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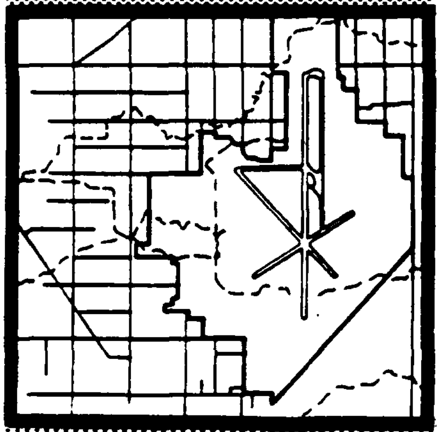

Soil Treatability Testing Work Plan for PCB-Contaminated Soil

for McCLELLAN AFB, CALIFORNIA

PREPARED BY:
Radian Corporation
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PREPARED FOR:
McCLELLAN AFB / EM
McCLELLAN AFB, CALIFORNIA 95652-5990

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United States Air Force
Air Force Center for Environmental Excellence
Environmental Services Office
Environmental Restoration Division (AFCEE/ESR)
Brooks Air Force Base, Texas 78235-5000

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United States Air Force
Air Force Center for Environmental Excellence
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Environmental Restoration Division (AFCEE/ESR)
Brooks AFB, Texas 78235-5000

NOTICE

This report has been prepared for the Air Force by Radian Corporation for the purpose of aiding in the implementation of a final remedial action plan under the Air Force Installation Restoration Program (IRP). As the report relates to the initial screening of remedial action alternatives, its release prior to an Air Force final decision on remedial action may be in the public's interest. The limited objectives of this report and the ongoing nature of the IRP, along with the evolving knowledge of site conditions and chemical effects on the environmental and health, must be considered when evaluating this report, since subsequent facts may become known that may make this report premature or inaccurate. Acceptance of this report in performance of the contract under which it is prepared does not mean that the Air Force adopts the conclusions, recommendations, or other views expressed herein, which are those of the contractor only and do not necessarily reflect the official position of the Air Force.

PREFACE

Radian Corporation is the contractor for the RI/FS program at McClellan AFB, California. This work was performed for the Air Force Center for Environmental Excellence (AFCEE/ESR) under Air Force Contract No. F33615-90-D-4013, Delivery Order 0004.

Key Radian project personnel were:

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John Clark, P.E. — Project Director

Radian would like to acknowledge the cooperation of the McClellan AFB Office of Environmental Management. In particular, Radian acknowledges the assistance of Mr. Bud Hoda and Mr. Tad Dean.

The work presented herein was accomplished between February 1991 and May 1992. Mr. Patrick Haas, AFCEE/ESR, was the Contracting Officer's Technical Representative.

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This work plan has been prepared for McClellan AFB as part of the Soil Remedial Technologies Screening Project, the purpose of which is to identify potentially applicable soil treatment technologies for contaminants found in Operable Unit (OU) B soils. The work plan presents the rationale and procedures for treatability testing of two technologies applicable to polychlorinated biphenyl (PCB), dioxin, and furan contaminated soil. The work plan proposes bench-scale testing of the treatment technologies on soil collected from Study Area 12 (SA-12) where PCB, dioxin, and furan contamination have been detected in samples collected over a wide area, and where initial discussions with agency personnel indicate that treatment of the soil will be required as part of the SA-12 remediation effort. The two technologies selected for testing are: glycolate dechlorination using the APEG-PLUS™ process available from GRC Environmental, Inc.; and the Base-Catalyzed Desorption Process (BCDP) developed by the U.S. Environmental Protection Agency.

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EXECUTIVE SUMMARY

This work plan has been prepared for McClellan Air Force Base (AFB) as part of the Soil Remedial Technologies Screening Project. The purpose of the work plan is to identify potentially applicable soil treatment technologies for contaminants found in Operable Unit (OU) B soils. The work plan presents the rationale and procedures for treatability testing of two technologies applicable to polychlorinated biphenyl (PCB), dioxin, and furan contaminated soil. It also proposes bench-scale testing of the treatment technologies on soil from Study Area 12 (SA-12) where PCB, dioxin, and furan contamination has been detected in samples collected from a 630,000 square foot area. Initial discussions with regulatory agency personnel indicate that treatment of some contaminated soils will be required as part of the SA-12 remediation effort.

The objectives of the bench-scale testing are to:

- Evaluate the effectiveness of the selected treatment technologies to decompose PCB, dioxin, and furan compounds from SA-12 soil;
- Compare the relative technical and economic feasibility of the selected treatment technologies;
- Determine potential need for further treatment and/or disposal of treated soil and residuals;
- Determine if one of the treatment technologies should be tested at the pilot-scale; and
- Acquire design and cost information for pilot- and full-scale operation of the selected dechlorination processes.

The following remedial alternatives were considered in selecting technologies for bench-scale testing:

- No action;
- On-site containment using a cap;

- Excavation and off-site landfilling at an appropriately licensed hazardous waste landfill; and

- Excavation and treatment to remove contaminants.

The rationale for selecting or rejecting each alternative is discussed further in the work plan; however, of these alternatives, excavation and treatment to remove contaminants is the most desirable alternative as it reduces the long-term liability associated with the contamination (by destroying or reducing the concentration of the contaminant). Excavation and treatment alternatives that were considered include:

- Incineration;
- Chemical dechlorination;
- Solvent extraction
- Thermal desorption;
- Soil washing; and
- Existing biological treatment.

The rationale for preliminary selection or rejection of alternatives for treatability testing is discussed in the work plan. Based on the types of contaminants detected at SA-12, the tentative remediation goals discussed with agency personnel, the available treatment technologies, and published data concerning their effectiveness and cost, chemical dechlorination was selected for bench-scale testing. The two processes selected for testing are:

- Glycolate dechlorination using the APEG-PLUS™[1] process available from GRC Environmental, Inc.; and

- Base-Catalyzed Decomposition Process (BCDP) developed by the U.S. Environmental Protection Agency.

Descriptions of each of these processes are given in the work plan, including both full-scale and bench-scale processes. Soil from SA-12 will be bench-scale tested with each of these processes to determine if either or both will reduce PCB concentrations to

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[1] APEG-PLUS™ is a trademark of GRC Environmental, Inc.

below the tentative remediation goal of 10 milligrams per kilogram (mg/kg) and the Toxic Substances Control Act (TSCA) incineration equivalency criterion of 2 mg/kg. The effect of the processes on dioxins and furans will also be monitored.

Soil samples for bench-scale testing will be collected from two PCB-concentration ranges from SA-12 as follows:

- 100 to 1000 mg/kg -- representative of surface and deep soil that will require remediation, including soils that are a principal threat for residential and industrial land use; and
- Greater than 1000 mg/kg -- representative of the highest concentrations detected at SA-12.

The analytical methods and procedures to be used prior to, during, and after treatability testing are described in the work plan. Procedures to be used for data collection, data management, and data analysis are also summarized. Sampling, sample handling, and analyses procedures and quality control objectives will comply with the McClellan AFB Quality Assurance Project Plan (Radian, 1992b) except when certain analyses are performed during treatment, for example, analysis performed by the treatment vendor. The OU B Remedial Investigation (RI) Health and Safety Plan (Radian, 1991a) will be followed during sampling. Potential deviations from these plans are identified.

1.0 INTRODUCTION

As part of the Soil Remedial Technologies Screening Project, this work plan has been prepared for McClellan Air Force Base (AFB) presenting plans and procedures for conducting bench-scale testing for polychlorinated biphenyls (PCB)-contaminated soil treatment. Soils contaminated with PCBs at concentrations of 1 to 100,000 parts per million (ppm) have been found during the remedial investigation of Operable Unit (OU) B at McClellan AFB.

1.1 Project Description

McClellan AFB is an Air Force Logistics Command Center located in Sacramento, California. Since 1936, McClellan AFB has been engaged in a wide variety of operations that involve the use, storage, and disposal of hazardous materials including: industrial solvents, caustic cleaners, electroplating chemicals, heavy metals, PCBs, low-level radioactive wastes, and a variety of fuel oils and lubricants.

On 22 July 1987, McClellan AFB was listed on the U.S. Environmental Protection Agency's (U.S. EPA) National Priorities List (NPL). McClellan AFB integrated the ongoing Installation Restoration Program (IRP), initiated by the Department of Defense in 1981, with the following: the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA); the National Oil and Hazardous Substances Contingency Plan (NCP); pertinent provisions of the Resource Conservation and Recovery Act (RCRA) statutes; Executive Order 12580; the Defense Environmental Restoration Program (DERP); and applicable or relevant and appropriate state laws and regulations. Since the addition of McClellan AFB to the NPL, investigations and remedial actions have been performed in accordance with the CERCLA Remedial Response Process illustrated in Figure 1-1. The three principal components of the CERCLA response process are identification, investigation, and cleanup. Identification and investigation activities are being performed in several geographic locations across McClellan AFB.

McClellan AFB has been divided geographically into preliminary operable units (Figure 1-2) because of the complexity of hydrogeologic conditions and the number and types of potential sources of contamination. The Remedial Investigation/Feasibility Study

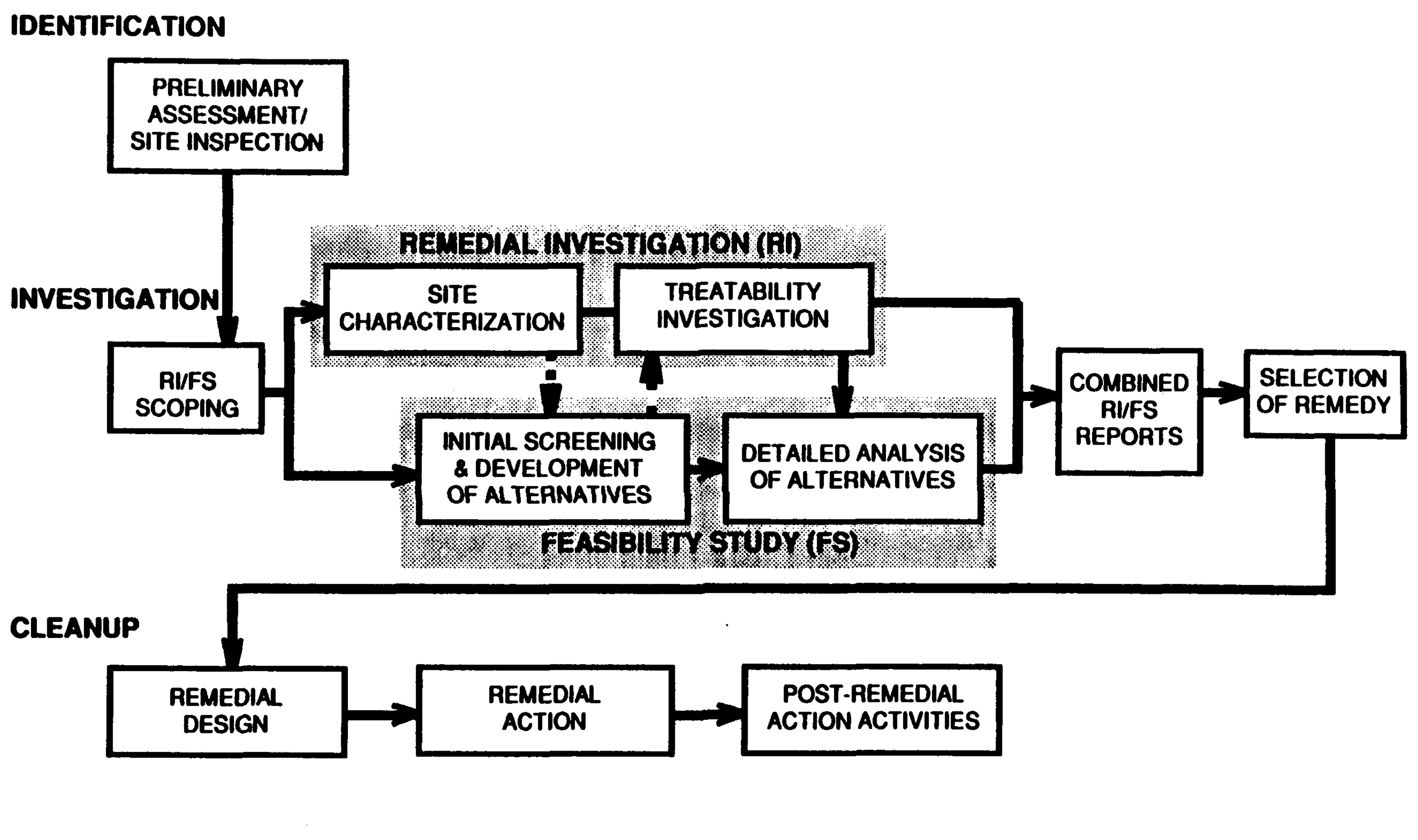

Figure 1-1. CERCLA Remedial Response Process

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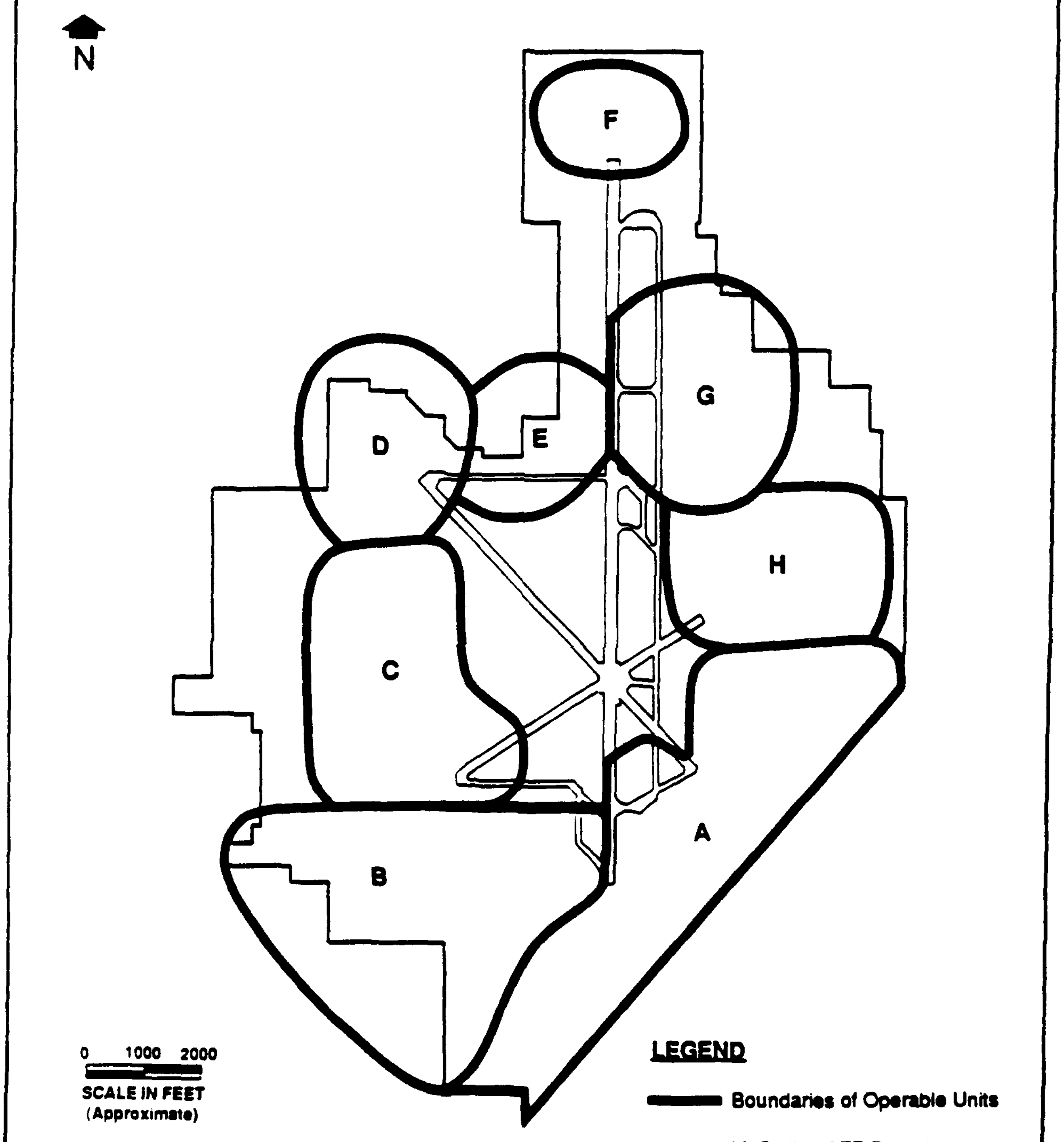

Figure 1-2. Approximate Boundaries of Operable Units at McClellan AFB

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(RI/FS) phase of the CERCLA Response Process is being conducted in OU B to determine the presence, magnitude, and extent of contamination within OU B locations and to evaluate the need for remedial actions.

Treatability studies are an integral part of the RI/FS process as shown in Figure 1-1. Treatability testing is being performed at McClellan AFB during the RI/FS process to evaluate the performance of a specific treatment technology on contaminated media detected in OU B, and determine size and cost of treatment units in sufficient detail so that a remedial action alternative can be recommended. Treatability studies can be performed as bench-scale and/or pilot-scale studies. Bench-scale treatability studies, the subject of this work plan, are laboratory studies performed to determine if treatment methods are effective for specific contaminated soil or waste. Bench-scale studies are also a cost-effective method for comparing competing treatment processes/methods. Pilot-scale studies are used to simulate the full-scale process and are usually performed on site.

The Soil Remedial Technologies Screening Project was conducted to identify potentially applicable cleanup technologies and to identify appropriate studies for treatment of contaminated soils identified within OU B. Technologies that would be appropriate for treatment of soils and waste in OU B were identified in the Soil Remedial Technologies Screening Technical Memorandum (Radian, 1992a). The technical memorandum was completed before most of the results of the OU B RI were available. However, treatment technologies for remediation of hazardous contaminants in soils were screened on the basis of analytical results from previous soil sampling and preliminary assessment/site inspection information (Radian, 1991b).

During Phase 1 of the OU B RI, PCB-contaminated soil was identified at Study Area 12 (SA-12). Analytical results for soils sampled in SA-12 were presented in meetings with the U.S. EPA, California EPA, and the California Regional Water Quality Control Board (RWQCB) in January, February, March, and April, 1992. Discussion of those results with regulatory agency representatives indicate that remedial action will likely be required for soils with concentrations exceeding 10 ppm PCBs. Dioxin and furan compounds at concentrations at 0.001 to 0.020 ppm were also detected in the PCB-contaminated soils.

Objectives of the bench-scale treatability testing are to:

- Evaluate the effectiveness of the selected treatment technologies to decompose PCB, dioxin, and furan compounds from SA-12 soil;
- Determine potential need for further treatment and/or disposal of treated soil and residuals;
- Compare the relative technical and economic feasibility of the selected treatment technologies;
- Determine if one of the treatment technologies should be tested at the pilot-scale; and
- Acquire design and cost information for pilot- and full-scale operation of the dechlorination processes.

1.2 Site Background

Soil for use in the treatability study will be collected from SA-12. Site SA-12 is the open storage lot northeast of Building 700 in the western part of OU B. The lot is currently used by the Defense Reutilization and Marketing Office (DRMO) for receipt, storage, and resale of useable materials. The western half of the lot has been used for this purpose since it was first developed in the early 1960s. The eastern half of SA-12 was used primarily as a soil holding area during the 1960s; since the mid-1970s, it has also been used for materials storage.

Most of the materials stored at SA-12 are considered nonhazardous; the exception is transformers, which are filled with PCB-containing oils. Three activities that included transformer storage or handling have been identified as potential sources of contamination. First, transformers may have leaked onto the ground surface while in storage. No specific transformer storage area has been identified, therefore, the entire area may be a potential contaminant source, and is being investigated as such during the OU B RI. Second, transformers were loaded and unloaded onto railroad cars in the northwest portion of SA-12 and oil may have leaked during loading. Third, transformer oil was reportedly disposed onto the ground northeast of Building 687.

Soil sampling has been performed at SA-12 during three investigations, including the current OU B RI (Radian, 1991c). Low concentrations of PCBs, VOCs, and semivolatile organics were detected during the pre-OU B RI sampling efforts. Analysis of samples from these efforts detected PCBs at a maximum concentration of 12.4 milligrams per kilogram (mg/kg) and VOCs and semivolatile organics at concentrations typically less than 0.1 mg/kg (Radian, 1991b).

The primary emphasis of the OU B RI at SA-12 has been to collect surface to 3 feet deep soil samples for PCB analysis. Screening for VOCs using soil gas probes, and analysis for semivolatile organics from a limited number of hand auger holes was also performed. To date, PCB-contaminated surface soil has been detected throughout much of SA-12 (unpublished data). Polychlorinated biphenyl soil concentrations exceeding 10 mg/kg have been measured throughout the northern third of the site. Samples from a limited area had concentrations from 100 to 100,000 mg/kg. Surface soil concentrations in the southern two-thirds of the site rarely exceed 10 mg/kg, with concentrations over most of the area being less than 1 mg/kg. Polychlorinated biphenyls have also been detected in subsurface samples, although at lower concentrations than surface soils. While the sampling at SA-12 has not been completed, and therefore, a complete evaluation of site conditions cannot be made, it appears that PCB-contaminated soil with concentrations exceeding 10 mg/kg will be limited to near-surface soils (i.e., less than 10-foot depth). Dioxins and furans contamination has also been identified in PCB-contaminated soil from SA-12, including octachlorodibenzo-p-dioxin (OCDD) and penta-, hexa-, hepta-, and octachlorodibenzo furan (PeCDF, HxCDF, HpCDF, and OCDF). Individual congener concentrations ranged up to 14 micrograms per kilogram (μg/kg), although not all data is currently available. All 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD) equivalencies are less than 10 μg/kg. Only limited VOC and semivolatile organic contamination has been detected in samples from SA-12.

Based on the available data and discussions with regulatory agencies, remediation of PCB-contaminated soil at SA-12 will be required. The preliminary remediation goals for SA-12 are as follows:

- Determine contaminant extent to an action level of 1 mg/kg PCBs;
- Primary remediation goal of 500 mg/kg PCBs;

- Postremediation goal (i.e., cleanup goal) of 10 mg/kg PCBs, considering industrial land use.

These remediation goals will be considered in evaluating the effectiveness of the treatment technologies selected for bench-scale testing. An additional goal that will also be considered is incineration equivalency as defined by the Toxic Substances Control Act (TSCA) (i.e., a residual soil concentration of less than 2 mg/kg PCB) (TSCA, 1976). (Note: TSCA has not been established as an Applicable or Relevant and Appropriate Requirement [ARAR] for SA-12 at this time.)

1.3 Technology Selection

During the Feasibility Study (FS) for soil contamination at SA-12, the following alternatives are likely to be considered:

- No action;

- On-site containment using a cap;

- Excavation and off-site landfilling in a cell designed and permitted for PCB wastes; and

- Excavation and on-site or off-site treatment to remove contaminants.

The no action alternative is not feasible because the site contains soils with PCBs in excess of the principal threat level (>500 mg/kg) that applies to an industrial site. U.S. EPA guidance for PCB-contaminated Superfund Sites (U.S. EPA, 1990a, 1990b) indicates a preference for treatment of soil exceeding the principal threat level. Options for soils in excess of the principal threat are: treatment by incineration or a technology that can demonstrate equivalent performance; or disposal in a TSCA-regulated landfill.

On-site containment is inexpensive, commercially proven, and commonly implemented for remediation of soils contaminated with low-level PCBs. Adequate containment may require a 3-foot cap that would raise the level of the site.

Off-site TSCA landfills are available at several locations and are cost-effective for the short term. While this option is technically feasible, the potential liability as a responsible party for future remediation of the landfill, if managed irresponsibly or closed, remains a significant concern. In addition, the presence of dioxins and furans in some soil may make landfilling infeasible. Location and costs for three TSCA landfills having the capacity to accept PCB-contaminated soils are shown in Table 1-1.

To evaluate the excavation and treatment alternatives in the FS, applicable technologies have been screened. The recently completed Soils Remedial Technologies Screening Technical Memorandum (Radian, 1992a) identified the following treatment technologies for remediation of soils contaminated with PCBs:

- Incineration;
- Chemical Dechlorination;
- Solvent Extraction;
- Thermal Desorption;
- Soil Washing; and
- Biological Treatment.

Off-site incineration is commercially proven, and the capacity is currently available. To incinerate soils containing greater than 50 mg/kg PCBs requires a TSCA permit which specifies 99.9999% destruction and removal efficiency (DRE). This DRE, which is designed to minimize air emissions, should easily permit reduction of PCBs to less than 2 mg/kg. There are no permitted TSCA incinerators in California; therefore, the cost of off-site incineration will include significant transportation costs. Transportation, incineration, and disposal of residuals currently exceeds $2,500 per ton; therefore, this option was preliminarily rejected on the basis of high cost. Locations of permitted off-site incinerators, the processes used, cost per ton, typical feed concentrations, and typical residue concentrations are also listed in Table 1-1.

Treatment technologies that are potentially applicable to site SA-12 soils are listed in Table 1-1 with laboratory test capacities, costs per ton, feed concentrations, and residue concentrations that have been achieved in previous tests.

Chemical dechlorination and biological treatment are innovative treatment technologies that actually destroy the PCB contaminants by chemically degrading them to less

TABLE 1-1. TECHNOLOGY OPTIONS FOR PCB REMEDIATION

Technology	Vendor	Process	Capacity	Cost^a ($/ton)	Typical Feed Concentrations (mg/kg)	Typical Residue Concentrations (mg/kg)
Off-Site Disposal						
Incineration	**Rollins** **Deer Park, TX**	RKI^b	Available	2880	10-15,000	<0.01-150
	APTUS **Coffeeville, KS**	RKI	Available	2420	10-15,000	<0.01-150
Landfill	**Chemical Waste Management** **Kettleman Hills, CA**	TSCA^c cell	Available	192	N/A	N/A
	Envirosafe **Idaho**	TSCA/RCRA^d cell	Available	170	N/A	N/A
	USPCI **Utah**	TSCA cell	Available	195	N/A	N/A
On-Site Treatment						
Chemical Dechlorination	**GRC Environmental, Inc.** **New York**	APEG-PLUS™^{e}	Lab test; 1 drum batch; 5 ton batch.	250-650	3-7,000	0.1-100
	US EPA **Cincinnati, OH**	BCDP^f	Lab test; 1 TPH pilot.	250	3,500	<10
Solvent Extraction	**Resource Conservation Company** **Bellevue, WA**	BEST™^{g}	Lab test; 150 lb/day batch.	50-150	3-15,000	0.1-2,000
Thermal Desorption	**Chemical Waste Management**	X-TRAX™	Lab test; 5 TPD pilot; 125 TPD commercial.	150-250	40-45,000	2-50
Biological	**Radian Corporation**	BSRP^h	Lab test; 16 gal batch; 2500 gal pilot.	200-400	10-500	N/A

(footnotes presented on following page.)

TABLE 1-1. (Continued)

[a] Cost estimates for off-site disposal technologies are based on vendor quotes for treatment of approximately 2,000 cubic yards of PCB-contaminated soil. Cost estimates for on-site treatment technologies are based on published vendor literature for a generic site.
[b] RKI = Rotary Kiln Incineration.
[c] TSCA = Toxic Substances Control Act.
[d] RCRA = Resource Conservation and Recovery Act.
[e] APEG-PLUS™ = Alkaline Polyethylene Glycol.
[f] BCDP = Base Catalyzed Decomposition Process.
[g] BEST™ = Basic Extractive Soils Treatment.
[h] BSRP = Bioslurry Reaction Process.

mg/kg = Milligram per kilogram.
N/A = Not applicable.
TPH = Tons per hour.
TPD = Tons per day.
USPCI = United States Pollution Control Inc.
US EPA = United States Environmental Protection Agency.

toxic forms and may be implemented at McClellan AFB. Although biological treatment methods promise to be less expensive than other destruction technologies (e.g., incineration and chemical dechlorination), optimization is required to control the process environment, encouraging growth of specific microorganisms that degrade PCBs. Extensive treatability studies will be required to develop this optimization, and the availability of commercial-scale equipment is limited. Therefore, biological methods were not considered further.

Chemical dechlorination has demonstrated excellent destruction of PCBs on the laboratory and pilot scales, and promises to be cost competitive with incineration at a projected cost of about $600 per ton. However, the availability of commercial scale equipment is limited. Several dechlorination processes have been tested, including APEG, KPEG, and BCDP. Treatability studies must be completed to verify feasibility of one or more of the processes for the soil matrices found at McClellan AFB, as well as to provide design information and order-of-magnitude costs for pilot testing and full-scale remediation. Based on the high destruction efficiency demonstrated in previous studies, cost incentive relative to incineration, and availability of testing equipment, chemical dechlorination is recommended for testing on soils obtained from SA-12.

A benefit to be derived from proving the effectiveness of an innovative technology at SA-12 is the potential for application of the remediation process to PCB-contaminated soils in other areas of McClellan AFB, thereby reducing the unit cost to develop the technology. Proactive technology development by the Air Force in an effort to expedite remediation may be viewed favorably by the local community. McClellan AFB Environmental Management could communicate the results of the bench- and pilot-scale testing through the Environmental Process Improvement Center (EPIC).

Solvent extraction, thermal desorption, and soil washing are technologies that remove PCBs from the soil matrix and then transfer them to another medium. Therefore, by using these technologies, PCBs must still be destroyed using another treatment process before remediation is complete, typically by incineration. For example, in thermal desorption, contaminants are volatilized from the soil matrix by indirect heating and gas stripping in a rotary dryer. The contaminants are condensed from the gases exiting the dryer. The contaminants are therefore concentrated into a much smaller volume waste stream than the original contaminated soil volume. If the removal technologies are effective, soils would be relatively easy to process and, if sufficiently clean after treatment (as defined by ARARs), may be returned to the excavation location. The extracted contaminants in the condensate must be further treated to destroy PCBs or disposed in a TSCA landfill.

Table 1-2 shows preliminary cost estimates for implementing different combinations of removal (solvent extraction and thermal desorption) and destruction technologies (incineration and chemical dechlorination or off-site disposal) based on unit costs that are applicable to processing of relatively large soil volumes (e.g., typically >5,000 cubic yards). The estimated costs for remediation of 6,400 cubic yards of PCB-contaminated soil (estimated volume of soil at SA-12 exceeding 10 mg/kg) indicate that the two-step processes are cost-competitive with chemical dechlorination. However, the following factors were considered in selection of technologies for bench-scale treatability studies:

- Implementation of a removal technology (thermal desorption or solvent extraction) for volume reduction prior to landfilling is not cost-effective due to the relatively low cost of direct off-site disposal. However, reduced voiumes may reduce future liability as a potentially responsible party (PRP) if fiscal responsibility for landfill remediation is based on disposal volume.

- The high cost of off-site incineration of the removed contaminants essentially offsets the economic advantage of a cheaper initial soil processing step when compared to direct chemical dechlorination. Thermal desorption or solvent extraction followed by incineration would be economically attractive if off-site incineration were the only available option for PCB destruction.

- Application of a removal technology prior to chemical dechlorination appears to be economically attractive. However, the unit cost for destruction of removed contaminants may be much higher than assumed ($600 per ton) due to the relatively low volume expected (about 1,350 tons or 15% of contaminated feed soil). For such low volumes, mobilization and demobilization costs for an on-site treatment system, will increase unit costs significantly.

TABLE 1-2. SA-12 PRELIMINARY REMEDIATION COSTS

Technology	Unit Cost[a] ($/ton)	Total Cost ($MM)
Off-site landfill	200	1.8
Off-site incineration	2,500	22.4
On-site chemical dechlorination	600	5.4
Thermal desorption & off-site landfill	250/200	2.5
Thermal desorption & off-site incineration	250/2,500	5.6
Thermal desorption & on-site dechlorination	250/600	3.0
Solvent extraction & off-site landfill	150/200	1.6
Solvent extraction & off-site incineration	150/2,500	4.7
Solvent extraction & on-site dechlorination	150/600	2.2

[a] Costs include transportation and final disposal of residuals, but exclude design and construction costs of on-site treatment plants.

ASSUMPTIONS:

1. 6,400 cubic yards of PCB-contaminated soil (PCB >10 mg/kg) based on soil analyses and volume estimates available 15 March 1992.
2. 1.4 tons/cubic yard soil density.
3. 15% by weight moisture (including contaminants).
4. $MM = Millions of dollars.

- In general, implementation of multiple treatment steps will be more complex from both a design and operation standpoint. As a result, remediation time will likely increase when compared to a single processing system.

- The expected performance of removal technologies may not be adequate to reach specified concentrations of PCBs. From the summary data presented in Table 1-1, thermal desorption has achieved 2 mg/kg PCBs in the treated soil as a best case; typical concentrations are much higher. Also, although solvent extraction has achieved 0.1 mg/kg for some soils, the residual concentrations achievable cover a very wide range. Very little data is available for the effectiveness of these technologies for removal of dioxins and furans. Chemical dechlorination has demonstrated destruction of these compounds as well as PCBs.

Therefore, the preliminary cost analysis presented in Table 1-2 shows that there may be a cost incentive to pursue solvent extraction or thermal desorption if the chemical dechlorination bench-scale tests demonstrate poor destruction efficiency or indicate higher unit costs than those estimated.

Soil washing was rejected for consideration as a removal technology option for SA-12 because previous treatability testing data presented in the Technical Memorandum (Radian, 1992a) indicates a wide range of removal efficiencies which implies that effectiveness of the technology may be unpredictable.

1.4 Recommendation

Based on the types of contaminants detected at SA-12 (PCBs, dioxins, and furans), the tentative remediation goals, and the available treatment technologies, two dechlorination processes have been selected for bench-scale treatability testing. These technologies are:

- Glycolate Dechlorination using the APEG-PLUS™ process available from GRC Environmental, Inc. (GRC).

- Base-Catalyzed Decomposition Process (BCDP) developed by the U.S. EPA.

The remainder of the report presents the technical approach for conducting bench-scale testing of these processes, including descriptions of the bench-scale tests and full-scale process.

2.0 REMEDIAL TECHNOLOGY DESCRIPTION

Two remedial technologies have been selected for bench-scale testing: glycolate dechlorination and base-catalyzed desorption. These technologies are summarized in the following subsections.

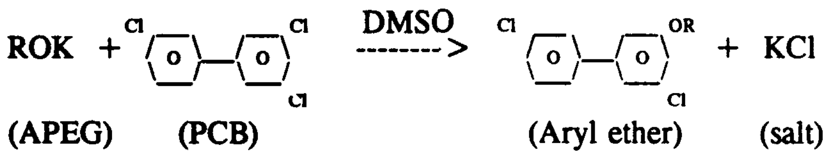
2.1 Glycolate Dechlorination

The glycolate dechlorination process selected for testing is the APEG-PLUS™ process from GRC Environmental, Inc. (GRC). Descriptions of the full-scale process and bench-scale testing procedure were provided by GRC (GRC, 1991a, 1991b).

2.1.1 Principle of Operation

Chemical dechlorination involves the removal of chlorine atoms from halogenated aromatic compounds by chemical reaction to form products that are less harmful and safer in the environment. The APEG-PLUS™ process uses the reagents potassium hydroxide and polyethylene glycol (PEG) to form an alkoxide (APEG) that is capable of reacting with polychlorinated biphenyl (PCB) type molecules, as shown below:

$$\mathrm{KOH} + \underset{\text{(PEG)}}{\mathrm{ROH}} \xrightarrow{\text{DMSO}} \underset{\text{(APEG)}}{\mathrm{ROK}} + \mathrm{H_2O}$$



The APEG reacts with the PCBs in a dimethyl sulfoxide (DMSO) carrier to form an ether and a salt. These reaction products are both water soluble and are relatively nontoxic.

2.1.2 APEG-PLUS™ Process Description

Figure 2-1 shows a Process Flow Diagram for full-scale treatment of soils by APEG-PLUS™ (glycolate dechlorination). The following is a description of the process:

- Soil is screened to less than 6 inches to remove large rock and debris and sent through a shredder.
- Oversize material is treated separately.
- Shredded soil is loaded on a conveyor and fed to the slurry mixing feed system.
- Reagents are added to the system and the mixture is worked into a slurry.
- The slurry is pumped to the reactor through a 1/4-inch screen. Oversize material is separated out for rock washing.
- The slurry is heated to 300°F with agitation in the reactor for several hours until contamination is reduced to required levels.
- Slurry samples are taken from the side of the reactor during the reaction for on-site analysis to determine when the "clean level" has been reached.
- A slight vacuum is maintained on the reactor to prevent escape of contaminants.
- Steam from the reactor is captured in a condenser and the recovered water is fed to the solid/liquid separator.
- Any condensable organics are removed from the system and are disposed of off-site or in an on-site bioreactor system.

SOURCE: GRC Enviromental, Inc.
APEG-PLUS™ Company History
and Process Description,
June 1991

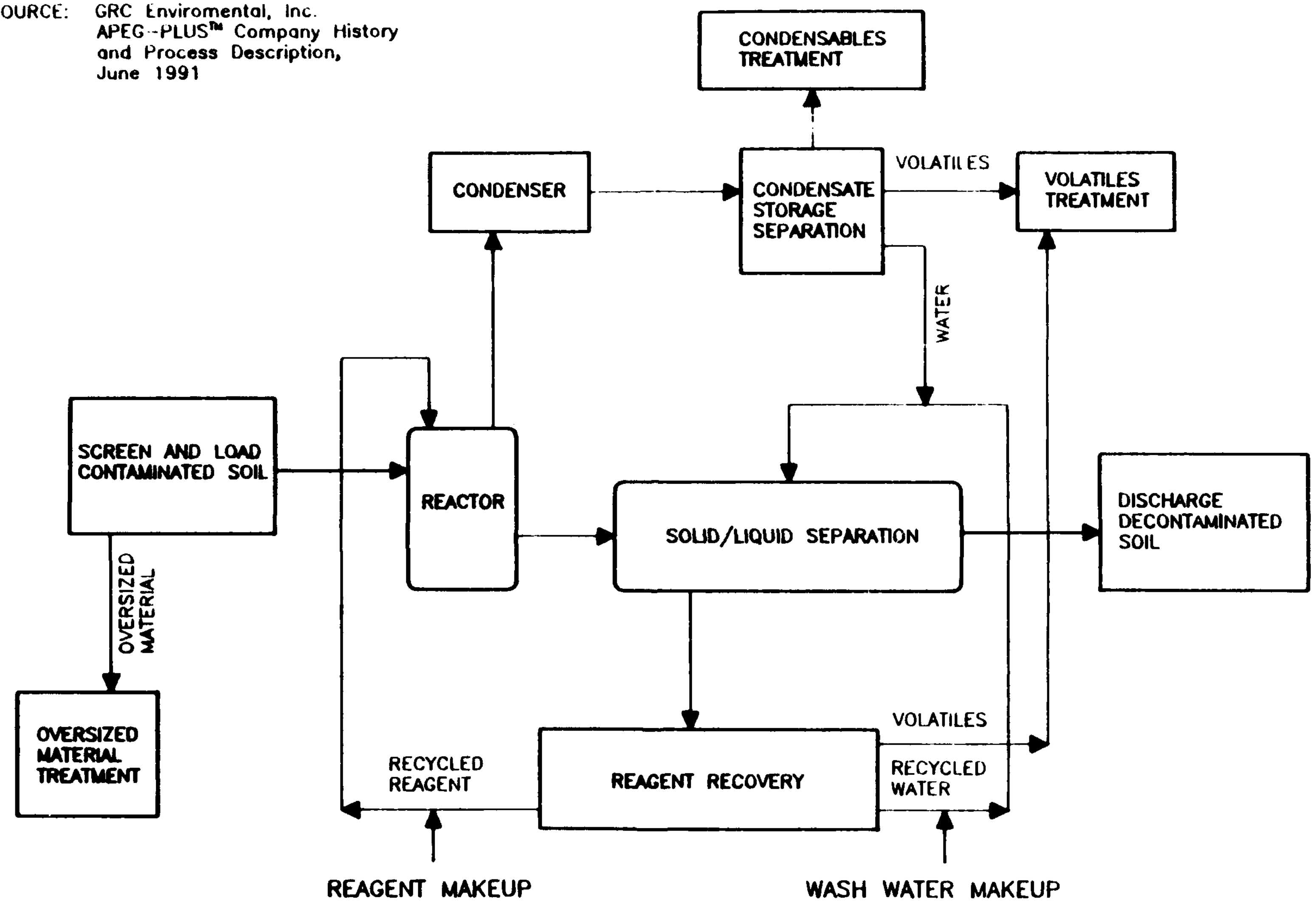


Figure 2-1. Chemical Dechlorination Process Flow Diagram

DWG\MCSOIL\FLOW-A\5-8-92\DMR

- When the "clean level" is reached, the soil slurry is pumped out of the reactor into a centrifuge where reagents are removed from the soil.

- Further removal of reagents is accomplished by washing the soil with water followed by centrifuging.

- During one of the washes, the soil is neutralized to a site-specific pH by addition of acid to the wash water.

- Reagents recovered from the centrifuge are recycled to the reactor with any reagent makeup required.

- The soil washing and centrifuging process is repeated until reagent concentrations are reduced to acceptable levels.

- Liquids from the centrifuging process are separated by a triple effect evaporator in the reagent recovery system. Volatiles including reaction products (ether) are removed, condensed, and stored for off-site disposal, water is recycled back for the soils washing steps, and the concentrated liquids (containing salts produced from the dechlorination reaction and other dissolved and suspended solids) are collected for off-site disposal.

- Volatiles from the reagent recovery process are condensed and combined with the volatiles from the reactor.

- Decontaminated soil is discharged from the centrifuge onto a conveyor and handled according to site requirements.

2.1.3 Advantages/Disadvantages of the Process

The advantages of application of glycolate dechlorination are:

- The process has been field tested and successfully reduced PCB and dioxin contamination;

- The treatment units are designed for batch operation and are mobile;
- Treatment time is relatively short (0.5 to 5 hours is a typical range);
- The process is self-contained so no by-products can escape to the environment;
- The chemical reaction products are nontoxic;
- Soil is not degraded during the treatment process and may be used as backfill; and
- The process appears to be cost-effective for relatively small volumes of contaminated soil compared to incineration for similar wastes.

The disadvantages of glycolate dechlorination include:

- The technology is limited to halogenated aromatic compounds and is not effective on metals, halogenated volatile organics, and other semivolatile organic compounds;
- Some wash waters and spent reagents may require further treatment and/or disposal actions. The need for further treatment can be determined by bench and pilot-scale testing;
- A biotreatment facility is needed for condensible, nonaromatic halogenated compounds;
- Elevated concentrations of chlorinated organics (e.g., greater than 5%) require excess reagent (although concentrations in this range have been detected locally at McClellan Air Force Base [AFB], they may be decreased by mixing with less contaminated soils prior to treatment);
- High water content in the soil (e.g., greater than 15%) will require excessive reagent and increased energy input;

- Low pH (less than 2) soils require excessive volumes of reagent;
- High humic content in soil increases the required reaction time; and
- Presence of other alkaline reactive materials (e.g., aluminum) in the soil will compete for the reagent (soils at McClellan AFB may have greater than 10% Al in minerals).

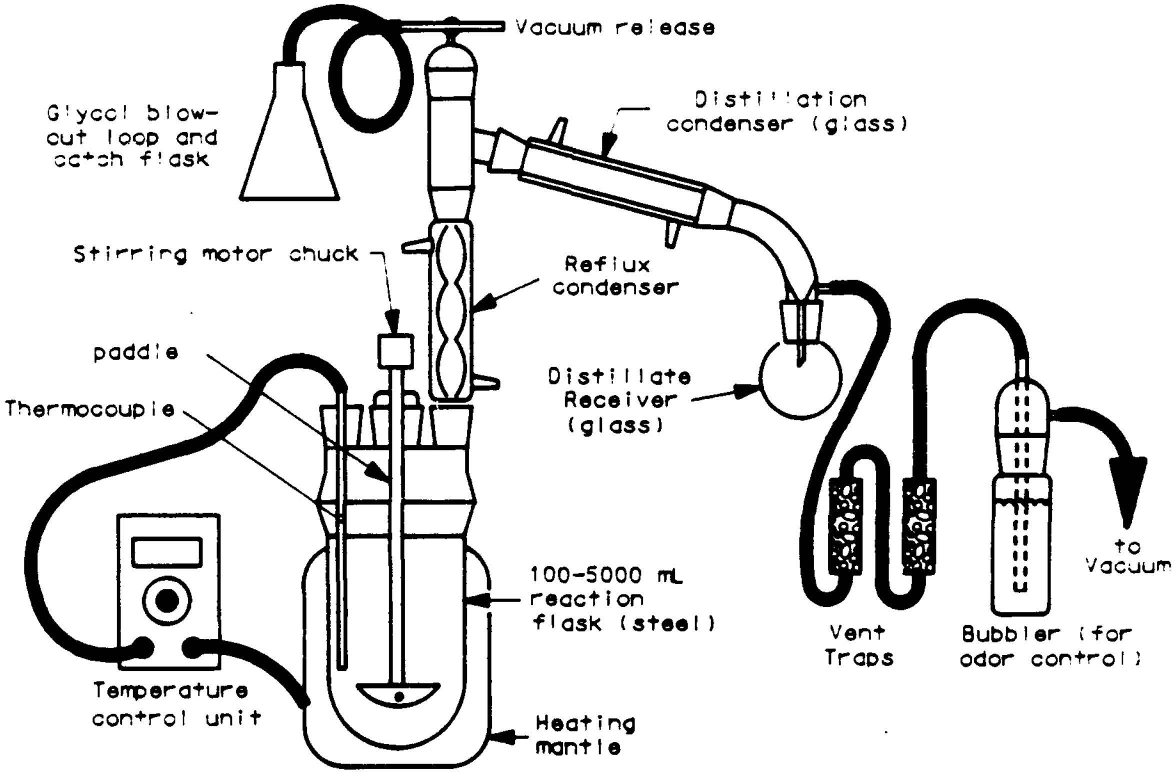
Advantages of the APEG-PLUS™ process include that it is a proven technology for treating PCBs to concentrations less than 2 milligrams per kilogram (mg/kg) and dioxins to concentrations less than 1 microgram per kilogram (μg/kg), the process equipment is mobile, self-contained, and emissions from the treatment process are minimal. The need for incineration with subsequent air emissions is eliminated by chemically altering the toxic compounds to nontoxic water-soluble forms.

The main disadvantage of the process is that the reaction is effective only for PCBs, dioxins, and other halogenated aromatic compounds, but not for halogenated alkanes, alkenes, oils, or metals. Typically the process includes a bioreactor to treat volatile hydrocarbons, but that still leaves metals and most of the semivolatile hydrocarbons unaffected by the process. Soils which are high in total aluminum cannot be treated by this process because of the formation of hydrogen gas as a reaction product. This disadvantage may be significant for McClellan AFB soils where Al has been detected at up to 4% of weight. Other conditions that would drive costs up are the presence of low pH, high humic acid levels, and high moisture content in the soils to be treated.

2.1.4 Bench-Scale Treatment of Soil

The purpose of a bench-scale study is to simulate full-scale soil treatment so that critical parameters such as reagent loading and reaction time can be determined. In addition, an estimate of cost for full-scale treatment can be calculated from the data generated during the study.

The following is a description of the bench-scale treatability process. Figure 2-2 shows a laboratory soils reactor used for bench-scale treatability studies. Before any reactions are done, soil samples are analyzed for the contaminant(s) of interest (in this case PCBs), percent moisture, and potassium hydroxide (KOH) absorption capacity. These



Source: REMEDIATION/SPRING 1991; Recent Development in Cleanup Technologies

Figure 2-2. Laboratory Testing Apparatus APEG-PLUS™ Process

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analyses help laboratory personnel decide on reagent formulation and loading for the initial reaction, and indicate required reaction times.

The reactor bottom, distillate receiver, and jars for reagent, soil, and washes are weighed before starting the reaction. Soil is weighed into the reactor bottom. The reactor is clamped together and set up in a fume hood. The thermocouple, condenser system, and condensate receiver are attached, and a thermostatically controlled heating mantle is positioned on the bottom of the reactor, as shown in Figure 2-2. Reagents are weighed and added through the neck that usually holds the thermocouple; and the soil and reagents are then mixed into a slurry.

Reactions are timed from the start of heating. During heating, a slight vacuum (less than 1 inch Hg) is applied at the exit from the vent trap. The vacuum simulates the negative pressure maintained on the full-scale reactor. The vent trap assures that no vapors escape from the system. Water boils between 230-265°F (due to boiling point elevation). Samples are taken throughout the reaction, usually about one per hour, and analyzed according to GRC's analytical method for the contaminant(s) in soil.

After the contaminant concentration in the soil has reached the desired "clean" level (less than 2 mg/kg PCB for this study), the reactor is cooled to about 212°F, and water is added to dissolve the KOH and restore the reagent to its original water content. The reactor is then cooled to room temperature.

Reagent recovery and soil washing are carried out using centrifugation as the separation method. The reactor is emptied into one or more centrifuge bottles. The bottles are centrifuged at approximately 1,500 revolutions per minute, for one to five minutes. The centrifuge speed and time are selected to simulate gravitational force and dwell time of the centrifuges to be used in full-scale soil treatment. The reagent is poured or pipetted off the soil into a preweighed jar. The soil is returned to the reactor and the reactor is reassembled so that the stirrer can be used. Wash water is weighed into the reactor and mixed with the soil. The reactor contents are heated to 195°F and held at that temperature for 20 minutes with constant agitation. The reactor is cooled, and the contents are emptied into the centrifuge bottles. The washing procedure is repeated three to five times.

When all liquids are in their preweighed jars, the jars (and the distillate receiver) are reweighed, and mass recoveries are calculated. The reagent, washes, and distillate are analyzed for the various reagent components. Mass balances for each reagent component are calculated. The reagent mass balance data are used to generate an estimate of reagent consumption and cost for full-scale treatment.

The contaminant data from the hourly monitoring samples are used to generate a concentration versus time graph for the soil. This graph can be used to estimate the difference in reaction time to achieve various "clean" levels. Reaction time affects treatment cost. The reagent, washes, distillate, and vent traps are also analyzed for the contaminant(s) to verify that the contaminant(s) are destroyed and not just removed. The aryl ether produced in the process are extremely difficult to analyze for; instead, the treated material is analyzed for extractable organic chlorine to demonstrate completeness of the dehalogenation.

2.1.5 Limitations of Bench-Scale Testing

Due to the high ratio of surface area to soil mass in a bench-scale reactor, some of the soil remains coated to the walls of the reactor and does not enter into the slurry reaction. For some soils, this can result in an error of ±50% in the estimation of full-scale costs (GRC, 1991b). For this reason and others, a pilot-scale study is recommended before full-scale treatment begins.

2.1.6 Existing Performance Data

The APEG-PLUS™ process has demonstrated significant destruction of PCBs in soil matrices. Table 2-1 summarizes the performance data provided by GRC for the APEG-PLUS™ treatment of PCBs, dioxins, and furans in various media including soils, sediments, sludges, and oil. This performance data is from bench, pilot, and full-scale tests at various sites. For PCB-contaminated soils, tests were conducted for feed concentrations that varied between 10 and 7,500 mg/kg PCBs. Treated soils (residues) contained between nondetectable and 49 mg/kg PCBs with about 50% of the residues containing less than 2 mg/kg PCBs. The performance data also shows significant destruction of dioxins and furans for a feed concentration of 120 μg/kg to residues of less than 1 μg/kg of these compounds. Therefore, based on this performance data, the APEG-PLUS™ process is a strong candidate for treatment of PCB-contaminated soils at SA-12, because high concentrations of PCBs and low concentrations of dioxins and furans have been detected at the site.

TABLE 2-1. PERFORMANCE DATA SUMMARY, APEG-PLUS™ PROCESS

Site	Contaminant and Matrix	Original Concentration	Final Concentration	Date
A	PCB (soil)	150 mg/kg	<2 mg/kg	1991
B	Dioxins, furans (ash)	18.9 μg/kg TE 2,3,7,8-TCDD	<1 μg/kg TE 2,3,7,8-TCDD	1990
C	Dioxin (sediment)	46 μg/kg 2,3,7,8-TCDD	0.02 μg/kg	1990
		39 μg/kg 2,3,7,8-TCDF	0.06 μg/kg	
D	PCB (soil)	125 mg/kg	<2 mg/kg	1990
E	PCB (oil)	69,000 mg/kg	<2 mg/kg	1990
F	PCB (soil)	5,000 mg/kg	44 mg/kg	1990
	Total dioxins	38,400 μg/kg PCDD (145 μg/kg TE 2,3,7,8-TCDD)	14 μg/kg PCDD (0.7 μg/kg TE 2,3,7,8-TCDD)	1990
	Total furans	7,120 μg/kg PCDF (83 μg/kg TE 2,3,7,8-TCDD)	0.2 μg/kg PCDF (0.02 μg/kg TE 2,3,7,8-TCDD)	1990
G	Polychlorinated dioxins (soil)	10.33 μg/kg	nondetect	1989
	Polychlorinated dibenzofurans	1,109.64 μg/kg	0.12 μg/kg	1989
	DDE	100 mg/kg	1.2 mg/kg	1989
	DDD	1,600 mg/kg	0.9 mg/kg	1989
	DDT	5,600 mg/kg	4.2 mg/kg	1989
	HCB	450 mg/kg	1.9 mg/kg	1989
H	Total dioxins (soil)	22,000n μg/kg PCDD	nondetect	1989
	Total furans	3,600 μg/kg PCDF	nondetect	1989
	PCP	1,100 mg/kg	31 mg/kg	1989
I	PCB (soil lab)	620 mg/kg	6.8 mg/kg	1987
	PCB (soil pilot)	276 mg/kg	1 mg/kg	1988
J	Dioxin, furans (sludge)	11,000,000 μg/kg PCDD + PCDF	nondetect	1988
K	PCB (soil)	300 mg/kg	<2 mg/kg	1988
L	PCB (soil)	790 mg/kg	6 mg/kg	1988
M	PCB (sand)	2,900 mg/kg	<1 mg/kg	1987

(Continued)

TABLE 2-1. (Contined)

Site	Contaminant and Matrix	Original Concentration	Final Concentration	Date
N	PCB (soil)	245 mg/kg	2.7 mg/kg	1987
O	Dioxin (sludge)	189 μg/kg 2,3,7,8-TCDD	<0.3 μg/kg 2,3,7,8-TCDD	1987
P	Dioxin, furans (oil)	422 μg/kg TCDD (>100,000 μg/kg PCDD) >16,000 μg/kg PCDF	<1 μg/kg TCDD (2.9 μg/kg PCDD) nondetect PCDF	1986
Q	Dioxin (oil)	120 μg/kg 2,3,7,8-TCDD	<1 μg/kg 2,3,7,8-TCDD	1986
R	PCB (oil)	1,000 mg/kg	<2 mg/kg	1986
S	PCB (sediment)	6,000-7,500 mg/kg	4 mg/kg	1986
T	PCB (oil)	1,000 mg/kg	<2 mg/kg	1985
U	Dioxin (soil)	2,000 g/kg TCDD	<1 μg/kg TCDD	1985
V	PCB (soil)*	108 mg/kg	27 mg/kg	1985

* Average of 51 drums, final concentration target was <50 mg/kg.

PCB = Polychlorinated biphenyls
PCDD = Polychlorinated dioxins
PCDF = Polychlorinated furans
PCP = Pentachlorophenol
TE = Toxicityequivalent of 2,3,7,8-TCDD
TCDD = Tetrachlorodibenzo-p-dioxin
TCDF = Tetrachlorodibenzofuran
DDE = Dichlorodiphenyl dichloroethylene
DDD = Dichlorodiphenyldichloroethane
DDT = Dichlorodiphenyl trichloroethane
HCB = Hexachlorobenzene
mg/kg = Milligrams per kilogram
μg/kg = Micrograms per kilogram

Site A-V = Site designations provided by GRC; the specific site names were not provided.

SOURCE: GRC Environmental, Inc., April 1991.

2.2 Base-Catalyzed Decomposition Process (BCDP)

The Base-Catalyzed Decomposition Process (BCDP), developed by the U.S. Environmental Protection Agency (U.S. EPA), was selected as an alternative dechlorination treatment process because of its potential to completely dechlorinate PCB molecules, whereas the APEG-PLUS™ process may result in only partial dechlorination. Descriptions of the full-scale process and bench-scale testing procedure were taken from the literature (U.S. EPA, 1991; NEESA, 1991) and conversations with U.S. EPA staff.

2.2.1 Principle of Operation

The BCDP has been demonstrated by U.S. EPA (Risk Reduction Engineering Laboratory) to destroy halogenated contaminants such as chlorinated solvents, polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and PCBs. When the process is most effective, all the halogen molecules in the halogenated compounds are completely replaced by the hydrogen radicals. The by-products from complete dechlorination of PCBs are biphenyl and salt.

The principle of the BCDP is the generation of hydrogen radicals (acceptor - H) from a hydrogen donor to completely replace the halogen molecules in the halogenated hydrocarbons. Key variables for the reactions are temperature, base catalyst concentration, and hydrogen donor concentrations.

The BCDP requires heating the soil with sodium bicarbonate for about one hour at 630°F in a rotary reactor. Polychlorinated biphenyls are decomposed and partially volatilized in this step. The BCDP produces biphenyl, low boiling olefinic compounds, and sodium chloride according to the following generalized reaction:

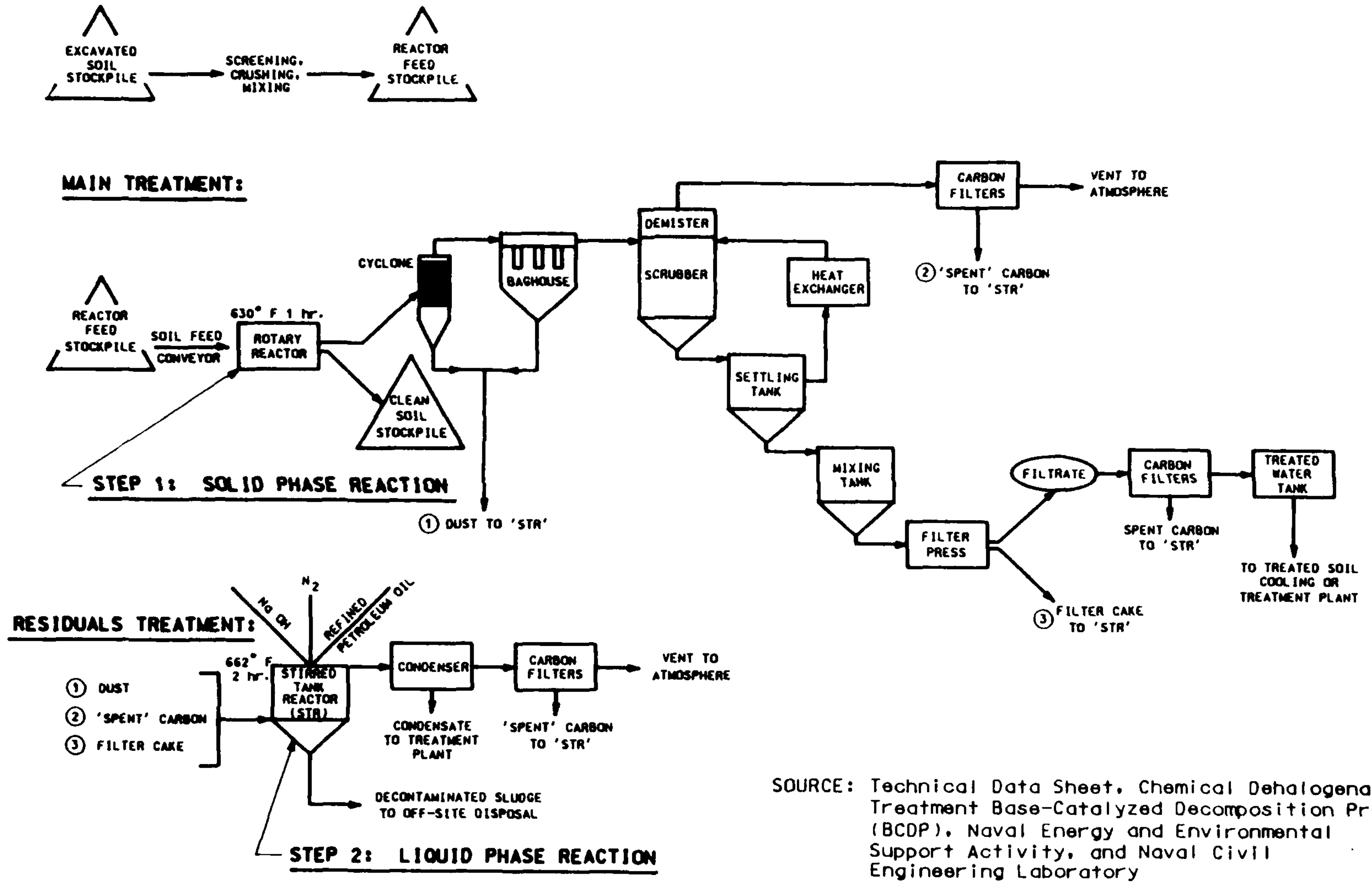
$$R\text{-}(Cl)_X + R' \xrightarrow[\Delta H]{A+} R\text{-}H + ACl + R''$$

$R\text{-}(Cl)_X$ can be any halogenated compound such as PCBs. In principal, R' is a hydrogen donor whose oxidation potential is sufficiently low to generate nucleophilic hydrogen in the presence of base A^+ (sodium hydroxide) and at temperatures between 480-660°F. Under these conditions, chlorine on $R\text{-}(Cl)_X$ is replaced by H to produce R-H with loss of hydrogen from R' to R" and the formation ACl (or sodium chloride). This reaction achieves complete dechlorination of chlorinated compounds. The biphenyl and low boiling olefinics are not water soluble and have lower toxicities than the byproducts of polyethylene glycol dechlorination processes.

2.2.2 BCDP Process Description

Figure 2-3 shows a Process Flow diagram for full-scale treatment of soils by sodium bicarbonate decomposition. The following is a description of the process:

- Contaminated soil is screened, crushed, and blended to less than 3/4 inch with a crusher and pug mill, and stockpiled.
- The soil is mixed with approximately 10% by weight of sodium bicarbonate and heated for one hour at 630°F in an indirectly heated rotary reactor.
- Offgas from the reactor, which contains dust and trace amounts of volatilized PCBs, are routed to a cyclone and baghouse for particulates removal.
- Acid gases are removed from offgas in a scrubber; residual organics are removed by activated carbon adsorption prior to discharge of offgas to the atmosphere.
- The scrubbing solution is recirculated and a blowdown stream removed for treatment of PCB-contaminated solids and wastewater after the two streams are separated in a filter press.
- All PCB-contaminated residuals, residual dust from the cyclone and baghouse, spent carbon, and filter cake from the scrubbing solution treatment unit are collected and fed to a batch stirred tank reactor (STR).
- Sodium hydroxide and refined petroleum oil (a hydrogen source) are mixed with the residuals in the STR and heated to 660°F for two hours to decompose remaining PCB compounds. Offgas from the STR is



SOURCE: Technical Data Sheet, Chemical Dehalogenation Treatment Base-Catalyzed Decomposition Process (BCDP), Naval Energy and Environmental Support Activity, and Naval Civil Engineering Laboratory

Figure 2-3. Base Catalyzed Decomposition Process Flow Diagram

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passed through a condenser and carbon adsorption unit before discharge to the atmosphere. The decontaminated sludge is combustible and may be used as fuel or treated and reclaimed by a waste-oil recycler.

- The treated water from the main treatment system and the condensate from the residuals treatment system may require further treatment. Bench-scale tests will indicate if additional treatment is required. The design of such a treatment system would be included in the pilot or full-scale stage of the remediation effort.

- Clean soil from the reactor can be returned to the site from which it was excavated.

2.2.3 Advantages/Disadvantages of the Process

Advantages of application of the BCDP are as follows:

- The process has demonstrated effectiveness for halogenated aromatic compounds (e.g., PCBs, pentachlorophenol [PCP], herbicides, pesticides, dioxins, and furans). It is reportedly possible to treat PCBs in concentrations as high as 6,000 to 7,000 mg/kg in soil.

- BCDP utilizes a high reactor temperature with a residence time of one hour to accomplish dechlorination of the PCB molecules.

- The main reactants, sodium bicarbonate (for hydrolysis) and aliphatic hydrocarbons (as a hydrogen source) are relatively inexpensive.

- Bench-scale testing results have demonstrated high decomposition efficiencies for both PCB- and dioxin-contaminated soils.

- Secondary, batch STR is used to further process treatment residuals to reduce their toxicity. Pollution control equipment on the gas streams exiting the process minimizes toxic air emissions.

- Soil is not degraded in the treatment process and may be used as backfill.

The disadvantages of the BCDP include:

- The process may be effective for halogenated volatile organic and halogenated semivolatile organic compounds, but has not been demonstrated in these applications. Heavy metals, if present, are usually converted to carbonates or hydroxides so that stabilization of the treated soil may be required to meet Toxicity Characteristic Leaching Procedure (TCLP) limits for soluble metals.
- Wastewater from the scrubbing system and decontaminated sludge from the STR will require management.
- Potential emissions of volatiles to air and their impact on permitting will require evaluation.
- BCDP has only been demonstrated on the bench scale to date, although pilot-scale testing will be conducted in the near future.
- Additional design and construction of a pilot-scale unit will be required to demonstrate the technical feasibility and cost effectiveness of BCDP for PCB-contaminated soils at McClellan AFB.
- BCDP efficiencies and reagent costs may be affected by soil moisture, alkaline metals, and high humic content in the contaminated soils, as with the APEG-PLUS™ process.

2.2.4 Bench-Scale Treatment of Soil

The U.S. EPA Risk Reduction Engineering Laboratory (RREL) has laboratory facilities for development and bench-scale testing of the BCDP. At the time of preparation of this work plan, details of the bench-scale equipment and procedures were not available. Based on telephone conversations with U.S. EPA staff (personal communication with Charles Rogers, U.S. EPA, 23 April 1992), a preliminary description of the bench-scale testing procedures was prepared and are shown in Figure 2-4.

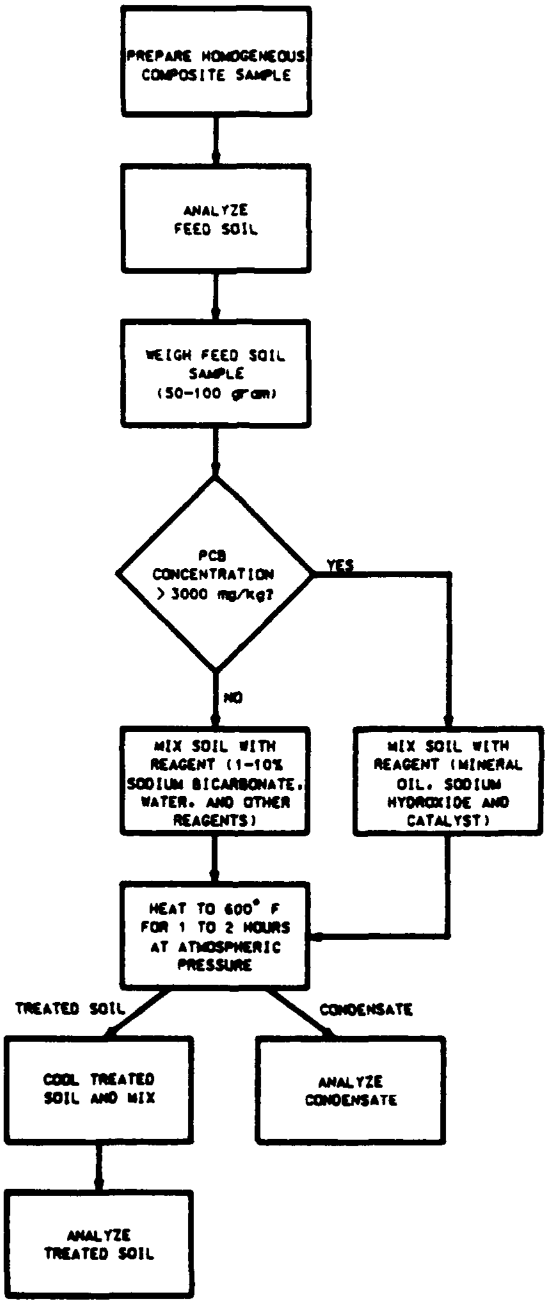

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Figure 2-4. Laboratory Test Protocol BCDP

Following sample preparation and analysis, soil is mixed batchwise with the reagents. For PCB concentrations in excess of about 3,000 mg/kg, the soil is mixed with mineral oil, sodium hydroxide, and a catalyst that simulates the STR used to treat residual streams in the pilot-scale version of the process. Soils containing less than about 3,000 mg/kg PCBs (personal communication with Charles Rogers, U.S. EPA, 23 April 1992) are mixed with 1 to 10% by weight of sodium bicarbonate, water, and other reagents. After mixing, the soil is heated to 600°F for one to two hours to complete the dechlorination reaction. Vapors evolved are collected, condensed, and analyzed for volatilized PCBs and other contaminants. The treated soil is cooled and then analyzed for residual PCBs and products of the dechlorination reaction.

2.2.5 Limitations of Bench-Scale Testing

A detailed evaluation of bench-scale testing limitations will be conducted when additional information on the testing protocol is received from the U.S. EPA, and after the tests have been witnessed. However, the most significant potential limitations in predicting full-scale results from bench-scale test are the loss of mixing efficiency as the scale of processing is increased to full scale and the mechanical reliability of full-scale equipment used to move solid streams between processing steps.

The U.S. Navy is currently planning to begin operations of the first 25-tons-per-day pilot-scale BCDP unit in Guam for remediation of 5,500 tons of PCB-contaminated soil. Operation of this system will provide data concerning the limitations of the BCDP as testing of McClellan AFB soils proceeds.

2.2.6 Existing Performance Data

Two sets of data for BCDP bench-scale tests on soil samples from the Guam site are provided in Tables 2-2 and 2-3. These tables summarize the results of testing the BCDP with variations in operating conditions, such as reaction temperature, residence time, and proportions of reactants added. Proper interpretation of these results requires some manipulation of the data. For example, the feed concentration is expressed in parts per million (ppm) of Arochlor 1260 and residual soil concentrations are expressed as ppm of specific PCB congeners. Arochlor 1260 is a trade name given to a commercially-produced mixture of different PCB congeners; the 1260 nomenclature indicates that the mixture contains 60% by weight of chlorine. This mixture typically contains different PCB homologs

TABLE 2-2. BCDP EXPERIMENTS AT U.S. EPA (JANUARY 1990)[a]

	Residual Concentration in Soil (ppm)					
PCB Congener	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
1ClBP[d]	ND[b]	1.09	0.97	ND	0.64	1.50
1ClBP[d]	ND	ND	3.21	ND	0.53	ND
2ClBP	ND	0.27	1.22	ND	0.43	0.49
2ClBP	ND	0.25	0.37	ND	ND	0.38
2ClBP	ND	0.73	0.74	ND	ND	ND
3ClBP	ND	1.57	0.46	ND	0.76	1.25
3ClBP	ND	0.71	0.81	ND	ND	ND
3ClBP	ND	0.44	2.60	ND	ND	ND
3ClBP	ND	ND	0.75	ND	ND	ND
4ClBP	0.26	0.55	0.70	ND	ND	ND
4ClBP	ND	0.93	0.61	ND	ND	ND
4ClBP	ND	0.35	ND	ND	ND	ND
5ClBP	0.51	0.23	ND	ND	ND	ND
5ClBP	0.26	ND	ND	ND	ND	ND
6ClBP	0.69	0.25	0.54	ND	ND	ND
6ClBP	0.81	0.16	ND	ND	ND	ND
6ClBP	0.59	ND	ND	ND	ND	ND
7ClBP	0.51	0.41	ND	0.68	ND	ND
Arochlor 1260 in soil, ppm initial	3631	3631	3631	3631	3631	3631
Arochlor 1260 in condensate, ppm	NA[c]	8	10	28	10	7
Arochlor 1260 in condensate and wash, ppm	385	NA	NA	NA	NA	NA
Temperature, C	300	320	340	300	340	320
Time, minutes	30	60	90	90	30	60
Base catalyst, g	1.2	1.2	1.2	1.2	1.2	1.2
Solvents, mL	0.25	0.25	0.25	0.25	0.25	0.25

[a] All PCB concentrations expressed on a dry basis; all tests performed with 25 g Guam soil samples, minus 1/4-inch size and containing 16% moisture.

[b] Not detected (ND).

[c] Not determined (NA).

[d] Data for multiple congeners (or isomers) are shown for each homolog.

C = Degrees Celsius
g = grams
mL = Milliliters
PCB = Polychlorinated biphenyl
ppm = parts per million

TABLE 2-3. BCDP EXPERIMENTS AT U.S. EPA (FEBRUARY 1990)[a]

PCB Congener	Residual Concentration in Soil (ppm)										
	Test 7[b]	Test 8	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17[c]
2ClBP	NA[d]	ND[e]	ND	NA	NA	ND	NA	ND	NA	ND	0.1
3ClBP	NA	1.0	0.3	NA	NA	ND	NA	ND	NA	ND	ND
4ClBP	NA	0.5	0.1	NA	NA	0.2	NA	0.3	NA	0.4	0.1
4ClBP	NA	1.2	ND	NA	NA	0.5	NA	0.8	NA	0.5	ND
4ClBP	NA	0.5	ND	NA	NA	0.4	NA	0.5	NA	ND	ND
5ClBP	NA	ND	ND	NA	NA	0.3	NA	0.7	NA	0.7	ND
5ClBP	NA	ND	ND	NA	NA	0.3	NA	0.7	NA	0.7	ND
5ClBP	NA	ND	ND	NA	NA	ND	NA	2.0	NA	1.2	ND
5ClBP	NA	ND	ND	NA	NA	ND	NA	0.9	NA	0.4	ND
6ClBP	NA	0.7	ND	NA	NA	0.2	NA	0.5	NA	0.7	ND
6ClBP	NA	ND	ND	NA	NA	0.6	NA	0.5	NA	0.5	ND
6ClBP	NA	ND	ND	NA	NA	0.8	NA	2.6	NA	2.6	ND
6ClBP	NA	ND	ND	NA	NA	ND	NA	0.6	NA	2.5	ND
6ClBP	NA	ND	ND	NA	NA	ND	NA	2.3	NA	0.8	ND
6ClBP	NA	ND	ND	NA	NA	ND	NA	0.7	NA	ND	ND
Arochlor 1260 in soil, ppm											
Initial	2779	2779	2779	2779	2779	2779	2779	2779	2779	2779	2779
Final	2300	NA	NA	192	325	NA	123	NA	21.2	NA	NA
Arochlor 1260 in condensate, ppm	NA	NA	9.5	NA	7.6	NA	NA	NA	NA	19.0	35.0
Arochlor 1260 in condensate and wash, ppm	55	638	648	513	418	525	404	752	585	645	552
Temperature, C	110	300	300	200	200	300	200	300	200	250	300
Time, minutes	25	60	60	60	60	60	60	60	60	60	60
Base catalyst, g	1.22	1.22	1.22	0.61	1.22	0.61	1.22	0.61	0.61	1.22	1.22
Solvents, mL	0.25	0.15	0.25	0.15	0.25	0.25	0.15	0.15	0.25	0.25	0.25

(Footnotes presented on following page.)

TABLE 2-3. (Contined)

[a] All PCB concentrations expressed on a dry soil basis; all tests performed with 25 g samples of Guam soil, minus 1/4-inch size and containing 18% moisture.

[b] Sample heated to 100 C and held for 25 minutes to distill off moisture from the sample.

[c] Fast heat-up of the sample; i.e., 12 minutes versus 31 to 52 minutes heat-up for other tests.

[d] Not determined (ND).

[e] Not detected (NA).

C = Degrees Celsius
g = Grams
mL = Milliliters
ppm = Parts per million
PCB = Polychlorinated biphenyls

(molecules with different numbers of chlorine atoms). For example, Arochlor 1260 contains 12% by weight pentachlorobiphenyl (5 ClBP), 42% by weight hexachlorobiphenyl (6 ClBP), 38% by weight heptachlorobiphenyl (7 ClBP), and 8% by weight of higher homologs (8 ClBP and 9 ClBP) (Erickson, 1986). Therefore, using the Test 1 data in Table 2-2, starting with an initial concentration of 3,631 mg/kg of Arochlor 1260 in the feed soil, 385 mg/kg was measured in the condensate and wash (this would be subsequently treated in the batch STR step of the BCDP) and approximately 3.4 mg/kg (the sum of residual concentrations of the 5 ClBP homologs and higher) in the treated soil. Consequently, the destruction and removal efficiency (DRE) for this test, expressed as destruction of Arochlor 1260, is calculated as 99.91% assuming total destruction of all PCBs remaining in the condensate through the subsequent batch STR.

3.0 TREATABILITY TEST PLAN

The treatability test plan is summarized in Figure 3-1. Treatability tests will be performed on polychlorinated biphenyl (PCB)-contaminated soil from SA-12 that are likely to contain dioxin and furan compounds. Three PCB-concentration ranges will be tested as follows:

• 100 to 1,000 mg/kg	Representative of surface and deep soils that may require remediation, and include soils that are a principal threat for residential and industrial land use.
• >1,000 mg/kg	These soils are a principal threat for industrial land use and represent the highest PCB concentration detected at SA-12.

3.1 Sampling and Analysis Plan

Soils will be collected from areas within SA-12 where results of field laboratory analyses performed during the Operable Unit (OU) B Remedial Investigation (RI) Phase 1 are available. Soil PCB concentration contour maps prepared from OU B RI data will be used to identify areas containing the desired contaminant-concentration ranges. Soil from several areas within each range will be collected and composited to achieve the desired concentration ranges. Soil will be collected from appropriate areas within the upper foot of SA-12 by hand excavation. Sufficient soil will be collected to perform all treatability tests and pretreatment analyses required. The soil will be placed on clean plastic sheeting, rocks and other debris removed, and mixed to form a semi-homogenous material. These soil samples will be screened at an off-site laboratory providing rapid turnaround results (i.e., less than 48 hours). While target concentrations within the test ranges are shown above, any concentration within the target range, based on laboratory screening, will be considered acceptable for soil collection and bench-scale testing. If acceptable, the soil will be collected in appropriate shipping containers, packaged, and shipped for testing and analyses. If the soil is not within the desired concentration range, it will be redeposited in the excavation, new locations selected, and the soil collection procedure repeated.

One soil sample from each concentration range will be shipped to an Air Force-approved and California-certified laboratory for analysis; these sample results will

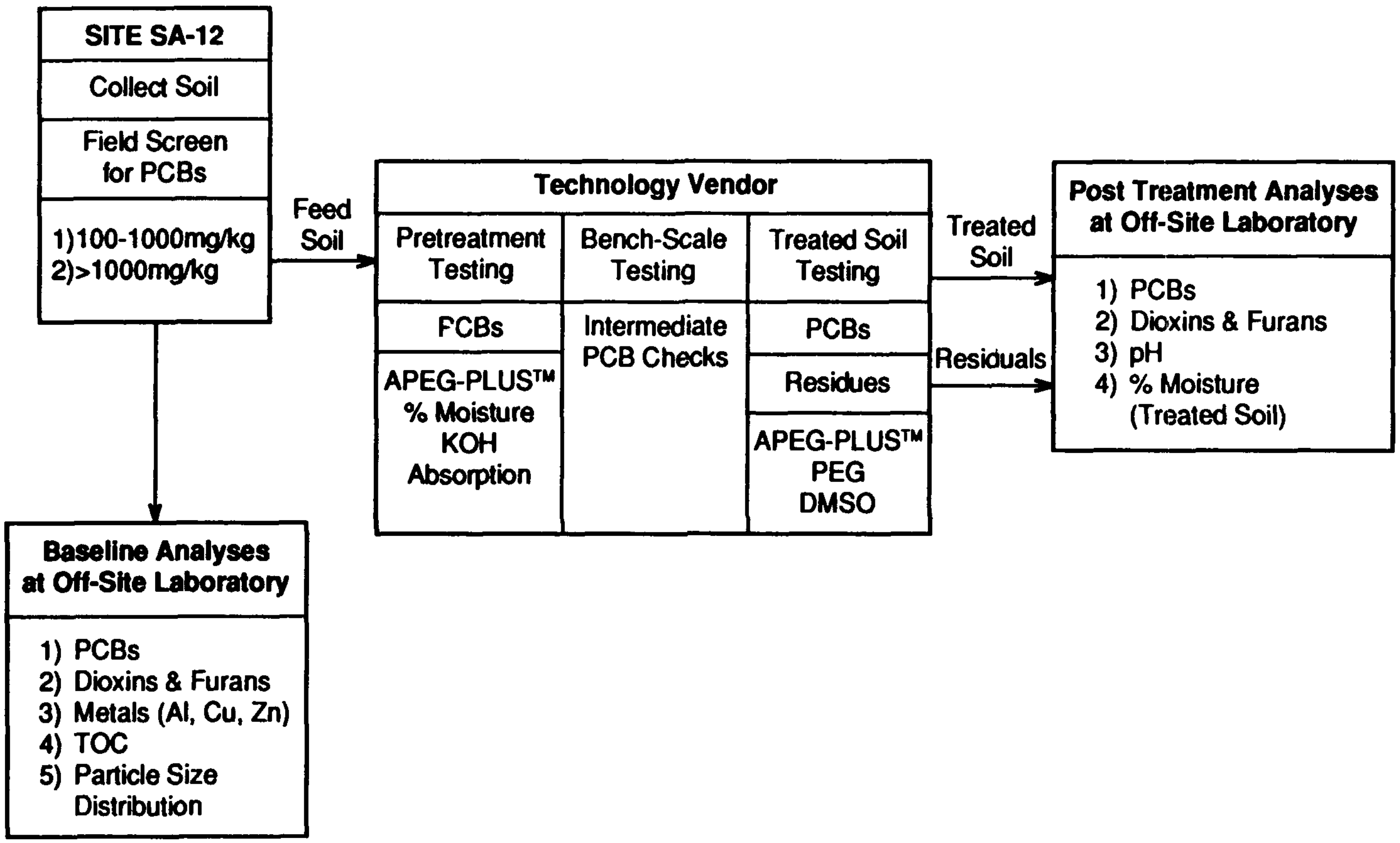

Figure 3-1. Treatability Test Plan

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serve as the baseline concentrations for determining treatment effectiveness. Analyses will be performed for PCBs, dioxins, furans, total organic carbon, selected metals, and particle size distribution. All analytical methods, sample preservation and storage methods, and transportation and custody requirements are described in Section 5.0.

Bench-scale testing (i.e., treatment) will be performed following vendors standard procedures as described in Section 5.0. Prior to treatment, each soil sample will be tested by the vendor for PCB concentrations; results will be used as control checks for comparison to the baseline analyses. The soil will also be tested for additional parameters specific to each technology to determine reagent requirements. For the APEG-PLUS™ process, these parameters will include percent moisture and potassium hydroxide (KOH) absorption capacity. For the BCD process, the additional parameters to be analyzed will be determined after the experimental procedures are available from EPA. The soil samples will then undergo treatment as described in Section 3.2.

Following treatment, the soil and residuals will be retested by the vendor for PCBs and reagents. Soil and residuals, as appropriate, will be collected for reanalysis to determine mass balance of the above parameters and to determine treatment effectiveness. Because the quantity of treated soil and residues will be small (typically less than 100 grams), the analyses will be prioritized as follows. The treated soil and residuals will be tested at an Air Force-approved and California-certified laboratory for PCBs, dioxins, and furans first. Post-treatment testing of APEG-PLUS™ treated soil for PCBs will be performed by GRC because the glycol residual in the soil will interfere with the standard PCB analysis method. Any remaining treated soil will be used to analyze for percent moisture and any remaining residuals will be used to analyze for pH.

3.2 Experimental Procedures

3.2.1 Bench-Scale Glycolate Dechlorination (APEG-PLUS™) Process

Bench-scale testing of the APEG-PLUS™ will be performed following GRC Environmental, Inc.'s (GRC) standard procedures as described below (GRC, 1991b).

Set Parameters

Before any reactions are done, results from soil samples analyzed for the contaminant(s) of interest (PCBs), percent moisture, and KOH absorption capacity will be used to decide on reagent formulation and loading for the initial reaction, and determine a schedule for the required reaction time. Analytical methods for the above parameters are described in Section 5.0.

Treatability Test Procedures

The following is a description of the bench-scale treatability process:

- A 500-gram soil sample is weighed into the preweighed reactor.
- The 1000-milliliter (mL) reactor is set up in a fume hood.
- The thermocouple, condenser system, and condensate receiver are attached and a heating mantle is placed under the reactor.
- Reagents are weighed out and added to the reactor through the neck holding the thermocouple.
- The stirring motor is activated and soil and reagents are mixed into a slurry.
- The heating mantle is turned on and the reaction timer is started. Temperature of the slurry is maintained at about 300°F.
- During heating a slight vacuum is applied at the exit from the vent trap.
- Two to 3 mL aliquots of the slurry are taken hourly from the reactor during the course of the test for analysis of PCB-contaminant levels.
- The reaction is stopped when a specified "clean level" (i.e., 2 mg/kg PCB) is reached or when contaminant levels remain unchanged within the precision of the analytical method for three consecutive hours.

- After the contaminant concentration has reached the "clean level," the reactor is cooled to about 212°F and water is added to liquefy the KOH and restore the original water content in the reactor.
- The reactor is then cooled to room temperature.
- The soil slurry is transferred from the reactor to centrifuge bottles and centrifuged at 1500 revolutions per minute (RPM) for one to five minutes.
- The supernatant reagent is decanted or pipetted off the soil into a preweighed jar.
- The soil is returned to the reactor and wash water is weighed into the reactor.
- The reactor contents are heated to 195°F and held at that temperature for 20 minutes with constant agitation of the slurry.
- The reactor is cooled and contents are emptied into the same centrifuge bottles as before.
- The washing procedure is repeated for the desired number of washes, usually three to five.
- When all the liquids are in their preweighed jars, the jars and the distillate receiver are reweighed and mass recoveries are calculated.
- The reagent, washes, and distillate are analyzed for the reagent components: polyethylene glycol (PEG), and dimethyl sulfoxide (DMSO).
- Mass balances for each reagent component are then calculated.
- The reagent mass balance data are used to generate an estimate of reagent consumption and cost for full-scale treatment.

- Contaminant data from the reactor monitoring samples are used to generate a concentration versus time graph for the soil. This graph can be used to estimate the difference in reaction time for various "clean levels" that may be requested.

- The reagent, washes, distillate, and traps are also analyzed for the contaminant to verify that the PCBs were destroyed and not just removed from the reactors. The materials are also analyzed for extractable organic chlorine to demonstrate completeness of dechlorination.

3.2.2 Base-Catalyzed Decomposition Process (BCDP)

At the time of preparation of this work plan, detailed information on the experimental procedures employed by the United States Environmental Protection Agency (U.S. EPA) Risk Reduction Engineering Laboratory (RREL) was not available. A summary of the process is provided in Section 2.2.2. Further details for this section of the work plan will be added when available.

4.0 SPECIALIZED EQUIPMENT AND MATERIALS

No specialized equipment or materials have been identified by GRC Environmental, Inc. (GRC) or the United States Environmental Protection Agency (U.S. EPA) (i.e., vendors) for bench-scale testing. Equipment and materials to be used during the testing is assembled from standard laboratory equipment or is compatible with standard laboratory equipment. No specialized equipment will be constructed to perform the treatability tests.

4.1 APEG-PLUS™ Process

GRC has identified the following equipment and material needs for performance of the APEG-PLUS™ treatability test:

Hardware

- Laboratory soil reactor (GRC);
- Gas chromatograph HP5890A with electron capture detector or equivalent;
- High-pressure liquid chromatograph (HPLC) HP1050 with 1047A R.I. detector or equivalent;
- CSC scientific moisture balance; and
- Centrifuge (capable of 1500 revolutions per minute).

Reagents and Chemicals

- Potassium hydroxide (KOH);
- Polyethylene glycol (PEG);
- Florisil;
- 0.1 N hydrochloric acid (HCL) solution;
- Dimethyl sulfoxide (DMSO);
- Hexane;

- Methanol;
- Decachlorobiphenyl;
- Copper dust; and
- Sulfuric acid (H_2SO_4).

4.2 Base-Catalyzed Dechlorination (BCDP) Process

A standard listing of equipment and materials used in the BCDP treatability testing was not available from the U.S. EPA. The following listing of reagents were compiled from the available literature:

Reagents

- Sodium bicarbonate;
- Sodium hydroxide;
- Catalyst;
- Hydrocarbon oil; and
- Nitrogen gas.

Further information on hardware and materials requirements will be obtained from the testing laboratory during treatability testing observation.

5.0 ANALYTICAL METHODS

The Soil Treatability Study will use the sample handling procedures, calibration procedures, and analytical methodology described in the McClellan Air Force Base (AFB) Quality Assurance Project Plan (QAPP) (Radian, 1992b). The QAPP procedures will be followed for the baseline and posttreatment analyses submitted to Air Force-approved and California-certified laboratories. Section 8.0 of the QAPP contains specific information on:

- Method detection limits;
- Laboratory standards and reagents;
- Extraction methods; and
- Analytical methods.

Additions and modifications to the methods outlined in the QAPP are discussed below. The vendors may use proprietary or nonstandardized methods (i.e., non United States Environmental Protection Agency [U.S. EPA] or American Society for Testing and Materials [ASTM] methods) for some of the analyses to monitor and control the treatment processes.

5.1 Sample Preservation and Storage

Soil samples collected during the Soil Treatability Study will be placed in containers, stored, and handled according to methods published in U.S. EPA SW-846, ASTM Annual Book of ASTM Standards, or Standard Methods for the Examination of Water and Wastewater (U.S. EPA, 1986). Each analytical method has different sample storage and preservation requirements, as listed in Table 5-1. Sample bottles are precleaned and certified "clean" by the manufacturers according to U.S. EPA protocols.

5.2 Sample Custody

Sample possession during all sampling efforts must be traceable from the time of collection to the time results are verified and reported. The sample custody procedures provide a mechanism for documenting sample collection and handling information.

TABLE 5-1. SAMPLE STORAGE AND PRESERVATION REQUIREMENTS FOR SOIL MATRIX

Reference Parameter	Method(s)	Holding Time	Container(s)[a]	Preservation	Storage Requirements
ORGANICS					
Organochlorine Pesticides and PCBs	EPA SW 8080	14 days until extraction(s), 40 days after extraction	250 mL widemouth glass jar with Teflon®-lined cap	None	4°C
Dioxins and dibenzofurans	EPA SW 8280	30 days maximum	250 mL glass jar with Teflon® liners	None	4°C
INORGANICS					
ICP Metals (Al, Cu, Zn)	EPA SW 6010	6 months	250 mL glass jar	None	4°C
Soil pH	EPA SW 9045	Analyze as soon as possible	250 mL glass jar	None	4°C
Total Organic Carbon	EPA SW 9060	28 days	250 mL glass jar	None	4°C
PHYSICAL PROPERTIES					
Moisture Content	ASTM D2216-80	Analyze as soon as possible	Stainless steel sleeve, or aliquot from glass jar	None	3°C to 30°C
Particle Size Distribution	ASTM D422-63	Analyze as soon as possible	Stainless steel sleeve	None	None

[a] All containers are pretreated and cleaned before being purchased by the laboratory.

ASTM = American Society for Testing and Materials.
C = Degrees Celsius.
EPA = U.S. Environmental Protection Agency.
mL = Milliliter.
SW = Test method from SW-846, Third Edition.
ICP = Inductively Coupled Plasma Atomic Emission Spectroscopy.
PCBs = Polychlorinated biphenyl.
Al = Aluminum.
Cu = Copper.
Zn = Zinc.

Sample custody procedures for the Soil Treatability Study will follow those described in Section 6.0 of the McClellan AFB QAPP, including field records, sample master logbook, and chain-of-custody procedures. Examples may be found in the QAPP.

5.3 Sample Shipping

All samples shipped to off-site laboratories will be preserved and packaged as described in the McClellan AFB QAPP and Operable Unit (OU) B Remedial Investigation (RI) Sampling and Analysis Plan (SAP) (Radian, 1991c). Samples will be shipped to off-site laboratories by either hand delivery or overnight carrier.

Soil samples from each concentration range will be shipped to treatment vendors for bench-scale testing. As required by the Toxic Substances Control Act (TSCA) PCB Notification and Manifesting Rule, the soil samples for the treatability tests will be shipped to the selected testing facilities by a licensed hazardous waste transporter. This transporter will be required to sign and data a manifest for each shipment of the PCB-contaminated soil samples. The soil samples for the BCD process will be packaged in 500-milliliter (ml) wide-mouth sample jars with Teflon®-lined lids. The soil samples for the APEG-PLUS™ process will be packaged in 5 to 10-gallon plastic pails with plastic tops. Soil samples for treatability testing will be shipped at ambient temperature.

5.4 Standard Analytical Methods and Calibration

Analytical methods that will be used in the Soil Treatability Study are listed in Table 5-1. Method descriptions, calibration procedures, and detection limits outlined in the McClellan AFB QAPP are not discussed here. These methods include:

Organic Analyses

- Pesticides and PCBs (U.S. EPA Method SW 8080);
- Dioxins and dibenzofurans (U.S. EPA Method SW 8280).

Inorganic Analyses

- Metals (U.S. EPA Method SW 6010);

- Soil pH (U.S. EPA Method SW 9045);
- Total organic carbon (U.S. EPA Method SW 9060).

Physical Properties

- Laboratory determination of water (moisture) content of soil, rock, and soil-aggregate mixtures (ASTM D2216-80).
- Particle size distribution (ASTM D422-63).

5.5 Field and Laboratory Quality Control

Quality control (QC) procedures that will be followed for the Soil Treatability Study are outlined in Section 10.1 and 10.2 of the McClellan AFB QAPP. Field and laboratory QC samples are required at the following frequencies:

- Reagent blanks at the frequency of one per day for each method or instrument and/or one per extraction batch;
- Laboratory control samples at the required frequency for each method;
- Matrix/spike matrix spike duplicates at a frequency of 5% of samples analyzed for each method where spikes are performed (for treated soil and residuals, performance of MS/MSD will be dependent on the quantity of material available);
- Laboratory duplicates at a frequency of 10% of samples analyzed for each method where matrix spikes are not required; and
- Surrogate spike recoveries for each sample, blank, matrix, duplicate, and standard where surrogates are required in the analytical method.

5.6 Vendor Analytical Methods

Additional analyses to those listed above will be used by the technology vendors to determine reagent needs, measure reagent residual concentrations in the treated soil and residues, and determine mass balance for reagents. Standard methods (i.e., U.S. EPA methods) for these analyses have not been specified by the vendors. As previously stated, standard methods will be used to measure contaminant concentrations in untreated and treated soil and in residues in order to determine treatment effectiveness. Nonstandardized or propriety methods may be used to perform the following analyses:

APEG-PLUS™ Process

- PCBs;
- Potassium hydroxide (KOH) absorption capacity;
- Percent moisture;
- KOH concentration;
- Polyethylene glycol (PEG) concentration; and
- Dimethyl sulfoxide (DMSO) concentration.

BCDP Process

- PCBs;
- Sodium bicarbonate ($NaHCO_3$) concentration; and
- Sodium hydroxide (NaOH) concentration.

If needed for use in selecting the most effective treatment method, analytical measurements performed by the vendors will be evaluated according to the project quality assurance (QA) objectives to assess the quality and comparability of the data. The vendors have been requested to provide additional information on their analytical methodologies.

6.0 DATA COLLECTION, MANAGEMENT, AND ANALYSIS

6.1 Data Collection

To meet the objectives of the bench-scale testing (see Section 1.1), the following data will be collected:

- Concentrations of soil contaminants at the time of collection (i.e., prior to bench-scale treatment). Sufficient soil will be collected and composited to allow for performance evaluation of the soil treatability tests and to allow analysis of the untreated soil for multiple contaminant classes. The soil to be used for the treatability studies will be tested for:

    - Polychlorinated biphenyls (PCBs);
    - Dioxins and furans;
    - Metals (Al, Cu, Zn);
    - Total organic carbon; and
    - Particle size distribution.

    These tests will be performed in an off-site laboratory location following standard methodologies given in the McClellan Air Force Base (AFB) Quality Assurance Project Plan (QAPP) (Radian, 1992b) and summarized in Section 5.0.

- Concentration of PCBs in soil, prior to, following, and at intermediate steps within the treatment process. The PCB concentrations will be measured at the treatment facility; the vendors may elect to use analytical methodologies that do not fully comply with the Quality Assurance/Quality Control (QA/QC) requirements of the McClellan AFB QAPP (Radian, 1992b) because of the need for quick analyses to monitor treatment and because baseline and posttreatment analyses for overall treatment performance evaluation will be performed following the QAPP. Polychlorinated biphenyls may also be measured in treatment residuals, as appropriate.

- Concentrations and quantities of process chemicals (reactants) and quantity of soil used in the treatment test will be measured. Additional test parameters, including mixing time, reactor temperature, quantity of rinse water used, quantity of pH adjustment chemicals required, and potassium hydroxide absorption capacity (APEG-PLUS™ only) will be measured. Where applicable, treatment residues will be analyzed by the vendor to determine mass balance of treatment chemicals.

- Samples of the treated soil and all residual fractions will be collected for off-site analysis using the standard methodologies given in the Operable Unit (OU) B Remedial Investigation (RI) QAPP. The analyses will be prioritized for PCBs, dioxins and furans. Analyses for pH and percent moisture will be performed if the quantities of residuals produced during the treatment process are sufficient. For the APEG-PLUS™ process, GRC will perform the PCB analyses on treat soil and residuals because the standard method used by off-site laboratories is subject to interference by residual polyethylene glycol in the soil.

Data evaluation for the bench-scale treatability testing will place an emphasis on reduction of PCB concentrations in treated soil. The primary evaluation will be on comparison of the final PCB concentration to potential remediation goals: 10 milligrams per kilogram (mg/kg) PCB tentative post-remediation goal for surface soils, and 2 mg/kg PCBs for incineration equivalency based on the Toxic Substances Control Act (TSCA) definition (TSCA, 1986). Percent reductions in PCB concentration will be measured as a secondary means of establishing cleanup goals through technology performance-based standards. The concentrations of PCBs in residual materials, such as rinse waters, will be used along with the soil data to perform a mass balance of the treatment [illegible] determine the percent destruction of PCBs.

A secondary evaluation of the treatability results will be performed to determine percent reduction of dioxin and furan concentrations. The final concentrations of dioxin and furan contaminants will also be compared to potential action levels complied in the Soil Remedial Technologies Screening Technical Memorandum (Radian, 1992a). The residuals data will be used to determine the percent destruction, if any, of these contaminants.

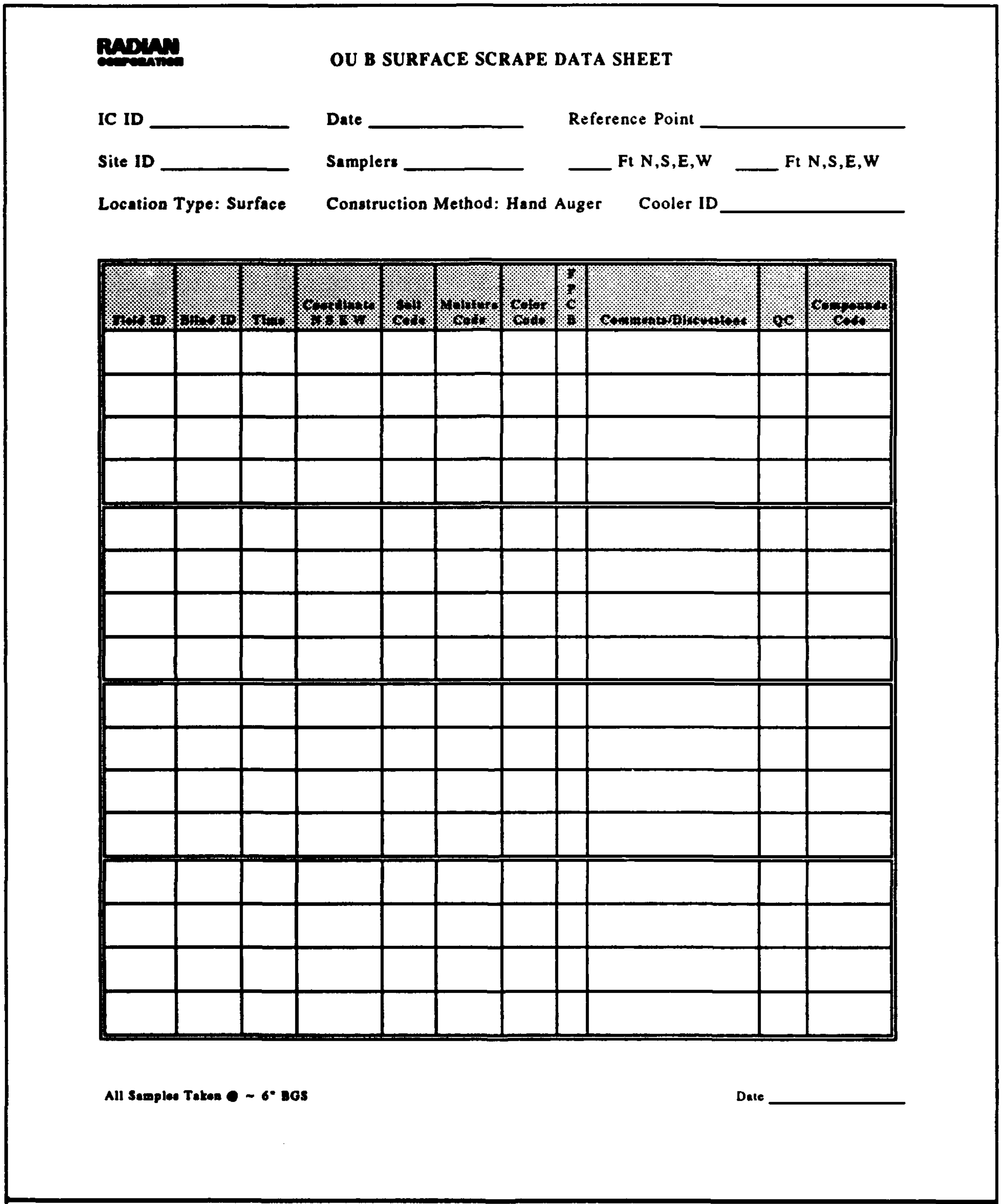
The relative effectiveness of the two treatment methods will be evaluated by comparing final contaminant concentrations and percent reductions in the soil. The latter comparison may have significant importance if vendor schedules do not allow for simultaneous collection of soil for both treatability tests, and if the baseline contaminant concentrations vary significantly between vendors.

Finally, operating costs will be estimated, including quantities of chemicals to be added during treatment, subsequent treatment requirements for residuals, and utilities consumption, for comparison between treatments with estimated costs for other technologies (i.e., incineration, solvent extraction, etc.). Design and construction and potential permitting costs of the more effective treatment technology will be estimated after the bench-scale tests.

6.2 Data Management

The data management subtask includes the following activities:

- Data loading from the field data sheets into the McClellan database, including field observations and sample location data;
- Electronic transfer of analytical data into the McClellan database;
- Development of "friendly" interface for unqualified data (normal samples only);
- Production of data tables (both unqualified and qualified) for Treatability Study Report and QA/QC purposes; and
- Development, installation, and support of the Electronic Master Log. All field data and observations made during soil collection will be entered onto the OU B Soil Sample Data Sheet (see Figure 6-1) and into a single field notebook for use throughout the treatability test. The same notebook will be used to record all observations by Radian personnel during laboratory bench-scale tests. Any pictures taken to record field sample collection and bench-scale testing will be recorded in the field notebook.



RADIAN CORPORATION

OU B SURFACE SCRAPE DATA SHEET

IC ID ____________ Date ______________ Reference Point __________________

Site ID ____________ Samplers ______________ ____ Ft N,S,E,W ____ Ft N,S,E,W

Location Type: Surface Construction Method: Hand Auger Cooler ID ________________

Field ID	Blind ID	Time	Coordinate N S E W	Soil Code	Moisture Code	Color Code	F P C B	Comments/Discussions	QC	Compounds Code

All Samples Taken @ ~ 6" BGS

Date ______________

Figure 6-1. Soil Sample Data Sheet

Analytical data for baseline (i.e., pretreatment) and posttreatment samples will be entered electronically into the McClellan AFB database. These data will result from analyses at preapproved laboratories, following the QA/QC requirements as outlined in the McClellan AFB QAPP (Radian, 1992b). Laboratories performing OU B RI sample analyses will be used to analyze baseline and posttreatment samples.

The vendor reports on the bench-scale testing will be included as appendices within the Treatability Test Report. Data from vendor analyses will be reviewed for compliance with OU B RI QA/QC requirements, and if appropriate, will be manually entered into the McClellan AFB database. However, it is anticipated that while vendor data will be used to evaluate the treatability test, it may not meet the QA/QC requirements for inclusion in the McClellan AFB database.

6.3 Data Analysis and Interpretation

The primary means of data interpretation will be: data review and validation against QA/QC requirements (laboratory data); comparison of treated soil PCB concentrations to potential cleanup levels; determination of percent reduction of PCBs and other contaminants in the soil; and determination of the percent destruction of PCBs and other contaminants by calculation of a mass balance for the soil and residue.

6.3.1 Comparison with Cleanup Levels

The posttreatment PCB soil concentration will be compared to two potential cleanup goals: 10 mg/kg, which is the tentative postremediation goal for SA-12; and 2 mg/kg, which is the incineration equivalency as defined by TSCA. The soil concentrations of dioxins and furans will be compared to potential action levels identified in the Soil Treatability Study Technical Memorandum. In addition, wash waters and condensate residuals will be compared to the potential action levels given in the Technical Memorandum to help determine the need for further treatment.

6.3.2 Determination of Percent Reduction

The percent reduction of PCBs and other contaminants will be determined as a means of evaluating treatment effectiveness and as a means of determining performance-based remediation goals. Percent reduction for individual contaminants will be determined as follows:

$$\%R_i = \left[1-\left(\frac{C_{f,i}}{C_{o,i}}\right)\right] \text{ x } 100$$

where:

$\%R_i$ = Percent reduction of contaminant i in soil;
$C_{o,i}$ = Concentration of contaminant i in untreated soil sample (mg/kg);
$C_{f,i}$ = Concentration of contaminant i in treated soil sample (mg/kg).

6.3.3 Determination of Percent Destruction

The percent destruction of PCBs and other contaminants also will be determined as a means of evaluating treatment effectiveness and performance based remediation goals. The percent destruction will be determined by comparing the quantity of contaminant in the treated soil and all residuals versus the quantity present in the untreated soil.

For the APEG-PLUS™ process:

$$\%D_i = 100 \text{ x } \left\{ 1- \left[\frac{(C_{f,i} \text{ x } W_{s,f}) + (C_{R,i} \text{ x } V_R) + (C_{RW,i} \text{ x } V_{RW}) + (C_{D,i} \text{ x } V_D) + (C_{VT,i} \text{ x } V_{VT})}{C_{o,i} \text{ x } W_{S,o}} \right] \right\}$$

where:

$\%D_i$ = Percent destruction of contaminant i;
$C_{f,i}$ = Concentration of contaminant i in the treated soil sample (mg/kg);

$W_{s,f}$ = Weight of treated soil (kg);
$C_{R,i}$ = Concentration of contaminant i in the reagent supernatant following soil treatment (milligrams per liter [mg/ℓ]);
V_R = Volume of reagent supernatant following soil treatment (ℓ);
$C_{RW,i}$ = Concentration of contaminant i in the rinse water (mg/ℓ);
V_{RW} = Volume of rinse water (ℓ);
$C_{D,i}$ = Concentration of contaminant i in the distillate (mg/ℓ);
V_D = Volume of distillate (ℓ);
$C_{VT,i}$ = Concentration of contaminant i in the vent trap (mg/ℓ);
V_{VT} = Volume of liquid in vent trap (ℓ);
$C_{o,i}$ = Concentration of contaminant i in the untreated soil sample (mg/kg); and
$W_{s,o}$ = Weight of untreated soil (kg).

For the Base-Catalyzed Decomposition Process (BCDP), a similar percent destruction evaluation will be performed. At this time, a full understanding of all types of residuals produced by the BCDP is not available.

7.0 RESIDUAL MANAGEMENT

Residuals from the bench-scale testing will consist of: untreated soil, treated soil, overhead condensates, rinse waters, recovered process liquids including process reagents, and unused portions of laboratory samples. It will be the responsibility of vendors and off-site laboratories to dispose of all unused residuals following standard industry practices. All materials will be disposed of at a United States Environmental Protection Agency (U.S. EPA) and/or state licensed disposal facility, as appropriate. The vendor or laboratory will be listed as the waste generator. The only exception will be for significant quantities of untreated soil, if any. Untreated soil may be returned to McClellan Air Force Base (AFB) for containment with other soil cuttings resulting from Operable Unit (OU) B Remedial Investigation (RI) investigative activities. Under no circumstances will material which did not originate at McClellan AFB, including soils that have been mixed with process reagents, be returned to the base, without prior approval from McClellan AFB personnel.

8.0 HEALTH AND SAFETY

Modifications to existing health and safety plans will not be required. Field soil collection will be performed following the health and safety procedures given in Operable Unit (OU) B Remedial Investigation (RI) Health and Safety Plan (Radian, 1991a). Operable Unit B RI field personnel familiar with SA-12 will select appropriate sample locations, collect and composite soil, ship samples to the screening laboratory, package and ship soil to selected testing facilities, and redeposit unused soil portions within SA-12 at locations where the soil was collected. If redepositing of unused soil portions is not possible, the soil will be contained with similar soil cuttings resulting from OU B RI field activities.

All treatability testing will be performed off site at vendor facilities. All treatability testing will be performed by vendor personnel, although Radian personnel will observe the testing. The standard health and safety practices for each vendor facility will be observed during treatability testing, as well as any specialized procedures, if any, required by the vendors for this testing.

9.0 REFERENCES

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APPENDIX A

Response to Comments on the Soil Treatability Testing Work Plan for PCB-Contaminated Soil

RESPONSE TO COMMENTS ON THE SOIL TREATABILITY TESTING WORK PLAN FOR PCB-CONTAMINATED SOIL

REVIEWER:

Martin W. Keck
Chief, Environmental Law
McClellan Air Force Base
Department of the Air Force

COMMENT 1

"Executive Summary, p. S-2: I question the absence of any reference to in-situ treatment under the alternatives discussion. While there may not, in fact, be any in-situ technologies available, that fact could be included to explain the absence of such an alternative."

RESPONSE 1

The in-situ treatment options were not included in the alternatives discussion because the only commercially demonstrated in-situ treatment currently available is chemical stabilization. This treatment process does not provide destruction of PCBs and thus is not the preferred treatment method by EPA. In fact, as recently as 1991, EPA rejected stabilization as a PCB-remediation technology for the Westinghouse Superfund Site in Sunnyvale. For this reason, in-situ stabilization is not discussed in the work plan and would only be considered as a back-up alternative if the selected process alternatives are determined to be infeasible.

COMMENT 2

"P. 1-1, paragraph beginning "On 22 July 1987...": CERCLA is amended only by SARA. The other referenced laws, regulations, Executive orders, etc., are authorities but they do not amend CERCLA."

RESPONSE 2

The second line of the above-mentioned paragraph has been revised to clarify the fact that CERCLA is only amended by SARA. The relevant statement now reads, "McClellan AFB integrated the ongoing Installation Restoration Program (IRP), initiated by the Department of the Defense in 1981 with the following: the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA); the National Oil and Hazardous Substances Contingency Plan (NCP); pertinent provisions of the Resource Conservation and Recovery Act (RCRA) statutes; Executive Order 12580; the Defense Environmental Restoration Program (DERP); and applicable or relevant and appropriate state laws and regulations."

COMMENT 3

"P. 1-4, footnote 1: I found the context in which this footnote appeared somewhat confusing. While I recognize the potential confusion surrounding the word "site," the sentence states that "PCB-contaminated soil was identified at... (site SA 12)." If "site" is not intended to imply the presence of confirmed contamination, why is the word "Site" not used in this sentence? I understand the footnote, but the context in which it was explained seems inappropriate."

RESPONSE 3

As noted by the reviewer, the phrase, "(site SA 12)" is confusing. Since the area under discussion is Study Area 12 the phrase, "(site SA 12)" has been replaced in the text with the phrase "(SA 12)." Also, it is not necessary in the context of this report to define the different meanings of "Site" versus "site." For this reason, footnote 1 on the bottom of page 1-4 has been deleted.

RESPONSE TO COMMENTS ON THE SOIL TREATABILITY TESTING WORK PLAN FOR PCB-CONTAMINATED SOIL

REVIEWER:

Katherine Moore
Environmental Engineer
U.S. EPA

COMMENT 1

"Before pilot-scale studies are initiated, the soil at site SA 12 should be tested for the aluminum content and for other alkaline metals present which may interfere with the chemical dehalogenation process. Additionally, pretreatment analysis of the soil should also *include moisture content*, humic content, pH and buffering since these parameters dictate the reaction time, energy input, and the required amounts of reagents which may drive up costs for both the proposed APEG-PLUS™ and BCDP technologies. Also, please indicate specifically what are the "additional parameters" for soil testing pertinent to both technologies as mentioned in Section 3.1 (p. 3-3)."

RESPONSE 1

The soil to be used for the treatability studies will be tested for the following:

- Polychlorinated biphenyls (PCBs);
- Dioxins and Furans;
- Metals (Al, Cu, Zn);
- Total organic carbon;
- Particle size distribution; and
- Moisture content.

This list of pretreatment analyses is the result of the following modifications to the list presented in the draft work plan:

- The particle size distribution analysis has been added since this parameter may dictate the economic feasibility of the dechlorination treatment processes.

- The number of metal analyses to be performed has been reduced to just those metals which may have an impact on the dechlorination process (i.e., Al, Cu, and Zn). Sufficient analytical data already exists to estimate the concentration of the other metals in the soil should that become necessary.

- Volatile and semivolatile organic analyses have been deleted because the level of volatile and semivolatile organic compounds detected to date in the upper foot of soil at SA 12 have been at very low levels.

To incorporate the above changes in the analytical plan, the text on pages S-1, 1-5, 3-3, 5-5, 5-6, and 6-1, as well as Figure 3-1, have been modified appropriately. With the exception of buffering capacity, all of the pretreatment analyses suggested by EPA will be performed. Although not included in the pretreatment analyses, the buffering capacity of the soil will be determined as part of the bench-scale treatability tests.

As indicated in the revised text, the soil will also be tested for additional parameters specific to each technology. For the APEG-PLUS™ process, the potassium hydroxide absorption capacity (i.e., buffering capacity) of the soil will be determined. For the BCD process, the additional parameters to be analyzed will be determined after the experimental procedures are available from EPA. These procedures will be available during the bench-scale testing of the BCD process.

COMMENT 2

"Both technologies will require a complete analysis of the by-products produced in the waste streams. If any waste streams or reagents require additional treatment not previously outlined in the process descriptions (pp. 2-2 to 2-4, and 2-13), then a detailed treatment and disposal plan needs to be provided (p. 2-5)."

RESPONSE 2

As indicated in the original text on p. 2-5, some wash waters and spent reagents may require further treatment and/or disposal actions. However, the need for further treatment is not known. Since this information will be determined during the bench and pilot-scale testing, it is not possible to give a detailed treatment and disposal plan at this time. However, this plan will be included in the final report presenting the treatability study results.

COMMENT 3

"In the APEG-PLUS™ Performance Data Summary presented in Table 2-1 (p. 2-10), it is unclear to which specific sites (labeled A-V) the table is referring. Also, please explain what is meant by "process testing" as mentioned in Section 2.1.6 (p. 2-9)."

RESPONSE 3

The sites labeled A through V in Table 2-1 are arbitrary site designations provided by GRC Environmental, Inc. These site designations simply serve to delineate the different sites at which GRC has implemented the APEG-PLUS™ process. For confidentiality reasons, the specific site names and locations were not provided by GRC. A footnote has been added to Table 2-1 to clarify the reason for the site designations.

The "process testing" mentioned in Section 2.1.6 (p. 2-9) refers to the bench-, pilot-, and full-scale tests that have been conducted at various sites using the APEG-PLUS™ process. To clarify this point and to better describe the data summarized in Table 2-1, the second line in Section 2.1.6 which begins with "Table 2-1 summarizes..." has been replaced with the following text:

> "Table 2-1 summarizes the performance data provided by GRC Environmental, Inc. for the APEG-PLUS™ treatment of PCBs, dioxins, and furans in various media, including soils, sediments, sludges, and oil. This performance data is from bench, pilot and full-scale tests at various sites."

COMMENT 4

"A proposed schedule (timeline) for the various treatability tests for both technologies needs to be provided."

RESPONSE 4

The work plan does not outline a proposed schedule for the various treatability tests. The reason for this omission is that the testing schedule is still being worked out with the treatment process vendors, the licensed hazardous waste transporter, and with Tad Dean of the McClellan AFB Environmental Management staff.

RESPONSE TO COMMENTS ON THE SOIL TREATABILITY TESTING WORK PLAN FOR PCB-CONTAMINATED SOIL

REVIEWER:

Alexander MacDonald
Project Engineer
California Regional Water Quality Control Board — Central Valley Region

The California Regional Water Quality Control Board had no comments on the Soil Treatability Testing Work Plan for PCB-Contaminated Soil.

RESPONSE TO COMMENTS ON THE SOIL TREATABILITY TESTING WORK PLAN FOR PCB-CONTAMINATED SOIL

REVIEWER:

Mark Malinowski
Associated Hazardous Materials Specialist
California Environmental Protection Agency — Department of Toxic Substances Control

The California Environmental Protection Agency had no comments on the Soil Treatability Testing Work Plan for PCB-Contaminated Soil requiring response.