**Decontamination Systems Information and
Research Program**

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**Quarterly Report
April - June 1995**

July 1995

Work Performed Under Contract No.: DE-FC21-92MC29467

U.S. Department of Energy
Office of Environmental Management
Office of Technology Development
Washington, DC

For

U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
West Virginia University
Morgantown, West Virginia

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1000 Independence Avenue
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Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-
0880

By
West Virginia University
P. O. Box 6103
Morgantown, West Virginia 26506

July 1995

EXECUTIVE SUMMARY

The projects reported for the Cooperative Agreement are categorized into the following three areas: 1.0 In Situ Remediation Process Development, 2.0 Advanced Product Applications Testing, and 3.0 Information Systems, Public Policy, Community Outreach, and Economics. Summaries of the significant accomplishments for the projects reported during period 1 April 95 through 30 June 95 are presented in the following discussions.

1.0 IN SITU REMEDIATION PROCESS DEVELOPMENT

Task 1.1: Research on the Drain Enhanced Soil Flushing (DESF) for Organic Contaminants Removal project made reported progress on the following two fronts: 1) development of the Economic Evaluation was prepared, and 2) experimental study soil change-over from a 100% sand to an 80% sand / 20% kaolin soil was initiated. The Economic Evaluation was developed by first surveying existing remediation technologies suitable for comparison with the DESF technology, then secondly developing criteria for rating the comparable technologies for clean-up of a typical one acre site, and thirdly, developing a cost comparison from up-to-date information obtained from literature and industry sources. The experimental portion of the project was slowed due to the change-over with the study soils. The new soil specimens have begun saturation prior to testing. Overall progress is consistent with the work proposed.

Task 1.2: Work this period for the In Situ Bioremediation of Organic Contaminants project continued with anaerobic and aerobic column studies. The anaerobic column was operated and the parameters investigated included: TCE concentration, potential nitrogen limitations, and methanol feed level. Significant findings for this work showed that with increases in the ammonia nitrogen level in the feed, and for increases in the methanol substrate did not improve the TCE removal efficiency. Aerobic column studies showed improved TCE removal with an increase in methane hydraulic retention time.

Task 1.3: Work performed on the Microbial Enrichment for Enhancing In Situ Biodegradation of Hazardous Organic Wastes in Soil this period focused on methods development. Examination of several assay configurations for optimum soil incubations and trapping was performed and has progressed with verification of optimum incubation times and trapping efficiencies.

Task 1.4: Progress on the Contaminant Movement Prediction in Permeable Subsurface Soils project has consisted of continued work on the literature review of numerical models dealing with subsurface flow and with obtaining and installation of one model on a personal computer. This project is set to officially commence next quarter during which work will begin on the final model selection and development consistent, with the experimental equipment used on the Drain Enhanced Soil Flushing for Organic Contaminants Removal project, METC #1.1.

Task 1.5: Progress on Development of a Standard Protocol and Barrier Design Model for In Situ Formed Barriers is separated into Chemical Grouting (1.5a) and Circulating Air Barrier (CAB) (1.5b). Accomplishments made this period include the completion and submittal of the literature review report to DOE/METC.

1.5a Chemical Grouting: The vinyl and urethane chemical grouts are being thoroughly tested for permeability, compressive strength using unconfined and tri-axial testing equipment, as well as experimentation into grout viscosity and immersion effects. The Sand Rain device designed for construction of large-scale testing has been constructed and delivered to a NRCCE lab where it will undergo commissioning prior to being deployed for full experimental use. The computer modeling research has consisted of employing BGROUT software to characterize actual injection experiments with computer simulations.

1.5b Circulating Air Barriers (CAB): Work in this area has included the following tasks: 1) submittal of a draft Operating Plan to METC, 2) submittal of the comprehensive literature review to METC, 3) experimentation into the sand-pack permeability and porosity testing have been performed with reproducible tests performed, and 4) testing into air-water equilibrium influencing porous media flow has begun.

2.0 ADVANCED PRODUCT APPLICATIONS TESTING

Task 2.1: Work this period on the Chemical Destruction of Chlorinated Organic Compounds project were focused on development of a low molecular weight oligomer containing sterically hindered triarylboryl functionalities as an electron carrier for dechlorination. Specifically, a synthetic procedure to a trimer by using a palladium-catalyzed process was successfully established. All research data so far indicate that the synthetic procedure is very efficient and the desired material as a model to guide future synthesis of new polymeric material was obtained.

Task 2.2: Progress on the Continued Development of an Atmospheric Monitoring Mass Spectrometry System project focused on development of water chemical ionization methods for benzene, toluene, ethylbenzene, and xylenes. Standards for instrument calibration were successfully formulated. Experiments to determine conditions under which ethylbenzene and xylenes can be determined by tandem mass spectrometry are ongoing and a new molecular beam sampling interface was designed. Additional funding to support a feasibility study has been acquired from ACF Industries of Earth City, MO. If the feasibility study is successful, the unit will be field tested at the Winfield, WV hazardous waste site and supported by ACF.

Task 2.3: During this reporting period the Capture of Hazardous Waste Materials Utilizing Fluidization Coating Technology project has begun. Reported progress has been made with the design and construction of the fluidized bed coating system.

Task 2.4: The Remediation of Hazardous Sites with Steam Reforming project reports continued work with equipment fabrication and assembly. Current plans are to complete construction during the next quarter and begin shakedown operations prior to beginning the experimental phase.

Task 2.5: The Environmental Pollution Control Devices Based on Novel Forms of Carbon project reported that flow electrolysis using carbon nanofibers was employed for decontaminating heavy metal solutions. Reduction of Cd(II), Pb(II), and Cu(II) ion concentrations in aqueous solutions was carried out under controlled flow and potential conditions. Removal efficiencies of 90% and greater were obtained using carbon nanofibers alone or grown on graphitic supports. The decrease in metal ion concentration was monitored using Anodic Stripping Voltammetry (ASV) downstream from the electrolytic cell. The performance of the carbon nanofibers competes with prevalent metallic and carbonaceous metal removal systems.

3.0 INFORMATION SYSTEMS, PUBLIC POLICY, COMMUNITY OUTREACH, AND ECONOMICS

Task 3.1: The Winfield Lock and Dam Remediation project reported that progress has been made on the off-site disposal of the contaminated soil. This work included the completion of plans and specifications which have been commented on by the citizens group in Eleanor. Construction excavation is expected to begin in late July 95. Work on real-time contaminant air monitoring has progressed and deployment of the MS/MS unit is expected this summer.

Task 3.2: Progress on the GIS-Based Infrastructure for Site Characterization and Remediation project this period included Work has continued on the Devising and specifying and integrated system for the GIS system. Computer software and hardware have been ordered and received. Joint work with the Huntington Corps personnel has on the computer equipment training has begun. Dialog with the Nashville District Corps office, through the Huntington office has commenced for acquiring real Hazardous, toxic & Radioactive Waste (HTRW) data. This information will enable the experiments to focus on actual data for evaluating the GIS system capabilities and limitations.

Task 3.3: Efforts on the Small Business Support Program for this period focused on development of four new tasks. The first task was with Spintek Corporation and another was with the Nilex Corporation. Both of these had to be shelved as money was not available to fund their research projects this period. It appears unlikely that funds will be available this year so these two tasks will become part of the 1996 WVU Cooperative Agreement Program.

The third task developed this period was with the West Virginia High Tech Consortium to support a small business incubator for site remediation technologies. The proposal has been forwarded to METC and will be funded in July as METC Task 3.7. Its period of performance is July 1-December 31, 1995. Dr. Cook will serve on the advisory committee for the incubator. The fourth task developed and funded was METC Task 3.6, Graduate Interns to the Interagency Environmental Technology Office (IETO). The purpose of IETO under the auspices of the National Science and Technology Council (NSTC) is to facilitate a new era of public and private technology collaboration and investment resulting in increased innovative technology use, domestic job creation and global market share growth while ensuring national environmental quality for a sustainable future. Five interns were sent from WVU to Washington, D.C. during this period.

Task 3.4 The Approach for Assessing Potential Voluntary Environmental Protection, Kanawha Valley Area project reports that discussions have taken place with individuals from three industries in the Valley and that interest exists for continuing discussion. A presentation to a group of industrial representatives has been arranged for July. Contact with industry representatives have been difficult to arrange and has caused delays with progressing with the program.

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2.3 CAPTURE OF HAZARDOUS CHEMICAL WASTE MATERIALS UTILIZING
FLUIDIZATION COATING TECHNOLOGY

R. Turton, Dept. of Chemical Eng.

2.4 SOIL DECONTAMINATION BY STEAM REFORMING

R. Lovett, NRCCE

2.5 CARBON PRODUCTS FOR WASTE STREAM CLEANUP

C. Irwin, NRCCE and J. Zondlo, Dept. of Chemical Eng.

3.0 INFORMATION SYSTEMS, PUBLIC POLICY,
COMMUNITY OUTREACH AND ECONOMICS

3.1 WINFIELD LOCK AND DAM ASSISTANCE PROGRAM

R. Lovett, NRCCE

3.2 A GIS BASED INFRASTRUCTURE FOR SITE CHARACTERIZATION
AND REMEDIATION

E. Cook, Dept. of Civil & Environmental Eng., and
J. Hooper, Marshall Univ.

3.3 SMALL BUSINESS SUPPORT PROGRAM

E. Cook, Dept. of Civil & Environmental Eng.

3.4 APPROACH FOR ASSESSING POTENTIAL VOLUNTARY
ENVIRONMENTAL PROTECTION - KANAWHA RIVER AREA

R. Lovett, NRCCE

ADMINISTRATIVE ISSUES

Administrative Summary

Background

West Virginia University (WVU) and the U.S. Department of Energy Morgantown Energy Technology Center (DOE/METC) entered into a Cooperative Agreement on August 29, 1992 titled "Decontamination Systems Information and Research Programs" (DOE Instrument No.:DE-FC21-92MC29467). Requirements stipulated by the Agreement require WVU to submit Technical Progress reports on a quarterly basis. This report contains the efforts of the fourteen research projects comprising the Agreement for the period April 1 to June 30, 1995.

Administrative Issues

The WVU College of Engineering, Department of Civil and Environmental Engineering has continued as the lead agency for administration of the Cooperative Agreement. The final phase-out of the National Research Center for Coal and Energy occurred during this reporting period. All administrative oversight for the Agreement after this reporting period will be coordinated in full through the Department of Civil and Environmental Engineering. The transfer of budgets between the organizations is being addressed and is expected to be resolved during the next reporting period. The transfer of information related to previous projects on the Agreement, current schedule information, and budgets is proceeding.

Project Variances, Accomplishments, and Problems

During this period three new projects have been funded by the Agreement. These projects are: 1) WERC National Design Contest, 2) Graduate Interns to the Interagency Environmental Technology Office under the National Science and Technology Council, and 3) WV High Tech Consortium.

Accounting Issues

All budgets were reviewed and prepared by WVU Department of Civil and Environmental Engineering for this period. As noted on the attached summary, modifications may be made next quarter to support additional projects at METC's discretion. The NRCCE has designated all administrative responsibilities to WVU Department of Civil and Environmental Engineering, therefore, administrative budgets will also be adjusted accordingly.

An accrual accounting system was adopted to accurately reflect expenses incurred since the inception of WUV Department of Civil and Environmental Engineering's management. This will reduce delays in expense reporting. The planned budgets reported herein may vary from

those reported for the period 1 January to 30 March 95 to represent the change in financial reporting. Meetings were held with each Principal Investigator and respective account to ascertain expense reporting and project budgeting. Budget reporting will continue on an accrual basis. This will enable one to better compare real time expenses with scheduled progress. A cash basis has been used in the past which accounts for expenses as they are paid. The time frame required to process expenditures results in a time lag in reported cash outlays. A reconciliation of this variance for the period 1/1 - 6/30/95 is included to demonstrate the difference.

The NRCCE will no longer be involved with budget reporting of WVU research projects. However, previous activity under FUND 7631 was under their direction. Since the cooperative agreement is a multi year grant all moneys are cumulated. The information needed to compile a cumulative summary to included the activity under this fund was obtained from the controllers reports.

All of the funds awarded under WVU Department of Civil and Environmental Engineering direction have been committed to funding research projects. A listing of current budget commitments can be found in this section. Three new projects will begin next quarter and additional funds will be allocated to support the In Situ Formed Barriers project.

Scheduling Issues

Discussion of the following projects is warranted:

Task 1.1 The project is on schedule however due to expenses posted on the extended budget, the main project budges shows a lag. This discrepancy is expected to be corrected during the next reporting period.

Task 1.3 The actual progress lags the planned by approximately 10 percent. For the next reporting period the progress should recover as an new researcher has joined the project.

Task 1.4 This project is scheduled to begin during the third quarter, therefore the apparent budge lag will be corrected accordingly.

Task 2.3 The project shows a lag in overall work completed. This is a result of funding delays which set-back the procurement and construction of the experimental equipment. It is expected that the project will recover. This project will be tracked over the next period for schedule compliance.

Task 2.4 Deviations in the project schedule and budget are expected to be reconciled during the next reporting period.

**RECONCILIATION OF DIFFERENCES IN REPORTING
CASH VS ACCRUAL BASIS
Period Covered: 1/1 - 6/30/95**

			<u>CASH</u>
<u>OUTLAYS</u>			<u>VARIANCE</u>
Cumulative outlays as of 12/31/94 (Previously reported)	3,271,571		
1/1 - 6/30 Cash outlays FUND 7631 - NRCCE	309,434		
1/1 - 6/30 Accrued outlays FUND 8527 - WVU	1,384,515		(660,339) *Note 1
<u>TOTAL OUTLAYS</u>	4,965,520		
<u>UNLIQUIDATED OBLIGATIONS</u>			
FUND 8731	2,725		
FUND 8527	<u>202,628</u>	<u>205,353</u>	571,137 *Note 2
<u>TOTAL SHARE OF OUTLAYS & & UNLIQUIDATED OBLIGATIONS</u>		<u>5,170,873</u>	<u>(89,202)</u>
<u>CUMULATIVE FUNDS AUTHORIZED</u>			
FUND 8731 (Prior to 1995)	4,749,048		
FUND 8527	<u>1,547,000</u>	<u>6,296,048</u>	
<u>AMOUNT of COMMITTED FUNDS REMAINING</u>		<u>\$1,125,175</u>	89,202 *Note 3

General Note:

Prior to the Department of Civil & Environmental Engineering's direction, the Cooperative Agreement was administered by NRCCE. Because the grant is a multiyear grant the cumulative amounts have been carried forward. Activity on FUND 7631 is not detailed here. The amounts shown were obtained from the controllers previous reports.

***Note 1:** Accrued outlays represent those expenses "incurred" during the period covered. Differences in cash outlays reported by the controllers office result due to the time required in obtaining the bill of sale from each college and the time needed to process and disburse the expense.

An accrual accounting system has been adopted to reflect a real time accounting of all disbursements made within the cooperative agreement under WVU's direction. The difference between the cash outlays and the accrual expenses reported herein will represent the expenditures in transit (Difference ~ - \$660,339).

***Note 2:** Unliquidated obligations mainly include those amounts reserved for subcontractors and salaries. Additional obligations may include those recorded as an account payable, not yet disbursed. The unliquidated obligations are usually less when accounted for on an accrual basis because they are shown in part as an accrued expense. (Difference ~ + 571,137)

***Note 3:** Total funds remaining represent the cumulative amount remaining in each research project, as summarized on the attached pages, plus the additional moneys allocated for new work to begin next quarter. All of the funds remaining have been committed to support research efforts.

METC Task	PROJECT TITLE	ACCRUED AMOUNT	CASH AMOUNT	CASH VARIANCE	Obligated ENCUMB Cash Basis	Obligated ENCUMB Accrual Basis	Obligated Encumbrances VARIANCE	COMMENTS
1.1	Use of Drain Enhanced Soil Flushing (DESF) for Organic Contaminants Removal	16,548	13,343	3,205	0	0	0	
1.1e	Extended Budget	7,082	7,082	0	0	0	0	
1.2	In-Situ Bioremediation of Chlorinated Organic Solvents	64,164	51,246	12,918	9,983	0	9,983	
1.2e	Extended Budget	16,006	7,082	8,924	0	0	0	
1.3	Microbial Enrichment for Enhancing In-Situ Biodegradation of Hazardous Organic Wastes	13,442	11,206	2,236	2,695	0	2,695	
1.3e	Extended Budget	4,545	3,784	761	761	0	761	
1.4	Contaminant Movement Prediction in Permeable Subsurface Soils	14,958	14,870	88	86	0	86	
1.5	Development of Standard Test Protocols & Barrier Design Models for In-Situ Formed Barriers							
	NRCCE - Administration & BDM	271,572	6,273	265,299	283,375	18,450	264,925	
1.5e	NRCCE - Extended Budget	13,677	829	12,848	0	0	0	
1.5a	CIVIL ENGR - Chemical Grout Barriers	30,580	23,036	7,544	586	0	586	
1.5ae	CIVIL ENGR - Extended Budget	28,025	16,173	11,852	2,040	0	2,040	
1.5b	PET ENGR - Circulating Air Barriers	22,881	22,881	0	0	0	0	
1.5be	PET ENGR - Extended Budget	16,421	11,778	4,643	4,647	0	4,647	
2.1	Chemical Destruction of Chlorinated Organic Compounds	23,597	23,594	3	0	0	0	
2.1e	Extended Budget	8,557	5,165	3,392	3,392	0	3,392	
2.2	Continued Development of an Atmospheric Monitoring Mass Spectrometry System	33,325	33,325	0	0	0	0	
2.3	Capture of Hazardous Chemical Waste Materials Utilizing Fluidization Coating Technology	4,562	1,426	3,136	3,136	0	3,136	
2.4	Soil Decontamination by Steam Reforming	258,012	226,858	31,154	67,026	67,026	0	
2.5	Carbon Products for Waste Stream Cleanup							
	NRCCE - Administration & Penn State	149,219	0	149,219	149,219	0	149,219	

METC Task	PROJECT TITLE	ACCRUED AMOUNT	CASH AMOUNT	CASH VARIANCE	ENCUMB Cash Basis	ENCUMB Accrual Basis	Encumbrances VARIANCE	COMMENTS
2.5e	NRCCE - Extended Budget	16,280	16,281	(1)	0	0	0	
	Chemical Engineering	33,962	32,431	1,531	0	0	0	
2.5e	Chemical Engineering - Extended Budget	30,786	16,547	14,239	0	0	0	
3.1	Winfield Lock and Dam Assistance Program	34,173	34,972	(799)	881	0	881	(overhead error)
3.2	A GIS Based Infrastructure for Site Characterization and Remediation	96,708	18,308	78,400	184,804	106,404	78,400	
3.3	Small Business Support Program	43,883	43,884	(1)	0	0	0	
3.4	Approach for Assessing Potential Voluntary Environmental Protection - Kanawha River Area	49,652	0	49,652	60,400	10,748	49,652	
MC-7	Development of Organic Sensors	9,999	11,440	(1,441)	0	0	0	overspent will adjust
MC-14	Improved Computer Model to Predict VOC Recovery	1,331	596	735	735	0	735	
4.1	General Administrative - WVU	45,994	45,190	804	0	0	0	
4.2	Research Administration - NRCCE	24,574	24,576	(2)	0	0	0	
4.3	Confinement Administration - NRCCE	0	0	0	0	0	0	
		=====	=====	=====	=====	=====	=====	
		1,384,515	724,176	660,339	773,765	202,628	571,137	*

*ACCRUAL ADJUSTMENTS

Allocation of Funds - Under the Department of Civil & Environmental Engr

TOTAL BUDGETED 2,507,100

As summarized on planned Vs actual expenses per METC Task No.

ADDITIONAL WORK

To begin next quarter

331,765

BUDGET MODIFICATION

To be made internally next quarter
to cover additional work request

(50,000) 281,765

TOTAL AMOUNT BUDGETED UNDER WVU DIRECTION 2,788,865

AMOUNT OF BUDGET EXPENDED 6/30/95 (1,384,515)

AMOUNT of COMMITTED FUNDS REMAINING \$1,404,350

UNLIQUIDATED OBLIGATIONS (202,628)

AMOUNT of COMMITTED FUNDS REMAINING 1,201,722
=====

RECONCILIATION of CUMULATED OUTLAYS (Pg. 3.)

AMOUNT OF COMMITTED FUNDS REMAINING 1,125,175

*ADDITIONAL FUNDS AWARDED 75,950

\$1,201,125
=====

*ADDITIONAL WORK SUMMARY

TASK NO.	DESCRIPTION	TOTAL BUDGETED	WVU SUPPORT	ADDITIONAL FUNDS AWARDED
3.5	Nat Environ. Design Contest	5,815	5,815	0
3.6	Graduate Interns to IETO	52,200	0	52,000
3.7	WV High Tech Consortium	73,750	50,000	23,750
1.5	Addition to original contract	200,000	200,000	0
		331,765	255,815	75,750

METC Task	PROJECT TITLE	PLANNED ACTUAL	PLANNED TOTALS	ACTUAL TOTALS	AMOUNT REMAINING	% of \$ EXPENDED	COMMENTS
1.0 IN-SITU REMEDIATION PROCESS DEVELOPMENT							
1.1	Use of Drain Enhanced Soil Flushing for Organic Contaminants Removal	PLANNED ACTUAL	\$105,999	\$16,548	\$89,451	16%	
1.1e	Extended Budget	PLANNED ACTUAL	\$7,219	\$7,082	\$137	98%	
	TOTAL TASK 1.1	PLANNED ACTUAL	\$113,218	\$23,630	\$89,588	21%	
1.2	In-Situ Bioremediation of Chlorinated Organic Solvents	PLANNED ACTUAL	\$95,690	\$64,164	\$31,526	67%	
1.2e	Extended Budget	PLANNED ACTUAL	\$13,930	\$16,006	(\$2,076)	115%	An Adjustment will be made
	TOTAL TASK 1.2	PLANNED ACTUAL	\$109,620	\$80,170	\$29,450	73%	
1.3	Microbial Enrichment for Enhancing In Situ Biodegradation of Hazardous Organic Wastes	PLANNED ACTUAL	\$79,466	\$13,442	\$66,024	17%	
1.3e	Extended Budget	PLANNED ACTUAL	\$5,000	\$4,545	\$455	91%	
	TOTAL TASK 1.3	PLANNED ACTUAL	\$84,466	\$17,987	\$66,479	21%	
1.4	Contaminant Movement Prediction in Permeable Subsurface Soils	PLANNED ACTUAL	\$32,246	\$14,958	\$17,288	46%	
1.5	Development of Standard Test Protocols & Barrier Design Models for In-Situ Formed Barriers						
	NRCCE - Administration & BDM	PLANNED ACTUAL	\$284,640	\$271,572	\$13,068	95%	
1.5e	NRCCE - Extended Budget	PLANNED ACTUAL	\$43,043	\$13,677	\$29,366	32%	
1.5a	CIVIL ENGR - Chemical Grout Barriers	PLANNED ACTUAL	\$158,669	\$30,580	\$128,089	19%	
1.5ae	CIVIL ENGR - Extended Budget	PLANNED ACTUAL	\$32,631	\$28,025	\$4,606	86%	
1.5b	PET ENGR - Circulating Air Barriers	PLANNED ACTUAL	\$102,541	\$22,881	\$79,660	22%	
1.5be	PET ENGR - Circulating Air Barriers	PLANNED ACTUAL	\$37,069	\$16,421	\$20,648	44%	

CONTINUED

METC Task	PROJECT TITLE	PLANNED ACTUAL	PLANNED TOTALS	ACTUAL TOTALS	AMOUNT REMAINING	% of \$ EXPENDED
TOTAL TASK 1.5		PLANNED ACTUAL	\$658,593	\$383,156	\$275,437	58%
TOTAL TASK 1.0		PLANNED ACTUAL	\$998,143	\$519,901	\$478,242	52%
2.0 ADVANCED PRODUCT APPLICATIONS TESTING						
2.1	Chemical Destruction of Chlorinated Organic Compounds	PLANNED ACTUAL	\$67,715	\$23,597	\$44,118	35%
2.1e	Extended Budget	PLANNED ACTUAL	\$8,557	\$8,557	\$0	100%
TOTAL TASK 2.1		PLANNED ACTUAL	\$76,272	\$32,154	\$44,118	42%
2.2	Continued Development - Atmospheric Monitoring Mass Spectrometry System	PLANNED ACTUAL	\$75,021	\$33,325	\$41,696	44%
2.3	Capture of Haz Chemical Waste Materials Utilizing Fluidization Coating Technology	PLANNED ACTUAL	\$30,595	\$4,562	\$26,033	15%
2.4	Soil Decontamination by Steam Reforming	PLANNED ACTUAL	\$342,526	\$258,012	\$84,514	Budget to be 75% modified nxt qtr
2.5	Carbon Products for Waste Stream Cleanup					
	NRCCE - Administration & Penn State	PLANNED ACTUAL	\$158,464	\$149,219	\$9,245	94%
2.5e	NRCCE - Extended Budget	PLANNED ACTUAL	\$16,902	\$16,280	\$622	96%
	Chemical Engineering	PLANNED ACTUAL	\$75,473	\$33,962	\$41,511	45%
2.5e	Chemical Engineering - Extended Budget	PLANNED ACTUAL	\$32,253	\$30,786	\$1,467	95%
TOTAL TASK 2.5		PLANNED ACTUAL	\$283,092	\$230,247	\$52,845	81%
TOTAL TASK 2.0		PLANNED ACTUAL	\$807,506	\$558,300	\$249,206	

CONTINUED

METC Task	PROJECT TITLE	PLANNED ACTUAL	PLANNED TOTALS	ACTUAL TOTALS	AMOUNT REMAINING	% of \$ EXPENDED
3.0 INFORMATION SYSTEMS, PUBLIC POLICY, COMMUNITY OUTREACH AND ECONOMICS						
3.1	Winfield Lock and Dam Assistance Program	PLANNED ACTUAL	\$81,182	\$34,173	\$47,009	42% Budget to be modified nxt qtr
3.2	A GIS Based Infrastructure for Site Characterization and Remediation	PLANNED ACTUAL	\$207,432	\$96,708	\$110,724	47%
3.3	Small Business Support Program	PLANNED ACTUAL	\$94,860	\$43,883	\$50,977	46%
3.4	Assessing Potential Voluntary Env. Protection - Kanawha River Area	PLANNED ACTUAL	\$90,208	\$49,652	\$40,556	55% Budget to be modified nxt qtr
TOTAL TASK 3.0		PLANNED ACTUAL	\$473,682	\$224,416	\$249,266	47%
OTHER EXTENDED BUDGETS						
MC-7	Development of Organic Sensors	PLANNED ACTUAL	\$10,000	\$9,999	\$1	100%
MC-14	Improved Computer Model to Predict VOC Recovery	PLANNED ACTUAL	\$2,694	\$1,331	\$1,363	49%
TOTAL OTHER		PLANNED ACTUAL	\$12,694	\$11,330	\$1,364	89%
ADMINISTRATIVE PROJECT SET-UP						
4.1	General Administrative - WVU	PLANNED ACTUAL	\$114,347	\$45,994	\$68,353	40% Budget to be modified nxt qtr
4.2	Research Administration - NRCCE	PLANNED ACTUAL	\$73,428	\$24,574	\$48,854	33% Budget to be modified nxt qtr
4.3	Confinement Administration - NRCCE	PLANNED ACTUAL	\$27,300	\$0	\$27,300	0% Budget to be modified nxt qtr
TOTAL ADMINISTRATION		PLANNED ACTUAL	\$215,075	\$70,568	\$144,507	33%
GRAND TOTAL						
		PLANNED ACTUAL	\$2,507,100	\$1,384,515	\$1,122,585	55%

Overall SUMMARY - Planned Versus Actual Budgets

METC Task	PROJECT TITLE	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS
1.0 IN-SITU REMEDIATION PROCESS DEVELOPMENT																
1.1	Use of Drain Enhanced Soil Flushing (DESf) for Organic Contaminants Removal	PLANNED ACTUAL	5,434 665	6,864 1,350	8,864 0	6,863 1,618	6,863 1,607	8,794 11,308	19,004	8,136	12,426	7,836	7,636	7,279	\$105,999	\$16,548
1.1e	Extended Budget	PLANNED ACTUAL	243 305	243 0	1,015 1,060	243 62	4,016 4,083	1,459 1,572							\$7,219	\$7,082
	TOTAL TASK 1.1	PLANNED ACTUAL	5,677 970	7,107 1,350	9,879 1,060	7,106 1,680	10,879 5,690	10,253 12,880	19,004	8,136	12,426	7,836	7,636	7,279	\$113,218	\$23,630
1.2	In-Situ Bioremediation of Chlorinated Organic Solvents	PLANNED ACTUAL	2,431 2,496	2,431 2,431	5,577 3,587	11,147 8,087	20,082 18,880	27,868 28,683	5,934	4,147	4,147	4,147	4,147	3,632	\$95,690	\$64,164
1.2e	Extended Budget	PLANNED ACTUAL	4,815 5,310	4,815 4,479	337 667	337 469	1,689 772	1,937 4,309							\$13,930	\$16,006
	TOTAL TASK 1.2	PLANNED ACTUAL	7,246 7,806	7,246 6,910	5,914 4,254	11,484 8,556	21,771 19,652	29,805 32,992	5,934	4,147	4,147	4,147	4,147	3,632	\$109,620	\$80,170
1.3	Microbial Enrichment for Enhancing In-Situ Biodegradation of Hazardous Organic Wast	PLANNED ACTUAL	3,536 0	3,536 0	4,108 0	4,108 3,536	4,108 3,536	20,930 6,370	4,354	4,354	10,789	9,216	6,073	4,354	\$79,466	\$13,442
1.3e	Extended Budget	PLANNED ACTUAL	0 0	0 0	1,250 0	1,250 526	1,250 2,369	1,250 1,650							\$5,000	\$4,545
	TOTAL TASK 1.3	PLANNED ACTUAL	3,536 0	3,536 0	5,358 0	5,358 4,062	5,358 5,905	22,180 8,020	4,354	4,354	10,789	9,216	6,073	4,354	\$84,466	\$17,987
1.4	Contaminant Movement Prediction in Permeable Subsurface Soils	PLANNED ACTUAL	0 0	0 0	0 0	0 0	5,065 4,959	14,984 9,999	2,902	1,859	1,859	1,859	1,859	1,859	\$32,246	\$14,958
1.5	Development of Standard Test Protocols & Barrier Design Models for In-Situ Formed Barriers															
	NRCCE - Administration & BDM	PLANNED ACTUAL	46,460 47,039	46,460 42,749	46,460 43,767	46,460 42,749	46,460 50,826	46,460 44,442	980	980	980	980	980	980	\$284,640	\$271,572
1.5e	NRCCE - Extended Budget	PLANNED ACTUAL	2,737 0	5,948 3,212	8,148 3,212	8,148 3,212	8,148 3,212	2,737 829	2,737	4,440					\$43,043	\$13,677
1.5a	CIVIL ENGR - Chemical Grout Barriers	PLANNED ACTUAL	11,458 8,839	2,538 1,288	1,684 4,093	1,308 984	3,654 2,993	10,184 12,383	25,979	24,304	21,140	21,140	21,140	14,140	\$158,669	\$30,580
1.5ae	CIVIL ENGR - Extended Budget	PLANNED ACTUAL	5,411 4,513	3,266 2,516	5,182 5,360	2,708 2,547	5,982 7,722	5,552 5,367	2,408	2,122					\$32,631	\$28,025
1.5b	PET ENGR - Circulating Air Barriers	PLANNED ACTUAL	0 0	0 0	0 0	7,577 6,518	11,922 11,061	7,577 5,302	17,159	32,487	20,351	2,734	2,734	0	\$102,541	\$22,881
1.5be	PET ENGR - Circulating Air Barriers	PLANNED ACTUAL	0 0	0 0	5,926 4,920	5,926 5,882	729 973	3,429 4,646	13,614	7,445					\$37,069	\$16,421

CONTINUED

METC Task	PROJECT TITLE	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS
	TOTAL TASK 1.5	PLANNED ACTUAL	66,066 60,391	58,212 49,765	67,400 61,352	72,127 61,892	76,895 76,787	75,939 72,969	62,877 0	71,778 0	42,471 0	24,854 0	24,854 0	16,120 0	\$658,593	\$383,156
	TOTAL TASK 1.0	PLANNED ACTUAL	82,674 69,167	76,250 58,025	88,699 66,666	96,224 76,190	119,536 112,993	155,132 136,860	95,071 0	90,274 0	71,692 0	47,912 0	44,569 0	32,244 0	\$1,000,277	\$519,901
2.0 ADVANCED PRODUCT APPLICATIONS TESTING																
2.1	Chemical Destruction of Chlorinated Organ Compounds	PLANNED ACTUAL	2,074 0	2,074 0	2,789 0	2,789 6,127	8,395 7,919	11,754 9,551	8,221	7,595	5,506	5,506	5,506	5,506	\$67,715	\$23,597
2.1e	Extended Budget	PLANNED ACTUAL	0 0	0 0	3,392 86	5,165 5,165	0 0	0 3,306							\$8,557	\$8,557
	TOTAL TASK 2.1	PLANNED ACTUAL	2,074 0	2,074 0	6,181 86	7,954 11,292	8,395 7,919	11,754 12,857	8,221	7,595	5,506	5,506	5,506	5,506	\$76,272	\$32,154
2.2	Continued Development of an Atmospheric Monitoring Mass Spectrometry System	PLANNED ACTUAL	0 0	0 0	0 0	0 0	14,647 10,533	19,019 22,792	16,880	10,649	4,704	4,704	4,418	0	\$75,021	\$33,325
2.3	Capture of Hazardous Chemical Waste Mat Utilizing Fluidization Coating Technology	PLANNED ACTUAL	0 0	0 0	0 0	0 0	4,145 0	2,145 4,562	4,074	4,074	3,431	4,003	5,433	3,290	\$30,595	\$4,562
2.4	Soil Decontamination by Steam Reforming	PLANNED ACTUAL	53,844 38,532	53,844 63,475	53,844 37,716	53,844 35,436	53,844 51,699	64,594 31,154	1,452	1,452	1,452	1,452	1,452	1,452	\$342,526	\$258,012
2.5	Carbon Products for Waste Stream Cleanup															
	NRCCE - Administration & Penn State	PLANNED ACTUAL	0 0	0 0	25,000 0	25,627 0	25,987 56,145	25,987 93,074	25,987	27,075	987	987	827	0	\$158,464	\$149,219
2.5e	NRCCE - Extended Budget	PLANNED ACTUAL	2,817 0	2,817 0	2,817 0	2,817 136	2,817 2,051	2,817 14,093							\$16,902	\$16,280
	Chemical Engineering	PLANNED ACTUAL	0 0	0 0	3,429 2,689	10,651 9,425	10,651 10,096	10,560 11,752	19,618	10,190	10,190	184	0	0	\$75,473	\$33,962
2.6e	Chemical Engineering - Extended Budget	PLANNED ACTUAL	14,639 12,044	3,839 2,113	3,243 7,234	3,243 2,332	3,243 1,663	4,046 5,400							\$32,253	\$30,786
	TOTAL TASK 2.5	PLANNED ACTUAL	17,456 12,044	6,656 2,113	34,489 9,923	42,338 11,893	42,698 69,955	43,410 124,319	45,605 0	37,265 0	11,177 0	1,171 0	827 0	0 0	\$283,092	\$230,247
	TOTAL TASK 2.0	PLANNED ACTUAL	73,374 50,576	62,574 65,588	94,514 47,725	104,136 58,621	123,729 140,106	140,922 195,684	76,232 0	61,035 0	26,270 0	16,836 0	17,636 0	10,248 0	\$807,506	\$558,300

CONTINUED

METC Task	PROJECT TITLE	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PLANNED TOTALS	ACTUAL TOTALS
3.0 INFORMATION SYSTEMS, PUBLIC POLICY, COMMUNITY OUTREACH AND ECONOMICS																
3.1	Winfield Lock and Dam Assistance Program	PLANNED ACTUAL	7,090 5,703	7,090 5,563	7,090 5,924	7,090 5,748	7,090 5,065	7,090 6,170	6,863	6,455	6,939	6,011	6,231	6,143	\$81,182	\$34,173
3.2	A GIS Based Infrastructure for Site Characterization and Remediation	PLANNED ACTUAL	3,602 2,570	9,690 10,691	4,886 3,834	17,342 10,943	15,072 8,580	47,083 60,090	26,219	26,893	18,213	13,290	11,908	13,234	\$207,432	\$96,708
3.3	Small Business Support Program	PLANNED ACTUAL	7,905 6,417	7,905 6,656	7,905 7,425	7,905 7,624	7,905 7,796	7,905 7,965	7,905	7,905	7,905	7,905	7,905	7,905	\$94,860	\$43,883
3.4	Assessing Potential Voluntary Env. Protection - Kanawha River Area	PLANNED ACTUAL	1,127 0	1,127 0	1,127 0	1,127 0	36,877 35,530	43,188 14,122	1,127	1,127	1,127	1,127	1,127	0	\$90,208	\$49,652
TOTAL TASK 3.0		PLANNED ACTUAL	19,724 14,690	25,812 22,910	21,008 17,183	33,464 24,315	66,944 56,971	105,266 88,347	42,114	42,380	34,184	28,333	27,171	27,282	\$473,682	\$224,416

OTHER EXTENDED BUDGETS

MC-7	Development of Organic Sensors	PLANNED ACTUAL	2,500 0	2,500 0	2,500 0	2,500 2,860	0 7,139	0 0							\$10,000	\$9,999
MC-14	Improved Computer Model to Predict VOC Recovery	PLANNED ACTUAL	0 0	0 0	0 0	898 14	898 83	898 1,234							\$2,694	\$1,331
TOTAL OTHER		PLANNED ACTUAL	2,500 0	2,500 0	2,500 0	3,398 2,874	898 7,222	898 1,234	0	0	0	0	0	0	\$12,694	\$11,330

ADMINISTRATIVE PROJECT SET-UP

4.1	General Administrative - WVU	PLANNED ACTUAL	8,219 5,777	8,791 5,873	16,791 14,040	9,327 6,303	8,791 6,825	10,791 7,176	8,791	9,327	8,791	8,791	9,327	6,610	\$114,347	\$45,994
4.2	Research Administration - NRCCE	PLANNED ACTUAL	6,119 3,632	6,119 3,632	6,119 3,632	6,119 4,971	6,119 4,971	6,119 3,736	6,119	6,119	6,119	6,119	6,119	6,119	\$73,428	\$24,574
4.3	Confinement Administration - NRCCE	PLANNED ACTUAL	2,275 0	2,275 0	2,275 0	2,275 0	2,275 0	2,275 0	2,275	2,275	2,275	2,275	2,275	2,275	\$27,300	\$0
TOTAL ADMINISTRATION		PLANNED ACTUAL	16,613 9,409	17,185 9,505	25,185 17,672	17,721 11,274	17,185 11,796	19,185 10,912	17,185	17,721	17,185	17,185	17,721	15,004	\$215,075	\$70,568

GRAND TOTAL

PLANNED	194,736	184,172	231,758	254,794	328,724	419,432	230,602	211,410	149,331	110,266	107,097	84,778	\$2,507,100	
ACTUAL	143,842	156,028	149,246	173,274	329,088	433,037								\$1,384,515

CUMULATIVE TOTAL

PLANNED	194,736	378,908	610,666	865,460	1,194,184	1,613,616	1,844,218	2,055,628	2,204,959	2,315,225	2,422,322	2,507,100	
ACTUAL	143,842	299,870	449,116	622,390	951,478	1,384,515							

CUM BUDGET VARIANCE

50,894	79,038	161,550	243,070	242,706	229,101	1,844,218	2,055,628	2,204,959	2,315,225	2,422,322	2,507,100	
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NOTE: Details of the above budgets can be found on the attached pages. These spreadsheets were formatted to round to the nearest dollar. As a result, whole numbers were used in the above summary and minor differences may be noticed. In no case did these differences exceed \$5.

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ADMINISTRATIVE BUDGETS

1.0 IN-SITU REMEDIATION PROCESS DEVELOPMENT

WVU ADMINISTRATIVE BUDGET

PRINCIPAL INVESTIGATOR: E. Cook

■ PLANNED SPENDING ♦ ACTUAL SPENDING

PROJECT: WVU General Administrative Budget

WVU Act. No.: 8527-229-3237

PRINCIPAL INVESTIGATOR: E.E. Cook

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
Director	planned actual	2,084 2,002	2,084 2,002	2,084 2,002	2,084 2,002	2,084 2,126	2,084 2,250	2,084	2,084	2,084	2,084	2,084	2,084	\$25,003	\$12,384	\$12,619
Engineering Scientist	planned actual	666 0	666 0	666 539	666 666	666 666	666 666	666	666	666	666	666	666	\$7,997	\$2,537	\$5,460
Secretary	planned actual	833 656	833 656	833 656	833 656	833 656	833 656	833	833	833	833	833	833	\$9,999	\$3,936	\$6,063
BENEFITS (29% of Salaries)	planned actual	1,039 771	1,039 771	1,039 927	1,039 964	1,039 1,000	1,039 1,036	1,039 0	1,039 0	1,039 0	1,039 0	1,039 0	1,039 0	\$12,470	\$5,469	\$7,001
STUDENTS	planned actual	0 611	0 666	0 127	0 0	0 0	0 0	0	0	0	0	0	0	\$0	\$1,404	(\$1,404)
SUPPLIES	planned actual	1,125 0	1,125 12	1,125 421	1,500 110	1,125 325	1,125 160	1,125	1,500	1,125	1,125	1,500	0	\$13,500	\$1,018	\$12,482
TRAVEL	planned actual	0 0	250 0	250 0	250 0	250 0	250 0	250	250	250	250	250	0	\$2,500	\$0	\$2,500
OTHER	planned actual	0 0	150 0	150 0	150 10	150 0	150 260	150	150	150	150	150	0	\$1,500	\$270	\$1,230
EQUIPMENT	planned actual	0 0	0 0	8,000 7,143	0 0	0 0	2,000 0	0	0	0	0	0	0	\$10,000	\$7,143	\$2,857
INDIRECT COSTS																
(43% of direct cost *excl/ equip & sub)	planned actual	2,471 1,737	2,643 1,766	2,643 2,225	2,805 1,896	2,643 2,052	2,643 2,168	2,643 0	2,805 0	2,643 0	2,643 0	2,805 0	1,988 0	\$31,377	\$11,833	\$19,543
PLANNED TOTALS: PER MONTH		8,219	8,791	10,791	9,327	8,791	10,791	8,791	9,327	8,791	8,791	9,327	6,610	\$114,345		
ACTUAL TOTALS: PER MONTH		5,777	5,873	14,040	6,303	6,825	7,176	0	0	0	0	0	0		\$45,995	\$68,351
CUMULATIVE PLANNED TOTALS		8,219	17,010	33,800	43,127	51,918	62,709	71,500	80,827	89,617	98,408	107,735	114,345	\$114,345		
CUMULATIVE ACTUAL TOTALS		5,777	11,650	25,690	31,994	38,819	45,995	45,995	45,995	45,995	45,995	45,995	45,995		\$45,995	\$68,351
CUMULATIVE BUDGET VARIANCE		\$2,442	\$5,360	\$8,110	\$11,134	\$13,099	\$16,714	\$25,505	\$34,832	\$43,623	\$52,414	\$61,741	\$68,351			

NRCCE ADMINISTRATIVE BUDGET

PRINCIPAL INVESTIGATOR: P. Ziemkiewicz

■ PLANNED SPENDING ◇ -- ACTUAL SPENDING

PROJECT: NRCCE ADMINISTRATIVE BUDGET

WVU Act. No.: 8527-224-1424

PRINCIPAL INVESTIGATOR: P. Ziemkiewicz

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
R. Lovette	planned actual	917 738	917 738	917 738	917 738	917 738	917 738	917 738	917 738	917 738	917 738	917 738	917 738	\$11,002	\$4,425	\$6,577
N. Reese	planned actual	1,267 1,232	1,267 1,232	1,267 1,232	1,267 1,232	1,267 1,232	1,267 1,234	1,267 1,267	1,267 1,267	1,267 1,267	1,267 1,267	1,267 1,267	1,267 1,267	\$15,202	\$7,391	\$7,811
P. Ziemkiewicz	planned actual	334 0	334 0	334 0	334 0	334 0	334 0	334 0	334 0	334 0	334 0	334 0	334 0	\$4,006	\$0	\$4,006
Staff	planned actual	541 0	541 0	541 0	541 726	541 726	541 0	541 0	541 0	541 0	541 0	541 0	541 0	\$6,496	\$1,451	\$5,045
BENEFITS (29% of Salaries)																
	planned actual	897 571	897 571	897 571	897 781	897 781	897 572	897 0	897 0	897 0	897 0	897 0	897 0	\$10,845	\$3,847	\$6,997
SUPPLIES	planned actual	125 0	125 0	125 0	125 0	125 0	125 70	125 0	125 0	125 0	125 0	125 0	125 0	\$1,500	\$70	\$1,430
TRAVEL	planned actual	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	\$2,500	\$0	\$2,500
INDIRECT COSTS																
(43% of direct cost *excl equip & sub)	planned actual	1,840 1,082	1,840 1,082	1,840 1,082	1,840 1,496	1,840 1,496	1,840 1,123	1,840 0	1,840 0	1,840 0	1,840 0	1,840 0	1,840 0	\$22,081	\$7,368	\$14,682
PLANNED TOTALS: PER MONTH		6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	\$73,431		
ACTUAL TOTALS: PER MONTH		3,632	3,632	3,632	4,971	4,971	3,738	0	0	0	0	0	0		\$24,574	\$48,058
CUMULATIVE PLANNED TOTALS		6,119	12,239	18,359	24,477	30,596	36,716	42,835	48,954	55,074	61,193	67,312	73,431	\$73,431		
CUMULATIVE ACTUAL TOTALS		3,632	7,264	10,897	15,867	20,838	24,574	24,574	24,574	24,574	24,574	24,574	24,574		\$24,574	\$48,058
CUMULATIVE BUDGET VARIANCE		\$2,487	\$4,974	\$7,461	\$8,610	\$9,759	\$12,142	\$18,261	\$24,381	\$30,500	\$36,619	\$42,738	\$48,858			

Drained Enhanced Soil Flushing for Organic Contaminants Removal

METC TASK 1.1 - PRINCIPAL INVESTIGATOR: M.A. Gabr

PROJECT: Drained Enhanced Soil Flushing (DESF) for Organic Contaminants Removal

METC TASK NO.: 1.1

WVU Act. No.: 8527-229-3243

PRINCIPAL INVESTIGATOR: M.A. Gabr

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	ATM REMAINING
SALARIES																
M.A. Gabr	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	5,000 0	0 0	0 0	0 0	0 0	0 0	\$5,000	\$0	5,000
Post Doc.	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	1,000 0	1,000 0	1,000 0	1,000 0	1,000 0	1,000 0	\$8,000	\$0	6,000
BENEFITS 29% of Salaries	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	1,740 0	290 0	290 0	290 0	290 0	290 0	\$3,180	\$0	3,180
STUDENTS																
3 Graduate	planned actual	2,550 0	2,550 0	2,550 0	2,550 0	2,550 825	2,550 1,650	2,550 0	2,550 0	2,550 0	2,550 0	2,550 0	2,550 0	\$30,600	\$2,475	28,125
2 Undergraduates	planned actual	750 0	750 0	750 0	750 234	750 128	750 2,165	750 0	750 0	750 0	750 0	750 0	750 0	\$8,000	\$2,528	6,474
SUPPLIES	planned actual	500 485	500 0	500 0	500 30	500 173	2,000 2,211	500 0	250 0	250 0	250 0	250 0	0	\$4,000	\$2,879	3,121
OTHER - NRCCE Lab Analysis	planned actual	0 0	0 0	1,000 0	300 867	300 0	500 1,374	400 0	500 0	500 0	500 0	500 0	500 0	\$5,000	\$2,241	2,759
TRAVEL	planned actual	0 0	1,000 944	0 0	0 0	0 0	0 143	1,000 0	0 0	3,000 0	0 0	0 0	0 0	\$5,000	\$1,037	3,913
EQUIPMENT (Under 500)	planned actual	0 0	0 0	0 0	0 0	0 0	0 364	0 0	0 0	0 0	0 0	0 0	0 0	\$0	\$364	(364)
EQUIPMENT (Over 500)	planned actual	0 0	0 0	2,000 0	1,000 0	1,000 0	500 0	500 0	500 0	500 0	200 0	0 0	0 0	\$8,200	\$0	6,200
INDIRECT COSTS																
43% of expenses (exc equip>500)	planned actual	1,834 200	2,084 406	2,084 0	1,753 486	1,753 483	2,494 3,400	5,584 0	2,296 0	3,598 0	2,296 0	2,296 0	2,189 0	\$30,010	\$4,876	25,034
PLANNED TOTALS: PER MONTH		6,434	6,664	6,664	6,663	6,663	8,794	18,004	8,136	12,428	7,836	7,836	7,278	\$108,000		
ACTUAL TOTALS: PER MONTH		665	1,360	0	1,618	1,607	11,308	0	0	0	0	0	0		\$16,548	89,452
CUMULATIVE PLANNED TOTALS		6,434	12,298	21,182	28,025	34,688	43,682	62,686	70,822	88,249	91,065	96,721	106,000	\$108,000		
CUMULATIVE ACTUAL TOTALS		665	2,015	2,015	3,633	5,240	16,548	16,548	16,548	16,548	16,548	16,548	16,548		\$16,548	89,452
UNDER BUDGET		\$4,769	\$10,283	\$19,147	\$24,382	\$29,648	\$27,134	\$46,138	\$54,274	\$66,701	\$74,537	\$82,173	\$89,452			

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Drained Enhanced Soil Flushing for Organic Contaminants Removal.

*** EXTENDED BUDGET *** METC TASK 1.1e - PRINCIPAL INVESTIGATOR: M.A. Gabr

■ PLANNED SPENDING ♦ ACTUAL SPENDING

METC TASK NO.: 1.1e
WVU Act No.: 8527-229-3240
PERIOD ENDING: 6/30/95

***** EXTENDED BUDGET *****

[illegible]

METC Task # 1.1

Task	Task Name	Duration	%Complete	1995												1st Quarter		
				1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter		
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	Effective Well Diameter	4.5M	50.00%	■	■	■	■	■	■									
2	Smear Effect	9.5M	50.00%			■	■	■	■	■	■	■	■	■	■			
3	Well Resistance	5M	50.00%						■	■	■	■	■	■				
4	PVD's Contaminant Transport Model Verification	7.5M	30.00%	■	■	■	■	■	■	■	■	■	■	■				
5	Economic evaluation & Field Implementation Pla	6M	50.00%						■	■	■	■	■	■	■			
6	Reporting	12M	50.00%	■	■	■	■	■	■	■	■	■	■	■	■			
7	Quarterly Report 1	0d	100.00%				◆											
8	Quarterly Report 2	0d	100.00%							◆								
9	Quarterly Report 3	0d	0.00%									◆						
10	Final Report	0d	0.00%												◆			
11	Overall Work Completed	12M	46.70%	■	■	■	■	■	■	■	■	■	■	■	■			

■ Critical	■ Noncritical	■ Complete	■ Summary	■ External
◆ Critical Milestone	◆ Noncritical Milestone	● Complete Milestone	◆ Summary Milestone	● External Milestone
▨ Free Float	▨ Total Float (+)	▨ Total Float (-)	— Baseline	 Non-Resource
..... Delay	▲ Effort %Complete			

Use of Drain-Enhanced Soil Flushing (DESF) for Organic Contaminants Removal

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TASK 1.2: In-Situ Bioremediation of Chlorinated Organic Solvents

PRINCIPAL INVESTIGATORS: W. Sack, P. Carrier, A. Shiemke

PROJECT: In-Situ Bioremediation of Chlorinated Organic Solvents METC TASK NO.: 1.2

PRINCIPAL INVESTIGATOR(S): W. Sack, P. Carrier & A. Shiemke

WVU Act. No.: 8527-229-3244

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
SALARIES																
W. Sack	planned	0	0	0	0	3,298	3,298	0	0	0	0	0	0	\$6,596		
	actual	0	0	0	0	3,298	3,298								\$6,596	\$0
P. Carrier	planned	0	0	0	0	2,836	2,836	0	0	0	0	0	0	\$5,671		
	actual	0	0	0	0	2,835	2,835								\$5,669	\$2
A. Shiemke	planned	0	0	0	0	1,150	1,150	0	0	0	0	0	0	\$2,300		
	actual	0	0	0	0	1,150	1,150								\$2,300	\$0
BENEFITS																
29% of Salaries	planned	0	0	0	0	2,112	2,112	0	0	0	0	0	0	\$4,224		
	actual	0	0	0	0	2,112	2,112	0	0	0	0	0	0		\$4,224	\$1
STUDENTS																
2 Graduate	planned	1,700	1,700	1,700	1,700	1,700	1,700	2,200	2,200	2,200	2,200	2,200	2,200	\$23,402		
	actual	1,700	1,700	1,700	1,700	1,700	1,700								\$10,200	\$13,202
OTHER	planned	0	0	0	0	0	200	50	0	0	0	0	0	\$250		
	actual	0	0	0	0	0	211								\$211	\$39
SUPPLIES	planned	0	0	2,000	1,000	1,000	1,000	1,000	500	500	500	500	140	\$8,140		
	actual	0	0	809	1,158	1,300	1,286								\$4,553	\$3,587
TRAVEL	planned	0	0	200	200	200	200	200	200	200	200	200	200	\$2,000		
	actual	0	0	0	0	0	0								\$0	\$2,000
EQUIPMENT (Under 500)	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0		
	actual	0	0	0	0	0	486								\$486	(\$486)
EQUIPMENT (*Over 500)	planned	0	0	0	7,000	2,500	10,000	1,000	0	0	0	0	0	\$20,500		
	actual	65	0	0	4,000	1,156	9,983								\$15,204	\$5,296
INDIRECT COSTS																
(43% of exp *exc/ Equip>500)	planned	731	731	1,677	1,247	5,287	5,373	1,484	1,247	1,247	1,247	1,247	1,082	\$22,610		
	actual	731	731	1,079	1,229	5,329	5,623	0	0	0	0	0	0		\$14,722	\$7,888
PLANNED TOTALS: PER MONTH																
		2,431	2,431	5,577	11,147	20,082	27,868	5,934	4,147	4,147	4,147	4,147	3,632	\$95,692		
ACTUAL TOTALS: PER MONTH																
		2,496	2,431	3,587	8,087	18,880	28,683	0	0	0	0	0	0		\$64,164	\$31,529
CUMULATIVE PLANNED TOTALS																
		2,431	4,863	10,440	21,588	41,670	69,539	75,472	79,619	83,766	87,913	92,060	95,692	\$95,692		
CUMULATIVE ACTUAL TOTALS																
		2,496	4,927	8,514	16,601	35,481	64,164	64,164	64,164	64,164	64,164	64,164	64,164		\$64,164	\$31,529
CUM BUDGET VARIANCE																
		(\$64)	(\$64)	\$1,926	\$4,987	\$6,189	\$5,375	\$11,309	\$15,456	\$19,603	\$23,750	\$27,897	\$31,529			

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TASK 1.2e - In Situ Bioremediation of Chlorinated Organic Solvents

PRINCIPAL INVESTIGATORS: W. Sack & P. Carriere - EXTENDED Budget

■ PLANNED SPENDING . → — ACTUAL SPENDING

PRINCIPAL INVESTIGATOR (S): W. Sack, P. Carriere & A. Shlemke

PERIOD ENDING: 6/30/95[illegible]

METC Task # 1.2

#	Task Name	Dura	%Compl	1995												1s
				1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	Optimization of Sequential Mineralization	11M	60.00%													
2	Design & Construction of Simultaneuos Min. Colu	2M	100.00%													
3	Dev. & Testing of Protocol to Locate Zones	4M	100.00%													
12	Optimization of Simultaneous Mineralization	7M	0.00%													
11	Assessment of Potential Bioremediation of High Co	4M	5.00%													
13	Design & Const. of Lysimeters Equpped with PVD's	8M	70.00%													
10	Amendments Delivery & Potential Clogging	8M	0.00%													
4	Reporting	12M	50.00%													
5	Quarterly Report 1	0d	100.00%													
6	Quarterly Report 2	0d	100.00%													
7	Quarterly Report 3	0d	0.00%													
8	Final Report	0d	0.00%													
9	Overall Work Complete	12M	48.10%													

Critical
 Critical Milestone
 Free Float
 Delay

Noncritical
 Noncritical Milestone
 Total Float (+)
 Effort %Complete

Complete
 Complete Milestone
 Total Float (-)

Summary
 Summary Milestone
 Baseline

External
 External Milestone
 Non-Resource

In-Situ Bioremediation of Chlorinated Organic Solvents

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TASK 1.3: Microbial Enrichment for Enhancing In Situ Biodegradation
of Hazardous Organic Wastes - PRINCIPAL INVESTIGATOR: A. Sextone

PROJECT: Microbial Enrichment for Enhancing In-Situ Biodegradation of Hazardous Organic Wastes

PRINCIPAL INVESTIGATOR: Alan Sextone

METC TASK NO.: 1.3

WVU Act. No.: 8527-205-7526

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
A. Sextone	planned actual	0 0	0 0	0 0	0 0	0 0	4,220 0	0 0	0 0	0 0	0 0	0 0	0 0	\$4,220	\$0	\$4,220
C. Atkinson	planned actual	0 0	0 0	0 0	0 0	0 0	4,899 0	0 0	0 0	0 0	0 0	0 0	0 0	\$4,899	\$0	\$4,899
Postdoctoral Associate	planned actual	1,917 0	1,917 0	1,917 0	1,917 1,917	1,917 1,917	1,917 1,917	2,050 2,050	2,050 2,050	2,050 2,050	2,050 2,050	2,050 2,050	2,050 2,050	\$23,802	\$5,751	\$18,051
BENEFITS (29% of Salaries)	planned actual	556 0	556 0	556 0	556 556	556 556	3,200 556	595 0	595 0	595 0	595 0	595 0	595 0	\$9,547	\$1,668	\$7,879
SUPPLIES	planned actual	0 0	0 0	400 0	400 0	400 0	400 1,798	400 400	400 400	400 400	400 400	400 400	400 400	\$4,000	\$1,798	\$2,202
TRAVEL	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	900 900	900 900	0 0	\$1,800	\$0	\$1,800
OTHER Chemical Anal.	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2,500 2,500	2,500 2,500	302 302	0 0	\$5,302	\$0	\$5,302
EQUIPMENT (*Under 500)	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$0	\$0	\$0
EQUIPMENT (*Over 500)	planned actual	0 0	0 0	0 0	0 0	0 0	0 184	0 0	0 0	2,000 2,000	0 0	0 0	0 0	\$2,000	\$184	\$1,816
INDIRECT COSTS																
(43% of direct cost *exc/ equip)	planned actual	1,063 0	1,063 0	1,235 0	1,235 1,063	1,235 1,063	6,294 1,915	1,309 0	1,309 0	3,244 0	2,771 0	1,826 0	1,309 0	\$23,895	\$4,042	\$19,853
PLANNED TOTALS: PER MONTH		3,536	3,536	4,108	4,108	4,108	20,930	4,354	4,354	10,789	9,216	6,073	4,354	\$79,465		
ACTUAL TOTALS: PER MONTH		0	0	0	3,536	3,536	6,370	0	0	0	0	0	0		\$13,443	\$66,023
CUMULATIVE PLANNED TOTALS		3,536	7,073	11,181	15,289	19,397	40,328	44,681	49,035	59,823	69,039	75,112	79,465	\$79,465		
CUMULATIVE ACTUAL TOTALS		0	0	0	3,536	7,073	13,443	13,443	13,443	13,443	13,443	13,443	13,443		\$13,443	\$66,023
CUMULATIVE BUDGET VARIANCE		\$3,536	\$7,073	\$11,181	\$11,753	\$12,325	\$26,885	\$31,239	\$35,592	\$46,381	\$55,596	\$61,669	\$66,023			

TASK 1.3e: Microbial Enrichment for Enhancing In Situ Biodegradation

of Hazardous Organic Wastes - PRINCIPAL INVESTIGATOR: A. Sextone - *Extended Budget*

■ PLANNED SPENDING ♦ ACTUAL SPENDING

PROJECT: Microbial Enrichment for Enhancing In-Situ Biodegradation of Hazardous Organic Wastes - *Extended Budget*
PRINCIPAL INVESTIGATOR: Alan Sextone

METC TASK NO.: 1.3e
WVU Act. No.: 8527-205-7527
PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SUPPLIES	planned actual	0 0	0 0	874 0	874 368	874 1,657	874 1,154	0 0	0 0	0 0	0 0	0 0	0 0	\$3,499	\$3,179	\$317
OTHER	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$0	\$0	\$0
INDIRECT COSTS																
(43% of direct cost *exc/ equip)	planned actual	0 0	0 0	376 0	376 168	376 712	376 496	0 0	0 0	0 0	0 0	0 0	0 0	\$1,503	\$1,387	\$136
PLANNED TOTALS: PER MONTH		0	0	1,250	1,250	1,250	1,250	0	0	0	0	0	0	\$4,999		
ACTUAL TOTALS: PER MONTH		0	0	0	526	2,369	1,650	0	0	0	0	0	0		\$4,545	\$454
CUMULATIVE PLANNED TOTALS		0	0	1,250	2,500	3,749	4,999	4,999	4,999	4,999	4,999	4,999	4,999	\$4,999		
CUMULATIVE ACTUAL TOTALS		0	0	0	526	2,896	4,545	4,545	4,545	4,545	4,545	4,545	4,545		\$4,545	\$454
CUMULATIVE BUDGET VARIANCE		\$0	\$0	\$1,250	\$1,974	\$854	\$454	\$454	\$454	\$454	\$454	\$454	\$454			

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METC Task # 1.3

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- Critical
- Noncritical
- Complete
- Summary
- External
- Critical Milestone
- Noncritical Milestone
- Complete Milestone
- Summary Milestone
- External Milestone
- Free Float
- Total Float (+)
- Total Float (-)
- Baseline
- Non-Resource
- Delay
- Effort %Complete

Microbial Enrichment for Enhancing In-Situ Biodegradation of Haz. Organic Waste

Contaminant Movement Prediction in Permeable Subsurface Soils

TASK 1.4: PRINCIPAL INVESTIGATORS: H. Bilgesu and S. Ameri

■ PLANNED SPENDING ◇ ACTUAL SPENDING

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PROJECT: Contaminant Movement Prediction in Permeable Subsurface Soils

METC TASK NO.: 1.4

WVU Act. No.: 8527-255-0434

PRINCIPAL INVESTIGATORS): H. Bilgesu and S. Ameri

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
SALARIES																
H. Bilgesu	planned	0	0	0	0	2,668	5,335	330	0	0	0	0	0	\$8,333		
	actual	0	0	0	0	2,668	5,335								\$8,003	\$330
BENEFITS																
29% of Salaries	planned	0	0	0	0	774	1,547	96	0	0	0	0	0	\$2,417		
	actual	0	0	0	0	774	1,547	0	0	0	0	0	0		\$2,321	\$96
STUDENTS																
1 Graduate	planned	0	0	0	0	0	0	0	1,200	1,200	1,200	1,200	1,200	\$6,000		
	actual					0	0								\$0	\$6,000
SUPPLIES																
	planned	0	0	0	0	50	50	50	50	50	50	50	50	\$400		
	actual					26	110								\$136	\$264
OTHER																
	planned	0	0	0	0	50	50	50	50	50	50	50	50	\$400		
	actual					0	0								\$0	\$400
EQUIPMENT																
	planned	0	0	0	0	0	5,000	2,150	0	0	0	0	0	\$7,150		
	actual					0	0								\$0	\$7,150
INDIRECT COSTS																
43% of exp	planned	0	0	0	0	1,523	3,002	228	559	559	559	559	559	\$7,546		
Exc Equip	actual	0	0	0	0	1,491	3,007	0	0	0	0	0	0		\$4,498	\$3,049
PLANNED TOTALS:																
PER MONTH		0	0	0	0	5,066	14,984	2,802	1,859	1,859	1,859	1,859	1,859	\$32,248		
ACTUAL TOTALS:																
PER MONTH		0	0	0	0	4,959	9,999	0	0	0	0	0	0		\$14,958	\$17,288
CUMULATIVE																
PLANNED TOTALS		0	0	0	0	5,066	20,049	22,851	24,810	26,669	28,528	30,387	32,246	\$32,248		
CUMULATIVE																
ACTUAL TOTALS		0	0	0	0	4,959	14,958	14,958	14,958	14,958	14,958	14,958	14,958		\$14,958	\$17,288
CUMULATIVE																
BUDGET VARIANCE		\$0	\$0	\$0	\$0	\$106	\$5,092	\$7,993	\$9,852	\$11,711	\$13,570	\$15,429	\$17,288			

METC Task # 1.4

Task	Task Name	Duration	%Complete	1994		1995														
						1st Quarter				2nd Quarter			3rd Quarter			4th Quarter			1st Quarter	
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
1	Model Evaluation & Ordering	1M	0.00%			-----						■								
2	Software Acquisition & Installation	1M	0.00%									■								
3	Model Calibration & Data Preparation	1M	0.00%										■							
4	Sensitivity Runs	3M	0.00%										■							
6	Final Report	1M	0.00%														■			

Critical	Noncritical	Complete	Summary	External
Critical Milestone	Noncritical Milestone	Complete Milestone	Summary Milestone	External Milestone
Free Float	Total Float (+)	Total Float (-)	Baseline	Non-Resource
Delay	Effort %Complete			

Contaminat Movement Prediction in Permeable Subsurface Soils

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TASK 1.5: In Situ Formed Barriers - NRCCE Reg. Budget

Development of Standard Test Protocols & Barrier Design Models

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PROJECT: Development of Standard Test Protocols and Barrier Design Models
for In Situ Formed Barriers
** NRCCE - Regular Budget *

METC TASK NO.: 1.5
WVU Act. Nos.: 8527-224-1419
and 8527-224-1420
PERIOD ENDING: 6/30/95

PRINCIPAL INVESTIGATOR: C. Black

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
On Campus - WVU Account No.: 8527-224-1419																
SALARIES	planned	292	292	292	292	292	292	292	292	292	292	292	292	\$3,500		
C. Black	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	\$3,500
BENEFITS	planned	85	85	85	85	85	85	85	85	85	85	85	85	\$1,015		
(20% of Salaries)	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	\$1,015
SUPPLIES	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0		
	actual	0	0	0	0	303	70	0	0	0	0	0	0		\$373	(\$373)
TRAVEL	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0		
	actual	0	0	0	0	494	0	0	0	0	0	0	0		\$494	(\$494)
OTHER	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0		
Cont/Prof SV	actual	3,000	0	0	0	0	0	0	0	0	0	0	0		\$3,000	(\$3,000)
INDIRECT COSTS	planned	162	162	162	162	162	162	162	162	162	162	162	162	\$1,941		
(43% of direct cost)	actual	1,290	0	0	0	343	30	0	0	0	0	0	0		\$1,663	\$278
Planned Sub Totals		538	538	538	538	538	538	538	538	538	538	538	538	\$5,456		
Per Month - On Campus																
Actual Sub Totals		4,290	0	0	0	1,140	100	0	0	0	0	0	0		\$5,630	\$926
Per Month - On Campus																
Off Campus - WVU Account No.: 8527-224-1420																
SARS	planned	392	392	392	392	392	392	0	0	0	0	0	0	\$2,350		
	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	\$2,350
GENERAL	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0		
	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	\$0
TRAVEL	planned	276	276	276	276	276	276	276	276	276	276	276	276	\$3,307		
	actual	0	0	604	0	0	0	0	0	0	0	0	0		\$604	\$2,703
OTHER	planned	83	83	83	83	83	83	83	83	83	83	83	83	\$1,000		
	actual	0	0	224	0	79	0	0	0	0	0	0	0		\$303	\$697
COMM/INFORM	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0		
	actual	0	0	0	0	0	1,298	0	0	0	0	0	0		\$1,298	(\$1,298)
CONT/PROF SV	planned	0	0	0	0	0	0	0	0	0	0	0	0	\$0		
	actual	0	0	0	0	0	0	0	0	0	0	0	0		\$0	\$0
EQUIPMENT	planned	2,250	2,250	2,250	2,250	2,250	2,250	0	0	0	0	0	0	\$13,500		
(Over 500)	actual	0	0	0	0	6,840	0	0	0	0	0	0	0		\$6,840	\$6,660
Sub Contractor	planned	42,749	42,749	42,749	42,749	42,749	42,749	0	0	0	0	0	0	\$258,492		
*BDM	actual	42,749	42,749	42,749	42,749	42,749	42,749	0	0	0	0	0	0		\$258,492	\$0
INDIRECT COSTS	planned	173	173	173	173	173	173	83	83	83	83	83	83	\$1,531		
(23% of direct cost	actual	0	0	190	0	18	288	0	0	0	0	0	0		\$506	\$1,025
*excl equip & sub)																
Planned Sub-Totals		45,922	45,922	45,922	45,922	45,922	45,922	441	441	441	441	441	441	\$278,180		
Per Month - Off Campus																
Actual Sub-Totals		42,749	42,749	43,767	42,749	49,686	44,342	0	0	0	0	0	0		\$266,041	\$12,140
Per Month - Off Campus																
MONTHLY GRAND TOTALS ON & OFF CAMPUS																
PLANNED		48,480	48,480	48,480	48,480	48,480	48,480	980	980	980	980	980	980	284,637		
ACTUAL		47,039	42,749	43,767	42,749	50,826	44,442	0	0	0	0	0	0		271,571	\$13,066
CUMULATIVE GRAND TOTALS ON & OFF CAMPUS																
PLANNED		48,480	92,920	139,380	185,840	232,300	278,760	279,739	280,719	281,698	282,678	283,657	284,637	\$284,637		
ACTUAL		47,039	89,787	133,554	176,303	227,129	271,571	271,571	271,571	271,571	271,571	271,571	271,571		\$271,571	\$13,066
BUDGET VARIANCE		(579)	3,133	5,826	9,537	5,171	7,189	8,169	9,148	10,128	11,107	12,087	13,066			

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1.5e: Standard Test Protocols & Design Models - In Situ Formed Barriers

NRCCE "Extended Budget" - PRINCIPAL INVESTIGATOR: C. Black

PROJECT: Development of Standard Test Protocols and Barrier Design Models
for In Situ Formed Barriers

** NRCCE - Extended Budget *

PRINCIPAL INVESTIGATOR: C. Black

METC TASK NO.: 1.5e

WVU Act. No.: 8527-224-1423

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
C. Black	planned actual	0 0	1,741 1,741	1,741 1,741	1,741 1,741	1,741 1,741	0 0	0 0	924 924					\$7,858	\$6,864	\$924
BENEFITS (29% of Salaries)	planned actual	0 0	505 505	505 505	505 505	505 505	0 0	0 0	268 0					\$2,287	\$2,020	\$268
SUPPLIES	planned actual	554 0	554 0	554 0	554 0	554 0	554 0	554 0	554 554					\$5,311	\$0	\$5,311
TRAVEL	planned actual	1,250 0	1,250 0	1,250 0	1,250 0	1,250 0	1,250 580	1,250 1,250	1,250 1,250					\$10,000	\$580	\$9,420
EQUIPMENT (OVER 500)	planned actual	0 0	0 0	2,200 0	2,200 0	2,200 0	0 0	0 0	0 0					\$6,599	\$0	\$6,599
INDIRECT COSTS																
(43% of direct cost *exc/ equip & sub)	planned actual	823 0	1,789 986	1,789 986	1,789 986	1,789 986	823 249	823 0	1,335 0					\$10,959	\$4,112	\$6,847
PLANNED TOTALS: PER MONTH		2,737	6,148	6,148	6,148	6,148	2,737	2,737	4,440					\$43,044		
ACTUAL TOTALS: PER MONTH		0	3,212	3,212	3,212	3,212	829	0	0						\$13,676	\$29,368
CUMULATIVE PLANNED TOTALS		2,737	8,885	16,033	24,982	33,130	35,867	38,603	43,044					\$43,044		
CUMULATIVE ACTUAL TOTALS		0	3,212	6,423	9,635	12,846	13,676	13,676	13,676						\$13,676	\$29,368
CUMULATIVE BUDGET VARIANCE		\$2,737	\$5,474	\$10,410	\$15,347	\$20,283	\$22,191	\$24,928	\$29,368							

TASK 1.5a: CHEMICAL GROUT - IN-SITU FORMED BARRIERS

PRINCIPAL INVESTIGATOR: M. A. Gabr

■ PLANNED SPENDING ♦ ACTUAL SPENDING

PROJECT: Development of Standard Test Protocols and Barrier Design Models
for In-Situ Formed Barriers

METC TASK NO.: 1.5a
WVU Act. Nos.: 8527-229-3236 & 3239

CIVIL & ENVIRONMENTAL ENGINEERING - DETAILED BUDGET

PRINCIPAL INVESTIGATOR(S): M. Gabr & B. Reed

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
***** ON-CAMPUS ***** WVU Act. No.: 8527-229-3236																
SALARIES																
Faculty	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	1,500 0	1,500 0	1,500 0	1,500 0	1,500 0	1,500 0	\$9,000	\$0	\$9,000
Secretary	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	362 0	362 0	362 0	362 0	362 0	362 0	\$2,173	\$0	\$2,173
BENEFITS 29% of Salaries	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	540 0	540 0	540 0	540 0	540 0	540 0	3,240	\$0	\$3,240
STUDENTS	planned actual	0 0	0 0	0 0	0 0	200 200	900 900	2,060 0	1,435 0	850 0	850 0	850 0	850 0	\$9,015	\$1,100	\$8,915
INDIRECT COSTS @ 43%	planned actual	0 0	0 0	0 0	0 0	88 88	387 387	1,919 0	1,659 0	1,398 0	1,398 0	1,398 0	1,398 0	\$9,644	\$473	\$9,171
SUB-TOTAL ON-CAMPUS	planned actual	0 0	0 0	0 0	0 0	288 288	1,287 1,287	5,381 0	5,516 0	4,851 0	4,851 0	4,851 0	4,851 0	\$32,072	\$1,573	\$30,499
***** OFF-CAMPUS ***** WVU Act. No.: 8527-229-3239																
SALARIES																
	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	1,301 0	2,240 0	2,240 0	2,240 0	2,240 0	2,240 0	\$12,501	\$0	\$12,501
BENEFITS 29% of Salaries	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	377 0	650 0	650 0	650 0	650 0	650 0	\$3,825	\$0	\$3,825
STUDENTS	planned actual	0 0	0 0	0 0	0 0	1,875 1,875	5,870 5,870	8,314 0	6,444 0	4,575 0	4,575 0	4,575 0	4,575 0	\$40,603	\$7,545	\$33,058
SUPPLIES	planned actual	5,000 4,639	1,000 1,047	308 2,875	0 800	0 526	0 2,812	0 0	0 0	0 0	0 0	0 0	0 0	\$8,308	\$12,698	(\$8,392)
COMMINFO	planned actual	0 0	0 0	0 0	0 0	0 0	300 283	0 0	0 0	0 0	0 0	0 0	0 0	\$300	\$283	\$17
TRAVEL	planned actual	250 0	250 0	250 0	250 0	250 0	250 0	250 0	250 0	250 0	250 0	250 0	250 0	\$3,000	\$0	\$3,000
EQUIPMENT (No Overhead)	planned actual	5,000 3,133	1,000 0	1,000 557	1,000 0	1,000 0	1,000 70	7,000 0	7,000 0	7,000 0	7,000 0	7,000 0	0	\$45,000	\$3,760	\$41,240
INDIRECT COSTS 23% of exp	planned actual	1,208 1,087	288 241	128 681	58 184	443 508	1,477 2,082	2,358 0	2,204 0	1,774 0	1,774 0	1,774 0	1,774 0	\$15,257	\$4,721	\$10,536
SUB-TOTAL OFF-CAMPUS	planned actual	11,458 8,839	2,538 1,288	1,684 4,093	1,308 984	3,388 2,707	8,897 11,098	16,998 0	18,788 0	16,489 0	16,489 0	16,489 0	16,489 0	\$128,592	\$29,006	\$97,586
PLANNED TOTALS: PER MONTH		11,458	2,538	1,684	1,308	3,654	10,184	25,878	24,304	21,140	21,140	21,140	14,140	158,685		
ACTUAL TOTALS: PER MONTH		8,839	1,288	4,093	984	2,993	12,383	0	0	0	0	0	0		30,579	\$128,085
CUMULATIVE PLANNED TOTALS		11,458	13,995	15,679	16,988	20,640	30,824	58,802	81,108	102,248	123,385	144,525	158,665	\$158,665		
CUMULATIVE ACTUAL TOTALS		8,839	10,127	14,219	15,203	18,196	30,579	30,579	30,579	30,579	30,579	30,579	30,579		\$30,579	\$128,085
CUMULATIVE BUDGET VARIANCE		\$2,619	\$3,868	\$1,460	\$1,783	\$2,444	\$244	\$28,223	\$50,527	\$71,668	\$92,808	\$113,946	\$128,085			

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TASK 1.5ae: CHEMICAL GROUT- IN SITU FORMED BARRIERS

PRINCIPAL INVESTIGATORS: M. Gabr and B. Reed - *Extende Budget*

■ PLANNED SPENDING ◇ — ACTUAL SPENDING

**PROJECT: Development of Standard Test Protocols and Barrier Design Models
for In-Situ Formed Barriers - CHEMICAL GROUT**

METC TASK NO.: 1.5ae
WVU Act. No.: 8527-229-3238

CIVIL & ENVIRONMENTAL ENGINEERING - DETAILED **EXTENDEDBUDGET**
PRINCIPAL INVESTIGATORS): M. Gabr & B. Reed

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
***** ON-CAMPUS *****																
STUDENTS	planned actual	1,484 860	1,484 1,000	1,484 1,369	1,484 1,677	1,484 2,557	1,484 1,330	1,484	1,484 0					\$11,870	\$8,783	\$3,088
SUPPLIES	planned actual	2,300 1,862	800 760	2,000 2,179	200 105	2,000 2,199	1,000 996	200	0					\$8,500	\$8,100	\$400
EQUIPMENT (Under \$500)	planned actual	0 444	0 0	0 200	0 0	0 0	0 315	0	0					\$0	\$959	(\$959)
EQUIPMENT (Over \$500)	planned actual	0 0	0 0	200 0	300 0	1,000 921	2,000 1,590	0	0					\$3,500	\$2,511	\$989
INDIRECT COSTS 43% of exp	planned actual	1,627 1,357	982 757	1,498 1,612	724 766	1,498 2,045	1,068 1,136	724 0	638 0					\$8,759	\$7,672	\$1,087
PLANNED TOTALS: PER MONTH		5,411	3,266	5,182	2,708	5,982	5,552	2,408	2,122					32,629		
ACTUAL TOTALS: PER MONTH		4,513	2,516	5,360	2,547	7,722	5,367	0	0						28,025	\$4,604
CUMULATIVE PLANNED TOTALS		5,411	8,677	13,859	16,566	22,548	28,100	30,507	32,629					\$32,629		
CUMULATIVE ACTUAL TOTALS		4,513	7,029	12,389	14,936	22,658	28,025	28,025	28,025						\$28,025	\$4,604
CUMULATIVE BUDGET VARIANCE		\$898	\$1,647	\$1,469	\$1,630	(\$110)	\$75	\$2,483	\$4,604							

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TASK 1.5b: CIRCULATING AIR BARRIERS

PRINCIPAL INVESTIGATORS: S. Ameri, K. Aminian and D. Molnar

Task 1.5: Development of Standard Test Protocols and Barrier Design Models for In-Situ Formed Barriers

PROJECT: Development of Standard Test Protocols and Barrier Design Models
for In-Situ Formed Barriers

METC TASK NO.: 1.5b

ORGS: 0416 & 0433

PETROLEUM ENGINEERING - DETAILED *Regular* BUDGET for CIRCULATING AIR BARRIERS

PRINCIPAL INVESTIGATORS): S. Ameri, K. Amnian and D. Molnar

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
***** ON-CAMPUS ***** WVU Act. No.: 8527-255-0416																
SALARIES																
K. Amnian	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	2,457 0	7,852 0	3,165 0	0 0	0 0	0 0	\$13,485	\$0	\$13,485
S. Mohaghegh	planned actual	0 0	0 0	0 0	0 0	2,355 2,355	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$2,355	\$2,355	\$0
S. Ameri	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2,914 0	2,752 0	0 0	0 0	0 0	\$5,666	\$0	\$5,666
BENEFITS 20% of Salaries	planned actual	0 0	0 0	0 0	0 0	683 683	0 0	713 0	3,122 0	1,713 0	0 0	0 0	0 0	\$5,231	\$683	\$5,548
INDIRECT COSTS 43% of exp	planned actual	0 0	0 0	0 0	0 0	1,306 1,306	0 0	1,383 0	5,972 0	3,277 0	0 0	0 0	0 0	\$11,918	\$1,306	\$10,612
SUB-TOTAL ON-CAMPUS	planned actual	0 0	0 0	0 0	0 0	4,344 4,344	0 0	4,532 0	19,800 0	10,898 0	0 0	0 0	0 0	\$39,635	\$4,344	\$35,291
***** OFF-CAMPUS ***** WVU Act. No.: 8527-255-0433																
SALARIES																
D. Molnar	planned actual	0 0	0 0	0 0	2,450 2,325	2,450 2,450	2,450 2,450	2,617 0	2,617 0	614 0	0 0	0 0	0 0	\$13,108	\$7,225	\$5,883
BENEFITS 20% of Salaries	planned actual	0 0	0 0	0 0	711 674	711 711	711 711	759 0	759 0	178 0	0 0	0 0	0 0	\$3,827	\$2,095	\$1,732
STUDENTS 3 Graduate	planned actual	0 0	0 0	0 0	3,000 2,300	3,000 2,300	3,000 1,150	3,000 0	3,000 0	3,003 0	0 0	0 0	0 0	\$18,003	\$5,750	\$12,253
TRAVEL	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	1,687 0	1,687 0	1,687 0	0 0	0 0	0 0	\$5,000	\$0	\$5,000
OTHER	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	190 0	190 0	190 0	190 0	190 0	0 0	\$952	\$0	\$952
EQUIPMENT (No Overhead)	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	2,500 0	2,500 0	2,500 0	2,500 0	2,500 0	0 0	\$12,500	\$0	\$12,500
INDIRECT COSTS 23% of exp	planned actual	0 0	0 0	0 0	1,417 1,219	1,417 1,258	1,417 961	1,894 0	1,894 0	1,300 0	44 0	44 0	0 0	\$9,426	\$3,486	\$5,940
SUB-TOTAL OFF-CAMPUS	planned actual	0 0	0 0	0 0	7,577 6,518	7,577 6,716	7,577 5,302	12,627 0	12,627 0	8,452 0	2,734 0	2,734 0	0 0	\$62,906	\$18,536	\$44,370
PLANNED TOTALS: PER MONTH		0	0	0	7,577	11,022	7,577	17,159	32,487	20,361	2,734	2,734	0	102,541		
ACTUAL TOTALS: PER MONTH		0	0	0	6,518	11,061	5,302	0	0	0	0	0	0		22,681	\$79,660
CUMULATIVE PLANNED TOTALS OVERALL		0	0	0	7,577	19,499	27,077	44,236	76,722	97,073	99,807	102,541	102,541	\$102,541		
CUMULATIVE ACTUAL TOTALS		0	0	0	6,518	17,579	22,881	22,881	22,881	22,881	22,881	22,881	22,881		\$22,881	\$79,660
CUMULATIVE BUDGET VARIANCE		\$0	\$0	\$0	\$1,059	\$1,920	\$4,198	\$21,355	\$53,841	\$74,192	\$76,926	\$79,660	\$79,660			

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TASK 1.5be: CIRCULATING AIR BARRIERS

PRINCIPAL INVESTIGATORS: S. Ameri, K. Aminian and D. Molnár - *Extended Budget

**PROJECT: Development of Standard Test Protocols and Barrier Design Models
for In-Situ Formed Barriers - Circulating Air Barriers**

METC TASK NO.: 1.5be
WVU Act. No.: 8527-255-0427

PETROLEUM ENGINEERING - Detailed ** EXTENDED Budget**
PRINCIPAL INVESTIGATORS): S. Ameri, K. Amnian and D. Molnar

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
***** ON-CAMPUS *****																
SALARIES																
S. Ameri	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	6,878 0	3,964 0					\$10,842	\$0	\$10,842
S. Mohaghegh	planned actual	0 0	0 0	2,980 2,667	2,980 2,980	0 312	0 0	0 0	0 0					\$5,960	\$5,959	\$1
BENEFITS 29% of Salaries	planned actual	0 0	0 0	864 773	864 864	0 90	0 0	1,996 0	1,150 0					\$4,873	\$1,728	\$3,144
GENERAL	planned actual	0 0	0 0	300 0	300 269	300 0	300 480	300 0	93 0					\$1,593	\$749	\$844
EQUIPMENT (Under \$500)	planned actual	0 0	0 0	0 0	0 0	0 278	0 0	0 0	0 0					\$0	\$278	(\$278)
EQUIPMENT (Over \$500)	planned actual	0 0	0 0	0 0	0 0	300 0	3,000 3,960	497 0	0 0					\$3,797	\$3,960	(\$163)
INDIRECT COSTS 43% of exp	planned actual	0 0	0 0	1,782 1,479	1,782 1,769	129 293	129 206	3,944 0	2,239 0					\$10,005	\$3,747	\$6,258
PLANNED TOTALS: PER MONTH		0	0	5,926	5,926	729	3,429	13,614	7,445					37,070		
ACTUAL TOTALS: PER MONTH		0	0	4,920	5,882	973	4,646	0	0						16,422	\$20,648
CUMULATIVE PLANNED TOTALS		0	0	5,926	11,852	12,581	16,010	29,624	37,070					\$37,070		
CUMULATIVE ACTUAL TOTALS		0	0	4,920	10,802	11,776	16,422	16,422	16,422						\$16,422	\$20,648
CUMULATIVE BUDGET VARIANCE		\$0	\$0	\$1,006	\$1,050	\$806	(\$412)	\$13,202	\$20,648							

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Project Name: Task 1.5 Barrier Project

WBS	Task Name	Dura	% Compl	1994												1995											
				Qtr2			Qtr3			Qtr4			Qtr1			Qtr2			Qtr3			Qtr4					
				Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan				
1.0	SARS COMPLIANCE / NEPA DOC.	3311h	25.23%																								
1.1	NEPA DOCUMENTATION	87h	100.00%																								
1.2	CONSTRUCTION PERMIT	435h	100.00%																								
1.3	OPERATING PERMIT (NRCCE)	174h	33.00%																								
1.4	GTC/CAB CONSTRUCTION PERMIT	174h	0.00%																								
1.5	GTC/CAB OPERATING PERMIT	0h	0.00%																								
1.6	PERMIT RENEWAL	0h	0.00%																								
2.0	LITERATURE REVIEW	522h	100.00%																								
2.1	BARRIER SYSTEM TECHNOLOGY ISSUES	348h	100.00%																								
2.2	PUF MATERIALS & APPLICATION	348h	100.00%																								
2.3	CAB CONCEPTS & APPLICATION	348h	100.00%																								
3.0	LAB EQUIPMENT & PRELIM. TESTING	2080h	85.00%																								
3.1	DESIGN GTC/CAB	174h	100.00%																								
3.2	ASSEMBLE GTC/CAB	522h	0.00%																								
4.0	BASIC MATERIAL PROPERTIES & TESTIN	1040h	80.00%																								
5.0	PRELIMINARY BARRIER EXPERIMENTATI	1040h	100.00%																								
6.0	SCALED MODEL EXPERIMENTATION	1215h	13.70%																								
7.0	DATA ANALYSIS & RECOMMENDATIONS	1215h	13.70%																								
8.0	DELIVERABLES	2080h	25.00%																								
8.1	NEPA DOCUMENT	0h	100.00%																								
8.2	SMALL SCALE CONST. PERMIT	0h	100.00%																								
8.3	LITERATURE REVIEW REPORTS	0h	100.00%																								
8.4	SMALL SCALE OPER. PERMIT	0h	0.00%																								
8.5	GTC/CAB CONSTR. PERMIT	0h	0.00%																								
8.6	GTC/CAT OPER. PERMIT	0h	0.00%																								
8.7	PHASE I FINAL REPORT	0h	0.00%																								
8.8	PUF RESULTS	0h	0.00%																								
8.9	CAB RESULTS	0h	0.00%																								
9.0	PROGRAM ADMINISTRATION	3311h	56.76%																								

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2.0 ADVANCED PRODUCT APPLICATIONS TESTING

TASK 2.1: Chemical Destruction of Chlorinated Organic Compounds

PRINCIPAL INVESTIGATOR: Kung Wang

PROJECT: Chemical Destruction of Chlorinated Organic Compounds

METC TASK NO.: 2.1

WVU Act. No.: 8527-211-0625

PRINCIPAL INVESTIGATOR: Kung Wang

PERIOD ENDING: Set up

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
SALARIES																
K. Wang	planned	0	0	0	0	2,303	2,303	0	0	0	0	0	0	\$4,606		
	actual	0	0	0	0	2,303	2,303								\$4,606	\$0
BENEFITS																
29% of Salaries	planned	0	0	0	0	668	668	0	0	0	0	0	0	\$1,336		
	actual	0	0	0	0	668	668	0	0	0	0	0	0		\$1,336	\$0
STUDENTS																
3 Graduates	planned	950	950	950	950	1,900	2,850	2,850	2,850	2,850	2,850	2,850	2,850	\$25,650		
	actual	0	0	0	3,800	1,900	2,850								\$8,650	\$17,100
SUPPLIES	planned	0	0	500	500	500	500	500	500	500	500	500	500	\$5,000		
	actual	0	0	0	367	667	858								\$1,892	\$3,108
ANALYSIS	planned	500	500	500	500	500	500	500	500	500	500	500	500	\$6,000		
	actual	0	0	0	117	0	0								\$117	\$5,883
TRAVEL	planned	0	0	0	0	0	0	500	500	0	0	0	0	\$1,000		
	actual	0	0	0	0	0	0								\$0	\$1,000
EQUIPMENT	planned	0	0	0	0	0	2,000	2,000	1,374	0	0	0	0	\$5,374		
	actual	0	0	0	0	0	0								\$0	\$5,374
INDIRECT COSTS																
43% of exp Exc Equip	planned	624	624	839	839	2,524	2,933	1,871	1,871	1,656	1,656	1,656	1,656	\$18,744		
	actual	0	0	0	1,842	2,381	2,872	0	0	0	0	0	0		\$7,095	\$11,649
PLANNED TOTALS:																
PER MONTH		2,074	2,074	2,789	2,789	8,395	11,754	8,221	7,595	5,506	5,506	5,506	5,506	\$67,710		
ACTUAL TOTALS:																
PER MONTH		0	0	0	6,127	7,919	9,561	0	0	0	0	0	0		\$23,596	\$44,114
CUMULATIVE																
PLANNED TOTALS		2,074	4,147	6,936	9,724	18,119	29,873	38,094	45,688	51,194	56,699	62,205	67,710	\$67,710		
CUMULATIVE																
ACTUAL TOTALS		0	0	0	6,127	14,046	23,596	23,596	23,596	23,596	23,596	23,596	23,596		\$23,596	\$44,114
CUMULATIVE																
BUDGET VARIANCE		\$2,074	\$4,147	\$6,936	\$3,597	\$4,074	\$6,277	\$14,497	\$22,092	\$27,597	\$33,103	\$38,608	\$44,114			

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TASK 2.1e: Chemical Destruction of Chlorinated Organic Compounds

PRINCIPAL INVESTIGATOR: Kung Wang - EXTENDED BUDGET

PROJECT: Chemical Destruction of Chlorinated Organic Compounds

METC TASK NO.: 2.1E

**** Extended Budget ****

PRINCIPAL INVESTIGATOR: Kung Wang

PERIOD ENDING: 6-30-95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMOUNT REMAINING
SALARIES																
K. Wang	planned	0	0	0	2,800	0	0							\$2,800		
	actual	0	0	0	2,800	0	0								\$2,800	\$0
BENEFITS																
29% of Salaries	planned	0	0	0	812	0	0							\$812		
	actual	0	0	0	812	0	0								\$812	\$0
GENERAL																
	planned	0	0	0	0	0	0							\$0		
	actual	0	0	60	0	0	(60)								\$0	\$0
TRAVEL																
	planned	0	0	0	0	0	0							\$0		
	actual	0	0	0	0	0	0								\$0	\$0
EQUIPMENT																
	planned	0	0	3,392	0	0	0							\$3,392		
	actual	0	0	0	0	0	3,392								\$3,392	\$0
INDIRECT COSTS																
43% of exp	planned	0	0	0	1,553	0	0							\$1,553		
Exc Equip	actual	0	0	26	1,553	0	(26)								\$1,553	\$0
PLANNED TOTALS:																
PER MONTH		0	0	3,392	5,165	0	0							\$8,557		
ACTUAL TOTALS:																
PER MONTH		0	0	86	5,165	0	3,306								\$8,557	\$0
CUMULATIVE																
PLANNED TOTALS		0	0	3,392	8,557	8,557	8,557							\$8,557		
CUMULATIVE																
ACTUAL TOTALS		0	0	86	5,251	5,251	8,557								\$8,557	\$0
CUMULATIVE																
BUDGET VARIANCE		\$0	\$0	\$3,306	\$3,306	\$3,306	\$0									

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METC Task # 2.1

Task	Task Name	Duration	%Complete	1995												1996		
				1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter		
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	Synthesis of Monomers	3M	100.00%	█	█	█												
2	Synthesis of Polymers	3M	75.00%	█	█	█												
3	Survey Dechlorination Technology	3M	0.00%	█	█	█												
4	PCBs Analysis Procedure	1M	100.00%	█														
5	Dechlorination by a Chemical Process	4M	0.00%	█	█	█	█											
6	Reports	12M	50.00%	█	█	█	█	█	█	█	█	█	█	█	█			
7	Quarterly Report 1	0d	100.00%				◆											
8	Quarterly Report 2	0d	100.00%							◆								
9	Quarterly Report 3	0d	0.00%									◆						
10	Final Report	1M	0.00%													█		
11	Overall Work Complete	12M	54.17%	█	█	█	█	█	█	█	█	█	█	█	█			

█ Critical ◆ Critical Milestone █ Complete █ Summary █ External
 ◆ Noncritical Milestone ◆ Noncritical Milestone ● Complete Milestone ◆ Summary Milestone ● External Milestone
 █ Free Float █ Total Float (+) █ Total Float (-) █ Baseline Non-Resource
 Delay ▲ Effort %Complete

Chemical Destruction of Chlorinated Organic Compounds

TASK 2.2: Atmospheric Monitoring Mass Spectrometry

PRINCIPAL INVESTIGATOR: Fred King

■ PLANNED SPENDING ◇ -- ACTUAL SPENDING

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PROJECT: Continued Development of an Atmospheric Monitoring Mass Spectrometry

METC TASK NO.: 2.2

WVU Act. No.: 8527-211-0623

PRINCIPAL INVESTIGATOR: Fred King

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
SALARIES																
Fred King	planned actual	0 0	0 0	0 0	0 0	2,060 2,060	4,120 4,120	4,120 4,120	2,060 2,060	0 0	0 0	0 0	0 0	\$12,360	\$6,180	\$6,180
Technician	planned actual	0 0	0 0	0 0	0 0	1,771 814	1,771 1,393	1,771 1,771	1,771 1,771	1,771 1,771	1,771 1,771	1,771 1,771	0 0	\$12,400	\$2,207	\$10,193
BENEFITS																
29% of Salaries	planned actual	0 0	0 0	0 0	0 0	1,111 833	1,709 1,599	1,709 0	1,111 0	514 0	514 0	514 0	0 0	\$7,180	\$2,432	\$4,748
STUDENTS and NON- BENEFIT SALARIES																
2 Graduate Students	planned actual	0 0	0 0	0 0	0 0	1,100 1,100	2,200 2,200	2,200 2,200	1,100 1,100	0 0	0 0	0 0	0 0	\$6,600	\$3,300	\$3,300
Technicians	planned actual	0 0	0 0	0 0	0 0	1,600 2,558	2,400 4,379	800 800	400 400	0 0	0 0	0 0	0 0	\$5,200	\$8,937	(\$1,737)
SUPPLIES	planned actual	0 0	0 0	0 0	0 0	1,100 0	1,100 1,139	804 804	804 804	804 804	804 804	804 804	0 0	\$8,220	\$1,139	\$5,082
TRAVEL	planned actual	0 0	0 0	0 0	0 0	1,500 0	0 1,109	400 400	200 200	200 200	200 200	0 0	0 0	\$2,500	\$1,109	\$1,391
INDIRECT COSTS																
43% of exp Exc Equip	planned actual	0 0	0 0	0 0	0 0	4,404 3,167	5,719 6,864	5,078 0	3,202 0	1,414 0	1,414 0	1,328 0	0 0	\$22,559	\$10,021	\$12,537
PLANNED TOTALS: PER MONTH		0	0	0	0	14,647	18,019	18,880	10,649	4,704	4,704	4,418	0	\$75,019		
ACTUAL TOTALS: PER MONTH		0	0	0	0	10,533	22,792	0	0	0	0	0	0		\$33,325	\$41,694
CUMULATIVE PLANNED TOTALS		0	0	0	0	14,647	33,666	50,545	61,194	65,898	70,601	75,019	75,019	\$75,019		
CUMULATIVE ACTUAL TOTALS		0	0	0	0	10,533	33,325	33,325	33,325	33,325	33,325	33,325	33,325		\$33,325	\$41,694
CUMULATIVE BUDGET VARIANCE		\$0	\$0	\$0	\$0	\$4,114	\$341	\$17,221	\$27,869	\$32,573	\$37,276	\$41,694	\$41,694			

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METC Task # 2.2

Task	Task Name	Duration	% Compl	1995														
				1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			1st Quarter		
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	Purchase Standards	1M	100.00%	■														
2	Hydrocarbon Determination	5M	21.25%		■	■	■	■	■									
3	Ethylbenzene/xylenes	2M	25.00%		■	■	■	■	■									
4	Ionization Optimization	3M	60.00%			■	■	■	■									
5	Environmental Interferences	2M	0.00%					■	■									
6	Winfield Demonstration	1M	0.00%						■									
7	Halogenated Hydrocarbon Determination	6M	16.67%						■	■	■	■	■	■				
8	Ionization Optimization	3M	50.00%						■	■	■							
9	Interference Evaluation	3M	0.00%							■	■	■						
10	Interference Amelioration	4M	0.00%								■	■	■	■				
11	Report Writing	12M	50.00%	■	■	■	■	■	■	■	■	■	■	■	■			
12	Quarterly Report 1	0d	100.00%				◆											
13	Quarterly Report 2	0d	100.00%							◆								
14	Quarterly Report 3	0d	0.00%									◆						
15	Final Report	0d	0.00%													◆		
16	Overall Work Complete	12M	46.98%	■	■	■	■	■	■	■	■	■	■	■	■			

■ Critical ■ Noncritical ■ Complete □ Summary ■ External
 ◆ Critical Milestone ◇ Noncritical Milestone ◆ Complete Milestone ◇ Summary Milestone ◆ External Milestone
 ▨ Free Float ▨ Total Float (+) ▨ Total Float (-) — Baseline Non-Resource
 Delay ▲ Effort %Complete

Continued Development on an Atmospheric Monitoring Mass Spectrometry System

TASK 2.3: Capture of Hazardous Materials Utilizing Fluidization Coating Technology

PRINCIPAL INVESTIGATORS: Richard Turton

PROJECT: Capture of Hazardous Waste Materials Utilizing Fluidization Coating Technology

METC TASK NO.: 2.3

WVU Act. No.: 8527-229-1792

PRINCIPAL INVESTIGATORS): Richard Turton

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
SALARIES																
R. Turton	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	1,046 0	1,046 0	1,046 0	1,046 0	1,046 0	1,047 0	\$6,277	\$0	6,277
BENEFITS																
29% of Salaries	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	303 0	303 0	303 0	303 0	303 0	304 0	\$1,820	\$0	1,820
STUDENTS																
1 Graduate	planned actual	0 0	0 0	0 0	0 0	750 0	750 0	750 0	750 0	750 0	750 0	750 0	750 0	\$6,000	\$0	6,000
SUPPLIES																
1	planned actual	0 0	0 0	0 0	0 0	400 0	400 897	400 0	400 0	300 0	300 0	300 0	0 0	\$2,500	\$997	1,503
TRAVEL																
1	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1,000 0	0 0	\$1,000	\$0	1,000
SUBCONTRACT																
1	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	400 0	400 0	200 0	\$1,000	\$0	1,000
EQUIPMENT (No Overhead)																
1	planned actual	0 0	0 0	0 0	0 0	2,500 0	500 3,136	500 0	500 0	0 0	0 0	0 0	0 0	\$4,000	\$3,136	864
INDIRECT COSTS																
43% of exp Exc Equip	planned actual	0 0	0 0	0 0	0 0	496 0	496 429	1,076 0	1,076 0	1,032 0	1,204 0	1,634 0	868 0	\$7,997	\$429	7,568
PLANNED TOTALS: PER MONTH																
		0	0	0	0	4,145	2,145	4,074	4,074	3,431	4,003	6,433	3,280	\$30,594		
ACTUAL TOTALS: PER MONTH																
		0	0	0	0	0	4,562	0	0	0	0	0	0		\$4,562	\$26,032
CUMULATIVE PLANNED TOTALS																
		0	0	0	0	4,145	6,290	10,363	14,437	17,868	21,871	27,304	30,584	\$30,594		
CUMULATIVE ACTUAL TOTALS																
		0	0	0	0	0	4,562	4,562	4,562	4,562	4,562	4,562	4,562		\$4,562	26,032
CUMULATIVE BUDGET VARIANCE																
		\$0	\$0	\$0	\$0	\$4,145	\$1,727	\$5,801	\$9,875	\$13,306	\$17,309	\$22,742	\$26,032			

METC Task # 2.3

#	Task Name	Dura	%Compl	1994																		1995																	
				1st Quarter				2nd Quarter				3rd Quarter				4th Quarter				1st Quarter				2nd															
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr																			
1	Design of Fluid Bed System	4M	100.00%																																				
2	Construction of Fluid Bed	4M	60.00%																																				
3	Chose Model Chems & Patrs	2M	100.00%																																				
4	Production fo Coated Sollds	4M	0.00%																																				
10	Evaluation of Coating Efficy.	3M	0.00%																																				
9	Report Preparation	12M	50.00%																																				
5	Report 1	0M	100.00%					◆																															
6	Report 2	0M	100.00%								◆																												
7	Report 3	0M	0.00%										◇																										
8	Annual Report - Year 1 (Final Report)	0M	0.00%														◇																						
11	Overall Work Completed	14M	35.00%																																				

Critical
 Critical Milestone
 Free Float
 Delay
 Noncritical
 Noncritical Milestone
 Total Float (+)
 Total Float (-)
 Complete
 Complete Milestone
 Summary
 Summary Milestone
 Baseline
 External
 External Milestone
 Non-Resource

Capture of Haz. Chemical Waste Mat. Utilizing Fluidization Coating Technology

TASK 2.4: Soil Decontamination by Steam Reforming

PRINCIPAL INVESTIGATOR: R. Lovette

PROJECT: Soil Decontamination by Steam Reforming

METC TASK NO.: 2.4

WVU Act. No.: 8527-224-1427

PRINCIPAL INVESTIGATOR: R. Lovette

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES	planned actual	432 0	432 0	432 0	432 0	432 0	432 0	432 0	432 0	432 0	432 0	432 0	432 0	\$5,182	\$0	\$5,182
BENEFITS (29% of Salaries)	planned actual	125 0	125 0	125 0	125 0	125 0	125 0	125 0	125 0	125 0	125 0	125 0	125 0	\$1,503	\$0	\$1,503
SUPPLIES	planned actual	42 65	42 292	42 677	42 0	42 0	42 0	42 0	42 0	42 0	42 0	42 0	42 0	\$500	\$1,034	(\$534)
TRAVEL	planned actual	417 0	417 0	417 0	417 0	417 0	417 0	417 0	417 0	417 0	417 0	417 0	417 0	\$5,000	\$0	\$5,000
SUB-CONTRACT (Under 25K)	planned actual	0 0	0 0	0 0	0 0	0 0	25,000 0	0 0	0 0	0 0	0 0	0 0	0 0	\$25,000	\$0	\$25,000
SUB-CONTRACT (Over 25K)	planned actual	52,392 38,439	52,392 63,067	52,392 36,748	52,392 35,436	52,392 51,699	27,392 31,154	0 0	0 0	0 0	0 0	0 0	0 0	\$289,353	\$256,633	\$32,820
INDIRECT COSTS																
(43% of direct cost *exc/ equip & sub)	planned actual	437 28	437 126	437 291	437 0	437 0	11,187 0	437 0	437 0	437 0	437 0	437 0	437 0	\$15,989	\$445	\$15,545
PLANNED TOTALS: PER MONTH		53,844	53,844	53,844	53,844	53,844	84,594	1,452	1,452	1,452	1,452	1,452	1,452	\$342,527		
ACTUAL TOTALS: PER MONTH		38,532	63,475	37,716	35,436	51,699	31,154	0	0	0	0	0	0		\$258,011	\$84,516
CUMULATIVE PLANNED TOTALS		53,844	107,688	161,533	215,377	269,221	333,815	335,267	336,719	338,171	339,623	341,075	342,527	\$342,527		
CUMULATIVE ACTUAL TOTALS		38,532	102,007	139,723	175,159	226,858	258,011	258,011	258,011	258,011	258,011	258,011	258,011		\$258,011	\$84,516
CUMULATIVE BUDGET VARIANCE		\$15,312	\$5,682	\$21,809	\$40,218	\$42,363	\$75,804	\$77,256	\$78,708	\$80,160	\$81,612	\$83,064	\$84,516			

[1] Program/Project Identification No. DE-FC21-90MC29467	[2] Program/Project Title Decontamination Systems Information and Research Program	[3] Reporting Period April - June 1995
[4] Name and Address Manufacturing and Technology Conversion International, Inc. P.O. Box 21, Columbia, MD 21045		[5] Program/Project Start Date June 17, 1993
		[6] Completion Date December 31, 1995

[illegible]

112	Remarks
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Signature of Recipient and Date <i>[Signature]</i> 7/26/95	[14] Signature of DOE Reviewing Representative and Date
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TASK 2.5: Carbon Products for Waste Stream Clean-up

PRINCIPAL INVESTIGATOR: C. Irwin - NRCCE Budget

TASK 2.5e: Carbon Products for Waste Steam Clean up

PRINCIPAL INVESTIGATOR: C. Irwin - NRCCE *Extended Budget

■ PLANNED SPENDING ◇ -- ACTUAL SPENDING

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PROJECT: Carbon Products for Waste Stream Clean up
 NRCCE - **Extended Budget
 PRINCIPAL INVESTIGATOR: C. Irwin

METC TASK NO.: 2.5e
 WVU Act. No.: 8527-224-1428
 PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
C. Irwin	planned actual	980 0	980 0	980 0	980 0	980 0	980 5,879							\$5,879	\$5,879	\$0
M. Reda	planned actual	315 0	315 0	315 0	315 0	315 1,112	315 778							\$1,890	\$1,890	(\$0)
Staff	planned actual	161 0	161 0	161 0	161 0	161 0	161 963							\$966	\$963	(\$17)
BENEFITS (29% of Salaries)	planned actual	422 0	422 0	422 0	422 0	422 322	422 2,216							\$2,533	\$2,538	(\$5)
SUPPLIES	planned actual	0 0	0 0	0 0	0 46	0 0	0 0							\$0	\$46	(\$46)
TRAVEL	planned actual	92 0	92 0	92 0	92 50	92 0	92 0							\$554	\$50	\$504
INDIRECT COSTS																
(43% of direct cost *exc sub contract)	planned actual	847 0	847 0	847 0	847 41	847 617	847 4,238							\$5,083	\$4,896	\$188
PLANNED TOTALS: PER MONTH		2,817	2,817	2,817	2,817	2,817	2,817							\$16,905		
ACTUAL TOTALS: PER MONTH		0	0	0	136	2,051	14,093								\$16,281	\$624
CUMULATIVE PLANNED TOTALS		2,817	5,635	8,452	11,270	14,087	16,905							\$16,905		
CUMULATIVE ACTUAL TOTALS		0	0	0	136	2,187	16,281								\$16,281	\$624
CUMULATIVE BUDGET VARIANCE		\$2,817	\$5,635	\$8,452	\$11,134	\$11,900	\$624	\$0	\$0	\$0	\$0	\$0	\$0			

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TASK 2.5: Carbon Products for Waste Stream Clean-up

** DETAILED REPORT FOR CHEMICAL ENGINEERING - Regular Budget - PI: John Zondlo

PROJECT: Carbon Products for Waste Stream Clean-up
Chemical Engineering - Detailed REGULAR Budget
PRINCIPAL INVESTIGATOR: John Zondolo

METC TASK NO.: 2.5
WVU Act. No.: 8527-229-1793
PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
SALARIES																
Stillier/Zondolo	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	5,161 0	0 0	0 0	0 0	0 0	0 0	\$5,161	\$0	\$5,161
Brennstelner	planned actual	0 0	0 0	0 0	2,292 2,292	2,292 2,292	2,292 2,292	2,292 2,292	2,292 2,292	2,292 2,292	0 0	0 0	0 0	\$13,752	\$6,876	\$6,876
Finklea	planned actual	0 0	0 0	50 51	50 0	50 0	50 0	50 0	100 0	100 0	100 0	0 0	0 0	\$550	\$51	\$499
Technician	planned actual	0 0	0 0	0 0	1,670 1,670	1,670 1,670	1,670 1,670	1,670 1,670	1,670 1,670	1,670 1,670	0 0	0 0	0 0	\$10,020	\$5,010	\$5,010
Clerical/Misc	planned actual	0 0	0 0	1,200 1,136	300 0	300 0	251 915	0 0	0 0	0 0	0 0	0 0	0 0	\$2,051	\$2,051	\$0
BENEFITS																
29% of Salaries	planned actual	0 0	0 0	363 344	1,250 1,149	1,250 1,149	1,236 1,414	2,660 0	1,178 0	1,178 0	29 0	0 0	0 0	\$9,145	\$4,057	\$5,088
STUDENTS																
Graduate Assistant	planned actual	0 0	0 0	0 0	1,100 1,010	1,100 1,100	1,100 1,100	1,100 1,100	1,100 1,100	1,100 1,100	0 0	0 0	0 0	\$6,600	\$3,210	\$3,390
SUPPLIES	planned actual	0 0	0 0	786 349	786 470	786 849	786 827	786 0	786 0	786 0	0 0	0 0	0 0	\$5,499	\$2,495	\$3,004
INDIRECT COSTS																
43% of exp Exc Equip	planned actual	0 0	0 0	1,031 808	3,203 2,834	3,203 3,036	3,175 3,534	5,899 0	3,064 0	3,064 0	55 0	0 0	0 0	\$22,694	\$10,212	\$12,482
PLANNED TOTALS: PER MONTH		0	0	3,429	10,651	10,651	10,560	18,818	10,180	10,190	184	0	0	\$75,472		
ACTUAL TOTALS: PER MONTH		0	0	2,689	9,425	10,096	11,752	0	0	0	0	0	0		\$33,962	\$41,511
CUMULATIVE PLANNED TOTALS		0	0	3,429	14,080	24,731	35,291	54,909	65,088	75,288	75,472	75,472	75,472	\$75,472		
CUMULATIVE ACTUAL TOTALS		0	0	2,689	12,114	22,210	33,962	33,962	33,962	33,962	33,962	33,962	33,962		\$33,962	\$41,511
CUMULATIVE BUDGET VARIANCE		\$0	\$0	\$741	\$1,966	\$2,521	\$1,329	\$20,947	\$31,137	\$41,326	\$41,511	\$41,511	\$41,511			

TASK 2.5E: Carbon Products for Waste Stream Clean-up

** DETAILED REPORT FOR CHEMICAL ENGINEERING - **Extended Budget** Pl: John Zondlo

PROJECT: Carbon Products for Waste Stream Clean-up
Chemical Engineering - Detailed EXTENDED Budget
PRINCIPAL INVESTIGATOR: John Zondolo

METC TASK NO.: 2.5E
WVU Act. No.: 8527-229-1791
PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	ATM REMAINING
SALARIES																
Brennstelner	planned actual	2,300 2,291	1,137 1,146	0 0	0 0	0 0	0 0							\$3,437	\$3,437	\$1
Technician	planned actual	1,670 1,670	0 0	0 0	0 0	0 0	0 0							\$1,670	\$1,670	\$0
Clerical/Misc	planned actual	2,000 1,750	200 0	200 0	200 0	200 0	635 1,685							\$3,435	\$3,435	\$0
BENEFITS																
29% of Salaries	planned actual	1,731 1,656	388 332	58 0	58 0	58 0	184 489							\$2,477	\$2,477	\$0
STUDENTS																
Graduate Assistant	planned actual	640 550	0 0	1,050 1,050	1,050 1,140	1,050 1,050	1,050 1,050							\$4,840	\$4,840	\$0
SUPPLIES	planned actual	962 0	960 0	960 4,009	960 491	960 113	960 553							\$5,762	\$5,165	\$597
TRAVEL	planned actual	0 0	0 0	0 0	0 0	0 0	0 0							\$0	\$0	\$0
EQUIPMENT	planned actual	1,335 722	0 0	0 0	0 0	0 0	0 0							\$1,335	\$722	\$613
INDIRECT COSTS																
43% of exp Exc Equip	planned actual	4,000 3,404	1,154 635	975 2,175	975 701	975 500	1,217 1,624							\$9,297	\$9,040	\$257
PLANNED TOTALS: PER MONTH																
		14,639	3,839	3,243	3,243	3,243	4,046							\$32,253		
ACTUAL TOTALS: PER MONTH																
		12,044	2,113	7,234	2,332	1,663	5,400								\$30,786	\$1,467
CUMULATIVE PLANNED TOTALS																
		14,639	18,478	21,721	24,964	28,208	32,253							\$32,253		
CUMULATIVE ACTUAL TOTALS																
		12,044	14,157	21,391	23,723	25,386	30,786								\$30,786	\$1,467
CUMULATIVE BUDGET VARIANCE																
		\$2,595	\$4,321	\$330	\$1,241	\$2,821	\$1,467									

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METC Task # 2.5

#	Task Name	Dura	%Compl	3rd Quarter					4th Quarter														
				Sep					Oct					Nov					Dec				
				29	5	12	19	26	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9
1	Preliminary Research	3M	95.00%																				
2	Electrochemical Remediation (ECR)	3M	95.00%																				
3	Technical Evaluation	2M	95.00%																				
4	Analytical Techniques	9M	95.00%																				
5	Preparation for Trials	6M	78.00%																				
6	Hire Post-Doctoral	2M	100.00%																				
7	Purchase Electrochemical System	3M	90.00%																				
8	Obtain Chemicals and Reagents	2M	90.00%																				
9	Obtain Carbon Samples	3M	60.00%																				
10	Characterize Carbon Samples	5M	50.00%																				
11	Testing	8M	47.80%																				
12	ECR-Sample A	8M	80.00%																				
13	ECR-Sample B	8M	50.00%																				
14	ECR-Sample C	8M	80.00%																				
15	ECR-Sample D	8M	10.00%																				
16	ECR-Sample E	8M	10.00%																				
17	ECR-Sample F	8M	50.00%																				
24	ECR -Sample G	8M	50.00%																				
23	ECR-Sample H	8M	50.00%																				
18	Trial Repeats (concurrent)	4M	50.00%																				
19	Analysis and Reporting	11M	80.00%																				
20	Analysis and Data Reduction	2M	60.00%																				
21	Reports and Manuscripts	11M	100.00%																				
22	Overall Work Complete	12M	79.16%																				

■ Critical

◇ Critical Milestone

▨ Free Float

↑..... Delay

■ Noncritical

◇ Noncritical Milestone

▨ Total Float (+)

▲ Effort %Complete

■ Complete

● Complete Milestone

▨ Total Float (-)

□ Summary

◇ Summary Milestone

— Baseline

▨ External

● External Milestone

..... Non-Resource

Carbon Products for Waste Stream Reforming

3.0
INFORMATION SYSTEMS,
PUBLIC POLICY,
COMMUNITY OUTREACH,
AND ECONOMICS

TASK 3.1 - WINFIELD LOCK AND DAM ASSISTANCE PROGRAM

PRINCIPAL INVESTIGATOR: R. Lovette

■ PLANNED SPENDING ◇ -- ACTUAL SPENDING

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PROJECT: Winfield Lock and Dam Assistance Program

METC TASK NO.: 3.1

WVU Act. No.: 8527-224-1426

PRINCIPAL INVESTIGATOR: Raymond Lovette

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
R. Lovette	planned actual	2,659 2,459	2,659 2,459	2,659 2,459	2,659 2,459	2,659 2,459	2,659 2,459	2,511 2,511	2,511 2,511	2,511 2,511	2,511 2,511	2,511 2,511	2,511 2,511	\$31,020	\$14,752	\$16,268
N. Reese	planned actual	172 317	172 317	172 317	172 317	172 317	172 317	172 317	172 317	172 317	172 317	172 317	114 317	\$2,002	\$1,802	\$100
Secretary	planned actual	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	208 0	\$2,499	\$0	\$2,499
BENEFITS (29% of Salaries)	planned actual	881 806	881 806	881 806	881 806	881 806	881 806	838 0	838 0	838 0	838 0	838 0	822 0	\$10,301	\$4,630	\$5,671
STUDENTS	planned actual	343 466	343 270	343 213	343 306	343 384	343 64	343 0	0	0	0	0	0	\$2,400	\$1,683	\$717
SUPPLIES	planned actual	667 766	667 766	667 766	667 787	667 62	667 606	667 0	667 0	667 0	667 0	667 0	667 0	\$8,000	\$3,783	\$4,267
MAINTENANCE CONTRACTOR	planned actual	0 0	0 0	0 0	0 0	0 0	0 780	0 0	0 0	0 0	0 0	0 0	0 0	\$0	\$780	(\$780)
TRAVEL	planned actual	1,029 0	1,029 69	1,029 428	1,029 146	1,029 220	1,029 288	1,029 0	1,029 0	1,456 0	655 0	640 0	640 0	\$12,000	\$1,161	\$10,839
INDIRECT COSTS																
(18% of direct cost *excl equip & sub)	planned actual	1,132 911	1,132 888	1,132 946	1,132 918	1,132 809	1,132 861	1,096 0	1,031 0	1,108 0	960 0	966 0	981 0	\$12,962	\$5,332	\$7,631
PLANNED TOTALS: PER MONTH		7,090	7,090	7,090	7,090	7,090	7,090	6,863	6,456	6,939	6,011	6,231	6,143	\$81,185		
ACTUAL TOTALS: PER MONTH		5,703	5,563	5,824	5,748	5,065	6,170	0	0	0	0	0	0		\$34,173	\$47,011
CUMULATIVE PLANNED TOTALS		7,090	14,180	21,270	28,360	35,450	42,540	49,404	55,859	62,798	68,810	75,041	81,185	\$81,185		
CUMULATIVE ACTUAL TOTALS		5,703	11,267	17,190	22,938	28,004	34,173	34,173	34,173	34,173	34,173	34,173	34,173		\$34,173	\$47,011
CUMULATIVE BUDGET VARIANCE		\$1,387	\$2,914	\$4,080	\$5,422	\$7,447	\$8,367	\$15,230	\$21,686	\$28,625	\$34,636	\$40,868	\$47,011			

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METC Task # 3.1

#	Task Name	Dura	%Compl	1992												1993												
				Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	D	4th Quarter	3rd Quarter	2nd Quarter	1st Quarter								
1	NEPA Documentation	1M	100.00%																									
2	Resource Group Development	60M	100.00%																									
3	Gather Members	2M	100.00%																									
4	Contact members	6w	100.00%																									
5	Send Formal requests	0d	100.00%																									
6	Meet with members	0d	100.00%																									
7	Gather resources	7.5M	100.00%																									
8	Maintain Resource Group	48M	100.00%																									
9	WINFIELD	60M	75.00%																									
10	Eval. Baseline Risk	8M	100.00%																									
11	Eval. Storage Plans	17.1M	100.00%																									
12	Eval. Decon/Demo Plans	0M	100.00%																									
13	Eval. Removal Risk Analysis	10.43M	100.00%																									
14	Eval. ACF Excav.	1M	100.00%																									
15	Eval. ACF Remedial Action Feasib.	1M	100.00%																									
16	Eval. Remed. Work	1M	100.00%																									
17	Develop MS/MS Monitor	7M	50.00%																									
18	Monitor Sampling	5M	0.00%																									
19	Implement Monitor	1M	0.00%																									
20	Monitor Site	7M	0.00%																									
21	Reports	60M	53.57%																									
22	Overall work Complete	60M	85.70%																									

Critical

Critical Milestone

Free Float

Delay

Noncritical

Noncritical Milestone

Total Float (+)

Effort %Complete

Complete

Complete Milestone

Total Float (-)

Summary

Summary Milestone

Baseline

External

External Milestone

Non-Resource

Winfield Lock and Dam Assistance Program

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TASK 3.2: A GIS Based Infrastructure for Site Characterization & Remediation

PRINCIPAL INVESTIGATOR: E. Cook - *Overall Budget

PROJECT: A GIS Based Infrastructure for Site Characterization

** OVERALL Budget **

PRINCIPAL INVESTIGATOR: E. Cook

METC TASK NO.: 3.2

WVU Act. No.: 8527-229-3245

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
E. Cook	planned actual	222 212	222 212	222 212	222 212	222 226	222 240	222	222	222	222	222	222	\$2,661	\$1,314	\$1,347
Secretary	planned actual	83 0	83 0	83 0	83 0	83 0	83 0	83	83	83	83	83	83	\$895	\$0	\$895
BENEFITS (29% of Salaries)	planned actual	88 61	88 61	88 61	88 61	88 66	88 70	88 0	88 0	88 0	88 0	88 0	88 0	\$1,060	\$381	\$679
*SUB-CONTRACT Marshall Univ	planned actual	3,040 2,179	9,128 10,300	4,324 3,443	16,780 10,552	14,510 8,163	46,521 59,647	25,657	26,331	17,651	12,728	11,346	12,672	\$200,688	\$94,284	\$106,404
INDIRECT COSTS																
(43% of direct cost *exc/ equip & sub)	planned actual	169 118	169 118	169 118	169 118	169 125	169 133	169 0	169 0	169 0	169 0	169 0	169 0	\$0 \$2,028	\$729	\$1,299
PLANNED TOTALS: PER MONTH		3,602	9,690	4,886	17,342	15,072	47,083	26,219	26,893	18,213	13,290	11,908	13,234	\$207,432		
ACTUAL TOTALS: PER MONTH		2,570	10,691	3,834	10,943	8,580	60,090	0	0	0	0	0	0		\$96,708	\$110,724
CUMULATIVE PLANNED TOTALS		3,602	13,292	18,178	35,520	50,592	97,675	123,894	150,787	169,000	182,290	194,198	207,432	\$207,432		
CUMULATIVE ACTUAL TOTALS		2,570	13,281	17,095	28,038	36,618	96,708	96,708	96,708	96,708	96,708	96,708	96,708		\$96,708	\$110,724
CUMULATIVE BUDGET VARIANCE		\$1,032	\$31	\$1,083	\$7,482	\$13,974	\$967	\$27,186	\$54,079	\$72,292	\$85,582	\$97,490	\$110,724			

*Note: A detailed accounting of the Sub Contractors expenses follows

A GIS Based Infrastructure for Site Characterization and Remediation

PRINCIPAL INVESTIGATOR: James Hooper/Marshall University

■ PLANNED SPENDING ◇ — ACTUAL SPENDING

PROJECT: A GIS Based Infrastructure for Site Characterization and Remediation

MECT TASK NO.: 3.2

PRINCIPAL INVESTIGATOR: James Hooper

*** MARSHALL UNIVERSITY - DETAILED REPORT ***

PERIOD ENDING: June 30, 1995

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUGUST	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMOUNT REMAINING
LABOR COST																
Personal	planned actual	1,300 1,225	3,300 3,280	1,800 1,788	6,000 6,173	4,500 4,569	15,708 15,575	14,266	10,703	6,162	6,568	5,808	6,480	\$82,594	\$32,608	49,986
Clerical	planned actual	150 140	250 260	350 350	400 380	450 450	650 670	450	400	450	400	350	500	\$4,800	\$2,250	2,550
Student	planned actual	0 0	0 0	0 0	0 0	0 0	1,026 1,026	960	1,200	480	480	480	480	\$5,106	\$1,026	4,080
BENEFITS (Variable per class)	planned actual	228 214	539 539	358 357	964 982	768 778	2,537 2,524	2,265 0	1,780 0	1,064 0	1,106 0	984 0	1,123 0	13,716	\$5,395	8,322
EQUIPMENT																
1 - Computers, Printers, ect	planned actual	0 0	0 0	0 0	0 0	0 0	14,000 13,984	0	6,000	5,500	0	0	0	\$25,500	\$13,984	11,516
2 - Software	planned actual	0 0	0 0	0 0	2,500 0	2,500 0	1,350 6,350	0	0	0	0	0	0	\$6,350	\$6,350	0
OTHER																
Training	planned actual	525 0	525 1,175	525 0	2,159 0	2,159 0	2,159 6,478	0	0	0	0	0	0	\$8,053	\$7,653	400
Travel	planned actual	0 0	2,000 2,210	100 0	100 95	100 109	99 384	550	550	550	550	500	500	\$5,599	\$2,797	2,802
Telephone, Reports, Misc.	planned actual	0 0	0 0	0 0	36 16.54	37 10.26	37 83.22	100	100	100	120	100	100	\$730	\$110	620
INDIRECT COSTS																
38% of exp Exc Equip-1	planned actual	837 600	2,513 2,836	1,191 948	4,621 2,906	3,995 2,248	8,955 12,574	7,065 0	5,598 0	3,346 0	3,505 0	3,124 0	3,490 0	\$48,240	\$22,111	26,129
PLANNED TOTALS PER MONTH																
		3,040	9,128	4,324	16,780	14,510	46,521	25,657	26,331	17,651	12,728	11,346	12,673	\$200,688		
ACTUAL TOTALS PER MONTH																
		2,179	10,300	3,443	10,552	8,163	59,647	0	0	0	0	0	0	0	\$94,283	106,405
CUMULATIVE PLANNED TOTALS																
		3,040	12,168	16,492	33,272	47,781	94,302	119,959	146,290	163,941	176,670	188,015	200,688	\$200,688		
CUMULATIVE ACTUAL TOTALS																
		2,179	12,478	15,921	26,473	34,636	94,283	94,283	94,283	94,283	94,283	94,283	94,283		\$94,283	106,405
BUDGET VARIANCE																
		\$861	(\$311)	\$571	\$6,799	\$13,145	\$19	\$25,676	\$52,007	\$69,658	\$82,386	\$93,732	\$106,405			

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METC TASK #: 3.2

GIS-BASED INFRASTRUCTURE FOR SITE CHARACTERIZATION AND REMEDIATION

#	Task Name	1st Qtr			2nd Qtr		3rd Qtr			4th Qtr			
		J a n	F e b	M a r	A p r	M a y	J u n	J u l	A u g	S e p	O c t	N o v	D e c
1	NEPA Documentation												
2	System Requirements												
3	Devise and Specify System Requirements												
4	Determine Operating Procedures												
5	Develop Materials for Technology Transfer												

Planned: —

Actual:

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TASK 3.3: SMALL BUSINESS SUPPORT PROGRAM

PRINCIPAL INVESTIGATOR: E. Cook

■ PLANNED SPENDING ♦ ACTUAL SPENDING

PROJECT: Small Business Program - Administrative Budget

METC TASK NO.: 3.3

PRINCIPAL INVESTIGATOR: E. Cook

WVU Act. No.: 8527-229-3242

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SALARIES																
Director	planned actual	1,535 1,476	1,535 1,476	1,535 1,476	1,535 1,476	1,535 1,569	1,535 1,661	1,535	1,535	1,535	1,535	1,535	1,535	\$18,414	\$9,133	\$9,281
Technical Assistant	planned actual	2,334 0	2,334 0	2,334 1,864	2,334 2,334	2,334 2,334	2,334 2,334	2,334	2,334	2,334	2,334	2,334	2,334	\$28,008	\$8,866	\$19,152
Secretary	planned actual	417 323	417 323	417 323	417 323	417 323	417 323	417	417	417	417	417	417	\$5,000	\$1,838	\$3,062
BENEFITS (29% of Salaries)	planned actual	1,243 621	1,243 622	1,243 1,069	1,243 1,199	1,243 1,226	1,243 1,262	1,243	1,243	1,243	1,243	1,243	1,243	\$14,912	\$5,779	\$9,134
STUDENTS	planned actual	0 2,168	0 2,334	0 480	0 0	0 0	0 0	0	0	0	0	0	0	\$0	\$4,962	(\$4,962)
INDIRECT COSTS																
(43% of direct cost *excl/ equip & sub)	planned actual	2,377 1,930	2,377 2,002	2,377 2,233	2,377 2,293	2,377 2,344	2,377 2,396	2,377 0	2,377 0	2,377 0	2,377 0	2,377 0	2,377 0	\$28,524	\$13,186	\$15,328
PLANNED TOTALS: PER MONTH																
		7,905	7,905	7,905	7,905	7,905	7,905	7,905	7,905	7,905	7,905	7,905	7,905	\$94,858		
ACTUAL TOTALS: PER MONTH																
		6,417	6,656	7,425	7,624	7,796	7,965	0	0	0	0	0	0		\$43,884	\$50,975
CUMULATIVE PLANNED TOTALS																
		7,905	15,810	23,715	31,619	39,524	47,429	55,334	63,239	71,144	79,048	86,953	94,858	\$94,858		
CUMULATIVE ACTUAL TOTALS																
		6,417	13,073	20,498	28,122	35,918	43,884	43,884	43,884	43,884	43,884	43,884	43,884		\$43,884	\$50,975
CUMULATIVE BUDGET VARIANCE																
		\$1,488	\$2,736	\$3,216	\$3,497	\$3,606	\$3,545	\$11,450	\$19,355	\$27,260	\$35,165	\$43,070	\$50,975			

METC TASK #: 3.3

SMALL BUSINESS SUPPORT PROGRAM

#	Task Name	1st Qtr			2nd Qtr			3rd Qtr			4th Qtr		
		J a n	F e b	M a r	A p r	M a y	J u n	J u l	A u g	S e p	O c t	N o v	D e c
1	Interact with METC for Business Needs	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	Meet with Small Businesses	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	Develop Proposals with Small Businesses	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Planned: ———

Actual:

-68 - 89

TASK 3.4: Assessing Potential Voluntary Environmental Protection

KANAWHA RIVER AREA - PRINCIPAL INVESTIGATOR: R. Lovette

■ PLANNED SPENDING ♦ -- ACTUAL SPENDING

PROJECT: Approach for Assessing Potential Voluntary Environmental
Protection - Kanawha River Area
PRINCIPAL INVESTIGATOR: R. Lovette

METC TASK NO.: 3.4
WVU Act. No.: 8527-224-1422
PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT Remaining
SUPPLIES	planned actual	71 0	71 0	71 0	71 0	71 0	71 0	71 0	71 0	71 0	71 0	71 0	0	\$785	\$0	\$785
TRAVEL	planned actual	717 0	717 0	717 0	717 0	717 0	717 0	717 0	717 0	717 0	717 0	717 0	0	\$7,888	\$0	\$7,888
SUB-CONTRACT (Under 25K)	planned actual	0 0	0 0	0 0	0 0	25,000 24,846	0 154	0 0	0 0	0 0	0 0	0 0	0	\$25,000	\$25,000	\$0
SUB-CONTRACT (Over 25K)	planned actual	0 0	0 0	0 0	0 0	0 0	42,061 13,902	0 0	0 0	0 0	0 0	0 0	0	\$42,061	\$13,902	\$28,159
INDIRECT COSTS																
(43% of direct cost *excl equip & sub)	planned actual	339 0	339 0	339 0	339 0	11,089 10,684	339 66	339 0	339 0	339 0	339 0	339 0	0	\$14,479	\$10,750	\$3,729
PLANNED TOTALS: PER MONTH		1,127	1,127	1,127	1,127	35,877	43,188	1,127	1,127	1,127	1,127	1,127	0	\$90,213		
ACTUAL TOTALS: PER MONTH		0	0	0	0	35,530	14,122	0	0	0	0	0	0		\$49,652	\$40,561
CUMULATIVE PLANNED TOTALS		1,127	2,255	3,382	4,510	41,387	84,575	85,703	86,831	87,958	89,086	90,213	90,213	\$90,213		
CUMULATIVE ACTUAL TOTALS		0	0	0	0	35,530	49,652	49,652	49,652	49,652	49,652	49,652	49,652		\$49,652	\$40,561
CUMULATIVE BUDGET VARIANCE		\$1,127	\$2,255	\$3,382	\$4,510	\$5,858	\$34,924	\$36,051	\$37,179	\$38,306	\$39,434	\$40,561	\$40,561			

Development of Organic Sensors - Extended Budget (MC-7)

PRINCIPAL INVESTIGATOR: H.O. Finklea

■ PLANNED SPENDING ◇ -- ACTUAL SPENDING

PROJECT: Development of Organic Sensors

Old Project No.: MC-7

** Extended Budget **

WVU Act. No.: 8527-211-0624

PRINCIPAL INVESTIGATOR: H.O. Finklea

PERIOD ENDING: 6/30/95

DESCRIPTION	PLANNED ACTUAL	1 JAN	2 FEB	3 MARCH	4 APRIL	5 MAY	6 JUNE	7 JULY	8 AUG	9 SEPT	10 OCT	11 NOV	12 DEC	PROJECTED TOTALS	ACTUAL TOTALS	AMT REMAINING
STUDENTS																
2 Graduate	planned actual	1,748 0	1,748 0	1,748 0	1,748 2,000	0 4,992	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$6,992	\$6,992	\$1
GENERAL EXP	planned actual	0 0	0 0	0 1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$0	\$1	(\$1)
EQUIPMENT	planned actual	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$0	\$0	\$0
INDIRECT COSTS																
43% of exp Exc Equip	planned actual	752 0	752 0	752 0	752 860	0 2,147	0 0	0 0	0 0	0 0	0 0	0 0	0 0	\$3,007	\$3,007	\$0
PLANNED TOTALS:																
PER MONTH		2,500	2,500	2,500	2,500	0	0	0	0	0	0	0	0	\$10,000		
ACTUAL TOTALS:																
PER MONTH		0	0	1	2,860	7,139	0							\$10,000	\$0	
CUMULATIVE																
PLANNED TOTALS		2,500	5,000	7,500	10,000	10,000	10,000							\$10,080		
CUMULATIVE																
ACTUAL TOTALS		0	0	1	2,861	10,000	10,000							\$10,000	\$0	
CUM BUDGET																
VARIANCE		\$2,500	\$5,000	\$7,499	\$7,139	\$0	\$0									

93

Improved Computer Model to Predict VOC Recovery

OLD NO. MC-14 - Extended Budget - PRINCIPAL INVESTIGATOR: S. Ameri

■ PLANNED SPENDING ♦ ACTUAL SPENDING

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Old Project MC-14
WVU Act. No.: 8527-255-0432

PERIOD ENDING: 6/30/95[illegible]

METC Task # 3.4

#	Task Name	Dura	%Compl		1995												
					1st Quarter			2nd Quarter			3rd Quarter			4th Quarter			
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		Ja
1	Initial contact of private parties	1M	33.00%														
2	Conduct confidential meetings with private parties	1M	0.00%														
3	Scoping meetings with USEPA Region 3 and WVDE	7w	0.00%														
4	Prepare summary of meetings	2w	0.00%														
5	Convene group meeting	1M	0.00%														

<p>■ Critical</p> <p>◇ Critical Milestone</p> <p>▨ Free Float</p> <p>..... Delay</p>	<p>■ Noncritical</p> <p>◇ Noncritical Milestone</p> <p>▨ Total Float (+)</p> <p>▲ Effort %Complete</p>	<p>▨ Complete</p> <p>● Complete Milestone</p> <p>▨ Total Float (-)</p>	<p>▨ Summary</p> <p>◇ Summary Milestone</p> <p>— Baseline</p>	<p>▨ External</p> <p>● External Milestone</p> <p>..... Non-Resource</p>
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Approach for Assessing Potential Voluntary Environ. Protection - Kanawha Valley

QUARTERLY TECHNICAL PROGRESS REPORTS

1.0
IN-SITU REMEDIATION
PROCESS DEVELOPMENT

IN SITU REMEDIATION PROCESS DEVELOPMENT

DRAIN-ENHANCED SOIL FLUSHING (DESF) FOR ORGANIC CONTAMINANTS REMOVAL

TASK 1.1

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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In the previous phase of this project progress was advanced along the following three fronts:

1. Contaminant and Soil Characterization: A study soil was developed and categorized in accordance with ASTM standards. The testing program included column and batch studies on contaminated soils with the study surfactant being anionic aqueous solution of sodium dodecylsulfate.
2. Injection/Extraction Flushing Concept: Several pilot scale Contaminant Recovery Cells (CRCs) were used to evaluate the flow characteristics of the soils sampled and the concept of using PVDs. Soil samples were prepared in the CRCs and PVDs were installed in rectangular and circular configurations.
3. A predictive model for PVD enhanced soil flushing was developed. The model was developed assuming full saturation and no diffusion or decay. Parameter studies were performed to predict soil flushing rates using a PVD system.

4.0 METHODOLOGY

An economic evaluation between the PVD technology and other U.S. Environmental Protection Agency (USEPA) recognized remediation technologies that may be used to recover and treat similar contaminant groups was developed. The comparisons are based primarily on cost, but consideration of such factors as: minimum contaminant concentration achievable, time to complete cleanup, system reliability/maintainability, awareness of the remediation consulting community, regulatory/permitting acceptability, and community acceptability.

The economic evaluation of the Prefabricated Vertical Drain technology for Drain Enhanced Soil Flushing is presented using two comparisons discussed separately below.

Comparison #1: The first comparison is a qualitative approach for comparing the PVD enhanced soil flushing with traditional EPA Site Demonstration Technologies. Several categories (cost, time to clean up, and contaminant concentration levels) report values in an order-of-magnitude range for the clean-up of a typical one acre site.

1.0 INTRODUCTION

This project researches the use of Prefabricated Vertical Drain (PVD) systems for remediation of contaminated sites with fine grained soils. PVD systems are relatively simple in operation and installation. They require no drilling rig equipment and are expected to significantly reduce remediation costs while at the same time increase the efficiency of the remediation effort.

The use of PVDs in the current state of practice has been in the area of soil improvement. Other than the work performed in the first phase of this project, no research work has been conducted to investigate the feasibility of using PVDs for soil flushing.

2.0 PURPOSE

The main objective of this research phase is to investigate major parameters influencing the efficiency of contaminant extraction using PVD systems. Research focused on conducting bench-scale tests with soils for simulation of in situ conditions. Specific objectives are as follows:

1. a) Development of the effective diameter for in situ characterization of the PVDs; b) Effect of smear and well resistance on the hydraulic efficiency of the PVDs, and c) Effect of the method of installation on the recovery efficiency of the PVD system.
2. Full development and Beta testing of the PVDs' contaminant transport model developed in Phase I.
3. Field demonstration program and testing, cost analysis, and performance of the recovery process using the PVDs.

3.0 BACKGROUND

The PVD system is used to shorten the drainage path of the groundwater flow and therefore promote subsurface liquid movement and expedite the soil flushing process in low permeability soils. Proved technologies exist for the in situ soil flushing for sites with granular soils (hydraulic conductivity approximately 1×10^{-2} cm/s). However in the case of sites where the soil is predominantly clay with corresponding hydraulic conductivity ranging 1×10^{-3} to 1×10^{-7} cm/s, implementation of the traditional soil flushing technology is ineffective and cost prohibitive.

Comparison #2: This comparison was developed to present quantitative cost measurements of the PVD enhanced soil flushing technique with conventional commercial pump-and-treat soil flushing systems. Actual remediation cost estimates are developed based on standardized criteria with existing commercial soil flushing systems for projects which have published cost information. This comparison is more applicable to a field demonstration scale site.

The Economic Evaluation is contained in Attachment A of this report.

5.0 WORK PERFORMED THIS PERIOD

Work performed during this reporting period included the following tasks:

1. Experimentation on the Effective Diameter and Smear Effects.
2. Experimentation on the influence of PVD layout on chloride capture efficiency.
3. Draft development of the Field Demonstration Plan.
4. Preparation of the outline for draft development of the Economic Evaluation.

Preliminary Effective Diameter, Smear Effects, & Contaminant Recovery: During this reporting period, the study soil was changed from a 100% Ottawa sand to a mix of 80% Ottawa sand and 20% Kaolinite soil. Test cells were constructed and the soil is currently undergoing saturation prior to the next round of testing.

Field Demonstration Plan: Preliminary field layouts of the PVD system were drafted and development of the field implementation plan was begun.

Economic Evaluation: Development of the draft Economic Evaluation is contained in Attachment A.

6.0 CONCLUSIONS

The results of the draft Economic Evaluation are not yet resolved as costs from the industry partner, NILEX, have not been determined.

7.0 WORK PLANNED FOR NEXT PERIOD

The following tasks are planned for the next reporting period.

1. Development of the draft Site Demonstration proposal.
2. Complete revisions to the draft Economic Evaluation.
3. Begin testing with 80/20 study soils.

ATTACHMENT "A"

**Economic Evaluation of
Drain Enhanced Soil Flushing
with Prefabricated Vertical Drains for
Organic Contaminant Removal**

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1.0 Introduction

1.1 Problem

There are a number of approaches to in-situ remediation that are used at contaminated sites. These include soil flushing, bioremediation, vacuum or air stripping, and immobilization techniques. Considering these approaches, only soil flushing and air stripping remove contaminant(s) from the contaminated zone without excavation the soil. Of these two, soil flushing is the process of the investigation in this research.

The effectiveness of the soil flushing process is limited by the extent to which the contaminant is extracted from the soil and solubilized in the flushing solution (surfactant), and the ease with which the surfactant moves through the contaminated soil. Generally, for fine grained soils, both the extraction of the contaminant from the soil and movement of surfactant are less than that observed for large grained soils (i.e., sands). Thus, soil flushing is not always effective for remediation contaminated aquifers and the use of "pump-and-treat" systems on extremely long term basis is often required. The soil flushing option is difficult to implement in soils with low permeabilities.

1.2 Solution

An innovative technology incorporating Prefabricated Vertical Drains (PVD) systems may be used for the in-situ remediation of contaminated sites where fine grained soils are present. The PVD system is used to shorten the drainage path of the groundwater flow and promote subsurface liquid movement which accelerates the soil flushing process. In comparison with conventional well fields and drains, the use of PV drains would expedite the contaminant recovery and reduce both labor and material costs. Installation of the PVD system is relatively simple and inexpensive with no drilling required and the fluid extraction process can prove to be practical and cost effective.

1.3 Research Objectives

The main objective of the research being performed in this discipline is to investigate the major parameters affecting the efficiency of contaminant extraction using PVD systems.

- 1 Investigation of the effective well diameter based on the PVDs dimensions and long term performance in a fine-grained soil due to the fluid injection/extraction operation.
- 2 Characterization of the PVD zone of influence and effect of smear. Investigation of the head losses to occur in the flow out of the drain due to the well resistance effects.
- 3 Verification with a contaminant transport model. Performance of economic evaluation of the PVD technology with existing in-situ technologies.
- 4 Development of a field implementation plan in cooperation with METC, a DOE facility, and the Nilex corporation, the industrial partner.

1.4 Applications and Benefits

PVD technology has many potential applications and benefits. Several of these benefits are listed below:

1. Suitable for removal of aqueous, dense non-aqueous phase liquids (DNAPLs), and light non-aqueous phase liquids (LNAPLs).
2. Effective for in-situ remediation in fine-grained soils with hydraulic conductivity ranging from 10^{-3} to 10^{-7} cm/s.
3. Applicable for use at existing facilities and for use on large or small scale sites.
4. Low cost for remediation of in-situ contaminants from fine-grained soil.
5. Promotes rapid remediation by efficiently promoting surfactant migration.
6. Technology developed with industrial partner NILEX Corp., Denver, Co; based on existing technology and off-the-shelf equipment for full operation.
7. PVD abandonment of injection and extraction drains uses bentonite grout and results in immobilizing the residual contaminants and develops an area of low hydraulic conductivity.
8. Not weather dependent, year round application and operation
9. Low operational requirements and does not pose significant or persistent safety or health problems.

1.5 Technology

The PV drains are designed for injecting a flushing solution into the in-situ soil and groundwater, and for subsequent removal of the flushing solution. The field installation uses a triangular grid layout with alternating off-set rows of injection and extraction PVDs. The in-situ soil is kept saturated to minimize soil settlement and a reduction in hydraulic conductivity.

The PVD is a composite system consisting of an inner core and an outer filter jacket and typically measures 100mm in width by 4.62mm in thickness. The flexible core is constructed of extruded polypropylene with formed flow path grooves on both sides along its length. The jacket serves as an outer skin to maintain the core's cross-sectional shape and hydraulic capacity of the flow path grooves. The jacket is constructed of a durable, non-woven polypropylene geotextile which functions as a filter to allow passage of groundwater into the drain core while preventing piping of fines from the adjoining soil (Figure 1).

Figure 1: NILEX Prefabricated Vertical Drains

The PVDs are installed using a crane mounted mandrel. The PVDs are driven with anchor plates that secure the drains when the mandrel is removed. Various methods of mandrel driving include: cable pull powered by a conventional crane, vibratory head attached directly to the mandrel, and a hydraulic cylinder powered by the hydraulics of an excavator. The PVDs are tied into collector piping for application of the vacuum and introduction of the surfactant. The entire site and all collector piping is covered with flexible PVC sheeting to minimize air infiltration and vacuum losses (Figure 2).

The purpose of this paper is to present the results of an economic comparison between the PVD technology and other U.S. Environmental Protection Agency (US EPA) recognized remediation technologies that may be used to recovery and treat various contaminant groups on similar sites. The comparisons are be based primarily on cost, but considers factors such as: minimum contaminant concentration achievable, time to complete cleanup, system reliability/maintainability, awareness of the remediation consulting community, regulatory/permitting acceptability, and community acceptability. Costs for PVD installation are not yet available, but can easily be compared to the existing technologies discussed in this paper when they do become available.

Prefabricated Vertical Drain Enhanced Soil Flushing

CROSS2R4

Figure 2: Prefabricated Vertical Drain Enhanced Soil Flushing

2.0 Department of Energy Background

The Department of Energy (DOE) is responsible for the clean-up of both national laboratories and nuclear weapons production and testing facilities (DOE, 1993). The DOE's Subsurface Science Program (Riley & Zachara, 1993) performed a study to identify the most common contaminant classes at 18 DOE facilities that included 91 waste sites. The frequency of thirteen possible contaminants impacting the DOE facilities was evaluated in both soils and groundwater. The constituents evaluated included: Alkylphosphates, Anions, Chlorinated Hydrocarbons, Complexing Agents, Explosives, Fuel Hydrocarbons, Ketones, Metals, Organic Acids, Pesticides, Phthalates, Polychlorinated Biphenyls, and Radionuclides (Riley & Zachara, 1993).

The most commonly found contaminants in soils sediments (by facility) were found to be fuel hydrocarbons, chlorinated hydrocarbons, metals, and Radionuclides (Riley & Zachara, 1993). Less commonly reported compounds included anions, ketones, and PCBs. Figure 3 below illustrates the distribution of the compound classes in soils/sediments at the 18 DOE facilities and the 91 waste sites that were studied.

Figure 3: Distribution of Compound Classes in Soils at 18 DOE Facilities and 91 Waste Sites (Riley & Zachara, 1993)

Groundwater contamination has occurred at these facilities as a result of compounds being disposed of to the ground and then transported through the soil to the ground water table (Riley & Zachara, 1993). The most commonly reported compounds in ground water at the 18 facilities were metals and chlorinated hydrocarbons, followed by radionuclides, anions, fuel hydrocarbons, and ketones (Riley & Zachara, 1993). Also reported, but with smaller frequencies, were phthalates, explosives, and organic acids. The least commonly reported compounds (pesticides, PCBs, and complexing agents) each occurred at only one facility (Riley and Zachara, 1993). Figure 3 illustrates the distribution of

the compound classes in ground water at the DOE facilities and waste sites surveyed.

Figure 4: Distribution of Compound Classes in Ground Water at 18 DOE Facilities and 91 Waste Sites (Riley & Zachara, 1993)

The concentration ranges of the seven most frequently occurring compounds in both soil and groundwater are discussed below (Riley & Zachara, 1993).

Metals: The higher concentration in groundwater exceeded regulatory guidelines by as much as 10^2 to 10^5 and at the lower end the constituent concentration in groundwater were below regulatory guidelines by a factor of 10 to 1,000.

Anions: Nitrate was recorded in groundwater in concentrations as high as 10 percent which exceeds regulatory standards by 10^4 .

Radionuclides: Tritium, strontium, uranium, cesium, and plutonium exceed interim drinking water standards.

Chlorinated Hydrocarbons: The highest concentrations in groundwater were for dichloromethane, trichloroethylene, and tetrachloroethylene. Contaminant concentrations were observed to exceed regulatory guidelines by a factor of 10^5 . Some sites reported levels that were below regulatory guidelines by a factor of 10 to 100.

Fuel Hydrocarbons: In groundwater, benzene, toluene, and xylene concentrations exceeded regulatory guidelines by a factor of 1,000. Regulatory levels for soil were exceeded by a factor of 10^5 .

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Ketones and Acetone: Ketones and Acetones are not currently listed as priority pollutants, but concentrations of ketones reached 1,500 micrograms per liter in groundwater and 57,000 micrograms per gram in soil.

3.0 Remediation Alternatives

There are several remediation alternatives for the contaminants listed above. Listed below are technologies that would be implemented in scenarios where PVDs may be used as a component in the remediation process. Prefabricated Vertical Drains (PVDs) are intended to enhance and optimize in situ remediation efforts. They serve as one component in the overall "treatment train", and are specific to fine-grained soils with hydraulic conductivities between 10^{-3} cm/s and 10^7 cm/s. The technologies discussed below include in-situ and ex-situ methods currently implemented for fine-grained soil remediation. The selection of remediation alternatives, when dealing with fine-grained soils, is very limited. The options available include:

In situ: dual phase extraction, soil vapor extraction, and possibly soil flushing

Ex-situ: soil washing, thermal desorption, and excavation and off-site disposal

The technologies, and subsequent information, were chosen from the US EPA's "Remediation Technologies Screening Matrix" (US EPA, 1993).

3.1 Soil Washing (ex-situ)

Soil washing is a process where contaminants that are sorbed onto soil particles are separated from the soil in an aqueous-based system. The fluid used to wash the soil may be augmented with a leaching agent, chelting agent, surfactant, and/or pH adjustment. Soil washing is commonly used in combination with bioremediation, incineration, and solidification/stabilization. The target contaminant groups for soil washing include halogenated and non-halogenated semivolatile organic compounds, fuel hydrocarbons, and inorganics. Soil washing also offers the potential for the recovery of metals and can clean a wide range of organic and inorganic contaminants from coarse-grained soils. Radioactive metals can be removed from soils if the proper washing fluid is used and some work has been performed to use soil washing as a method to remove fuel hydrocarbons (Manchilovich). No records were found where soil washing was used to treat ketones, acetones, and chlorinated hydrocarbons.

3.2 Excavation and Off-Site Disposal (ex-situ)

Excavation and off-site disposal is defined as removing the contaminated material and transporting it to a RCRA permitted off-site treatment and/or disposal facility. The contaminated media is usually pre-treated in order to meet land disposal restrictions. Excavation is often the first step in the use of many ex-situ treatment technologies, but when combined with off-site disposal it is considered a stand-alone remediation alternative. Excavation and off-site disposal is applicable to all contaminants with no particular target group.

3.3 Thermal Desorption (ex-situ)

Thermal desorption, whether high or low temperature, involves heating the waste to volatilize water and organic contaminants. The volatilized water and organics are then transported to a gas treatment system. Metals with boiling points below 900 degrees Fahrenheit can also be treated (McCabe, 1993). Thermal desorption is only one part of a "treatment train" that may also utilize incineration, solidification/stabilization, or dechlorination. The target contaminants are halogenated and non-halogenated volatile organic compounds, fuels, pesticides, and some heavy metals.

3.4 Dual Phase Extraction (in-situ)

Dual phase extraction utilizes a high vacuum system to simultaneously remove liquid and gas from low permeability or heterogeneous formations. The vacuum extraction well includes a screened section in the zone of contaminated soils and groundwater. As the vacuum is applied to the well, soil vapor is extracted, and groundwater is entrained by the extracted vapors. Once above grade, the extracted vapors and groundwater are separated and treated. Contaminants treated with dual phase extraction include halogenated and non-halogenated volatile organic compounds and fuel hydrocarbons. Dual phase extraction is a recovery process that may be used in conjunction with bioremediation, air sparging, or bioventing.

3.5 Soil Vapor Extraction (in-situ)

Soil Vapor Extraction (SVE) also utilizes a vacuum to create a pressure gradient that induces volatiles to diffuse through the soil to extraction wells. This process includes a system for the handling of off-gasses. The target contaminant groups for SVE are halogenated and non-halogenated volatile organic compounds, and fuel hydrocarbons. While SVE is considered a stand-alone technology, it also can be used as part of a treatment train to address semivolatiles:

3.6 Soil Flushing

Soil flushing implements water, or fluids containing an additive (surfactant) to enhance contaminant solubility. This flushing fluid is applied to the soil or injected into the groundwater to raise the water table into the contaminated soil zone. Contaminants are then leached into the groundwater. This process generally includes extraction of the groundwater and capture/treatment/removal of the leached contaminants before the groundwater is re-circulated. Soil flushing is typically used as a stand alone technology but is sometimes used with other technologies, such as in-situ bioremediation. The target contaminant groups for soil flushing are halogenated and non-halogenated volatile organic compounds, and inorganics. It can be used to treat halogenated and non-halogenated semivolatile organic compounds, fuels, and pesticides, but it may be less effective and may only be applicable to some compounds in these contaminant groups. The technology offers the potential for the recovery of metals and can clean a wide range of organic and inorganic contaminants from coarse-grained soils (hydraulic conductivity $> 10^{-3}$ cm/s).

4.0 Technology Effectiveness and Limitations

Each of the technologies considered above have specific limitations and advantages. All of the following, information except, where otherwise stated, was taken from the US EPA's "Remediation Technologies Screening Matrix." (US EPA, 1993). The technologies discussed are specific to remediation of fine-grained soils with low hydraulic conductivities where in-situ techniques are otherwise not feasible

4.1 Soil Washing (ex-situ)

Usually, soil washing is performed as an ex-situ remedy, which may pose a potential health and safety risk to site workers through skin contact and air emissions. Personal protective equipment is normally required during excavation operations. Factors that may limit the effectiveness of soil washing include the following. It is often difficult to remove fine soil particles from the washing water. Generally, no more than 40% of the soils should pass a 63 micron sieve and the soil should contain no more than 20% organics (Manchilovich, 1993)). Mixed wastes are also a problem because it is difficult to formulate a washing fluid to treat several wastes simultaneously. High humic content in soil may also inhibit desorption. This process produces both solid and liquid residuals that will have to be treated or disposed of after the washing procedure.

An attribute of soil washing is its effectiveness in remediating fine-grained soils. Once contaminated fines have been excavated and separated the coarse-grained soils may be returned clean to the site. Soil washing has been demonstrated to remediate 20,000 tons of soil in less than three months (US EPA, 1993). In general, soil washing has been accepted by the public as a safe method of treatment.

4.2 Excavation and Off-Site Disposal (ex-situ)

Although excavation and off-site disposal may alleviate the contaminant problem at the specific site, it does not treat the contaminants. Often times, fugitive (release of air-borne) emissions are created during excavation activities. The cost of off-site disposal is often high, especially when it is a great distance from the site to the nearest disposal facility. Land Ban Restrictions must be considered when choosing off-site disposal. Here again, workers at the site would have to be required to wear personal protective equipment during excavation activities. Transportation to the off-site disposal facility introduces a potential risk to the community if an accidental release should occur during transport.

One of the advantages of this procedure is that the equipment necessary is readily available. Sites where excavation and off-site disposal can be applied can generally be cleaned up in a relatively short period of time. The excavation of 20,000 tons of contaminated soil would require approximately 2 months to complete (US EPA, 1993). A final advantage to excavation and off-site disposal is that this process is generally accepted by the community.

4.3 Thermal Desorption (ex-situ)

The primary limitation of thermal desorption is that it is only economical for treating moderately to highly volatile organic contaminants in fine-grained soils. Contaminants, such as metals, with boiling points of over 200 degrees Fahrenheit must be treated with a high energy unit producing temperatures of up to 900 degrees Fahrenheit. Another limitation is that dewatering of the soils may be necessary before treatment to achieve acceptable moisture content levels. The equipment used also has specific feed size and material handling requirements that can impact its applicability at some sites. After the soils are treated there still may be liquid residuals that remain to be treated as a product of the dewatering process. The machinery involved is both expensive to purchase and maintain. To implement thermal desorption the contaminated soils must be excavated which could pose a health and safety threat to site workers. Workers may also be at risk to the emissions from the desorption unit.

There seems to be several advantages to using thermal desorption as part of a treatment train for fine-grained soils. The approximate overall cost is relatively low at between \$100 and \$300/ton (US EPA, 1993). The minimum contaminant concentration achievable with this technology has been as low as 5 mg/kg for its target contaminants. It is also effective over the long term because treatment with this technology is considered to be permanent. The time to clean up a 20,000 ton site is a quick four months (US EPA, 1993).

4.4 Dual Phase Extraction (in-situ)

The geology of a site is only one of the limitations of dual phase extraction. Sites with high permeabilities can pose a problem by dissipating or "short circuiting" the vacuum applied to the subsurface. This technology does not recover in-situ metals, but can recover metals in groundwater for treatment. By itself, it can not treat long-chained hydrocarbons. Dual phase

extraction may also have to be combined with other technologies, such as pump-and-treat, to recover groundwater from high yielding or deep aquifers. High maintenance costs are a problem with dual phase extraction. Once groundwater and vapors have been recovered with a dual phase extraction system they will need to be treated at the surface, which is an additional cost.

Dual phase extraction units are readily available and this technology is readily accepted by most regulatory agencies. Most consultants are also aware of the benefits and usefulness of this technology. Dual phase extraction can effectively volatilize compounds with efficiencies of up to 85 to 99 percent while being extracted from the wells which can eliminate treatment processes such as air stripping (Dames and Moore, 1993). Finally, dual phase extraction is considered a permanent solution for specific contaminant groups and soil conditions.

4.5 Soil Vapor Extraction (in-situ)

Only treating the unsaturated zone is one of SVEs limitations. Treatment of the saturation zone can occur if the water table is artificially lowered by pumping or drains which can be expensive. Soils with high humic contents can inhibit the volatilization of contaminants. Heterogeneous soil conditions may results in inconsistent removal rates and low soil permeabilities limit subsurface air flow rates and reduce the process efficiency. A SVE can only recover volatile compounds with a Henry's law constant greater than 0.01 or a vapor pressure greater than 0.5 kPa. Once the vapors are recovered they must be treated before being released to the atmosphere. Finally, SVE systems are typically operation and maintenance (O&M) cost intensive requiring expensive regular on-going maintenance.

Although O&M costs for SVE systems can be quite high, the initial cost of the equipment is considered to be low and therefore it has a good overall cost. SVE systems have been used greatly and are readily available through many consultants. Because SVE has been used so much in the past it is generally accepted by both regulatory agencies and communities.

4.6 Soil Flushing (in-situ)

Because soil flushing usually utilizes a soil flushing fluid, it is generally applicable only to sites with favorable hydrology, where the flushed contaminants and flushing fluids can be contained and recaptured. Soil flushing generally does not work well at sites where fine-grained soils are present. The surfactants used in soil flushing can adhere to the soil and reduce the effective porosity, and possibly "clog" finer grained soils. Sometimes the solvent reactions that occur with the soil can reduce the contaminants mobility and reduce the recovery capabilities. The soil flushing fluid must be disposed of at an additional cost to the operator of the system. These fluids, which are usually toxins, may alter the physical and chemical properties of the soil system.

One of the principal advantages of soil flushing is that it is readily available. Another advantage, as mentioned previously, is that it can be used to treat metals, which are usually difficult to remediate. It is also considered to be a permanent treatment technology, where the technology has been implemented, no further problems with the target contaminant group should arise.

The PVDs will augment the soil flushing operation by allowing for the treatment of fine-grained soils. Where previously their remediation was handled by an ex-situ technology.

5.0 Economic Comparisons

The economic evaluation of the Prefabricated Vertical Drain technology for Drain Enhanced Soil Flushing is presented using two comparisons discussed separately below.

Comparison #1: The first comparison is a qualitative approach for comparing the PVD enhanced soil flushing with traditional EPA Site Demonstration Technologies as discussed in Sections 3 and 4 of this report. The comparison is based on a rating criteria discussed in Table 1, with explanations of the criteria. Several categories (cost, time to clean up, and contaminant concentration levels) report values in an order-of-magnitude range for the clean-up of a typical one acre site. This comparison is presented in Section 5.1.

Comparison #2: This comparison was developed to present quantitative cost measurements of the PVD enhanced soil flushing technique with conventional commercial pump-and-treat soil flushing systems. Actual remediation cost estimates are developed based on standardized criteria with existing commercial soil flushing systems for projects which have published cost information. This comparison is more applicable to a field demonstration scale site. This comparison is presented in Section 5.2.

5.1 EPA Comparisons

To determine the cost effectiveness of PVDs, they were compared to the treatment technologies discussed in the sections above. The first comparison performed utilized a rating system created by the EPA in it's Remediation Technologies Screening Matrix. This system is comprised of thirteen different factors on which each technology is rated. These factors address specific cost, performance, technical, developmental, and institutional issues. Five of the factors in the system pose performance-related questions. Answers to these questions are shown in the comparison. The remaining eight criteria involve a comparative rating. The four ratings for each criteria are: Better, Average, Worse, or Inadequate Information. These ratings are explained in detail in Table 1.

There were standardized conventions used by the EPA for screening the remediation technologies. These conventions are listed below.

1. The contaminants considered are grouped as follows: (1) halogenated volatiles; (2) halogenated semivolatiles; (3) non-halogenated volatiles; (4) non-halogenated semi-volatiles; (5) fuel hydrocarbons; (6) pesticides; and (7) inorganics.
2. While all contaminant groups to which the technology or process is applicable are identified, each technology is evaluated based on the contaminant group(s) that it is primarily designed to treat.
3. A "standard" site profiles was developed to provide a baseline for rating the soil and groundwater technologies consistently against the "Time To Complete Cleanup" factor.

A calculation of the time required to clean up the "standard" site is shown in the text only when the technology's processing rate was generally known. No "standard" was developed for air emissions/off-gas technologies, because cleanup time is dependent on the primary technology or process they support. Air emissions/off-gas treatment technologies are not rated against the "Time To Complete Cleanup" factor.

The "standard" for soil is a normalized site of 1 acre, 10 feet deep (.41 hectare, 3.04 meters deep). Site volume is 20,000 tons (18,200 metric tons).

The "standard" for groundwater is a normalized site of 1 acre, 10 feet deep (.41 hectare, 3.04 meters deep) with an average porosity of 30% ($n=0.30$) and a shallow aquifer. Site volume is 1,000,000 gallons (3,785,000 liters).

For the PVD comparison, an insertion depth of ten feet was assumed.

4. For *ex situ* soil, sediment, and sludge technologies, the ratings in the Overall Cost category include an assumption that excavation costs an average of \$50/ton (\$55.00/metric ton). For *ex situ* groundwater technologies, it is assumed that pumping costs an average of \$0.25/1,000 gallons (\$0.07/1,000 liters).

Table 1: Rating Criteria for EPA Remedial Technology Comparisons

FACTORS AND DEFINITIONS	INADEQUATE INFORMATION (I)	WORSE (W)	AVERAGE (A)	BETTER (B)
Overall Cost Design, construction, and operations and maintenance (O&M) cost of the core process that defines each technology, exclusive of mobilization, demobilization, and pre- and post-treatment. (For <i>ex situ</i> soil, sediment, and sludge technologies, it is assumed that excavation costs an average of \$50/ton (\$55/metric ton). For <i>ex situ</i> groundwater technologies, it is assumed that pumping costs an average of \$0.25/1,000 gallons (\$0.07/1,000 liters).)	There is insufficient information with which to rate the technology in this category.	More than \$300/ton (\$330/metric ton) for soils; More than \$10/1,000 gal. (\$2.64/1,000 liters) for ground water; More than \$25/lb. (\$11.33/kg) for air emissions and off-gases	\$100-\$300/ton (\$110-\$330/metric ton); \$3.00-\$10.00/1,000 gal. (\$0.79-\$2.64/1,000 liters); \$7-\$25/lb. (\$3.17-\$11.33/kg.)	Less than \$100/ton (\$110/metric ton); Less than \$3.00/1,000 gal. (\$0.79/1,000 liters); Less than \$7/lb. (\$3.17/kg)
Commercial Availability Number of vendors than can design, construct, and maintain the technology.	There is insufficient information with which to rate the technology in this category.	Less than 2 vendors	2-4 vendors	More than 4 vendors
Minimum Contaminant Concentration Achievable Minimum contaminant concentration level achievable by the technology, measured in milligrams per kilogram for soil technologies, micrograms per liters for groundwater, and milligrams per kilogram and micrograms per kilogram for air emissions and off-gases.	There is insufficient information with which to rate the technology in this category.	More than 50 mg/kg; More than 100 µg/L More than 250 mg/kg	5-50 mg/kg; 5-100 µg/L 250 mg/kg-250 µg/kg, but detectable	Less than 5 mg/kg; Less than 5 µg/L; Not detectable
Time to Complete Cleanup Time required to clean up a "standard" site using the technology. (The "standard" site is 20,000 tons (18,200 metric tons) for soils and 1 million gallons (3,785,000 liters) for groundwater.	There is insufficient information with which to rate the technology in this category.	More than 3 years for <i>in situ</i> soil technologies; More than 1 year for <i>ex situ</i> soil technologies; More than 10 years for groundwater technologies	1-3 years; 0.5-1 year; 3-10 years	Less than 1 year Less than 0.5 years Less than 3 years
System Reliability/Maintainability The degree of system reliability and level of maintenance required when using the technology.	There is insufficient information with which to rate the technology in this category.	Low reliability and high maintenance	Average reliability and average maintenance	High reliability and low maintenance
Regulatory/Permitting Acceptability Degree to which use of the technology is acceptable to the regulatory and permitting community.	There is insufficient information with which to rate the technology in this category.	Below average	Average	Above average
Community Acceptability Degree to which use of the technology is acceptable to the public.	There is insufficient information with which to rate the technology in this category.	Serious public involvement is likely and the outcome is uncertain.	Public involvement usually occurs, but the technology is generally accepted.	Minimal opposition from the community is likely.

Table 2: Remediation Technology Comparison

Evaluation Criteria	Soil Washing	Excavation and Off-Site Disposal	Thermal Desorption	Dual Phase Extraction	Soil Vapor Extraction (SVE)	Soil Flushing	Prefabricated Vertical Drains
Contaminants Treated	1-6	1-7	1-6	1,3,5	1,3,5	1-4, 6, 7	1-7
Overall Cost	Average	Worse	Average	Average	Better	I	Better
Capital or O&M Intensive	Both	Neither	Both	O&M	O&M	O&M	O&M
Commercial Availability	Average	Better	Better	Better	Better	Better	Average
Typically Part of a Treatment Train?	Yes	No	Yes	Yes	No	No	No
Residuals Produced	S,L	NA	L	L,V	L	L	L
Minimum Contaminant Concentration Achievable	Average	NA	Better	Worse	Average	Worse	Average
Addresses (T)toxicity, (M)mobility, or (V)volume	Volume	Mobility	Volume	Volume	Volume	Volume	Volume
Long-Term Effectiveness/ Permanence?	Yes	No	Yes	Yes	Yes	Yes	Yes
Time to Complete Cleanup	Better	Better	Better	Better	Average	Worse	Worse
System Reliability/ Maintainability	Average	Better	Average	Worse	Better	Average	Average
Awareness of Remediation Consulting Community	Average	Better	Better	Worse	Better	Average	Average
Regulatory/ Permitting Acceptability	Average	Worse	Average	Average	Better	Worse	Worse
Community Acceptability	Better	Better	Average	Average	Better	Average	Average

Legend: I=Inadequate Information, S=Solid, L=Liquid, V=Vapor, NA=Not Applicable

Contaminant Codes:

- 1 - Halogenated volatile organics 2 - Halogenated semivolatile organics
- 3 - Non-halogenated volatile organics 4 - Non-halogenated semivolatile organics
- 5 - Fuel hydrocarbons 6 - Pesticides
- 7 - Inorganics

5.2 Cost Comparison

To get a better cost comparison of remediation technologies for various sites and contaminants, actual costs from environmental consultants and contractors will be compared. Costs from Warzyn, Inc. presented from a conference titled Estimating, Tracking, and Controlling Costs of Environmental Remediation (Adams, 1991). Warzyn provided costs for groundwater pump-and-treat systems with soil vapor extraction. One of Warzyn's cost estimates included a cost for disposal of soils in addition to the pump-and-treat/SVE system. Costs for dual-phase extraction were provided by Blake & August Environmental Inc., of Morgantown, West Virginia.

To ensure that the costs for each technology compared were equivalent, a set of site characteristics were assumed. These characteristics are listed below.

In-Situ treatment of 750 cubic yards of petroleum hydrocarbon contaminated soils:

Contaminated area measures 35 feet by 105 feet with a contamination and groundwater depth of eight feet.

Soil permeability is approximately 10^{-3} cm/sec

5 SVE and 4 groundwater recovery wells are required (Where SVE & Pump-and-Treat are employed)

75 cubic yards of soil from trenching and well cuttings is contaminated

65 cubic feet per minute soil vapor flowrate

5 gallon per minute design water flowrate

No vapor phase treatment required for SVE system or air stripper (if required)

Reinfiltration of treated groundwater into shallow aquifer via 3 wells.

Prices of identical line items were set to Warzyn prices so that the cost of the technology was compared and not the cost of identical materials or labor costs.

Although the site was assumed to be contaminated with petroleum hydrocarbons the three employed treatment technologies can be used for the remediation of other contaminants. Both the SVE and the Dual Phase Extraction systems can also treat halogenated volatile organics and non-halogenated volatile organics. Virtually all forms of contamination in the recovered groundwater can be treated by using various treatment technologies as part of a "treatment train".

Table 3 Warzyn, Inc. Cost Approximation for Groundwater Pump-and-Treat System with Soil Vapor Extraction and Incineration of Excavated Soils (Adams, 1993)

	No. Units	Unit Cost	Item Total
<u>Groundwater Treatment System</u>			
GW Wells, 6-Inch, 12-foot Deep	48 lf	\$93	\$4,464
Manhole Covers, 24-inch, Steel Plate	4 ea	\$120	\$480
Misc. Concrete, Per Well Cover	4 ea	\$20	\$80
Threaded Well Cap	4 ea	\$29	\$116
Well Pumps, Timco Pneumatic	4 ea	\$175	\$700
Well Pump Controls	4 ea	\$750	\$3,000
Pitless Adapter	4 ea	\$50	\$200
Discharge Tubing, 3/4" Polyethylene	175 lf	\$0.22	\$39
Pneumatic Air Tubing, 1/2" Copper	125 lf	\$0.90	\$113
500-Gallon Holding Tank	1 ea	\$1,000	\$1,000
Diffused Air Stripper	1 ea	\$6,950	\$6,950
Oil Free Air Compressor, Dryer	1 ea	\$1,100	\$1,100
Transfer Pump	2 ea	\$300	\$600
Filter Cartridge System	1 ea	\$680	\$680
Two Stage Carbon System	1 ea	\$1,650	\$1,650
Reinfiltration Well Construction	3 ea	\$1,000	\$1,000
TOTAL GW TREATMENT SYSTEM			\$24,171
<u>Soil Vapor Extraction System</u>			
SVE Blower System, 5HP	1 ea	\$13,500	\$13,500
SVE Wells, 6-inch, 8-Foot Deep	35 lf	\$93	\$3,255
SVE Pipe, 2" Polyethylene	135 lf	\$1.08	\$146
Manhole Covers, 24-Inch, Steel Plate	5 ea	\$120	\$600
Misc. Concrete, Per Well Cover	5 ea	\$20	\$100
Threaded Well Cap	5 ea	\$29	\$145
TOTAL SVE SYSTEM			\$17,746
<u>Common System Costs</u>			
Misc. Mechanical Allowance	1 ls	\$2,000	\$2,000
Mechanical Labor	15 md	\$275	\$4,125
Misc. Electrical Allowance	1 ls	\$2,000	\$2,000
Control Panel	1ls	\$2,000	\$2,000
Underground Feeder, 1000 amp	100 lf	\$18	\$1,800
Electrical Labor	10 md	\$275	\$2,750
Trenching/Backfill (5.5 feet deep)	215 lf	\$10.80	\$2,322
Soil Incineration, Hazardous Waste	75 yd ³	\$2,170	\$162,750
Misc. Materials Allowance	1 ls	\$2,000	\$2,000
Civil Labor	18 md	\$275	\$4,950
Building, 15' x 20', Per Code	300 ft ²	\$60	\$18,000
TOTAL COMMON SYSTEM COSTS:			\$204,697
SUBTOTAL			\$246,614

Table 4: Warzyn, Inc. Cost Approximation for Groundwater Pump-and-Treat System with Soil Vapor Extraction and Disposal of Excavated Soils (Adams, 1991)

	No. Units	Unit Cost	Item Total
Groundwater Treatment System			
GW Wells, 6-Inch, 12-feet Deep	48 lf	\$93	\$4,464
Manhole Covers, 24-inch, Steel Plate	4 ea	\$120	\$480
Misc. Concrete, Per Well Cover	4 ea	\$20	\$80
Threaded Well Cap	4 ea	\$29	\$116
Well Pumps, Timco Pneumatic	4 ea	\$175	\$700
Well Pump Controls	4 ea	\$750	\$3,000
Pitless Adapter	4 ea	\$50	\$200
Discharge Tubing, 3/4" Polyethylene	175 lf	\$0.22	\$39
Pneumatic Air Tubing, 1/2" Copper	125 lf	\$0.90	\$113
500-Gallon Holding Tank	1 ea	\$1,000	\$1,000
Diffused Air Stripper	1 ea	\$6,950	\$6,950
Oil Free Air Compressor, Dryer	1 ea	\$1,100	\$1,100
Transfer Pump	2 ea	\$300	\$600
Filter Cartridge System	1 ea	\$680	\$680
Two Stage Carbon System	1 ea	\$1,650	\$1,650
Reinfiltration Well Construction	3 ea	\$1,000	\$1,000
TOTAL GW TREATMENT SYSTEM			\$24,171
Soil Vapor Extraction System			
SVE Blower System, 5HP	1 ea	\$13,500	\$13,500
SVE Wells, 6-inch, 8-Foot Deep	35 lf	\$93	\$3,255
SVE Pipe, 2" Polyethylene	135 lf	\$1.08	\$146
Manhole Covers, 24-Inch, Steel Plate	5 ea	\$120	\$600
Misc. Concrete, Per Well Cover	5 ea	\$20	\$100
Threaded Well Cap	5 ea	\$29	\$145
TOTAL SVE SYSTEM			\$17,746
Common System Costs			
Misc. Mechanical Allowance	1 ls	\$2,000	\$2,000
Mechanical Labor	15 md	\$275	\$4,125
Misc. Electrical Allowance	1 ls	\$2,000	\$2,000
Control Panel	1ls	\$2,000	\$2,000
Underground Feeder, 1000 amp	100 lf	\$18	\$1,800
Electrical Labor	10 md	\$275	\$2,750
Trenching/Backfill (5.5 feet deep)	215 lf	\$10.80	\$2,322
Soil Disposal	75 yd ³	\$271	\$20,325
Misc. Materials Allowance	1 ls	\$2,000	\$2,000
Civil Labor	18 md	\$275	\$4,950
Building, 15' x 20', Per Code	300 ft ²	\$60	\$18,000
TOTAL COMMON SYSTEM COSTS:			\$62,272
SUBTOTAL			\$104,189

Table 5: Blake & August Environmental, Inc. Cost Approximation for Dual-Phase Extraction System with No Excavated Soils (Brocius, Personal Communication)

	No. Units	Unit Cost	Item Total
Groundwater Treatment System			
GW Wells, 6-Inch, 12-foot Deep	48 lf	\$93	\$4,464
Manhole Vaults (30"x30"x42")	4 ea	\$475	\$1,900
Misc. Concrete, Per Well Cover	4 ea	\$20	\$80
Threaded Well Cap	4 ea	\$29	\$116
Liquid Ring Vacuum Pump	1 ea	\$7,700	\$7,700
Diffused Air Stripper	1 ea	\$6,950	\$6,950
Reinfiltration Well Construction	3 ea	\$1,000	\$1,000
Oil/Water Separation System	1 ea	\$3,680	\$3,680
500-Gallon Holding Tank	1 ea	\$1,000	\$1,000
Piping	1 ls	\$200	\$200
TOTAL GW TREATMENT SYSTEM			\$27,090
Common System Costs			
Misc. Mechanical Allowance	1 ls	\$2,000	\$2,000
Mechanical Labor	15 md	\$275	\$4,125
Misc. Electrical Allowance	1 ls	\$2,000	\$2,000
Control Panel	1ls	\$8,000	\$8,000
Electrical Labor	10 md	\$275	\$2,750
Misc. Materials Allowance	1 ls	\$2,000	\$2,000
Civil Labor	18 md	\$275	\$4,950
Building, 15' x 20', Per Code	300 ft ²	\$60	\$18,000
TOTAL COMMON SYSTEM COSTS:			\$43,825
SUBTOTAL			\$70,915

Table 6: Cost Approximation of Materials Necessary for a PVD/DESF treatment systems

	No. Units	Unit Cost	Item Total
Groundwater Treatment System			
Prefabricated Vertical Drains	I	I	I
Sand Cover	I	I	I
PVC sheeting	I	I	I
Liquid Ring Vacuum Pump	1 ea	\$7,700	\$7,700
Diffused Air Stripper	1 ea	\$6,950	\$6,950
Oil/Water Separation System	1 ea	\$3,680	\$3,680
500-Gallon Holding Tank	1 ea	\$1,000	\$1,000
Piping	I	I	I
TOTAL GW TREATMENT SYSTEM			I
Common System Costs			
Misc. Mechanical Allowance	1 ls	\$2,000	\$2,000
Mechanical Labor	15 md	\$275	\$4,125
Misc. Electrical Allowance	1 ls	\$2,000	\$2,000
Control Panel	1ls	\$8,000	\$8,000
Electrical Labor	10 md	\$275	\$2,750
Misc. Materials Allowance	1 ls	\$2,000	\$2,000
Civil Labor	18 md	\$275	\$4,950
Building, 15' x 20', Per Code	300 ft ²	\$60	\$18,000
TOTAL COMMON SYSTEM COSTS:			\$43,825
SUBTOTAL			I

I=Inadequate Information

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The figures provided in Tables 3-6 give are a general cost estimate for the materials needed to construct and install a particular type of treatment system at a site with the aforementioned parameters. These estimates do not include costs of permitting, oversight, an estimating contingency, and operations and maintenance. All of the above would be equal with the exception of operations and maintenance. Costs for O&M would include electricity, O&M labor (site maintenance and monitoring), laboratory analysis, quarterly reports, and project administration. These costs would also be identical for each system since they operate on relatively similar principles. The Warzyn systems would have the additional O&M costs of replacement of ground activated carbon and filter bags. This additional cost would amount to approximately an additional \$7,600 per year.

If the PVDs were used as an alternative to recovery wells in a dual-phase extraction system treatment costs would be identical. The only cost difference would be the difference in cost for installation of PVDs versus the installation of recovery wells. Presently, the cost for installation of a PVD system has not been determined. The major limitation of both the dual-phase recovery system and the PVD system is the vacuum required to recovery groundwater. The largest liquid ring vacuum pumps currently available on the market are capable of pulling over a head of approximately 24 feet. This distance is also decreased when losses in the piping network is considered. A major drawback of the Warzyn system of pump-and-treat combined with SVE is the complexity of the system. Such a system requires air compressors and high maintenance pump control units. The Warzyn system, with sufficiently large compressors, could, theoretically, pump over much greater heads than a vacuum driven system. Table 7 is a compilation of all of the costs incurred for each system for easy reference.

Table 7: Cost Comparisons

Technology	Table #	Groundwater Treatment	Soil Vapor Extraction	Common Costs	Total
Pump and Treat w/Soil Incineration	3	\$24,171	\$17,746	\$204,697	\$246,614
Pump and Treat w/Soil Landfilling	4	\$24,171	\$17,746	\$62,272	\$104,189
Dual Phase Extraction	5	\$27,090	*	\$43,825	\$70,915
PVDs/DESF	6	I	I	I	I

I=Inadequate Information

*Costs for soil vapor extraction and groundwater recovery are combined in one cost because components are common for dual phase extraction

6.0 Conclusions

Prefabricated vertical drains may prove to be a useful technology in the recovery of soil vapors and groundwater at contaminated sites. PVDs should be especially useful at sites where fine-grained soils are present. They can be used as a substitute for conventional well fields in the recovery of contaminated soil vapors and groundwater. Although costs for installing PVDs are not currently available, they can be compared to competing remediation technologies using the information supplied in this paper. Once the initial design of the PVD system is complete, the cost of a PVD system can be compared to the traditional methods in the cost comparison section of this report. After pilot tests have been performed, PVD technology can be compared to the technologies listed in the EPA's Remediation Technologies Screening Matrix. If installation costs are low enough, PVDs should be considered as an alternative to traditional recovery wells.

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SITE REMEDIATION TECHNOLOGIES
IN SITU BIOREMEDIATION OF ORGANIC CONTAMINANTS
METC TASK No. 1.2

Quarterly Technical Progress Report
for Period April 1 through June 30, 1995

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For
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Abstract

In situ bioremediation offers a number of advantages over other processes for destruction of organics in groundwater. Advantages include the potential for complete or near complete destruction of contaminants in place, avoidance of transfer of pollutants to another medium, less risk of health hazards due to human exposure and cost-effectiveness in many cases. This research seeks to exploit the natural symbiotic relationship between methanogenic and methanotropic microorganisms. The methanogens are able to carry out the anaerobic reductive dehalogenation (RD) of highly chlorinated solvents producing methane. The methanotrophs, in turn, utilize the end products of the methanogens, including methane, to aerobically degrade the residual compounds to environmentally acceptable end products. Both groups of organisms work cometabolically and require a primary substrate.

The project is divided into two main tasks and a number of subtasks. Under task 1, controlled testing will be performed in columns to find optimum conditions for the complete mineralization of trichloroethylene (TCE) to innocuous end products. Columns will be set up to examine both sequential and simultaneous mineralization. In the sequential columns, RD will be accomplished first with conditions that favor methanogens followed by aerobic conditions that favor methanotrophs. In the simultaneous column, an attempt will be made to set up conditions which promote anaerobic microzones within the columns so that RD and aerobic oxidation take place almost continuously along the column. It is planned to use hydrogen peroxide as an electron acceptor for the methanotrophs.

In task 2, delivery of amendments (such as the primary substrate and electron acceptor) to low permeability soils using prefabricated wick drains (PVD's) will be evaluated using a box lysimeter. Use of wick drains for delivery of amendments and possible ground water recirculation is a unique application of this technology and offers significant improvement over existing methods which require a large number of wells in "tight" soils.

Executive Summary

In situ bioremediation offers a number of advantages over other processes for destruction of organics in groundwater. Advantages include the potential for complete or near complete destruction of contaminants in place, avoidance of transfer of the pollutants to another medium, less risk of health hazards due to human exposure and cost-effectiveness in many cases. The objective of this research is to evaluate and optimize the ability of methanotrophic, methanogenic, and other selected bacteria for cost-effective biotransformation of a mixture of chlorinated solvents as are often found at DOE sites. A five phase workplan is utilized which involves the systematic manipulation of environmental conditions to enhance the rate and extent of biodegradation of the candidate VOC's. It is planned to take advantage of the natural symbiotic relationship between the methanogenic and methanotrophic bacteria so as to promote sequential anaerobic/aerobic mineralization of the chlorinated solvents.

The anaerobic column was operated this quarter under a variety of conditions. Parameters investigated included TCE concentration, potential nitrogen limitation, and methanol feed level.

It was found that an increase in the ammonia nitrogen level in the feed (from 14.4 to 19.6 mg/L) did not improve TCE removal. The percentage removal was approximately 40%. The mass removal rate of TCE was approximately 10 ug/h. However, the concentration of daughter products was about the same at both feed nitrogen levels.

The feed concentration of the primary substrate (methanol) had an insignificant effect on TCE removal. As methanol was increased from 185 to 598 mg/L, TCE removal did not improve. It was approximately 47%. It is not clear at this time as to why the high primary substrate level did not improve TCE removal.

The aerobic column was operated this quarter under a variety of conditions. Parameters investigated included the concentration of methanol, hydrogen peroxide, and hydraulic retention time, and frequency of methane pulsing.

It was found that the percent TCE removed at the top port was approximately 30.3% when the methane was pulsed every two days. When the hydraulic retention time was increased from 24 to 48 hours, the percent TCE removed was approximately 30.42%.

The anaerobic and aerobic columns were joined together near the end of the quarter with the aerobic column receiving the effluent from the anaerobic column. Before the columns could be joined, much preparatory work had to be done in order to assure that nothing sent from the anaerobic column could affect the degradation occurring in the aerobic column. Parameters as total organic carbon (TOC), methane, ammonia-nitrogen, and basal salts were measured or evaluated to assess the potential impact these constituents might have when the columns were combined.

A microsystem for measurement of ORP was located and purchased. The system consists simply of an external cell in which the ORP electrode is mounted and which requires only microliter size samples. It is anticipated that the microsystem for ORP measurement will allow location and control of the anaerobic and aerobic zones.

The 24 inch simultaneous column set-up was completed and the column is now ready for integrity tests. In addition the box lysimeters were planned and designed.

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1.0 INTRODUCTION

A variety of toxic organic contaminants are found at DOE sites including fuel hydrocarbons, polychlorinated biphenyls (PCB's) and volatile organic solvents such as trichloroethylene (TCE), perchloroethylene, and carbon tetrachloride. These compounds may occur as single contaminants, but are often found in conjunction with heavy metals or in mixed wastes containing radioactive components.

In-situ bioremediation has a number of advantages for destruction of organic contaminants in groundwater. Other processes such as sorption and volatilization do not destroy contaminants, but rather just concentrate them or transfer them to another medium. Abiotic (chemical) transformation is not normally cost-effective in groundwaters and may even result in production of more toxic chemical species.

Clean-up methods often involve soil flushing to mobilize the contaminants for transport to the surface for treatment. However, because many organic contaminants sorb to soils, they are not readily leached from the soils often leaving toxic residuals in place even after flushing. Furthermore, bringing the contaminants to the surface increases the risk of health hazards due to human exposure. There is increasing recognition that bacteria are present and active in the subsurface and that *in situ* biotransformation offers a potentially more effective and economical method of contaminant destruction.

2.0 PURPOSE

The purpose of the research is to evaluate and optimize the ability of methanotrophic, methanogenic, and other selected bacteria for cost-effective biotransformation of TCE and other volatile organic compounds (VOC's) found at DOE sites. The approach outlined involves the systematic manipulation of environmental conditions in the subsurface for the purpose of enhancing the rate and extent of biodegradation of candidate (VOC's). This approach takes advantage of the ubiquity of methanotrophic and methanogenic bacteria and introduction of non-native organisms should not be necessary. Also, only relatively benign enhancing compounds will be added in non-toxic concentrations. It is envisioned to take advantage of the natural symbiotic relationship between the methanogenic and methanotrophic bacteria so as to promote sequential anaerobic/aerobic mineralization of the chlorinated solvent contaminants.

3.0 BACKGROUND

A number of exciting developments are occurring in the field of environmental biotechnology (engineering applications of microbial ecology). For example, while trace concentrations of some organic contaminants cannot support microbial growth as the sole electron donor, they can still be biotransformed by engineering the system so that the microbial population obtains the majority of its energy and carbon from a different compound that serves as the primary substrate. This is sometimes referred to as *secondary utilization*. There are also many organic contaminants that are biotransformed in the environment for which no microorganisms have been found which are able to use them as sole carbon source. This is a special case of secondary metabolism often termed *cometabolism*. Cometabolism has been defined (Dalton, 1982) as the "transformation of a non-growth substrate in the obligate presence of a growth substrate or another transformable compound". As an example, halogenated methanes, ethanes, and

ethylenes are poor growth substrates for bacterial growth but may be degraded by methanotrophs growing aerobically on methane (Henson et al., 1988).

4.0 METHODOLOGY

The principal focus of the investigation is to develop methods which will enhance bacterial metabolism of organic contaminants in sub-surface environments in order to increase the rate and extent of biodegradation. Our original proposal was organized into five phases, as follows:

Phase 1: Literature Review.

Phase 2: Batch Studies to Evaluate Optimum Concentration of Growth Enhancing Agents in Both Liquid and Soil Cultures.

Phase 3: Column Studies to Evaluate the Rate and Extent of Degradation of Candidate VOC's.

Phase 4: Comparison of TCE Biotransformation by Particulate and Soluble Methane Monooxygenase.

Phase 5: Investigation of the Utilization of the Symbiotic Relationship Between Methanogenic and Methanotrophic Bacteria for VOC Degradation Without Addition of Exogenous Methane.

A comprehensive literature review of biodegradation of chlorinated solvents was completed and submitted as part of the second quarterly report. As a result of this review we realized the potential for developing the relationship between the methanotrophs (aerobic) and the methanogens (anaerobic) for mineralization of both highly chlorinated and less chlorinated compounds. Emphasis was given to this approach in subsequent phases of the workplan.

The methanotrophs have an obligate requirement for methane, which is complemented by the methane production of methanogenic organisms. Furthermore, the methanogens ability to dehalogenate more oxidized (more halogenated) pollutants, generating vinyl chloride, is complemented by the ability of the methanotrophs to mineralize vinyl chloride and other small mono-chlorinated hydrocarbons. The rate limiting step of mineralization under anaerobic conditions is the dehalogenation of vinyl chloride. Thus, it might be advantageous to induce methanotrophic growth at the point where all (or most) of the more chlorinated compounds have been dehalogenated to vinyl chloride. The number of chlorines dramatically effects the rate of anaerobic degradation: the more chlorines the faster the rate of degradation (Sims et al., 1990). A higher number of halogen substituents results in a more oxidized compound making it more susceptible to biological reduction.

Although methanogenic bacteria will not grow in the presence of oxygen, the reductive dehalogenation reaction is somewhat oxygen tolerant. The rate of TCE degradation is reduced under micro-aerophilic conditions, but not completely blocked (Freedman and Gossett, 1989). Under these conditions a suitable source of reducing equivalents must be provided (eg. methanol, hydrogen, acetate, and formate). It is interesting to note in this regard that Kastner (1991) reported that an aerobic enrichment culture's ability to dechlorinate cis-1,2-dichloroethylene was shown to be dependent on a cyclic transition from aerobic to anaerobic conditions and limited oxygen supply. It may also be possible to increase biodegradation rates by alternating methanogenic and methanotrophic growth conditions, thus limiting the accumulation of potentially toxic byproducts, as well as optimizing the alternating production of methane rich and

3.0 Preparation and Submission of Quarterly and Final Reports--50 % Complete

Assuming equal weight for each of the 8 project tasks noted above, it is estimated that the overall project is 48.1 % complete.

6.0 RESULTS AND DISCUSSION

6.1 Anaerobic Studies

Evaluation of TCE removal in a separate anaerobic column was continued this quarter. The column was operated in a continuous upflow mode under a variety of conditions. Much of the data was collected to aid in the combining of the anaerobic and aerobic columns in series. The major parameters that were studied this quarter were influent nitrogen and influent methanol. A TCE feed concentration of 5.0 mg/L was used in all cases this quarter.

As noted in earlier reports, anaerobic decomposition of chlorinated solvents is cometabolic and a primary substrate is needed to accomplish the desired reductive dehalogenation (RD) of the solvents. During RD, the halogenated compound becomes an electron acceptor and chlorine atoms are sequentially replaced by hydrogen atoms. Reduction of TCE proceeds via the formation of one of three isomers of dichloroethylene (trans-, cis-, or 1,1-DCE) or vinyl chloride.

Methanol and acetic acid are being used as the primary substrates to provide reducing equivalents and accomplish RD of TCE. The concentrations of TCE, the primary substrates and ammonium chloride fed to the column during the quarter are shown in Table 1. The composition of the basal salts media utilized (as well as the TCE and primary substrates) is presented in Table 2. It should be noted that the basal salts added remain unchanged during the quarter (except for ammonium chloride) while primary substrate and ammonia nitrogen were modified as shown in Table 1. The column was operated at a hydraulic detention time of 48 hours with a feed flow rate of approximately 5 mL/hour. The pH varied only slightly between 7.0 to 7.2.

6.1.1 Effect of Nitrogen

This quarter the ammonium nitrogen level ($\text{NH}_4\text{-N}$) was raised from 14.4 to 19.6 mg/L to investigate the effect of nitrogen on TCE removal. Results are presented in Figures 1 to 5. The concentration of TCE added to the column this quarter was 5.0 mg/L corresponding to a loading rate of 0.0306 mg/d cm^2 or 1.02 mg/d L. Mass flowrate and percent removal data are presented in Figures 1 to 3. Prior to increasing the nitrogen concentration, ($\text{NH}_4\text{-N}$ concentration of 14.4 mg/L) TCE removal was found to be about 12.9 ug/h yielding a percent TCE removal of 47 %. As the nitrogen was increased, the average mass rate of removal and the percent removal were observed to decrease to 9.8 ug/h and 38%, respectively. It is not clear at this time as to why TCE removal fell as the nitrogen concentration was increased.

Figures 4 and 5 show the mass flow rate data for the daughter products. Last quarter at a nitrogen concentration of 14.4 mg/L, the average 1,1-DCE and 1,2-DCE mass flow rates were 0.11 and 0.20 ug/h, respectively or showing a ratio of 1:1.8. When the $\text{NH}_4\text{-N}$ level was increased from 14.4 to 19.6 mg/L, the

oxygen rich conditions.

5.0 WORK PERFORMED THIS PERIOD

This quarter, the anaerobic and aerobic columns continued to be operated separately in an upflow mode. Late in the quarter, the columns were combined so as to operate in a sequential mode. A variety of parameters were evaluated for each columns prior to joining them in sequential system. For the anaerobic columns, parameters evaluated included influence of nitrogen and methanol. For the aerobic column, evaluation was carried out of the influence of methanol level, the effect of methane pulsing, and hydraulic retention time. Work was also carried out on system design for both the sequential and simultaneous systems. The lysimeter was designed to evaluate the performance of PVD drains for amendments delivery.

A brief summary of progress on the tasks is presented below.

1.1 Optimization of Sequential Mineralization--60 % Complete

This task was continued this quarter in the individual columns by investigating the influence of a variety of variables on performance. Work was carried out to prepare for combining the individual columns in simultaneous operation and the columns were combined late in the quarter.

1.2 Design and Construction of Simultaneous Mineralization Column-100% Complete

This task was completed last quarter when the funds became available (in March).

1.3 Development and Testing of Protocol to Locate Zones--100 % Complete

Last quarter, it was decided to put this task on hold because of potential difficulties anticipated in obtaining reliable measurements. However, a microsystem was located that allows measurement of the oxidation reduction potential (ORP) externally and preliminary measurements carried out on both the anaerobic and aerobic columns. It is anticipated that the system will allow the use of ORP measurements to locate the anaerobic and aerobic zones and aid in obtaining optimum removal of the TCE.

1.4 Optimization of Simultaneous Mineralization--0 % Complete

The system is now constructed and work on this task will begin next quarter.

1.5 Assessment of Potential Bioremediation of High Concentrations of CAH Compounds --5 % Complete

This task was briefly worked on last quarter when accidental shock loads of TCE entered both the anaerobic and aerobic columns.

2.1 Design and Construction of Lysimeters Equipped with PVD's--70 % Complete

The lysimeters were designed this quarter and will be constructed early in the next quarter.

2.2 Amendments Delivery and Potential Clogging--0 % Complete

corresponding mass flow rates changed significantly as 1,1-DCE rose to 0.20 ug/h and 1,2-DCE fell to 0.14 ug/h for a ratio of 1.4:1. It is also interesting to note that vinyl chloride first started becoming evident during this time (data is provided below).

Table 1. Concentration of TCE, primary substrates, and ammonia feed to the column.

Dates	TCE Conc (mg/L) (1)	TCE Loading (mg/d L)	Methanol Conc. (mg/L)	Acetic Acid Conc. (mg/L)	Ammonia-N Conc. (mg/L)
4/1 - 5/1	5.0	1.02	598	183	14.4
5/2 - 6/19	5.0	1.02	598	183	19.6
6/20 - 6/30	5.0	1.02	900	183	19.6

(1) The TCE values shown are target values, while the actual concentration fed to the column varies from syringe to syringe.

Table 2. Composition of Media

Chemical	Conc. in Stock Solution	Conc in Media/Syringe	Conc entering column
NH ₄ Cl	1432 mg/L	57.3 mg/L	55 mg/L
K ₂ HPO ₄	76 mg/L	3.04 mg/L	2.92 mg/L
KH ₂ PO ₄	55 mg/L	2.2 mg/L	2.11 mg/L
MgCl ₂ *6H ₂ O	150 mg/L	6 mg/L	5.76 mg/L
MnCl ₂ *4H ₂ O	50 mg/L	2 mg/L	1.92 mg/L
CoCl ₂ *6H ₂ O	100 mg/L	4 mg/L	3.84 mg/L
ZnCl ₂	50 mg/L	2 mg/L	1.92 mg/L
CaCl ₂ *2H ₂ O	165 mg/L	6.6 mg/L	6.34 mg/L
HBO ₃	15.1 mg/L	0.604 mg/L	0.580 mg/L
NiCl ₂ *6H ₂ O	50 mg/L	2 mg/L	1.92 mg/L
Na ₂ MoO ₄ *2H ₂ O	20 mg/L	0.8 mg/L	0.768 mg/L
L-Cysteine C ₃ H ₇ NO ₂ S*HCl*H ₂ O	450 mg/L	18 mg/L	17.28 mg/L
NaHCO ₃	2000 mg/L	80 mg/L	76.8 mg/L
Yeast Extract	50 mg/L	2 mg/L	1.92 mg/L
FeCl ₂ *4H ₂ O	30 mg/L	1.2 mg/L	1.15 mg/L
Resazurin	0.001 mg/L	0.04 ug/L	0.0384 ug/L
TCE	10000 mg/L	125 mg/L	5.0 mg/L
Na ₂ CO ₃	30000 mg/L	6000 mg/L	264 mg/L
CH ₃ COOH	1049000 mg/L	4582 mg/L	183 mg/L
CH ₃ OH	792400 mg/L	14,950 mg/L	598 mg/L

6.1.2 Effect of Methanol

In an attempt to increase TCE removal, the single carbon primary substrate, methanol was increased twice this quarter. As noted earlier, last quarter ended, the methanol level was 185 mg/L and the mass rate and % TCE removal were respectively 11.6 ug/h and 49 %. This quarter, the methanol level was step-increased to 598 and then to 900 mg/L.

The methanol concentration was increased to 598 mg/L on 4/1/95 and TCE removal is shown in Figures 1 to 5. It should be noted that the following discussion refers to the lefthand side of Figures 1 to 5 before the ammonia nitrogen

concentration was raised. TCE mass flow rate (ug/h) in the influent, at the bottom, middle, and top ports are shown in Figure 1. Figures 2 and 3 show the mass rate of removal and percent removal respectively across the column length (influent to top port). Examination of Figure 3 shows that increasing the methanol concentration did not significantly increase the degradation of TCE. The percentage removal was observed to be about the same at 47. The degradation rate did increase, however, by a small amount (from 11.6 ug/h to 12.9 ug/h).

The mass flow rate of the daughter products, 1,1-DCE and 1,2-DCE are shown in Figures 4 and 5, respectively. 1,1-DCE and 1,2-DCE leaving the columns averaged 0.14 ug/h and 0.22 ug/h, respectively, corresponding to a 1,1-DCE to 1,2-DCE ratio of 1:1.6. These values are about the same as reported last quarter at a methanol concentration of 185 mg/L.

The methanol concentration was raised to 900 mg/L on 6/19. Figure 6 shows the TCE mass flow rate in the influent and at each port during this period. The mass rate of removal and percent removal are shown in Figures 7 and 8, respectively. Examination of Figure 8 shows that the percent removal increased somewhat from an average value of 38% to a value of 40%. The mass removal rate of TCE correspondingly increased from 9.8 to 10.4 ug/h.

Figures 9, 10, 11, and 12 show the mass flow rates of 1,1-DCE, cis-1,2-DCE, trans-1,2-DCE and vinyl chloride, respectively. It may be noted that 1,1-DCE was produced at an average flowrate of 0.19 ug/h, cis-1,2-DCE at 0.12 ug/h, trans-1,2-DCE at 0.10 ug/h, and vinyl chloride at 0.12 ug/h. The ratio of 1,1-DCE to 1,2-DCE is 1:1.2.

6.1.3 Total Organic Carbon (TOC) Removal in the Anaerobic Column

Examination of Figure 1 shows that almost all TCE removal was occurring from the influent to the bottom port (the first four inches) of the column. Total organic carbon measurements were made to determine the pattern of primary substrate removal along the column. Figure 18 shows the amount of TOC in the influent and at each of the three ports. It may be seen that almost all of the TOC is removed in the first four inches (bottom port). The concentration of TOC then falls only a small amount through the column. It is likely that the TOC at the top port represents just the carbon in the cells of the biomass and is not free substrate. As noted earlier, the methanol concentration was increased from 598 to 900 mg/L on 6/19. It may be noted from Figure 18 that the higher methanol shows up for a few days as a higher TOC at the bottom port, but soon falls back to previous levels as the microorganisms in the column adjust the higher substrate level and remove it. Based on the above data, it is clear that the primary substrate is being removed in the first four inches of the column and that TCE removal correlates with primary substrate removal.

6.1.4 Summary of Performance Data for Quarter

Table 3 provides a summary of performance data for the variety of conditions evaluated during the quarter. All period tests were performed for an approximate TCE feed concentration of 5.0 mg/L.

Table 3. Summary of Performance Data-Anaerobic Column

Period	CH ₃ OH (mg/L)	NH ₃ -N (mg/L)	TCE Rem. (ug/h)	% TCE Rem.	1,1-DCE (ug/h)	1,2-DCE (ug/h)	VC (ug/h)
Last Quart.	185	14.4	11.6	49	0.11	0.20	
4/1-5/1	598	14.4	12.9	47	0.14	0.22	
5/2- 6/19	598	19.6	9.8	38	0.20	0.14	trace
6/20- 6/30	900	19.6	10.4	40	0.19	0.22	0.12

6.2 Aerobic studies

6.2.1 Aerobic Column Studies

Evaluation of the aerobic mineralization of TCE using methanotrophs and other heterotrophs in an upflow column was continued this quarter.

Methanotrophic bacteria produce methane monooxygenase (MMO) to begin catabolism of methane (the primary substrate) for assimilation into biomass or mineralization. The MMO is relatively non-specific, and the enzyme also is active (cometabolically) in transforming TCE to TCE-diol and eventually biological mineralization to CO₂ and H₂O. It is the nature of cometabolic processes that the presence of the primary substrate both increases cometabolic transformation by increasing the available biomass and decreases cometabolic transformation by competing for the active site of the enzyme. The competitive inhibition of methane has been demonstrated both in the laboratory and the field (Semprini, 1994). The presence of methane is inhibitory to TCE degradation are the results of work by Smith (1993, EPA Proceedings) indicating that transformation of high concentrations of TCE (5 to 9 mg/L) was enhanced by the presence of methane. Additional research (Speitel, 1991) has indicated that low concentrations of methane (1 % methane/air atmosphere) or 1.5 mg/L (Lanzarone, 1990) did not result in inhibition of TCE oxidation. These investigators also demonstrated the ability of methanotrophs to continue TCE oxidation for several weeks in the absence of methane. It is clear that careful application of methane, either in a pulse feed mode or at low concentrations will be necessary to avoid problems with competitive inhibition.

While the MMO enzyme is responsible for the initial epoxidation of methane to methanol, other enzymes are responsible for further metabolism for biomass assimilation or energy production in the form of reduced nicotinamide adenine dinucleotide (NADH₂). Further oxidation of methane oxidation products (methanol, formaldehyde and formate) yields reducing equivalents in the form of NADH.

Methanol has been investigated as both an electron acceptor and a carbon source. Broholm et al. (1993) reported field investigations showing TCE transformation could be supported by methanol addition in the absence of methanol for a period of 60 hours. Thus, the addition of methanol as an alternative primary substrate to methanol as a source of electrons and as a growth substrate along with pulse feeding of methane seems an attractive alternative to maintain a viable population while avoiding problems with competitive inhibition of methane.

Methane and methanol are being used as the primary substrates to accomplish the oxidation of TCE. The concentration of TCE, methanol and hydrogen peroxide fed into the column this quarter are shown in Table 5. One of the major changes made at the end of last quarter was the frequency of methane pulse entering the column. Pulse feeding on alternate days followed by pulse feeding every two days was initiated. Purchase of a methane cylinder and its subsequent installation at the Engineering Sciences Building made these changes possible. The composition of the basal media is the same as the last quarter (Table 4). The hydraulic retention time of the column was however changed from 24 hrs to 48 hrs on 5/27/95. This decreased the ground water flow rate from 10.2 ml/hr to 5.2 ml/hr. This was done in order to prepare the aerobic column for linking sequentially with the anaerobic column (the anaerobic column has been operated with an HRT of 48 hours). Analysis of the aerobic column performance under the low flow rate would then serve as background information when the two columns (aerobic and anaerobic) are connected in the sequential mode. The effluent temperature, pH and DO were measured daily. The temperature ranged from 21° C to 30.1° C. Data from 4/7/95 to 6/28/95 are present in Fig. 13. The pH was consistent at 6.9 to 7.2. The DO varied between 4.75 and 14.94 during this time period.

The wide range in DO is due to the rate at which the hydrogen peroxide was fed into the influent ground water. The ground water flow rate in the column ranged between 9.17 ml/hr and 12.69 ml/hr during the time period. Between 5/27/95 and 6/28/95 the flow rate was 4.42 ml/hr to 6.1 ml/hr. This had a direct effect on the influent TCE concentration. The column is fed 5 mg/L of TCE at a rate of 0.2 ml/hr using a syringe pump. Variation in the ground water flow rate was taken into account while determining the influent TCE concentration which ranged from 3523 mg/L to 6780 mg/L.

Table 4. Composition of Column Feed

Compound	Concentration in Stock Solution (mg/l)	Concentration in the Feed (mg/l)
Higgins Medium at 9:1 dilution		
NaNO ₃	850	85
KH ₂ PO ₄	530	53
Na ₂ HPO ₄	860	86
K ₂ SO ₄	170	17
MgSO ₄ .7H ₂ O	37	3.7
CaCl ₂ .2H ₂ O	7	0.7
Trace Elements		
FeSO ₄ .7H ₂ O	0.5	.05
ZnSO ₄ .7H ₂ O	0.4	.04
MnCl ₂ .4H ₂ O	.02	.002
CoCl ₂ .6H ₂ O	.05	.005
NiCl ₂ .6H ₂ O	.01	.001
H ₃ BO ₃	.015	.0015
EDTA	.25	.0025
CuSO ₄ .5H ₂ O	2496	.0125
Phosphate Buffer (pH 6.8) @ 1ml/100ml broth		
KHPO ₄	260	2.6
Na ₂ HPO ₄	330	3.3
Vitamins		
Biotin	.02	.0002
Folic Acid	.02	.0002
Thiamine HCl	.05	.0005
Calcium Pantothenate	.05	.0005
B ₁₂	.01	.0001
Riboflavin	.05	.0005
Nicotamide	.05	.0005

measurement will allow location and control of the anaerobic and aerobic zones.

The oxidation-reduction potential (ORP) of an aqueous solution is a measure of the electron activity within the environment. For the environment to be reducing, electrons are donated and the ORP is low or negative, while a high ORP signifies oxidizing conditions (Gupta et al. 1994). Until recently ORP was considered an inaccurate measuring device for biological systems due to the variance in absolute ORP between any two probes. A discovery was made that though a system could give a variance in absolute ORP values of up to 50 mV for two different electrodes, the values for the ORP variation in time did not change (Wareham et al. 1993). An excellent use for ORP probes is in the determination of aerobic and anoxic zones of sludge activity. From the ORP, the oxygen breakpoint can be found as defined by Marshall et al. (1995). The authors defined the oxygen breakpoint as the point where the oxygen demand (created by the BOD and the ammonia found in the anoxic portion of the cycle) is satisfied and the dissolved oxygen can become free residual oxygen measurable by a dissolved oxygen probe. This process was used in finding aerobic and anoxic zones in an oxidation ditch. They found that BOD removal occurred at an ORP of between +50 and +250 mV, nitrification occurred at approximately +100 mV or greater, and denitrification was found between -50 and +50 mV. They also found that denitrification (facultative anaerobes) cannot survive in a medium in which the ORP value is greater than +250 mV. This corresponds to a dissolved oxygen concentration of about 2 mg/L.

Other work on this matter was done by Stumm (n.d.). The ORP of a water system at equilibrium with atmospheric oxygen at pH of 7 would be approximately +800 mV. Also, it was determined organic material oxidation (reductive dehalogenation) is greatest at an ORP level of approximately -250 mV at a pH of 7. This was found to be the case for chloroform removal. As the system became more reducing in nature, lower ORP, more of the chloroform went through reductive dehalogenation (Gupta 1994).

To get methanogenic conditions, a reducing agent is often used to lower the ORP. Haddad (1990) pointed out that it is impossible to get the ORP into the range of -330 mV, which is the optimum ORP for methanogens, by just removing the oxygen. Two of the most common reducing agents are sodium sulfide (Na_2S) and cysteine hydrochloride ($\text{C}_3\text{H}_7\text{NO}_2\text{S} \cdot \text{HCl} \cdot \text{H}_2\text{O}$). Sodium sulfide is alkaline in nature with an redox potential (E_0) value of -571 mV and is normally added as 0.01-0.025% in the media. Cysteine hydrochloride is acidic in nature with an E_0 value of -210 mV and is normally added as 0.02-0.08% in the media. For pH control, these two reducing agents are commonly used together with a concentration of 0.025% each in the media (Ljungdahl and Wiegel 1986).

Currently, the reducing agent added to our anaerobic column is L-cysteine. A number of ORP measurements (see Table 9) have been made for both the anaerobic and aerobic columns in preparation to combining the columns into both the sequential and simultaneous modes. Measurements to date have shown an average ORP in the bottom port of -171.25 mv. The ORP becomes more negative due to microbial activity throughout the column increasing to an average of -171.9 mv in the middle port and -176.8 mv at the top port. Consideration is being given to changing from the use of L-cysteine to sodium sulfide to decrease the ORP to a value of -250 mV or lower. The major problem with this change is that it may result in precipitation of metal sulfides and it may also require an increased dosage of hydrogen peroxide in the aerobic portion of the system.

Table 8 also shows recent ORP measurements in the aerobic column. It may be noted that the ORP averages +169.4 mV in the bottom port and then falls up the column due to microbial oxidation of the organics present as would be expected. It falls

Table 5. Column Conditions

Time Span	Desired Eff. Flow Rate (ml/hr)	Eff. DO (mg/L)	pH	Infl. Meth. Conc (mg/L)	Infl. TCE Conc. (mg/L)	Infl. H ₂ O ₂ Conc. (mg/L)	Hyd. Ret. Time
4/7/95 - 5/6/95	10.2	7.88	7.02	32	5	75	24
5/7/95 - 5/26/95	10.2	7.45	6.95	32	5	75	24
5/27/95 - 6/28/95	5.2	10.45	7.04	32	5	75	48

6.2.2 Effect of Methane Pulsing

The concentration of TCE (ppb) at the bottom, middle, and top ports is shown in Fig. 14. Figs. 15 and 16 show the overall percent removal of TCE in the column. The average percent removal was found to be 25.4% during 4/7/95 to 5/6/95 when the ground water was sparged with methane on alternate days. The decrease in influent methane concentration, brought about by sparging every two days between 5/7/95 and 5/26/95 increased the average removal rate to 30.3%. Table 6 and Fig. 17 gives an account of the change in removal rate at different ports due to a decrease in the influent methane concentration. The table clearly indicates a 33% increase in the removal rate at the middle and bottom ports and a 16% increase in the removal rate at the top port. Thus, the decrease in frequency of pulsing methane increased the overall degradation rate of TCE by 16%. This suggests that methane inhibition plays a role in aerobic biodegradation of TCE by methanotrophs.

Table 6. Effect of Methane Pulsing

Time Period	Hydraulic Retention Time (hrs)	Methane Pulsing	% TCE Removal with respect to the influent conc.		
			Top Port	Middle Port	Bottom Port
4/7/95 - 5/6/95	24	alternate days	25.4	16.2	16.1
5/7/95 - 5/26/95	24	every two days	30.3	24.5	23.8
% Increase in Removal Rate			16	33	33

6.2.3 Effect of Hydraulic Retention Time

The hydraulic retention time was increased from 24 hrs to 48 hrs on 5/27/95. Pulsing of methane was continued as before (every two days). The concentration of TCE at the bottom, middle and top ports is shown in Fig. 14. Fig. 15 shows the overall percent removal of TCE at the top port. The average percent removal was found to be 30.42% during this time period. Table 7 and Fig. 17 give an account of the change in TCE removal at different ports due to the increase in hydraulic retention time while keeping the methane pulsing rate constant (every two days). The table clearly indicates that change in hydraulic retention time does not bring about a significant change in the TCE removal rate. In fact, the removal rate is practically the same before and after increasing the retention time to 48 hrs.

6.2.4 TOC Measurements for the Aerobic Column

In the aerobic column, TOC analyses of the influent and effluent ground water was carried out on two occasions in order to interpret the functioning and TCE removal in terms of the TOC. In order to obtain consistent data, analysis on both occasions was done on the day corresponding to the end of the two-day methane pulse feed cycle. The results are shown in Fig. 19. The influent TOC was theoretically determined to be 21.9 ppm, by assuming an influent TCE concentration of 5 ppm and a methanol concentration of 32 ppm in the column. The influent methane concentration was assumed to be 12 ppm based on the maximum solubility of methane in water (24 ppm). Figure 19 indicates an average 71.4% decrease in the influent TOC. The TOC concentration also seems to logically decrease from the bottom to the top port.

Table 7 Effect of Hydraulic Retention Time

Time Period	Hydraulic Retention Time (hrs)	Methane Pulsing	% TCE Removal with Respect to the Influent Conc.		
			Top Port	Middle Port	Bottom Port
5/7/95 - 5/26/95	24	every two days	30.3	24.5	23.8
5/27/95 - 6/28/95	24	every two days	30.4	23.3	22.3

6.3 Measure of Oxidation Reduction Potential Values in Individual Anaerobic and Aerobic Columns

As noted in the last quarterly report, Subtask 1.3 is "Development of Protocol to Locate Anaerobic and Aerobic Zones". After review of the literature, it was decided to use the oxidation reduction potential (ORP) in order to estimate the boundaries of the anaerobic and aerobic zones. For reasons noted in the last quarterly report, reliable measurement of ORP was not felt to be possible without a significant amount of work and it was stated that this subtask would not be pursued. However, after completion of the last report, a microsystem for measurement of ORP was located and purchased. The system consists simply of an external cell in which the ORP electrode is mounted and which requires only microliter size samples. It is anticipated that the microsystem for ORP

to +158.7 mV in the middle port and to +148.5 mV in the bottom port. As noted earlier, aerobic bacteria function best at an ORP of greater than +100 mV.

Based on measurements to date, it is anticipated that use of ORP measurements will be helpful in locating the anaerobic and aerobic zones and aid in producing conditions to optimize the mineralization of the TCE.

Table 8. ORP Data on the Individual Anaerobic and Aerobic Columns

Date	Top Port Aerobic	Mid Port Aerobic	Bot Port Aerobic	Top Port Anaer.	Mid Port Anaer.	Bot Port Anaer.
June 22	+68 mV	+121 mV	+136 mV			
June 23	+135.6 mV	+129 mV	+140.7 mV			
June 24	+99.3 mV	+129.3 mV	+142.8 mV	-173 mV		
June 26	+158.1 mV	+155 mV	+159.1 mV	-151 mV		
June 27	+158.1 mV	+158.9 mV	+169.9 mV	-158.7 mV		
July 7	+171.8 mV	+179.4 mV	+192.7 mV	-178.5 mV	-171.4 mV	-164.4 mV
July 9	+186.4 mV	+191.0 mV	+198.7 mV	-186 mV	-171.8 mV	-168.3 mV
July 11	+172.4 mV	+176.3 mV	+188.7 mV	-190.8 mV	-171.4 mV	-183.4 mV
July 12	+186.4 mV	+188.3 mV	+195.7 mV	-199.7 mV	-173 mV	-168.9 mV
Average	+148.5	+158.7	+169.7	-176.8	-171.9	-171.2

6.4 Sequential Anaerobic/Aerobic Column Set-up

The anaerobic and aerobic columns were joined together near the end of the quarter with the aerobic column receiving the effluent from the anaerobic column. A schematic diagram of the of the sequential column setup is given in Figure 21. Before the columns could be joined, much preparatory work had to be done in order to assure that nothing sent from the anaerobic column could affect the degradation occurring in the aerobic column. Such parameters as total organic carbon (TOC), methane, ammonia-nitrogen, and basal salts were measured or evaluated to assess the potential impact these constituents might have when the coluns were combined.

6.4.1 Evaluation of Effluent Methane from Anaerobic Column

The level of methane in the effluent of the anaerobic column was measured to determine if adequate methane was being produced to provide methane to the aerobic column with externally adding this primary substrate. To do this, the effluent from the anaerobic column was sealed in order to keep the off-gas from escaping. Because of the high volatility of the methane, all that is in the effluent would transfer quickly to the gas phase. This gas was then sampled for percent methane and from these results the amount of methane in the effluent could be approximated. The results for the two samples showed a methane concentration of 19.8% and 19.3%. These results suggest that no extra methane will need to be added to the system.

6.4.2 Ammonia-Nitrogen Level

The ammonia-nitrogen level was determined in the effluent from the anaerobic column as ammonia competes with the degradation of TCE found in the aerobic column. Evaluation showed that the actual ammonia nitrogen entering the column was 21.41 mg/L, while the effluent contained 7.41 mg/L. Because of the excess ammonia leaving the anaerobic column which might cause a decrease in TCE removal due to competition, it was decided to decrease the ammonia nitrogen feed concentration of to 14.72 mg/L.

6.4.3 Modification of Basal Salt Composition to be Fed to the Sequential Column

The composition of the basal salts added to each of the systems in the simulated ground water was compared to see if the correct nutrients were available to assure optimum growth. An incompatibility with L-cysteine ($C_3H_7NO_2S \cdot HCl \cdot H_2O$), which is used as extra protection to insure that no oxygen enters the anaerobic system, was noticed for the aerobic column. It was decided to add only 5 mg/L instead of the previous level of 17.28 mg/L. Sulfates were added to the system for the aerobic column. This was accomplished by adding $MgSO_4$ to the ground water instead of $MgCl_2$. Copper also had to added to the column for the aerobic column to assure soluble MMO could be formed. Therefore a concentration of 0.0125 mg/L $CuSO_4$ was added to the system. The composition of the new ground water for the sequential columns is given in Table 9.

Table 9. Composition of Sequential Column Ground Water

Chemical	Conc. in Stock Solution	Conc. in Media/Syr.	Conc. entering column
NH ₄ Cl	500 mg/L	20 mg/L	18 mg/L
K ₂ HPO ₄	76 mg/L	3.04 mg/L	2.92 mg/L
KH ₂ PO ₄	55 mg/L	2.2 mg/L	2.11 mg/L
MgSO ₄	150 mg/L	6 mg/L	5.76 mg/L
MnCl ₂ *4H ₂ O	50 mg/L	2 mg/L	1.92 mg/L
CoCl ₂ *6H ₂ O	100 mg/L	4 mg/L	3.84 mg/L
ZnCl ₂	50 mg/L	2 mg/L	1.92 mg/L
CaCl ₂ *2H ₂ O	165 mg/L	6.6 mg/L	6.34 mg/L
HBO ₃	15.1 mg/L	0.604 mg/L	0.580 mg/L
NiCl ₂ *6H ₂ O	50 mg/L	2 mg/L	1.92 mg/L
Na ₂ MoO ₄ *2H ₂ O	20 mg/L	0.8 mg/L	0.768 mg/L
L-cysteine C ₃ H ₇ NO ₂ S*HCl*H ₂ O	130.2 mg/L	5.21 mg/L	5.0 mg/L
NaHCO ₃	2000 mg/L	80 mg/L	76.8 mg/L
CuSO ₄	0.325 mg/L	.0130 mg/L	0.0125 mg/L
Yeast Extract	50 mg/L	2 mg/L	1.92 mg/L
FeCl ₃ *4H ₂ O	30 mg/L	1.2 mg/L	1.15 mg/L
Resazurin	0.001 mg/L	0.04 ug/L	0.0384 ug/L
TCE	10,000 mg/L	125 mg/L	5.0 mg/L
Na ₂ CO ₃	30,000 mg/L	6000 mg/L	264 mg/L
CH ₃ COOH	1,049,000 mg/L	4582 mg/L	183 mg/L
CH ₃ OH	792,400 mg/L	18,750 mg/L	750 mg/L

6.5 Simultaneous Anaerobic/Aerobic Column

The 24 inch simultaneous column set-up was completed and the column is now ready for integrity tests. The configuration of the column is given in Figure 22.

6.6 Evaluation of Prefabricated Vertical Drains for Field Application of Amendments Using Lysimeters

Prefabricated vertical drains (PVD's) offer a unique potential for delivery of amendments and possible recirculation of groundwater, especially in low permeability soils where a large number of closely spaced wells might be needed.

The main objectives of this task are to 1) determine the suitability of PVD's for adding amendments such as hydrogen peroxide and methanol and 2) to evaluate potential clogging (biological and/or chemical) in and near the drains.

PVD's consist of a plastic (HDPE) core (often fluted) surrounded by a geotextile filter. A wide variety of geotextiles are manufactured. The structure may be woven or nonwoven. Polymer materials utilized are typically polypropylene, polyester, PET, or a combination of the polymers. Permeability is often described based on apparent opening size (AOS). AOS sizes typically range from 20 to 200 based on U.S. Standard Sieve size. This range of sieve sizes corresponds generally to a range of from 0.075 to 0.8 mm. PVD's are often termed strip drains because of their normal functional use.

The use of PVD's for delivery of amendments is attractive. However, there is a concern that, over time, clogging may occur within or at the surface of the PVD. It is also possible that clogging may occur around the PVD where amendment concentration is high promoting excess growths of microorganisms or precipitation of insoluble products. There is also a concern that amendments such as hydrogen peroxide may chemically degrade the PVD or even that biological degradation may take place.

A variety of studies (Rohde and Gribb, 1990, Cazzuffi and Cossu, 1993) have been carried out to evaluate the filtration performance of geotextiles for applications such as leachate collection. However, clogging evaluation relating to the use of PVD's for delivery of organics and oxidants does not appear to have been evaluated and reported. Mlynarek and Rollin (1995) suggest four possible clogging mechanisms of geotextiles: a) solid particle retention, b) biological clogging, c) iron oxide precipitation, and 4) salt precipitation. Solid particle retention occurs when migrating particles are stopped and accumulate upstream of the geotextile interface. This should not be important for our system in that the amendments moving through the geotextile will not contain particulate matter. Precipitation of salts should not be a problem because of the type of amendment under consideration. Iron oxide precipitation may be possible under some conditions in the zone of influence of the PVD, but probably not within the PVD itself.

Biological clogging seems to be the most important potential mechanism of clogging for our intended use of the PVD's. Koerner (1993) and Mlynarek and Rollin (1995) note that bacteria enhance their chance for survival by adhering to a solid surface such as a PVD. In addition to normal adhesion to the solid surface, under certain conditions bacteria form an extracellular fibrous polysaccharide-containing matrix which results in further biofouling.

While biological degradation of the PVD's is a concern, it is unlikely. All polymeric resins used in geocomposites and geotextiles have very high molecular weights with very few chain endings for attack of microorganisms. There is a possibility that certain additives to the geocomposites such as plasticizers or processing aids may be vulnerable to biodegradation. Ionescu et al (1982) evaluated six fabrics (polypropylene, polyester, and composite) in eight media for from 5 to 17 months. The media included a variety of organic and inorganic substrates and with and without various bacteria. Fabric evaluation was by permeability, tensile strength, and infrared spectroscopy. Results showed no measurable effect of permeability, only small variations in tensile strength and no structural changes as viewed by the infrared spectroscopy.

6.6.1 Design and Construction of Lysimeters.

The delivery of amendments and potential clogging of the PVD's will be evaluated using box lysimeters. Two plexiglas lysimeters are currently under construction. They are 4 inches wide, 12 inches deep and 16 inches long. The soil will be 9 inches deep resulting in a total soil volume of 576 cubic inches or 0.333 cubic feet. Conditions in one box will be aerobic while the other box will be anaerobic. Initially, Ottawa sand will be utilized in the boxes until protocols are developed. In later testing, a sand/clay mixture will be used to simulate a low permeability soil.

A schematic of the lysimeter is shown in Figure 23. Simulated groundwater will be flow through the box from the headwater section exiting at the tailwater end through a series of holes. One inch wide PVD's will be installed as shown in the center near the front end of the lysimeter for delivery of amendments. The PVD's will be taped on the back side so as to direct added amendments in the direction of the groundwater flow.

Methanol and acetic acid will be added to the anaerobic box as is currently done for the anaerobic column. Methanol and hydrogen peroxide will be added to the aerobic box as currently practiced for the aerobic column. Since the objective of the work is to study the feasibility of adding amendments and clogging, it is not planned to add TCE at this time. Because of its toxicity and high volatility, the use of TCE would significantly complicate the work without aiding in fulfillment of the stated objectives. Any clogging which may occur will be due to growth of biomass utilizing the primary substrates (methanol and acetic acid). The primary substrates are added in concentrations that are much higher than concentrations of chlorinated solvents typically encountered. A small inoculum of appropriate microorganisms will be initially fed to the box in the groundwater so as to develop a suitable population of biomass in the box. The water leaving the box will be analyzed for residual organic matter using the total organic carbon test.

The box will be lined with geotextile fabric so as to avoid water moving along the walls. In order to evaluate potential clogging over time, 1/8 or 3/16 inch plastic tube piezometers (inside diameter) will be utilized (see Figure 1). The first or reference piezometer will be slipped inside the PVD fabric with other piezometers placed along the length of the lysimeter as shown to evaluate losses in the soil outside of the PVD and along the box. The piezometers will extend almost to the bottom of the lysimeter and have small holes drilled along their length. Wires attached to a simple ohm meter will be inserted down the piezometer to locate the water surface.

7.0 CONCLUSIONS

The anaerobic column was operated this quarter under a variety of conditions. Parameters investigated included potential nitrogen limitation and methanol feed level.

It was found that an increase in the ammonia nitrogen level in the feed (from 14.4 to 19.6 mg/L) did not improve TCE removal. The percentage removal was approximately 40%. The mass removal rate of TCE was approximately 10 ug/h. The concentration of daughter products was about the same at both feed nitrogen levels.

The feed concentration of the primary substrate (methanol) had an insignificant effect on TCE removal. As methanol was increased from 185 to 598 mg/L, TCE removal did not improve. It was approximately 47%. It is not clear at this time as to why the high primary substrate level did not improve TCE removal.

The aerobic column was operated this quarter under a variety of conditions. Parameters investigated included the concentration of methane and hydraulic retention time.

It was found that the percent TCE removed at the top port was approximately 30.3% when the methane was pulsed every two days. When the hydraulic retention time was increased from 24 to 48 hours, the percent TCE removed was approximately 30.42%.

The anaerobic and aerobic columns were joined together near the end of the quarter with the aerobic column receiving the effluent from the anaerobic column. Before the columns could be joined, much preparatory work had to be done in order to assure that nothing sent from the anaerobic column could affect the degradation occurring in the aerobic column. Such parameters as total organic carbon (TOC), methane, ammonia-nitrogen, and basal salts were measured or evaluated to assess the potential impact these constituents might have when the columns were combined.

A microsystem for measurement of ORP was located and purchased. The system consists simply of an external cell in which the ORP electrode is mounted and which requires only microliter size samples. It is anticipated that the microsystem for ORP measurement will allow location and control of the anaerobic and aerobic zones.

The 24 inch simultaneous column set-up was completed and the column is now ready for integrity tests. In addition the box lysimeters were planned and designed.

8.0 WORK PLANNED FOR NEXT QUARTER

The existing anaerobic and aerobic columns have already been joined together to evaluate sequential mineralization (Subtask 1.1) after gathering further data from the aerobic column with respect to potential benefits from the pulsing of methane. Initial data collection has begun with respect to ORP and CAH concentration. Further analysis will be done this quarter.

As noted earlier, the simultaneous system (Subtask 1.2) has been assembled and is ready for initial set up. After set up, ORP analyses will be done to demarkate the aerobic and anaerobic zones based on the background information obtained from the ORP analyses done this quarter. Also, further data will be collected to evaluate the simultaneous mineralization based on which parameters like influent nutrient concentration, influent primary substrate concentration, and initial H_2O_2 concentration will be optimized.

Both sequential and simultaneous columns will initially be operated at a detention time of 48 hours and a TCE feed of 5.0 mg/L. Assessment of bioremediation of high concentrations of TCE will be evaluated next quarter (Subtask 1.5) in one or both of the systems. Ports have been designed to add a high concentration shock load of TCE to the columns.

Evaluation of prefabricated vertical drains (PVDs) for field application of amendments using lysimeters (Task 2) is planned for early next quarter. A literature review related to the use of geotextiles as well as lysimeter design

has been completed. Construction and lysimeters operations will be undertaken early next quarter.

9.0 TECHNICAL/ADMINISTRATIVE DIFFICULTIES

Technical difficulties were experienced this quarter when the gas chromatometer (GC) malfunctioned. GC measurements are vital in determining the amount of TCE that occurs in the influent and throughout the column. The GC started malfunctioning (not holding to a standard curve) in earlier May, but this was thought to be a consequence of several power outages. On 5/29, the GC would not give any peaks and no leaks could be found. A representative from Hewlett-Packard came and fixed the problems (leaks were occurring because of improper parts being installed and a defective septa). During this time a new column was purchased, as the old column was thought to be the problem. The new column was installed on 6/19 allowing evaluation of samples. A Tekmar autosampler for the purge and trap was purchased to enhance reproducibility, accuracy, and productivity.

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11.0 APPENDIX 1

Figure 1. Mass Flowrate of TCE @ Approx. 5.0 mg/L TCE

24
-162-

Figure 2. Mass Flowrate of TCE Removed in Top Port with Respect to Influent

25
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Figure 3. Percent Removal in Top Port with Respect to Influent

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IN SITU REMEDIATION PROCESS DEVELOPMENT

**MICROBIAL ENRICHMENT FOR ENHANCING
IN SITU BIODEGRADATION OF HAZARDOUS
ORGANIC WASTES IN SOIL**

TASK 1.3

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

BY

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July 1995

INTRODUCTION AND PURPOSE

Superfund and RCRA regulations have mandated the restoration of millions of cubic yards of contaminated soils nationwide. The cost of excavation and hauling large volumes of soil, combined with the tighter environmental regulation of landfills has severely restricted this cleanup option. Both industry and government are actively seeking additional innovative organic waste cleanup technologies to remedy this problem. Bioremediation is often proposed as a cost-effective treatment option for on-site hazardous waste clean-up, particularly where large soil volumes are involved and incineration is not considered feasible. However, biodegradation results are influenced by local site conditions making effective remediation difficult to predict and insure. We have been investigating the effectiveness of commercially available microbial inocula for use in bioaugmented remediation of hazardous mixed organic wastes in soil. At present, we are examining *ex-situ* remediation and surface composting, a process ideally suited to incorporation of a microbial inoculant. Bioaugmentation holds great promise for degradation of compounds which are now recalcitrant in soil, however efficacy of available microbial inocula must first be critically evaluated. We are developing a generalized testing procedure and expertise, which we can employ to examine bioaugmentation / biodegradation of a variety of wastes and / or waste sites (Figure 1).

During the 1994 we concentrated on identification of superior commercially available microbial inocula for bioremediation of organic wastes. Inocula were screened for biodegradation kinetics in surface and subsurface soil samples artificially contaminated with a chemically defined model mixed organic waste. During the coming year we propose that superior products selected by our screening procedure must next be tested for effectiveness in the variety of mixed organic wastes and soils expected in real world conditions. Therefore, we will obtain soil samples from waste contaminated sites, return them to the laboratory, and quantify the effectiveness of selected inocula for bioaugmented soil remediation. We will assess effectiveness of biodegradation by monitoring substrate disappearance of parent organic compounds following their extraction from soil. To facilitate screening of a large number of soils we will also develop and apply a rapid radiorespirometric technique based on the ability of microorganisms to biodegrade ^{14}C labeled recalcitrant compounds directly injected into the mixed waste milieu of the contaminated sample. Identification of suitable inocula and development of rapid screening methods for waste biodegradation represent the next necessary step prior to large-scale deployment of bioaugmentation technology in the field.

Objectives

The overall research objective is delineation of conditions under which bioremediation can effectively be employed to enhance remediation of hazardous organic wastes. Specific objectives for the 1995 work are: 1) Verify the effectiveness of bioaugmentation in soils collected from sites previously contaminated with hazardous mixed organic wastes. Superior commercially available microbial inocula selected during our year one laboratory trials will be utilized. 2) Develop and apply a radiorespirometric technique for the rapid screening of bioaugmentation effectiveness in soil samples

previously contaminated with hazardous mixed organic wastes. A diagrammatic representation of our research approach is presented in Figure 1.

(3.0-4.0)

BACKGROUND AND METHODOLOGY

The 1995 study will be performed by researchers in WVU's Division of Plant & Soil Sciences. Contaminated soils for the study will be obtained from industrial and government sites as well as from existing production sites identified by regional oil and gas cooperatives with whom we cooperate (IOGA / WVONGA). We will concentrate on soils contaminated with hydrocarbons and solvents and will study five sites.

Waste contaminated bulk soil will be returned to the laboratory and stored at 40°C prior to use. Soils will be amended with NH_4NO_3 and K_2HPO_4 to fall within C:N:P:K ratios determined as optimum for waste degradation. Soil samples (10 g wet weight) will be distributed to replicate 250-ml Erlenmeyer flasks and adjusted to 25 % gravimetric moisture content (approximately 60 % water filled porosity, a level optimum for aerobic microbial activity in soil). Sterile control soils will be prepared by autoclaving flasks at 121°C and 103 kPa for 20 minutes on 2 consecutive days. The waste contaminated soil will be then mixed 1:1 with glass beads to improve porosity and aeration, a typical procedure for soil composting. Soils will also be amended with a water soluble dispersant chosen from the EPA/ NCPPS to enhance release of the waste from soil particles and maximize contact with the soil microflora. Half of the treated soils will be amended with the commercial microbial inocula at rates recommended by the manufacturer. Inocula selected are produced by Sybron, Interbio, and Hydrobac.

Radiorespirometry will be employed to follow mineralization of individual compounds within the mixed waste. Individual ^{14}C labeled compounds will be added to the contaminated soil at 0.9 μCi per 10 gram soil. The working assumption is that the added radiolabeled compound does not significantly increase the pool size of the component within the mixed waste, thus does not affect the mineralization rate of the compound. ^{14}C - CO_2 will be trapped into sodium hydroxide and aliquots counted in a Scintiverse cocktail using a Wallac 1409 Scintillation counter. Direct injection of a known radiolabeled hydrocarbon or solvent into the mixed waste milieu of the soil should allow rapid assessment of relative biodegradation potential. If successfully developed, this technique will allow us to rapidly screen a larger number of soil samples for effectiveness of bioaugmentation.

Well equipped laboratories in Brooks Hall and the Agricultural Sciences Bldg are available for this study. They contain equipment necessary for the culture and maintenance of both aerobic and anaerobic microorganisms and for the chemical analyses of soil, sediments, and water. Major permanent analytical equipment includes: Super speed and Ultra centrifuges, a Coy anaerobic chamber, gas chromatographs (ECD, FID, TCD); HPLC (UV/Vis, Conductivity, RI), a scintillation counter, an inductively coupled plasma emission spectrophotometer, atomic absorption spectrophotometers, a Dionex ion chromatograph, a Technichon autoanalyzer, and other routine laboratory equipment. We also have the full support of the NRCCE Analytical Facility.

(5.0-7.0)

**PROGRESS THIS PERIOD (April-June, 1995)
RESULTS, DISCUSSION, CONCLUSIONS**

During the first quarter of 1995 (Jan. to March) we began the preliminary work on our objectives. We have monitored cumulative AMOW mineralization in the presence and absence of inocula. Inoculum addition significantly increased soil respiration compared with uninoculated soil and soil amended with sterile inocula. Addition of waste to inoculated soil inhibits soil respiration compared to non-waste amended soil. These data emphasize that use of ^{14}C labeled substrates in a radiorespirometric assay is necessary to monitor specific organic pollutants.

The majority of the past quarter has been spent in methods development. We have examined a variety of assay configurations for optimum soil incubations and subsequent CO_2 trapping. We have decided to use a passive base trap as illustrated in Figure 2, rather than an active gas train setup. Our rationale for this decision is ease of use and increased experimental replication. This configuration will allow use to measure mineralization of the labeled substrate by LSC as well as total mineralization by titration of the base trap. We are currently verifying optimum incubation times and base trapping efficiency.

During our meeting at METC on April 27, we discussed the feasibility of obtaining contaminated soils from government hazardous waste sites for use in our laboratory experiments and simulations. The decision was reached that this was not immediately feasible. Therefore, we will initially concentrate on our model contaminants in a variety of soils, and we will pursue obtaining contaminated soils from industrial production sites.

During the past quarter Ms Payal Malhotra, M.Sc. joined our lab for two months as a visiting scientist. She will assist the current project by performing microbial characterizations of the commercial inoculants used in the study.

(8.0) WORK PLANNED FOR NEXT PERIOD

During the coming quarter we will apply the radiorespirometric assay in bioremediation trials as discussed in our 1995 milestones chart (see below and attached).

(9.0) DIFFICULTIES: None.

Percentage of Project Completion, MC-18, METC Task 1.3, Year 2 (1995)

1.0	Preliminary Research	8w	100
2.0	Analytical Techniques		
2.1	Evaluate Radiorespirometry	8w	90
2.2	Develop Radiorespirometric Assay	8w	50
3.0	Preparation of Trials		
3.1	Site Identification	12w	50
3.2	Site Characterization	12w	50
3.3	Waste Characterization	12w	50
3.4	Finalize QA/QC	8w	0
4.0	Bioremediation Trials		
4.1	Trial 1	6w	0
4.2	Trial 2	6w	0
4.3	Trial 3	6w	0
4.4	Trial 4	6w	0
4.5	Trial 5	6w	0
5.0	Trial Repeats (concurrent)		
6.0	Analysis and Reporting		
6.1	Analysis and Data Reduction	8w	10
6.2	Reports and Manuscripts	40w	0
7.0	Overall Work Complete	50w	0

$\text{CO}_2/^{14}\text{CO}_2$ *In vitro* rapid
mineralization assay and
Substrate disappearance

Biodegradation kinetics
Assessment and
recommendations

Efficacy of Treatments?

Fig. 1. Diagrammatic representation of research approach on
METC project 1.3.

Fig. 2. CO₂/¹⁴CO₂ *In vitro* rapid mineralization assay : Passive base trap method.

CONTAMINANT MOVEMENT PREDICTION IN PERMEABLE SUBSURFACE SOILS

METC Task No. 1.4

Quarterly Technical Progress Report
Reporting Period: April 1, 1995 - June 30, 1995

Work Performed Under Contract
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For:
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:
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July 1995

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ABSTRACT

Contaminations of the subsurface soils are problems encountered in many areas and especially locations with various underground and surface tanks used for storage of hazardous materials. The subsurface conditions vary at a site and the prediction of contaminant movement is a difficult task. This work focuses on the flow behavior of fluids in the porous media where drainage with prefabricated vertical drains (PVD) are used to flush the soils.

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EXECUTIVE SUMMARY

This subtask was funded for the initial 60% of the requested amount in mid March 1995 and subsequently the remaining 40% were funded in May 1995. Presently, the literature search continues to gather information on the recent developments in subsurface contaminant movements. Three numerical models were received, however only one is installed on a personal computer (PC) due to limited storage space. Some laboratory data regarding previous drainage experiments on contaminant recovery cells were received.

INTRODUCTION

Contaminations of the subsurface soils are problems encountered in many areas and especially locations with various underground and surface tanks used for storage of hazardous materials. Environmentally hazardous conditions are experienced when an existing container leaks or ruptures due to natural or man caused actions. As a result, the contents, defined as hazardous to health and attributed mainly to hydrocarbon derivatives, leak from their environment.

The subsurface conditions vary at a site and the prediction of contaminant movement is a difficult task. The plumes can partially be absorbed by soils as well as changing from one state to another through condensation or vaporization. The prediction of movements of these contaminants as a liquid or gas is a very difficult task due to the nature of the formations involved at a particular site. Additional difficulty results from the need for a knowledge of multiphase transport process that describes the movement of these chemicals.

PURPOSE

The purpose of this study is to investigate the flow mechanisms through different numerical models and to select at an existing model to study the subsurface flow mechanisms. The selected model will be used to predict the behavior of fluids in a laboratory scale contaminant recovery cell.

BACKGROUND

Fresh water aquifers are subject to contamination from a variety of activities such as spills of hazardous materials. When a spill occurs the fate of the contamination depends on many factors. The most important factor is the transmissibility property of the soils or permeable media. Proper knowledge and understanding of the heterogeneity of subsurface can provide a useful tool in understanding the fate and remediation of the contamination.

METHODOLOGY

A commercially available numerical model will be selected for the investigation of prefabricated vertical drains (PVD) on both laboratory and field scale investigation. Different grid designs will be considered for the representation of the experimental setup presently available in the West Virginia University's Civil Engineering laboratories. Some important soil properties that will be considered are porosity, thickness and conductivity of the porous medium, injection rates and subsurface fluid velocities, spacing between PVD's.

WORK PERFORMED THIS PERIOD

The literature search continued. Three different numerical models dealing with subsurface flow were received. One model with a pre and post processor was installed on a personal computer. The program was compiled and test runs were started. Limited data regarding drainage experiments were received and work initiated to prepare physical and operational parameters for model runs.

WORK PLANNED FOR NEXT PERIOD

The followings are planned for the next quarterly period:

1. The installed software will be calibrated to verify the proper installation. Procedure to conduct runs with the model will be reviewed and runs will be conducted using published data.
2. Work will continue on the selection of grid systems suitable for numerical model studies based on the laboratory scale experimental setup. Drainage tank setups used in the laboratory experiments will be reviewed.
3. Different numerical models will be evaluated for their suitability in representing additional features of the experimental flow system.

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USEPA, "Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples," October 1989, EPA/540/2-89/057, Office of Emergency and Remedial Response, Washington, D.C. 20460.

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Guido, V.A., and Ludewig, N.M., "A Comparative Laboratory Evaluation of Band-Shaped Prefabricated Drains," Consolidation of Soils: Testing and Evaluation, ASTM Technical publication 892, Philadelphia, PA., p. 642-662, 1985.

**DEVELOPMENT OF A STANDARD PROTOCOL AND BARRIER
DESIGN MODEL FOR IN-SITU FORMED BARRIERS
Task 1.5**

Quarterly Technical Progress Report
for the Period of April 1, 1994 to June 30, 1994

Work Performed Under
Contract Number: DE-FC21-92MC29467

For
U.S. Department of Energy
Morgantown Energy Technology Center
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Executive Summary

During this period of performance, work on the project has progressed at West Virginia University. The research team fully intended to be in the B-17 facility at METC but delays in the review of items required for the Construction Permits have prohibited the utilization of the building. The Sand Rain Device and Large Scale Grout Columns are being built and will be finished during early July. When complete these devices will be located in the NRCCE High Bay. The research team is currently completing the Space Allocation application for using laboratory space in the NRCCE.

Also during this quarter, Mr. Black attended the Technology Information Exchange (TIE) Workshop in Cincinnati, Ohio. Contact was made with several Focus Area Managers who showed considerable interest in the Circulating Air Barrier concept. Information on the CAB has been delivered to those interested parties and will become incorporated into the Plume Focus Area presentation. Additional contact is being made with other DOE Laboratories and sites for the use of the barrier concepts being developed on this project.

The report for this project is divided into three major sections. The first section (1.5) reports on the Administration of the Project. The second section (1.5a) reports on the progress of the Chemical Grouting research being conducted by the West Virginia University Department of Civil and Environmental Engineering. This research team is headed by Drs. Mohammed Gabr and Brian Reed. The Chemical Grout section is subdivided into four sections on which the graduate research assistants report separately. The third major section (1.5b) reports on progress of the Circulating Air Barrier (CAB) team. The CAB team consists of Drs. Sam Ameri, Khashayar Aminian and Shahob Mohaghegh of the WVU Petroleum and Natural Gas Engineering (PNGE) department and David Locke, William Overby and Dr. Greg Johnson of BDM Federal, Inc.

Results from work performed on tasks as follows:

Task 2 Literature Review

The literature review has been completed and delivered to U.S. DOE/METC.

Task 3 Laboratory Equipment and Preliminary Testing

Chemical grouts are being thoroughly tested. Testing parameters include permeability, compressive strength, tri-axial strength, viscosity and immersion.

The Sand Rain Device is being constructed and will be delivered to the NRCCE High Bay during early July.

Additional tests were designed by the CAB team to test the effect of dry air on an unconsolidated porous medium at irreducible water saturation.

Task 5 Preliminary Barrier Experimentation

The preliminary barrier experimentation for the chemical grouts is complete. The next step is to proceed with scaled model experimentation (Task 6.0). Task 6 will require the Sand Rain Device and Large Scale Columns as well as the CAB vessel.

Additional accomplishments and reports of progress on the tasks can be found in the reports for each project group (1.5a & 1.5b).

Plans for next quarter:

Completion of Safety Documentation for NRCCE Space Allocation Policy for placement of Sand Rain Device in NRCCE High Bay.

Complete Safety Documentation for Large Scale Grout Columns and other equipment to be moved into NRCCE High Bay.

Initiate testing of the Sand Rain Device and Large Scale Grout Columns in NRCCE High Bay.

Contact DOE Facilities to seek interest in the use of the barrier concepts being developed on this project.

DEVELOPMENT of STANDARD TEST PROTOCOLS and BARRIER DESIGN MODELS
for
IN SITU BARRIERS
METC Task No. 1.5a
(Chemical Grouts)

Quarterly Technical Progress Report
Reporting Period: 04/01/95 - 06/31/95

Work Performed Under Contract
No.: DE-FC21-92MC29467

For:
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:
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1.5a: CHEMICAL GROUTS TO CONTROL LEACHATE

RESEARCH OBJECTIVES:

- Choose and evaluate various chemical grouts which exhibit properties making their use feasible in the development of a bottom seal at hazardous waste sites.
- Determine the chemical and physical properties of the grouts selected for further study.
- Characterize and develop the chemical grouts as a low permeability barrier to various chemicals and water.
- Conduct performance testing and establish a systematic test protocol.

PART 1.0: VINYL MONOMER TO CONTROL LEACHATE

GRADUATE RESEARCH ASSISTANT: David A. Bolten

PROJECT STATUS

From information found in the literature review, the immersion tests have been expanded to include constant immersion of the grout plugs in various chemicals. At present, baseline permeability values are slowly being reached with the column permeability tests. Unconfined compression are being conducted at various times to determine the grouts change in strength with time. Also, Q-type triaxial test are being conducted on the grout and on sand and grout molds to take confining pressure into account. With the purchase of a Brookfield viscometer, viscosity tests have been conducted to determine the grouts viscosity with time.

Immersion Testing

The original immersion test of a period of soaking followed by a equal period of drying has been expanded to include constant immersion on the grout plugs in the waste solution. After five soaking and drying periods, the grout plugs are left immersed in the waste solution and checked daily for weight and volume. The grout plugs are left in the waste solution until the grout becomes stable (no change in weight or volume), or the grout plugs lose physical and chemical structure. Also, immersion testing of grouted sand plugs has been conducted that mimic the grout plugs immersion test.

If a waste solution is found to affect the grout, the waste solution is diluted until no changes in the grout occurs. This procedure is conducted to find at what point the waste solution starts to affect the grout.

Permeability Testing

The grout (vinyl monomer) has proven to have a very low permeability, do to this the column permeability tests had to be adjusted. The columns were pressurized using a top cap fitted with two valves. One valve was connected to an air source and the other used for a pressure relief. The columns were static tested to 20 psi. With sixteen columns currently running, five are pressurized at 2 psi. A baseline permeability with water is slowly being

approached with the permeability constantly dropping. A baseline permeability will be calculated when the flow becomes constant.

Compression Testing

Mentioned in the last quarterly report, unconfined compression test have been conducted on sand and grout molds at optimum curing time (1 hour). Also, it was mentioned that unconfined compression tests could not be conducted on grout alone do to the grouts physical characteristics.

Unconfined compression tests have been conducted on sand and grout molds after being immersed in various waste solutions for 7, 14, and 21 days. This was conducted to determine the rate at which various waste solutions affected the compressive strength of the sand and grout molds at different time intervals.

Since unconfined compression tests could not be conducted on the grout molds, Q-type triaxial test were utilized. The Q-type triaxial test is used to model in situ conditions with the ability to apply a confining pressure for the determination of the undrained shear strength. Triaxial tests have been conducted on grout molds at a confining pressure of 10, 20, and 30 psi. For compression, triaxial tests have also been conducted on sand at minimum density for the same confining pressures. Sand and grout molds are currently being made for the triaxial test.

Viscosity Testing

With the purchase of a Brookfield viscometer, viscosity tests are currently being conducted. The viscometer performs well at the mid range viscosity of the grout, but as the grout starts to polymerize, the viscosity quickly goes off the viscometers scale. Still, very informative graphs can be plotted that show the two stage gelling rate of the grout that was predicted from the computer model.

Viscosity tests at various grout temperatures and grout mixes are currently being designed to determine how temperature affects the gel time. Also, viscosity tests with small amounts of waste solutions added to the grout mix are being designed to determine how the waste solutions will affect the gel time of the grout.

Shear Vane

Recently a shear vane device was located in the lab. Unfortunately the instruction manual was not found. The original manufacture of the vane is not in business, but a instruction manual was located and is currently being sent. Upon its arrival, shear testing of the grout will commence

PROBLEMS

No substantial problems have arose.

PART 2.0: URETHANE GROUTS TO CONTROL LEACHATE

GRADUATE RESEARCH ASSISTANT: Tara D. Judy

PROJECT STATUS

Permeability Tests

To determine the optimum grout to extender (or water) ratio, several permeability tests will be conducted using a solution head with a pH of 9.5. This pH was chosen because, according to literature by D. A. Turner, this is the existing pH at Hanford. The following grout to extender ratios will be employed: 1:8, 1:10, 1:12, 1:14. These tests will be duplicated to ensure accurate results, however if similar results are not obtained, a total of three permeability tests will be conducted for each ratio. The two with similar results will be averaged to determine the hydraulic conductivity. Also, for each ratio, two permeability columns with a solution head of distilled water will also be employed. This will provide a baseline for comparison of the 9.5 pH solution heads. Thus, a total of at least 16 permeability tests will be conducted. The grout and sand will have a thickness of approximately 5 inches to provide a minimum density of 94.8 lb/ft³. A solution head of 3.5 feet will be used and will be pressurized with nitrogen to ensure the pH doesn't vary. If time allows, permeability tests will also be conducted under worst case conditions--when the ground is saturated with chemical leachate. This test is described below.

Viscosity Tests

Viscosity tests are also currently being conducted on the grout ratios mentioned previously. Also, the effect on gel time when adding varying amounts of strengthener is also being investigated. From previous dip tests, the strengthener appears to make the grout more chemical resistant, and is thus favorable as long as the gel time (time to thicken) doesn't decrease greatly.

Immersion Tests

Lastly, more immersion tests will be conducted using the concentrations of various elements found in the Hanford leachate. For example, immersion in solutions of silver, copper, iron etc. will aid in determining which is most damaging to 5610 urethane gel grout. Sand and grout molds will be allowed to soak in each waste solution, then the new weight and volume will be recorded. Compression tests will be used to determine the change in strength. Also, more immersion tests have been conducted on grout alone using the following two waste solutions--sodium hydroxide and cupric sulfate. These two waste solutions were chosen because they caused a decrease in grout volume. Concentrations ranging from .5 to 20% were used in the immersion test. The object was to determine the least concentration of waste solution which caused noticeable effect.

Specimen Preparation Procedures for Permeability Testing

1. Grout and Sand Specimen Under Optimum Conditions

1. Place the fitted plastic cap in the clean out plug and tighten with wrench.
2. Place a preweighed amount of sand in the column following the ASTM standard for minimum density.
3. Calculate the pore volume amount of grout.
4. Prepare a pore volume amount of grout.

5. Tilt the column with care to reduce disturbance of the sand lift.
6. Pour the grout solution through a funnel and tubing.
7. Pressurize with air so grout will soak into the sand.
8. Allow to cure for 1-2 hours.
9. Pour 1 liter of tap water (or pH solution) into the column and let sit for at least 24 hours.
10. If no leakage is observed, add an additional 5 L of distilled water (or pH solution)

Grout and Sand Specimen Under Worst Case Conditions

1. Place the fitted plastic cap in the clean out plug and tighten with wrench.
2. Place a preweighed amount of sand in the column following the ASTM standard for minimum density.
3. Calculate the pore volume amount of grout.
4. Saturate the sand with the 9.5 pH solution.
5. Prepare a pore volume amount of grout.
6. Pour the grout solution through a funnel and tubing.
7. Pressurize with air so grout will soak into the sand.
8. Allow no time for curing.
9. Pour 1 liter of 9.5 pH solution into column and let sit for at least 24 hours.
10. If no leakage is observed, add an additional 5 L of pH solution.

Results

Permeability tests were conducted on a 1:9 (grout:extender) ratio grout, using 3.5 feet of water as the head solution. No leakage occurred after two months for the grout alone nor when grout was mixed with sand. Therefore, it has been decided to pressurize next set of permeability tests. For the immersion tests, even the low concentrations of NaOH adversely effected the grout. Cupric sulfate appears to only adversely effect grout at very high concentrations--20%.

PART 3.0: LARGE DIAMETER COLUMN TESTING

GRADUATE RESEARCH ASSISTANT: Jacob S. Freshwater

RESEARCH OBJECTIVES:

- Establish and develop a testing protocol for evaluation of various chemical compounds as a permeation grout for forming in-situ barriers.
- Evaluate the performance of these grouts as a barrier to plume migration.
- Determine the durability of these grouts when exposed to chemical agents.

- Determine the structural integrity of the grout by simulating in-situ stress conditions.

PROJECT STATUS:

Injectability Testing

Nine columns were recently manufactured and placed in the WVU Geo-Environmental Laboratories. The 5610 Urethane grout has been successfully injected into three large diameter columns (LDC) containing Ottawa sand at its minimum density (94.8 pcf). A 10:1 (gel time extender:gel) mix was utilized for each of the successful grouts. The problems relayed in previous reports (short circuiting, bulb diameter) were overcome through use of a new well design, application of a surcharge, and adjustments in the injection flowrates. The resulting barriers are developed from approximately 6 L of the grout mix and have a average thickness of 4.5 in. The average injection pressure observed is 7 psi with a flow rate of 0.3 - 0.4 L/min.

The Duraseal (vinyl monomer) has not been injected to date. This material will be injected in the near future. Because of the Duraseal's low initial viscosity and the media being injected, gel time control will be critical. If the gel time is too long, the grout will simply flow through and out of the porous media. On the other hand, if the gel time is too short, the grout will foul the injection system and the sand. Gel times experiments are yet being conducted.

Future injectability tests will investigate the effects of alternative well designs (i.e., perforation size and length, well diameter, etc.), permeation into the Ottawa sand at maximum density, and injection of the gels into saturated medias (with water and contaminated solutions). In addition, the grout pump for the Grout Testing Chamber (GTC) phase of the project has been purchased and will be used in some of the LDC injectability testing. It will permit higher injection rates (similar to field operations) and precise component mixing and yield more accurate injection rates and pressures.

Permeability Testing

At present, three in-column permeability tests are in progress on the 5610 gel. A constant head permeability test was performed on the grout barrier using tap water as the permeant. The headwater pressure has been increased to approximately 25 psi for all three columns and no liquids have penetrated through the barrier.

Because of the barriers impermeability, sand and grout specimens were formed and placed in flexible wall permeameters and permeated with deionized water to determine the baseline permeability of the barrier. Specimens were approximately 1 inch in height. These tests are yet in progress and are estimated to take approximately 90 days to complete. Initial results indicate that the Duraseal permeability ($\sim 10^{-7}$ cm/s) is higher than the 5610. As mentioned, DI water has been utilized as the permeant; however, representative wastes and a Hanford surrogate waste will be used in later studies to ascertain barrier durability.

Strength Testing

The strength properties of both grouts are also being extensively investigated through both unconfined compression testing and triaxial compression testing in accordance with

ASTM Methods D 4219-83 and D 5202-91. Because the unconfined compression test is conducted with no lateral pressures (which only occurs at ground surface), triaxial testing is required to replicate actual field stress conditions and give the actual strength of the grouted specimen. However, the unconfined compression test is being utilized for comparative purposes (e.g., immersion sample testing and mix design). Samples are cast or collected and immediately tested by one of the above methods. It has been found that samples permitted to dry for 24 hours exhibit strengths 200% more than the "wet" samples. Because the barrier environment will most likely be in moist conditions, the "wet" samples should prove more representative. The results of past studies have been scrutinized for not taking this into account.

Cylindrical sand and grout samples have undergone immersion and subsequent strength testing at specified time intervals. The 5610 gel swells immediately upon immersion in water resulting in a short term (i.e., 8 hours) immersion test program. After 4 hours the samples were unsuitable for unconfined compression testing. During these tests infiltration rate of the immersion liquid, change in volume, and change in mass are also recorded. Strength change with time when immersed in other solutions will be quantified in proceeding studies.

Mix Design

Numerous viscosity/gel time tests in accordance with ASTM Method D-4016 have been conducted. A sample for viscosity testing is collected during each injectability test as a QA/QC measure. Based on the preliminary results, a 10:1 mixture utilizing chilled (10°C) gel time extender as the activator is most suitable for 5610 barrier development. At higher mix ratios, there is unreacted free liquids in the specimen. The gel time is the limiting factor for the lower ratios (5:1 ~ 11.5 min). The initial viscosity for the 10:1 grout mix is approximately 400 cP and exhibits a gel time of 25 minutes.

PROBLEMS:

No problems or difficulties have arose.

PART 4.0: SAND RAIN DEVICE

GRADUATE RESEARCH ASSISTANT: James Moseley

RESEARCH OBJECTIVES:

-Construct a device that will produce a uniformly dense sand sample for large-scale grout testing.

PROJECT STATUS:

There are three phases to the sand rain device portion of the barrier design project. They are design, construction, and testing. Currently, the construction portion of the project is 80% completed having finished the literature review and the design of the device. Preparing a lab facility for housing and storage of the apparatus and devising standard tests to insure desired and uniform densities are both possible and consistently formed are the next tasks.

Results

The initial design, as expected, evolved and developed into the functional and durable device that can be seen on the attached diagram.

The most difficult portion of the construction phase was fabricating the diffuser assembly. The diffuser is made up of three sieves each of which is simply a mesh attached to a 35" outside diameter ring. Three different sizes of wire mesh were utilized so that the falling sand will fall through progressively smaller openings as it travels through the sieve assembly to help produce the desired uniform densities. It was difficult finding someone willing to produce these sieves because of the difficulty in welding small wire diameters as well as insuring the wire mesh is taut across the diameter of the ring. Furthermore, it was necessary for the sieves to be connected to each other as well as detachable which was an additional complication.

Using concentric rings overcomes these difficulties by trapping the wire mesh between the two rings, one inside the other. This also allows a continuous support mechanism that keeps the wire very taut all the way around the sieve. These are made by stretching the mesh flat out across the diameter of the larger ring and pushing the smaller ring down inside the larger one. However, it turned out to be a slow process and one which can be done best by hand (without the use of power equipment). Each of the three sieves required about 16 man-hours to produce although their manufacture became easier with time as the unconventional construction process became routine. In hindsight, it may be beneficial to pursue another design for the sieves in the future.

Sand rain devices in the past have had a single valve that allowed sand to run out of the reservoir typically from a central location. These designs depended solely upon the diffuser to distribute the sand evenly and thus achieving the desired uniform density. The sand rain device shown in the attached figure has a perforated plate at the bottom of the reservoir with approximately 30 holes arranged in a grid pattern which can be opened via a sliding plate underneath with the same pattern. The plate moves by turning a handle attached to a screw allowing for an extremely precise determination of the opening size of the hole pattern which is a critical parameter in determining the density of the sand sample.

PROBLEMS

Determining the type and size of the electric motor was trying in that it is difficult to estimate the range of speeds needed in the motor assembly. The diffuser must rise at the same rate the sand continues to pile up to keep the drop height of the sand constant. A large range was determined with a small scale device using a standard set of 8" sieves from the soils laboratory and dropping a fixed amount of sand through the sieves while calculating the time it takes for all the sand to fall through as well as measuring the final height. From this, rpms of 0.5 to 12 were considered the boundaries. Furthermore, the motor must be reversible as well as variable in speed. All these factors combine into a very expensive motor that still

would require some kind of periodic change of the speed reducer mechanism to cover the entire range of rpms required much like the transmission in a car. These motors were between \$1200-\$1400.

Fortunately, an unused motor was found in the basement of the engineering building that has an shaft speed of 6 rpm. With some rewiring, it was made reversible and the variable speed characteristic is accomplished by plugging a voltage regulator in series with the motor. It is quite possible this motor, with some further enhancement, will work satisfactorily. Even if the motor doesn't prove adequate, it will serve a purpose in that with some experimental runs, a much closer estimate of the range of rpms required by the motor assembly can be determined. If another motor is required, a closer estimate should save a substantial amount of funds and could eleminate the need for a "transmission."

PART 5.0: COMPUTER MODELING

GRADUATE RESEARCH ASSISTANT: Edward L. Hakala

RESEARCH OBJECTIVES:

- Personalize BGROUT to model specific meso-scale grout injection experiments.
- Effectively use COLORGRID in analyzing output created by BGROUT.
- Use the revised model to investigate grout injection strategies.

PROJECT STATUS:

The numerical model, BGROUT, is well on its way to becoming an effective grout injection simulator. Successful grout simulations of the 5610 large diameter column injectability tests have been executed with the grout penetration results resembling those derived from the actual injection experiments.

The pertinent data used in these simulations include the following: initial grout viscosity of 400 cP; 6000 md and 2222 md for the horizontal and vertical permeabilities of the sand; a 3 inch perforated injection zone; and a constant injection rate of 0.353 L/minute over an injection period of 17.0 minutes. The vertical permeability was determined from actual experiments, but the horizontal permeability, K_x , is an estimate. Slight changes (1000 md) in K_x can be seen in the results by altering the penetration radius of the grout. The injection rate of the grout was also modified in order to simplify things. With this initial setting, the simulator determined the penetration radius of the grout to slightly exceed 0.5 feet from the injection site. Several other executions were, and are, being made using modified values to evaluate the effects those changes would have on the results.

PROBLEMS:

There still remains the problem of insufficient data for more accurate model parameters. Additional data that would be beneficial includes the actual horizontal permeability of the sand and more accurate injection rates and/or pressures.

Although BGROUT was able to match penetration distances with the experiments, during the execution very unreasonable pressures were being produced at the injection site. The model would create injection pressures exceeding 200 psi in order to maintain the set injection rate. On the other hand, if the grout injection was set to be controlled by pressure, then the volume of grout injected would be insufficient. More research into this problem will take place.

2.0
ADVANCED PRODUCT
APPLICATIONS TESTING

Chemical Destruction of Chlorinated Organic Compounds

METC TASK NUMBER: 2.1

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.: DE-FC21-92MC29467

for
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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July 1995

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ABSTRACT

Chlorinated organic compounds, such as carbon tetrachloride, trichloroethylene, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and polychlorinated biphenyls (PCBs), have been widely used as organic solvents, pesticides and herbicides, dielectric fluids for transformers and capacitors, and for a variety of other purposes. The environmental problems and health risks associated with these chlorinated organic compounds have been well recognized. The chemical structures of some representative compounds are shown below.

It is the objective of this research program to develop chemical treatment procedures to transform chlorinated organic compounds to less or nontoxic materials. We discovered that sterically hindered triarylboranes are excellent electron carriers for sodium metal and can be used to effectively dechlorinate PCBs from greater than 500 PPM to less than 8 PPM, far less than the 50 ppm standard set by EPA. Because PCBs are among the most inert chlorinated organic compounds, it is likely that this treatment procedure developed for PCBs could also be easily adopted for other chlorinated molecules, including particularly 2,3,7,8-TCDD because of similarity of chemical structures. We will develop a practical procedure to extend this treatment procedure further by synthesizing and fabricating new materials of triarylborane for use in dechlorination of a variety of chlorinated organic compounds. Other chemical treatment procedures for dechlorination of PCBs by using the very reactive hydroxyl radical and by nitration of PCBs to activate the aromatic ring for subsequent dechlorination will also be investigated.

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EXECUTIVE SUMMARY

A synthetic procedure to produce a trimer having the electron-carrying dimesitylboryl substituents has been developed. The successful synthesis of this trimer serves as a model to guide the development of a procedure for electron-carrying polymers. The palladium-catalyzed process appears to be an efficient method to connect various pieces together to produce trimers and oligomers with higher molecular weights. The synthetic procedure is very flexible and allows the introduction of necessary functional groups for subsequent structural elaborations.

1.0 INTRODUCTION

Polychlorinated biphenyls, commonly referred to as PCBs, are one of the major organic pollutants in the environment. The chemical structures of three representative polychlorinated biphenyls are shown in Figure 1. The large scale use of PCBs for a variety of purposes, especially as a dielectric material in capacitors and transformers as well as plasticizers and solvents in plastics and printing inks, coupled with the chemical stability of PCBs against degradation have resulted in their worldwide accumulation in the environment.

Figure 1. Chemical Structures of Three Representative Polychlorinated Biphenyls

The total worldwide production of PCBs through 1980 is estimated to be approximately 2.4 billion pounds. Of the 1.25 billion pounds of PCBs estimated to have been produced in the United States, mainly by Monsanto under the registered trademark of Aroclor, about 24 million pounds are believed to have been released to the environment.

The toxic effects of PCBs have been well documented. One of the most famous cases occurred in Japan in 1968 when PCBs from a defective heat exchanger were leaked into rice oil which was then consumed by more than 1000 people.¹ For those who consumed more than 0.5 grams (average consumption was 2 grams), severe acne, darkened skin, and eye damage developed. Recovery was slow and these symptoms were still present even after three years. Numerous studies have also reported the toxic effect of PCBs to a wide range of wildlife, including mink, some species of shellfish, shrimp, and fish, and especially those birds that are at the top of the food chain, such as eagles, hawks, falcons, and pelicans.² The chronic (long-term) toxicity to humans and other species is yet to be fully realized.

Because of the thermodynamic stability of PCBs, destruction by incineration and other chemical degradation processes are difficult. Disposal of untreated PCBs by landfill is virtually banned by the Resource Conservation and Recovery Act (RCRA). Currently, incineration is still the most widely used method for treating many hazardous wastes, including PCBs. Incinerators are strictly regulated to assure effective destruction of PCBs. For example, the regulation requires 99.9999% (six-9's) efficiency for the degradation of nonliquid PCBs by incineration.

However, despite such strict regulations it is possible that trace amounts of PCBs as well as other combustion byproducts, including the much more toxic polychlorinated benzofurans and dioxins, could still be released to the environment through stack emission. Concerns about the health impact of PCBs, dioxins, and other organic compounds formed and emitted into the environment have on surrounding communities have created many controversies and strong opposition from various environmental groups. It is now typical to take more than ten years and prolonged legal battle before an incinerator for industrial hazardous wastes could be constructed and operated. One recent example involves the Waste Technologies Industries (WTI) facility in East Liverpool, Ohio which recently began its test burn only after 13 years of planning and construction, more than 20 court cases, and even the intervention of the Vice President of the United States. In an article of the *Chemical and Engineering News*, many issues concerning hazardous waste incineration were raised and discussed.³ It is clear that there is a need to continue research and development of alternative chemical processes for treating hazardous wastes in general and PCBs and other chlorinated aromatic compounds in particular.

2.0 Purpose

It is the purpose of this research project to first evaluate the existing technologies for in situ dechlorination of PCBs-contaminated soil. Development of a new chemical treatment procedure for dechlorination of PCBs will also be a major goal.

3.0 Background

Development of chemical process for the destruction of PCBs and other chlorinated aromatic compounds continues to be a research area of intense interest. Limited success has been achieved in some specific cases. We recently discovered that sterically hindered triarylboranes are excellent electron carriers for sodium metal and can be used to effectively dechlorinate PCBs from greater than 500 PPM to less than 8 PPM, far less than the 50 ppm standard set by EPA. Because PCBs are among the most inert chlorinated organic compounds, it is likely that this treatment procedure developed for PCBs could also be easily adopted for other chlorinated molecules, including particularly 2,3,7,8-TCDD because of similarity of chemical structures. The use of the very reactive hydroxyl radical for dechlorination of PCBs was also found to be a promising process.

4.0 Methodology

We will develop a practical synthetic procedure to prepare and fabricate new materials containing triarylboranes as electron carriers for dechlorination of PCBs. Synthetic methods involving organic reactions will be employed to produce these new materials. The use of the very reactive hydroxyl radical, to be generated by the Fenton reaction ($\text{FeSO}_4/\text{H}_2\text{O}_2$) and other methods, for dechlorination of PCBs will also be investigated. Furthermore, an alternative strategy involving an initial activation of the benzene rings of PCBs by nitration ($\text{HNO}_3/\text{H}_2\text{SO}_4$) followed by attacking of the activated benzene rings with NaOH could also provide a solution for degradation of PCBs.

5.0 Work Performed This Period

We focused our efforts in producing a low molecular weight oligomer containing sterically hindered triarylboron functionalities as an electron carrier for dechlorination. Specifically, a synthetic procedure to a trimer by using a palladium-catalyzed process was successfully established. This trimer was characterized by the ^1H and ^{13}C NMR spectroscopy to provide informations of its chemical structure. A sample was also submitted for mass analysis in order to determine its molecular weight. All the data obtained so far indicate that the synthetic procedure is very efficient and the desired material as a model to guide future synthesis of new polymeric materials was obtained.

6.0 Results and Discussion

The synthetic sequence outlined in Figure 2 has been developed to provide an efficient route to trimer 3. The essence of the strategy involves the use of a palladium-catalyzed cross-coupling reaction between dibromide 1 and boronic acid 2. Trimer 3 containing three electron-carrying triarylboron groups was produced in 72 % yield. The presence of two trimethylsilyl groups in 3 provides additional handles to allow subsequent elaborations to produce materials with higher molecular weights.

Figure 2. The Synthetic Sequence for Trimer 3.

The synthetic route to dibromide **1** was established previously (Figure 3). Treatment of 1,3,5-tribromobenzene with *n*-butyllithium followed by dimesitylfluoroborane (**4**) furnished **1** in 70 % yield.

Figure 3. Synthesis of Dibromide **1** for the Subsequent Coupling Reaction

The boronic acid **2** was synthesized in three steps (Figure 4.). The first step again involves lithiation of 1,3,5-tribromobenzene with *n*-butyllithium followed by treatment with chlorotrimethylsilane to afford **5** in 69 % yield. The dimesitylboryl substituent in **6** was introduced in a straightforward manner in 46 % yield by a second lithiation reaction followed by the addition of dimesitylfluoroborane (**4**) to the reaction mixture. Finally, a third lithiation reaction followed by treatment with methyl borate furnished, after hydrolytic workup, **2** in 89 % yield.

Figure 4. Synthesis of Boronic Acid **2** for the Subsequent Coupling Reaction

7.0 Conclusions

The successful synthesis of trimer 3 serves as a model to guide the development of a procedure for electron-carrying polymers. The palladium-catalyzed process appears to be an efficient method to connect various pieces together to produce trimers and oligomers with higher molecular weights. The synthetic procedure is very flexible and allows the introduction of necessary functional groups for subsequent structural elaborations.

8.0 Work Planned for Next Period

We will further extend the procedure to producing oligomers and polymers with higher molecular weights. We will also contact commercial vendors to determine whether there are any practical technologies for in situ dechlorination of PCBs-contaminated soil.

References

- (1) Bailey, R.A.; Clarke, H.M.; Ferris, J.P.; Krause, S.; Strong, R.L., *Chemistry and the Environment*, Academic Press: New York, 1978; p 158.
- (2) See reference 1 pp 172-174.
- (3) Hanson, D.J., *Chemical and Engineering News* **1993**, 71, 7.

CONTINUED DEVELOPMENT OF AN ATMOSPHERIC
MONITORING MASS SPECTROMETRY SYSTEM

METC TASK # 2.2

Quarterly Technical Progress Report
4-1-95 - 6-30-95

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For:
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Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

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ABSTRACT

The objective of this project is the development of a mass spectrometric methodology applicable to the field determination of Volatile Organic Compounds (VOC's), such as BTEX components (Benzene, Toluene, Ethylbenzend, and Xylenes). A combination of chemical ionization, selective ion storage, and tandem mass spectrometry will be employed with an ion trap mass spectrometry system. The Gas Chromatography Mass Spectrometry (GC-MS) interface on the ion trap system will be modified to permit direct atmospheric monitoring. Through the use of tandem mass spectrometry methods the need for chromatographic separation will be eliminated reducing the overall size and complexity of the system. Existing literature methods and newly developed methods will be compared for sensitivity, accuracy, and precision.

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EXECUTIVE SUMMARY

During this quarter water chemical ionization methods were developed for benzene, toluene, ethylbenzene and xylenes. Standards for calibration of the instrument were successfully formulated during this quarter. Experiments to determine conditions under which ethylbenzene and xylenes can be determined by tandem mass spectrometry are ongoing presently. A new molecular beam sampling interface was designed and will be installed at the beginning of the third quarter. Necessary modifications for field operation have been evaluated. A laptop computer will be acquired by the NRCCE for use in field tests of the system. At the present time we are searching with assistance from the NRCCE for a source of electrical generators powered by natural gas.

During the middle of this quarter personnel were hired to work on the project, two students who had worked on the project previously for credit were hired as part-time technicians, another summer intern student was hired from Case Western, and a third student was hired as a full time technician.

Closer ties were developed between Varian's technical support personnel and the researchers on the project. One benefit of this contact was the ability to obtain a test version of new software capable of isolating multiple masses from Varian at no cost. The software arrived in late June and will be tested in the next quarter for its ability to permit discrimination of ethylbenzene from xylenes. The NRCCE has provided additional support of this project by paying two technicians for time beyond that allowed by the budget.

1.0 Introduction

In the general area of Characterization, Sensors, and Monitoring, analytical systems are needed that can provide near real-time measurements of hazardous materials and their degradation products at sites where contamination is suspected. Of particular interest are the volatile organic compounds (VOC'S) associated with petrochemicals. Presently, we are investigating the utility of atmospheric sampling mass spectrometry for the determination of benzene, toluene, ethylbenzene, and xylenes in ambient air. Preliminary methods relying on chemical ionization (CI) and/or tandem mass spectrometry (MS/MS) have been identified in a survey of the literature. It is proposed to continue this work by developing methods that employ a combination of CI and MS/MS techniques with the ion trap mass spectrometer for the identification of components in mixtures. This expands upon the previous work by examining the influence of potential interferences on the accuracy of the methods and by developing appropriate protocols to eliminate these interferences or correct for them.

2.0 Purpose

The overall objective of this project is the development of an atmospheric monitoring ion trap mass spectrometry system and associated methods for determination of volatile organic compounds. One of our ultimate goals is to develop methods that can be employed by technician level operators. We believe that this is an essential first step toward the development of truly field portable mass spectrometry systems. Toward the end of the project we anticipate using the system at field sites to demonstrate the methods' capabilities. During the summer, at the Winnfield site in West Virginia the BTEX capabilities will be examined. This demonstration is planned to further our second goal, to gain the interest of a manufacturer in developing field portable MS systems. The manufacturer of the NRCCE trap, Varian, has expressed interest in the project. Prof. King has also been in contact with Finnigan MAT, the manufacturer of the original ion trap mass spectrometers. Finnigan MAT has agreed to loan Prof. King their newest generation ion trap for use during a three-year period beginning in late 1994. Our group will be in a unique position of having both traps available for a comparison of capabilities during the course of this project. We will keep both manufacuters informed regarding the results of our research.

During the 1995 project year specific goals are:

Develop and demonstrate a method for speciation of the components in a Gasoline Range Hydrocarbons standard containing aromatic and alkyl constituents.

Develop and demonstrate a method for the speciation of the components in a neutral chlorinated hydrocarbons standard containing aromatic and alkyl chlorinated hydrocarbons.

3.0 Background

During 1994, the NRCCE acquired an ion trap mass spectrometry system for use in atmospheric monitoring. Through funding of a project entitled "Evaluation of IR and Mass Spectrometric Techniques for On-Site Monitoring of Volatile Organic Compounds" mass spectrometric methods for separation and determination of the principal components in BTEX, (Benzene, Toluene, Ethylbenzene, and Xylenes) were identified in the literature. The literature methods indicate some interference problems that must be considered to obtain accurate data, ie. the separation of xylenes and ethylbenzene. In the 1995 project year it is proposed to develop complete methods for the speciation of 10 components in an environmental petroleum standard and the speciation of 9 components in an environmental halogenated hydrocarbon standard. Our interest in the petroleum standard is to test the ability of the system to identify components in the atmosphere near a leaking petroleum tank; whereas, the interest in the halocarbons stems from a desire to develop monitoring for off gas from hazardous waste incinerators. During the course of the work potential interferences arising from both the sample and the monitoring environment will be identified. The original methods will then be modified by employing selective reagent chemical ionization and/or tandem mass spectrometry to selectively identify the species of interest and to eliminate the influence of the interfering species.

4.0 Methodology

Water chemical ionization will be employed to provide strong, characteristic molecular ion signals for the analytes. Selective ion storage software was obtained from the manufacturer in late June 1995. This software will facilitate the use of ion integration for calibration and any MS/MS methods. Any interferences will be identified, and MS/MS routines developed to eliminate the interference problem. The potential of using negative ion CI will also be investigated for the halogenated hydrocarbons as well when an ion trap system with negative ion capabilities becomes available in the Fall of 1995.

5.0 Work Performed This Quarter

During this quarter development of methods for the determination of benzene, toluene, ethylbenzene and xylenes continued. Ionization parameters were determined for chemical ionization of benzene using atmospheric water vapor. See attached spectrum. Initial evaluation of MS/MS of benzene indicated that the fragmentation pattern was concentration dependent. We believe that this is due in part to self CI, reaction of the analyte with itself, at higher benzene concentrations. Improved software recently acquired from Varian should permit cleaner isolation of parent ions and reduce self CI effects.

Standards of the BTEX compounds in methanol and methylene chloride were prepared to provide vapor concentrations of 1, 10, 100, and 1000 ppm for the BTEX components. The solvents methanol and methylene chloride were found to create spectral interference and chemical noise. The problems with methylene chloride were so severe that it has been ruled out as a solvent for future standards.

New software was obtained from contacts at Varian, at no cost, in late June. This software should permit the isolation of parent ions for up to five different m/z ratios. The evaluations of MS/MS performance for the ethylbenzene-xylene separation are continuing at the present time.

6.0 Conclusions

Water CI is viable for the production of parent ions characteristic of benzene, toluene, ethylbenzene, and xylenes. Observation of these ions permits identification of benzene and toluene but not differentiation between

ethylbenzene and xylenes. Suitable standards have been developed for instrument calibration. Ongoing experiments in tandem mass spectrometry will permit discrimination of ethylbenzene from xylenes. Once the new software is operational an investigation of time integration of signals for quantitation will be investigated.

7.0 Technical Administrative Matters

It was decided to hire two graduate students, appointments beginning May 15, to work on the project during the summer. Robert Steiner is a second year graduate student in the Ph.D. program with general expertise in ionization mechanisms and operational theory of mass spectrometry systems. Chris Lewis is a first year masters student whose thesis will focus on environmental applications of ion trap mass spectrometry. These students have been responsible for the development and evaluation of the atmospheric monitoring interface. During the first half of this quarter work on the project consisted of efforts by unpaid undergraduate research assistants. These students worked with the ion trap mass spectrometer to gain with its operating principles and the application of tandem mass spectrometry procedures. Because of their experience with the system, I hired these students as research assistants during the summer of 1995. One of the students, Nate Sams, is graduating in May 1995 and will be hired for the duration of the project. Nate's excellence in analytical chemistry was recognized by receipt of the Society for Analytical Chemists of Pittsburgh College Chemistry Award. This team continues to be responsible for the development of analytical methods.

ADVANCED PRODUCT APPLICATIONS TESTING
CAPTURE OF HAZARDOUS WASTE MATERIALS UTILIZING
FLUIDIZATION COATING TECHNOLOGY

TASK 2.3

Quarterly Report for Period
April 1 through June 30, 1995

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For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:

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July 1995

Abstract

The purpose of this research is to investigate how fluidization coating technology can be utilized to capture and stabilize hazardous waste materials. In particular, the fate of aqueous solutions of heavy metal compounds will be addressed. These solutions will be sprayed into a high temperature fluidized bed containing different types of solids. Due to evaporation of the solution, the non-volatile inorganic materials will either concentrate on the fluidized particles or will form an aerosol of fine particles (<1 micron) due to spray drying. The capture efficiency of the fluidized bed will be determined by evaluating the fraction of the heavy metals which is captured by the fluidized solids. The chemical form of the metals on the solids will also be determined and the leachability of the metals from the solids will be found. Techniques to further stabilize the metals on the fluidized particles will be addressed and may include a secondary spraying of stabilizing chemicals with an additional thermal treatment and over-spraying the fluidized particles with a low melting point glass.

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Executive Summary (Current Work)

During the second period of this project, the design and construction of the fluidized bed coating equipment was completed. All components of the fluidized bed system have been built using stainless steel to allow for high temperature operations. The bed consists of a 70mm diameter tube which is flanged top and bottom to expander and plenum sections. The liquid spray, consisting of an aqueous solution of heavy metals, will be introduced into the bed, limestone or sand, via a hydraulic spray nozzle centrally located in the distributor plate. Nitrogen will be used to fluidize the bed solids, while the heat required for the bed will be supplied by a three zone furnace into which the fluid bed will be immersed. Flow and pressure instrumentation are currently being connected and calibration and test runs are to be started in the near future.

1.0 Introduction

The capture and disposal of hazardous inorganic chemicals from liquid solutions and liquid-solid slurries currently is of great concern. Such hazardous chemicals typically contain heavy metal compounds, for example mercury, lead, cadmium, and sometimes radioactive species. The sources of these chemicals are diverse, and include: aqueous streams produced from washing contaminated soils; organic streams such as lead bearing paint; and dilute aqueous solutions of radioactive elements used in hospitals. The source and characteristics of the waste stream will often dictate the method of treatment. Methods such as adsorption on to activated carbon, incineration and gasification are all currently used to dispose of hazardous wastes containing heavy metals and radioactive species. The fate of the heavy metals and the their final chemical form is unclear, Barton et al. (1), for many treatment processes and this forms the *raison d'etre* for this research.

2.0 Purpose

The purpose of this research is to investigate the use of fluidized bed coating technology in the collection, concentration and stabilization of hazardous inorganic chemical compounds. Fluidization technology has been utilized in the destruction of waste streams in such applications as Municipal Solid Waste (MSW), Medical Waste and Hazardous Waste Incinerators. However, the emphasis has been on maximizing the destruction efficiency for organic compounds. Recently, with the increasing concern regarding the formation of dioxins and dibenzofurans in such devices, it has been suggested that gasification, rather than combustion, should be considered for the destruction of waste streams, Gallaway and Sprung (2). However, regardless of the method of destruction, if a waste liquid stream containing heavy/radioactive metals is to be fed to an incinerator/gasifier then the mechanism by which the inorganic material leaves the system needs to be investigated. Therefore, it is the purpose of this work to address what happens to such metal species when solutions of them are fed to fluidized bed waste incinerators/gasifiers.

3.0 Background

When considering the fate of liquid solutions of heavy metals fed to equipment containing fluidized solids, several removal mechanisms must be considered. It is assumed that the liquid stream will be sprayed into the bed via an atomizing or hydraulic spray nozzle. Clearly, it is important to disperse the liquid into the bed as a fine spray, in order to prevent excessive agglomeration and "wet quenching" of the bed. For waste incineration/gasification equipment typical bed temperatures will be high compared to the boiling point of the liquid and undesirable

spray drying of the liquid waste may occur. The object when spraying the liquid feed into the fluid bed is to coat the fluidized particles with feed solution and to avoid spray drying. The efficiency of capture of the liquid is very important since liquid not deposited on particles will evaporate quickly in the vapor phase and effectively spray dry. When spray drying occurs the inorganic material, including any heavy metals, will tend to form a fine solid/aerosol mist that will be very difficult to clean from the gas stream. In fact, the formation of aerosols may so severely affect the efficiency of capture in such devices as scrubbers, bag houses and electrostatic precipitators that the majority of the metals end up in the stack gas. Therefore, the efficiency of spray capture by the fluidized particles is a very important factor in fluidized bed coating operations. For typical coating operations, the capture efficiency ranges from 95 - 99%. However, typical coating operations do not use the level of superheat expected in combustion and gasification equipment.

The second consideration is the fate of the metals once they have been deposited on the solids surface and the liquid evaporated. Obviously, this will depend on the temperature and pressure (usually 1 atm) in the bed, the chemical composition of the bed material and the gas phase composition. The gas phase composition will be mainly, nitrogen, water, carbon dioxide and oxygen with smaller amounts of hydrogen chloride, hydrogen sulfide (gasification) and sulfur dioxide (combustion). Evidence suggests that binding of the metals with the bed material is a strong function of the bed material, Ho et al. (3,4) and that the leachability of metals from bed material is generally low.

Thus two key elements to be investigated are capture efficiency and stabilization of metals once they are on the bed material.

4.0 Methodology

The overall objectives of this work are to assess the potential of fluidized bed coating techniques to capture, concentrate and stabilize hazardous inorganic chemicals present in solution. The specific objectives are:

Identify model compounds to represent hazardous waste chemicals containing heavy metals.

Demonstrate that aqueous solutions of these model compounds may be sprayed onto a bed of fluidized particles resulting in the capture and concentration of these compounds on the particles.

Evaluate the capture efficiency of the fluidized bed coating process.

Investigate different routes to stabilize the model compounds so

that the resulting bed particles have very low levels of leachable heavy metals and are hence non-hazardous.

With the above objectives in mind the specific tasks/deliverables for this project are given below:

Year 1

1. Design of a fluidized bed capable of operating at high temperatures (up to 900°C) to be used in the coating experiments.
2. Construction of fluidized bed system.
3. Choice of a model chemical system for the hazardous waste and the size and materials to be used for the fluidized particles.
4. Production of samples of solid particles, impregnated with model compounds, produced via spraying solutions of these compounds into a fluidized bed.
5. Evaluation of the efficiency of capture of solutions of model compounds sprayed into the fluidized bed.

Year 2

6. Evaluation of the total heavy metal content and leachability of the heavy metals deposited on the fluidized particles and production of samples of such particles.
7. Evaluation of methods to stabilize heavy metals on fluidized particles. Variables to be considered are Temperature, Bed Material and addition of additional chemicals if required. Stabilization will be determined by leachability tests on the solids. Production of samples of stabilized particles.
8. Evaluation of over-spraying fluidized bed particles with glass to stabilize heavy metals. This will be attempted if other methods of stabilization are unsuccessful. Production of samples of glass coated particles.

The work plan for this project is given in Table 1.

Table 1: Work Schedule

#	Task Name	Dur	% Compl	1995											
				Q1			Q2			Q3			Q4		
				J	F	M	A	M	J	J	A	S	O	N	D
1	Design of Fluid Bed System	4M	100 %												
2	Construction of Fluid Bed	4M	60 %												
3	Choose Model Chems & Part	2M	100 %												
4	Production of Coated Solids	4M	0 %												
5	Evaluation of Coating Efficacy	3M	0 %												
6	Report Preparation	12M	50 %												
7	Report 1	0M	100 %												
8	Report 2	0M	100 %												
9	Report 3	0M	0 %												
10	Annual Report - Year 1	0M	0 %												
11	Overall Work Completed	12M	35 %												

5.0 Worked Performed in this Period

The start of the experimental portion of this project was delayed until March 8, 1995 due to funds not being available until this time. During the period 4/1/95-6/30/95, for which this report is written, the following work was accomplished:

Item 1: The model compounds, identified in the first quarterly report, were ordered and are in hand.

Item 2: The final design of the fluidized bed was completed. A list of the most pertinent design parameters is given below. A copy of the calculations used to establish the design parameters is included in the Appendix of this report.

1. The bed is constructed of 304 stainless steel
2. The bed is manufactured from 70mm O.D. tube.
3. The furnace surrounding the bed will be a 3 zone solid-tube furnace manufactured by Blue-M. The maximum operating temperature for the furnace is 1100°C with a power rating of 11kW.
4. A distributor plate has been manufactured from 304 stainless steel sheet and contains 16-1mm holes and 8 -2.5mm holes.
5. The hole pattern is shown in the figure in the Appendix.
6. A central hole is drilled in the plate to accept the spray nozzle.
7. The spray nozzle is a 1/4LN-SS1 hydraulic nozzle from Spraying Systems Inc. which has a spraying capacity of approx. 1gal/hr.
8. The liquid to be sprayed into the bed will be fed from a pressurized tank at about 40 psi (2800 kPa). The use of atomizing air has been eliminated since the need for very fine droplets from the spray is not required.

Item 3: Construction of the bed has started. The top section for particle disengagement has been completed and the bottom section including the connections for the liquid spray, fluidizing gas and cooling media have been made. The rotameters and regulators for the fluidizing gas, liquid spray and the instrumentation for the pressurized vessel have been ordered and are in house.

Item 4: The fluidized bed and associated instrumentation will be mounted on a UnistrutTM frame in room B65 in the Engineering Sciences Building. Since the fluid bed must pass through the center of the furnace a shelf arrangement must be used to support the furnace. The preliminary design of the frame has been completed and the UnistrutTM channel has been ordered and is in house.

6.0 Results and Discussion (Current Period)

The design and construction of the fluidized bed coating system has proceeded smoothly. Due to a delay in the funding of this project the experimental phase has not yet started. As can be seen from the Work Schedule given in Table 1 the experimental program was due to start in June, it is expected that the experiments will start in late July.

7.0 Conclusions (Current Period)

Despite the delay in starting the experimental program it is expected that the work schedule for the first year of this project will be completed on time.

8.0 Work Planned for Next Period

The exhaust system for the fluidizing gas will be completed. A cold trap and particulate filter is currently being designed and will be built in the near future.

Cold and hot testing of the fluidized bed are scheduled for the next period. The bed and coating feed system will be commissioned and calibration of instrumentation will be performed. Fluidization quality will be assessed and final bed material selection will be made.

References

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2. T.R.Gallaway and J.L.Sprung, "Destruction of UST Organics and Nitrates, Polymeric Organic Wastes, and Chlorocarbon Solvents by Steam Reforming", *Proc. Waste Retrieval, Treatment and Processing Meeting*, Houston, TX, 215-221, March (1993)
3. T.C. Ho, H.W.Chu and J.R.Hopper, "Metal volatilization and separation during incineration", *Waste Mgmt.*, 13,455-466 (1993)
4. T.C.Ho, C.Chen, J.R.Hopper and D.A.Oberacker, "Metal capture during fluidized bed incineration of Wastes contaminated with lead chloride", *Combustion Sci. Technol.*, 85, 101-116 (1992)

Acronyms and Abbreviations

MSDS - Material and Safety Data Sheets

MSW - Municipal Solid Waste

RCRA - Resource Conservation and Recovery Act (1976)

Appendix - Calculations for Design of Fluidized Bed

Fluid Bed Calcs for H₂Wast Coating

Particle Properties - $\rho_s = 2500 \text{ kg/m}^3$ $d_p \sim 500 - 1000 \mu\text{m}$
 Gas Properties - $T = 900^\circ\text{C}$ $\rho = 1 \text{ atm}$ $\left. \begin{matrix} \\ \end{matrix} \right\} \text{N}_2$ $\rho = 0.291 \text{ kg/m}^3$
 $\mu = 50 \times 10^{-6} \text{ kg/m.s}$

Fluidizing Vel

$$R_{omf} = \frac{d_p \mu_{mf} \rho_g}{M_g} = \left\{ (33.7)^2 + 0.0408 \text{ Ar} \right\}^{1/2} \quad \text{From WBV \& Yu}$$

$$\text{Ar} = \frac{d_p^3 \rho_g (\rho_s - \rho_g) g}{M_g^2} = \frac{(500 \times 10^{-6})^3 (2500) (2500) 9.81}{(50 \times 10^{-6})^2} = 357 \quad (2855)$$

$$\frac{d_p = 500 \mu\text{m}}{M_g^2}$$

$$\frac{d_p = 1000 \mu\text{m}}{M_g^2}$$

R_{omf}

$$0.215 \text{ L}$$

$$1.686$$

$$U_{mf} = \frac{M_{g,omf}}{d_p \rho_g}$$

$$0.074 \text{ m/s}$$

$$0.2897 \text{ m/s}$$

Inventory of Material

$$\left. \begin{matrix} 2\frac{1}{2}'' \text{ Diam} \\ 6'' \text{ Height} \end{matrix} \right\} \text{Vol} = \frac{\pi}{4} (D)^2 h = 1.93 \times 10^{-4} \text{ m}^3 = V_{bed}$$

$$\text{Weight of Solids} = V_{bed} (1 - \epsilon) \rho_s = 0.241 \text{ kg}$$

Spray Rate

Solution Contains 1% WT of

	MW	WT of H ₂ O
Cr (NO ₃) ₂ · 6H ₂ O	284	52
Ni (NO ₃) ₂ · 6H ₂ O	291	59
Pb (NO ₃) ₂	331	207
Cd (NO ₃) ₂ · 4H ₂ O	308	112

Consider 1 kg of Solution

WT of	Cr	10 (52/284)	= 1.831
	Ni	10 (59/291)	= 2.027
	Pb	10 (207/331)	= 6.254
	Cd	10 (112/308)	= 3.636
		<u>13.748</u>	g

$$\left. \begin{matrix} \\ \\ \\ \end{matrix} \right\} \text{TOTAL METAL CONCN} = 1.375 \text{ WT\%}$$

IF WE WANT TO DOSE BED SOLIDS TO SWT % METALS

WE REQUIRE : $\frac{(0.241 \times 0.05)}{13.748 \times 10^{-3}} = 0.876 \text{ kg/solution}$

SAY WE SPRAY 1 kg OF SOLUTION in 1/2 Hr. } USE A 1/4 LN-SS1 FROM SPRAYING SYSTEMS
FLOW RATE $\approx 0.53 \text{ gal/h.}$ } ~ HYDRAULIC NOZZLE WITH Cap $\approx 1 \text{ gal/hr}$

HEAT BALANCE ON BED

HEAT INTO BED = (CONDUCTION / CONVECTION LOSSES) + HEAT TO VAPORIZE LIQUID + HEAT TO WARM FLUIDIZING GAS.

① UNKNOWN AT THIS TIME $\propto \Delta T_{\text{BED-AMBIENT}}$ ②

③

② HEAT TO VAPORIZE LIQUID

LIQUID IN @ 25°C } $\Delta H = 1874 - 180 = 1694 \text{ BTU/lb} = 3.94 \text{ MJ/kg}$
STEAM OUT @ 900°C }

HEAT REQUIRE TO VAPORIZE & HEAT LIQUID = $(3.94 \times 10^3) \frac{1}{(1800)} = 2.19 \text{ kW}$

WE MAY HAVE TO REDUCE SPRAY RATE OR OPERATE @ LOWER TEMP DEPENDING ON HEATER SIZE.

③ HEAT TO WARM FLUID. GAS.

SAY OPERATE BED AT $\sim 4 \text{ Umf} = 1.2 \text{ m/s} \Rightarrow \text{Vol} = \frac{\pi}{4} (D_v)^2 \cdot 1.2 = 3.8 \times 10^{-3} \frac{\text{m}^3}{\text{s}}$

@ STP VOL OF GAS = $(3.8 \times 10^{-3}) \frac{(273)}{(273+900)} = 0.884 \times 10^{-3} \text{ m}^3/\text{s}$
 $= 1.06 \times 10^{-3} \text{ kg/s}$

NOW $\overline{C_p}_{25-900^\circ\text{C}, \text{N}_2} \approx 7.4 \text{ BTU/lbmol} \cdot ^\circ\text{F} = (7.4)(1055)(2.2048)(1.8) = 30.98 \frac{\text{kJ}}{\text{kmol} \cdot ^\circ\text{C}}$
 $= 1.107 \text{ kJ/kg} \cdot ^\circ\text{C}$

$\therefore$ ENERGY TO HEAT GAS = $(1.107)(1.06 \times 10^{-3})(900-25) = 1.03 \text{ kW}$

TOTAL HT REQUIRED = $2.19 + 1.03 + ① = 3.22 + ① \text{ kW}$

FURNACE — OUR FURNACE HAS HEATIN = 11 kW SHOULD BE OK.

LOOK AT DISTRIBUTOR DESIGN.

NOZZLE diameter = 19 mm

$$\text{FREE AREA FOR FLOW} = \frac{\pi}{4} \left((2.5 \times 25.4 \times 10^{-3})^2 - (19 \times 10^{-3})^2 \right) = \underline{2.883 \times 10^{-3} \text{ m}^2}$$

DISTRIBUTE AIR PREFERENTIALLY THROUGH CENTER — 80% THROUGH CENTER
20% THROUGH SIDES

$$\frac{\Delta P_{\text{DIST}}}{\Delta P_{\text{BED}}} \approx 0.2 \quad \Delta P_{\text{BED}} = 6 \text{ "H}_2\text{O}$$

$$\Delta P_{\text{DIST}} = (0.2)6 = 1.8 \text{ "H}_2\text{O} \approx 448 \text{ Pa}$$

$$\Delta P_{\text{DIST}} = C_D \frac{\rho V^2}{2} = (0.65) \left(\frac{1}{2} \right) (0.291) V^2 = 448$$

$$V^2 = 4737 \text{ m}^2/\text{s}^2 \Rightarrow \underline{V = 69 \text{ m/s}} \quad \text{!!} \quad @ 900^\circ\text{C}$$

VOL. FLOW RATE OF GAS = $3.8 \times 10^{-3} \text{ m}^3/\text{s}$ (actual)
900°C

$$\therefore \text{CSA FOR FLOW} = \frac{3.8 \times 10^{-3}}{V} = 5.5072 \times 10^{-5} \text{ m}^2 = \underline{55.07 \text{ (mm)}^2}$$

$$\therefore \% \text{ OPEN AREA} = \frac{(5.5072 \times 10^{-5})}{(2.883 \times 10^{-3})} \times 100 = \underline{1.91 \%}$$

IN CENTER CSA = $(0.80)(55.07) = 44.6 \text{ (mm)}^2$
OUTSIDE " = 10.5 (mm)^2

LARGE HOLES IN SIDE

$$A_{\text{HOLE}} = (44.6) / 8 = 5.575 \text{ (mm)}^2$$

$$d_{\text{HOLE}} = \sqrt{\frac{4(5.575)}{\pi}} = \underline{2.66 \text{ mm}} \quad (\sim 1/8") \rightarrow 1/8"$$

USE 8 - 2.5 mm HOLES in CENTER } AS per FIGURE 1.
16 - 1mm HOLES on OUTSIDE

$$\text{TOTAL HOLE AREA} = 8 \frac{\pi}{4} (2.5)^2 + 16 \frac{\pi}{4} (1)^2 = 51.83 \text{ mm}^2$$

$$\therefore \text{VELOCITY THROUGH HOLES} = \left(\frac{55.07}{51.83} \right) (69) = 73.3 \text{ m/s}$$

$$\Delta P_{\text{PLATE}} = \left(\frac{73.3}{69} \right)^2 (44.8) = 505 \text{ Pa} = 2.03 \text{ "H}_2\text{O}$$

FLOWMETER CALCS.

GAS

$$\text{DESIRED FLOW} = 0.8844 \times 10^{-3} \text{ m}^3/\text{s} = 1.87 \text{ SCFM} \quad (112 \text{ SCFH})$$

COLE PALMER - H-03294-36 ~ \$150
MAX P = 200 psi

LIQUID

MAX FLOW 2 GPH ! $\Rightarrow 2.1 \text{ ml/s} \Rightarrow 126 \text{ ml/min}$

$\Rightarrow$ COLE-PALMER H-32112-08 or H-32111-08 ~ \$255
P_{MAX} = 200 psi

NITROGEN Regulation

FISHER 10-572 @

121.91 CONTRACT.
\$148

Figure A1: Hole Pattern for Distributor Plate

ADVANCED PRODUCT APPLICATIONS TESTING

REMEDIATION OF HAZARDOUS SITES WITH STEAM REFORMING

TASK 2.4

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.: DE-FC21-92MC29467
(MTCI No. 10070)

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:

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Manufacturing and Technology Conversion
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July 1995

ABSTRACT

Subsystem procurement, installation and checkout is proceeding. The evaporative heat exchanger was received and the steam superheater was designed and is being fabricated.

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1. TECHNICAL BACKGROUND

A complete discussion of the technical background was presented in the quarterly report for the period July 1, 1993 through September 30, 1993. For continuity of the discussion in this part, the following summary paragraph has been included herein.

The MTCI thermochemical reactor system has easily demonstrated at commercial levels its superior performance in the steam reforming of a wide variety of biomass, industrial and municipal waste feedstocks containing chlororganics as well as coal, coal liquefaction bottoms, and mild gasification char at ambient (atmospheric) conditions. The system processed a wide spectrum of feedstocks producing a hydrogen-rich product gas that is free of the diluents (primarily N_2) found in air-blown steam reforming systems and is more cost-effective than oxygen-blown systems. In addition, liquid and solid waste streams from the MTCI system show extremely low levels of toxics and leachability, permitting easier landfill or industrial toxic by-product recovery. The feasibility of developing a pressurized system based on the MTCI technology would permit even greater gains in processing yields, system modularity, and capital and operating costs for processing hazardous and other waste. This would especially be applicable to the cleanup and treatment of large volumes of soils contaminated with toxic organics, i.e., PCBs, pesticides, cyanides, RCRA metals, and dioxin/furans. Reformation of toxic organics in the oxidizing environment of incinerators are completely eliminated because of the reducing environment present in the MTCI thermochemical reactor (steam reformer).

2. EXPERIMENTAL METHODOLOGY

The test plan and methodology remain the same as previously reported.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

During this reporting period, the venturi scrubber (VS-1) and its circulating tank (C-4) were installed (*Figure 1*). The second-stage scrubber (C-6) and its circulating tank (C-7) were also installed.

The steam superheater (E-5) refractory pouring was completed. The steam superheater refractory was cured and the steam superheater installed.

The flue gas plumbing from the pulse combustor tube bundle to the steam superheater was completed.

The process gas plumbing from the reactor to the venturi scrubber and from the venturi scrubber to the second-stage scrubber was also completed.

The process water plumbing from the second-stage to the evaporative air cooler was also completed.

The second-stage circulating water pump, the venturi scrubber water pump, and various other pumps were selected, purchased and received. The natural gas compressor was also selected, purchased and received.

4. CONCLUSIONS

With procurement and receipts of materials and parts proceeding normally, it is anticipated that the pressurized system will be assembled and ready for checkout and shakedown by the end of August 1995.

PLANS FOR NEXT REPORTING PERIOD

- Complete the plumbing.
- Start electrical and instrumentation.
- Start shakedown testing.

ADVANCED PRODUCT APPLICATIONS TESTING

**ENVIRONMENTAL POLLUTION CONTROL
DEVICES BASED ON NOVEL FORMS OF CARBON**

TASK 2.5

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
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ABSTRACT

The use of electrochemistry is an effective means to remove heavy metal contaminants from aqueous effluent streams. Electrochemical processes also exist for the removal of salts as well as bacteria and organic compounds from water. This project deals with the development and testing of carbon nanofibers for the cathodic removal of heavy metals from the effluent stream.

The concentration of heavy metal ions in the effluent stream is usually very low: 1 to 1000 ppm. These low concentrations lead to relatively low current densities and low conversion of electroactive species at electrodes with small surface area. Therefore, the electrolytic cell must be designed to increase the degree of conversion of the electroactive species (metal ion) as it passes through the cell. This increase in conversion can be obtained by two means; (1) the use of a 3-dimensional electrode (increases surface area and residence time) and (2) turbulence (rotated electrode or flowing stream). The desire is to create a very high ratio of electrode surface area to electrolyte volume within the cell, coupled with turbulent mass transport within the cathode material. In this type electrode, it is possible to control the conversion efficiency using the length of electrode through which the effluent solution must pass.

This work is to develop and test a cathodic material with an extremely large ratio of surface area to electrolyte volume. This will be accomplished by using a packed-bed of carbon nanofibers or by growing carbon nanofibers on a conductive support. The surface area can be increased by 2-3 orders of magnitude. This increased surface area can help minimize the length of electrode through which the solution must pass. This decreased distance leads to reduced resistance to solution flow.

All experimental parameters will be optimized for the removal of cadmium, lead and copper from laboratory prepared samples using a small-scale model of the electrolytic cell. Subsequent work shall examine the use of this electrolytic cell on "real" samples and for the selective removal and recovery of precious metals. The final objective will be to transfer this technology for use in industrial applications.

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EXECUTIVE SUMMARY

Flow electrolysis using carbon nanofibers, either loosely or grown on a conductive support, was employed for decontaminating heavy metal solutions. Reduction of Cd(II), Pb(II) and Cu(II) ion concentrations in aqueous solutions was carried out under controlled flow and potential conditions. Removal efficiencies of 90% and greater were obtained using carbon nanofibers alone or grown on graphitic supports. For initial metal ion concentrations of 100 ppb, this corresponds to an effluent metal ion concentration at the outlet of the electrolytic cell of 10 ppb or less. The decrease in metal ion concentration was monitored using Anodic Stripping Voltammetry (ASV) downstream from the electrolytic cell. The performance of the carbon nanofibers competes with prevalent metallic and carbonaceous metal removal systems. The ease with which modifications and optimizations can be accomplished makes this a simple and economic method for metal ion removal and recovery.

Contained herein are data for test runs made on a variety of carbon materials. Results are presented for cation removal on reticulated vitreous carbon foam, loosely packed carbon nanofibers and nanofibers grown on both graphite mats and graphite felt. Results are also shown for the bare graphite felt and the platinum mesh screen without any carbon cathode material.

ELECTROCHEMICAL STUDY OF CARBON NANOFIBERS

INTRODUCTION

PURPOSE

The purpose of this research is to assess the feasibility of using carbon nanofiber devices to remove heavy metal contaminants from aqueous streams. This work will address the fabrication, behavior and analytical utility of these novel carbonaceous materials. Standard electrochemical techniques will be employed to meet this objective.

BACKGROUND

Electrochemical techniques pertain to measurements involving the flow of electrons during a reduction-oxidation (redox) reaction. These measurements involve current, potential, charge and/or time as the primary variables. Electrochemical studies typically incorporate the use of a three electrode system. This systems includes a working, reference and auxiliary electrode. The redox reaction occurs at the surface of the working electrode as a result of the applied potential. Therefore, it is critical to choose a suitable material for the working electrode. The material must meet certain requirements. The electrode material should exhibit high electrical conductivity, be chemically inert over the potential region of interest, show favorable electrochemical behavior with the analyte(s), have a low background current and have an easily reproducible surface (1). Carbon materials are well suited for use as working electrodes. Graphite (2,3), carbon paste (4), glassy carbon (5) and reticulated vitreous carbon (RVC) (6) are a few examples of carbonaceous materials that have been used. A detailed discussion of carbon electrodes has been compiled by Dryhurst and McAllister (7).

Carbonaceous materials have been used to produce flow-through porous electrodes. Electrode materials have included graphite chips (8) or granules (9), glassy carbon grains (10), crushed graphite (11), screens of graphite (12) or carbon (13) and RVC (14). These porous flow-through electrodes have been used to remove metal ions from aqueous solutions. This is of major importance to industrial processes and environmental applications.

The large surface area of porous flow-through electrodes makes them excellent candidates for the removal of metal ions from solution. Removal efficiencies approaching 100% can be achieved (14). The present work will address the use of various carbon materials, including carbon nanofibers to produce porous flow-through electrodes for the

removal of metal ions from aqueous media. The resulting effluent will be monitored downstream using anodic stripping voltammetry to assess the decrease in analyte concentration and hence the electrode efficiency.

EXPERIMENTAL METHODOLOGY

A schematic diagram of the apparatus used to carry out these experiments is shown in Figure 1. It was designed in the WVU lab and was produced by the WVU machinist. It is a two-cell system. The upstream, working cell removes metal ions from the flowing stream. The downstream, analytical cell is used to measure the metal ion concentrations in the resulting effluent. The analysis of the analyte concentration leaving the working cell will be measured on-line by anodic stripping voltammetry. This is necessary since the ion concentration of the metals leaving the working cell is expected to be in the parts-per-billion (ppb) range and such an analytical cell is essential to obtain sensitive and accurate measurements at these low concentration levels. A typical 3-cell electrode system, using a silver/silver chloride (Ag/AgCl) reference electrode will be used for all studies.

METAL REMOVAL CELL

The upper cell is used to test the various carbonaceous electrode materials for their ability to remove certain heavy metal ions from an aqueous stream. The cylindrical body of the upper (working) flow-through cell was made of Lexan. A solution flow channel was drilled through the Lexan body. The working electrode material is held in place by glass wool or by a snug fit, dependent upon the nature of the material. Contact to the working electrode is accomplished using a platinum wire through an access port in the Lexan wall. The Ag/AgCl reference electrode and platinum wire auxiliary electrode are introduced into the flow channel by similar access ports in the wall. Teflon tubing is used to connect the sample reservoirs, the pump and the upper and lower cells.

The sample is pumped into the upper working cell and through the carbonaceous working electrode material. A peristaltic pump is used to control the flow rate for all experiments. An applied potential more negative than the standard reduction potential of the metal ions of interest is applied to the working electrode (see Table I). This applied potential forces the plating of the metals onto the electrode surface thus removing the contaminant metals from solution. Experimental parameters will be optimized to maximize the removal of these metals. These parameters include pH, buffer concentration, solution flow rate (v) and applied potential (E). Conversion efficiency, long-term stability and loading capacity will also be assessed. Finally, the pressure drop and flow rate characteristics of the solution flowing through the upper cell will be assessed.

DETECTOR CELL

The lower flow detector (analytical cell) is used to determine metal ion concentration in the effluent stream. The detector working electrode is a glassy carbon disk. The reference electrode is Ag/AgCl and the stainless steel body of the cell acts as the auxiliary electrode (Figure 2). A thin mercury film is deposited onto the working electrode surface by applying a negative potential (usually -1.00 V) while a solution containing mercuric ions (Hg^{2+}) flows past the glassy carbon electrode. Mercuric ions are reduced to mercury metal forming a thin film of mercury on the glassy carbon surface. The mercury film preconcentrates the metal ions of interest (i.e. Cd, Pb, Cu and Zn) at the electrode surface prior to measurement. The metal ion concentration in the mercury film can be 10-100 times greater than the metal ion concentration in the effluent stream. In order to accumulate the metal ions, the mercury solution flow is stopped and the analyte solution is passed over the mercury-coated disk. A potential more negative than the standard reduction potential of the metals being removed is applied to the glassy carbon working electrode as the effluent stream flows past. Any metal ions not removed by the upper flow-through cell will be preconcentrated into the mercury film at the detector. The metal ions are subsequently stripped (removed) from the mercury film by scanning the potential in the positive direction.

This forces the oxidation of the metal ions near their standard redox potential. The electron transfer involved in this oxidation is measured as a current flow at the working electrode surface. The current response obtained from this anodic stripping of the metals from the mercury film is used to determine the metal ion concentration of the effluent stream. Once the concentration is known, the efficiency of the upper flow-through cell and hence the carbon material under test can be evaluated. In order to determine the metal ion concentration, the flow rate through the upstream working cell and the downstream analytical cell must be measured accurately. This is accomplished by collecting a known amount of the solution at the cell outlet in a precisely calibrated graduated burette while measuring the time using a stopwatch. Accurate and reproducible flow rates are calibrated to one-hundredths of a milliliter/minute.

An important feature of this system is that it allows continuous, on-line monitoring of the analyte species in the effluent stream. Measurement of metal ion concentration levels down to and below 0.2 ppb are possible with this detection method dependent upon the metal under investigation.

SAMPLES

Several carbonaceous electrode materials have been obtained from a variety of sources for comparison. To date, the following samples have been obtained:

Carbon Nanofibers (#1094-A) from PSU (University Park, PA)

Carbon Nanofibers (#1094-B) from PSU (University Park, PA)

Carbon Nanofibers Grown on Graphite Fiber Mats (# 0295-A) from PSU (University Park, PA)

Vapor Grown Carbon Fibers (VGCF) (PYROGRAF III, Lot ADNH-104-107) from Applied Sciences, Inc. (ASI, Cedarville, OH)

Reticulated Vitreous Carbon (RVC) foam (Duocel[®], 3% density) from Energy Research and Generation, Inc. (ERG, Oakland, CA). (10, 20, 30, 45, 80 and 100 ppi)

Graphite Felt (0695-A) from PSU (University Park, PA)

Carbon Nanofibers Grown on Graphite Felt (NF46) from PSU (University Park, PA)

The complete physical properties of these materials are currently being measured both at WVU and PSU. Each additional sample will undergo similar characterization as it is received. All samples are characterized and tested as received without any further treatment unless otherwise noted.

CARBON NANOFIBERS

The carbon nanofibers were produced by our collaborators at Pennsylvania State University (PSU) under the supervision of Dr. R. Terry K. Baker. This new type of fibrous material is generated using the catalytic carbon vapor deposition technique. The nanofiber material is a microscopic version of carbon fibers. It is produced by the metal catalyzed decomposition of certain hydrocarbons (15,16). Various degrees of graphitization are possible. A more detailed description is included in the original project proposal.

VAPOR GROWN CARBON FIBER (17)

The VGCF manufactured by Applied Sciences, Inc. (ASI) are produced by a combination of catalytic and chemical vapor deposition processes which allow for control of the fiber dimensions, such as filament length and diameter. Lengths are available from 1 mm to tens of centimeters and diameters can vary from under 0.1 to over 100 mm. The resulting fiber has a lamellar morphology and is highly graphitic. VGCF can be heat treated

to further improve the graphitization. Cross section and overall views of these samples were provided in the first quarterly report.

RETICULATED VITREOUS CARBON (18)

Reticulated Vitreous Carbon (RVC) is an open-pore material with a honeycomb (foam) structure (14). RVC is a form of carbon that combines some of the properties of glass with normal industrial carbon. RVC has a large void volume (97%) and surface area ($0.09 \text{ m}^2/\text{gram}$). It has a self-supporting rigid structure, a low resistance to flow and is resistant to temperatures up to 600°F in air (6330°F in a non-oxidizing environment) (19). A more thorough discussion of vitreous carbon is available in the literature (20-24). The samples obtained had various pores sizes. Sizes included 10, 20, 30, 45, 80 and 100 ppi (pores per inch). The 100 ppi RVC foam will be analyzed in our study.

All materials were used as received without any further pretreatment. If necessary to help activate or clean the surface, mild electrochemical or chemical methods will be employed.

WORK PERFORMED THIS PERIOD

EXPERIMENTAL

Surface Area

The surface area of the samples has been determined and the data are shown in Table II. The surface areas were obtained using a Gemini III 2375 Surface Area Analyzer (Micrometrics Instrument Corporation, Norcross, GA). Standard operating procedures have been followed as outlined in the operator's manual.

A pre-weighed sample of the carbonaceous material was placed into a clean, dry sample tube. The sample was thoroughly degassed using nitrogen. The dewar was filled with liquid nitrogen and the system prepared for analysis.

The sample tube was connected to the analysis port and the balance tube was connected to the balance port. Care was taken to minimize exposure of the sample to air. The doors to the sample station were closed and the analysis initiated. Saturation pressure was set to 740.53 mm Hg and the evacuation rate to 599 mm Hg/min. The Gemini III 2375 Surface Area Analyzer performs automated analysis. It is capable of simultaneously performing BET multipoint and single point surface area, Langmuir surface area, t-method

micropore, and BJH adsorption/desorption distribution. The resulting data was recorded on an Epson plotter (Model P84FA).

Electrochemical Apparatus

A two-cell system is used for this study. The upper, or working cell removes metal ions from the flowing stream. The downstream or analytical cell is used to assess the performance of the working cell by measuring the metal ion concentration in the effluent. The upper flow-through cell design is shown in Figure 1. The cylindrical body of the upper cell is made of Lexan (1.9 cm diam., 8.0 cm length). The flow channel (0.90 cm I.D.) was drilled through the Lexan body. The Ag/AgCl reference electrode (3M NaCl, Model RE-4, BioAnalytical Systems, Inc. (BAS) West Lafayette, IN) is introduced into the flow channel through a Lexan sleeve positioned 90 degrees to the flow channel. Leakage is prevented using an O-ring and compression-type fitting. A piece of coiled platinum wire inserted at the top of the cell is used as the auxiliary electrode. Contact to the working electrode is established via platinum mesh positioned through the cell wall and sealed with an o-ring.

The thin-layer flow cell, as shown in Figure 2, was purchased from BioAnalytical Systems (Model LC-44-01000). The working electrode is a glassy carbon disk (0.3 cm diameter) over which the solution flows. Two 50 μm spacers are used to produce the flow channel and direct the effluent flow across the carbon disk. The glassy carbon disk is polished using successive slurries of 1.0, 0.3 and 0.05 μm alumina until a mirror-like surface is obtained. The glassy carbon electrode is then washed thoroughly with deionized water. All potentials are measured relative to the Ag/AgCl reference electrode (BAS). The thin-layer flow cell is connected to the upper cell using Teflon tubing so that the effluent from the working cell flows to the bottom analytical cell.

Solution reservoirs for the mercury (II) plating solution and samples are 1000 ml Nalgene jars fitted with covers. The solution reservoirs are connected to the working cell using Tygon tubing. Solution flow is controlled with a peristaltic pump (Cole-Parmer Instrument Co., Niles, IL) located upstream from the upper cell. All solutions were deaerated using nitrogen gas prior to use. A nitrogen head space is maintained above the solutions to prevent the re-dissolution of oxygen.

The potential of the upper flow-through cell is controlled using an BAS Model PWR-3 Power Module. Stripping voltammograms at the thin-layer flow cell are obtained using the BAS Model CV-27 Voltammograph in conjunction with a HP Model 7044b X-Y recorder.

Reagents

Stock solutions of 1 ppm Cd, Pb and Cu ions are prepared using standard solutions (1000 ppm, Fisher Scientific, Fair Lawn, NJ) and deionized water. These solutions are

stored in polyethylene containers to avoid contamination. Portions of these solutions are diluted as needed for experimentation. The $1 \times 10^{-4} \text{M}$ Hg(II) solution used for mercury plating is prepared from $\text{Hg}(\text{NO}_3)_2$ as needed. The mercury ion and sample solutions are prepared in 0.1M KNO_3 supporting electrolyte. The pH is adjusted to 3.9 using HNO_3 . (All chemicals were certified ACS grade purchased from Fisher Scientific unless otherwise noted).

PROCEDURE

Metal Removal Cell

The carbon material to be studied was pretreated to oxidize and assist in the wetting of the carbonaceous surface. This was accomplished by placing the carbon material in a dilute solution (1M) of nitric acid overnight in a covered beaker. The material was then thoroughly washed using distilled-deionized water. The carbonaceous material was then positioned into the lower end of the flow channel in the upper working cell using a clean glass rod. Glass wool was packed below the fibrous samples to support them and prevent them from flowing out of position. Various thicknesses of the carbon nanofibers (1094-A) were packed into the flow channel using different amounts of force. The particles were packed loosely, lightly and tightly. Loosely packed nanofibers showed little resistance to solution flow, but did not establish a good electrical contact to the platinum wire. Tightly packed nanofibers resulted in good electrical contact but stopped solution flow. Lightly packed carbon nanofibers produced some resistance to solution flow but irreproducible electrical contact. A procedure will be developed to pack the carbon nanofibers so that the resistance to solution flow is minimized while good electrical contact is maintained.

Using a new cell design (Figure 3), it is not necessary to use glass wool to pack the fibrous carbon nanofiber material. A threaded plug is used to press the material between a platinum mesh and a piece of filter paper. The carbon material is placed into the working cell and the threaded plug is screwed into place snugly against it. The pressure on the carbon nanofibers can be easily adjusted by turning the threaded plug. Rigid samples, such as Reticulated Vitreous Carbon were positioned using a snug fit. Electrical contact to the working electrode material was established using the platinum wire. The reference electrode was inserted into the sleeve and the cell was connected to the pump using Tygon tubing. A 0.1M KNO_3 electrolyte solution was pumped through the flow cell. In order to help remove air bubbles and wet the electrode surface, a mild electrochemical pretreatment was used. The cell potential was held at $+1.00$ for 10 minutes followed by -1.00 V for 10 minutes. Further details about the new cell are discussed below.

The performance of the carbonaceous material under study was tested by placing a solution containing a known concentration of metal ions (Cd , Pb and/or Cu) into the sample

reservoir. The solution was then allowed to pass through the metal removal (working) cell at a known flow rate and applied potential. The performance was assessed by measuring the metal ion concentration in the effluent and comparing it to the initial ion concentration. The percentage efficiency of the cell is equal to the percentage of metal ions removed from the solution by the electrolytic cell.

For these studies, the effluent was collected in a Nalgene bottle for subsequent analysis using the downstream analytical cell.

Analytical Cell

A pre-plated mercury film is used for downstream anodic stripping voltammetric (ASV) detection of the metal ions in the effluent stream. A $1 \times 10^{-4} \text{ M}$ Hg(II) solution in 0.1M KNO_3 is purged with nitrogen for 20 minutes. The mercury film is produced by applying a potential of -1.00 V at the glassy carbon electrode while passing the Hg(II) solution through the cell at 0.87 ml/min for 5 minutes. After this period, the potential is held at +0.05 V for 90 seconds. Following this conditioning, the stopcock is turned to stop the flow of mercuric ions and allow the flow of the deaerated sample through the cell. This flow is continued for 3 minutes to flush any mercuric ions from the system and replace all of the solution in the system with the sample to be studied.

While the solution is flowing at a known flow rate (0.87 ml/min), the ASV plating potential is applied to the thin-layer flow cell (usually for 1 minute) and the metal ions are accumulated. At this point, the solution flow is stopped to the analytical cell and after a 30 second equilibrium period, a ramp is initiated (-1.00 V to + 0.200 V) and the stripping voltammogram recorded. The scan is terminated at + 0.200 V. Sample solution flow is renewed and the electrode cleaned at + 0.05 V for 90 seconds to prepare the system for the next determination.

The mercury film and plated metals are removed at the end of a series of experiments using a moist Kimwipe. The electrode is subsequently polished for the next series of studies.

RESULTS and DISCUSSION

After preliminary testing of the initial cell design (as shown in Figure 1), it was found that some modifications were required.

First: If varying thicknesses of carbonaceous electrode material are to be tested, the distance between the working and the reference electrodes would not be constant. This would lead to differences in the solution resistance and therefore, differences in uncompensated potential (iR) losses.

Second: There was great difficulty in establishing good electrical contact between the working electrode material (the carbon nanofibers) and the Pt wire lead. This problem induced large cell resistance and high voltage drops across the carbon electrode.

In order to maintain a constant distance between the working electrode and the reference electrode and minimize cell resistance, a new cell design was created. This new design is shown in Figure 3.

A major complication involved the carbon nanofibers in the earlier cell. Loosely packed carbon-fibers allowed solution flow, but electrical contact was sacrificed. If the particles were packed more tightly, improved (although not great) contact was established, but a high resistance to solution flow resulted. Further work is being performed to help eliminate this problem. One step taken in the new cell design is the addition of the threaded plug so that the amount of compression of the nanofibers can be carefully adjusted and controlled.

A threaded plug is used to press the carbonaceous working electrode material firmly against a Pt mesh. This platinum mesh is used as the working electrode contact. The surface area of the platinum mesh is negligible relative to the surface area of the carbon material, but should still afford much better contact with the carbonaceous material than the single Pt wire used in the previous design. Therefore, minimal electrolytic contribution will be gained from the platinum mesh while maximizing the electrical contact. The reference electrode was positioned as close as possible to the working electrode through a Lexan sleeve. Special care was taken to allow varying amounts of carbon material to be used, while maintaining constant electrode distances. Through the use of flanges and an o-ring, the design also allows easy removal and replacement of the carbon material.

ANALYTICAL CELL

The inherent sensitivity of Anodic Stripping Voltammetry (ASV) makes it an excellent choice for the detection of heavy metal ions in solution. The detectable limits are often

below those attainable using Flame and/or Flameless Atomic Absorption / Emission Spectroscopy. Figure 4 demonstrates the ability to detect these low limits using a thin mercury film coated on a glassy carbon electrode. The mercury film yields well-defined and sharp peaks, good resolution between neighboring signals and a low background current. The response shown is for a sample solution containing 10 parts per billion (ppb) cadmium, lead and copper in 0.1 M KNO_3 at various deposition times (0, 30, 60, 90 and 180 seconds). The increased accumulation of the metals in the mercury film with time is quite evident. The dependence of the peak current on the deposition time is shown in Figure 5. The effect of the deposition time on the peak current was studied using a solution containing 100 ppb copper and lead. As expected, a linear relationship was obtained with a slope of $2.293 \mu\text{A}/\text{min}$ (Cu) and $1.180 \mu\text{A}/\text{min}$ (Pb) with correlation coefficients of 0.9937 (Cu) and 0.9926 (Pb). The peak current is used to calculate the concentration of metal ions in the effluent stream.

Figure 6 examines the effect of the ASV scan rate on the stripping response of 100 ppb copper and lead. The peak current increases with the increased scan rate. However, at scan rates above 10 mV/sec, the peaks begin to broaden, leading to an overlapping of neighboring peaks.

Calibration data acquired with a flowing (0.87 ml/min) solution of lead (1-5 ppm) yielded well-defined and sharp peaks. The resulting calibration plot (Figure 7), was highly linear ($R=0.9932$), with a slope of $1.066 \mu\text{A}/\mu\text{g}$.

The response for 6 repetitive measurements of cadmium, lead and copper was examined. Figure 8 shows the exceptional precision of the response for 30 second deposition of 2 ppm copper and lead. An average peak current and relative standard deviation of $14.413 \mu\text{A}$ and 2.05% for copper and $7.272 \mu\text{A}$ and 3.42% for lead demonstrate the degree of reproducibility. The precision of 1 ppm cadmium (not shown) did not produce such outstanding results. The relative standard deviation of 7.80% illustrates this point. Fine tuning of the experimental procedure is necessary to obtain the desired response.

METAL REMOVAL

The effectiveness of a cylindrical piece of Reticulated Vitreous Carbon (RVC) (6 mm diam., 6 mm length) was examined for its performance as the cathode material of the upstream electrolytic (metal removal) cell. Cathodic removal of the metal ions via reductive plating on the RVC was investigated. Figure 9 shows the performance of this cell. A sample solution containing 50 ppb cadmium, lead and copper was analyzed using a flow rate of 1.22 ml/min. Curve "A" shows the response of the solution prior to passing it through the electrolytic cell. Further, Curve "B" shows the negligible removal of the metals

ions in the cell due to adsorption alone on the carbonaceous surface ($E_{\text{applied}} = 0.00\text{V}$). Only the response for cadmium was affected (16% decrease). Upon applying a potential well negative of the reduction potentials of all three metals, a significant decrease in peak current is observed due to the removal of the metals (Curve "C"). A 64.7% and 50.0% efficiency was observed for copper and cadmium, respectively. A small 10% efficiency was seen for lead. At -1.000 V and using a slower flow rate of 0.87 ml/min (not shown), preliminary removal efficiencies of 90% or greater were obtained for the three metals.

In order to improve these efficiencies, several parameters must be addressed. By increasing the ratio of cathode surface area to electrolyte solution volume, increasing the time that the solution remains in the electrode material and/or by optimizing the potential applied to the cell, greater efficiencies can be obtained. One option would be to lower the flow rate of the solution through the cell. This would allow more time for the metal ions to be removed, but would increase the process time. A simpler solution would be to increase the electrode surface area. This can be accomplished in any number of ways. A longer flow path through the cathode would increase the surface area and the residence time. Another method is to increase the surface area of the solid 3-dimensional support by growing carbon nanofibers onto the surface. This should produce a cathode material with a 2-3 orders of magnitude increase in surface area. Testing is underway using carbon nanofibers grown on either a graphite mat or a graphite felt produced at Penn State University. Surface area measurements of this material have been performed (see Table II). Attempts by co-workers at Pennsylvania State University to grow carbon nanofibers on the RVC surface were unsuccessful.

Initial attempts to use the loose carbon nanofibers were halted when the Plexiglas working cell was broken. In order to eliminate this problem, a new cell was constructed using Lexan, a more rugged material.

Two samples of loose carbon nanofibers were received from Pennsylvania State University. The more conductive and graphitic sample (#1094-A) was used for analysis. The carbon nanofibers were treated overnight in 0.1 M HNO_3 . This treatment also improved the wetting ability of the nanofibers. The surface area of these loose nanofibers has been measured ($115\text{ m}^2/\text{g}$). This is 1000 times greater than the surface area of the reticulated vitreous carbon material tested previously. This large surface area should enhance the removal efficiencies of the working cell.

Using the new cell design, good electrical contact was established between the loose carbon nanofibers and the platinum mesh lead. The ability of these nanofibers to remove cadmium and lead from water was addressed. No effect was observed for the removal of the metal ions due to adsorption alone. Application of a negative potential, greatly improved this materials' ability to remove the metal ions. Figure 10 shows the effectiveness of these loose carbon nanofibers to remove cadmium and lead. Removal

efficiencies of 91% for cadmium and 95% for lead were obtained at these conditions. These enhanced removal efficiencies, relative to those shown using RVC, show great promise for the use of these novel carbon nanofibers for the reductive removal of metal ions from aqueous streams.

A sample of carbon nanofibers grown on graphite fiber mats was obtained from Terry Baker at our March 17, 1995 meeting. Upon completion of the new Lexan cell, this material was prepared for analysis. The carbon nanofibers grown on graphite fiber mats were pretreated as discussed earlier to oxidize the carbon surface. The surface area of the material was then determined and was relatively large, $99.9 \text{ m}^2 / \text{gram}$.

The performance of this material was assessed. Good electrical contact and conductivity were obtained between the cathode material and the platinum mesh lead. The effectiveness of the carbon nanofibers grown on graphite fiber mats to remove metal ions from an aqueous stream was then studied. The removal of the metal ions by adsorption only (no applied potential) onto the cathode resulted in minimal removal of the metal ions. Upon applying a sufficiently negative potential to the cathode, improved ion removal was attained. Figure 11 illustrates the performance of the cathode material. Curve "A" shows the response of the sample solution prior to passing it through the electrolytic cell. Curve "B" shows the decrease in peak current due to the removal of the metal ions using a potential of -0.80V . The response for the effluent when applying potential of -1.00V to the cell is shown in Curve "C". Removal efficiencies of 99%, 91% and 88% were obtained for Cu, Pb and Cd, respectively. At an applied of -1.20V (not shown), no response was seen for any of the metals. (i.e. removal of metal ions to concentrations below detectable limits.) We are currently waiting for the Penn State group to send a sample of the bare graphite mats (i.e. containing no carbon nanofibers) for comparative testing.

A conductive graphite felt was analyzed in the next study. Both unmodified graphite felt and graphite felt with carbon nanofibers grown on it were utilized. Surface area measurements demonstrate the ability to increase the surface area of the sample using the carbon nanofibers. Prior to growing carbon nanofibers, the surface area of the graphite felt was $0.17 \text{ m}^2/\text{g}$. Upon growing carbon nanofibers onto the surface, the surface area of the sample was increased to $55.41 \text{ m}^2/\text{g}$, over a 300-fold increase.

The performance of the bare graphite felt was first assessed. Minimal removal was seen due to adsorption alone. Upon applying a potential of -1.00 V to the cathode, most of the lead (97%), but only 22% of the cadmium was removed. The resulting voltammograms are shown in Figure 12. No reason could be found for the low removal of the cadmium although we suspect the properties of the graphite felt may be causing a severe overpotential. Application of a more negative potential (-1.20 or greater) should remove the cadmium as well.

The response for solutions collected under the same conditions using the graphite felt with nanofibers is shown in Figure 13. Once again a minimal amount of the metal is removed by the carbonaceous material in the absence of an applied potential. When a reductive potential is applied, almost complete removal of lead, as well as a improved removal of cadmium is acquired (46%).

To confirm minimal contribution from the platinum mesh to the working electrode, the system was tested in the absence of any carbonaceous cathode material. The response for the original feed solution was compared to the response of the effluent collected at -1.00 V. It was shown that the platinum mesh does not contribute significantly (<2%) to the removal of the metal ions from solution (see Figure 14). Therefore, the removal of metal ions seen so far is due to their reductive removal onto the carbonaceous cathode materials and is not significantly influenced by the platinum mesh.

CONCLUSION

To date, we have met the majority of our proposed objectives (see Table III). An extensive search of the literature has been conducted in the areas of heavy metal removal, waste water treatment and water remediation. More than 150 papers have been amassed in these areas with special interest in the areas of electrochemistry and electrowinning using carbonaceous materials.

The thin-layer flow-cell to be used as the on-line detector has been assembled and has been thoroughly tested. This testing included characterization, calibration and verification. The flow-cell will be connected on-line and used to monitor the effluent stream of the upstream metal removal cell.

The preliminary cell design for metal removal from aqueous streams has been tested. Modifications have been made to the cell design and the new cell has been produced. The modifications and problems they solve have been discussed earlier.

The performance of the RVC cell was satisfactory. Good removal efficiencies were obtained for slow flow rates. Due to the problems with growing carbon nanofibers, the RVC could not be used as a support. The RVC was destroyed in all attempts to grow carbon nanofibers on it. Therefore, no conclusions can be drawn on the enhanced performance due to the increase in surface area due to carbon nanofibers grown on the surface of the RVC.

Loose carbon nanofibers with relatively large surface areas of $100^+ \text{ m}^2/\text{g}$ effectively removed over 90% of cadmium and lead from an aqueous sample. Electrical contact was easily established using the new cell design. Further chemical and physical activation

surface area (approximately 100 m²/g). Analysis of this sample to remove metal ions from the aqueous sample were favorable. The carbon nanofibers grown on graphite fiber mats performed well for removing the metal ions. Removal efficiencies of 90% and above (99%+ for Cu) were easily obtained. Through the use of several mats, these metal removal efficiencies should be maintained at even higher solution flow rates due to the large increase in cathode surface area. A sample of the same graphite fiber mats is currently being acquired for comparative testing.

Another material on which carbon nanofibers were grown was graphite felt. Samples of the graphite felt with and without carbon nanofibers were studied. A removal efficiency above 95% was obtained for both samples for the removal of lead. Small removal efficiencies were seen for cadmium. Application of a more negative potential than -1.00 V should increase the amount of cadmium removed. Further analysis will be conducted to optimize the removal of cadmium.

A study to determine the contribution of the platinum wire mesh to the removal of metal ions demonstrated that the contribution was negligible. The metal ion removal is accomplished predominantly by the carbonaceous cathode material.

WORK PLANNED FOR NEXT PERIOD

Analysis will continue on testing a variety of carbon nanofiber systems for the removal of heavy metal ions from water. Carbon nanofibers will be grown on additional support materials and their properties tested. Bulk, loose carbon nanofibers, as well as, the carbon nanofibers/support materials will be tested and their performance evaluated. Samples available for analysis are listed in Table II. Each will be tested to determine which ones merit further studies. Comprehensive preliminary screening of the samples will be completed and suitable carbon nanofiber materials will be selected for further development. The effect of several experimental parameters, including flow rate and pH will be ascertained. The loading capacity of the various carbon materials will also be measured. Industrial contact is being pursued to help guide the development, fabrication and implementation of this study.

FIGURE 1: Electrochemical Remediation Cell and Detector

FIGURE 2: Thin-layer Flow Cell for Metal Detection

FIGURE 3: Modified Remediation Cell

Figure 4: ASV Response for 10 ppb Cadmium, Lead and Copper at a Mercury Film Electrode.

(Mercury Film Plating: 5 min @ -1.00V, 1×10^{-4} M Hg(II), 90 sec @ +0.05 V, flow = 0.87 ml/min. ASV: Deposition: 30 (a), 60 (b), 90 (c) and 120 (d) seconds @ -1.00V, 10 ppb Cd, Pb and Cu in 0.10 M KNO_3 , pH=3.9, flow = 0.87 ml/min; EQ time = 15 sec; Stripping: -1.00 to -0.300 V, 10 mV/sec, stopped flow)

Figure 5: Time Study

(Conditions: same as Figure 4. 100 ppb Pb and Cu)

Figure 6: Scan Rate

(Conditions: same as Figure 4. 30 second deposition, 100 ppb Pb and Cu)

Figure 7: Calibration of Lead
(Conditions: same as Figure 4. 2 minute deposition)

Figure 8: Precision

(Conditions: Same as Figure 4. 5 minute deposition)

Figure 9: Metal Ion Removal Using RVC Electrode

(Conditions: Same as Figure 4. 50 ppb Cd, Pb and Cu, 60 second deposition)

Metal ion solution response prior to passing through working cell (FEED).

Solution response after passing through working cell with no applied potential (0.00 V) and -1.00 V.

Figure 10: Metal Ion Removal Using Loose Carbon NanoFibers
(100 ppb Cd, Pb and Cu, 60 second deposition) Metal ion solution response prior to passing through working cell (FEED). Solution response after passing through working cell with no applied potential (0.00 V) and -1.00 V.)

Figure 11: Metal Ion Removal Using Carbon NanoFibers on a Graphite Fiber Mat
(Conditions: Same as Figure 10).

Figure 12: Metal Ion Removal Using Graphite Felt
(Conditions: Same as Figure 10).

Figure 13: Metal Ion Removal Using Carbon NanoFibers grown on a Graphite Felt
(Conditions: Same as Figure 10).

Figure 14: Metal Removal Using Bare Platinum Wire Mesh
(Conditions: Same as Figure 10)

Table I

STANDARD REDUCTION POTENTIALS OF THE METAL
IONS OF INTEREST

<u>Metal Ion Reaction</u>	<u>E°, (vs. Ag/AgCl)</u>
$\text{Zn}^{+2} + 2\text{e}^{-} \rightleftharpoons \text{Zn (s)}$	-0.986 V
$\text{Cd}^{+2} + 2\text{e}^{-} \rightleftharpoons \text{Cd (s)}$	-0.624 V
$\text{Cd}^{+2} + 2\text{e}^{-} \rightleftharpoons \text{Cd (in Hg)}$	-0.602 V
$\text{Pb}^{+2} + 2\text{e}^{-} \rightleftharpoons \text{Pb (s)}$	-0.348 V
$\text{Pb}^{+2} + 2\text{e}^{-} \rightleftharpoons \text{Pb (in Hg)}$	-0.343 V
$\text{Cu}^{+2} + 2\text{e}^{-} \rightleftharpoons \text{Cu (s)}$	+0.115 V
$\text{Cu}^{+2} + 2\text{e}^{-} \rightleftharpoons \text{Cu (in Hg)}$	+0.123 V

Table II

PROPERTIES of CARBON MATERIALS

SURFACE AREA

Material	Surface Area (m ² /gram)	
	BET	Langmuir
VGCF	76.78	122.66
RVC		
100 ppi	0.0923	-
80 ppi	44.80	-
Carbon Nanofibers		
1094-A	115.13	186.78
1094-B	182.77	286.03
NF46 (unsupported)	43.28	
Graphite Felt	0.17	-
Carbon Nanofibers on Graphite Felt		
NF46	55.41	-
F100	54.54	-
CF37	13.96	-
CN37	35.31	-
Activated Carbon	784.32	-
Carbon Nanofibers on Graphite Mats	99.92	-

Table III

TABLE OF REMOVAL EFFICIENCIES

<u>Cathode Material</u>	<u>Metal Removed</u>		
	<u>Cathode Potential, V</u>	<u>Cd</u>	<u>Pb</u>
RVC	0.00	16%	0%
	-1.00	50%	8%
Loose Carbon Nanofibers (#1094-A)	0.00	0%	0%
	-1.00	91%	95%
Carbon Nanofibers on Graphite Mats	0.00	0%	0%
	-1.00	90%	92%
Graphite Felt	0.00	13%	7%
	-1.00	22%	97%
Carbon Nanofibers on Graphite Felt	0.00	0%	0%
	-1.00	46%	99%
Platinum Mesh	0.00	0%	0%
	-1.00	0%	9%

Table IV

"ENVIRONMENTAL POLLUTION CONTROL DEVICES BASED ON NOVEL FORMS OF CARBON"

PERCENTAGE of PROJECT COMPLETION

TASK #	WBS CODE	TASK NAME	DUR	% COMPLETION			
				Q1	Q2	Q3	Q4
1	1.0	PRELIMINARY RESEARCH					
2	1.1	Electrochemical Remediation (ECR)	OCT-DEC	75%	90%	94%	95%
3	1.2	Technical Evaluation	NOV-DEC	50%	60%	70%	95%
4	2.0	ANALYTICAL TECHNIQUES	OCT-JUN	25%	50%	70%	95%
5	3.0	PREPARATION FOR TRIALS					
6	3.1	Hire Post-Doctoral	SEP-OCT	100%	100%	100%	100%
7	3.2	Purchase Electrochemical System	SEP-NOV	25%	60%	75%	90%
8	3.3	Obtain Chemicals and Reagents	OCT-NOV	90%	90%	90%	90%
9	3.4	Obtain Carbon Samples (A-?)	OCT-DEC	10%	25%	40%	60%
10	3.5	Characterize Carbon Samples	OCT-FEB	5%	10%	25%	50%
11	4.0	TESTING					
12	4.1	ECR - Sample A: Nanofibers (1094-A)	NOV-JUN	0%	15%	70%	80%
13	4.2	ECR - Sample B: Nanofibers (1094-B)	NOV-JUN	0%	5%	50%	50%
14	4.3	ECR - Sample C: RVC (100 ppi)	NOV-JUN	0%	15%	70%	80%
15	4.4	ECR - Sample D: RVC (80 ppi)	NOV-JUN	0%	10%	10%	10%
16	4.5	ECR - Sample E: PYRIGRAF III (LOT ADNH)	NOV-JUN	0%	10%	10%	10%
17	4.6	ECR - Sample F - Nanofibers on C Mat (0295-A)	NOV-JUN	0%	0%	5%	50%
18	4.7	ECR - Sample G - Graphite Felt	NOV-JUN	0%	0%	0%	50%
19	4.8	ECR - Sample H - Nanofibers on Graphite Felt	NOV-JUN	0%	0%	0%	50%
20	4.9	Trial Repeats (Concurrent)	MAR-JUN	0%	5%	20%	50%
21	5.0	ANALYSIS and REPORTING					
22	5.1	Analysis and Data Reduction	JUN-JUL	0%	5%	40%	60%
23	5.2	Reports and Manuscripts	OCT-JUL	25%	50%	75%	100%
24	6.0	CLOSURE	JUL				
25	7.0	OVERALL WORK COMPLETE	AUG				

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3.0
INFORMATION SYSTEMS,
PUBLIC POLICY,
COMMUNITY OUTREACH,
AND ECONOMICS

**INFORMATION SYSTEMS, PUBLIC POLICY,
COMMUNITY OUTREACH AND ECONOMICS**

WINFIELD LOCK AND DAM ASSISTANCE PROGRAM

TASK 3.1

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:

Raymond J. Lovett
National Research Center for Coal and Energy
Environmental Technology Division
West Virginia University
Morgantown, West Virginia 26506

July 1995

Abstract

The United States Army Corps of Engineers (ACE) must remediate a contaminated industrial site, formerly owned by ACF Industries, Inc., in order to build a new lock on the Kanawha River at Winfield, WV. The original remediation plan, to incinerate the contaminated soil, generated much controversy in the surrounding communities, notably Eleanor, WV.

West Virginia University became involved in the project in August of 1992. Shortly after that time, a formal program to involve WVU in the solution to the remediation problem began. The WVU involvement has been two-pronged. WVU has interacted extensively with the citizens of Eleanor (and Putnam County) providing technical, logistical and financial assistance in their efforts to understand and evaluate the ACE plans for remediation. A primary objective for WVU is to inform the citizens of possible health and safety problems with proposed operations. Additionally, WVU has interacted with the U.S. Army Corps of Engineers to implement appropriate technology at the site.

These investigations are being conducted by the National Research Center for Coal and Energy (NRCCE) Environmental Technology Division (ETD) staff and WVU faculty.

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EXECUTIVE SUMMARY

The Lock and Dam contamination will probably be excavated and shipped to Utah. Plans and specifications have been established and commented upon by the citizens group in Eleanor. Excavation will probably begin mid to late July. West Virginia University will implement an air monitoring plan to attempt to determine real time volatile emissions and dust generation.

1.0 INTRODUCTION

The site of the former ACF Industries, Inc. railroad tank car maintenance shop is contaminated by various organic and inorganic chemicals. The company abandoned the site in March 1986 and the U.S. Army Corps of Engineers (ACE) acquired the site, which was needed for the approach to expansion of the Winfield Locks and Dam. The extent of contamination, and most explicitly, the presence of dioxin at the site, had been inadequately documented before the ACE took possession of the land. The ACE, when it became aware of the extent of contamination, undertook a study which culminated in the publication of an Engineering Evaluation and Cost Analysis (EE/CA) in May 1992. The EE/CA was made public with a 30 day response period. The net conclusion of the EE/CA was that the ACE would incinerate the contaminated soil. The combination of citizen perception that they had not been appropriately informed of the problem and the proposal to incinerate the soil led to a concerted effort by the citizens to have the EE/CA reconsidered. The concerted effort, which included the involvement of the WV Congressional delegation, successfully led to reconsideration of the issue by the Army.

The subsequent reevaluation by the Army took nearly 7 months; the results, an Action Memorandum for the site, was released in December 1992. The Action Memorandum proposed that the soil be excavated, stored in temporary buildings, then remediated after further study.

As a result of the public involvement in the lock issue, Senator Robert C. Byrd of West Virginia and the Senate appropriations committee published some language which involved the Department of Energy and West Virginia University in the problem. The role of the DOE was to assist WVU financially in their efforts to safeguard the health and safety of the citizens and investigate the application of DOE technology in remediation of the site. The DOE-WVU effort is, thus, funded by this Cooperative Agreement and consists of direct assistance to the area around the site as well as certain technological investigations directed towards the choice of the eventual remediation technology (or technologies).

2.0 WORK PERFORMED THIS PERIOD

The air monitoring proposal (appended) was submitted to ACF, which has funded the feasibility study. In conjunction with Dr. Fred King's work, we will place the MS/MS unit he is developing in the field. An interface for air sampling is nearly fabricated, a propane/natural gas generator is ordered, water chemical ionization has been evaluated and improvements in software are being developed in cooperation with the instrument manufacturer, Varian Instruments.

Dr. Mridul Gautum of WVU's Mechanical and Aerospace Department is investigating the requirements needed for the real time dust monitoring equipment. He will specify which instrument to purchase and evaluate it's operation. If delivery can be made soon enough, it will be installed in mid-July.

MEETINGS.

Meeting with ACF and ACE at L&D Site 7 April 1995

This meeting began at 10:30 A.M. at the L&D Remediation Site Office. Present were Richard Hyink of ACF, Dr. Steven Foster, a consultant from Boulder, CO, Dave Meadows of the Corps and me. The meeting was arranged as a result of Tim McCoy's letter to ACF regarding our air monitoring proposal. I presented the details of the proposal, which includes a feasibility stage and an implementation stage. Foster asked a number of questions, largely regarding quantification. The major concern from ACF was the expectation level of the citizen's group. The MS/MS unit proposed for the volatile chemical monitoring could be so sensitive that emissions will be detected. ACF wanted to discuss how the citizens would react to very low levels. They would like some indication of how the citizens would interpret the data. I presented ACF with a draft budget for the feasibility study and promised to send them an implementation budget ASAP [FAXed 4/11].

Winfield Umbrella Committee Meeting of 11 April 1995

The meeting was held at the Eleanor Town Hall at 7:00 P.M. Present were Umbrella Committee members, Susan Small of Congressman Wise's staff, Dave Meadows and Mark Kessinger from the Corps and me.

Dave Meadows brought the group up to date on the issues between ACF and the Corps. A consent decree has been drafted and the workplan and an amended EECA developed. The EECA will be submitted for public review soon (30 days for the review) and the consent decree and workplan will be submitted for comment later. Currently some pre-excavation testing is being conducted. The rail cars are to be loaded inside of the existing buildings. The cars will be lined and covered with a tarpaulin. The Umbrella Committee expressed some concern that better top sealing was not planned.

The air monitoring plan was discussed. The Umbrella Committee consultant, Fred Youngs, produced a critique of the original Corps plan which was discussed to some degree. The ACF air plan is not yet known; its debut will be at the public comment period. The WVU proposal and the meeting with ACF on 7 April were discussed and the citizens agreed to develop an understanding of their expectations with ACF. The objective will be to derive a set of agreeable criteria which will delineate response levels for citizen concern. Once this issue is resolved (and it will require citizen-ACF meetings), ACF will consider supporting the real-time monitoring proposal.

The status of the buildings (the 150x700 foot temporary storage buildings) was discussed. Fish and Wildlife have first option, then federal surplus.

The \$100,000 consultant was discussed. The Committee and Corps developed an agreeable scenario for advertising and choosing the consultant. All agreed that hiring the consultant was an urgent issue.

Winfield Umbrella Committee Meeting of 9 May 1995

The meeting was held at the Eleanor Town Hall at 7:00 P.M. Present were the Committee, Susan Small from Rep. Wise's office, Corps of Engineers staff, representatives from ACF and me.

Dave Meadows (COE) reported that the consent decree was with the Department of Justice (ACF and the Corps had agreed on a clean-up plan). The new EE/CA has been developed and once the DOJ approved the plan, a 30 day comment period would begin. After that 30 day period, all comments would be addressed and a Federal judge would rule on the decree. Realistic start time for the excavation is mid-July. ACF will get some on-site work done on site preparation before excavation begins.

The citizens are most concerned about the air monitoring during the clean-up. The proposal to ACF was discussed, and ACF (Jon Meyer) said that ACF would fund the feasibility study (\$43,000). The citizens were concerned about who would decide on implementation of the air monitoring portion. ACF agreed that I would decide the issue. E

An information fair to be held May 17 was discussed. The purpose of the fair was to provide access to all of the remediation parties for any interested citizens of the area. I indicated that I would attend.

Information Fair of May 17.

The fair was held by ACF and representatives of ACF, the Corps of Engineers, the Umbrella Group, ECDC (the landfill operators from Utah), USPCI (the contractors for ACF) and Phillip Environmental (the remediation planners) were present. Each answered questions posed by citizens who came to learn more about the ACF plan. There was no formal agenda, just some displays. I learned that the consent decree had been signed by the DOJ and the 30 day comment period had begun May 10.

Winfield Umbrella Committee Meeting of 6 June 1995

The meeting was held at the Eleanor Town Hall at 7:00 P.M. Present were the Committee, the Corps of Engineers staff, representatives from ACF and me.

I presented a report on the air monitoring. The MS/MS unit being developed by Fred King was designed and the labor was in place. A proposal to support a feasibility study and enhance field operation had been given to ACF. ACF guaranteed funding of the proposal. [Funding arrived 9 June]. Dust monitoring equipment was not yet ordered.

The Corps had received 11 proposals for their technical assistant ad. The Umbrella Committee were invited to observe the decision process on June 12-13.

Comments on the Removal Action workplan followed. Fred Youngs (the Umbrella Group consultant) wondered what the wrecking ball would be used for [Concrete slab cracking]. Concerns were expressed over the use of 6 mil HDPE to cover the rail cars, better strength was desired. Soil clean-up criteria were discussed. The levels which were designated to be allowable in the soil were thought to be too high by the group. Further study and discussion were promised by the Corps. Lew Baker (WVDOH) asked numerous questions about the water treatment plant and dioxin release into the Kanawha River. He felt that WVDEP requirements were lax and requested the Corps to establish limits that were much stricter than required by law. The Corps was reluctant to do this. Concerns over real-time monitoring (which will be handled by WVU) and misting for dust control (whether done reactively or proactively) were expressed.

The Umbrella Group will submit written comments by June 19. The Corps will then answer the comments. Original plans and comments will be placed before a judge, who will decide whether to sign the consent decree authorizing the clean-up. Excavation should start in mid-July if all proceeds smoothly.

Current Situation

The storage buildings are under construction. ACF is laying railroad track in anticipation of the signing of the consent decree. Further chemical analysis is being conducted to refine the knowledge of the extent of the contamination at the site. The volatiles air monitor is still under development. The dust monitors will be ordered shortly. The excavation will begin near July 20.

3.0 WORK PLANNED FOR NEXT PERIOD

The air monitoring equipment should be completed and installed at the site. Personnel need to be trained and sent to Winfield. As soon as the excavation begins, WVU must conduct the air monitoring for the duration of the remediation. By September 30, the monitoring will have been underway for 2 months. During the monitoring, the instrumentation will continually be upgraded and improved to improve performance.

4.0 TECHNICAL/ADMINISTRATIVE DIFFICULTIES

The development of the MS/MS system was slowed due to mechanical problems. Otherwise, no specific difficulties were encountered.

**INFORMATION SYSTEMS, PUBLIC POLICY,
COMMUNITY OUTREACH AND ECONOMICS**

**A GIS - BASED INFRASTRUCTURE
FOR SITE CHARACTERIZATION AND REMEDIATION**

TASK 3.2

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:

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July 1995

ABSTRACT

The primary goal of this proposed work is to determine an effective GIS-based infrastructure for describing, characterizing, and remediating contaminated sites. The work is being carried out using the remediation needs of the U.S. Army Corps of Engineers Huntington, WV district office as a basis--giving the benefit of real needs of on-going remediation projects. The work includes devising and specifying an integrated system with features targeted to site remediation/restoration needs, establishing operational procedures for effective use of the integrated system, and establishing methods for effective technology transfer. The effort will also result in the establishment of a professional team at Marshall University with capability and availability to provide supporting services in the application of GIS-based tools and methods in site restoration efforts.

EXECUTIVE SUMMARY

This document constitutes the required Quarterly Report for the second quarter of 1995, for Task No. MC28-95MU under the DOE/METC/WVU Cooperative Agreement, contract no. DE-FC21-92MC29467. It documents technical accomplishments and projections, and also provides cost status and projections as of June 30, 1995.

We have made very good progress during this quarter, and have overcome the effects of the delay experienced in the first quarter which was due to a late award announcement. This puts us in an excellent position to successfully complete all tasks during the calendar year. Of five tasks, we have completed tasks 1 and 2, and are on schedule for task 3. We have acquired most of the necessary hardware and software and are currently setting up all the equipment and software. We have completed the training on Intergraph MGE, the major GIS under consideration.

We continue to have a very productive working relationship with personnel of the Corps Huntington district office, and anticipate a very fruitful collaborative effort to acquire real-world data to test the experimental setup of hardware and software.

In summary, we are in an excellent position to successfully complete all tasks during this calendar year, and thus to achieve the overall goal of determining an effective GIS-based infrastructure for describing, characterizing, and remediating contaminated sites.

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1.0 INTRODUCTION

This effort focuses on determining GIS-based capabilities for site characterization and remediation. This is a pressing need, largely unsatisfied at the current time. Although there are numerous available GIS systems, and many different software components that could be useful in site characterization and remediation, there is no available system that brings together the numerous needed capabilities. The approach is to base a needs assessment for such a GIS-based system on the on-going work of the Huntington Corps district office. This will provide a realistic needs determination: the Huntington Corps office is faced with an immediate need for effective GIS-based software tools to more effectively manage site remediation in the district. Further, a working relationship has already been established between the Marshall University team and personnel within the Corps office. The U.S. Department of Energy (DOE) Morgantown Energy Technology Center (METC), and other agencies, stand to benefit from the results of this work, since it will be grounded in real needs of real, on-going remediation projects.

2.0 PURPOSE

The primary goal of this work is to determine an effective GIS-based infrastructure for describing, characterizing, and remediating contaminated sites. Objectives involved in achieving this goal include:

- (a) devising and specifying an integrated system whose features are targeted to specific needs for site remediation/restoration--including a set of GIS-based software tools and supporting computer hardware,
- (b) establishing operational procedures for effective application of the system,
- (c) establishing methods for effective transfer of technology (system, procedures) to a user organization (USACE Huntington District office, in the first instance), and
- (d) simultaneously establishing a professional team at Marshall University with the capability and availability to provide supporting services and consultation in the application of GIS-related tools in site restoration efforts.

3.0 BACKGROUND

Geographic Information Systems (GISs) are increasing rapidly in numbers and areas of application. No doubt the expansion is influenced strongly by the growing national interest in environmental protection and restoration. Numerous GIS systems are available--including commercial (e.g., ARC/INFO, Intergraph MGE, MapInfo), government-sponsored (GRASS), and university research based (IDRISI, ICASE/GRACE). The desired applicability of GISs is extremely broad (e.g., air quality monitoring, groundwater contamination, areas in a city accessible by public transport). Thus the GIS systems must be very generic in their capabilities. This genericness is attractive in providing versatility of application breadth, but of necessity limits the depth of features for a given application area.

The nation faces a massive problem relative to contaminated sites. The U.S. Department of Energy, the U.S. Army Corps of Engineers, and many other government agencies are faced with requirements to remediate contaminated sites under their purview. The Huntington District of the U.S. Army Corps of Engineers (USACE) has undertaken to assemble computer-based tools to help them in describing, characterizing, and remediating contaminated sites. They have obtained the Integrated Computer Assisted Site Evaluator / Graphical Remedial Assessment and Cost Evaluation (ICASE/GRACE) system, developed at the University of Cincinnati, for evaluation. They have also obtained and installed Intergraph's MGE system, and anticipate obtaining Intergraph's ERMA (for Environmental Resource Management Application) system,

intended to support site assessment, modeling and remediation. Under a previous METC task, Marshall University evaluated ICASE/GRACE for use by the Huntington USACE District.

4.0 METHODOLOGY

Following are descriptions of the tasks to be conducted, and associated schedules.

Task 1: Information Required for the National Environmental Policy Act

To be supplied within 60 days after contract award.

Task 2: Determine System Requirements

Interview USACE Huntington District office personnel involved with remediation projects, assess needs as they perceive them for describing, characterizing, and remediating contaminated sites. Consider approaches of other organizations with remediation requirements, including other USACE offices, and other Department of Energy-funded work. From this input, determine and specify system requirements necessary to fulfill the identified needs.

Schedule: January 1 through March 31, 1995.

Task 3: Devise and Specify an Integrated System

Undertake to determine and specify a system that satisfies the requirements identified in Task 2. Note that the outcome of this task will be a specification of a recommended system, and not an implementation as such.

Determine a GIS system to serve as the basis for the overall system--evaluating candidate GIS systems based on their inherent suitability for the role, as well as their current importance to organizations with whom data interchange may be necessary. We will emphasize commercially-available systems and government-sponsored systems to the maximum extent feasible. One GIS system we will evaluate is Intergraph's MGE system, Windows NT version, due to the fact that the USACE Nashville District office uses this MGE version, and the Huntington office must be able to interchange data with the Nashville office.

Determine a means to integrate other needed software and data sources--currently existing and anticipated--into an overall system based on an identified GIS system, with the overall system having a uniform "look and feel". Examples of other needs are a cost modeling tool in current USACE use, Modflow software, and various features of ICASE/GRACE. Means to integrate other components into a GIS system could include data translation software utilities and windows-based dialog boxes, for example. The means will be provided to augment the software complement with additional capabilities in the future.

The most desirable outcome would be that carefully-selected software can be integrated, without modification or additional software development, into a system that fully satisfies all identified requirements. In the event that is not a feasible outcome, we will determine and recommend approaches for meeting the unsatisfied requirements.

A necessary, and interwoven, aspect of this task is to ensure that the software system being devised can be accommodated by an acceptable range of computing hardware; i.e., by both lap-top PCs and high-end Pentium PCs, and even by Unix-based workstations if that is found to be a requirement.

It may be that multiple feasible approaches will be identified to accomplish some aspects of the required system. If so, we will document the options, and give trade-off considerations for making choices.

Schedule: January 1 through November 30, 1995.

Task 4: Determine Operating Procedures

Determine and describe effective procedures for using the system. This will include guidance concerning combinations--and sequences--of software tools to use for certain classes of applications, set-up assumptions for each tool, and inter-tool control and data management. Representative scenarios will be devised and documented.

If it is found to be necessary to modify some software or to develop some additional software to achieve all requirements, we will nonetheless summarize procedures involving the system features expected to be available after modification and/or development, so that a comprehensive understanding of the full resulting system can be gained, and also to offer perspective and guidance in developing and providing any additional features.

Schedule: October 1 through November 30, 1995.

Task 5: Develop Materials for Technology Transfer

Establish means for effective transfer of technology--the integrated system and operating procedures --to a user organization. The USACE Huntington District office will be the initial user organization, in concept, since we will be basing much of our requirements determination efforts on their needs. However, our efforts in technology transfer will be guided by the need for various user organizations to be accommodated.

Emphasis will be placed on development of tutorial materials, including on-line materials, and on development of seminar presentation materials to provide an overview of the tools and procedures. Full documentation of system requirements, system specification, and operating procedures will, of course, be provided as well.

Schedule: November 1 through December 31, 1995.

Deliverables:

Deliverables from this work will be:

- A written statement of requirements for software and hardware necessary to conduct site description and characterization, and assess remediation strategies--based on detailed analysis of needs of the Huntington Corps office, with participation and cooperation of their personnel
- Written descriptions of in-depth evaluations of various candidate software and hardware approaches for meeting the statement of requirements, with the relative merits of specific approaches, and rationale for each approach recommended
- A detailed description of a recommended system: hardware and software components--including use of available commercial or government software, strategies for integrating the components, and if necessary, details of a limited amount of software requiring development in order to achieve a satisfactory system
- Operating procedures for effective application of the system
- Educational/training tutorial materials to enable technology transfer for system capabilities and operating procedures
- Recommendations concerning strategies for undertaking system implementation based on the system description

5.0 WORK PERFORMED THIS PERIOD

5.1 Activities

Most of the effort this period was expended on Task 3 (Devise and Specify an Integrated System). Tasks 1 and 2 were completed during this period. They were originally scheduled to be completed by the end of the first quarter, but were delayed due to the late award announcement.

Task 1: Information Required for the National Environmental Policy Act

This material was prepared and delivered during the first half of April.

Task 2: Determine System Requirements

Most of the work for this task was completed in the first quarter. In particular, the hardware/software requirements determination for processing the geographic data was completed in the first quarter. In this quarter we have completed the requirements for integrating some of the management related software, as well as integrating other external modeling software. The first quarterly report described the evaluation efforts for the software and hardware and the basis for the systems requirements for processing the geographic data. Since the decisions made in Task 3 are based on the systems requirements, we include below, for convenience, from the first quarterly report, discussion of the evaluation of hardware and software. We have added the section on requirements determination for integrating external software (section 1.e.).

1. Evaluation of software:

a. Geographic Information Systems (GISs):

The three software packages that we considered were: ICASE/GRACE (evaluated under METC summer contract 1994--see Reference 1), ESRI's ARC/INFO, and Intergraph's MGE.

Jim Hooper and Akhtar Lodgher attended a forty-hour ARC/INFO workshop at the University of Vermont during February 13-17, 1995, to get a better understanding of the PC ARC/INFO system. PC ARC/INFO is a popular, generic GIS and has several components for processing and viewing data in different forms. However, the PC system is not suitable for handling large amounts of data; this would require the use of ARC/INFO on a Unix platform. Also, ARC/INFO, even for a Unix platform, does not have groundwater or 3-D modeling packages available (such as ERMA or Voxel for MGE). Such packages, if they were available, would have to be purchased from third party vendors.

Intergraph's MGE is a fully functional GIS which runs on a Windows NT platform. In terms of its functional capabilities, it evaluates much better than ARC/INFO for the needs identified. The Huntington District Corps of Engineers has made the decision to acquire Intergraph's MGE. Their decision strongly influences our choice, since we are committed to support them in their GIS work. We plan to purchase an educational copy of MGE in the next quarter, and attend Intergraph training on MGE.

b. Database systems:

The databases we are considering will have to operate under the Windows NT platform using a client-server architecture. The possible considerations are: Oracle, MS SQL Server, and Sybase SQL Server.

The Corps uses Oracle (on the Unix platform) as their standard database for all projects. Oracle is in the process of introducing the Windows NT version of the software. Subsequently Intergraph will supply the necessary "hooks" to interact with Oracle. Currently MGE interacts with MS SQL Server and Sybase SQL Server, both of which already operate under the NT system. The underlying database--as long as it is an SQL database--is transparent to MGE. We are not at this time planning to use Oracle because Marshall University does not have a site license agreement for the system operating under NT, and this would make the use of Oracle very expensive. We are more inclined to the use of MS SQL Server because it can be acquired at relatively low cost, due to Microsoft's volume discount program with the university. Also, based on our review of evaluations of Oracle and MS SQL found in commercial literature, these two products compare equally on all functional and speed factors. The use of MS SQL will allow us to test MGE using a different database (as compared to the Corps), which will test the desirable "transparency" feature of MGE relative to the database.

c. Operating systems:

The operating systems considered were MS DOS, Windows NT and Unix. MS DOS-based systems are small and are not suited for development work of large systems. Packages that work under the Unix system require the use of workstations. Unix based workstations are generally not portable and are not easily usable for field sites. Windows NT provides the flexibility of installation on portable laptop computers, as well as the power to do development work. Also, the Intergraph MGE system runs under Windows NT. Thus Windows NT is our current operating system of choice.

d. Network software:

The Windows NT networking component will be used for networking the machines. The machines will be connected physically by Ethernet cables.

e. Integrating External Software:

Some of the external software packages with which a GIS will have to communicate are: project management software, cost modeling software, and physical phenomenon modeling software (such as groundwater modeling). Various commercial off-the-shelf (COTS) software products are available for each of these needs. The project management software under consideration are: MS Project and Primavera. The cost modeling software under consideration is MCACES. The modeling software under consideration is Modflow for groundwater modeling. Integration of remediation modeling software will also be considered.

2. Evaluation of Hardware:

The hardware under consideration is one main workstation to be used as the server, one development workstation to be used as the client, and one laptop system which can be used as the "field" computer.

a. The server workstation:

This machine would serve both as a server and as a workstation for development work. Requirements include at least 32 MB of RAM, at least a 2 GB hard drive, CD-ROM, Ethernet card and a 17 inch monitor. The processor would be either a 90 MHZ or a 100 MHZ Pentium. The use of dual processors would be advantageous to increase the "crunching" power required by packages such as Intergraph's Voxel. Possible contenders are Intergraph's TD4 (which is a dual processor system) and other 100 MHz Pentium systems available on the market from vendors such as Zeos.

b. The client workstation:

This machine would serve as the client, or as an independent workstation. The hardware requirements are very much the same as the server, except that a dual processor may not be necessary and the hard disk could have the capacity of 1 GB. A 20 inch monitor will be necessary since a lot of development work will be done on this machine. Possible contenders are Intergraph's TD3 and machines from other vendors

c. The laptop field computer:

The requirements for this machine are 32 MB RAM, 1 GB Hard drive, 100 MHZ Pentium processor, Ethernet card and a CD ROM. The display could be an LCD with a resolution of 640x480.

Task 3: Devise and Specify an Integrated System

Based on the systems requirements of Task 2, we have devised a system which will allow us to successfully integrate the data processing and visualization software (GISs), along with external commercial project management and modeling software. Our decisions for some of the components listed in Task 2 are discussed below.

1. Software:

a. Geographic Information Systems (GISs):

The two GISs we decided to acquire are: MGE from Intergraph and PC ARC/INFO from ESRI. MGE runs under the Windows NT platform. PC ARC/INFO runs under MS DOS as well as under Windows NT as a DOS product. Acquiring PC ARC/INFO will allow us to model the same data using a different GIS. This will give us a better perspective of GIS technology.

b. Database system:

The database system we decided to acquire is MS SQL Server which operates under Windows NT. The structure of MGE is such that the underlying database (relational) is transparent to the application. This is because MGE uses a Relational Interface System (RIS) to communicate between MGE and the database. RIS supports automatic conversion, and querying of data from various relational databases such as MS SQL and Oracle. The choice of MS SQL Server was made because it could be acquired at a relatively low cost due to Microsoft's volume discount program with the state of West Virginia, and as was mentioned previously it will allow us to verify the transparency of the database.

c. Operating System:

The operating system we decided to acquire is Windows NT Server. The purchase of the desktop workstations includes Windows NT Workstation. In order to network the machines we will acquire Windows NT Server. Windows NT will also allow us to run PC ARC/INFO.

d. Network Software:

As mentioned in the earlier subsection, we will use the networking capabilities of Windows NT Server for network support

e. Integrating External Software:

The project management software and remediation software will be evaluated during the third quarter.

2. Hardware:

The computing hardware we decided to acquire consists of: one server workstation, one development workstation and one laptop system which can be used as a "field computer".

a. The server workstation:

The server workstation we decided to acquire is the Technical Desktop 4 (TD4) from Intergraph. The technical specifications of the machine are: dual Pentium 90 MHZ processors, 32 MB RAM, 1 GB hard drive, Ethernet card, 17 inch color monitor and a G91 accelerated graphics card.

b. The client workstation:

The client workstation we decided to acquire is the Technical Desktop 3 (TD3) from Intergraph. The technical specifications of the machine are: Pentium 90 MHZ processor, 32 MB RAM, 1 GB hard drive, Ethernet card, 20 inch monitor and a G91 accelerated graphics card.

Marshall University issued a contract to MTI Corporation of Saint Albans, WV, for the above software and hardware components during this period. MTI is a "business partner" of Intergraph Corporation, and was a convenient nearby source for the products. Most of the hardware and software components have been received, and we are in the process of installing and checking out the components.

Six professional personnel from Marshall University and twelve from the Huntington District Corps office participated in a joint week long training session on MGE. The training was conducted by an Intergraph trainer at MTI Technology Center in Charleston, WV. The training was a comprehensive introduction to the MGE components and included a systematic approach for setting up and using data for an application. The Marshall University Environmental Center contracted with Intergraph Corporation for the training, and contracted with MTI Corporation for use of their Technology Center facilities. The Corps is reimbursing Marshall for their portion of the costs. The cost summary below includes training costs for only the Marshall University personnel.

5.2 Schedule and Costs

Due to a late task award, we were slightly behind our original plan in both schedule and spending rate in the first quarter. Thus we had to "catch up" on both the schedule and spending rate in the second quarter.

The Task status is as follows:

- Task 1: Completed
- Task 2: Completed
- Task 3: We began later than scheduled, but have caught up and are now on schedule. Task 3 is about 50% complete.
- Task 4 and 5: Scheduled to begin later in the year

Costs for the second quarter are summarized below. Note that the training, hardware and software costs incurred in this quarter are not being invoiced during this quarter, but will be invoiced during the next quarter. These totals are shown under the Committed column in the table below.

	Expended	Committed	Total
Personnel (including fringe benefits)	\$ 33,126.07		\$33,126.07
Travel and Training	587.39	\$ 6,477.54	7,064.93
Telephone/Report Preparation	110.02		110.02
<u>Equipment</u>			
Hardware		\$13,984.00	13,984.00
Software		6,350.00	6,350.00
Indirect Cost (less Hardware)	12,852.92	4,874.47	17,727.39
Total	46,676.40	31,686.01	78,362.41

6.0 RESULTS AND DISCUSSION (CURRENT PERIOD)

We have completed Task 1 and Task 2 successfully.

We had begun Task 3 (Devising and specifying an integrated system) in the first quarter, and continued the effort on it in this quarter. We are now approximately on schedule, for both effort and expenditure, for this task. We have ordered the software and hardware (mentioned in section 5.1, Task 3) and we have received almost all the components. We are in the process of setup and installation of the software and hardware. We will continue our efforts on this task to set up an integrated system.

We are working in close cooperation with the Huntington Corps personnel. We jointly participated in the Intergraph MGE training which gave both groups a comprehensive introduction to the product. We are seeking to acquire real Hazardous, Toxic & Radioactive Waste (HTRW) data from the Nashville District Corps office, through the Huntington District. This will enable us to experiment with the features of the GIS software on actual data, giving us a better basis for assessing the capabilities and limitations.

7.0 CONCLUSIONS (CURRENT PERIOD)

We are now approximately on schedule, in terms of both effort and expenditure, at the end of this quarter. This puts us in an excellent position to complete all tasks during this calendar year. For the hardware and software acquired in this quarter, as well as the training, we have committed the funds, and will expend it in the third quarter.

We have delivered the National Environmental Policy Act material, and have completed the systems requirements determination. We have attended training on both PC ARC/INFO and MGE, the two most popular GIS systems available.

We are continuing our productive relationship with the Huntington district Corps personnel and hope to acquire real HTRW data through them in the near future.

8.0 WORK PLANNED FOR NEXT PERIOD

8.1 Activities

Following is a summary of the various activities planned during the third quarter of 1995.

Task 3: Devise and Specify an Integrated System

We will set up and install the hardware and software. The hardware consists of the server and the desktop workstations. The software includes the MGE components and the PC ARC/INFO components. The machines will be networked, and the network software will be installed.

We will purchase the laptop computer and the color printer, and set them up so that they can be integrated into the network.

We will acquire data from the Corps and assess the capabilities of the various GIS components using that data.

We will explore the possibility of integrating external COTS packages with the GIS system.

8.2 Schedule and Costs

Personnel (including fringe benefits)	\$40,179.65
Travel and Training	1,650.00
Hardware/Software	11,500.00
Telephone and Report Prep.	300.00
Costs (38% excluding hardware)	16,009.27
Total:	\$69,638.92

Following is a chart which summarizes schedule and costs--both actual and projections--as of June 30, 1995. For convenience, a summary of task titles and durations are repeated here.

Task 1 Information Required for the National Environmental Policy Act: due within 60 days after award

Task 2 Determine System Requirements: January 1 through March 31, 1995

Task 3 Devise and Specify an Integrated System: January 1 through November 30, 1995

Task 4 Determine Operating Procedures: October 1 through November 30, 1995

Task 5 Develop Materials for Technology Transfer: November 1 through December 31, 1995

Schedule and Costs: Status and Projections as of June 30, 1995

1995	first qtr.	second qtr.	third qtr.	fourth qtr.								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Tasks:

1												
2	=====											

3	=====											
4												
5												

Legend: == original
 *** revised
 ^ completion

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first qtr.	second qtr.	third qtr.	fourth qtr.								

Costs by quarter:

\$15,920.79	\$78,362.41	\$69,638.92	\$36,746.79
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Cumulative:

\$15,920.79	\$94,283.20	\$163,922.12	\$200,668.91
Actual	Projected		

9.0 TECHNICAL/ADMINISTRATIVE DIFFICULTIES

None.

APPENDICES

A. LIST OF ACRONYMS AND ABBREVIATIONS

CD-ROM	compact disk read only memory
DOS	Disk Operating System
ERMA	Environmental Resource Management Application (an Intergraph product)
GB	gigabyte; approximately 1,000 MB
GIS	geographic information system
HTRW	Hazardous, Toxic & Radioactive Waste
ICASE/GRACE	Integrated Computer Assisted Site Evaluator/Graphical Remedial Assessment and Cost Evaluator
LCD	liquid crystal display
MB	megabyte; approximately one million bytes
MGE	Modular GIS Environment (an Intergraph product)
MHZ	megahertz
MS	Microsoft
NT	New Technology (as part of Windows NT)
PC	personal computer
RAM	random access memory
SQL	System Query Language
USACE	United States Army Corps of Engineers

**INFORMATION SYSTEMS, PUBLIC POLICY,
COMMUNITY OUTREACH AND ECONOMICS**

SMALL BUSINESS SUPPORT PROGRAM

TASK 3.3

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:

E.E. Cook
Department of Civil Engineering
West Virginia University
Morgantown, West Virginia 26505-6101
July 1995

ABSTRACT (Executive Summary)

From Task 3.3, four new tasks were developed with small business/governmental agencies and state consortiums. The two new tasks with small businesses had to be put on hold because of money not being available. Task 3.7 was developed to form a small business incubator for site remediation technologies. Task 3.6 was developed to provide five interns to the Interagency Environmental Technology Office (IETO) located in Washington, DC, whose charge is to facilitate a new era of public and private technology collaboration and investment resulting in innovative technology use, domestic job creation and global market share growth while ensuring national environmental quality for a sustainable future.

Task33.abs

1.0 Introduction

Task 3.3, Small Business Support Program, was initiated to address the technical problems or barriers to commercialization of the innovative site remediation technologies developed by the small businesses that are funded by METC. Once a problem or opportunity was defined, researchers from WVU, Marshall or other sources would be solicited to work with the small business in a research project to solve the problem or alleviate the barrier.

Additionally, a new small business incubator program targeted towards site remediation and small businesses in the West Virginia region was initiated.

2.0 Purpose

The Small Business Support Program was initiated to explicitly address the problems and barriers to commercialization of the innovative site remediation technologies developed by the small businesses funded by METC.

3.0 Background

Over the past two years the METC/WVU Cooperative Agreement has funded numerous projects at WVU and Marshall University. This has resulted in defining at least three areas of core competencies at WVU which may be called upon to provide assistance to the small businesses that METC funds in the area of site remediation.

The core competencies are found mainly in the in-situ remediation area including:

- * Remediation Processes such as surfactant flushing of soils and chemical and biological destruction of polyaromatic chlorinated hydrocarbons
- * Confinement Barriers such as the Circulating Air Barrier and Chemical Grouting Barriers
- * Fluid Recirculating Systems such as the Drain Enhanced Surfactant Flushing

4.0 Methodology

By attending the kickoff meetings and other periodic meetings of the small businesses funded by METC an understanding of the project is obtained. During the presentations, value added opportunities for collaboration between the small businesses and university researchers are carefully watched for. Discussions with program managers also provide opportunities for interaction. The newly formed

Environmental Waste Management Technical Product Team will also provide an opportunity to determine needs of the small businesses and resulting research opportunities. For the long range research opportunities, the new initiative at DOE HQ level bringing together elements from DOE, DOD, NASA, Commerce and others to coordinate interagency site remediation capabilities and needs will be very helpful.

Also, attendance at various meetings and conferences on site remediation provides insights to research needs.

From all of the previous sources research opportunities are ferreted out and projects are developed with university faculty to carry them out.

5.0 Work Performed This Period

During this period four new tasks were developed. One was with Spintek Corporation (a centrifugal membrane technology using novel membranes to treat hazardous wastes) and another was with Nilex Corporation using wick drains in a field demonstration for enhancing flow through low permeability soils (10^{-6} - 10^{-5} cm/sec). Both of these had to be shelved as money was not available to fund them this period. It appears unlikely that funds will be available this year so these two tasks will become part of the 1996 WVU Cooperative Agreement Program.

The third task developed this period was with the West Virginia High Tech Consortium to support a small business incubator for site remediation technologies. The proposal has been forwarded to METC and will be funded in July as METC Task 3.7. Its period of performance is July 1-December 31, 1995. Dr. Cook will serve on the advisory committee for the incubator.

A fourth task developed and funded this period was METC Task 3.6, Graduate Interns to the Interagency Environmental Technology Office (IETO). Its period of performance was May 15, 1995 to August 15, 1995 with a probable extension to December 31, 1995. The purpose of IETO under the auspices of the National Science and Technology Council (NSTC) is to facilitate a new era of public and private technology collaboration and investment resulting in increased innovative technology use, domestic job creation and global market share growth while ensuring national environmental quality for a sustainable future. The five interns sent from WVU are being utilized mainly in the following areas:

- * Organizing various workshops/seminars for the IETO technical seminar series
- * Developing IETO outreach materials for use with both internal and external clients (briefing packets, weekly fax update on domestic/international ET issues, etc.)
- * Working with Federal agencies to develop global contacts and outreach systems in the international sector
- * Gathering information on Associations that would be potential players with IETO
- * Working with the Environmental Enterprise Assistance Fund (EEAF) in identifying technical experts for the EEAF September Symposium and other possible co-sponsored IETO technical seminars
- * Working with the IETO international sector to help develop global contacts and information systems
- * Assist in creating a site catalog for new technology testing. The catalog is intended for use by mostly small to medium sized businesses with new environmental technologies that need testing at full scale
- * Providing quality control checks for a budget database, prepare memos of meetings and updating the filing system
- * Initiate legal research as applicable to IETO

6.0 Results and Discussion N/A

7.0 Conclusions N/A

Task33.out

**INFORMATION SYSTEMS, PUBLIC POLICY,
COMMUNITY OUTREACH AND ECONOMICS**

**APPROACH FOR ASSESSING POTENTIAL VOLUNTARY
ENVIRONMENTAL PROTECTION,
KANAWHA VALLEY AREA**

TASK 3.4

Quarterly Report for Period
April 1 through June 30, 1995

Work Performed Under Contract
No.:DE-FC21-92MC29467

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By:
Raymond J. Lovett
National Research Center for Coal and Energy
Environmental Technology Division
West Virginia University
Morgantown, West Virginia 26506

James J. Kohanek
Clean Sites, Inc.
Alexandria, VA

Paul Hill
National Institute for Chemical Studies
Charleston, WV

July 1995

ABSTRACT

This project concerns investigation of the feasibility of establishing voluntary remediation programs in the Kanawha Valley, WV.

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