TRANSPORTABLE SYSTEM FOR BIODEGRADING LEACHATE/EXTRACT FROM CERCLA-SITE EXCAVATED SOIL

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abondoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments, and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report describes a transportable soil-based bioreactor that uses sequential aerobic and anaerobic microbes for the on-site degradation of hazardous and toxic organic substances from Superfund sites. The evaluation shows that a 2880 gpd bioreactor system can be developed, transported to waste sites, set up with minimal effort, and operated in a cost-effective manner. The information in this report is useful to those who are concerned with the cleanup of hazardous waste sites.

For further information, please contact the Land Pollution Control Division of the Hazardous Waste Engineering Research Laboratory.

Thomas R. Hauser, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

A preliminary design and budget cost estimate was performed to determine the practicality of developing a transportable soil-based microbial treatment system to renovate high-strength aqueous wastes. Leachate is delivered to the bioreactor after adjustment in a truck-based pretreatment system. Several contaminated site leachates were studied in order to design a pretreatment system that can operate over a wide range of influent characteristics. The biological system design utilizes a sequential aerobic and anaerobic microbials that have been demonstrated in field studies. The ability to accelerate site clean-up is provided through a caustic or acidic forced extract system. Treatability studies, as defined in Section 7, need to be performed before deploying the unit at a specific site.

This report was submitted in fulfillment of EPA Contract Number 68-03-3255 by Enviresponse, Inc. with substantial interaction with Rutgers University under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from June 20, 1986 to September 30, 1986, and work was completed as of September 30, 1986.

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SECTION 1
INTRODUCTION

Rutgers University, in conjunction with the U.S. EPA under EPA Cooperative Agreement No. CR-807805, has demonstrated in laboratory, pilot plant, and field studies that a dumpsite soil leachate with an original Total Organic Carbon (TOC) Content of approximately 1-3 weight percent can, after some preprocessing including dilution to 1 weight percent, be treated to the 95 to 99.5 percent removal level in one pass through a soil-based bioreactor utilizing aerobic and anaerobic microbial communities in series (1, 2). Rutgers University further demonstrated that this land-based biological treatment process represents a practical in-situ treatment process (3).

Preliminary estimates by Rutgers University for the implementation of this process indicated the renovation of a contaminated site could be accomplished at substantial cost reductions compared to traditional treatment technology. Thus, a field pilot was designed, constructed and operated to demonstrate the process (4).

Based upon the success of the pilot plant, Enviresponse, Inc. (EI) developed a program to review the Rutgers process and to extend the technology to a transportable system for biodegrading leachate or extract (referred throughout this report as leachate) from a wide range of potential sites. The subject of this report, which constitutes Phase 1 of the program, is the development of the preliminary design and cost of such a generic unit and the identification of work to be performed before it can be demonstrated.

SECTION 2
CONCLUSIONS

Based on the review of the in-situ treatment technology developed by Rutgers University, we have concluded that:

1. The soil-based bioreactor system has been successfully demonstrated in the field and is applicable to at least some Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Sites. Variables affecting the operation of the bioreactor, such as identification of pollutants, heavy metals content, and soils description, make it impossible to ensure that the unit will work at a specific site without extensive site studies prior to deployment.

2. A transportable system for the extraction, pretreatment and monitoring of a generic CERCLA-SITE leachate has been developed. This system can feed the Rutgers University bioreactor or any other system of biological degradation.

3. The transportable system represents the lowest end of commercially available equipment and can readily be scaled-up for even more rapid site renewal.

SECTION 3
RECOMMENDATIONS

The biodegradation of CERCLA site leachate represents an effective and desirable method for in-situ clean up and should be pursued. It is recommended that work continue in two additional phases.

Phase 2 of the work should be divided into the following tasks:

Task 1. Select the site and perform initial treatability studies.
Task 2. Review adequacy of original scale-up in view of time requirements.
Task 3. Compare the feasibility of trucks and modular units.
Task 4. Develop detailed design for the transportable unit.

Phase 3 of the work should be divided into the following tasks:

Task 1. Establish QA/QC for the unit.
Task 2. Obtain permits, purchase equipment,t and construct unit.
Task 3. Field test the unit at the selected site.
Task 4. Evaluate test results.

It is recommended that bench scale optimization biodegradation experiments be carried on concurrently with the above phases. These bench scale operations should address the parameters outlined in Section 7 concurrent field operations will yield additional pertinent knowledge that can only be obtained through first-hand experience. In addition, there is the potential for increased public acceptance and favorable publicity that can be obtained from an effective transportable treatment system.

SECTION 4

PROCESS DESCRIPTION

BASIS OF DESIGN

The process design of the transportable biodegradation unit is based on a scale-up of work done by Rutgers University under EPA Cooperative Agreement No. CR-807805. A packed bed bioreactor utilizing aerobic and anaerobic microbial communities in series forms the basis for biological treatment (1). Ongoing technical discussions between the U.S. EPA, EI and Rutgers University have provided further definition of the process design basis.

General criteria for the unit are as follows:

1. The unit is capable of processing 2880 gpd of either contaminated leachate or forced extract.

2. Forced extract is obtained through fixed bed leaching of contaminated soils with neutral, basic, or acidic solutions. The unit will have the ability to adjust these solutions to the required concentration on site.

3. The unit is mobile to the maximum possible extent. Where units must be constructed on site, as in the case of the treatment beds, necessary construction materials will be maintained on a trailer which is to be part of the mobile unit.

4. The unit is self-sufficient and therefore operable at remote locations. Power to the unit will be provided by on-site diesel generators at remote locations.

5. Properties of the incoming streams are based on the Rutgers University field study [2]. Leachate characteristics of other sites are examined to insure that the unit is generic. Table 1 shows the leachate characteristics and Table 2 shows a range of characteristics from another site.

TABLE 1. TYPICAL/LEACHATE EXTRACT CHARACTERISTICS

pH	6.5 - 13.0
TOC (mg/1)	170-10,000
Acetic Acid (mg/1)	50-3300
Propionic Acid (mg/1)	ND-850
Iso - Butyric Acid (mg/1)	ND-450
Butyric Acid (mg/1)	ND-450
NH_3 (mg N/1)	10-620
TKN (mg N/1)	25-820
NO_3 (mg/1)	0.01
Total P (mg/1)	1.5
Cl (mg/1)	20
Residue (24 hr) (mg/1)	2700-4300
TDS (mg/1)	2600-4100

Metallic Species (mg/1)

Ag	.01 - 0.1	Mn	1.0 - 11
Al	0.1 - 1.1	Na	11.0 - 110
B	.001 - .01	Ni	.01 - 0.1
Ba	.01 - 0.1	Pb	.01 - 0.1
Ca	100 - 1100	Si	1.0 - 11
Cr	.001 - .01	Sn	.001 - .01
Cu	.01 - 0.1	Ti	.01 - 0.1
Fe	1.0 - 11	Zn	0.1 - 1.0
Mg	11 - 110		

Note: ND - Not Detected

TABLE 2. DATA USED TO INSURE TRANSPORTABLE SYSTEM GENERIC DESIGN

Species	Sample 1	Sample 2	Sample 3
Arsenic	12	1	ND
Cadmium	9.3	3	0.004
Chromium (T)	270	50	0.068
Copper	58	10	ND
Lead	740	5	ND
Mercury	0.063	0.01	0.3
Nickel	81	20	0.053
Silver	ND	ND	ND
Zinc	130	50	0.13
Total Toxic Organics	32.2	15	2.7
pH	2.6	3.5	5.0

Note: All Concentrations in mg/l
ND = Not Detected

General

The unit consist of three operations: extraction, pretreatment and biological degradation. These operations are contained on three trailers and four in-ground beds.

Trailer 1 contains the equipment for the extraction and pretreatment processes. These processes occur at a rate of 8 gpm for 6 hr per day. This allows the operator-intensive processes to be carried out during a single 8-hr shift. Each process provides sufficient material to allow the bioreactors to operate continuously. Instrument signals from the process are fed to a computer (PC) which monitors and records the operations. The PC is located in this trailer. In addition to the equipment on the trailer, a chemical staging area is established near the trailer for chemical additions and for handling sludge from the clarifier and recarbonation vessel.

Trailer 2 is a tank trailer providing intermediate and final storage capability. Each tank has a 24-hr storage capacity.

Trailer 3 contains materials to construct and maintain the on-site equipment. This includes the bioreactor, extract bed, and off-gas collection system. In addition, trailer 3 contains safety and emergency equipment and living facilities for the operators.

The biological treatment unit consists of a minimum of three treatment beds located near the trucks. Each bed receives influent sequentially for 8 hrs at a feed rate of 2 gpm. Effluent is collected continuously from each treatment bed.

The extraction bed is located in the contaminated area. As each bed area is cleaned, a new bed will be developed.

In order for the biological treatment unit to operate properly, the feed to the unit must meet certain criteria. Table 3 summarizes the pretreatment objectives of the transportable unit.

TABLE 3. PRELIMINARY PRETREATMENT OBJECTIVES

Total Organic Carbon (TOC)	adjustable to between 500 and 10,000 mg/1*
pH	adjustable to between 7.0 and 8.0*
Cl^-	less than 1000 mg/1**
TOC: N: P	approximately 100: 10: 1*
TDS	less 5000 mg/1*
Sodium Adsorption Ratio (SAR) between 1 and 15, based on treatment bed packing properties*	
TSS	less than 30 mg/1*

* These parameters must fall within the selected range to provide a nontoxic microbial environment.

** The selected ratio will provide a balanced biological growth environment.

*** Selected to assure suitable soil properties. For a description of SAR see reference (2).

PROCESS DESCRIPTION

A block flow diagram for the proposed generic process is presented in Figure 1. Figures 2 and 3 show a more detailed process flow diagram for the transportable unit. Leachate from the extraction bed can be directed to either the clarifier or the metals removal section, depending upon the site.

Extraction

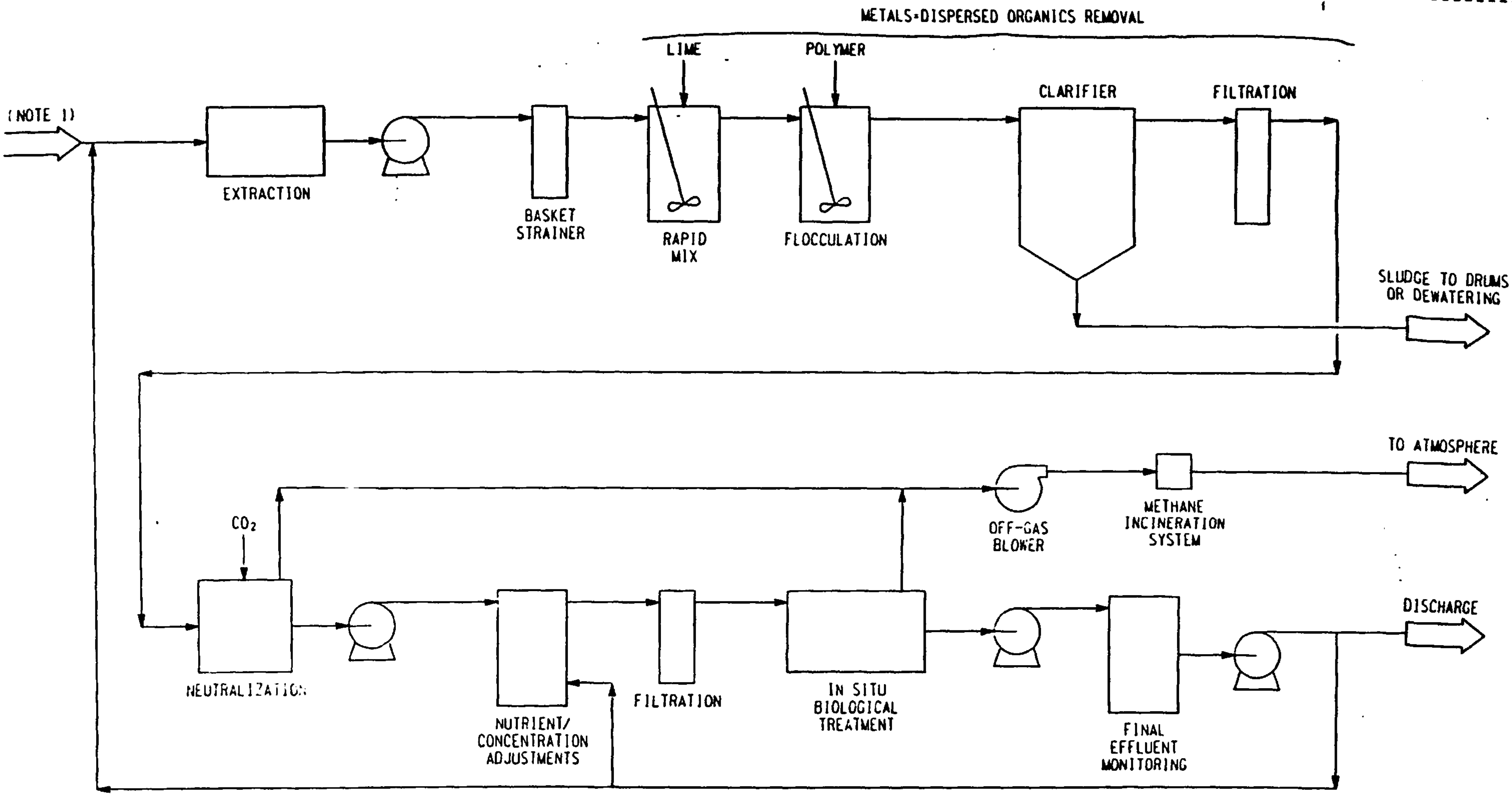
A caustic, acidic or neutral aqueous stream is pumped to the extraction bed. Leachate from the bed is pumped to the unit for renovation.

Pretreatment Process

The proposed pretreatment train includes lime precipitation for the removal of metals and dispersed organic phases followed by clarification, mixed media filtration, and neutralization. Should polymer addition be required to aid flocculation it can be added in the pretreatment package. Although metals precipitated with lime demonstrate relatively good dewatering characteristics no dewatering equipment is included in the current design because of the small quantities involved. Sludge will be collected in drums and stored on site prior to ultimate disposal at an appropriate location.

Should treatability studies indicate significant pretreatment sludge quantities will be generated, additional dewatering equipment will need to be specified and purchased. These costs are not included in this estimate.

It is anticipated that the equipment for the above operations will be provided as a package unit by a suitable vendor.



NOTES:

1. INFLUENT IS AN AQUEOUS STREAM, pH ADJUSTED TO FACILITATE SITE CLEAN-UP, AS REQUIRED.
2. OVERALL SYSTEM DESIGN FLOW IS 2880 GPD.
3. PRETREATMENT SYSTEM CONFIGURATION WILL BE ESTABLISHED DURING TREATABILITY STUDIES FOR A SELECTED SITE.

GENERAL FLOW DIAGRAM
FOR A TRANSPORTABLE SYSTEM
FOR BIODEGRADING LEACHATE/
EXTRACT FROM CERCLA-SITE
EXCAVATED SOIL

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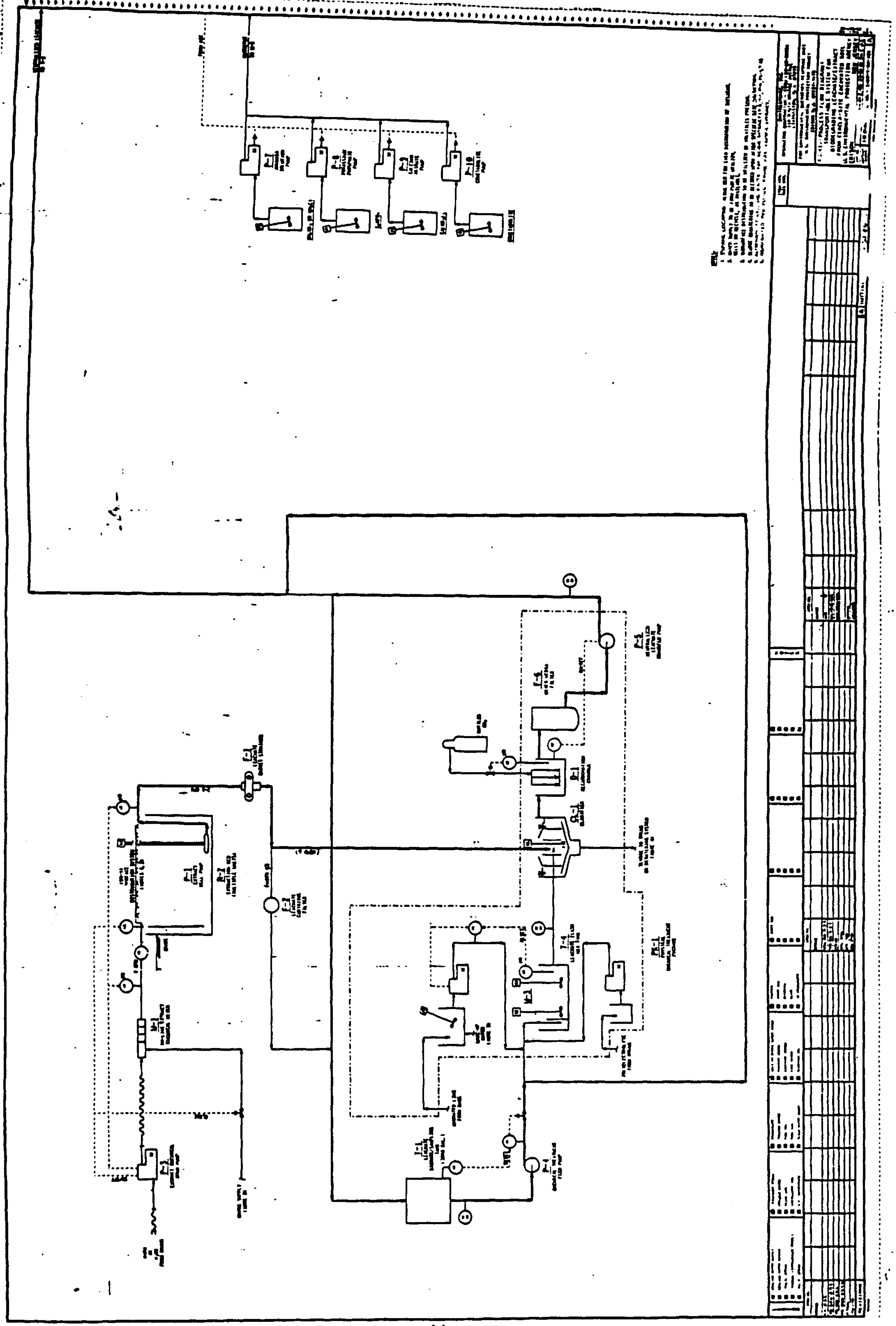
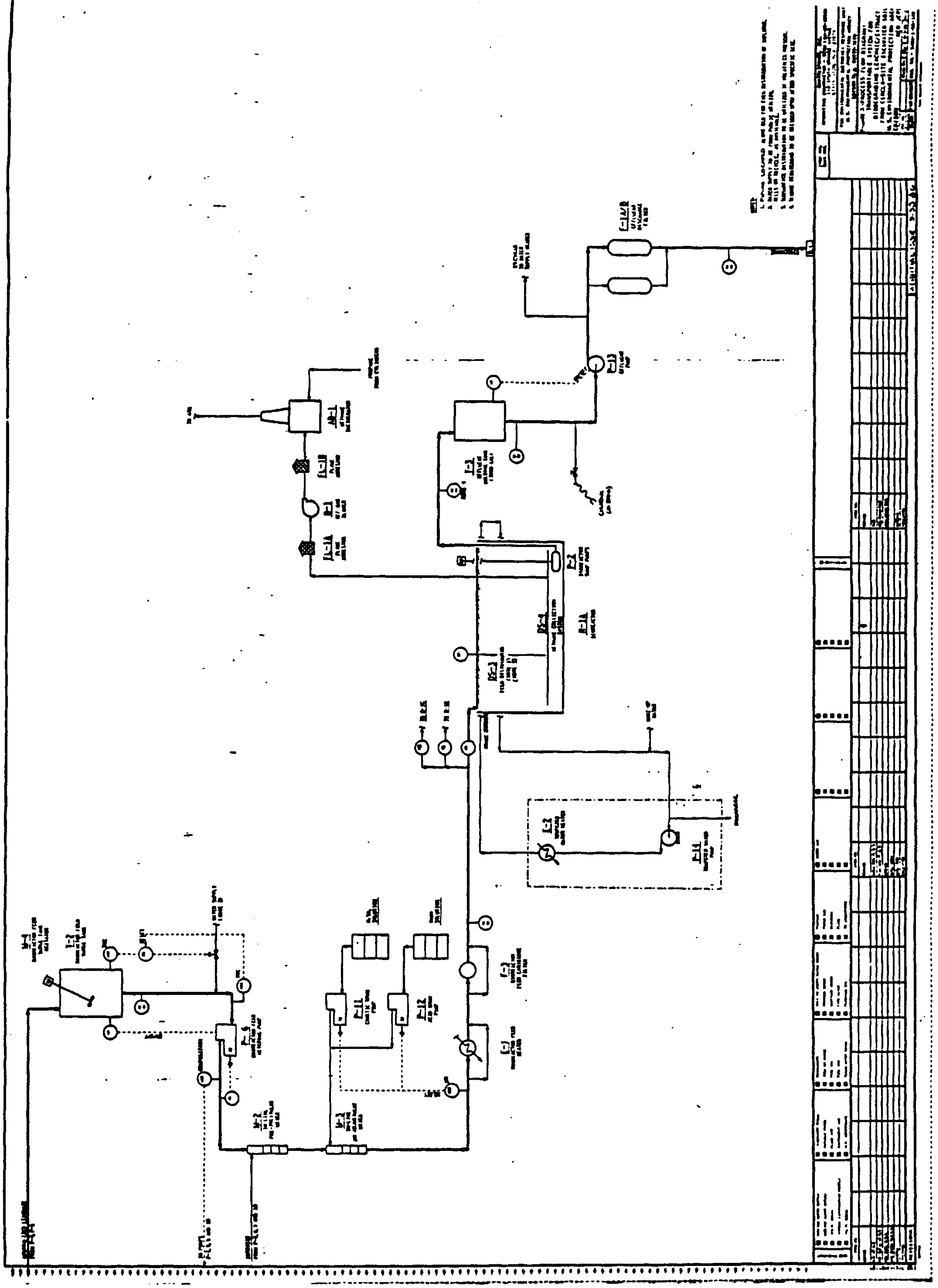




Biological Treatment

After pretreatment, the leachate nutrient, TOC, and ion concentrations are adjusted by chemical additions in an in-line mixer. Phosphate adjustment is made with Potassium Phosphate, ion adjustment with Calcium Nitrate, and Nitrogen adjustment with Ammonium Chloride or Ammonium Nitrate. Cometabolites, such as beer slops, can also be added in-line if required. Each biological treatment bed receives the pretreated leachate for 8 r to insure stability of the biological system. Continuous treatment is achieved by the sequential use of three beds. During winter operation the leachate stream is preheated. In addition, tempered water circulates around the treatment beds to maintain the viability of the aerobic treatment section and prevent freezing. Leachate is distributed to the beds through a fixed distribution system located along the two long sides of each bed.

Effluent from the biological treatment unit is pumped to a holding tank for monitoring. From there it is recycled to the extraction process or discharged. Provisions for chlorine addition and final filtration are included.

MAJOR EQUIPMENT COMPONENTS

Table 4 presents a preliminary equipment list for the proposed unit. Preliminary sizing criteria used for the various process equipment is presented in Table 5. Some equipment sizing represents minimum standard vendor packages. Utilizing standard packages rather than small custom units will provide ease of getting spare parts. Higher volumetric throughputs are cost effective and may also be possible using these standard packages.

TABLE 4

FORM NO. 135-904

ENVIRESPONSE, INC.	CONTRACT: 3-60-054000 SECTION:	EQUIPMENT LIST	NAME OF UNIT Mobile Biodegradation	PAGE 1 OF 3

CLIENT: U.S. Environmental Protection Agency

LOCATION: Edison, N.J.

REVISION	ORIGINAL	1	2	3	4	5
DATE	9/30/86					

CLASS	ITEM NO.	DESCRIPTION	EFO	QTY.	LOCATION		REV
REACTORS	R-1	BIOREACTOR					
		RD-1 Feed Distributor					
		RD-2 Methane Collection System					
		RL-1 RCRA Liners					
	R-2	EXTRACTION BED					
		RD-3 Distributor for Extractant					
		RL-2 RCRA Liners					
VESSELS	T-1	Leachate Storage/Sampling Tank				Part of Truck 2	
	T-2	Bioreactor Feed Surge Tank				Part of Truck 2	
	T-3	Effluent Storage Tank				Part of Truck 2	
	T-4	Leachate Flash Mix Tank				Part of PK-1	
	T-5	Diesel Fuel Storage Tank					
	D-1	Recarbonation Chamber				Part of PK-1	
	D-2 A/Y	Sludge Holding Drums					
EXCHANGERS	E-1	Bioreactor Feed Heater					
	E-2	Tempered Water Heater					
	E-3 A/P	Drum Warmers					

FORM NO. 135-904

TABLE 4

EQUIPMENT LIST

ENVIRESPONSE, INC.	CONTRACT: 3-60-00540000	NAME OF UNIT: Mobile Biodegradation	PAGE 2 OF 3
CLIENT: U.S. Environmental Protection Agency	SECTION:		
LOCATION: Edison, N.J.			

REVISION	ORIGINAL	1	2	3	4	5
DATE	9/30/86					

CLASS	ITEM NO.	DESCRIPTION	EFD	QTY.	LOCATION		REV.
FILTERS	F-1	Leachate Basket Strainer					
	F-2	Leachate Cartridge Filter					
	F-3	Bioreactor Feed Cartridge Filter					
	F-4 A/B	Effluent Discharge Filter					
	F-5 A/B	Fuel Oil Filter					
	F-6	Mixed Media Filter				Part of PK-1	
PUMPS	P-1	Extract Well Pump					
	P-2	Bioreactor Sump Pump					
	P-3	Extract Chemical Drum Pump					
	P-4	Chemical Treatment Feed					
	P-5	Neutralized Leachate Transfer Pump				Part of PK-1	
	P-6	Bioreactor Feed Metering Pump					
	P-7	Ammonia Solution Metering Pump					
	P-8	Potassium Phosphate Metering Pump					
	P-9	Calcium Nitrate Metering Pump					
	P-10	Cometabolite Metering Pump					
	P-11	Caustic Drum Pump					
	P-12	Acid Drum Pump					
	P-13	Effluent Pump					
	P-14	Tempered Water Pump					
	P-15 A/B	Diesel Fuel Pump					
BLOWERS	B-1	Off Gas Blower					

FORM NO. 136-904

TABLE 4

ENVIRESPONSE, INC.	CONTRACT: 3-60-00540000 SECTION:	EQUIPMENT LIST	NAME OF UNIT Mobile Biodegradation	PAGE 3 OF 3

CLIENT: U.S. Environmental Protection Agency	REVISION	ORIGINAL	1	2	3	4	6
LOCATION: Edison, N.J.	DATE	9/30/86					

CLASS	ITEM NO.	DESCRIPTION	EFD	QTY.	LOCATION		REV.
MIXERS	M-1	In-Line Extractant Mixer					
	M-2	In-Line Pre-Treatment Mixer					
	M-3	In-Line pH Adjustment Mixer					
	M-4	Bioreactor Feed Surge Tank Agitator					
MISC.	Cl-1	Clarifier				Part of PK-1	
	AB-1	Methane Incinerator					
	GN-1 A/B	Diesel Generator					
	FL-1A/B	Flame Arrestor					
PACKAGE ITEMS	PK-1	Physical Chemical Treatment Package					

TABLE 5. PRELIMINARY EQUIPMENT SIZING CRITERIA

Unit	Criteria
Pretreatment System	Flowrate = 8 gpm
Physical Chemical Treatment Package	
Rapid Mix Tank	1 minute detention time
Flocculation Tank	20 minute detention time
Clarifier	300 gpd/ft^2 overflow rate
Recarbonation Chamber	5 minute detention time
Mixed Media Filter	2 gpm/ft^2
Bioreactor Treatment Bed Flowrate = 2 gpm	960 gpd capacity at 0.96 g/ft^2/day
Leachate Storage/Sampling Tank	24-hr detention time
Bioreactor Feed Surge Tank	24-hr detention time
Effluent Storage Tank	24-hr detention time
Methane Incinerator	max. loading to treatment beds of 10,000 mg/l TOC, 50% of which goes to methane

Most pretreatment equipment is mounted in a special closed-top semi-trailer van. The van is fitted for transportation by tractor-truck in accord with all applicable requirements and regulations. To avoid special permit delays, the van meets all width-height-length-weight limitations when in transit. The basic trailer measures approximately 8 ft wide X 45 ft long X 13.5 ft high when closed for storage or transit. The side panels open when the unit is operational to provide equipment access walkways and protection awnings. When opened, the measurements are approximately 21 ft wide X 53 ft long. A second truck contains three 3000 gallon compartments for storage. Those items that do not fit on the trailer is set up on pads in the field. All equipment is easily removable to minimize lost time from equipment failure. Trailer 3 contains a supply of spare equipment that can readily be replaced in the field. Piping shall be PVC with screw connection assembly/disassembly. All outdoor piping is traced and insulated against freezing. A concrete pad for storage and handling of chemicals and sludge from the clarifier shall be established next to Trailer 1. Liquids sensitive to freezing are kept warm by electric drum heaters. Chemical storage areas will have a 6-inch curb to contain any spills.

The extraction and treatment beds are 10 ft x 100 ft x 6 ft deep trenches excavated at the site. Trenches are double lined with 20-mil PVC liners and include provision for drainage between liners and above the upper liner. Trenches are backfilled with top soil, sand, and granular activated carbon. In addition to the drainage pipe, the treatment beds contain piping to collect methane gas produced during the anaerobic process. Off gas will be sent to a package incineration unit set up on a pad near the treatment beds. Treatment beds will also contain sensors to prevent flooding.

PRCCESS CONTROLS

Process controls are provided by a PC based control system housed in Trailer 1 (Figures 2 and 3). Primary control include the monitoring of pH, TOC, and nutrient requirements.

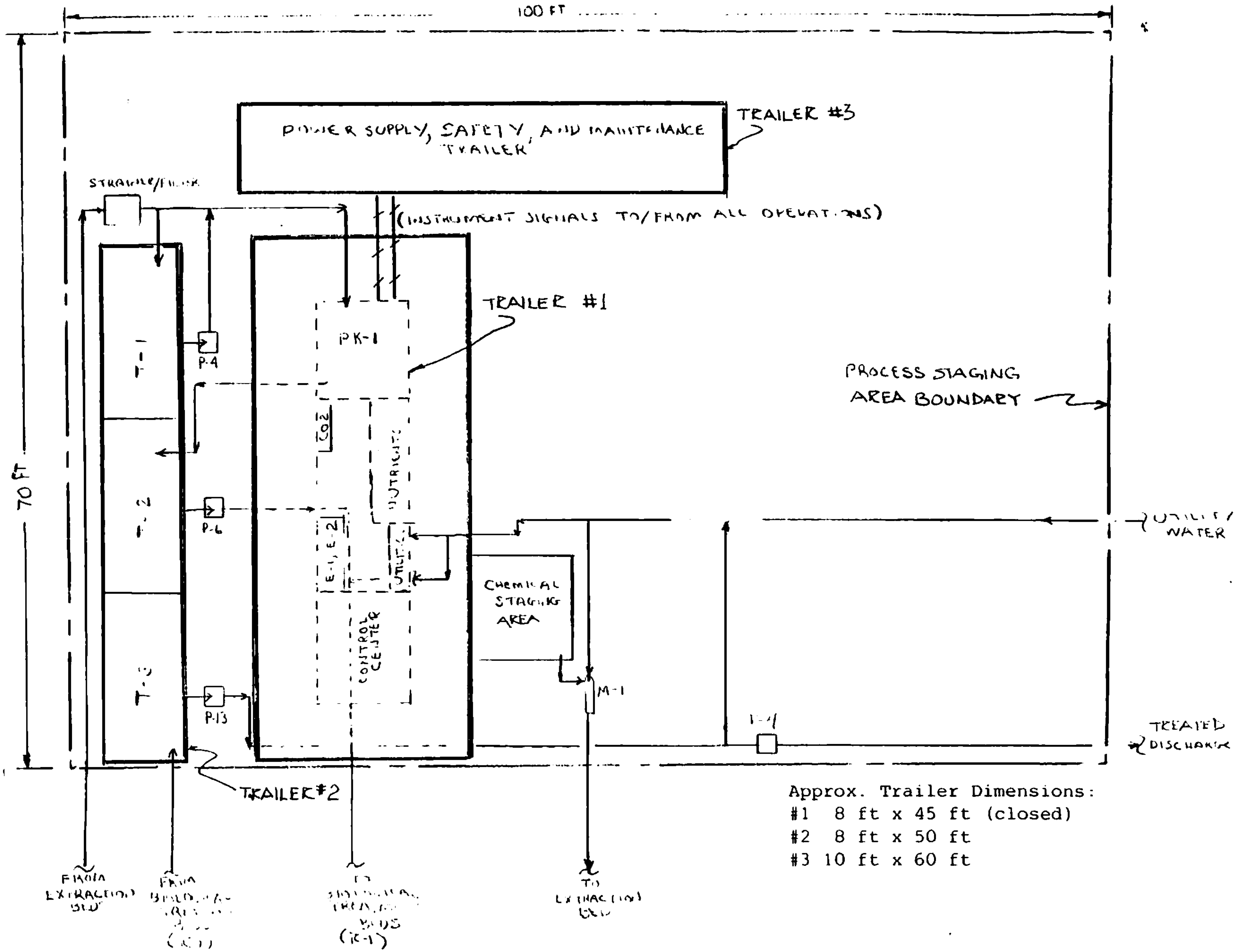
In addition to the automatic controls, appropriate points in the process streams must be sampled and assayed on a regular basis. Total Dissolved Solids (TDS), Total Kieldahl Nitrogen (TKN), and volatile salty acids in the treatment bed influent must be monitored regularly. Elemental analyses should be performed and core samples from the treatment beds should be examined frequently. These requirements should be examined on a less regular basis. These requirements are further defined below. It should be noted that these controls and monitoring are for process control only and are not necessarily intended to satisfy QA/QC requirements.

EQUIPMENT LAYOUT

Figure 4 presents the preliminary process layout for the transportable unit. The required site for process equipment is approximately 100 ft X 100 ft. It is preferable that the site be level and free from obstructions. The area under the trailers is paved with gravel (approximately 50 ft X 50 ft). In placing the trailers, allow a minimum of 3-ft clearance for access to equipment and sampling points. Treatment beds should be excavated as close to the trailers as possible to minimize piping and allow the operators to view the beds. Piping to the beds will be buried in shallow trenches and backfilled.

SAMPLING AND ANALYTICAL REQUIREMENTS

Sampling and analytical requirements are presented in Table 6. The SC numbers refer to Figures 2 and 3.



Approx. Trailer Dimensions:
#1 8 ft x 45 ft (closed)
#2 8 ft x 50 ft
#3 10 ft x 60 ft

FIGURE 4. PRELIMINARY EQUIPMENT LAYOUT

TABLE 6. SAMPLING AND ANALYTICAL REQUIREMENTS FOR PROCESS CONTROL

	Sampling Location							
Analysis	SC10	SC20	SC30	SC40	SC50	SC60a,b,c	SC70	SC80
pH	a	f	a	a	a	a	a	a
TDS	c	f	c	c	c	c	c	c
TSS	c	f	c	c	c	f	f	c
TOC	b	f	c	c	b	b	b	c
VFA	d	f	f	c	c	c	f	f
GC Scan	e	f	f	e	e	e	f	d
COD	c	f	c	c	c	c	f	d
TKN	d	f	f	d	d	e	f	f
NH_3	d	f	f	d	d	e	f	f
Critical Heavy Metals	c	f	b	f	c	e	c	c
Na	c	f	f	c	c	d	f	f
Ca	c	f	f	c	c	d	f	f
K	d	f	f	c	c	d	f	f
K	d	f	f	c	c	d	f	f
Total P	d	f	f	f	d	d	f	f
Turbidity	a	f	a	f	a	a	f	f

Treatment Bed
Packing Samples: soil cores to be taken every 6 months for soil analysis.

Key:
a = daily
b = every 3rd day
c = weekly
d = semi-monthly
e = monthly
f = occasionally, when indicated based on operating results

Notes:

1. Additional sampling may be required based on regulatory requirements.

2. A personal computer program will be developed to provide data management and indicate process operator adjustments in response to analytical results and operating data.

SECTION 5

OPERATING PROCEDURES

Following is a brief description of the sequence of operations and flows as shown in Figure 1, more detailed description of operation can only be developed after the detailed design of the transportable unit is complete. At that time an operating and maintenance (O&M) manual will be written to provide: (1) a general description of the unit and its controls; (2) the recommended procedures for startup, normal operation, shutdown, and maintenance of equipment; (3) information on the safety aspects of operation; and (4) a list of recommended spare parts. The manual will be accompanied by (1) specific sampling, analytical or safety instructions for a selected site; (2) site-specific emergency contingency plans; (3) detailed vendor information on installation, setup, testing, calibration, routine maintenance, repair or replacement, and operation of equipment' (4) site-specific data collection requirements including operating long sheets, sample log sheets, and specific measurements or observations; and (5) applicable health and safety data information for all materials used or expected to be encountered in site renewal operations.

Sodium hydroxide or sulfuric acid is mixed in-line with water in M-1 to form 8 gpm of extractant. The extractant is distributed along the surface of the extract bed, R-2.

Liquid collected in R-2 is pumped through a basket strainer and cartridge filter to the Leachate Storage/Sampling Tank, T-1. Leachate is pumped from T-1 to the Physical Chemical Treatment Package PK-1, where it is contacted with lime, allowed to settle out metals and dispersed organic phases, and then recarbonated to a pH of 7.5. Recarbonated leachate is pumped to the Bioreactor Feed Surge Tank T-2.

Liquid from T-2 is mixed with recycle water to adjust TOC concentration and pumped at 2 gpm to 1 of 3 treatment beds R-1A to C. Nutrient cometabolite, and calcium are added to the feed in-line in M-2. A final pH adjustment occurs in M-3 with acid or caustic added as required. The bioreactor feed stream passes through heat exchanger E-1, to maintain the feed at a minimum of 50°F. A final filtration to remove any suspended solids occurs in the Bioreactor Feed Cartridge Filter F-3.

Treated effluent from R-1A/C is continuously collected and pumped to Effluent Storage Tank T-3. Methane generated in R-1A/C is collected and burned in the Methane Incinerator AB-1.

Treated effluent in T-3 is sampled and can be recycled or discharged. Final effluent passes thought he Effluent Discharge Filter F-4 prior to discharge.

The key to the successful operation of the transportable unit is careful sampling and analysis of effluent as outlined in Section 4.

SECTION 6

COST ESTIMATE

Table 7 presents capital cost estimates for the proposed transportable system. Total capital costs for the system are estimated at $1,961,000. This estimate includes equipment costs, contingencies, construction costs, engineering, legal, and administration fees. Also included in the capital costs is $200,000 for the site and laboratory work necessary before deployment of the proposed unit. It is estimated that approximately 12 months are needed to complete this task.

Table 8 presents estimated annual operating and maintenance costs for the proposed unit. Included in the table are costs of chemicals, power, and operating labor and maintenance. Projected annual costs are $592,300.. Due to the tremendous variability of sites, these costs cannot be predicted reliably and may vary significantly after the initial treatability studies.

Items not covered by the cost estimate include permitting costs, fee, surveys, insurance, costs of disposal of sludges and treated leachate, QA/QC work and cost of lab analyses during the operation the unit. Such costs depend on the requirements placed on the system by the specific site, ease of disposal, and local and federal regulatory requirements. If frequent analyses for priority pollutants are required, these costs could have a significant impact on the total cost of the system. Cometabolite needs will be identified on a site-specific basis. Appropriate cometabolites will be identified locally and priced at that time.

In order to perform the cost estimate it was necessary to make a number of assumptions regarding the ultimate site and treatment prices. Any variations in the selected site will necessarily cause revisions to the cost estimate.

- The site is assumed to be level, approximately 800 ft X 350 ft.
- Water will be available locally. approximately 100 ft from the process area. Should well water be required the estimate would be adjusted accordingly.
- Discharge of treated leachate will be 100 ft from the process area.
- Areas to be extracted are easily excavated and free of obstructions, e.g., buried tanks, foundations.
- The appropriate ratio of soil:sand for the treatment bed exists at the site.
- Initial freight costs are included; however, the cost of moving the transportable unit to a specific site is not.

- Paving will be limited to a 50 ft X 50 ft section of gravel in the process area.
- The unit will be insulated and traced for winter operation.
- Electric power will be generated on site by two 90-kw diesel generators.
- The extent of protection from vandalism is limited to perimeter fencing and lights in the process area.
- Sludge will be drummed at the site and not dewatered.
- Leachate can be distributed on the surface of the treatment beds (no volatile organics present).
- Nutrient requirements and CO_2 usage are in line with the concentrations used in Rutgers University field work.
- Granular Activate Carbon will be approximately 5.8 percent by weight of the treatment beds. Cost is for virgin carbon. Considerable costs savings are available by using regenerated carbon.
- Seed for the mixed microbial population will come from a local sewage treatment plant or equivalent at little or no cost.

Disclaimer

The cost estimate presented in this section are based on conceptual design and were prepared from available information. Final costs of the proposed system will depend on the actual site selection, suitability of the biological unit, actual labor and material costs, competitive market conditions, final project scope, regulatory requirements, schedule, and other variables. As a result the final costs will vary from the estimated costs presented herein.

TABLE 7. PRELIMINARY TRANSPORTABLE BIODEGRADATION SYSTEM CAPITAL COST ESTIMATE SUMMARY

Item	Estimated Cost
Equipment Including tank trailer:	$323,100
Civil Including treatment bed construction	$176,600
Piping	$ 64,200
Instrumentation Including Microcomputer	$185,000
Electrical Power Lighting Tracing	$ 90,300
Insulation	$38,700
Miscellaneous Includes: Equipment Trailer Operating trailer Initial charge of chemicals/lubes Spare Parts Start-up Sales Tax	$159,100
Subtotal	$1,037,000
Construction Management	$ 103,700
Subtotal	$1,140,700
Engineering, Legal and Administration Fees (20%)	$ 228,100
Lab and Site Data Work	$ 200,000
Subtotal	$1,568,800
Contingencies (25%)	$ 392,200
Total	$1,961,000

Notes: Costs are in 1986 dollars.
Costs are subject to change.

TABLE 8. PRELIMINARY TRANSPORTABLE BIODEGRADATION SYSTEM OPERATING AND MAINTENANCE COST ESTIMATE SUMMARY

Item	Annual Cost
Chemicals	
Lime	
Caustic	$ 105,000
Ammonium Nitrate	
Potassium Phosphate	
Calcium Nitrate	
CO_2	
Polymer	
Diesel Fuel	$ 115,000
Operating Labor/Maintenance	$ 292,300
Monitoring and Supervision	$ 80,000
Total	$ 592,300

Note: Fuel costs are based on $1.00/gal.
Costs are in 1986 dollars.
Costs are subject to change.
Operating costs based on 2 operators for 8 hr/day. plus 1 operator for 16 hr/day.

SECTION 7
APPLICABILITY OF RUTGERS TECHNOLOGY

REVIEW OF RUTGERS TECHNOLOGY

The proposed transportable treatment system objective is to the biological degradation of toxic organic compounds held within a soil matrix at CERCLA sites. Rutgers Technology accomplishes this objective through a three-step process:

1) an in-situ forced extraction to release soil-bound organic contaminants into an aqueous phase,

2) pretreatment of the forced extraction leachate or naturally occurring leachate commonly found at CERCLA sites, and

3) soil-based aerobic/anaerobic biodegradation leachate treatment.

Rutgers Technology is a proven in-situ treatment process. Bench and pilot scale studies achieved leachate TOC reductions in excess of 99.5 and 95 percent, respectively. During recent pilot tests at an industrial sludge-contaminated lagoon researchers reported that process effluent pH was between 6 and 8, effluent TOC and TDS were less than 50 mg/l and 900 mg/l, respectively.

Process simplicity is a virtue that favors the use of the technology at a variety of sites. With in-situ extraction and on-site, quickly assembled treatment beds, the process lends itself to transportable operation. Extractants are relatively inexpensive and universally obtainable. The packed bed treatment unit uses soil as a packing, an inexpensive and universal matrix containing indigenous biological seed. A sequential aerobic and anaerobic biological treatment degrades a wide range of both volatile and nonvolatile organic compounds, in natural or extracted leachate. Process control, (influent loading rate) is readily performed and the entire process can be easily automated, hence one operator can tend and sample several processes.

A few limitations of this biodegradation scheme need to be mentioned. There is no biological destruction for metals reduction. The calcium carbonate scavenges protons, releasing hydroxides that form stable, low solubility metal hydroxide precipitates. Sequential aerobic/anaerobic treatment can mineralize a wide range of organic compounds. Since passive oxygen diffused into the soil bed yields a generally anaerobic bed and aromatic compounds are aerobically ring-cleaned to dicarboxylic acids before further aerobic and anaerobic degradation, a process modification may be needed to handle high concentrations of aromatic compounds. Ambient temperature is a seasonal constraint because ice formation inhibits leachate soaking into the treatment bed.

RECOMMENDATIONS FOR FURTHER TESTING AND REVIEW

Rutgers researchers have reported that high treatment bed influent TOC causes high cell respiration and low cell growth, desirable packed bed treatment conditions. The maximum influent TOC, limited by the maximum forced extract leachate TOC, should be explored to determine the maximum utilizable TOC levels before biological inhibition occurs. Alternative extractant examination is recommended.

Aqueous phase solubility of organic compounds is a process-limiting phenomenon; therefore, surfactant forced leach and treatment may decrease site remediation duration. It is suggested to integrate gas chromatography-mass spectrophotometry analysis of the treatment bed influent and effluent with future efforts. These analyses will show effluent biological degradation products that may be a function of recalcitrant influent compounds.

The final limiting stage of anaerobic degradation is accomplished by a biochemically and phylogenetically unique group of microorganisms - the methanogens. These microbes' trace nutrient requirements are only recently being reported in the literature. For example, the addition of iron and cobalt with B and B_{12} components increases substrate consumption ninefold, and the addition of nickel, a unique requirement of methanogens which is incorporated into cofactor F_{430}, results in the highest reported methane production rate. Even though soil contains a myriad of metal ions, these trace nutrients may be unavailable or insufficient because of tenacious soil binding, hence, it is recommended that trace nutrient supplements be examined.

Investigation of optimum treatment bed packing matrices is worth serious consideration. Hydraulic conductivity (permeability), a function of the bed packing matrix, increases influent volumetric flux which increases. The bed's TOC loading. However the resulting biomass accumulation (bioslime) reduces permeability and TOC destruction. A packing that allows high permeability and high biocatalyst concentration would yield optimum TOC loading.

SECTION 7

REQUIRED SITE SELECTION INFORMATION AND PREDEPLOYMENT SITE TESTING PROCEDURES

Selection of CERCLA sites for possible deployment of the transportable unit requires substantial information regarding: (1) identification of the composition and properties of the contaminated aqueous waste stream or soils to be treated; (2) the physical and hydraulic properties and the extent of contamination at the site; (3) physical and chemical properties of contaminated soils to be treated; and (4) regulatory goals and constraints pertaining to site remediation. Necessary information is summarized as follows:

A. Identification of Contaminant Species in Aqueous Phase

1. Priority Pollutants + 40
2. Semiquantitative elemental scan
3. Quantification of heavy metal concentrations
4. Presence and nature of dispersed or suspended phases
5. pH, EC, TDS, TSS, TOC, COD, Total P, Na, Ca, K Cl^-, SO_4, Temp., DO, TKN, NH_3, NO_3, titration curves

B. Site Description

1. Nature and extent of contamination
2. Soil and/or water contamination problem?
3. Local hydrology (surface water and groundwater)
4. Site topography
5. Site geology and stratigraphy

C. Soils Description

1. Particle size distribution and classification (texture)
2. Organic carbon content
3. pH
4. Cation Exchange Capacity
5. Semi-quantitative elemental scan
6. Na, Ca, K, P and critical heavy metals
7. Presence and nature of any hydrophobic phases
8. Adsorption isotherms (as necessary)

D. Regulatory Goals and Constraints

1. Permit requirements
2. Target clean-up levels
3. Discharge locations and types
4. Available utilities
5. Restrictions on atmospheric discharges
6. Schedule requirements and proposed demonstration period

Initial screening should be conducted on the basis of available information. Sites passing this phase of evaluation should be investigated thoroughly to provide the information indicated above. A detailed laboratory investigation program should be carried out for potential deployment sites, after collection and evaluation of the indicated data.

A site-specific laboratory program prior to on-site development should verify process effectiveness and provide essential detailed information for optimum process management. Several major considerations must be addressed. Partitioning of contaminants between contaminated soils and aqueous extractants, as well as between treatment bed influent and treatment bed packing should be delineated. This can be accomplished through the development of appropriate isotherms. In addition, partitioning of contaminants between soil, aqueous, and hydrophobic phases should be investigated. This information will aid in defining effective extractants and the fate of individual species.

Laboratory experiments should be carried out to define operating conditions and loadings for operation of pretreatment processes. Effective removal of dispersed and suspended phases and separation of heavy metals should be verified.

Preliminary laboratory soil column experiments should be carried out to verify process feasibility for potential sites. Materials (soil, leachate, etc.) employed for these investigations must be samples obtained from the site under consideration. Subsequently, detailed laboratory studies should be carried out to evaluate potential treatment bed packings, loading rates, application cycles, and process control.

It is anticipated that the entire predeployment program will take approximately 12 months.

REFERENCES

1. Ahlert, R. C. and D. S. Klosson, "Remediation of an Industrial Dump Site - A Case History, "Proceedings of 12th Annual Hazardous Waste Symposium, In Press.

2. Kosson, D. S. and R. C. Ahlert, "Design Criteria for In-Situ and On-Site Renovation of an Industrial Sludge Lagoon", 3rd International Symposium on Operating European Hazardous Waste Management Facilities, Denmark, September 1986.

3. Kosson, D. S. and R. C. Ahlert, "In-Situ and On-Site Biodegradation of Industrial Landfill Leachate, "Environmental Progress, 3(3):176-183, August 1984.

4. Kosson, D. S., E. A. Dienemann, and R. C. Ahlert, "Field Studies of In-Situ Extraction and Soil-Based Microbial Treatment of an Industrial Sludge Lagoon," Proceedings of Hazardous Waste and Hazardous Materials, Atlanta, GA., March 4-6, 1986.

5. CH_2M Hill Co., Final Fast-Track Remedial Investigation Feasibility Study Stringfellow Site Riverside California. May 18, 1984. pp. 7-3.

BIBLIOGRAPHY

1. Dienemann, E. A., J. F. Magee II, D. S. Kosson, and R. C. Ahlert, "Rapid Renovation of a Sludge Lagoon," Environmental Progress, In Press.

2. Kosson, D. S., I. A. Legiec, E. A. Dienemann, and R. C. Ahlert, "Operation and Control of a Soil-Based Microbial Treatment System," AIChE Summer National Meeting, Boston, MA., August, 1986.