies indicate that FTR spectroscopy is a more mature vendor supported technique which has been proven for characterization of solid waste Decontamination and Decommissioning samples and 183-H basin simulant sludges.

C-10.2 Summary of Advantages:

- Nondestructive technique (requires no sample preparation)
- Amenable to fiber optic applications
- Proven for process application (currently used in petroleum pipelines, Dow and Eastman process lines)

C-10.3 Summary of Limitations:

- FTRaman instruments are large but vendors are considering manufacture of more portable units
- Dispersive instruments are largely research oriented but can be made to operate as turnkey systems.
- Limited libraries are available (WHC is developing an in-house library for FTR)

C-10.4 Applications:

- Process monitoring
- Sample screening
- Qualitative/Quantitative analysis of mixtures of 4 components or less
- Molecular characterization

C-10.5 Specifications:

Vendor(s):

DISPERSIVE RAMAN:

EIC Laboratory Inc.
Michael Carrabba: (617) 769-9450

Chromex Corporation
Alexander Glass: (505) 344-6270

Laser Raman Systems
Michael Gallagher: (713) 797-1860

FTRAMAN SYSTEM:

BioRad
David Compton: (617) 499-519

Bruker
Lenian Shen: (508) 667-9580

Nicolet Instrument Corporation
Mike Canavan: (208) 336-5452

Perkin Elmer
Tim Cuff: (800) 452-3747

Model Number(s):

Weight: <200 lbs in most cases

Dimensions: <3 ft. x 3 ft. x 3 ft.

Space Requirements: can be mounted on a cart

Power Requirements: 208 V 10 Amp

Description of System Operation: sample is probed; spectra are collected; and a library search is performed. The result gives the best match for the library or combination of libraries used.

Intended Application: identification of molecular species; possible quantitation on a case by case basis.

Technology Maturity: 5 - 8 years

C-10.6 Analysis Capacities/Capabilities:

Analytes Detected: solid inorganic salts, pure solvents and reagents and concentrated solutions.

Range of Detection: weight percent (SERS claims ppm)

Precision/Accuracy: 20% (mainly qualitative)

Capacity/Throughput: 1 sample/2 minutes

C-10.7 Sample Preparation/Limitations:

Sample Volume: measures 2-4 mm surface directly

Sample Conditioning: no sample prep needed

Sample Configuration/Phase: all phases (including gases)

Interferences: problems with fluorescence at short wavelengths

C-10.8 System Operation:

Mode of Operation: remote or bench top

Manpower Requirements: 0.5 technician with a chemist on call for interpretation and trouble shooting

Calibration: standard analytical curve

Environmental Restrictions: optimally dust free; will operate between 40 to 90 °F

Safety Considerations: laser light must be in closed path or a nominal hazard zone must be established

C-10.9 Life Cycle Cost:

System Cost: <130K (dispersive may cost 80 to 90 K)

Operating Cost: equivalent to 1 FTE support and 10 K/year for fiber replacement

Maintenance Cost: contracts for service with vendor are on order of 3 to 4K

Life Expectancy: 5 years

C-11 TITLE: FIELD GAS CHROMATOGRAPH/MASS SPECTROMETER (GC/MS)

C-11.1 Description

GC/MS is typically a laboratory analytical method used for organic analysis, including speciation and quantification. Recent advances in field transportable GC/MS instruments now make it feasible to perform field environmental testing without the need for further laboratory confirmation. The gas chromatograph separates organics so the mass spectrometer can identify and quantify the organics in the sample.

Viking Instruments SpectraTrak™ has several alternative sampling modes for handling solid, liquid, gaseous, and atmospheric samples. Volatile species on solid matrices can be thermally desorbed and injected into the GC/MS. Atmospheric samples can be directly sampled by the mass spectrometer. Liquid samples can be analyzed by direct head-space sample, purge-and-trap, or direct injection of samples prepared by extraction.

C-11.2 Applications

Quantitative analysis (including speciation) of organics (volatile and semi-volatile) in a variety of matrices (solid, liquid, and gas). Semi-volatiles are more difficult because extraction/sample preparation is required before injection into the GC/MS.

C-11.3 Summary of Advantages:

- Highly sensitive analytical method for organics.
- Able to handle a variety of sample matrices.
- Can identify/speciate volatile organics in unknown samples.
- Quantitative

C-11.4 Summary of Limitations:

- Semi-volatile organic analysis requires sample preparation.
- Basically laboratory procedures/analysis in the field, and requires laboratory-level of attention to detail.
- Not an in situ method, and requires more time to perform the analysis.
- Parts and developed software is not readily available
- High Maintenance.
- Relatively expensive.

C-11.5 Specifications:

Vendor(s): Ruska Instrument Corp.
 3601 Dunvale
 Houston, TX 77063
 (713) 975-0547 FAX: (713) 975-6338
 Doug King, Product Manager
 (Thermal inlet system for GC/MS is useful for analyses of solids and soil samples, eliminating need for solvent extraction)

Viking Instruments Corp.
 12007 Sunrise Valley Dr.
 Reston, VA 22091
 (703) 758-9339 FAX: (703) 391-2910
 Pat Dempsey

Model Number(s): Viking Instruments: SpectraTrak

Weight: medium, between 100 and 200 lbs, and can be operated in the field from a utility vehicle. There may be others that are smaller.

Dimensions: medium. SpectraTrak is 13.8" H x 21.0" W x 32.3" D

Space Requirements: medium.

Power Requirements: medium. SpectraTrak needs 1250 W surge at start-up and typical operation at 650 W. Operating range of power is 99-127 V or 198-254 V, single phase with a line frequency of 50/60 Hz.

Description of System Operation: Depends on the sample type (solid, liquid, gas, or atmosphere). Sample preparation will be required for semi-volatile analysis.

Intended Application: Field organic analysis of solid, liquid, gas or atmospheric samples.

Technology Maturity: high.

C-11.6 Analysis Capacities/Capabilities:

Analytes Detected: volatile and semi-volatile organics.

Range of Detection: high, ppb to weight percent, but must be configured properly to the range of interest for accurate analysis.

Precision/Accuracy: excellent, but will depend on the sample matrix and proper sampling and extraction procedures.

Capacity/Throughput: medium to high, depending on the level of sample preparation.

C-11.7 Sample Preparation/Limitations:

Sample Volume: extremely low.

Sample Conditioning: depends on sample matrix and organics being investigated (volatile vs. semi-volatile).

Sample Configuration/Phase: liquid, solid, gas, or atmospheric samples.

Interferences: variable, and will be a concern, especially with unknown samples.

C-11.8 System Operation:

Mode of Operation: depends on the sample matrix and organic analytes of interest. Basically a laboratory instrument in the field.

Manpower Requirements: low, but technically-skilled user will be required.

Calibration: very important for accurate quantification.

Environmental Restrictions: none.

Safety Considerations: GC operates at high temperature (300°C), using compressed gas as the carrier gas.

C-11.9 Life Cycle Cost:

System Cost: high, between \$150,000 and \$200,000.

Operating Cost: low material costs, but expected to require skilled users to operate.

Maintenance Cost: expected to be high.

Life Expectancy: unknown.

C-12 LASER ABLATION METHODS FOR ANALYSIS

Laser Ablation-Inductively Coupled Plasma Atomic Emission Spectrometry (LA-ICP-AES) and other laser ablation methods.

C-12.1 Description

Laser plasmas or optically-induced breakdowns are generated by focusing the output of a pulsed laser onto a small spot. The breakdown threshold is the minimum power density necessary for a plasma to form. Breakdown thresholds are generally on the order of several megawatts per square centimeter. The plasma causes breakdown of the target analyte, usually metals, and the a sample can either be drawn into an instrument for analysis (e.g., ICP, AA) or the emissions from the plasma can be analyzed directly by a detector (monochromator). Direct measurement of a plasma is called Laser-Induced Breakdown Spectroscopy (LIBS). In LA-ICP-AES, a sample is ablated to the breakdown threshold, in the same manner as in LIBS, but the ablated sample is fed using a flow of argon into an inductively-coupled plasma (ICP) which then generates a spectrum based on the plasma. There is also LA-ICP with mass spectroscopy (LA-ICP-MS), where the ICP is used as the ion source for mass spectroscopy. LA-ICP-MS works well for metals analysis.

C-12.2 Applications

Field and in situ analysis of metals are the currently demonstrated applications. A majority of development of laser ablation analytical technologies are being developed in the national and federal laboratories. For instance, Ames Laboratory has demonstrated a transportable unit for soils characterization at Fernald. There are some commercial instruments available for laboratory analysis.

C-12.3 Summary of Advantages:

- Characterization of solids with essentially no sample preparation.
- Potentially available for remote/field and in situ applications.
- Small sample requirements.

C-12.4 Summary of Limitations:

- High technology equipment operation, reliability, and maintenance concerns.
- Not a completely developed technology.
- Laser ablation produces localized, short-lived "hot spots".
- Matrix dependent.
- Ease of calibration and quantitative data interpretation uncertain.
- Ratio of volatile to nonvolatile compound detected doesn't match that of sample.

C-12.5 Specifications:

Vendor(s): National laboratories (developers)
(e.g., PNL, Ames Lab)

Finnigan (laboratory instrument)

Model Number(s):

Weight: Variable, but expected to be higher than conventional laboratory instrumentation.

Dimensions: Variable.

Space Requirements: Variable.

Power Requirements: Variable.

Description of System Operation: In one method, a laser is used to ablate a sample and produce a plasma that can be detected and quantified, and a detector and accompanying hardware are used to resolve the spectra produced. In another method, a laser is used to ablate a sample, a gas flow is used to carry that sample to an analyzer, and analysis is performed using an applicable instrument (e.g., ICP).

Intended Application: Chemical characterization of solids, typically metals (elemental analysis only).

Technology Maturity: Low to medium. The spectroscopy technology is well developed, but the laser ablation method for sampling is still being developed. Field and portable instrumentation is not very practical currently because of the complexity and delicate nature of some of the spectrometers employed. However, Ames Laboratory has developed a transportable/mobile laboratory that was employed for onsite soils characterization using laser ablation to obtain samples, and directly injecting these samples into analytical instrumentation located in a mobile lab.

C-12.6 Analysis Capacities/Capabilities:

Analytes Detected: Depends on the accompanying instrumentation, but the current applications are for metals analysis.

Range of Detection: Varies with the instrumentation, but expected to be high.

Precision/Accuracy: Unknown and variable, expected to be an area of concern because of the uncertainty in the precision/accuracy of the laser ablation sampling method.

Capacity/Throughput: Unknown.

C-12.7 Sample Preparation/Limitations:

Sample Volume: Low.

Sample Conditioning: None.

Sample Configuration/Phase: Solid or liquid, but most applicable to solids.

Interferences: Unknown

C-12.8 System Operation:

Mode of Operation: Field and laboratory analysis, with high potential for in situ analysis.

Manpower Requirements: High.

Calibration: Unknown, but expected to be extensive.

Environmental Restrictions: Use of laser

Safety Considerations: User of laser (power supply, electronics, beam intensity, and plasma produced), and particulates produced by ablation.

C-12.9 Life Cycle Cost:

System Cost: Unknown, but expected to be very high.

Operating Cost: Unknown.

Maintenance Cost: Unknown, but expected to be high.

Life Expectancy: Unknown.

C-13 BIOSENSORS

C-13.1 Description

A biosensor is a biologically-active sensing element connected to a physical transducer of some type. The sensor can be prepared by coating, doping, or some other method, and the biological activity of this sensor is converted by a transducer into a signal which can be amplified and processed. "Biologically-active" refers to techniques which use biochemical reactions as an indicator. For instance, the immunoassay field kits described in a

separate sheet uses a biochemical reaction to produce a colorimetric change which can be detected and quantified. Other types of sensing elements have been, and are being, developed.

Biosensors can be divided into three categories based on the type of bioactive material employed: cell products, cell parts, and whole cells/organisms. Cell products include biochemicals, enzymes, and antigens/antibodies. Cell parts include cell membranes and receptor sites. And whole cells/organisms include proteins, bacteria, yeast, and other whole organisms. As an example, the enzyme electrode has very good specificity, and a number of researchers have developed it for environmental detection of organic contaminants (e.g., phenol). An enzyme catalyzes reactions in organic solvents to produce observable and quantifiable results.

The physical detection component of the biosensor systems (i.e., to translate the biosensor reaction to a signal that can be interpreted/quantified) can be chosen from electronic, mechanical, and optical systems. For instance, an amperometric biosensor measures the electric current across a membrane or directly at a reference electrode or other transducing surface. Piezoelectric detectors are popular mechanical components, and fiber optics are excellent optical detectors.

C-13.2 Applications

Much of the work done to date has been for biological monitoring and medical diagnostics. Researchers and vendors are developing biosensing technologies for environmental applications (e.g., groundwater monitoring).

C-13.3 Summary of Advantages:

- High specificity and sensitivity in an almost infinite variety of applications.
- Fast, real-time response.
- Multiple detectors can be used in a single probe.
- Applicable to field and in situ analysis.

C-13.4 Summary of Limitations:

- Some biochemical reactions are irreversible, reducing the practicality of the technology as a monitoring technology. Depending on the application, single-use analytical tests may be acceptable (e.g., immunoassay field test kits).
- New technology for this application.
- Currently, limited availability of sensors for environmental applications.
- Sensor lacks durability.
- Applicable mainly to liquid samples.

C-13.5 Specifications:

Vendor(s): The Foxboro Company (508) 543-8750

Ohmicron Corporation (215) 860-5115

ImmunoSystems, Inc. (207) 883-9900

Universal Sensors, Inc. (504) 885-8443

Model Number(s):

Weight: low.

Dimensions: low.

Space Requirements: low.

Power Requirements: low.

Description of System Operation: There are many types of biosensing systems and accompanying detection systems. The most common method for environmental applications are immunoassay field test kits which are described in a separate sheet. Interest in in-situ sensing is increasing, and offers a high cost savings potential for reducing laboratory analysis. For in situ sensing, the sensors directly contact the material under investigation, and the biochemical reaction is detected, and the response signal is transmitted and analyzed.

Intended Application: Many biosensing technologies are used in biological and medical diagnostics applications. For environmental applications, biosensing methods have been developed for measuring organic contamination in water/groundwater.

Technology Maturity: high for biological and medical diagnostics, but still mostly in the development stage for environmental applications, especially in situ applications.

C-13.6 Analysis Capacities/Capabilities:

Analytes Detected: Mostly organics currently, but the technology offers potential for detection of a wide range of contaminants, including metals. However, the technology will not discriminate between isotopes.

Range of Detection: variable, but expected to be high. Validation, calibration and data interpretation will be important.

Precision/Accuracy: high. For in situ applications, validation, calibration and data interpretation will be important.

Capacity/Throughput: expected to be high, especially if in situ.

C-13.7 Sample Preparation/Limitations:

Sample Volume: low.

Sample Conditioning: none for in situ applications, variable for sample analysis (refer to immunoassay field test kits for example).

Sample Configuration/Phase: generally for liquid applications.

Interferences: unknown.

C-13.8 System Operation:

Mode of Operation: field test or in situ.

Manpower Requirements: expected to be low.

Calibration: expected to be high. In fact, for quantitative analysis, this will be very important.

Environmental Restrictions: none.

Safety Considerations: none, other than disposal/replacement of sensors.

C-13.9 Life Cycle Cost:

System Cost: unknown, but expected to be low. However, development and validation are required to implement the technology for specific applications.

Operating Cost: unknown, but expected to be low.

Maintenance Cost: other than replacement of sensors, expected to be low.

Life Expectancy: unknown.

C-14 ION MOBILITY SPECTROMETER (IMS) (COMBINED WITH GC) (GC/IMS)

C-14.1 Description

Ion mobility spectrometry (IMS) is a method for detection of low level concentrations of organic vapors using gas phase ion mobilities in small drift tubes with weak electric fields. There are two steps in IMS, ion creation and ion separation. Molecules undergo ionization through proton or electron transfers in air at ambient pressure. The chemical ionizations in air at atmospheric pressure result in robust ions that survive passage through an electric field and collisions with other species with little fragmentation. The ions are separated by differences in mobilities (drift times).

The primary information obtained from an ion mobility spectrometer is the mobility spectrum, which can be compared to reference spectra of known compounds for identification. With the addition of a GC, mixtures of organic vapors can be separated and analyzed.

C-14.2 Applications: The main application of IMS and GC/IMS is the detection, identification, and quantification of low concentrations of organic vapors in air.

C-14.3 Summary of Advantages:

- Smaller than GC/MS.
- Low detection limits.
- Selectivity can be modified/improved by the use of dopant chemicals or alternate reagent ion chemistry. In this way, only vapors or specific composition will be passed to the detector.

C-14.4 Summary of Limitations:

- Gas analysis only (organics).
- Newer technology.
- Not applicable to liquids or solids.

C-14.5 Specifications:

Vendor(s): Mostly R&D currently, including Department of Defense and Department of Energy. Also New Mexico State University.

Model Number(s):

Weight: unknown, but expected to be lower than field GC/MS.

Dimensions: unknown, but expected to be lower than field GC/MS.

Space Requirements: low (less than field GC/MS).

Power Requirements: low.

Description of System Operation: as described above.

Intended Application: measurement of low concentrations of organics in air.

Technology Maturity: low. Mostly in the R&D and applications development phase. A hand-held unit has been developed by the DOD for nerve gas applications. Not yet a commercial/off-the-shelf technology.

C-14.6 Analysis Capacities/Capabilities:

Analytes Detected: organics.

Range of Detection: ppb or lower limits of detection; unknown upper range.

Precision/Accuracy: excellent in low concentration ranges.

Capacity/Throughput: expected to be high.

C-14.7 Sample Preparation/Limitations:

Sample Volume: low.

Sample Conditioning: none.

Sample Configuration/Phase: gas.

Interferences: unknown.

C-14.8 System Operation:

Mode of Operation: Field monitoring and analysis with no sample preparation.

Manpower Requirements: low, just user.

Calibration: unknown.

Environmental Restrictions: none.

Safety Considerations: none.

C-14.9 Life Cycle Cost

System Cost: unknown, since no vendor or commercial unit has been identified.

Operating Cost: expected to be low.

Maintenance Cost: unknown.

Life Expectancy: unknown.

C-15 FOURIER TRANSFORM INFRARED (FTIR) SPECTROMETERS

C-15.1 Description:

Fourier Transform Infrared Spectroscopy (FTIR) is an analytical technique sometimes used in conjunction with chromatography. FTIR employs an interferometer which splits the light source and reflects it by means of mirrors. An interferogram is generated, representing the signal in the time domain. From the interferogram, a spectrum in the frequency domain is generated by means of a Fourier Transform.

Infrared spectroscopy is based on the physics that the vibrations of molecules in lattices result in small displacements of the atoms about their resting positions. The energy levels in a lattice are quantized in each mode of vibration. The number of modes depends on the number of atoms in a molecule. An incoming photon having the correct energy will be absorbed and excite the lattice. The vibrational frequency of this excitation is characteristic of the molecule. In addition to the fundamental vibrational frequencies, combination bands (frequencies) can also be produced by the addition of frequencies from two different vibrational modes.

FTIR is one of the fastest growing areas of analytical instrumentation development, with industrial applications driving technology development. It has many applications for detecting organics. FTIR is often combined with some form of chromatography because of similar sampling needs. IR spectroscopy is often not appropriate for analyzing complex matrices because

of the elemental interferences with the signal. FTIR spectrometry is much better in terms of sensitivity than dispersive IR. The technique works best for sampling and analysis of gaseous samples, as it is suited best for organics. No sample preparation is required for this application.

FTIR analysis can be performed in two different ways: sampling with diffuse reflectance, or using attenuated total reflection (ATR) sampling. Diffuse reflectance generally uses parabolic mirrors, and does not require sample contact, while ATR requires touching, through a coupling between a fiber optic and the probe cover. Dow has used for remote sensing.

C-15.2 Applications: Spectra-Tech Inc. has developed FTIR fiber optics for remote/ field analysis. Applications include liquids and solids, with environments such as hazardous, corrosive, high/low temperature, high/low pressure. The technology can also be used for process and reaction monitoring.

The DOE complex has been interested in fiber optic spectroscopic techniques, including FTIR an Raman, and has been developing the technology for specific radioactive waste applications.

C-15.3 Summary of Advantages:

- Remote, in situ.
- Non-destructive analysis.
- Easy to access head space samples during retrieval.
- Less labor intensive than GC techniques.

C-15.4 Summary of Limitations:

- Most applicable to organics.
- Concern about interferences and interpreting spectra, such as water.
- Not accurate for liquids and solids.
- Less accurate for complex mixtures containing greater than 4 components.
- Concern with maturity of signal/data analysis for in situ (fiber optic) technology.

C-15.5 Specifications:

Vendor(s): Spectra-Tech Inc.
652 Glenbrook Rd.
Bldg. 8, Box 2190-G
Stamford, CT 06906
(203) 357-7055 (800) 243-9186 FAX: (203) 357-0619

Analytical Technology, Inc. (ATI)
1001 Fourier Drive
Madison, WI 53717
(608) 831-5515 FAX: (608) 831-2093

Model Number(s): Spectra-Tech: FieldSpec and Personal Spectrometer II

ATI: Mattson FTIR

Weight: medium. Sensing system (e.g., fiber optic probe) is not large, but accompanying hardware may be.

Dimensions: same as weight.

Space Requirements: same as weight.

Power Requirements: unknown, but expected to be low.

Description of System Operation: Spectra-Tech's patented Needle Probe utilizes attenuated total reflectance (ATR) technology to measure the infrared absorbance of liquids and soft powders. The Needle Probe has a unique sampling head that is 3 mm in diameter. The actual sample interface area is approximately 1 mm square,

Spectra-Tech's patented Reflectance probe works with Spectra-Tech's FiberLink and fiber optic cables to provide excellent sensitivity for the analysis of reflective and solid materials.

Spectra-Tech's Industrial Probe is a self-contained fiber optic accessory that has its own dedicated detector. The probe has a connection line to the spectrometer that can be used for long distances. This allows for long-range remote sampling without significant loss of signal.

Intended Application:

Applications for Spectra-Tech's Needle Probe include:

- Remote analysis of liquid and solids,
- Aqueous and non-aqueous liquids,
- Soft powders,
- Hazardous materials,
- Biomaterials,
- Reactions in-situ, and
- Radioactive materials.

Applications for Spectra-Tech's Reflectance Probe include:

- Remote analysis of solids and reflective materials,
- Electronic components,
- Powders and crystals,
- Pharmaceuticals,
- Over-sized samples, and
- Hazardous samples.

Applications for Spectra-Tech's Industrial Probe include:

- Remote analysis of hazardous liquids,
- Chemical waste analysis, and
- High-sensitivity measurement of weakly absorbing liquids.

Technology Maturity: high for some laboratory applications, lower for field and fiber optic applications.

C-15.6 Analysis Capacities/Capabilities:

Analytes Detected: Mainly organics, i.e., spectral responses from IR radiation in the range described below.

Range of Detection: Needle, Reflectance, and Industrial Probes all have a sampling range of 4000 - 900 cm^{-1} .

Precision/Accuracy: Unknown.

Capacity/Throughput: Unknown, but expected to be high.

C-15.7 Sample Preparation/Limitations:

Sample Volume: expected to be small.

Sample Conditioning: None for field and in situ instruments. Unknown for laboratory instruments.

Sample Configuration/Phase: Mostly applicable to liquids and gases.

Interferences: Spectral interferences from complex matrices may increase the difficulty of resolution and interpretation.

C-15.8 System Operation:

Mode of Operation: In situ probing using fiber optics seems to be the preferred mode of operation.

Manpower Requirements: expected to be low.

Calibration: unknown, but expected to be high for quantitative analysis, and lower for qualitative analysis.

Environmental Restrictions: none.

Safety Considerations: none.

C-15.9 Life Cycle Cost:

System Cost: unknown, but expected to be medium (more expensive than disposable field kits, for example, but less than high technology instruments like laser ablation/mass spectroscopy).

Operating Cost: unknown, but expected to be low.

Maintenance Cost: unknown, but expected to be low. Replacement of probes will be a maintenance cost.

Life Expectancy: unknown.

C-16 OTHER FIELD PORTABLE OPTICAL/SPECTROSCOPIC METHODS

C-16.1 Description

A number of optical methods have been, and are being developed for field and in situ use, including IR, FTIR, UV, NIR, and Raman.

Analytical Spectral Devices Inc., for example, has two field instruments, the FieldSpecTM-Chem and the Personal Spectrometer II. The FieldSpec uses a fiber-optic cable to sample the light field being measured. Light enters the end of the cable, and is split into three signals, one going to each of three spectrometers. The unit uses a silicon photodiode array overlaid with an order separation filter to measure the Visible/Near Infrared (VNIR) region from 350 nm to 1000 nm, and two scanning spectrometers are used to measure the near infrared region from 1000 nm to 2500 nm. Measurement modes include reflectance, transmittance, absorbance, and transreflectance; the unit has a number of probes available, including a fiber-optic reflectance probe (for gas and solids analysis) and an immersible transmission probe (for liquid analysis). The data from the unit is downloaded to a portable PC for interpretation. The Personal Spectrometer II just utilizes a VNIR spectrometer, but basically operates the same as the FieldSpec, and only utilizes a fiber-optic reflectance probe.

C-16.2 Applications: Analytical Spectral Devices, Inc. has identified applications for their FieldSpec and Personal Spectrometer II units, including:

- Mineral identification,
- Plant physiology,
- Ocean color,
- Medical diagnosis,
- Process control, and
- Analytical chemistry, and
- Gas/atmosphere analysis.

C-16.3 Summary of Advantages:

- Sampling is nondestructive.
- Field portable analysis with a variety of measurement modes.
- Good screening tool.
- Range of media (liquid, solid, gas).
- Accurately detects moisture content.
- Fast response requiring minimal sample preparation for liquids and no sample preparation for solids.

C-16.4 Summary of Limitations:

- Chemometrics development required to interpret data.
- Geometry is critical.
- Wavelength range is applicable to organics, water, and some gases, though the unit has been used for mineral identification (looking at O-H bonds).
- Interference occurs with multiple compounds.
- Water creates interferences when sampling organics.

C-16.5 Specifications:

Vendor(s): Analytical Spectral Devices Inc.
4760 Walnut St., Suite 105
Boulder, CO 80301
303-444-6522 FAX: 303-444-6825

Model Number(s): FieldSpec™ UV/VNIR

Personal Spectrometer II

Weight: 7 to 12 lbs.

Dimensions: low, unit can be carried by a user.

Space Requirements: low.

Power Requirements: low, battery operated.

Description of System Operation: as described above.

Intended Application: as described above.

Technology Maturity: mature, but chemometric/data interpretation models need to be developed for specific applications.

C-16.6 Analysis Capacities/Capabilities:

Analytes Detected: analytes that absorb in the VNIR and NIR region, mostly organics, water, and some gases.

Range of Detection: 350 nm to 2400 nm.

Precision/Accuracy: variable, will depend on a variety of factors, especially chemometrics software developed for data interpretation. The FieldSpec and Personal Spectrometer II have a resolution accuracy of 1 nm, and is accurate to within 7% when calibrated to NIST standards. However, this does not mean that measurement accuracy is 7% because a variety of other factors will affect the accuracy (e.g., sample matrix, data interpretation software).

Capacity/Throughput: high, since no sample needs to be taken or prepared.

C-16.7 Sample Preparation/Limitations:

Sample Volume: low.

Sample Conditioning: none.

Sample Configuration/Phase: solid, liquid, or gas.

Interferences: unknown, but expected to be an important factor in the applicability of the technology.

C-16.8 System Operation:

Mode of Operation: Depending on the measurement mode and the type of probe used, can be field sampling/analysis or in situ measurement.

Manpower Requirements: low, just the user.

Calibration: calibration routines and standards are provided by the vendor, but validation and qualification will be needed to correctly apply the technology to the sample matrix of interest.

Environmental Restrictions: none.

Safety Considerations: none.

C-16.9 Life Cycle Cost:

System Cost: between \$50,000 and \$100,000 for the hardware, but chemometrics development may be required for specific applications, and validation and qualification costs should also be considered.

Operating Cost: low.

Maintenance Cost: low (replacement of measurement probes).

Life Expectancy: unknown, but expected to be high.

C-17 ION-SELECTIVE ELECTRODES (ISE)

C-17.1 Description:

Determining the concentration of specific inorganic ion species with an electrode involves measuring the flow of ions across a membrane. Ion selective electrodes (ISE) are a type of electrochemical sensor, but is described separately in this sheet.

Solid-state (sealed) electrodes have a sensing membrane permanently mounted in the electrode tip. An ion potential develops across this membrane. Electrodes are available to measure a variety of ion species. Solid-state electrodes are resistant to most inorganic reagents, and can be used with some organic solvents. They require no filling solution, and can be stored dry, making the virtually maintenance free.

Gas sensing electrodes are used to measure gases dissolved in solution. A gas sensing electrode has a gas permeable/ion impermeable membrane. The dissolve gas diffuses across the membrane into a small volume of filling solution that is specific for each electrode. The gas of interest reacts with the filling solution, causing the pH of the filling solution to change. This change is detected by an internal pH sensing element.

Liquid membrane electrodes have a water-insoluble liquid ion exchanger held in place by an inert porous membrane. The membrane allows contact between the sample and the liquid ion exchanger, but minimizes mixing. There are two types of liquid membrane electrodes:

- Traditional liquid membrane, in which the electrodes contain a porous membrane that is soaked and saturated with the ion exchanger, and
- Plastic liquid ion exchange electrodes (or PVC membrane electrodes), similar to the traditional liquid membrane, except that the sensing module is a non-porous polyvinyl chloride (PVC) gel containing the ion exchanger.

ISEs sensing elements are connected to a pH/mV meter (i.e., voltmeter) for accurate measurement of

C-17.2 Applications: Used for measuring/monitoring dissolved inorganics and gases in solution.

C-17.3 Summary of Advantages:

- Low cost.
- Fast analysis.
- Monitoring capability requiring little attention.
- Equipment is reversible.

C-17.4 Summary of Limitations:

- Applicable only to liquid media.
- Susceptible to interference.
- Equipment plugs up/dries out frequently.
- Analysis is labor intensive.
- Not performed in the lab.
- Generates secondary wastes.
- Requires sub-samples to be taken.

C-17.5 Specifications:

Vendor(s): Cole-Parmer Instrument Company
(800) 323-4340

Orion

Model Number(s):

Weight: low.

Dimensions: low.

Space Requirements: low.

Power Requirements: low.

Description of System Operation: Much like a pH probe/meter, an ISE is inserted in a liquid sample (or in situ) and a measurement is taken as soon as the reading stabilizes.

Intended Application: Analysis of specific ions in liquid samples.

Technology Maturity: High.

C-17.6 Analysis Capacities/Capabilities:

Analytes Detected: many dissolved inorganic ions in solution (e.g., NH_4^+ , Cd^{+2} , Cu^+ , Pb^{+2} , Cl^- , NO_3^- , Na^+ , CN^- , F^-) and dissolved gases (CO_2 , NH_3 , NO_x).

Range of Detection: variable, but generally in the ppb through ppm range, and as high as 0.1%.

Precision/Accuracy: variable, and depends on the sample matrix, but expected to be more than adequate for field screening (i.e., at least ppm precision and accuracy).

Capacity/Throughput: high, and can be used for continuous monitoring.

C-17.7 Sample Preparation/Limitations:

Sample Volume: low, enough to immerse the ISE element (the electrodes are on the order of the size of a thick pen).

Sample Conditioning: none.

Sample Configuration/Phase: liquid.

Interferences: Sample matrix composition is expected to affect measurements.

C-17.8 System Operation:

Mode of Operation: Sample/analysis, in situ/probe analysis, or continuous monitoring in situ.

Manpower Requirements: low, user only.

Calibration: Ranges of operation are calibrated using calibration solution standards. The response over a range of operation of a unit calibrated with two standards is assumed to be linear between the values of the two standards.

Environmental Restrictions: none.

Safety Considerations: none.

C-17.9 Life Cycle Cost:

System Cost: low, less than \$1000 for the pH/mV meter, and less than \$500 per ISE.

Operating Cost: low, calibration solution standards and replacement electrodes must be factored in.

Maintenance Cost: low.

Life Expectancy: high, other than replacing electrodes. Life of electrodes will depend on the environment and sample matrix.

C-18 CHEMICAL IDENTIFICATION FIELD TEST KITS (HAZCAT KITS)

C-18.1 Description

The HazCat Chemical Identification System is designed for the qualitative identification of unknown materials. HazCat kits are an emergency response tool designed specifically for on-site identification or categorization of virtually any spilled or abandoned material, liquid or solid. HAZTECH's HazCat system consists of 100 easily-performed field tests which allow a non-chemist to quickly and precisely identify or categorize chemical substances.

The HazCat system guides the user through a decision-tree process to final identification of the chemical hazard. The user simply follows step-by-step procedures in the manual. Test systems for both liquids and solids are part of the kit, and more than 100 tests can be run with the reagents provided to identify and categorize over 1,000 substances.

C-18.2 Summary of Advantages:

- Low cost.
- Fast turnaround, 20-minute typical on-site assay time.
- Versatile, able to identify and categorize over 1,000 substances.
- Can handle both liquids and solids.

C-18.3 Summary of Limitations:

- Qualitative, with no quantitative analytical capabilities.
- Sensitivity/detection limit not as low as other methods; most tests can not get below about 50 ppm.

C-18.4 Applications: Typical applications of the HazCat system are spill identification and environmental assessments.

C-18.5 Specifications:

Vendor(s): HAZTECH SYSTEMS™ Inc.
(415) 822-5776/(800) 543-5487/FAX: (415) 822-5777

Model Number(s): HazCat Kit

Weight: low, entire kit is contained in a hand-carried in a plastic case.

Dimensions: 19" x 11" x 11"

Space Requirements: low.

Power Requirements: none.

Description of System Operation: The user performs wet reagent chemistry tests for quantitative identification of unknown materials. The user goes through a decision-tree process based largely on the user's observations to systematically identify unknowns.

Intended Application: The vendor's advertised use is for the quick identification of an unknown material in cases where a sample can be collected at its source, or where a visible solid or liquid can be seen.

Technology Maturity: high, kits are commercially available, and method is wet reagent chemistry.

C-18.6 Analysis Capacities/Capabilities:

Analytes Detected: wide range of analytes, including a variety of metals (e.g., Pb, Cr, Hg, Ni), anions (e.g., Cl^- , F^- , CN^-), inorganic/organic acids, asbestos, ammonia, etc. The standard kit has 48 reagents for quantitative analysis, and also includes Sensidyne Indicator Tubes for gas detection, Dexsil™ (test packer to identify PCB oils and contaminated oils), Colorphast™ pH test strips, EM Quant test strips, and an Enzytech organophosphate indicator test kit.

Range of Detection: limit of detection is generally about 50 ppm.

Precision/Accuracy: method is only qualitative, and will provide no quantitative analysis, except indicating analyte is above detection limit.

Capacity/Throughput: high, assay time of less than 20 minutes is typical.

C-18.7 Sample Preparation/Limitations:

Sample Volume: low (milliliter sample volumes generally required), but higher than sample volumes generally required for instrumental methods of analysis (e.g., microliter sample volumes for chromatography).

Sample Conditioning: none.

Sample Configuration/Phase: liquid or solid, though the HazCat kit also contains Sensidyne Indicator Tubes for gas detection/identification.

Interferences: unknown.

C-18.8 System Operation:

Mode of Operation: field analysis, though reagents can be added directly to sample in place if reaction can be visually observed and confirmed.

Manpower Requirements: low, just field user.

Calibration: none, qualitative method only.

Environmental Restrictions: waste disposal.

Safety Considerations: handling of sample (exposure of user to unknown sample) and use of reagents (concern for unknown reactions).

C-18.9 Life Cycle Cost:

System Cost: around \$3,000 for complete kit.

Operating Cost: low; cost for replacement reagents and hardware.

Maintenance Cost: none.

Life Expectancy: high, other than replacement of reagents and glassware.

C-19 POLARIZED LIGHT MICROSCOPY

C-19.1 Description

Inorganic salts form crystalline structures that are optically active. Because these structures can rotate polarized light they are referred to as intrinsically birefringent. In addition, structures consisting of elongated particles in a parallel array or stacked discs embedded in a medium whose refractive index differs from that of the structure exhibit form birefringence. This means that the structures will pass plane polarized light only if the plane of polarization is parallel to the long axis of the particles. This is true even if the particles are not intrinsically birefringent - that is, if the particles transmit polarized light with equal probability for all angles of incidence.

Substances that exhibit intrinsic or form birefringence are easily observed using a polarized light microscope, and detailed information about molecular architecture can be obtained in a relatively short time. Since various molecules have unique crystalline structures, sizes and internal architecture, this technique be used analytically to determine the identity of inorganic salts and other molecules. Asbestos is easily viewed under a polarized light microscope. If the quantity and dilution of the sample placed on the microscope slide is known, it is possible to obtain a semi-quantitative estimates of analyte concentration.

The essential components of a polarizing light microscope are a polarizer held between the light source and the condenser; a rotating stage or sample holder; an analyzer, situated between the objective and the eyepiece, which can be set so that its axis is perpendicular to the polarizer axis; and a compensator. Because polarized light is partly depolarized by reflection and refraction, the condenser is adjusted so that the object is illuminated by nearly parallel light.

C-19.2 Summary of Advantages:

- Low cost.
- Fast turnaround.
- Minimal sample preparation.
- Minimal space required.

C-19.3 Summary of Limitations:

- Semi-quantitative only.
- Requires a specially trained technician to interpret unknown samples.

C-19.4 Applications: In WRAP-1, polarizing light microscopy would be used primarily for asbestos fiber counting. In addition, this equipment can be used to identify various inorganic salts due to their crystalline structures, even if those salts occurred in mixtures.

C-19.5 Specifications:

Vendor(s): Buehler Ltd.
(708) 295-6500; fax - (708) 295-7979

Many other vendors are available.

Model Number(s): Nikon Optiphot-2 Pol

Weight: Low, microscope is completely portable.

Space Requirements: Low.

Power Requirements: One 120 V standard power outlet cord.

Description of System Operation: The user places sample on a microscope slide then views the slide under the microscope. Asbestos fibers are identified and counted. If inorganic salts are being identified, the user must be familiar with the crystalline structures of the salts that might be present.

Intended Application: Asbestos identification and counting; identification of inorganic salts.

Technology Maturity: High, numerous models and brands available on the market.

C-19.6 Analysis Capacities/Capabilities

Analytes Detected: Asbestos and salts that form birefringent crystalline structures.

Range of Detection: Theoretically, a sample could be diluted until individual fibers/crystals were separated sufficiently to allow identification and counting.

Precision/Accuracy: Semi-quantitative.

Capacity/Throughput: Depending on the concentration, screening a slide for an asbestos fiber count can take 45-60 minutes. The time required to identify a given analyte is dependent on the expertise of the technician, the number of analytes that may be present in the sample, and the separation of crystals on the slide.

C-19.7 Sample Preparation/Limitations:

Sample Volume: Low, enough to place on a microscope slide. Dilution of the sample may be required to get adequate separation of the fibers/crystals on the slide.

Sample Conditioning: Dilution may be required. Samples are often mixed with a solvent and placed on the slide. The solvent is allowed to evaporate prior to viewing the slide.

C-19.8 System Operation:

Mode of Operation: Onsite analysis, if power source is available.

Manpower Requirements: Low, just one trained technician.

Calibration: None.

Environmental Restrictions: Disposal of samples on microscope slides.

Safety Considerations: Potential exposure of technician to samples containing unknown substances while preparing slides.

C-19.9 Life Cycle Cost:

System Cost: Initial cost of a research grade, polarizing light microscope for asbestos fiber counting is approximately \$13 K.

Operating Cost: Low, supply costs of microscope slides and replacement cost for tungsten halogen bulbs.

Maintenance Cost: Low.

Life Expectancy: High, for parts other than bulbs.