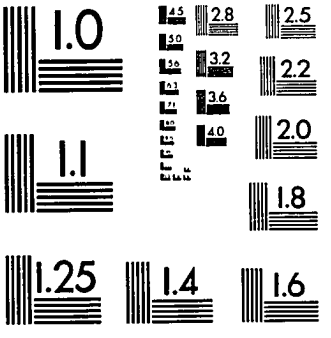

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STATE-OF-THE-ART OF LAND TREATMENT OF CORROSIVE AND IGNITABLE WASTE

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GRADUATE COLLEGE

STATE-OF-THE-ART OF LAND TREATMENT OF CORROSIVE AND IGNITABLE WASTE

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

By

BERNADETTE F. VILLACORTA

Norman, Oklahoma

1985

STATE-OF-THE-ART OF LAND TREATMENT OF

CORROSIVE AND IGNITABLE WASTE

A DISSERTATION

APPROVED FOR THE DEPARTMENT OF

CIVIL ENGINEERING AND ENVIRONMENTAL SCIENCE

By

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ABSTRACT

This research was conducted to provide state-of-the-art information on land application of ignitable (D001) and corrosive (D002) waste (ICW). Land application is considered a relatively new technology and there is very little experience in industry on land application of ICW. The information in this document therefore relied heavily on secondary information obtained from direct correspondence with generators and disposers of ICW in all 10 EPA Regions. Additional information was obtained through site visits, direct contact with technical people in industry and a laboratory study on the effect of ignitable waste on bacterial populations in a soil column.

The report provides information on existing current practices relating to land treatment of ignitable and corrosive wastes. Data is presented on current disposal methods, characteristics and quantities of ICW generated by EPA Region, total number of facilities generating ICW, current pretreatment and post-treatment technology. An important section discusses the general considerations, design criteria and site-specific design for land application of ICW. The laboratory study emphasizes the

concept of biodegradation in the assimilative capacity of the soil for ICW whereby the effect of solvent recovery waste on bacterial populations in the unsaturated zone was studied. The final section of this report discusses life cycle cost, site specific life cycle cost, and a comparative technique to evaluate alternative treatment technologies and risk assessment which are important parameters of land application.

STATE-OF-THE-ART OF LAND TREATMENT OF CORROSIVE AND IGNITABLE WASTE

CHAPTER I

INTRODUCTION

A major problem facing the nation today is the disposal of a wide variety of wastes that poses a threat to human health and the environment. Many of these hazardous wastes as they dissipate into the environment, cause irreversible damage through their carcinogenic, teratogenic or mutagenic effects. The environment is also adversely affected if these wastes eventually find their way into aquatic systems, food chain crops and other ecosystems.

The U.S. Environmental Protection Agency (EPA) was mandated by Congress to administer the Resource Conservation and Recovery Act (RCRA). The administration of RCRA involved a regulatory overhaul of the hazardous waste management industry by imposing a "cradle-to-grave" manifest system designed to track wastes from generator to final site of treatment or disposal. Subtitle C, Section 3001 of the Act identifies and lists all hazardous wastes

generated as part of a waste tracking network.

In addition, Section 1004 of the Act specifically addressed the problem of hazardous waste management, and it includes guidelines for treatment and disposal of hazardous waste. With the growing threat of continued improper disposal of hazardous wastes, the Act was recently amended to include deadlines for the final treatment and disposal of hazardous waste.

In May of 1980, EPA promulgated criteria to implement the identification and listing of hazardous wastes in the Federal Register (1,2). The realm of regulated hazardous wastes is comprised of substances with recognized carcinogenic, teratogenic or mutagenic characteristics which may cause short or chronic illness to man, or which may render them toxic the environment. Subpart C lists four criteria for identifying characteristics of hazardous wastes as ignitable, corrosive, reactive and toxic (Table 1.1). Substances with these characteristics could cause damage to human health and the environment.

This study focuses on ignitable and corrosive wastes (ICW), with EPA codes D001 and D002. ICW is generated by a wide variety of sources and in considerable quantities annually. Table 1.2 is a summary of the industrial categories generating ICW together with quantities generated per industry. The total estimated amount generated in 1983 was 887×10^9 gallons.

Table 1.1 EPA Listed Wastes Based on Hazardous Characteristics

Characteristic	Subpart	Considerations	Hazard Code
Ignitable	261.21	1. liquids with flashpoint of less than 140°F (60°C).	(I)
		2. non-liquids liable to cause fires through friction, spontaneous chemical change, etc.	
		3. ignitable compressed air	
		4. oxidizers	
		5. a liquid with an alcohol content of LE 24%	
Corrosivity	261.22	1. aqueous wastes exhibiting a pH of LE 3 or GE 12.	(C)
		2. liquid wastes capable of corroding steel at rate greater than 0.250 inches/year	
Reactivity	261.23	1. readily undergo violent chemical change	(R)
		2. react violently or form potentially explosive mixtures with water	
		3. generate toxic fumes when mixed with water or mild acidic or basic conditions.	
		4. explode when subject to a strong initiating force.	
		5. explode at normal temperatures and pressures.	
		6. DOT forbidden explosives, and Class A and B explosives.	
Toxicity (Extraction Procedure)	261.24	1. a representative sample of the waste contains concentrations equal to or greater than the 8 metals listed:arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver; or the 6 organic compounds: endrin, lindane, methoxychlor, toxaphene, 2,4-D, 2,4-TP Silvex.	(E)
		2. a solid waste that exhibits the characteristic of EP toxicity.	

Source: Adapted from 40 CFR Part 261, May 19, 1980, Subpart C, pp. 33107-33112.

Table 1.2. Summary Production of D001 and D002 by SIC Code*

a. D001 Quantity Produced (gal/year)	SIC
1.04×10^9	2865 Cyclic crude and intermediates
0.65×10^9	2800 Chemical and Allied Products
0.60×10^9	2833 Medicinal and botanical
0.26×10^9	2900 Petroleum and coal products
0.13×10^9	2869 Industrial Organic Chemicals

b. D002 Quantity Produced (gal/year)	SIC
8.4×10^{10}	2600 Paper and allied products
1.1×10^{10}	2865 Cyclic crude and Intermediates
1.0×10^{10}	4911 Electrical services
8.0×10^9	2631 Paper board mills
6.3×10^9	2819 Industrial inorganic chemicals
5.2×10^9	2869 Industrial organic chemicals
3.6×10^9	2911 Petroleum refining

*US EPA National Inventory of Hazardous Waste Generators, 1983.

The improper disposal of hazardous wastes into the environment has been the subject of numerous investigations, due to leachate and groundwater contamination, runoff and surface water contamination, as well as indirect poisoning from crop contamination (3). At the present time, scientists are still looking for acceptable solutions to the treatment and disposal of hazardous wastes. The goal of present treatment technology is to offer economically and politically acceptable alternatives to current technology such as landfilling, deep well injection, and incineration.

The past state-of-the-art of land treatment technology was primitive. Rarely were leachate collection systems used to prevent leaching into groundwater resources. Thus, contaminated leachate has become a chronic pollution event. Waste site selection decisions often ignored simple planning criteria designed to segregate this form of land use from wetlands, floodplains, surface water supplies, population centers, and endangered species habitats (3,4). Land application facilities generally did not segregate wastes potentially subject to hazardous reactions. Essentially, land application facilities, landfills and dumpsites were poorly designed, operated and sited.

In recent years, land application has been found to be a safe and economical means for the disposal of a wide

variety of organic or inorganic wastes (5,6,7,8). Land application is the intimate mixing or dispersion of wastes into the upper zone of the soil-plant system with the objective of microbial stabilization, adsorption, immobilization, selective dispersion or crop recovery, leading to an environmentally acceptable assimilation of the waste (5). The design of a land application facility considers the following: (1) the source or generation of waste, (2) the terminal or ultimate receiver system, and (3) those intermediate pretreatment unit processes that alter the wastes prior to the terminal receiver.

Land application is already widely practiced by some industries, particularly the petroleum and food processing industries. The former has to some extent developed the state-of-the-art of land application of oily wastes, but information is still wanting in systematic studies, design considerations, monitoring for important parameters, cost considerations and risk assessment for other hazardous wastes that have potential for land treatment.

This study presents state-of-the-art information on the management and operation of a land application facility for ICW. It includes information on current production of ICW, the representative categories of industries generating ICW, pretreatment and disposal technology being utilized, design criteria for land application and environmental risk assessment for ICW. Since land appli-

cation is greatly dependent on the ability of viable bacteria to degrade ICW and render it non-toxic, a predemonstration study was also conducted to determine the effect of ignitable waste on soil bacterial populations.

Information was gathered from a sampling procedure of all ICW generators from seven EPA regions, supplemented by telephone interviews and plant visits. The industries singled out for further study were those that were generating significant volumes of ICW (greater than a hundred tons/year).

The estimates of ICW generated by different industries are the result of intensive efforts to build a foundation of essential information so that the design criteria for an efficacious land application facility for ICW can be developed.

1.2 BACKGROUND

The data base obtained from six EPA regions revealed that significant quantities of ICW are stored temporarily in containers, their final fate still undetermined (Tables 1.3 and 1.4). Over 2,000 plants keep them in containers, barrels or drums. Approximately 65 percent of these companies use treatment and disposal methods such as surface impoundment, incineration and stabilization in tanks. The final disposal technology used by most of these companies is through secured landfills.

The safety and stability of secured landfills are seriously being questioned because of documented cases of groundwater contamination (3). There is a need, therefore, to look for alternative technologies that have been tested to be safe and economically feasible. Land application has been used extensively by numerous industries for the disposal of oily sludges and other organic and inorganic wastes.

This study was undertaken to determine current practices and environmental effects associated with land application of ICW. As a starting point, a compilation of all hazardous waste generators provided by the regional offices was used to identify those industries that are currently land applying, in order to assess the current data base and identify loopholes in the technology. In addition, the USEPA National Inventory of Hazardous Waste Generators revealed numerous companies generating significant quantities of ICW (Tables 1.3 and 1.4).

The selected industries generating ICW were studied in depth in order to define the source of ICW through process flow charts, quantities generated, regional distribution and treatment and disposal technology used. The selection was narrowed down further to four industries: petroleum refining, citrus processing, chemicals and steel industries. The wastes produced by these four industries will be the subject of most of the discussion

Table 1.3 Number of Companies with Treatment, Storage and Disposal Methods for D001

Process Code*	Total	EPA REGIONS 2	3	4	6	9
S01	1064	181	292	149	221	221
S02	463	62	96	52	151	102
S03	16	2	3	2	9	-
S04	46	-	10	3	22	11
T01	141	19	29	23	45	25
T02	72	10	9	13	31	9
T03	110	24	27	21	29	9
T04	171	34	31	20	68	18
D79	17	4	-	3	7	3
D80	54	2	-	9	32	11
D81	30	2	9	5	7	7
D82	1	-	-	-	-	1
D83	18	-	-	3	9	6
Total	2203	340	506	303	631	423

Table 1.4 Number of Companies with Storage, Treatment and Disposal Methods for D002

Process Code*	Total	EPA REGIONS 2	3	4	6	9
S01	610	103	181	80	114	132
S02	431	46	95	67	126	97
S03	20	-	7	5	6	2
S04	155	7	20	48	64	16
T01	42	60	89	89	118	66
T02	231	13	29	89	81	19
T03	42	7	10	6	17	2
T04	172	31	35	28	57	21
D79	38	3	1	4	26	4
D80	69	7	17	7	26	12
D81	17	2	2	3	3	7
D82	4	-	-	1	1	2
D83	73	1	6	28	28	10
TOTAL	2284	280	492	455	661	390

* PROCESS CODES

STORAGE

S01 Container (barrel, drum, etc.)

S02 Tank

S03 Waste Pile

S04 Surface impoundment

TREATMENT

T01 Tank

T02 Surface Impoundment

T03 Incinerator

T04 Other (use for chemical, physical, thermal, or biological treatment processes not occurring in tanks, surface impoundments, or incinerators).

DISPOSAL

D79 Injection Well

D80 Landfill

D81 Land Application

D82 Ocean Disposal

D83 Surface Impoundment

* From Application for a Hazardous Waste Permit, Consolidated Permits Program, EPA Forms 3510-1 and 3510-3, June 1980. (1)

in the following chapters.

1.2 OBJECTIVES

The objectives of this dissertation are:

1. To identify generators and disposers of ICW, their geographic location, total volumes generated and industry category.
2. To collect and assemble information through literature search and surveys on the characteristics of ICW, and the treatment and disposal technology currently being utilized.
3. To identify ICW land application sites and obtain information on design, application rates, monitoring data, and operation problems.
4. To demonstrate the effect of ignitable waste in the form of spent solvents on bacterial populations in a soil column.
5. To conduct an economic feasibility of land application of ICW through an evaluation of its different cost components.
6. To identify environmental risks and consequences attendant to land application of ICW.

CHAPTER II

LITERATURE REVIEW

2.1 GENERAL

In order to determine the industries that are presently land applying D001 and D002, an exhaustive literature search was conducted. Of particular interest was a survey by Brown and Associates (9) whereby all land treatment facilities in the United States were identified, along with important information on regional distribution, facility size and type and amount of waste applied annually. Most of these facilities had listed D001 and D002 as part of the hazardous waste generated, therefore these companies were included in the survey. However, after communicating with these facilities by telephone, it was found that over half of the facilities identified in Brown's list were no longer in existence while others have changed disposal practices.

The current EPA list also needed to be updated to exclude those industries who have stopped land application operations or have ceased to generate ICW, as well as those who have instigated closure procedures on their land application facilities. Some of these companies

have requested to be deleted from the EPA hazardous waste list.

In order to generate the data base required in this study, a list of hazardous waste generators together with the quantities and types of wastes generated was obtained from each of the nine EPA regions. Those facilities with land application facilities and which were generating ICW were identified, and a random sample from this list was sent survey forms. Some of the design criteria for land application of ICW were obtained from the results of this survey.

Despite the preponderance of wastes that have a potential for land application, the data base for determining the requirements of a sound land application system is still in its infancy. There is no publication at present on land application of ignitable and corrosive waste. The subject of land application of oily sludge and other organic waste products however, has received unprecedented attention in recent years, and many research institutions have completed or have ongoing studies in this area (10,11,12,13,14,15,16,17,18,19).

A wide diversity of industrial categories are currently operating full or pilot-scale land application systems. These include, according to their order of importance, the petroleum industry, food processing, textiles, pulp and paper, metal plating, leather tanning,

printing, ink, paint, munitions, foundries, inorganic chemicals, organic chemicals and the pharmaceutical industry (18). The petroleum refining industry, however, has been the predominant industry utilizing this treatment and disposal technology, followed by the food processing industry, particularly the citrus processing industry.

Historically, the petroleum industry has been the prime user of land application for the disposal of a variety of wastes, primarily oily sludge. The food industry has also been extensively involved in the use of land application for disposal of its aqueous wastes. It generates significant volumes of corrosive or caustic wastes. These are combined with other aqueous wastes from various plant processes, the final effluent being almost neutral, with a pH ranging from 6-8. The steel and chemical industries generate both ignitable and corrosive wastes which have potential for land application.

There are still many unknowns related to land application systems. Industry has indicated a need for more effective and sound treatment and disposal methods for its wastes, particularly reactive, flammable/ignitable and corrosive wastes which are generated in large quantities yearly. There is a need to fill in the gaps of information relative to the design, and operating criteria of land application systems in general. The assoc-

iated waste/soil complexities and interactions are still the subject of numerous research studies.

Overcash and Pal (5) have studied the fundamental concepts of the entire land treatment design process. They have put together the complete methodoloy or design procedures for land application of virtually all types of wastes, thereby promoting the concept of limitless applicability of land application technology. They believe that virtually any kind of waste is amenable to land treatment, so long as guidelines are taken to ensure proper loading rates, as well as proper management procedures that will ensure continued use of the land even after closure procedures. The land limiting constituents must be continuously evaluated during and after the land application process. An environmentally acceptable rate of application to a plant-soil system can be determined for any and all industrial waste constituents, according to these authors, with the possible exception of radioactive wastes. They further concluded that wastes from all industrial categories can be assimilated satisfactorily in a land-based treatment system. The methodology they developed holds for all waste streams (raw waste, treated effluents, sludges and solids). The mechanics and equipment used in the actual land application will depend on the particular wastes. The reference contains a methodology or procedure for the design of a combined pretreat-

ment-land application system for selected waste types, and will thus be a very valuable source of information for the design of a land treatment facility for ICW.

EPA has also published numerous documents on hazardous waste land treatment. A particular publication entitled "Hazardous Waste Land Treatment" (6) contains information on site selection, waste characterization, treatment demonstration studies, land treatment unit design, operation and closure and other topics for design and management of land treatment units. Information on the fate of both inorganic and organic compounds in the soil is included. Methods for calculating loading rates and determining limiting constituents and management of soil pH are also discussed. Although the reference does not contain specific information on the design criteria for land application of ICW, general information on waste-site interactions, facility design and operation, monitoring, closure and post closure procedures, are very useful information for treatability studies.

Parr, et al. (20) has provided a reference that presents a critical review and assessment of current knowledge and management practices for ultimate disposal of a number of hazardous waste chemicals. The paper provides information and strategies for the design, development and effective management of land treatment systems for hazardous wastes, and identifies areas of research that

are needed to maximize the potential value of land treatment systems and to minimize associated risks.

In line with the concept of pretreatment land application technology for ICW, various state-of-the-art pretreatment technologies currently being used are reviewed by Berkowitz (21) and Edwards (22). They describe and examine over forty unit operations or processes and ways of combatting pollution from hazardous waste materials through the use of basic unit operations. These unit operations are either physical, such as neutralization and precipitation, or biological.

2.2 SOIL MICROBIAL DEGRADATION OF ICW

There are numerous textbooks, journals and articles in the literature that address the problem of biodegradation of various types of wastes in the soil by microorganisms. Some of these references are highly relevant to the study of degradation of ICW in the soil. Hillel (23), Sprangler et al. (24) and Buckman et al. (25) described the various mechanisms by which various hazardous constituents undergo biodegradation, immobilization and transformation in the soil. In addition, numerous articles in the literature have dealt with the degradation and movement of specific organic compounds in the soil to determine their treatability (26,27,28).

2.3 RISK ASSESSMENT OF ICW

Majeti and Clark (10) did an overview of the literature on the potential health effects from viable emissions and toxins associated with land application facilities and wastewater treatment plants to the workers and nearby populations. The different types of microorganisms present in wastewater and sludge and the effectiveness of the various treatment processes in their removal or inactivation are discussed thoroughly.

There are other articles that deal with health effects associated with land application of effluents which may be used in risk assessment of ICW. Kates (29) studied the preliminary pollutant limit values for human health effects of various toxicants. This information is very useful in the development of estimates of potential exposure of humans to hazardous constituents and the determination of exposure adjustment factors in the study of risk assessment of ICW.

Hinesly (30) studied the environmental changes from long-term land application of effluents. The report contains the results of various chemical analyses performed on soil and plant samples collected at disposal sites and could be used in determining exposure adjustment scores in risk assessment.

2.4 COST CONSIDERATIONS OF LAND APPLICATION FACILITIES

The overall cost considerations in a land application facility for ICW will depend primarily on the sophistication of pretreatment technology to be utilized as well as the availability of land at reasonable cost close to the generating facility. The complexity of the pretreatment to be used will influence its costs considerably and will depend on the nature and characteristics of the waste stream.

There are a number of articles in the literature that deal with the costs of various design parameters of land application facilities (3,5,7,29,31). Estimates of operational and maintenance costs were also reviewed by several authors (3,7,31,32). It should be noted however, that these figures should be adjusted to wage scales that reflect the standards of living in many regions. The costs of equipment may also differ considerably from region to region. The proper adjustments should therefore be made when making estimates of overall costs of land application facilities for ICW.

Because of the nature of corrosive and ignitable wastes, special equipment may be required such as corrosion resistant tanks, pipes, and applicators. Some publications (7,32) had listed some of these specifications.

The total costs of a land application facility have also been estimated by some authors (2,3,7). These fig-

ures are influenced considerably by the total cost of land required and pretreatment technology to be used.

CHAPTER III

APPROACH AND METHODOLOGY

The methodology used in this study took the following factors into consideration:

1. The source or generation of wastes;
2. The terminal or ultimate receiver system;
3. The economic feasibility through an evaluation of cost components of land application facilities; and
4. The risks posed by ICW to human health and the environment.

The first step was to determine the characteristics and quantities of ICW generated, and the types, categories and geographical distribution of companies producing ICW. The data base for generators and disposers was obtained from Brown's study and the EPA list of hazardous waste generators in all of the EPA regions. A random sample of these companies was obtained and these companies were sent survey questionnaires. The survey questionnaire was developed to obtain information on design criteria of land application facilities.

The second step was to study the effect of ignitable waste on the ultimate receiver system, which is the

bacterial population in the soil. Standard methods for isolation and examination of soil bacteria were used to determine their response to ignitable waste.

The third step was to determine the overall cost components of land application facilities in order to assess their economic feasibility. The results of this study are presented in Chapter IV.

Finally, it is important to study the risks posed by ICW to human health and the environment. The model presented in the study weighs the various ignitable and corrosive components in the effluent produced by selected industries according to the severity of risks to man and the ease of its dissipation in the environment.

The design procedure or methodology used with its various components is illustrated in Figure 3.1.

3.1 PRELIMINARY ASSESSMENT

3.1.1 Brown's List

Brown and Associates published a survey of existing hazardous waste land treatment facilities in the U.S. The list included information on facilities that are currently land applying in each EPA region, the type and amount of waste applied per year, and industrial categories by SIC code. The bulk of the information was obtained from Part A RCRA permit applications which were on file in the EPA Regional offices. In addition, state and

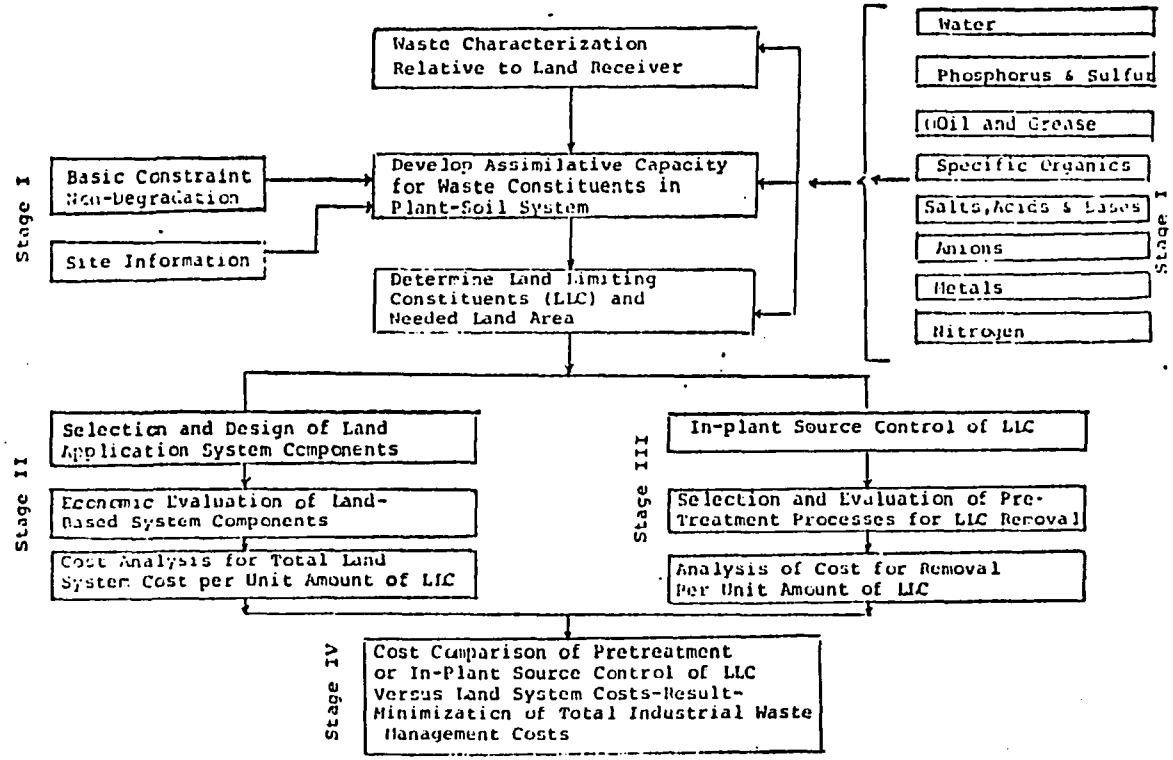


Figure 3.1 Four-stage Procedure or Methodology for Complete Pretreatment Land Application Design System.

Source: Overcash (5)

territorial environmental agencies were contacted to contribute missing information.

Brown's list identified 197 land treatment facilities in the U.S. (Table 3.1). Over 50 percent of these facilities were located in Regions 4 and 6. Our task was therefore to identify those facilities who were generating ICW and to determine if they were land applying their waste. These facilities were contacted by phone and the results of the survey are presented in the next section.

3.1.2 EPA Mailing List

A list of land treatment facilities along with important information on volumes of ICW generated annually, and treatment technology currently being used were obtained from each of the ten EPA Regional offices. Each region, however, had data bases with varying degrees of completeness. Volumes of waste generated were available from six regions. Some regions could furnish only the names and addresses of the facilities with ICW together with process codes for each facility (Table 3.2). However, the bulk of information gathered was considered adequate to evaluate current technology and state-of-the-art of land application. Those who are currently land applying were identified from the EPA computer printouts and a survey form was sent to each facility.

Table 3.1. Geographic Distribution by Region and State of 197 Land Application Facilities in the U.S.*

Region	Regional Office	Number of Facilities
VI	Dallas, TX	58
IV	Atlanta, GA	45
IX	San Francisco, CA	19
VIII	Denver, CO	18
V	Chicago, IL	16
VII	Kansas City, MO	15
X	Seattle, WA	12
II	New York City, NY	8
III	Philadelphia, PA	7
I	Boston, MA	0
	Total	197

*Brown and Associates (9).

Table 3.2 Companies Generating D001 and D002 in 8 EPA Regions.

	Number of Companies			
Region	D001	D002	D001/D002	Total
1	88	153	87	328
2	150	166	252	568
3	151	109	76	336
4	172	179	136	487
6	137	132	221	490
7	104	46	136	286
8	145	115	140	400
9	110	72	173	355
Grand Total	1057	972	1221	3250

The results of the survey are presented in the next section.

3.2 INSTRUMENT

3.2.1 Reuter Report

Life Systems Inc. was contracted to provide guidance and information concerning the following:

a. A hazard evaluation indicating the risk posed by land treating wastes from each industrial category.

b. The potential treatment and pretreatment methods used in conjunction with land application and the use of other alternatives.

c. The construction of a viable methodology for data generation on the project.

The risk model presented by Life Systems Inc. is presented in Chapter VIII, on Risk Assessment. It includes a model description, factors considered in the model, exposure adjustment for environmental medium, limitations of the model, and the results of the risk assessment.

3.2.2 Trial Survey from Brown's List

The facilities listed in the study by Brown and Associates, which were generators and land appliers, were contacted by telephone. There were a total of 27 facili-

ties included in the survey and these companies were classified as follows:

Refinery	11
Government Installation	5
Electric Company	4
Fruit Processing	3
Transportation	1
	27

The results of the survey showed that most of those facilities listed in Brown's List as land appliers have either stopped operations of their land application facility or have opted to contract out their disposal of ICW. These wastes are deposited in landfills off-site or incinerated.

It was therefore determined that a more comprehensive and updated list of land appliers had to be obtained from the EPA Regional offices in order for the study to be completed.

3.2.3 Actual Survey

The primary object of the survey was to collect data for establishing a reliable data base. This was accomplished by: (1) literature search; (2) trial survey from Brown's List; (3) actual mail survey, and (4) site visits and interview technical people in the field.

As mentioned earlier, the literature on land appli-

cation of corrosive and ignitable waste is practically nonexistent. Therefore, a mail instrument had to be relied on as well as telephonic contact with people in industry and site visits for needed information. Most mail surveys result in a high rate of no response; therefore follow-up personal phone interviews were also conducted.

The addresses of facilities with land application systems (Appendix A) as well as those that generate ICW but use other treatment technologies (Appendix B) were obtained from computer printouts furnished by the 10 EPA Regional offices. A copy of the survey form is included in Appendix C and the results of the survey are presented in Tables 4.5 and 4.6.

The survey form sought to obtain the following information:

1. Total size of the facility in acres
2. Application rates
3. Volume of D001 and D002 wastes generated and quantities land applied
4. Land limiting constituents of the waste
5. Preconditioners used in the soil
6. pH range of corrosive waste
7. Flash point of ignitable waste
8. Alcohol content of the waste
9. Availability of operating records, unsaturated

zone monitoring plan and analytical results

10. Constraints of land application as a treatment technology.

A random survey of facilities that generate ICW, but do not land apply was also conducted in each of the EPA regions. The EPA computer printouts again provided the addresses of facilities and contact persons in each facility. Basically, the same information as in the former survey was used in the survey form. The reason for this survey was to obtain information on other treatment and disposal technologies for ICW. This will form an essential part of alternative technologies available for the treatment and disposal of ICW. A copy of the form used in the survey is in Appendix C. The results of the survey are presented in Chapter IV.

3.2.4 Site Visits

A total of 5 facilities, three in Oklahoma and two in Florida were visited to provide in-depth information on the design criteria, monitoring and analytical results in land application facilities. The three land application facilities visited in Oklahoma were petroleum refineries while those in Florida were citrus processing plants that generate corrosive/caustic waste.

3.3 SOIL COLUMN STUDY ON THE EFFECT OF IGNITABLE WASTE ON BACTERIA

In this study solvent recovery waste from an industrial facility in Houston, Texas was obtained to determine its effect on soil bacterial populations and thus determine its land treatability. Some organic compounds may cause direct biocidal effects on soil microorganisms or exert inhibitory responses to their growth and metabolic processes for extended periods. The effects of numerous organic compounds and metals are found in the literature, but no study has addressed the microbiological responses to solvent recovery waste of known composition and structure in the unsaturated zone.

3.3.1 Materials and Methods

3.3.1.1 Media Preparation

A modified standard plating technique was used (33) to determine the total bacterial colonies in the unsaturated zone.

Nutrient agar was autoclaved for 20 minutes at 15 pounds pressure (121°C), and cooled at 55°C. Twenty five mls of nutrient agar were poured into disposable sterile petri dishes that contained different dilutions of soil samples. The procedure for the preparation of the culture medium used is in Appendix E.

3.3.1.2 Sample Collection and Preparation

Uncontaminated soil samples were collected under

sterile conditions in the unsaturated zone in Ada, Oklahoma (Figure 3.2). The soil samples were collected in sterile plastic sacs at one foot intervals from the surface to a depth of 4 feet, in the unsaturated zone, from a cross section of 1.5 m^2 in the field.

A glass column four feet long previously sterilized by exposure for 6 hours under an ultraviolet lamp (Figure 3.3) was carefully packed with soil collected from the unsaturated zone, using a sterile glass rod.

The soil samples were analyzed for moisture content, nitrate nitrogen, phosphorus, and pH. One gram of soil sample from each of the soil layers was diluted appropriately using the standard plating technique and inoculated in nutrient agar plates to determine the initial total bacterial colony counts. These served as the control plates. The procedure used in the analyses of the soil samples is in Appendix E.

3.3.1.3 Sampling and Plating Technique

The solvent recovery waste was obtained from Dr. K.W. Brown of the Texas A & M University, College Station, Texas (Figure 3.4). It had the following hazardous organic constituents:

(1) Base/Neutral Fraction

Napthalene

Acenapththylene

Fluorene

Figure 3.2 Trench in Ada, Oklahoma where soil samples were collected under sterile conditions at different depths of the unsaturated zone.

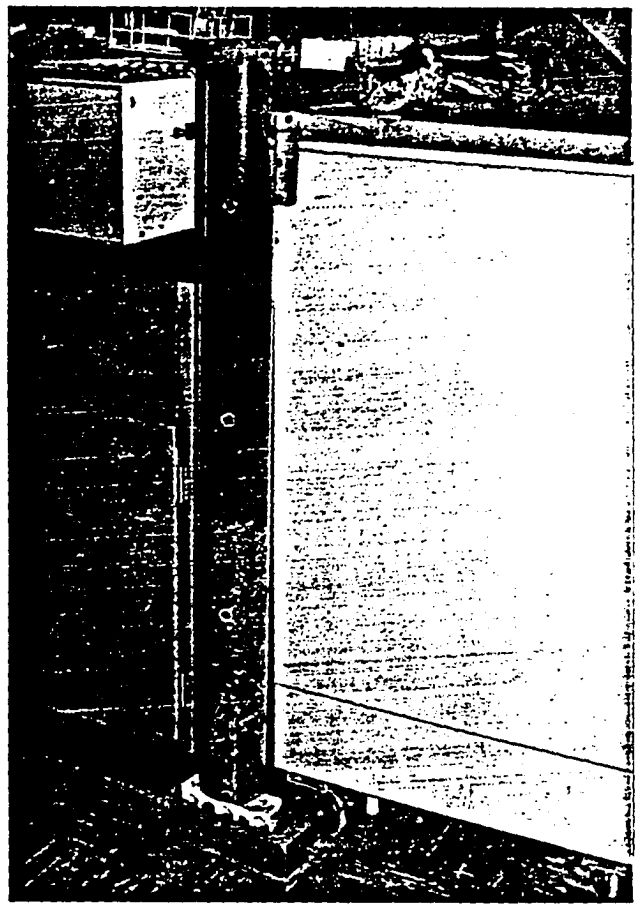


Figure 3.3 Glass column, four feet long packed with soil from the different layers of the unsaturated zone.

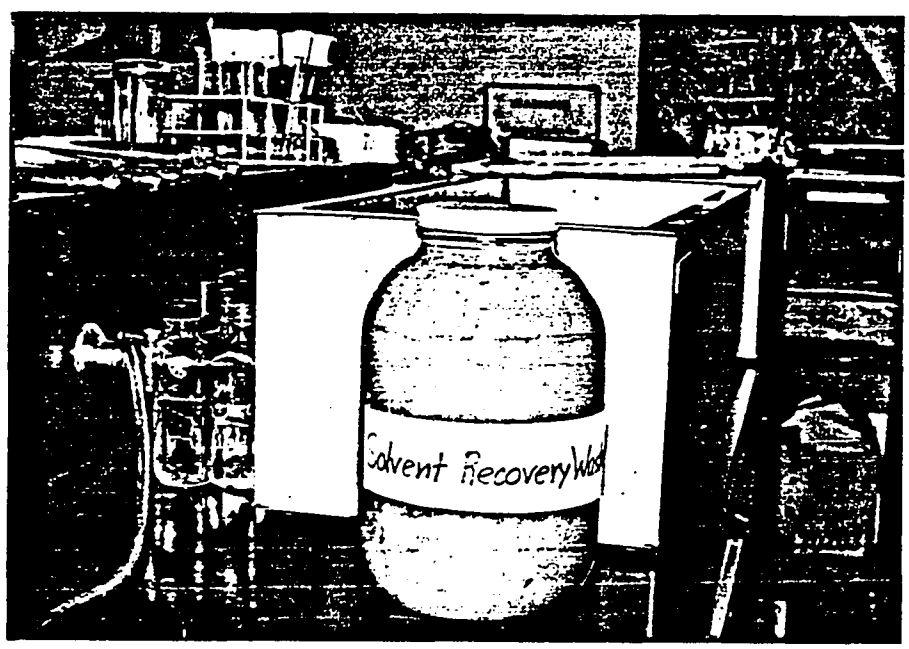


Figure 3.4 Flammable waste in the form of spent solvents from a Solvent Recovery Waste Plant in Houston, Texas.

Phenanthrene

Fluoranthene

Pyrene

(2) Acid Fraction

Benzene, ethyl

Benzene, methyl

Benzene dicarboxylic acid

Toluene

Xylene

The gas chromatographic analyses of the solvent recovery waste is in Appendix E.

CHAPTER IV

RESULTS

4.1 RESULTS OF INVENTORY

4.1.1 Distribution of Companies by EPA Regions

The nine EPA regions surveyed reported a total of 3,245 companies nationwide generating ICW. Table 4.1 presents the generators of D001 and D002 with land application facilities from Brown's list and the EPA list. Figures 4.1 and 4.2 show the distribution of companies by EPA region and total volumes of ICW generated per region.

Seven EPA regions were able to send information on total volumes of D001 and D002 generated in each facility in their respective regions. These are presented in Table 4.2.

In seven EPA regions above, a total volume of 33,506,880 and 147,992,699 metric tons of D001 and D002, respectively, are generated annually. There were a total of 339 companies generating greater than a 100 metric tons and 765 companies generating less than a hundred tons of D001 per year. There were a total of 576 companies generating greater than a hundred metric tons

Table 4.1 Generators of D001 and D002 with Land Application Facilities from Brown's List and the EPA List.

Region	Number of Facilities Brown's List	Percent	EPA List	Percent
1	-	-	3	7.5
2	-	-	4	8.4
3	1	3.7	18	2.8
4	5	18.5	15	14.0
5	-	-	13	10.3
6	13	48.1	14	10.3
7	2	7.4	11	11.2
8	4	14.8	19	21.5
9	1	3.7	8	8.4
10	1	3.7	5	5.6
TOTAL	27	100.0	110	100.0

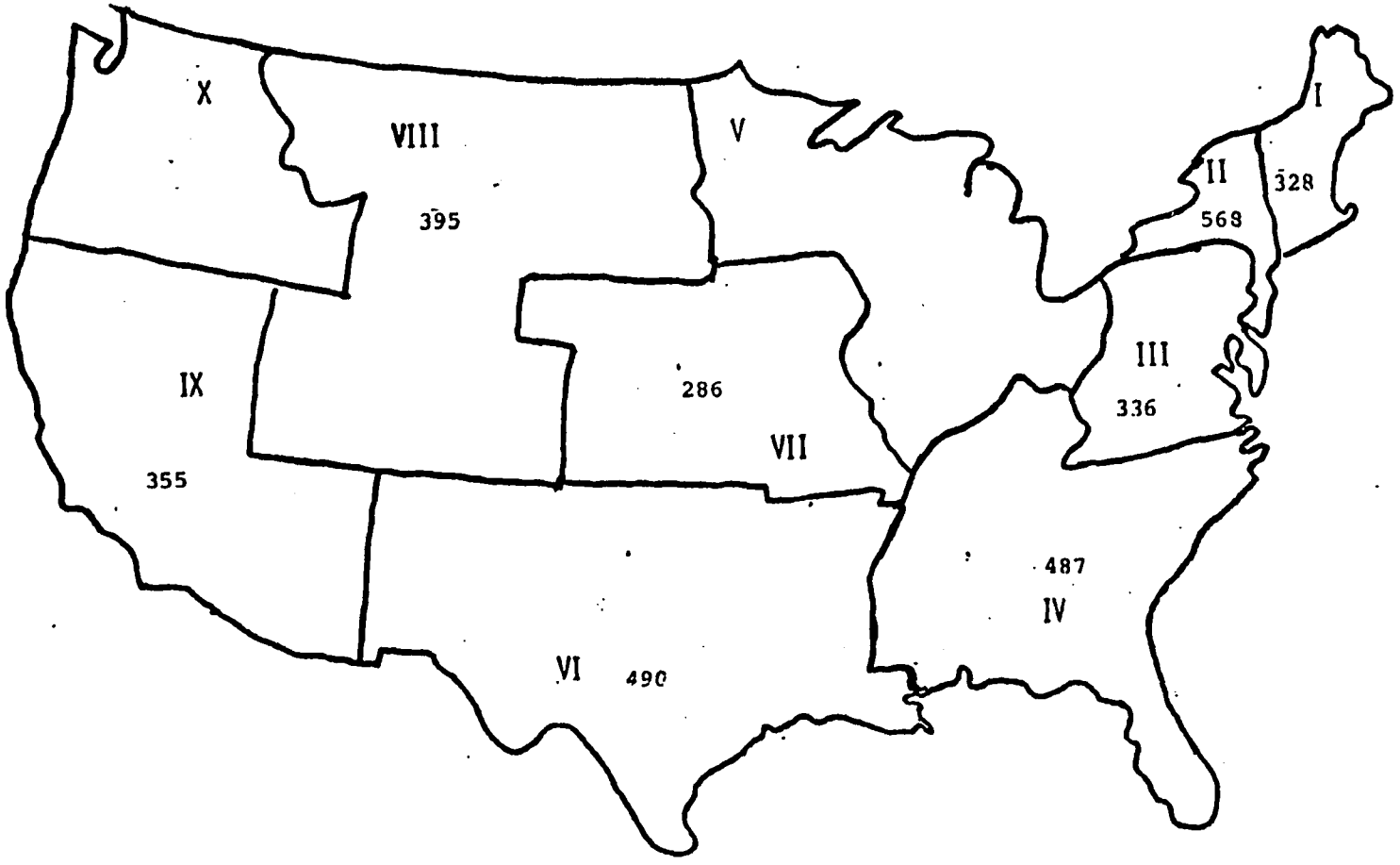


Figure 4.1 Distribution of companies generating ICW in 8 EPA Regions.

Table 4.2 Quantities of D001 and D002 Generated in 7 EPA Regions (MT per year)

REGION	D001	D002	TOTAL
1	367,264	3,025,919	3,393,183
2	1,711,814	10,833,533	12,545,347
3	3,861,597	19,274,184	23,135,781
4	9,064,196	12,588,223	21,652,419
6	8,238,434	89,542,033	97,780,467
7	1,248,242	6,823,973	8,072,215
9	9,015,333	5,904,834	14,920,167
TOTAL	33,506,880	147,992,699	181,499,579

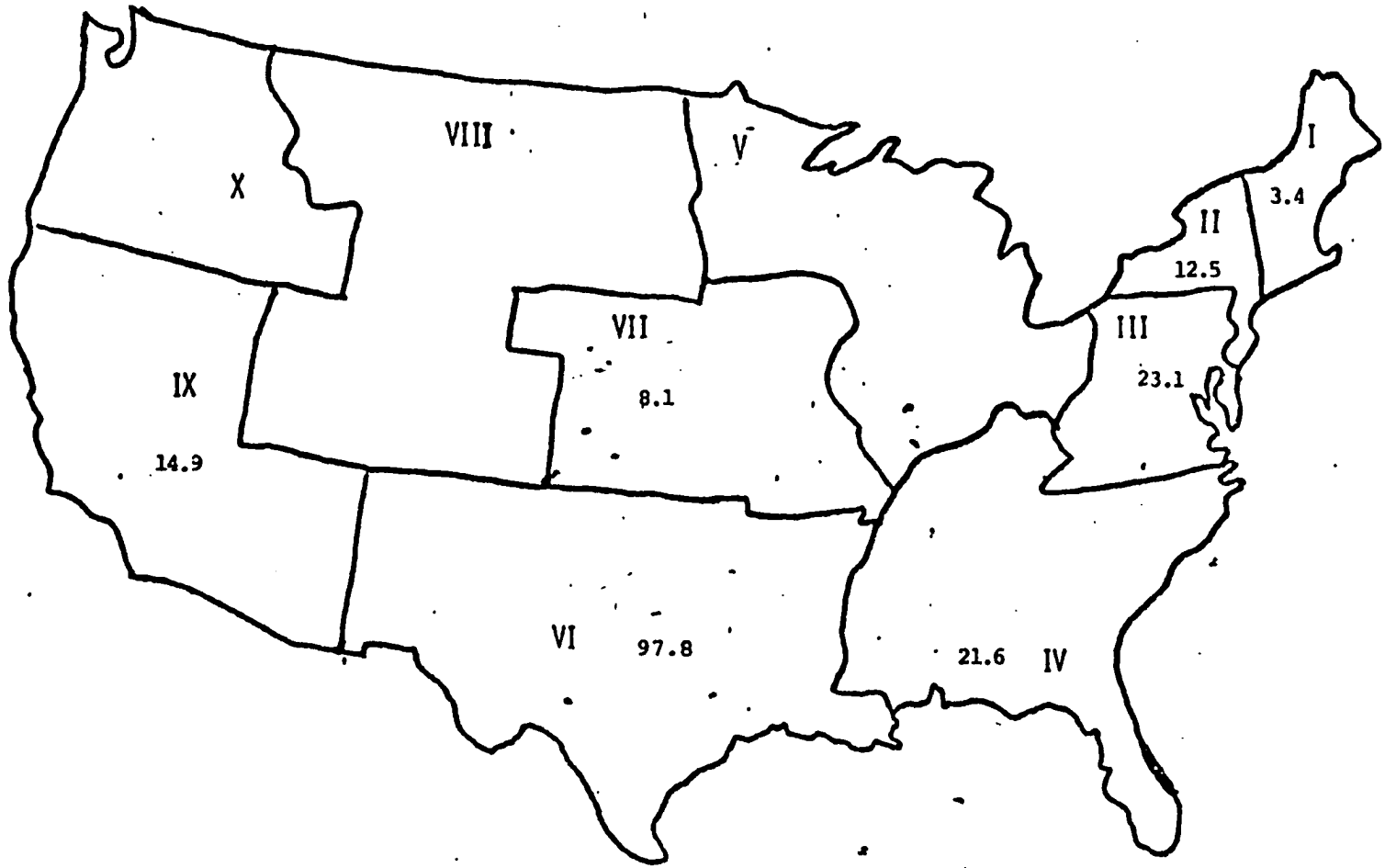


Figure 4.2 Volume of ICW Generated in Seven EPA Regions, million metric tons/year.

and 520 companies generating less than a hundred metric tons of D002 per year (Table 4.3) in five EPA regions.

There were more companies generating D002 wastes than D001 wastes. Approximately 82 percent of these companies were generating D002 while only 18 percent were generating D001.

The regional distribution of facilities generating ICW is presented in Table 4.4. Regions 2 and 6 topped the list with 568 and 490 companies, respectively.

4.1.2 Distribution of Companies by Climatic Zones

A total of 110 land application facilities were surveyed from nine EPA regions. The distribution of these facilities by climatic zones is presented in Figure 4.3. Figure 4.4 presents the land application facilities by state and EPA regions.

There are 5 climatic zones designated A to E (Figure 4.5). Survey forms were mailed to a total of 107 land application facilities generating ICW in these climatic zones.

4.2 RESULTS OF SURVEY OF LAND APPLICATION FACILITIES

A total of 55 land application facilities generating both D001 and D002 waste were listed in Brown's survey. The EPA inventory list had a total of 110 facilities. All the facilities in Brown's survey were contacted by telephone while those from the EPA Regional inventory

Table 4.3 Distribution of Companies Generating More than or Less than a Hundred Metric Tons of ICW per Year.

Region	D001 (metric tons/year)			D002 (metric tons/year)		
	>100	<100	Total	>100	<100	Total
1	37	145	182	51	97	148
4	27	96	123	128	122	250
6	143	215	358	250	109	359
7	58	180	238	38	60	98
9	74	129	203	109	132	241
TOTAL	339	765	1,104	576	520	1,096

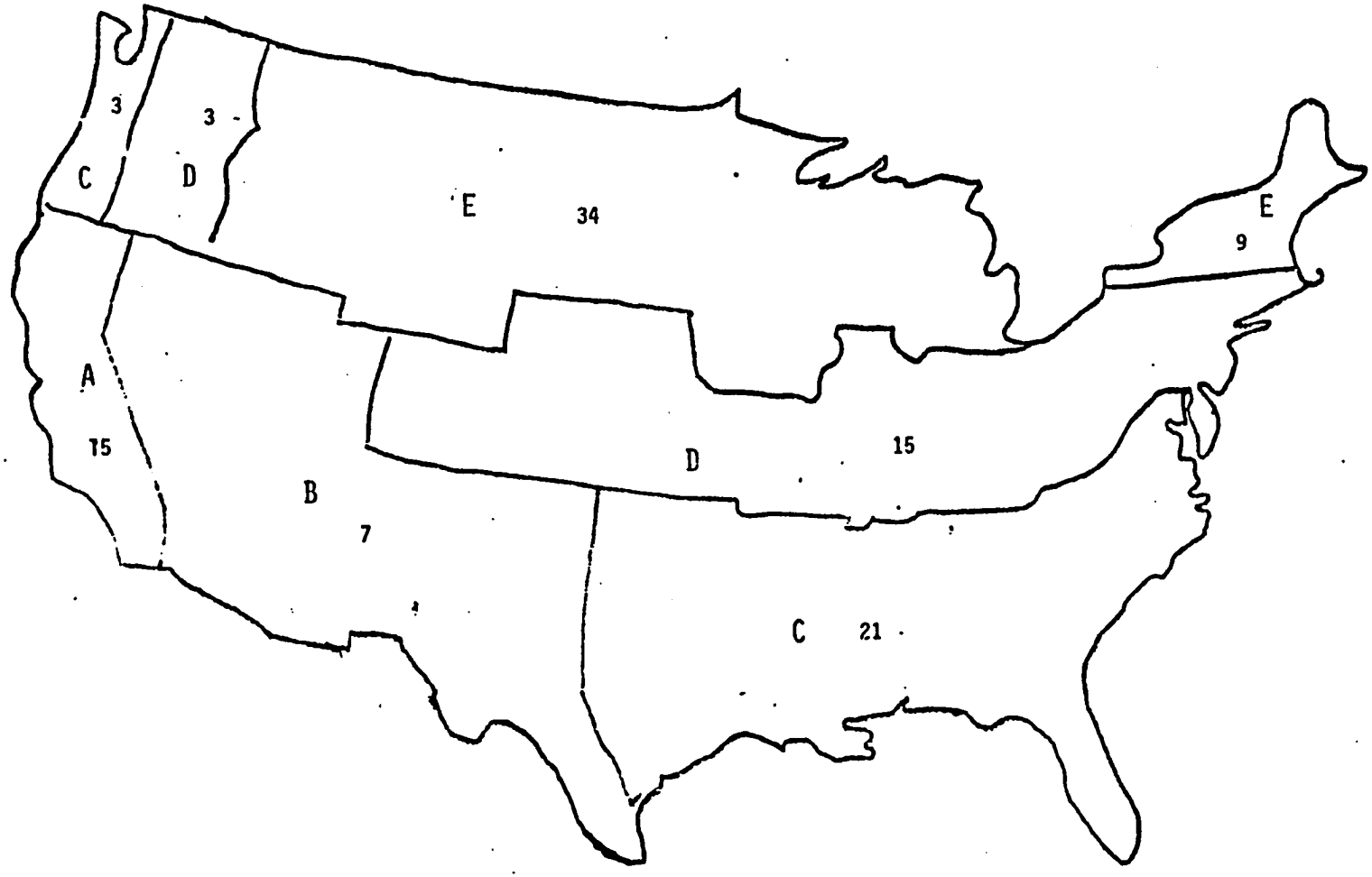


Figure 4.3 Distribution of land application facilities surveyed by climatic zones.

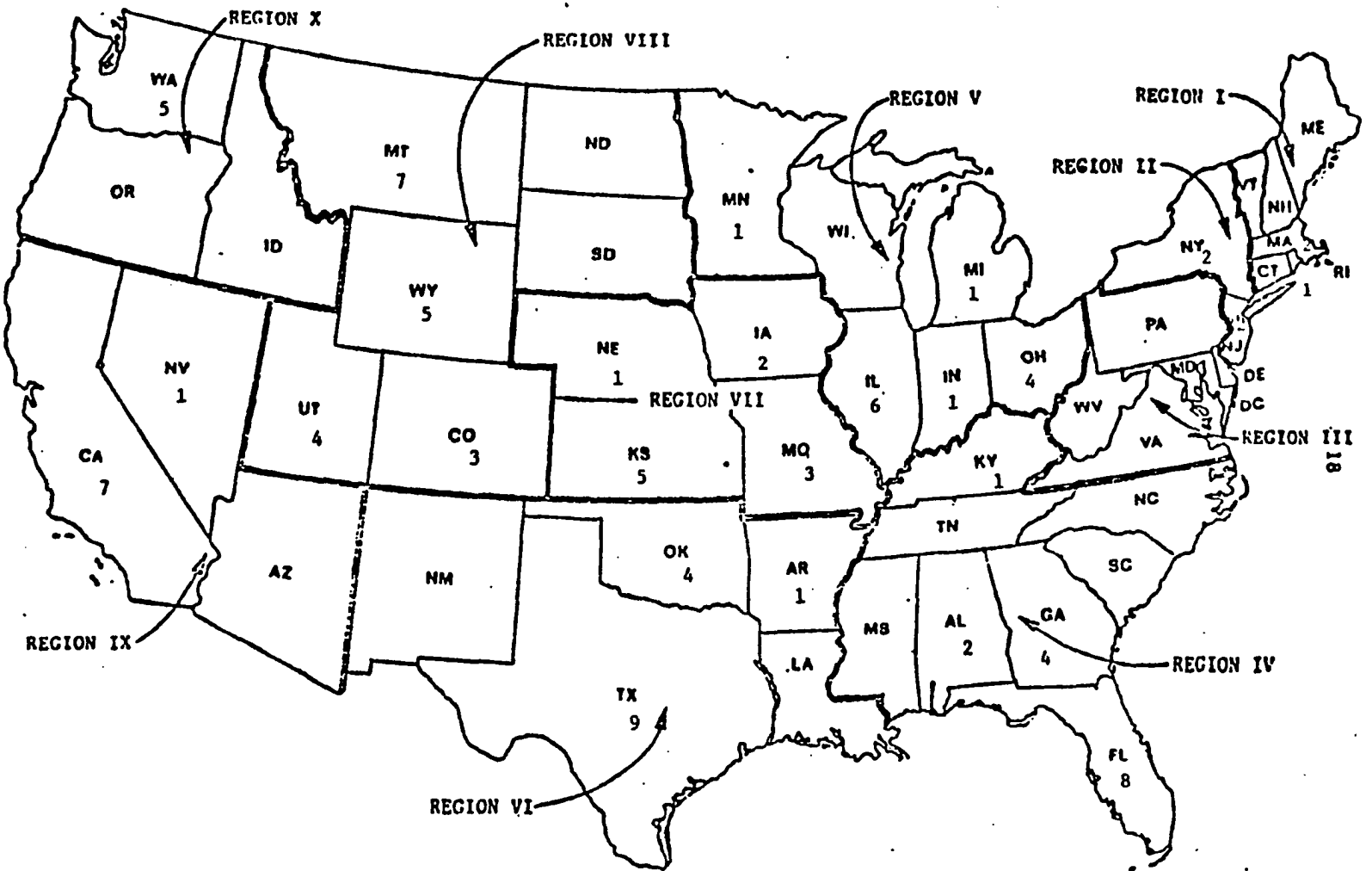
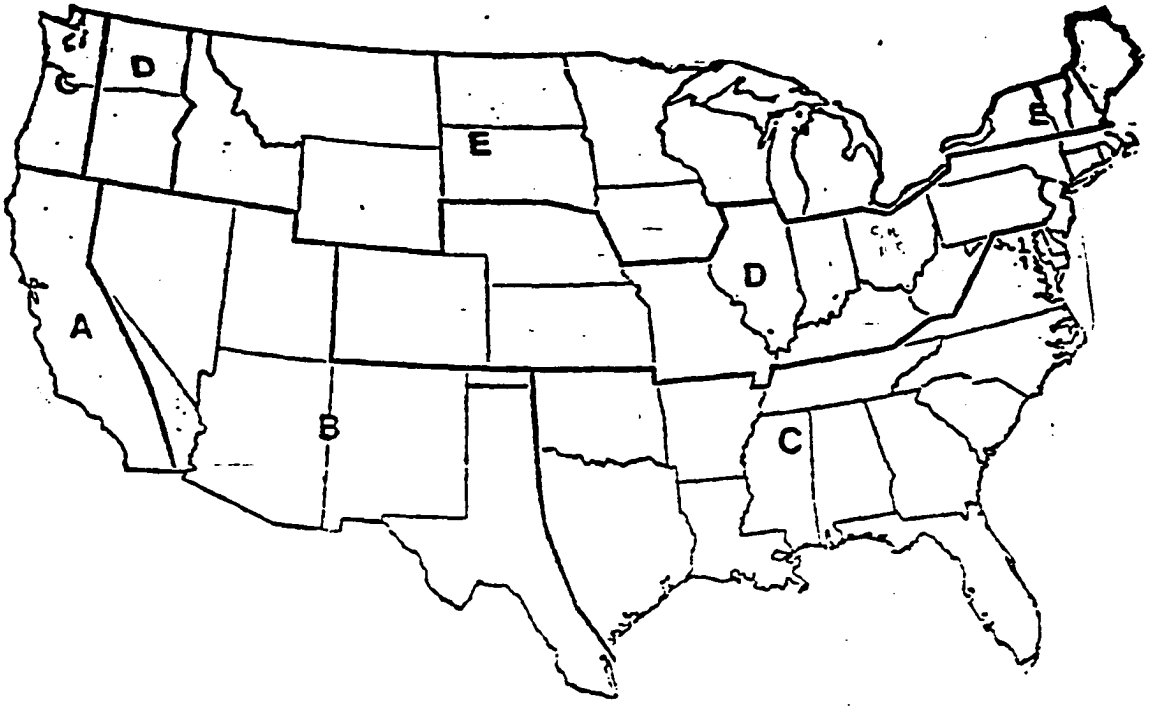


Figure 4.4 Land application facilities surveyed by State and EPA regions.



A Mediterranean Climate–
Dry summer – mild, wet winter
B Arid Climate – hot, dry
C Humid Subtropical – mild winter
hot, wet summer (Wash., Ore.,
area mild, moist summer)
D Humid Continental – short
winter, hot summer
E Humid Continental – long
winter, warm summer

Figure 4.5 Five climatic zones in the U.S.

Table 4.4 Distribution of Companies Generating ICW in eight EPA Regions.

Region	Total Number of Companies with D001 and D002
1	328
2	568
3	336
4	487
5	-
6	490
7	286
8	400
9	355
Total	3,250

list were sent survey forms.

Fifty-five companies from Brown's list were reported generators of D001 and D002 waste and were listed as land application facilities. All of these facilities were contacted by telephone and 34 of the facilities were verified to have either ceased operations of their land application sites or switched to other disposal technology. A total of 21 companies generating ICW still had operational land treatment facilities. These are classified as follows:

Petroleum Refinery	13
Citrus Processing	5
Transportation	1
Chemical Manufacturing	1
Electric	1
Total	21

Table 4.5 shows the results of the survey on land application facilities. A total of 21 companies with land application facilities and generating ICW were included in the results of this survey. Of these companies, 15 or 71.4 percent had a Part A Permit to operate a hazardous waste facility, 1 or 9.6 percent had a Part A and Part B Permit, while 4 or 14.3 percent had an Interim Permit. A majority of these facilities had operating records available (66.7 percent), whereby information was available on loading rates, nature and characteristics of waste applied, and prevailing environmental conditions. This information will be used for planning and policy purposes and is essential for establishing an efficacious hazardous waste management strategy as mandated by RCRA. Records of analytical results were also available in 66.7 percent of these facilities. Unsaturated zone monitoring plans were available in 71.4 percent of these facilities.

The survey indicated highly variable responses to the composition of ICW generated. They reported ICW as consistent, 28.6 percent; variable, 23.8 percent; and highly variable, 4.8 percent. The nature of ICW was in the form of a sludge/slurry in 42.9 percent of the facilities and aqueous in 19.0 percent of the facilities.

There were 66.7 percent of the companies generating D001 with an alcohol content of <24 percent, and 19 per-

cent with an alcohol content of >24 percent. In the case of ignitable waste, 57.2 percent report a flash point of less than 60°C.

About half (47.6 percent) of these facilities use some kind of pretreatment technology, 38 percent use a soil conditioner, 28.6 percent use lime, 23.8 percent use fertilizer and 4.8 percent rototilled the soil.

Among the constraints listed for land application of ICW, these facilities considered Federal constraint and regulations (47.6 percent) as the single most limiting factor for the operation of a land application facility. On the other hand, approximately 24 percent of these facilities considered land availability as their main constraint, while 14.3 percent thought it was economics.

All of these companies, as mentioned earlier, were using one or several pretreatment technology. For D002 waste it was neutralization (41.6 percent). The final disposal technologies used for ICW waste was incineration (16.7 percent), aeration/settling (12.5 percent), and landfilling (8.3 percent).

These results would indicate an increasing awareness among generators, operators and disposers of hazardous waste of the importance of monitoring information for proper planning and management of land application facilities.

Table 4.5 Results of the Survey on Land Application Facilities

	Number	Percentage
1. Hazardous Waste Permit		
Part A	15	71.4
Part A and B	1	9.6
Interim Permit	4	14.3
No Permit	1	4.7
2. Operating Records Available		
Yes	14	71.4
No	1	4.8
No Response	6	28.5
3. Application Loading Rate		
Daily	5	23.8
Weekly	2	9.5
Monthly	3	14.3
Variable	7	33.3
No Response	4	19.1
4. Type of Process Used		
Batch	12	57.1
Continuous	1	4.8
No Response	8	38.1
5. Composition of ICW		
a. Consistent	6	28.6
Variable	5	23.8
Highly Variable	1	4.8
No Response	9	42.8
b. Sludge/Slurry	9	42.9
Aqueous	4	19.0
Solid/Others	1	4.8
No Response	7	33.3

Table 4.5 (Continued)

	Number	Percentage
6. Alcohol Content of ICW		
<24%	14	66.7
>24%	4	19.0
No Response	3	14.3
7. Pretreatment of ICW		
Yes		47.6
No		47.6
No Response		4.8
8. pH Range of Corrosive Waste		
<2	5	23.8
2-6	2	9.5
7-12	2	9.5
>12	7	33.3
No Response	5	23.9
9. Flash Point		
<60°C	12	57.2
No Response	7	33.3
10. Use of Soil Conditioner		
Yes	12	57.1
No	4	19.0
No Response	5	23.9
11. Soil Conditioner Used		
Lime	6	28.6
Fertilizer	5	23.8
Not Used	9	42.9
12. Unsaturated Zone Monitoring Plan		
Yes	15	71.4
No	1	4.8
No Response	5	23.8

Table 4.5 (Continued)

		Number	Percentage
13.	Analytical Results Available		
	Available	14	66.7
	Not Available	4	19.0
	No Response	3	14.3
14.	Constraints Considered in Land Treatment		
	Economics	3	14.3
	Land Availability	5	23.8
	Federal Constraints/Regulations	10	47.6
	Others	3	14.3
15.	Other Treatment Disposal Technology Used		
	Landfill	2	8.3
	Incineration	4	16.7
	Contracted Out	1	4.2
	Recycle	3	12.5
	Dilution	1	4.2
	Neutralization (D002)	10	41.6
	Aeration/Settling	3	12.5

4.3 RESULTS OF SURVEY ON GENERATORS OF ICW WITHOUT LAND APPLICATION FACILITIES

The second part of the survey consisted of those companies generating ICW but having no land application facilities. It was necessary to obtain information on current technology on treatment and disposal methods being utilized by generators and disposers of ICW. A random sample of generators and disposers from nine EPA regions was obtained. A total of 380 survey forms were mailed to generators of ICW producing greater than a hundred metric tons of ICW per year. It was decided that the big generators should be the primary concern of this study since it is in this section of industry where disposal problems are of great concern. Table 4.6 shows the distribution and type of facility surveyed per region.

The survey was a representative random sample from the EPA Regional list of generators and disposers of ICW. A total of 86 responses were received over a span of 8 weeks after the survey forms were mailed, a response rate of approximately 23 percent. There were a total of 56 completed survey forms received, while the remaining 30 wrote to decline participation in the survey.

Among the number of generators surveyed, 17.9 percent were generators of D001, 32.1 percent were generators of D002, and 35.7 percent were generators of both D001 and D002 waste (see Table 4.7).

Table 4.6 Generators of D001 and D002 per Region Surveyed

		1	2	3	4	6	7	8	9	10	Totals	Percentage
1.	Chemical/Agricultural Chemical Fertilizers	5	15	18	4	20	6	10	15	13	106	27.9
2.	Pharmaceutical	2	3	4	-	1	1	-	1	-	12	3.2
3.	Equipment	5	2	4	1	2	-	2	4	2	22	5.8
4.	Petroleum Refining	2	4	1	2	9	2	10	8	2	40	10.5
5.	Plating/Metals Forming Steel	1	3	5	1	1	1	3	2	10	27	7.1
6.	Paint	1	1	2	-	-	-	1	-	7	12	3.2
7.	Electric Power	4	3	4	1	4	1	3	-	1	21	5.5
8.	Paper/Wood Processing	1	4	-	1	-	-	-	-	3	9	2.4
9.	Dyeing	1	1	1	-	-	-	-	-	-	3	0.7
10.	Glass Manufacturing	1	1	1	-	-	1	-	-	-	4	1.1
11.	Transportation/ Communication	1	1	3	1	3	1	4	3	5	22	5.8
12.	Food/Beverage/Canning	-	3	-	3	-	1	2	-	6	15	3.9
13.	Explosives	-	1	-	-	-	-	-	-	-	1	0.2
14.	Disposal Services/ Transfer Stations	-	3	1	3	-	-	4	6	1	18	4.7
15.	Rubber Manufacturing	-	-	-	-	-	-	1	-	-	1	0.2
16.	Construction	-	-	-	-	-	-	-	-	-	9	-
17.	Government/Research Institutes	-	3	1	-	1	1	2	-	1	9	2.4
18.	Miscellaneous	7	10	11	2	14	2	4	3	5	58	15.3
	TOTALS	31	58	56	19	55	17	46	42	56	380	100.0

D001 was characterized as aqueous by 40 percent of the respondents. Twenty-three percent said it was in the form of a sludge or slurry, while 16.7 percent said it was solid. D002 was characterized as aqueous by 42.1 percent; sludge and slurry by 26.3 percent; and solid by 7.9 percent. Approximately half of those surveyed generated D001 and D002 wastes from batch processes.

The pH of corrosive waste also varied whereby 31.6 percent and 36.8 percent of those surveyed reported a pH of <3 and >12, respectively. Among these companies, 43.3 percent reported the flash points of D001 waste as less than 60°C, while 16.7 percent had D001 waste with greater than 24 percent alcohol. The most popular disposal method currently utilized among the generators of D001 and D002 waste was landfilling (33.3 percent and 10.5 percent, respectively). There were more than ten types of disposal methods used for ICW, and these were in decreasing order of importance, contract disposal (26.8 percent), landfilling (21.4 percent), incineration (17.9 percent), the use of a lagoon or pond for biodegradation (7.1 percent), deep well injection (5.4 percent), and discharge to a receiving stream (5.4 percent).

A majority of those surveyed, 36.5 percent, agreed that Federal and local regulations were the main constraints for the land application of ICW.

The rest of those surveyed listed contamination of

Table 4.7 Results of the Survey on Generators of ICW

	D001		D002	
	No.	%	No.	%
1. Classification of Generators				
D001 Generators	10	17.9		
D002 Generators			18	32.1
Both D001 and D002	20	35.7		
No Response	8	14.3		
2. Nature of Waste				
Aqueous	12	40.0	16	42.1
Sludge/Slurry	7	23.3	10	26.3
Solid	5	16.7	3	7.9
No Response	6	20.0	9	23.7
3. Type of Process				
Batch	15	50.0	19	50.0
Continuous	9	30.0	10	26.3
No Response	6	20.0	9	23.7
4. Use of Pretreatment Methods				
Yes	4	13.3	19	50.0
No	17	56.7	10	26.3
No Response	9	30.0	9	23.7

Table 4.7 (Continued)

	D001		D002	
	No.	%	No.	%
5. Methods of Pretreatment used and Disposal of ICW				
Chemical Coagulation	3	10.0	4	10.5
Neutralization	1	3.3	15	39.5
Precipitation/Filtration	-	-	1	2.6
Incineration	2	6.7	2	5.3
Flocculation	-	-	4	10.5
Bioxidation	-	-	1	2.6
Ponding	-	-	3	7.9
Evaporation	1	3.3	3	7.9
Dilution	-	-	1	2.6
Stripping	1	3.3	-	-
Distillation	1	3.3	-	-
Landfill	10	33.3	4	10.5
None	11	-	-	-

(Continued)

Table 4.7 (Continued)

	D001		D002	
	No.	%	No.	%
6. HWLT Permit Available				
Part A	24	80		
Interim Status	6	20		
7. pH Range of Corrosive Waste				
< 2			12	31.6
2-6			7	18.4
7-12			5	13.2
> 12			14	36.8
8. Flash Point				
< 60°	13	43.3		
> 60°	11	36.7		
No Response	6	20.0		
9. Alcohol Content				
< 24%	19	53.3		
> 24%	5	16.7		
No Response	6	20.0		
10. Constraints for Land Application				
Regulations/Federal Constraints	19	36.5		
Contamination of Groundwater	16	30.8		
Land Availability	7	13.5		
Economics	7	13.5		
Others	3	5.7		
No Response	4			

(Continued)

Table 4.7 (Continued)

11.	Current Disposal Technology Used		
	Incineration	10	17.9
	Lagoon/Pond	4	7.1
	Solidification/Encapsulation	1	1.8
	Contract Disposal	15	26.8
	Recycle/Reuse	4	7.1
	Landfill	12	21.4
	Deep Well	3	5.4
	Discharge to Stream	3	5.4
	Dewatering/Evaporation	1	1.8
	Land Application	2	3.6
	None	1	1.8
12.	Endorsement of Land Application for Treatment of ICW		
	Yes	17	30.0
	No	15	27.8
	No Response	24	42.9
13.	Willingness to Participate in a Feasibility Study		
	Yes	16	28.6
	No	18	32.1
	No Response	22	39.3

groundwater, 30.8 percent, and land availability and economics, both 13.5 percent, as the limiting factors in land application of ICW. Approximately 30 percent of the companies generating ICW believed land application to be a feasible method for disposal of ICW, while 27.8 percent had certain reservations, due to the constraints mentioned earlier.

4.4 RESULTS OF SOIL COLUMN STUDY

The objective of the laboratory study was to provide a preliminary study on the effect of solvent recovery waste with ignitable compounds on microbial populations in the unsaturated zone. This study could aid in understanding the different processes by which soil bacteria biodegrades ICW.

Hazardous waste land treatment systems are designed to utilize the diverse microbial populations in the soil responsible for degradation, immobilization and transformation of the hazardous organic constituents of the wastes applied to the land. Soil is an ideal medium for degradation of organic matter because of its ability to absorb nutrients and hold sufficient water to sustain life. The physical and chemical properties of the soil affect the ability of bacteriato degrade, detoxify and inactivate toxic waste constituents. The soil also functions as a natural filter in the adsorption and

retention of waste constituents, thereby preventing or minimizing transport, leaching and contamination of surface and groundwater (18).

An indirect measure of the rate of decomposition of hazardous organic matter applied in the soil is the agar-plating technique, which gives an index of the bacterial population in the soil from the time of waste application. The growth and activity of microorganisms in terms of their types and numbers can be monitored and determined after land application of hazardous waste. Certain compounds will exhibit greater toxic and biocidal effects on soil bacteria than others. In some cases partial sterilization could occur, resulting in marked quantitative changes in the soil bacteria that may require longer periods to reestablish a climactic microbial population that can again degrade waste chemicals.

Table 4.8 is a summary of the chemical analyses of the soil samples collected. The results of the bacterial colony counts before application of the solvent recovery waste is presented in Table 4.9. The dilution chosen in order to obtain reliable results was 1:20,000 since the bacterial colony counts ranged from 5 to 120. This dilution was used for all of the plates subsequently inoculated with soil samples after application of the solvent recovery waste on top of the column (Fig. 4.6). Table 4.10 is a summary of the bacterial colony counts after

Table 4.8 Basic Parameters Measured for Soil Samples

Depth (ft.)	Phosphorus ppm	Nitrate-N ppm	Temp. °F	pH
Surface	25.9	0.55	70	7.1
1	5.9	0.48	70	7.0
2	5.9	0.45	70	6.9
3	5.9	0.45	69	6.9
4	5.9	0.10	69	6.9

Table 4.9 Total Bacterial Colony Counts in the Unsaturated Zone Before Application of Solvent Recovery Waste (Control)

	Depth (feet)				
Dilution	Surface	1	2	3	4
1:200	TNC*	TNC	260	116	23
1:2000	TNC	TNC	125	65	13
1:20,000	120	100	56	13	5
1:200,000	65	45	9	1	1
1:2,000,000	44	3	7	1	-

* Too numerous to count.

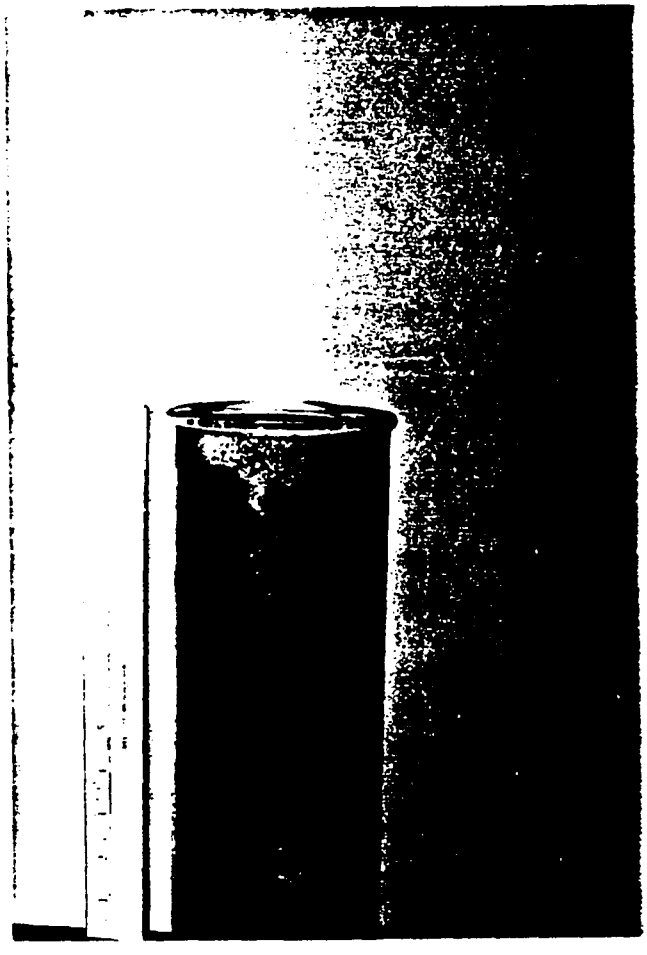


Figure 4.6 Soil column with 500 ml of ignitable waste in the form of solvent recovery waste applied at the top.

application of the solvent recovery waste. One gram of soil sample was collected from different points in the glass column representing varying depths of one to four feet, diluted appropriately and poured into nutrient agar plates.

The counts significantly decreased from more than 500 colonies at the surface to about 22 bacterial colonies at a depth of four feet, using a dilution of 1:200. The other dilutions yielded similar results. Figure 4.7 shows the bacterial colonies from different points in the soil column in nutrient agar prior to application of flammable waste. The number and size of the bacterial colonies on the soil surface significantly decreased following a single application of solvent recovery waste (Figure 4.8). However, the number of bacterial colonies gradually increased and reached normal counts (same as control) after 4 weeks, indicating a gradual recovery from the effects of the hazardous constituents in the waste (Fig. 4.9).

The solvent recovery waste partially sterilized the surface of the soil column and apparently had a deleterious effect on the microbial population. However, these bacterial colonies were able to recover and increase in number after four weeks.

Where wastes are applied at acceptable loading rates, the potential problems associated with waste dis-

Table 4.10 Bacterial Colony Counts per gram of soil in the unsaturated zone before and after application of solvent recovery waste.

Days in which soil samples were taken	Bacterial Colony Counts Per Gram of Soil* (X 1000)				
	Surface	1 ft.	2 ft.	3 ft.	4 ft.
Control	2,420	2,000	1,120	260	100
1 hour post ap.	200	1,900	1,000	220	40
7	940	1,680	600	240	60
14	1,600	1,240	560	200	20
21	1,870	1,541	1,080	240	80
28	2,620	1,940	1,100	260	100
35	2,601	1,980	1,131	252	95

* Means differed significantly at P=0.05 using Duncan's Multiple Range Test.

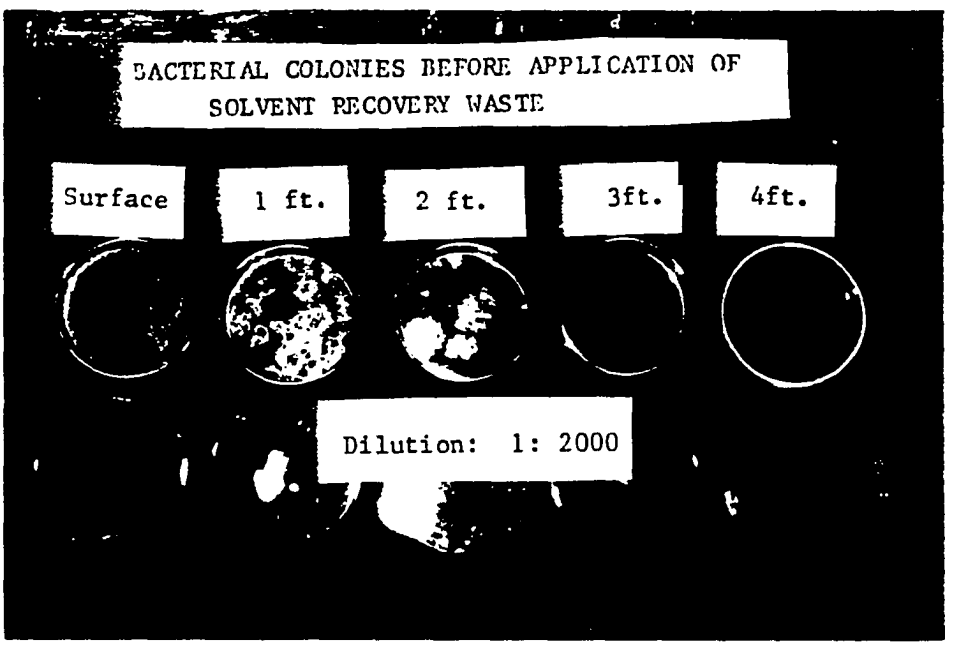


Figure 4.7 Bacterial colonies from different points in the soil column prior to application of ignitable waste (control plates). Note the lower numbers of bacterial colonies at 4 feet below the surface.

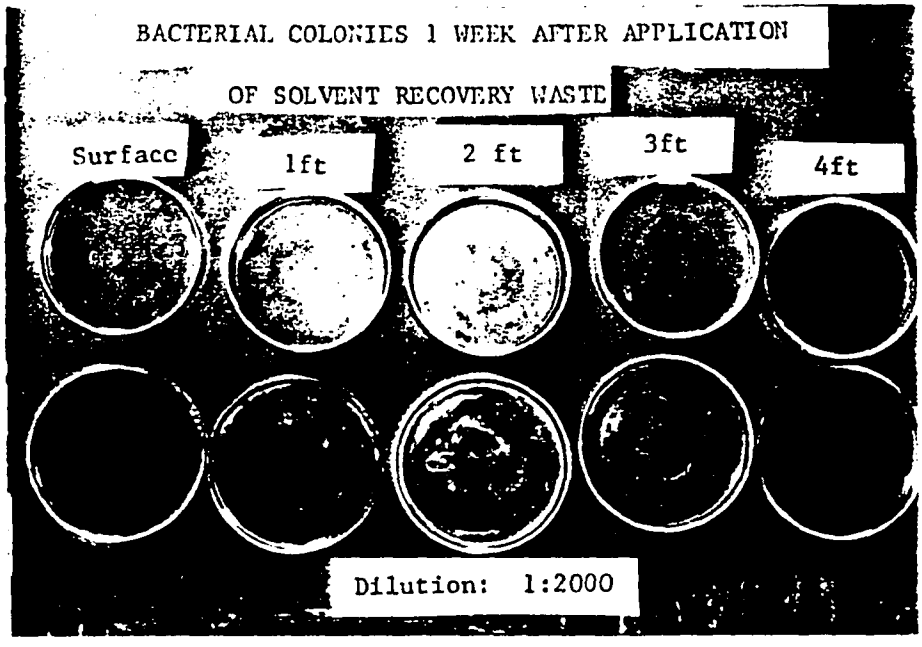


Figure 4.8 Bacterial colonies 1 week after application of ignitable waste on top of the column. Note the marked reduction in colony counts at all depths in the soil column. Compare with control plates in Figure 4.7.

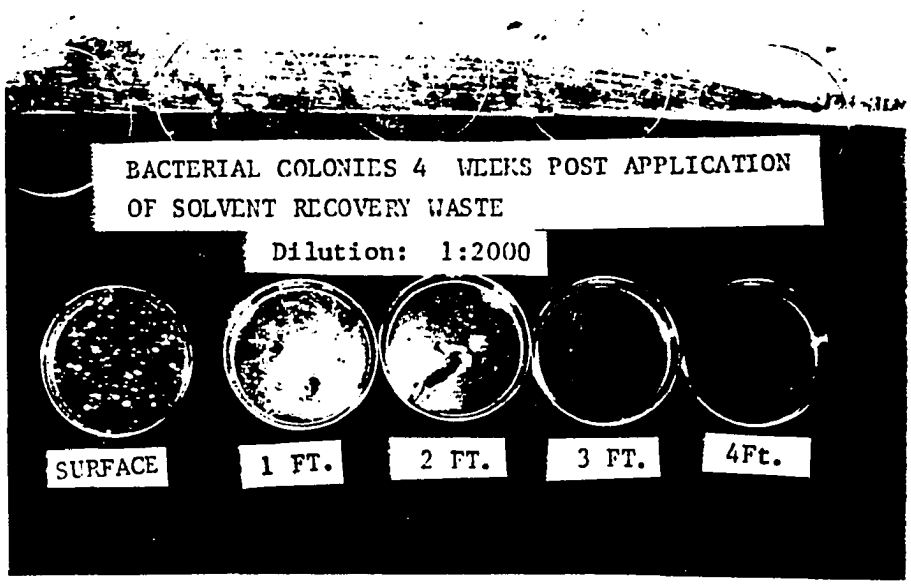


Figure 4.9 Bacterial colonies in nutrient agar plates four weeks after application of ignitable waste on top of the column. Note the apparent recovery of soil bacteria at the surface after four weeks.

posal, including extended anaerobiasis and production of undesirable end products, can be prevented or minimized. However, such soil has certain physical, chemical and biological limits as to how much of a particular chemical waste it can accommodate at one time, and if loaded excessively will display certain deleterious effects of rapid oxygen depletion, extended anaerobiasis, chemical reduction, and the accumulation of odorous, and/or phytotoxic end products which will impair the soil's fertility and productivity for some time.

Shock loadings of certain chemical wastes and their excessively toxic and biocidal effects on the soil microflora should be avoided, if possible, to prevent serious and lasting impairment of the soil's biodegradative potential. The biological degradation of specific organic chemicals is dependent on the chemical characteristics of the organic compounds in question. The longer chain hydrocarbons and ring-compounds have been found to degrade more slowly than shorter chain, single ring aromatic compounds. Degradation is also dependent on soil characteristics, as well as the location of the chemical in the unsaturated zone.

CHAPTER V

GENERAL CRITERIA FOR LAND APPLICATION OF ICW

5.1 GENERAL

In the design of a land treatment system for ICW, consideration must be made for the following:

(1) Source, quantity and quality of the waste streams, or waste characteristics. Corrosive waste may either be aqueous or in slurry form, while ignitable waste is usually aqueous. The nature of the waste stream will determine the method of application of the waste to the land as well as the loading rate.

(2) Climate and plant-soil systems. Most facilities surveyed indicated that loading rates must be considerably reduced during wintertime as a result of cold weather, when biodegradation of waste takes place at a slower rate. Warm weather is considered ideal for biodegradation, consequently loading rates can be higher during the warmer months. Land application systems in the southern states will probably function more efficiently than those found in the northern states. The influence of climate and different soil types on the efficiency of land

application systems cannot be overemphasized.

(3) Intermediate pretreatment processes that make the waste amenable to land treatment. It must be emphasized that land application per se of corrosive or ignitable waste would destroy the capacity of the soil to degrade, immobilize or transform the waste, which is the very essence of the effectiveness of land application systems. Pretreatment of ICW prior to land application should be incorporated in the design criteria.

The design methodology deals predominantly with the plant-soil-system. On the other hand, the constituents of the waste will determine the acceptable assimilative capacities of the plant-soil system. Therefore, the design criteria is based on four major stages, as outlined by Overcash (5):

Stage 1. The determination, on a constituent-by-constituent basis of:

(1) Plant-soil assimilation characteristics

(2) Assessment of waste generation

(3) Determination of the land limiting constituent (LLC)

Stage 2. Design evaluation of all required components and a cost analysis, expressed in investment costs or average annual costs per unit amount of LLC.

Stage 3. The selection and cost analysis of pretreatment or in-plant alternatives for reducing the total level of LLC.

Stage 4. A cost-benefit analysis weighing the cost of the total land receiver against cost of the pretreatment processes to put the total system cost at a minimum. Comparison is made with other industrial management alternatives to allow selection of the most cost-effective alternative.

Table 5.1 summarizes the typical design features of two types of land treatment processes on pretreated hazardous waste, the slow rate (SR) and the rapid infiltration land treatment systems. The range of values given represents successful experience in a variety of locations in the United States.

The design of all land treatment processes, is based on the land limiting constituents (LLC) which could be determined. It is necessary to identify the critical factors or parameters that limits or controls the design. The volume of flow or hydraulic loading can be an independent or controlling variable in the design of a land treatment system. For example, a grass covered hay field might be able to receive 3 in/week of pretreated wastewater, and still satisfy nitrogen requirements in the percolate. However, if the soil were a slowly permeable

Table 5.1 Typical Design Features for Two Types of Land Application Processes.

Parameter	Slow Rate	Rapid Infiltration
Application Method	sprinkler or surface	usually surface
Annual Loading, ft.	2-20	20-400
Treatment areas for 1 mgd, acres	60-700	70-60
Weekly application, in.	0.5-4	4-96
Minimum preapplication treatment	primary	primary
Need for vegetation at closure	required	sometimes used to stabilize
Organic Loading lbs BOD/acre/day	45-450	130-890
Soil Permeability range	0.06-20	less than 2.0
Permeability class range	moderately slow to moderately rapid	rapid
Textural class range	clay loams to sandy loams	sandy and sandy loams
Unified Soil Classification	GM-d, SM-d, ML, OL, MH, PT	GW, GP, SW, SP

Source: Berkowitz, et.al. (19)

clay the application rate might be limited to 1 in/week or less due to the hydraulic constraints. In this case, the hydraulic loading capacity is the land limiting constituent.

Each industry's waste has unique characteristics of its own and therefore the land limiting constituent will also differ from one industry to another and from site to site.

5.2 LAND LIMITING CONSTITUENT ANALYSIS

Land limiting constituent analysis (5) involves the determination of assimilative capacities in kg/ha/year, which is based on site-specific characteristics and detailed waste characterization. The waste characterization for each constituent is expressed in kg/year. The ratio of waste generation to assimilative capacity gives the total area required for an environmentally acceptable land application system. A comparison of the constituents will show one requiring the greatest land area, and this one is designated the land limiting constituents (LLC). This constituents will be used to determine the total land area required.

5.2.1 Waste Characterization

An evaluation of the characteristics of ICW is an important step in selecting ICW management alternatives. Laboratory analyses (pH, conductivity, flash point,

alcohol content) are required for ICW. A detailed analysis of present and projected volumes is also required. The evaluation should include the following:

(a) present and projected quantities of ICW, and

(b) detailed chemical analysis of ICW.

5.2.2 Environmental Considerations

(a) Climate - Although restrictive climatic conditions exist in some regions in the U.S., conditions usually vary greatly within a given region. The atmosphere modifies soil-waste interactions and acts to transport waste in the environment. Table 5.2 summarizes the various influences of atmospheric variables on land treatment operations and processes.

(b) Winds - It is necessary to minimize public risk from treatment operations caused by prevailing winds. Hot weather or recent waste applications cause volatilization and transport of waste constituents. Land treatment facilities, therefore, should be placed downwind of major population centers.

(c) Temperature and Moisture - Facilities located in cold northern or mountainous regions have seasonal treatment restrictions and may need to have storage capabilities, as land application in winter is usually not feasible. Temperature and moisture also affect the rate of microbial activity in the soil,

Table 5.2 The Influence of Atmospheric Variables on Land Treatment Operations and Processes.

Operation or Process	Atmospheric Variable	Effect
Biodegradation	Temperature	Indirect-controls soil temperature which controls microbial populations and activity
	Precipitation-Evapotranspiration	Indirect-controls soil moisture which controls (1) soil aeration, the supply of oxygen for microbes, and (2) adequacy of water supply
Waste Application	Temperature	Direct-cold temperatures increase waste viscosity, thus decreasing ease of handling and hot temperatures may restrict application due to waste volatility hazard
		Indirect-cold temperatures keep soil temperature low, which can limit soil workability and waste degradation, and may increase the amount of runoff
	Precipitation-Evapotranspiration	Indirect-soil wetness can inhibit field accessability and enhance the waste leaching hazard
	Winds	Direct-hazard of off-site pollution due to transport of particulates and volatile constituents
	Atmospheric Stability	Direct-surface inversions can lead to fumigation of the surface layer by volatile waste constituents
Site Selection	Winds	Direct-potential hazard to public from advected particulates and volatile constituents.

Source: Hazardous Waste Land Treatment, EPA SW-874, April, 1983.

thus affecting degrading rates of ICW.

Regions with excess moisture may require special designs or operational procedures such as field drainage systems, increased waste storage capacity, major run-off and run-on structures, etc.

(d) Plant-Soil Systems - An analysis of soil in the suggested site should include information on soil texture, permeability, available water holding capacity, shrink-swell potential, pH and cation exchange capacity. The chemical and physical/hydraulic properties of a soil determine how effective it is in attenuating potential contaminants, controlling run-off and leachates. Permeability classes for saturation are presented in Table 5.3. Typical ranges of Cation Exchange Capacity (CEC) of various types of soils are presented in Table 5.4 and Figure 5.1.

(e) Regional Geology - The following significant geologic features of the area are required to determine the proper design and monitoring needs of the treatment facility (11):

1. depth to bedrock and characteristics of the bedrock
2. characteristics of soil above the bedrock
3. outcrops
4. aquifer recharge zones

Table 5.3 Permeability Classes for Saturated Soil

Soil Permeability (cm/s)	Class	Representative Soil Classification
4.2×10^{-5}	Very Slow	Clay
4.2×10^{-5} to 1.4×10^{-4}	Slow	Clay & Loam
1.4×10^{-4} to 4.2×10^{-4}	Moderately Slow	Clay, Loam & Silt
4.2×10^{-4} to 1.4×10^{-3}	Moderate	Loam & Silt
1.4×10^{-3} to 4.2×10^{-3}	Moderately Rapid	Sand & Silt
4.2×10^{-3} to 1.4×10^{-2}	Rapid	Sandy Gravel
$> 1.4 \times 10^{-2}$	Very Rapid	Gravel

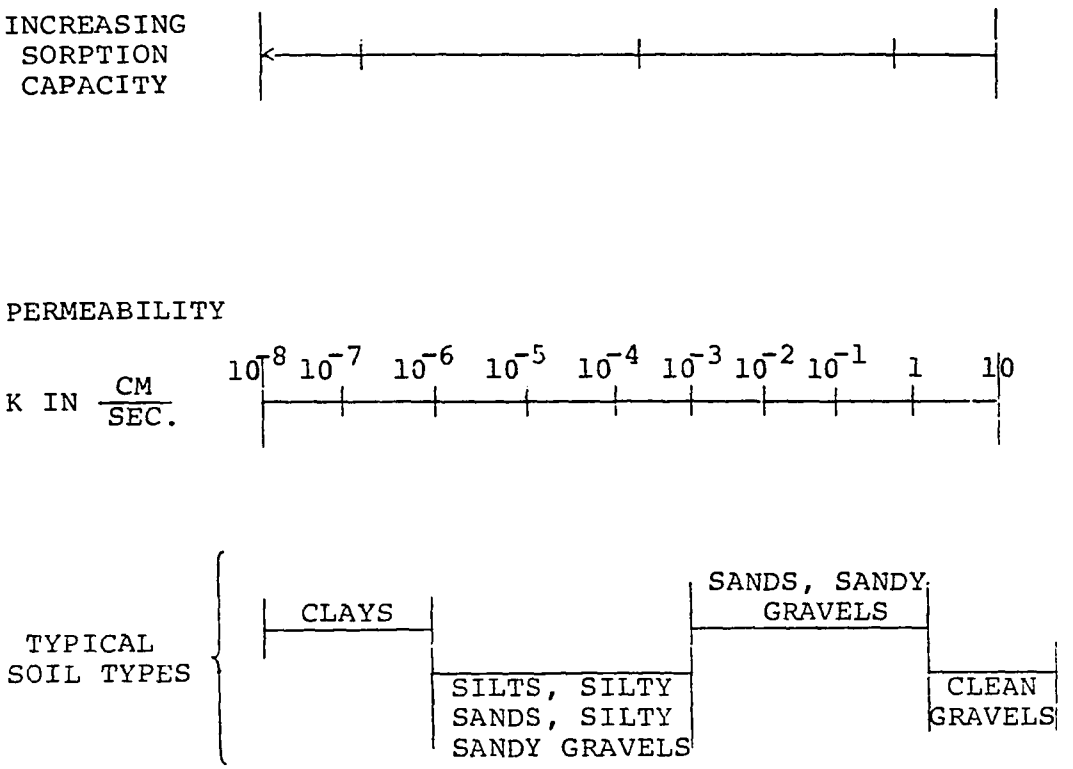
Source: Overcash (5)

Table 5.4 Typical Ranges of Cation Exchange Capacity of Various Types of Soils.*

Soil Type	Range of CEC, meq/100 g
Sandy Soils	1 to 10
Silt Loams	12 to 20
Clay and Organic Soils	Over 20

Source: US EPA, Process Design Manual, EPA-625/1-78-010, Oct. 1978. (34)

Figure 5.1 Soil Permeabilities and Sorptive Properties of Selected Soils.



Source: U.S. EPA, Process Design Manual: Municipal Sludge Landfills, Document No. EPA-625/1-78-010; Cincinnati. Ohio. Oct. 1978.(34)

5. discontinuities such as faults, fissures, joints, fractures, sinkholes, etc.

(f) Topography and Drainage - Drainage patterns for the area should be determined. A 1 percent grade is usually sufficient to avoid standing water and prevent anaerobic conditions. Too steep locations prevent adequate surface drainage. A topographic map of the area will aid in assessing required topographic parameters for land treatment design.

5.3 SITE SPECIFIC CONCEPT DESIGN

There are several options for operating a land application facility for ICW in an environmentally sound manner under different general conditions. The specific design and management will be established on a case-by-case basis, and will depend on the following factors:

1. quantity and quality of ICW
2. terrain and area involved
3. access needs, service areas, parking
4. pattern of application- strip or contour application
5. collection and disposal of run-off and run-on water
6. buffer zones
7. land preparation- cleaning trees or brush, leveling, etc.

8. Water control and management- cumulative periods of rainfall, available storage volume, temperature and pan evaporation are needed to develop a water balance, acceptable hydraulic loading rates and sizing run-off diversion and retention structures. Diversion structures must be designed to prevent flow onto the treatment zone from the peak discharge of at least a 25-year storm.
9. Subsurface drainage- the seasonal high water table should not rise higher than 1 meter (3 feet) below the bottom of the treatment zone (6). Subsurface drainage may be needed to lower and maintain the water table below some desired depth, to increase aeration in the surface soil, and to decrease the hazard of groundwater contamination.
10. Air emission control- wind dispersal of contaminants and dust from traffic on facility roads may also present a problem. On an operational basis, wind, atmospheric stability, and temperature are important considerations for timing the applications of wastes, especially volatile wastes (6).
11. Management of soil pH- a neutral soil pH is important to maintain plant nutrition, keep

soil microorganisms active and ensure survival of symbiotic nitrogen fixing bacteria for waste degradation. Acidity in soils may be reduced by addition of calcium or magnesium compounds (liming). Soil sampling and testing should be done periodically. Alkaline soils have been treated with dilute sulfuric acid solutions from some industries with some success (5,23).

12. Vegetation cover- revegetation is generally required at closure (11). It is desirable to establish a permanent cover following closure to prevent long-term erosion hazards. Appropriate species should be selected and adequate seedbeds maintained.
13. Soil fertility- nutrient imbalances affect plant growth and reproduction of microbes, and thus limit waste degradation. Fertilizer must be applied periodically for nutrient deficient soils. A carbon nitrogen ratio greater than 38 is desirable (23).
14. Waste application techniques- sprinkler irrigation may be utilized for wastes with 95 percent to 100 percent water, while dry, volatile, or toxic materials may require subsurface injection techniques. There must be uniform application of waste to the soil. Surface

spreading and mixing is the typical method for sludges or semiliquids.

15. Equipment- equipment for hauling and spreading the wastes is commonly available.
16. Records and reporting- a checklist of items needed for a thorough record of operations at a land treatment site is presented in Table 5.5.

5.4 MONITORING

The topics to be considered in developing a monitoring program for a hazardous land treatment site are presented in Figure 5.2. In addition, current regulations (EPA, 1982) require the following types of monitoring, listed in Table 5.5.

a. Groundwater detection monitoring to determine if a leachate plume has reached the edge of the waste management area (40 CFR 264.98).
b. Groundwater compliance monitoring to determine if the facility is complying with groundwater protection standards for hazardous constituents (40 CFR 264.99).
c. Soil pH and concentration of cadmium in the waste when certain food-chain crops are grown on HWLTs where cadmium is disposed (40 CFR 264.276).
d. Unsaturated zone including soil cores and soil-

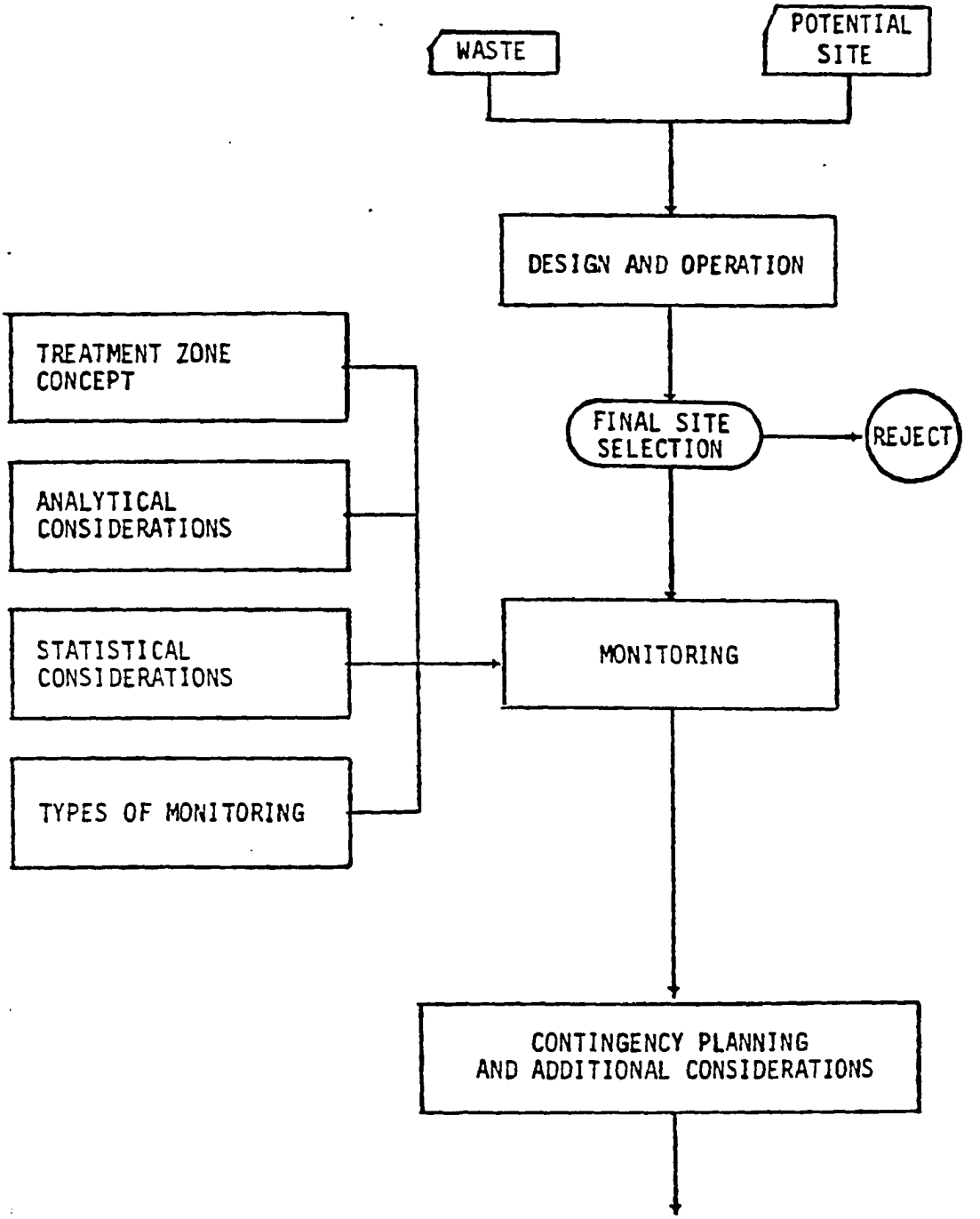


Figure 5.2 TOPICS TO BE CONSIDERED IN DEVELOPING A MONITORING PROGRAM FOR AN HWLT UNIT

Source: Hazardous Waste Land Treatment, EPA, SW-874, April, 1983. (6)

Table 5.5 Checklist of Items Needed for a Thorough Record of Operations at a Land Treatment Unit

1. Plot layout map
2. Inspections
   a. weekly observations on levees and berms*
   b. observations of odor, excessive moisture, need for maintenance, etc.*
3. Waste Applications
   a. Date
   b. Amount and rate
   c. Location
4. Waste Analysis
   a. Original
   b. Quarterly waste analysis reports
   c. Any changes in application rate needed due to change in waste
5. Fertilizer and lime applications*
   a. Date
   b. Amount
   c. Location
6. Vegetation Efforts*
   a. Planting date
   b. Species planted
   c. Fertilizer applied
   d. Emergence date
   e. Groundwater

(Continued)

Table 5.4 (Continued)

7. Monitoring Sample analyses
   a. Soil samples
   b. Waste samples
   c. Groundwater samples
   d. Leachate samples
   e. Runoff samples*
   f. Plant tissue samples*
8. Climatic parameters*
   a. Rainfall
   b. Pan evaporation
   c. Air temperature
   d. Soil temperature
   e. Soil moisture
   f. Wind velocity and direction
9. Water depth in retention basins*
10. Accidents
   a. Personal injury
   b. Amount and type of waste spilled
   c. Location
11. Breaches of security
12. Breaches of runoff retention resulting in uncontrolled off-site transport
13. Maintenance schedule
   a. Levees and berms
   b. Regrading of plots
   c. Grassed waterways
   d. Tilling activities
   e. Roads

*Not required by regulation but important to successful management of an HWLT unit.

Source: EPA SW-874, April, 1983 (6)

pore liquid monitoring to determine if hazardous constituents have migrated out of the treatment zone (40 CFR 246.278).

e. Waste analysis of all types of waste to be disposed at the HWLT (40 CFR 264.13).

A sound monitoring program should account for potentially harmful effects of all waste constituents. Facility permits normally address both hazardous and nonhazardous constituents. The frequency of sampling and the parameters to be analyzed depend on the characteristics of the waste being disposed. Waste streams need to be routinely sampled and tested to check for changes in composition. Guidance for an operational monitoring program at hazardous waste land treatment sites is presented in Table 5.6.

5.5 CLOSURE AND POST CLOSURE

Monitoring continues as before with some modification during closure and post closure of a hazardous land application site. The time required will vary considerably from site to site based on the rate of degradation of wastes applied and final cover requirements.

Except where no significant concentrations of hazardous constituents remain in the treatment area, the final surface must be covered with permanent vegetative cover to prevent water and wind erosion and off-site

Table 5.6 Guidance for an Operational Monitoring Program at HWLT Units.

Media to be Monitored	Purpose	Sampling Frequency	Number of Samples	Parameters to be Analyzed
Waste	Quality Change	Quarterly composites if continuous stream; each batch if intermittent generation.	One	At least rate and capacity limiting constituents, plus those within 25% of being limiting, principal hazardous constituents, pH and EC
Soil cores (unsaturated zone)	Determine slow movement of hazardous constituents	Quarterly	One composited from two per 1.5 ha (4 ac); minimum of 3 composited from 6 per uniform area.	All hazardous constituents in the waste of the principal hazardous constituents, metabolites of hazardous constituents, and nonhazardous constituents of concern.
Soil-pore liquid (unsaturated zone)	Determine highly mobile constituents	Quarterly, preferably following leachate generating precipitation snowmelt.	One composited from two samplers per 1.5 ha (4 ac); minimum of 3 composited from 6 per uniform area.	All hazardous constituents in the waste or the principal hazardous constituents, mobile metabolites of hazardous constituents, and important mobile nonhazardous constituents.
Groundwater	Determine mobile constituents	Semiannually	Minimum of four suggested--one upgradient, three down gradient.	Hazardous constituents and metabolites or select indicators.
Vegetation (if grown for food chain use)	Phytotoxic and hazardous transmitted constituents (food chain hazards)	Annually or at harvests.	One per 1.5 ha (4 ac) or three of processed crop before sale.	Hazardous metals and organics and their metabolites.
Runoff water	Soluble or suspended constituents	As required for NPDES permit.	As permit requires, or one.	Discharge permit and background parameters plus hazardous organics.
Soil in the treatment zone	Determine degradation, pH, nutrients, and rate and capacity limiting constituents	Quarterly	7-10 composited to one per 1.5 ha (4 ac).	
Air	Personnel and population health hazards	Quarterly	Five	Particulates (adsorbed hazardous constituents) and hazardous volatiles.

Source: Hazardous Waste Land Treatment, EPA SW-874, April 1983 (6)

transport of soil and waste materials (35).

Along with the establishment of permanent vegetation, the collection, treatment and disposal of run-off water must continue until the water meets water quality standards. Acceptability of run-off water quality for direct discharge should be based on a series of samples taken over a period of time, preferably three consecutive sampling events from representative storms. When water quality criteria are met, direct discharge to sewers or receiving streams may be permitted.

During the closure period, soil core and groundwater monitoring also must continue. Once it has been determined that the water and soil are free from hazardous and key nonhazardous constituents, run-off water monitoring and soil-pore liquid sampling may be discontinued.

The intent of post-closure care is to complete waste treatment and stabilization of the remaining soil and waste residuals while checking for unforeseen long-term changes in the system. Present regulations call for continuation of post-closure activities for up to 30 years unless it has been demonstrated that a shorter period is acceptable (6).

5.6 SITE SELECTION

The technical considerations that must be considered

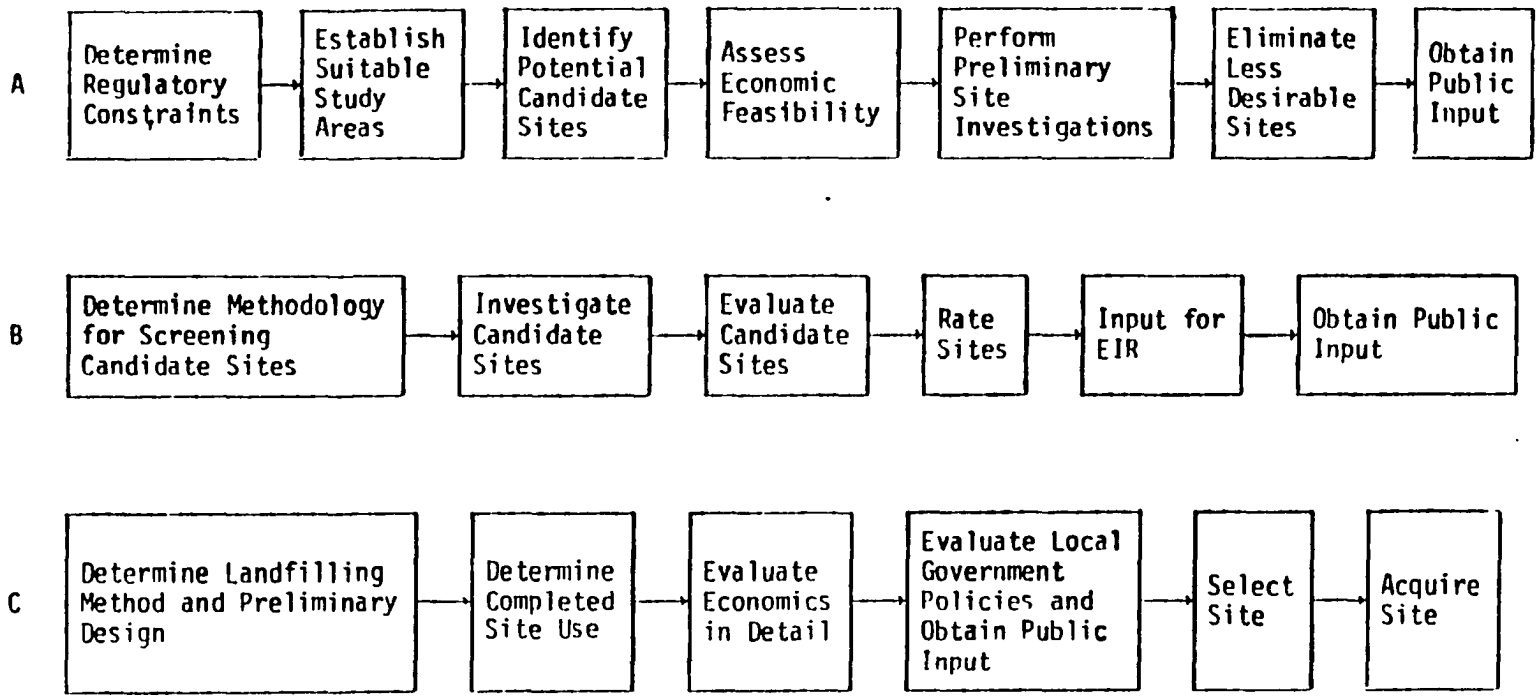
in site selections are:

a. site life and size
b. topography
c. surface water
d. soils and geology
e. ground water
f. vegetation
g. site access
h. land use
i. archeological and historical significance
j. environmentally sensitive areas
k. cost

Figure 5.3 is a summary of site selection methodology.

5.7 CORROSIVE WASTE

Table 5.7 presents the pretreatment and final disposal technology for some selected major industrial generators of D002. Landfilling as a final treatment/-disposal technology, was more commonly used by the pharmaceutical, pulp and paper, textile mill and paint industries. Incineration was used by the pharmaceutical, pulp and paper and the organic dyes/pigments industries. Those that generated large quantities of organic wastes such as pulp and paper, pharmaceutical and cyclic crude and intermediates, used biological ponds as a pretreatment technology.



A = Initial Assessment of Sites
B = Screening of Candidate Sites
C = Final Site Selection

Figure 5.3 Site Selection Methodology.

Source: U.S. EPA, Process Design Manual: Municipal Sludge Landfills, Document No. EPA-625/1-78-010; Cincinnati, Ohio, Oct. 1978. (33)

Table 5.7 Major Industrial Generators of D002, Pretreatment and Final Disposal Technology.

	Industry	D002 Waste	Pretreatment Technology	Final Disposal Technology
1.	Petroleum Refining	-Alkaline wastes from cracking process -Acidic wastes from alkylation and polymerization -Sulfidic spent caustics -Phenolic spent caustics	-Dilution with cooling and wash water -Dilution and neutralization with lime or soda ash	Land application
2.	Pharmaceutical (organic chemicals)	- Spent acids, bases, and solvents	-All aqueous wastes streams to biological wastewater treatment facility	Biological sludges are landfilled Incineration
3.	Pulp & Paper	- Green liquor dregs (NaOH) -Chlorinated resin, acids, phenolics -Lime muds	Biological Treatment -Neutralization	Landfill Incineration
4.	Textile Mills	-Scouring Solution -Bleaching Wastes -Mercerizing/Dyeing/ Printing Solutions	-Neutralization	Landfill
5.	Paint	-Process Cleaning Solutions (spent solvents, acids, bases)	-Neutralization/Dilution	Landfill
6.	Cyclic Crude & Intermediates	-Run-off from process areas -Sour Water Stripper -H_2S	-Electrostatic precipitator for suspended solids and particulates -Dilution -Scrubbers for gaseous pollutants as NO_x and SO_x.	Biopond for liquid effluents Pond sludges are landfilled Incineration for H_2S

Table 5.7 (continued)

	Industry	D002 Waste	Pretreatment Technology	Final Disposal Technology
7.	Organic Dyes/ Pigments	- Stripping wastes -Slab washdowns -Vessel cleanouts -Acidic effluents	-Carbon Adsorption beds - do - - do - -Neutralization with lime	Secondary treatment in a municipal sewage treatment plant Incineration/Landfill
8.	Citrus Processing	-Spent caustic cleaning solutions	-Recycle Neutralization	Land application
9.	Fertilizer Industry	-Gypsum slurry -Off-gas scrubber liquor -Acid sludge -Steam condensate	-Recycle of acidic gypsum slurry -Neutralization	Gypsum pond
10.	Steel Industry	-Spent pickle liquor -Acidic rinse waters	-Dilution -Neutralization	Landfill
11.	Inorganic Chemicals (hydrofluoric acid)	-Gypsum solids -Drip acid -Scrubber waste water	-Neutralization with lime -Wastewater treatment plant	Settling storage gypsum ponds
12.	Explosives/ Munitions Industry	-Red and Pind Water -Red Water	-Chlorination,bromination for color removal -Neutralization with lime or soda -Evaporation in rotary kilns -UV-light catalyzed ozonation and reduction	Final sludge sold or incinerated Red water used as fuel

The use of land treatment for the disposal of corrosive waste is a very viable one. Five alternative strategies for the development of a land application system based on pH can be employed utilizing the following options.

1. Neutralization of acids or bases prior to land application.
2. Dilution of acids or bases thus reducing their corrosive properties and bring the pH to allowable limits.
3. Utilization of existing soil buffering capacity.
4. Addition of soil conditioners to bring the soil pH to normal before or after application of the waste.
5. The use of highly buffered soils or use of acid wastes on alkaline soils or alkaline wastes on acid soils.

The amount of base required for a constant change in pH is highly dependent on the nature of the soil. Figure 5.4 shows the limestone requirements for correction of soil pH. The clay loam soil needs much larger quantities of limestone as compared to sandy loam. This, therefore, indicates different management strategies for different soil types and climatic zones. Data from waste soil interaction studies must be interpreted to determine fea-

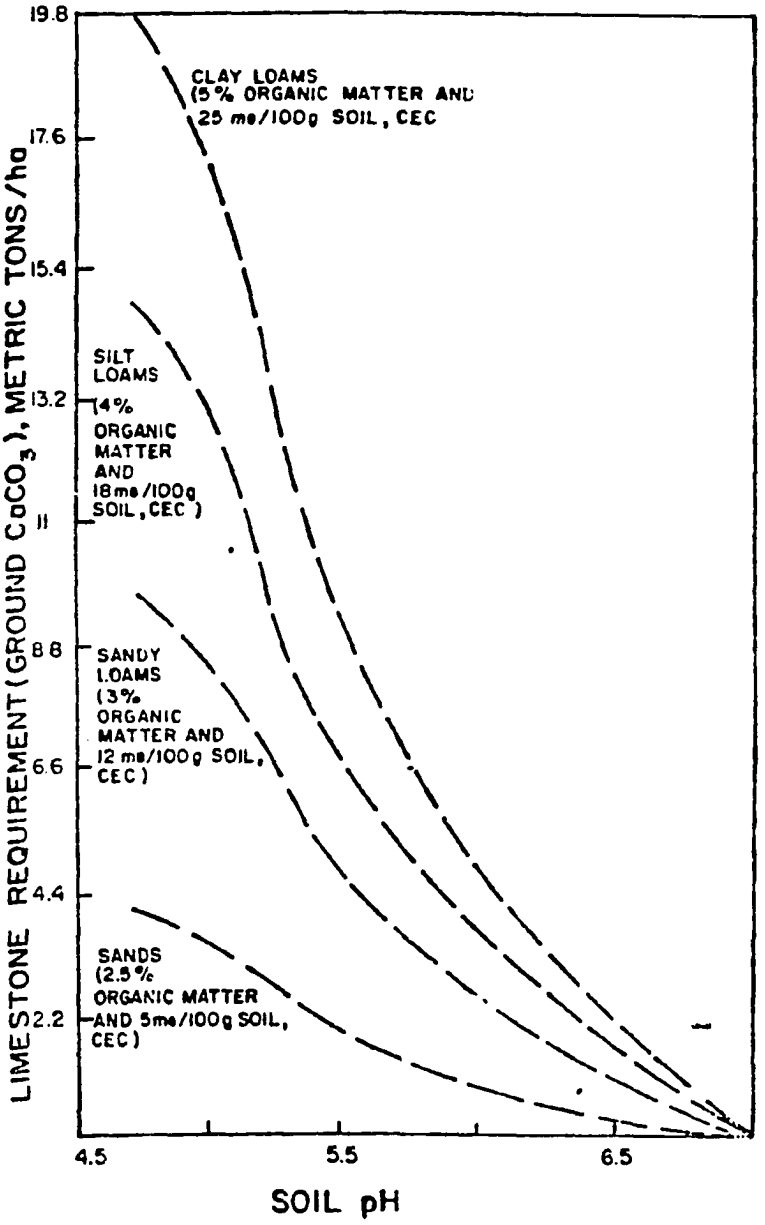


Figure 5.4 Limestone correction of soil pH.

Source: Overcash (5)

sibility, acceptable loading rates, management needs, and monitoring requirements.

In the design of a land treatment system for corrosive wastes, consideration must be given to the assimilative capacity of the soil for acids or bases, and in the case of strong acids neutralization by strong bases and salts. When acids or bases are applied to a plant soil system, an initial reaction occurs. A neutralization takes place to an extent dictated by the reactive soil fraction or soil buffering capacity, and by the strength and dissociation of applied acid or base (5).

After initial plant-soil response, organic acids and bases would be expected to undergo microbial degradation and thus be converted to soil organic matter or gaseous microbial end products (CO_2). Organic acid decay improves soil physical conditions by improving soil texture and structure. The inorganic acids and bases behave as conservative or nondecomposable species. Inorganic acids dissociate to a greater extent than organic acids. These inorganic acids or bases will eventually migrate with the movement of water, applied wastewater or rainfall, in a manner analogous to the movement of cations and anions in a natural plant-soil system. Thus, in the long term, cumulative storage capacity of soils is exceeded and an ion balance must again be determined (6).

The first portion of the design for waste assimilation is to minimize the dose effect of the initial soil reactions. That is, waste acids or bases are not applied at such a high ratio of the soil buffering capacity that there is a severe loss of vegetation or soil microbial populations. Avoidance of these dose effects, which are primarily waste concentration dependent, can be accomplished through waste pretreatment. The second portion of assimilative capacity is to ensure that there is a long term correction for acid or base imbalances. In other words, the waste-soil complex must be amended with supplementary chemicals that will maintain functional agricultural capacity of the soil system. The final portion of the assimilative capacity design is to determine the parameters necessary to keep the impact of the cations and anions on receiving waters within acceptable limits. From soil hydraulic assimilative capacity, it can be found what percentage of the applied water and rainfall moves through the soil to surface waters and to groundwater. Therefore, sufficient land must be used so that the concentration of material reaching groundwater or surface waters does not exceed the respective water quality standards.

The buffering capacity of the soil can be altered with the application of corrosive wastes. Changes in pH result in altered relationships, which in turn affect the

assimilative capacity of plant-soil systems for waste constituents. One relationship that is changed is the nature of the ions present on the soil cation exchange complex. As pH is lowered, greater amounts of Al^{+3} and H^{+} dominate the soil complex. Both high and low pH reduce the availability of essential nutrients like Ca, Mg, P, to the plant (18). Alternative strategies for the development of the assimilative capacity of the soil could therefore be employed as mentioned earlier. This includes various pretreatment methods such as neutralization of corrosive wastes, or correction of substantial pH changes in soils by the addition of soil conditioners, use of acid wastes on alkaline soils and vice versa.

5.8 IGNITABLE WASTE

The results of the survey indicated that most of the ignitable wastes generated by industry in the U.S. are disposed using other technology such as incineration, landfilling, recycling, or deep well injection (35,36, 37,38,39). These methods have a variety of constraints in their application because they are either prohibitive, uneconomical, or undesirable. Incineration is undesirable because of air pollution problems and higher cost (18).

The application rate of flammable solvents and their breakdown products in the soil could be determined on an

annual basis and the land limiting constituent analysis could be performed. The significance of this parameter in the design of a land application facility should be emphasized.

Toluene is an example of an ignitable compound present in industrial waste. It has been shown that a large dose rate of toluene (1.7 g/g day soil 3.4 x 10^6 kg/ha) leads to soil sterilization (41). However, when applied at low or intermediate levels, toluene is degraded rapidly in soil. Aromatic compounds, when applied at 500 ppm level, disappear from the soil within 3 to 13 days.

It was further determined that soil pH determines the potential for leaching of aromatic compounds. A pH range of 5-7 will tightly hold aromatics in the soil by adsorption and insolubilization, thus enhancing bacterial degradation. A high pH decreased adsorption (18).

Figures 5.5 and 5.6 show the breakdown of toluene to benzoic acid and hydrocarboxylic acids and other organic acids. The biological breakdown of these compounds takes place at a fairly rapid rate in soil, and application rates could be determined knowing the specific decomposition rate constants, as determined for other compounds in an earlier discussion.

Since one of the constraints for land application of organic solvents and other ignitable compounds is their

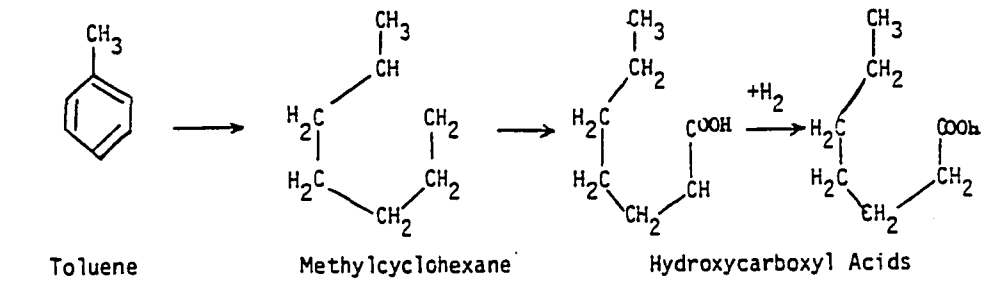
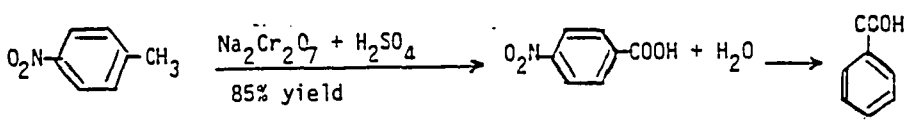


Figure 5.5 Breakdown of toluene to methycyclohexane and hydrocarboxylic acids.
Source: Brewster (44)



or Toluene → Benzyl alcohol → Benzaldehyde → Benzoic acid

Figure 5.6 Breakdown of toluene to benzoic acid.
Source: Roberts (40)

organic solvents and other ignitable compounds is their apparent toxicity to fish, copepods, oyster larvae and other land and aquatic animals, run-off and run-on control measures in a land application facility should reduce this risk considerably (18).

Other alternative treatment techniques such as sorption by activated carbon or ion exchange resins or coagulation and filtration prior to land application is utilized by many industries. The use of chemical treatment as a pretreatment method for munitions waste has been successful for PGDN and cellulose nitrate wherein the end-products could be treated biologically (37,38,39).

CHAPTER VI

LAND TREATMENT LIFE CYCLE COST CONSIDERATIONS

6.1 INTRODUCTION

Reed and Crites (36) identified eight major categories of capital costs for land treatment systems. These are transmission, pumping, preapplication treatment, storage, field preparation, distribution, recovery and land. In addition, there are costs associated with monitoring, administration buildings, roads and service and interest factors. There also may be costs for fencing, relocation of residents and purchase of water rights (36).

The relative disposal cost of land application is $12 to $25 per ton. The costs of alternative technology other than land farming is presented in Table 6.1. It therefore, appears that land application is economically the least expensive disposal method for ICW. Detailed cost information is difficult to procure from the literature and varies greatly from author to author and regionally. Cost effective analyses for land application systems should include estimates for pretreatment, site preparation (clearing, roads, fences, and monitoring

Table 6.1 Cost of Alternative Waste Treatment Technologies*

Neutralization/Precipitation	$30 - 150/Ton
Including: screening, sedimentation, flotation, neutralization & precipitation	
Solvent Recycling	$50 - 100/Ton**
Including: distillation, steam stripping, extraction	
Landfilling	$6 - 12/Ton
Incineration	$250 - 500/Ton
Range includes all types of thermal treatment	
Cement Kiln Co-Combustion	$50 - 70/Ton
Aqueous Organic Treatment	$30 - 60/Ton
Includes: sedimentation, filtration, steam stripping, carbon adsorption and biological treatment	
Chemical Stabilization/Solidification	$100 - 120/Ton
Oil/Water Separation	$25 - 125/Ton
Includes: sedimentation, emulsion breaking	
Chemical Oxidation/Reduction	$50 - 175/Ton
Includes: neutralization, precipitation, solid/liquid separation	
Evaporation Ponds	$20 - 30/Ton

* All estimates include costs for the disposal in Class 1 landfills of the residue remaining after the waste has been processed.

** Does not include credit for recovered solvent.

Source: EPA -430/9-75-003

wells), operational costs (including: equipment, personnel, vehicle maintenance and operation and fertilizer application), monitoring for pollutants (including technicians and analyses of samples), and closure costs (cultivation of vegetative cover and monitoring). The complete land application system cost can be developed from the above components.

Some of the data on cost criteria was derived from a study by Murphy et al. (7), on navy facilities. The 1984 figures were arrived at by using an inflation rate of 10% per year. The values for clearing the land and building roads and fences were obtained from Reed, 1979 (42). The cost analysis was obtained from Figs. 6.1 and 6.2. For the site clearing, it is assumed that the field is grass only and all debris will be disposed of onsite. The service roads will be 12 feet wide with gravel surfaces and will be located around the perimeter of the area and within larger fields. If fencing is used, it will consist of a 4 foot stock fence around the perimeter of the area. A maintenance cost for the service roads and fencing includes major repairs after ten years.

6.2 COST COMPONENTS

6.2.1 Monitoring Wells

Walsh, 1983 (32) listed the cost components for the upper and lower U.S. for the drilling of monitoring

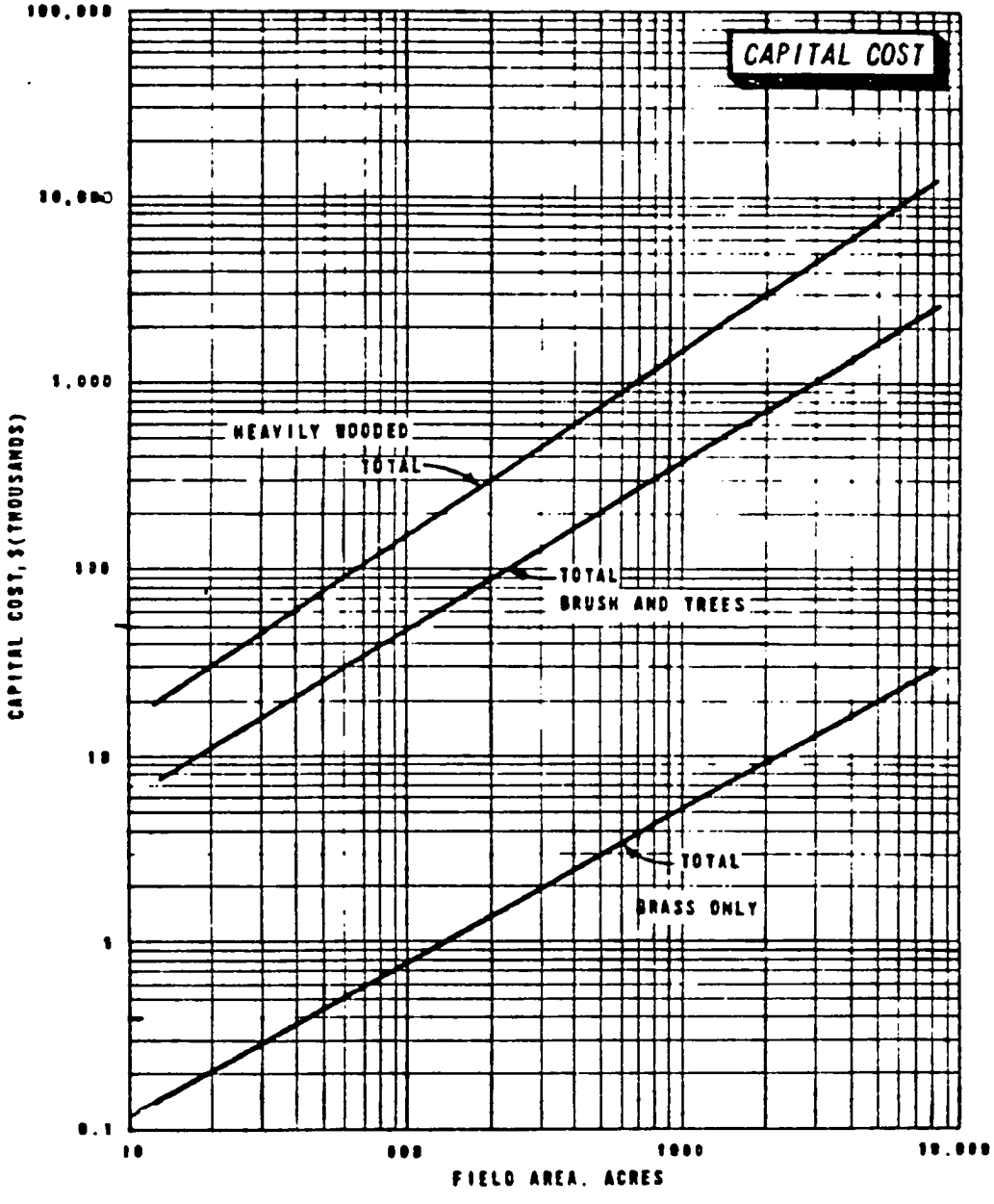
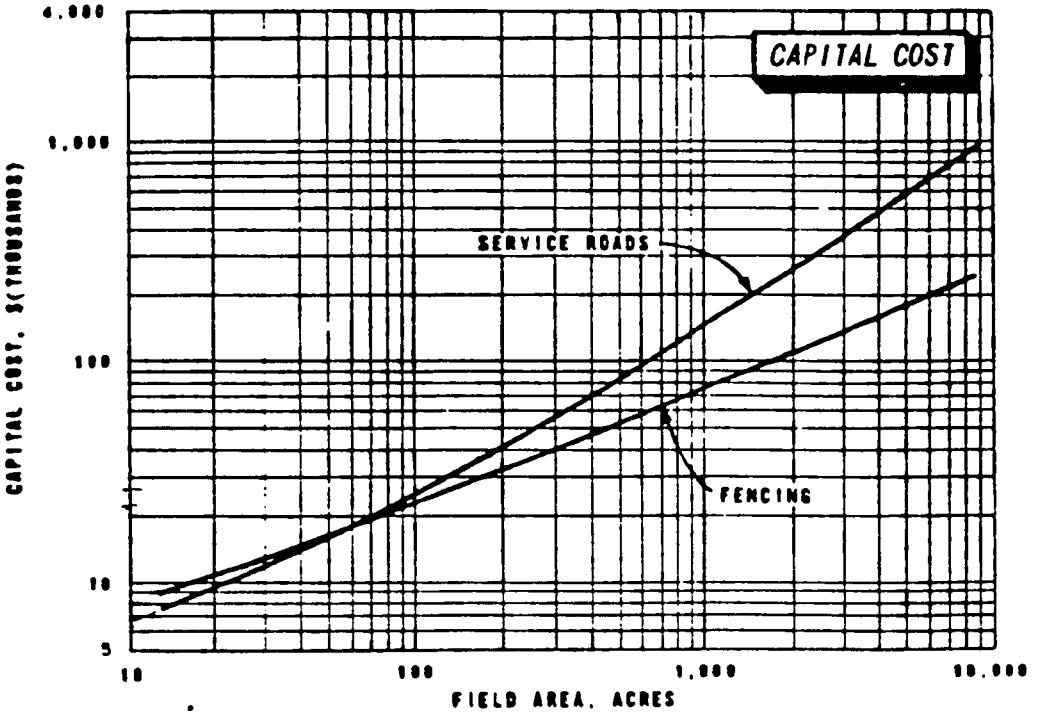


Figure 6.1 Cost of site clearing, rough grading.
Source: Reed, 1979 (42)



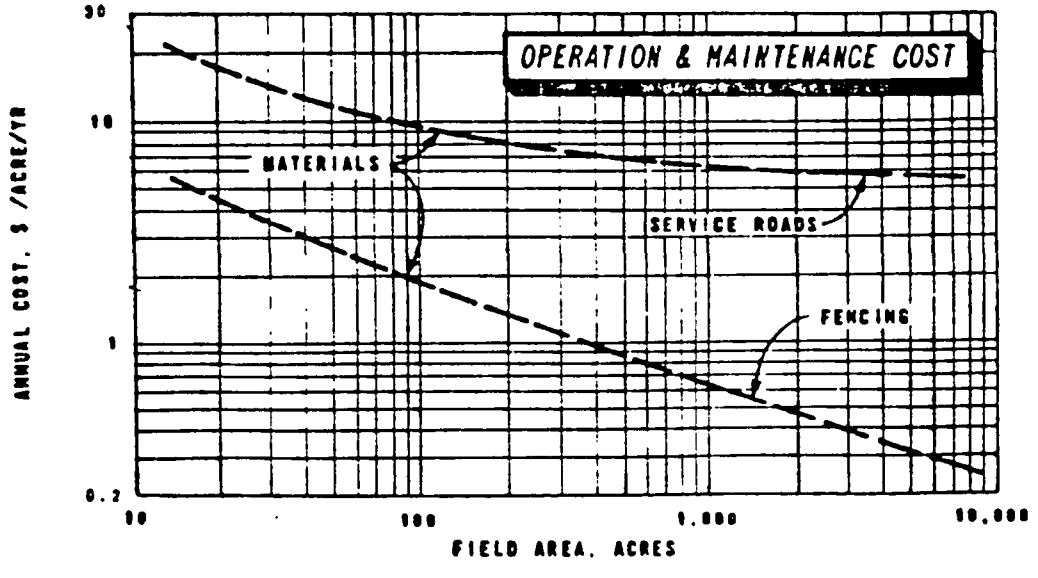


Figure 6.2 Cost of service roads and fencing.
Source: Reed, 1979 (42)

wells. These cost components updated to 1984 dollars are presented in Table 6.2.

Table 6.2 Cost Components for the Upper and Lower U.S. for Drilling Monitoring Wells, 1984

Cost Components	Costs ($) Upper U.S.	Lower U.S.
Geotechnical Investigation	$27,300	$13,300
Drill Rig Rental (1 day)	658	392
Well Points (3m)	285	168
Well Point Fittings (1)	20	11
Total	$28,263	$13,871

Source: Walsh, 1983 (32)

6.2.2 Equipment Costs

Equipment and techniques in land spreading consist of a movable tank in which mixing or agitation can be attained and from which the waste is applied to land by a spreader mechanism. There are two methods currently in use: tractor hauling of the tank and spreading equipment and truck mounted equipment. Since application is year-round, flotation tires are installed to aid in vehicle movement across wet fields. Flotation tires allow for a low compaction factor of approximately 15 psi, thus permitting increased field access. Table 6.3 shows the equipment costs obtained from Overcash and Pal, 1979 (5).

There are three types of spreading devices: 1) "T" pipe-waste which flows freely, 2) pressurized spray or rotating spinner disc (wide coverage 12m), 3) subsurface injection device (15-25 cm deep and buried), used for waste containing volatiles.

6.2.3 Labor Costs

To estimate the cost of a driver, the haul time must first be calculated. This calculation includes tank loading time (5 minutes for the 13,500 liter tank and 2 minutes for the 5,600 liter tank; Overcash and Pal, 1979 (5)); transport time (distance/ vehicle speed, truck-50 km/hr, tractor-25 km/hr), unloading time (distance to be covered/vehicle speed during unloading-injection operations = 6-9 km/hr), and return time. This number can be compared to the figures shown in Figure 6.2 to derive cost per day/ton ($/T). (See Table 6.3 and Figure 6.3.)

Once the haul time is calculated for each site, the following wage scale from Waste Oil Recovery Practices State of the Art 1972 (35) can be used. (See Table 6.4.) Vehicle maintenance and operation, including repairs, fuel, oil, and insurance for one tank truck or tank trailer unit plus tractor in 1984 is estimated at $2,170 (35).

Table 6.3 Equipment costs for Land Application.

	1984$
Tractor w/Flotation Tires	$24,000
Tank Wagon (13,500 l)	21,120
Tank Wagon (5,600 l)	10,560
Injection Unit	5,600
Tank Truck Spreader (14,250 l)	31,200
Injection Option	15,500
Disc Harrow (cultivating)	4,000
Mower/Conditioner 2.7m	9,400
Seeder (for closure)	1,120

Table 6.4 Wage Scale Updated to 1984 Dollars*

	1984$
Driver's Hourly Wage	12.00
Health & Welfare	.71
Pensions	.74
	$13.45/hr

*Waste Oil Recovery Practices State of the Art, 1972 (35).

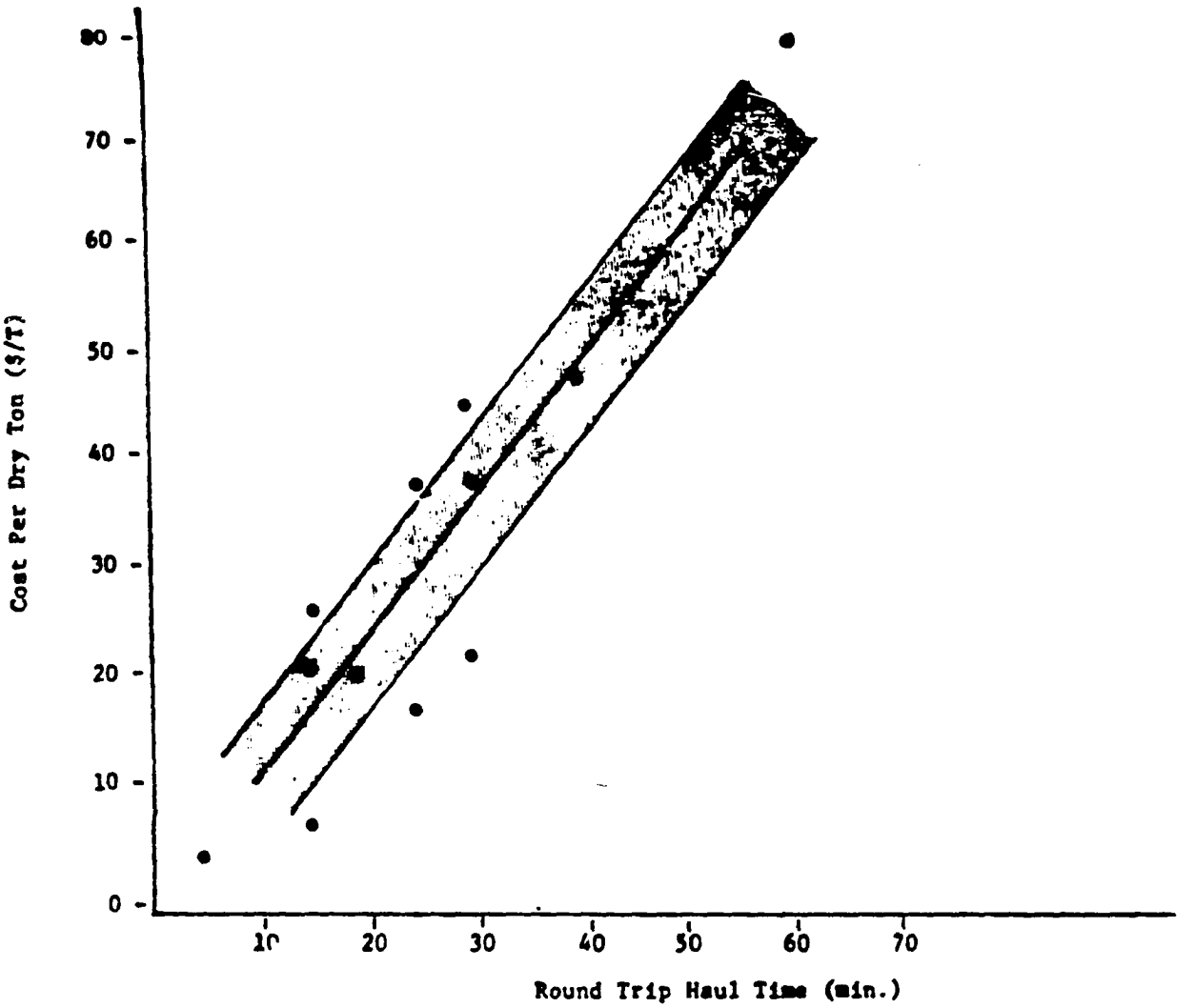


Figure 6.3 Cost of haul time for liquid sludge
Source: Anderson, 1977 (31).

6.2.4 Fertilizer Application

Nitrogen and phosphorous and other nutrients if necessary must be added for optimal microbial action. A fertilizer application of 1,000 pounds nitrogen and 500 pounds phosphorous per acre per year may be used (34), (see Table 6.5 for cost per acre).

Table 6.5 Cost of Fertilizer Application

	Nitrogen lbs/yr	Phosphorous lbs/yr
Cost/lb	$ .33	$ .32
Cost/yr/acre	330.00	160.00
Spreading cost/acre	132.00	132.00

6.2.5 Buffer Zones

Buffer zones of 5-10m are normally required for industrial wastes to contain pathogenic microorganisms or substantial adverse odor. Shrubs and trees are maintained in a buffer zone to render the land application site more aesthetically pleasing to the public and block the view of the landfarm. The maintenance cost for such a zone would be $1,440 - $1,600/100m shrub, tree line per year (2).

6.2.6 Security

Security should be maintained by fencing the site, having locked gates, and posting signs. The costs will

vary and will depend on the total land area to be fenced.

6.2.7 Sampling Methodology

The overall dual objectives of monitoring land treatment areas have been agreed upon by most researchers. These objectives are:

a. To corroborate its performance as a waste treatment system subject to the nondegradation type of constraint and to verify long-term plant soil viability.

b. To maintain the needed essential elements for microbial action and plant growth.

Monitoring to evaluate land treatment of various constituents is categorized in four phases related to the behavior of the critical constituents in the plant-soil system and to the methods used to collect samples.

a. plant and soil surface zone

b. soil and water subsurface zone

c. groundwater

d. surface water

These parameters must be analyzed prior to waste application. To sample soils, 5-15 subsamples are composited to obtain a sample. Each soil type in each area must be sampled separately. Groundwater samples are taken from onsite wells and offsite or perimeter wells in the direction of hydrologic flow. Surface water samples

are required where there is a lateral movement of waste constituents across the surface of the site. The cost of equipment used in sampling is as follows (6):

Grab Sampler (surface waters)	$ 215
Soil and Plant Preservation (for organic and inorganic species)	1,960
Weighing Scales and Drying Equipment	1,200

The following values were reported for sampling and analyses (34), modified by 10 percent inflation for 1984 (Table 6.6). These values were also evaluated by obtaining data from a local analytical firm (see Table 6.6).

Sampling, 12 days (96 hrs/yr) ... $1,064

6.2.8 Transmission

This involves gravity pipes, open channels or force mains. Costs of transmission will depend on the pipe and channel size (Table 6.7).

6.2.9 Pumping

This ranges from full pumping stations to tailwater pumping facilities. A fully enclosed wet well/dry well structure, pumps, piping and valves, controls and electrical work will cost $300,000 for a 1 mgd peak flow and 150 ft. head. For structures built into the dike of ponds, the cost of pumping for distribution would be approximately $210,000 (32).

Table 6.6 Cost for Sampling and Analysis, 1984

Soil Samples	$/Sample
Oil Content	30
pH	6
Total N	40
P	30
Most Metals	10 each
As	13
Ag	13
	$212/sample
Water Samples	
Oil	25
TOC	25
TIC	20
Phenols	40
Most Metals	10
As	13
Ag	13
Total N	40
NH_3	18
P	30
Cl	13
SO_4	20
pH	4
Conductivity	4
Total	$345/sample

Source: Mead Compu. Chem., N.C.

Table 6.7 Cost of Underdrains

Capital Costs, 400 ft. spacing	$750
O & M Costs, 400 ft. spacing	15
Materials, 400 ft. spacing	60
Tailwater Return	
0.1 mgd of Recovered water	
Capital, $	40,000
O & M	
Power	300
Labor	250
Materials	120
Runoff Collection	
Capital Cost, open ditch system	250
Labor, open ditch	20
Materials, open ditch	30
Recovery Wells	
Capital, $	20,000
O & M, power, 50 ft. depth	6,300

Source: Reed and Crites (36).

6.2.10 Preapplication Treatment

This ranges from preliminary screening to advanced secondary treatment. The costs will vary according to the preapplication treatment required.

6.2.11 Storage Ponds

The cost of storage ponds varies depending on initial site conditions, and the depth and volume of wastewater to be stored (32).

6.2.12 Field Preparation

This includes site clearing and rough grading, land leveling and overland slope construction (Table 6.8).

6.2.13 Distribution

This involves the use of a wide variety of sprinkler and surface distribution systems, which may include the following:

Materials.....	$ 50
Operation and Maintenance (100 acres/year)	$500

6.2.14 Recovery

This includes underdrains, tailwater return, and run-off collection systems for overland flow systems and recovery wells.

6.2.15 Closure Costs

Closure costs are not well documented in the litera-

Table 6 .8 Costs of Field Preparation*

Site Preparation	Capital Cost, $/acre
Site Clearing	20
Grass only	150
Open Field, some brush	1,000
Brush and Trees	3,000
Land Leveling	
200 yd^3/acre	250
500 yd^3/acre	500
750 yd^3/acre	700
Overland Flow Slope Construction	
500 yd^3/acre	900
1000 yd^3/acre	1,500
1400 yd^3/acre	2,000

* From Reed and Crites (36).

ture. Kincannon, 1972 (43), lists cultivation costs for existing cleared fields.

Cultivation, hours/plowing	8 hrs/10 acres
Cost/hour	$ 13.45
Cost/day/acre	$ 440.00
Cost/year/10 acres	$5,280.00

Fertilizer costs would be the same as that used for the application phase of the landfarm.

The overall cost considerations in a land application facility for ICW will depend on the nature of the waste stream, and this will in turn, determine the land limiting constituent, an important parameter in land application of any type of waste. The waste stream, aside from its corrosive and ignitable characteristics may also have other hazardous constituents which must be considered if land application is to be used as a treatment/disposal technology. For instance, the presence of heavy metals together with ICW will alter the land limiting constituent of the waste and thus influence the loading rate. On the other hand, the quantity of effluents can be controlled through in-plant changes whereby the amount and nature of the effluents produced from various manufacturing processes can be reduced. This is considered one of the most cost-effective alternatives in the management of ICW. Recycling of waste streams is another method that will reduce the volume of ICW considerably, and thus reduce the overall waste pretreatment

cost. Other effective methods of reducing waste quantities is the recovery of some of the components of the waste stream for reuse or sale. This is a very attractive alternative in terms of its economic return to the company.

CHAPTER VII

RISK ASSESSMENT

The risk model used in this report is a modification of a RCRA/Risk Policy Model (RCRA Risk/Cost Policy Model Project, Phase 2 Report, June, 1982) (45) used to identify trade-offs between the risks posed by wastes and costs associated with their disposal. This model was developed by Life Systems, Inc. (46) for the University of Oklahoma. The portion of the model used here assesses the likelihood and the severity of human exposure to hazardous compounds.

The risk posed by a waste stream is related to a number of factors, the most important of which are:

1. The inherent hazard and physical properties of the waste stream, which depend primarily on the nature of the waste stream and its chemical constituents;
2. The quantity of the chemicals released and the medium into which they are released, which depend on the size and the nature of the waste stream, and on the technology;
3. The persistence of the chemicals, and the rate

of their dispersion, and other factors governing exposure which depend primarily on the nature of the waste stream and on the environment;

4. The size of the human population potentially exposed to the chemicals, which depends primarily on the environment; and
5. The presence of nonhuman systems that can be adversely affected, such as sensitive ecosystems which depend primarily on the environment.

The score obtained for each compound is composed of two factors, an Inherent Hazard and an Exposure Adjustment for each media considered (i.e., air, surface water and groundwater). These two factors are added to obtain an Adjusted Inherent Risk by medium. The framework in which this model operates is a screening device for identifying areas of special concern due to risks involved. This is an analysis on a general level. While this estimate is not detailed enough to be useful in a regulatory process, it can serve to point out situations that are extremely risky or relatively safe and identify better candidates for land application.

7.1 FACTORS CONSIDERED IN THE MODEL

The Inherent Hazard Score attempts to relate

potential hazardous effects at a given probability of an occurrence per unit dose. The adverse effect on human health is the only factor considered. No provisions are made for ecological damage or economic risk. Two estimation scales are used in the derivation of the inherent hazard: dichotomous response and a graded response. These two responses encompass the entire range of possible health effects. A dichotomous response represents an all-or-nothing situation such as carcinogenesis, teratogenicity or mutagenicity. A graded response includes dose dependent effects that occur in a continuum ranging from slight to substantial impairment or illness. The sequence of rules in the scoring system are presented in Fig. 7.1.

A dichotomous response corresponds to the EPA's unit risk estimate which is defined as the slope of the dose-response relationship. For carcinogenic compounds then, the EPA's estimate of unit risk has been either used when available or calculated using EPA's procedure for unit risk assessment.

The calculation of the graded response utilizes a minimum-effective-dose (MED) which is the lowest dose that produces an observable adverse effect. The score for graded response is based on an estimate of the daily dose required to produce an adverse effect in about 1 percent of the exposed population. In typical cases the

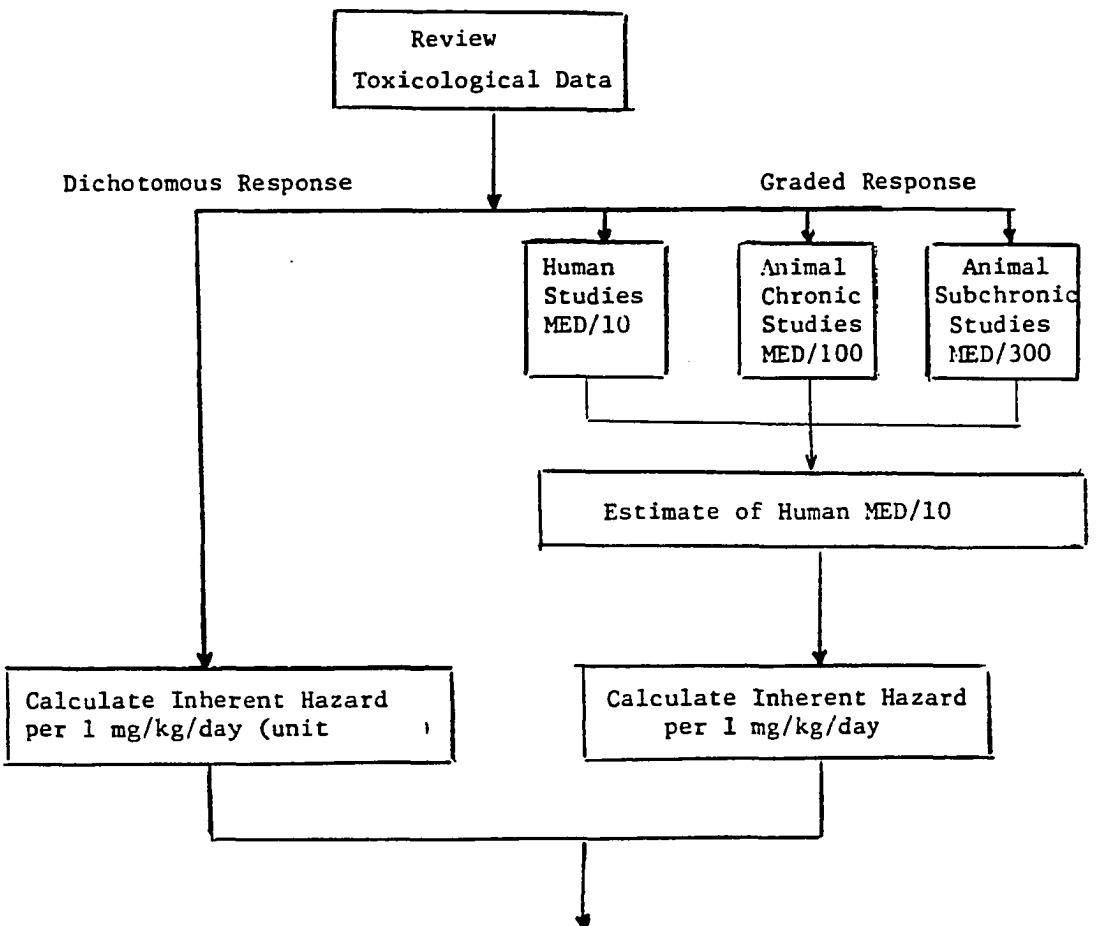
smallest effect than can be detected with statistical reliability is about 10 percent. The score is based accordingly on the MED required to produce a measurable effect. For human data, the MED is divided by 10 to approximate the dose that would yield a 1 percent probability of producing an adverse effect. For animal data, the MED is divided by 100 if the study is chronic; 300 if the study is subchronic. Determining if such a dose from toxicological data on animals is dependent on: 1) the age, sex and strain of exposed animals, 2) the route, frequency and duration of the exposure, 3) an assumption of dose-response linearity. In this model primary weight has been placed on chronic effects on animals or epidemiological data.

The inherent hazard score is then assigned according to the limits presented in Fig. 7.1. Carcinogens with the highest unit risk scores and noncarcinogens with the lower MEDs are assigned to the higher inherent hazard scores.

7.2 EXPOSURE ADJUSTMENTS FOR ENVIRONMENTAL MEDIUM

To provide an estimate of the potential exposure of humans to the hazardous constituents, exposure adjustment factors were developed for the hazardous constituents in three media: air, surface water and groundwater. The environment has the ability to dilute, degrade and/or

Figure 7.1 FLOW CHART FOR SCORING INHERENT HAZARD



Inherent Hazard per 1 mg/kg/day	Inherent Hazard Score Score
0.0005	0
0.0005 to 0.005	1
0.005 to 0.05	2
0.05 to 0.5	3
0.5 to 5.0	4
5.0 to 50.0	5
50.0	6

Source: RCRA (45).

transport the compound and thus the potential for a population to be exposed will depend, in part on the magnitude of these mechanisms. The adjustment factor is essentially the half-life of the compound, and the scores are roughly equivalent to the log of the expected half-life of each compound in each medium. Several processes which tend to reduce the hazardous effects of the compound are taken into consideration in calculating the exposure adjustment factors (i.e., half-lives). Air scores include removal by atmospheric washout. Surface water scores take into consideration oxidation, hydrolysis, biodegradation and/or volatilization. Groundwater scores consider adsorption and hydrolysis. In each medium the attenuation is usually dominated by one mechanism, which is used in the scoring. Table 7.1 summarizes the scoring procedure.

7.3 LIMITATIONS OF THE MODEL

There are a number of limitations inherent in this model. A number of simplifying assumptions have been made, including:

1. Weighing all adverse effects equally.
2. Assuming linearity in dose response relationships.
3. Including only human adverse effects.

Additionally, the model does not accommodate syner-

Table 7.1 Exposure Adjustment Scores

Half-Life	Air	Surface Water*,**	Groundwater**,***
3 minutes	0	-	-
30 minutes	1	0	-
1 hour	2	1	0
3 days	3	2	1
30 days	4	3	2
1 year	5	4	3
10 year	6	5	4
100 years	-	6	5
1,000 years	-	-	6

* If bioaccumulation factor in fish is 10^K, add K-2 points for $K \geq 3$; leave score unchanged for $K \geq 2$.

** If chemical is removed by conventional water treatment, subtract factor based on degree of removal (90 percent removal = -1; 99 percent removal = -2).

*** If adsorped to solid surfaces, subtract points according to degree of adsorption (99 percent adsorption = -2; 99.9 percent adsorption = -3.

Source: RCRA (45).

gism or antagonism among compounds. Even though wastes are chemical mixtures, the model evaluates compounds separately. There is a measure of uncertainty involved in evaluating the toxicological data. In many instances data is either absent or insufficient and, therefore, in many instances judgement was used to derive risk scores, particularly in using animal data to assess possible human health risks and to evaluate exposure to compounds.

It must also be assumed for this model that the concentrations of hazardous constituents in the waste are sufficient to cause the chronic or acute health effects in humans.

Another simplification made in this model was the use of one or at most two mechanisms (i.e., biodegradation, hydrolysis, volatilization, etc.) for each media to estimate the half-life of a substance in that media. A single mechanism was used if the half-life estimated for the particular medium was 10 times greater than any other mechanism. If two mechanisms had half-life estimates within 10 times of each other, both were used. In no instance was more than two mechanisms used. Thus, some degradation mechanisms that could be important (i.e., photolysis or neutralization) may not be considered in the media exposure adjustment.

The model also does not take into consideration effects on the environment but only on human health. The authors note, however, that rarely does chemical pollution pose a threat to the environment without also posing a threat to human health and consider human health to be the most critical factor.

In many instances, best scientific judgement was used to derive risk scores, particularly in using animal data to access possible human health risks and to evaluate exposure to compounds.

7.4 ADDITIONAL FACTORS THAT COULD BE CONSIDERED

Additional information is being obtained to aid in a more accurate estimate of the risk posed by land treatment of ICW. These are:

1. Climatological parameters such as mean annual rainfall, temperatures and wind speed, since these parameters will affect transport and degradation of wastes being land treated. Evapotranspiration rates could also be used to establish a climatological factor.
2. Soil types in each climatic region. Parameters that might be considered in developing factors for soil type would include those parameters that extend the most influence on the assimilative capacity such as pH, microbial activity, soil moisture content, cation exchange capacity, and hydraulic conductivity. Availability of this information for geographical areas where land treatment is most prevalent would be required for development of these factors.

The risk model developed by ICF, Inc. (45) also incorporates an adjustment for environmental settings. Three factors were considered: 1) potential population exposed, 2) assimilative capacity of surface waters, and 3) groundwater contamination potential.

The potential population exposed was defined by

three ranges of populations:

1. High (520 people/km^2 and over)
2. Medium (52-519 people/km^2)
3. Low (less than 52 people/km^2)

Assimilative capacity of surface water was characterized by two broad categories:

1. Those with a high assimilative capacity (i.e., discharge to streams with a flow rate greater than 3×10^3 m^3/day.
2. Those with a low assimilative capacity.

Groundwater contamination potential was divided into three categories:

1. Low soil permeability (less than 10^{-6} cm/sec) and moderate depth to groundwater saturation zone (greater than 10m) - low risk.
2. Moderate soil permeability (less than 10^{-4} cm/sec) and large depth to the groundwater saturation zone - moderate risk.
3. All locations not meeting the criteria for 1 or 2 - high risk.

These environmental setting adjustments should be incorporated in the risk assessment model.

7.5 RESULTS OF RISK ASSESSMENT

8.5.1 Introduction

As noted above, the following components of the risk

model were used to evaluate risks posed by each industry category:

a. Inherent Hazard. Provides a single score that estimates the toxicological effects on humans of the hazardous constituent. Chronic effects are given priority.

b. Environmental Medium Adjustment. Provides a score for each hazardous constituent for three media (i.e., air, surface water, and groundwater) that estimates the potential for exposure to a hazardous constituent based on its dispersion/degradation in each media. The half-life of the hazardous constituent was used to describe this factor using one or two dominant attenuation mechanisms for each medium to derive the half-life.

It should be noted that the above scores are derived by taking the logs of the actual numbers derived so that an increase or decrease of one in the score represents a 10-fold increase or decrease in that score.

c. Waste Origin Adjustment. This is an additional factor also used to determine risk scores. Scores of these factors are arbitrarily assigned. If the hazardous waste constituents used in the assessment were measured in the

land treated waste, then a factor of 0 (log of 1 indicating no uncertainty) was assigned. For hazardous constituents used in the assessment measured in another waste stream (e.g., waste water) a factor of 1 (log of 10 indicating a 10-fold uncertainty of the hazardous constituent being in the land treated waste) was assigned. Note that an assumption was made that sludge generated from these wastes would be ignitable or corrosive and would contain the hazardous constituents. If the hazardous constituents used in the assessment were identified as being in raw materials or products used in the production process, then a factor of 2 (log of 100 indicating a 100-fold uncertainty) was assigned since the uncertainty of these constituents being present in land treated wastes was greatest.

7.5.2 Procedure for Scoring

The following steps were taken in ranking the industrial category wastes in regard to their applicability to land treatment:

a. Hazardous constituents of wastes generated by each industry category were identified from the available literature. Hazardous constituents

of land treated waste were of course used where the information was available. Hazardous constituents from other waste streams were used otherwise and it was assumed that these constituents would be present in wastes potentially land treated.

b. All hazardous constituents identified in each industry category for which scores were available in the ICF report were then listed along with their appropriate scores (i.e., Inherent Hazard, Exposure Adjustment for each media, and Adjusted Inherent Risk for each media).

c. The Adjusted Inherent Risk scores for each media were then summed. The rationale for summing these is that exposure through each media is possible for land treated waste.

d. Based on the sum of the Adjusted Inherent Risk scores the hazardous constituents with the highest scores (i.e., highest risk) were selected for further consideration. Where possible, the four hazardous constituents with the highest scores were selected; however, the lack of data on some industrial category wastes allowed less than four constituents to be evaluated.

e. The hazardous constituents now remaining were

checked against the Appendix VIII list in 40 CFR Part 261. The land treatment regulations under RCRA require that owners/operators identify and monitor Appendix VIII constituents present in land treated wastes. If the hazardous constituent were listed in Appendix VIII they were retained; if not, they were deleted.

f. From the remaining hazardous constituents in each industrial category, a score was selected to represent the industry. Where scores were equal, one was randomly chosen.

g. Next, the waste origin factor was applied. This factor is discussed above in item 3. It should be noted that this factor is more a measure of uncertainty concerning the data available. This factor when added to the summed Inherent Hazard Risk Scores yields the final score for each category.

In deriving risk scores in this report, all three media (i.e., air, surface water, groundwater) were taken into consideration. In certain instances, however, it may be appropriate to omit one or more of the media from the weighted scores. For instance, if it was determined that most land treatment would be performed in areas a large distance from population centers, it might be appropriate to eliminate air from the assessment. If

facilities were located a great distance from surface waters, the surface water factors could be omitted.

7.5.3 Results

The lower the score obtained, the lower the risk involved in regard to land treating the hazardous wastes. Table 7.2 presents a ranking of the industry categories according to the final scores obtained for each.

Table 7.2 Ranking by Industry Category

Industry Category	Score
Citrus Processing	9
Explosives and Munitions	14
Cyclic Crude and Intermediates	22
Medicinal and Botanicals	22
Organic Dyes and Pigments	22
Chemical and Allied Products	24
Petroleum Refining	25
Industrial Inorganic Industry	27
Pulp and Paper	28

The citrus processing industry followed by the explosives and munitions industry, had the lowest risk scores while the industrial inorganic and the pulp and paper industries had the highest risk scores.

A comparison was made on the inherent hazard and risks associated with various compounds generated present in the waste stream of selected categories of generators.

The scores for the selected waste constituents are presented in Table 7.3. These compounds were chosen from industries that generate ICW as determined by a study of manufacturing processes in each industry selected. This information was available in the literature.

The risk assessment scores are presented in Table 7.4, by industrial category. These scores are based on information again available in the literature and the limitations inherent in this risk assessment. Final results indicate that wastes generated by the explosives/ munitions industry as well as the cyclic crude and intermediates, medicinals and botanicals, organic dyes and pigments industries pose the least risk to human health when land treated.

In deriving risk scores in this report, all three media (i.e., air, surface water, groundwater) were taken into consideration. In certain instances, however, it may be appropriate to omit one or more of the media from the weight to the remaining and more important factor(s). For instance, it was determined that most land treatment would be performed in areas a great distance from population centers. It might, therefore, be appropriate to eliminate air from the assessment. If facilities were located a great distance from surface waters, the surface water factors could be omitted.

Scientific studies of risk are usually severely

Table 7.3 Scores for Selected Waste Constituents.

Constituents	Inherent Hazard	Exposure Adjustment Air	Surface Water	Ground Water	Adjusted Inherent Risk Air	Surface Water	Ground Water
Lead	5	4	3	2	9	8	7
Benzene	2	4	0	6	6	2	8
Toluene	1	3	0	7	4	1	8
Benzidine	2	3	0	7	4	1	8
Creosote	2	2	1	7	4	3	8
Naphthalene	1	4	0	6	5	1	7
Pentachlorophenol	4	3	3	6	7	7	10
Phenol	4	2	1	6	6	5	10
Anthracene	3	4	4	5	7	7	8
Chlorobenzene	3	4	0	6	7	3	9
1,2 Dichloroethane	3	4	0	6	7	3	9
Chloroform	3	5	0	6	8	3	9
Methylene Chloride	2	4	0	7	6	2	9
Carbon Tetrachloride	3	8	0	6	11	3	9
1,1,2,2, Tetrachloro Ethane	4	6	0	6	10	4	10
Chrysene	4	4	6	5	8	10	9
Hydrogen Sulfide	4	4	N/A	N/A	8	N/A	N/A
Fluorides	3	4	7	7	7	10	10
2-Naphthylamine	2	3	3	6	5	5	8
Nitrosodimethylamine	4	3	0	5	7	4	9
N-Nitrosodiphenyl Amine	1	3	0	5	4	1	6
Chromium	5	4	7	7	9	12	12

Source: Life Systems (46)

Table 7.4 Risk Assessment Scores.

Industrial Category	SIC Code	Hazardous Constituents	Sum of Adjusted Inherent Hazard Scores	Appendix VIII Constituent Yes	Appendix VIII Constituent No	Selected Constituent	Waste Origin Factor	Final Score
Cyclic Crude and Intermediates	2865	Phenol	21	X		Phenol		22
		Benzene	16	X		Benzene	1	
		Toluene	13	X				
		Creosote	16	X				
Chemical and Allied Products (Paint Industry)	2800	Pentachlorophenol	24	X		Pentachlorophenol	0	24
		Phenol	21	X				
		Anthracene	22	X				
		Chlorobenzene	19	X				
Medicinals and Botanicals	2833	Phenol	21	X		Phenol	1	22
		1,2 Dichloroethane	19	X				
		Chloroform	20	X				
		Methylene Chloride	17	X				
Industrial Organic Chemicals	2869	Insufficient Information						
Pulp and Paper	2600	Carbon Tetrachloride	23	X		Chrysene	1	28
		1,1,2,2-Tetrachloroethane	24	X				
		Chrysene	27	X				
		Pentachlorophenol	24	X				
Petroleum Refining	2911							
		Lead	24	X		Lead	1	25
		Chromium	33	X				
		Zinc	18	X				

(Continued)

Table 7.4 (Continued)

Industrial Category	SIC Code	Hazardous Constituents	Sum of Adjusted Inherent Hazard Scores	Appendix VIII Constituent Yes	Appendix VIII Constituent No	Selected Constituent	Waste Origin Factor	Final Score
Industrial Inorganic Compounds	2819	Sulfuric Acid (hydrogen sulfide)	8	X		Hydrofluoric Acid/Calcium	0	27
		Hydrofluoric Acid and calcium fluoride (fluorides)	27	X				
Organic Dyes and Pigments	2865	2-Naphthylamine[a]	18	X		Nitrosodimethylamine	2	22
		Nitrosodimethyl amine[a]						
		N-Nitrosodiphenyl amine[a]	11		X			
Explosives & Munitions	2892	Toluene	13	X		Toluene	1	14
		Benzene	16	X				
Citrus Processing	2037	Sulfuric Acid (hydrogen sulfide)	8	X		Sulfuric Acid	1	9

(a) These hazardous constituents were specifically identified in the available literature. Only amines as a general category were noted as being in the waste. These three were chosen from the 140 compounds scored in the IFB report.

constrained by data limitations and by the lack of understanding of underlying physical, biological, chemical, economic and social processes. Risk assessment is going to be increasingly used in hazardous waste management. It is important to remember, however, that different sites require different approaches and techniques for estimating risk. This will depend on the nature of the hazardous waste under consideration, knowledge of its movement in the environment and site specific constraints or factors, that require different site containment, remedy and restoration procedures. Our knowledge of the hazards caused by exposure of man and/or the environment to ICW is very limited. Therefore, further investigation is needed in this area.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

The goal of treatment and disposal technology for ICW should be to offer economically and politically acceptable and environmentally compatible alternatives to current technology being used such as landfilling and incineration. The use of land application as a treatment alternative is a very promising one. It will depend on the nature of the waste stream, the quantity of the effluents, the pretreatment technology available, its economic feasibility and the satisfaction of federal and state regulatory requirements.

The nature and characteristics of ICW were identified in this study as well as the industries generating ICW, and the quantities produced annually. In addition, a survey of industries generating ICW was made, and state-of-the-art information was obtained on loading rates, pretreatment and disposal technology currently being utilized, permitting requirements and constraints of land application facilities. All of these parameters were dealt with in detail in Chapters III, IV and V.

Based on the objectives outlined in Chapter I, the

following conclusions can be drawn from this study:

1. The generators and disposers of ICW were identified by geographic location and climatic zones. The data base for generators and disposers were obtained from the EPA list of hazardous waste generators. The generators of ICW are distributed all over the United States. Approximately 30 percent of these facilities are located in Region 6, 23 percent in Region 4 and 10 percent each in Regions 9, 8 and 5. A majority of the land application facilities in the U.S. are petroleum refineries, 41 percent, followed by government installations and electric companies, 19 percent and 15 percent, respectively.

   The distribution of these companies by climatic zones indicates the existence of more land application facilities in the humid, continental climatic zone (Zone E), 40 percent, followed by the humid, subtropical climate (Zone C), 22 percent. The least number of ICW land application facilities were located in the arid, hot and dry climatic zone (Zone B), 7 percent.

2. A total volume of 33,506,880 and 142,992,699 metric tons of D001 and D002 are generated annually. There were more companies generating D002 than D001. Region 6 produced the largest volume of ICW followed by Regions 3 and 4. Region 2, however, had the most

number of companies generating ICW followed by Regions 6, 4 and 8.

3. The survey of land application facilities generating ICW indicated a highly variable waste stream. A majority of the facilities reported ICW in the form of a sludge/slurry (43 percent), while the rest were aqueous (19 percent). The nature and characteristics of ICW will determine the design criteria to be utilized for land application of ICW. For instance, an aqueous waste stream will require the use of a sprinkler system while a sludge/slurry type of waste stream may require underground injection techniques.

   Among the land application facilities surveyed, the pretreatment technology most commonly used for corrosive waste was neutralization, 42 percent. For ignitable waste the most commonly used disposal technology was landfilling (33 percent).

   Application rates varied highly and depended on the nature of ICW. The citrus processing industry for instance, had an aqueous waste stream, and the rapid infiltration method was used based on soil characteristics and percolation rates. Waste was also applied to the land daily. Those that generated ignitable wastes in slurry form used an underground injection system. The total treatment area also varied from 60 to 700 acres, with a loading

rate of 1 to 10 mgd.

4. The soil column study proved an initial biocidal effect of ignitable waste on soil bacteria. The bacterial counts decreased more than ten fold a week after application of ignitable waste on top of the soil column. However, the soil bacteria gradually recovered with time. The number of bacterial colonies gradually increased and reached normal counts (same as control) after four weeks. The results of the soil column study demonstrated the ability of soil bacteria to degrade and utilize the carbon from ignitable waste in the form of spent solvents, indicating its biodegradability.

5. The results of the economic feasibility study of treatment and disposal technology for ICW showed that land application for ICW is economically feasible. It is one of the least expensive disposal methods for ICW after landfilling. The relative disposal cost for land application is $14 - $25 per ton. Because of the current stringent regulations for landfills, the costs today may be higher than the one estimated for the land application. The costs of solvent recycling may also be considerably decreased after credit for recovered solvent is considered (see Table 6.1 for a comparison of the cost of other treatment technologies). As in any

other system, the overall cost considerations in a land application facility for ICW will depend on the nature of the waste stream, the availability of land at reasonable costs, and federal and state regulatory constraints.

6. The risk assessment on ICW generated by selected industries showed the citrus processing had the lowest risk scores, while the industrial inorganic and the pulp and paper industries had the highest risk scores. For selected waste constituents, the final risk results, indicated that wastes generated by the explosives/munitions industry as well as the cyclic crude and intermediates, medicinals and botanicals, and the organic dyes and pigment industries pose the least risk to human health when land treated.

We still are in the process of developing or refining the technology that is currently available to treat and dispose of ICW. Numerous researchers have indicated the viability of land application of a variety of organic and inorganic wastes to which ICW belongs. The decision to use land application as a treatment/disposal technology for ICW lies in its economic feasibility. The single most limiting constraint identified by the companies surveyed was the availability of land, at a reasonable cost, close to the generator. This requirement is important in determining the cost effectiveness of land application

for ICW. The total cost as estimated by various authors is approximately $600,000 to $800,000 for a total life span of about 30 years. The cost is considerably less than any other treatment and disposal technology currently available (see Chapter VI).

The primary concept of land application as reiterated by numerous authors in the literature (5,6,) is that the industrial waste, when considered on a constituent-by-constituent basis, shall be applied to the plant-soil system at such rates or over such limited time spans that no land is irreversibly removed from other societal usage (agriculture, development, forestation, etc.). Land application rates can be specified for any and all industrial categories and subcategories delineated by EPA. It is possible to outline and develop the specifications for landbased treatment systems for ICW.

The nature of the waste stream will affect the design parameters for land application of ICW. Aside from its corrosive and ignitable characteristics, the waste stream may also have other hazardous constituents. In this case, the land limiting constituent will have to be altered to take into consideration these other factors. The total land area required for land application of ICW may therefore increase or decrease depending on the presence of other hazardous constituents in the waste. Of course, the overall consideration should be to decrease

these constituents in order to meet state and federal regulatory standards. A reduction in the total volume of ICW generated will require the use of some kind of pretreatment technology. Again, the choice of the kind of pretreatment technology to be used will depend on the nature of the waste stream and economic considerations. Other options available to the design engineer are in-plant changes that will reduce the quantity and the nature of ICW produced. This method is a very cost-effective alternative. Recycling or recovery of waste constituents are other options, that will reduce the volume of ICW considerably, and thus reduce the overall waste pretreatment cost. Of course, the best option is not to create the waste at all. This can be accomplished by finding substitutes in production materials that will not result in a waste stream that is hazardous but instead creates process streams ideal for recycling. This will require long range planning on the part of manufacturers and is not likely to be achieved within the next decade.

This study is not to provide detailed designs of a land application system for ICW since design criteria are very site specific (see Chapter IV). Rather, it aims to provide state-of-the-art information on land application of ICW that will aid subsequent system designers in selecting relevant parameters applicable to their own fa-

cilities. This report provides general guidelines for selecting those design parameters which are potentially applicable to corrosive and ignitable wastes of particular characteristics.

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APPENDIX A

ICW FACILITIES WITH LAND APPLICATION SYSTEMS

LAND APPLIERS SURVEYED

Region 2

1. Royal Altreuter, Coordinator
   Amerada Hess Corp.
   1 Hess Plaza
   Woodbridge, NJ 07095

2. The Manager
   Exxon Bayway Refinery
   P. O. Box 2180
   Houston, TX 77001

3. Leslie Lakie, Supervisor
   Texaco USA
   Box 98
   Westville, NJ 09093

4. W. Bailey Barton, Director
   Borden, Inc.
   180 East Broad St.
   Columbus, OH 43215

5. Paul Letki, Env. Manager
   SCA Chemical Services, Inc., NY Div.
   1550 Balmer Rd.
   Model City, NY 14109

6. Albert Leonardis, Supervisor
   Edwin B. Stimpson Co., Inc.
   Bayport, NY 11705

7. Sol Colon
   Servicios Carbareon Inc.
   Compania Ganadera Del Sur Inc.
   Firm Delivery
   Ponce, Puerto Rico 00731

8. Rolando Mendez, Director Env. Control
   Box 1166
   Guayama, Puerto Rico 00654

9. R. L. Sagebien, VP and General Manager
   Hess Oil Virgin Islands Corp.
   Box 127
   St. Croix, Virgin Islands

Region 3

1. The Manager
   American Cyanamid Co.
   South Cherry St.
   Wallingford, CT 06492

2. The Manager
   Crane Company Indian Orchard Plant
   203 Hampshire St.
   Indian Orchard, MA 01151

3. The Manager
   Genrad, Inc.
   Rte 117
   Bolton, MA 01740

Region 4

1. Herbert Knight, Tech. Supv.
   Hercules, Inc.
   P.O. Box 190
   Bessemer, AL 35020

2. Ralph Stanford, Chief Engineer
   USAF Gunter Air Force Station
   3800 Air Base Group/DE
   Maxwell Air Force Base, AL 36112

3. Preston Troutman, VP
   Ben Hill Griffin Citrus Co.
   P. O. Box 2000
   Frostproof, FL 33843

4. Leo Sputts, President
   Continental Circuits, Inc.
   P.O. Drawer F
   Longwood, FL 32750

5. John May, Vice President
   Holly Hill Fruit Products Co. Sprayfield
   P. O. Box 708
   Davenport, FL 33837

6. J. R. Katic, Director PDR & GO
   Olin Corp.
   P.O. Box 222
   St. Marks, FL 32356

7. Joanne Lynch, Engineer
   Tropical Circuits
   P.O. Box 21355
   Ft. Lauderdale, FL 33334

8. Roland Allen, Environmental Engineer
   USAF Homestead Air Force Base
   31 CSG/DEEV
   Homestead AFB, FL 33039

9. Brandon Blonshine, Environ. Coord.
   USAF MacDill Air Force Base
   56 Combat Support Group/DE
   MacDill AFB, FL 33608

10. A. McDonald
    USAF Tyndall Air Force Base
    4756 Civil Engr. SQ DEEV
    Tyndall AFB, FL 32403

Region 4 (cont'd)

11. John Considine
Amoco Oil Company/Refinery
P.O. Box 1881
Savannah, GA 31498

12. Francis Simmons, Manager
General Electric Co. Service Shop
Box 5646
Augusta, GA 30906

13. D. Cunningham
EA/OH Dept H
Union Carbide Agric. Products Co.
P.O. Box 428
Woodbine, GA 31569

14. Joseph Hajek, Factory Mgr.
Wm Wrigley Jr. Co.
P.O. Box 1750
Gainesville, GA 30503

15. Harold Armstrong, Plant Engineer
Borden Inc./Borden Chemical Division
6200 Camp Ground Rd.
Louisville, KY 40216

Region 5

1. Brian Bonamico, Plant Engineer
   Gilbert and Bennett Mfg. Co.
   P.O. Box 56
   Blue Island, IL 60406

2. Larry Echelberger, Environmental Coordinator
   Marathon Oil Co.
   Robinson, IL 62454

3. William Schwartz, Executive Vice President
   Peoria Disposal Co.
   1113 N. Swords Ave.
   Peoria, IL 61604

4. Oliver Goodlander
   Texaco Inc. Texaco USA Division
   P.O. Box 200
   Lockport, IL 60441

5. L.D. Erchull
   Union Oil Co. of California Chicago Refinery
   135th St & New Ave.
   Lemont, IL 60439

6. David Williams, Chief Chemist
   Indiana Farm Bureau Coop. Assn. Inc.
   1200 Refinery Rd.
   Mt. Vernon, IN 47620

7. C. J. Fulton
   Total Petroleum Inc. Alma Refinery
   East Superior St.
   Alma, MI 48801

8. Segar Thomas, Chief Env. Engr.
   Kock Refining Co.
   St. Paul, MN 55164

9. James Hamilton
   FEI Landfarm Site #3
   876 Otter Creek Rd.
   Oregon, OH 43616

10. Ed Maxley
    Gulf Oil Co. US Refinery
    P.O. Box 7
    Cleves, OH 45002

11. Clarence Tyler
    Standard Oil Co. Ohio
    P.O. Box 696
    Toledo, OH 43694

Region 6

1. Karline Tierney
   Ciba-Geigy Corp.
   Route 75 River Road
   St. Gabriel, TX 70776

2. Henry Hethcoat
   Gulf Alliance Refinery
   Hwy 23
   Alliance, TX 70037

3. C. Blake Harmon, Env. Engr.
   Marathon Oil Co. Louisiana Refining Div.
   US Hwy 61
   Garyville, TX 70051

4. John Weld, Plant Mgr.
   Warren Petroleum Co., Venice Gas Plant
   Tidewater Rd.
   Venice, TX 70091

5. George O'Brien
   Conoco Inc. Ponca City
   1000 S. Pine
   Ponca City, OK 74601

6. R. K. Reid
   Firestone Tire & Rubber Co.
   2500 S. Council Rd.
   Oklahoma City, OK 73114

7. B. G. Hawthorne, Mgr.
   Sun Petro Products Co. Tulsa Refinery
   1700 S. Union
   Tulsa, OK 74120

8. Windle Taylor, Jr., Env. Engr.
   Coastal States Petroleum Co.
   1300 Cantwell Dr.
   Corpus Christi, TX 74807

9. Denneth Wright, Mgr.
   Cominco American Inc., Camex Operation
   FM 1551 near Hwy 136
   Borger, TX 79007

10. J. R. Kempfhenkel
    Sun Exploration & Production Co.
    Suntide Rd.
    Corpus Christi, TX 78403

11. Kenneth Ladd, Sr. Engr.
    SW Public Service Co.
    Nichols Station
    N. Lakeside & Texas Hwy 136
    Amarillo, TX 79170

Region 7

1. John Maier, Facility Repr.
   P.O. Box 282
   Fort Madison, IA 52627

2. Richard Carlisle
   Facility Engr.
   Ft. Riley & 1st Infantry Div.
   Dir of Facility Engr Bldg 187
   Ft. Riley, KS 66442

3. John McKone, Col. USAF
   Offu-t Air Force Base
   3902 ABW
   Offutt Air Force Base, NE 68113

4. Cordell Peterson, President
   Landfill Service Corp.
   104 Black Hawk
   Reinback, IA 50669

5. John Pruitt, Mgr. Engr & SFE
   Farmland Industries
   P.O. Box 570
   Coffeyville, KS 67337

6. David Cutler, Pollution Control Director
   Getty Refining & Marketing Co.
   P.O. Box 1121
   El Dorado, KS 67042

7. Jim Pierce, Env. Control Coord.
   Pester Refining Co.
   Box 751
   El Dorado, KS 67042

8. J.M. Hazen
   Total Petroleum Inc.
   P.O. Box 857
   Arkansas City, KS 67005

9. John Lamkin
   Amoco Oil Co., Sugar Creek Refinery
   P.O. Box 8507
   Sugar Creek, MO 64054

10. Michael Gill, Manager
    Bobs Home Service Inc.
    RR 1, Box 116F
    Wright City, MO 63390

11. Gene Wallace
    Syntex Agribusiness
    P.O. Box 1246 SSS
    Springfield, MO 65805

12. C.W. Durham, Superv.
    Kerr McGee Chem Corp
    P.O. Box 2815
    Springfield, MO 65803

Region 8

1. Gary Refining Co.
   Nordhausen Lloyd Plant Supt.
   Fruita, CO 81521

2. Michael Halla, Env. Prog. Director
   USA-Ft. Carson
   DFAE Bldg. 304 AFZC-FE-EQ
   Fort Carson, Co 80913

3. The Manager
   Simmons Great Falls Refinery
   1900 10th Street
   Black Eagle, MT 59414

4. R.B. Blomeyer, Plant Mgr.
   Conoco Land Fram
   P.O. Box 2548
   Billings, MT 59103

5. Louis Day, Jr., Refinery Mgr.
   Farmers Union Central Exchange/Cenex
   P.O. Box 909
   Laurel, MT 59044

6. T.N. Schug, Coord. Environ. Affairs
   Exxon Billings Refinery
   P.O. Box 1163
   Billings, MT 59103

7. Daniel Drumiler, Supt. EC & S
   Amoco Oil Co. SLC Remote Tank Farm
   474 W. 900 North
   Salt Lake City, UT 48103

8. B.F. Ballard, Dir. Env. Control
   Phillips Petroleum Co.
   1004 Phillips Bldg.
   Bartlesville, OK 74004

9. T.E. Ferris, Refinery Mgr.
   Husky Oil Co.
   P.O. Box 175
   North Salt Lake, UT 84054

10. Larry Butler, V. Pres. Operations
    5662 S. 300 West
    Salt Lake City, UT 84107

11. James Speer, Refinery Manager
    Husky Oil Co., Cody Refinery
    P.O. Box 380
    Cody, WY 82414

Region 8 (cont'd)

12. Pat Havener, Asst. Plant Mgr.
Wyoming Refining Co.
Newcastle Refinery
P.O. Box 820
Newcastle, WY 82701

13. L. R. Corpuz, Mgr. Safety & Environ.
Sinclair Oil Corp.
P.O. Box 277
Sinclair, WY 82334

14. R.L. Masica, Plant Mgr.
Texaco Inc.
P.O. Box 320
Casper, WY 82602

15. Lorin Lefevre, Supt. Environ.
Amoco Pipeline Tank Farm
P.O. Box 160
Casper, WY 82602

16. The Manager
Colorado State University
17 State Services Bldg.
Denver, CO 80203

17. Dener's Livestock
2400 Sweetwater Rd.
Dillon, MT 59725

18. The Manager
Conoco Landfarm
P.O. Box 2548
Billings, MT 59103

19. The Manager
Exxon Billings Refinery
P.O. Box 2180
Houston, TX 77001

20. The Manager
Montana Sulphur & Chemical E. Billings
P.O. Box 31118
Billings, MT 59107

21. The Manager
Amoco Oil Company SLC Remote Tank Farm
200 East Randolph Dr.
Chicago, IL 60601

Region 8 (cont'd)

22. The Manager
Phillips Petroleum Co.
P.O. Box 196
Woods Cross, UT 84087

23. The Manager
Sinclair Oil Corp.
P.O. Box 277
Sinclair, WY 82334

Region 9

1. Jose Guaderrama, Plant Supt.
   AZ Public Service Co., Octilla Sta.
   1500 E. University
   Tempe, AZ 85251

2. Hugh Thompson, Dir. Env. Affairs
   Aerojet - General Corp.
   P.O. Box 13222
   Sacramento, CA 95813

3. James McBride, Dir. Tech. Services
   Casmalia DSPL
   P.O. Box 5275
   Santa Barbara, CA 93108

4. Craig McKenzie, Mgr.
   Chemical Waste Mgt. Kettleman Hills
   P.O. Box 255
   Kettleman City, CA 93239

5. William Park, President
   Environmental Protection Corp.
   3040 19th Street, Suite 10
   Bakersfield, CA 93301

6. David L. Bauer, Vice President
   It Corp. Imperial Facility
   338 West Anaheim St.
   Wilmington, CA 90744

7. D.W. DeBuse, Env. Engr. Supervisor
   Union Oil Co. of California, San Francisco RDF
   Country Road
   Rodeo, CA 94572

8. Patrick McReaken
   Hq 43rd Combat Support Group
   APO San Francisco, CA 96334

9. James Ryan
   Hawthorne Army Ammunition Plant
   Hawthorne, NV 89416

Region 10

1. Frank Dement
   Chem - Security Systems
   Cedar Springs Rd.
   Arlington, OR 97812

2. R. Ogar, Mgr.
   ARCO Petroleum Products Co. Cherry
   4519 Grandview Rd.
   Ferndale, WA 98248

3. C. Miller
   Mobil Oil Corp.
   3901 Unick Rd.
   Ferndale, WA 98248

4. Mark Warner
   Pringle Mfg. Co.
   3301 East Isaacs
   Walla Walla, WA 99362

5. R. Flickinger
   Shell Oil Co.
   March Point Rd.
   Anacortes, WA 98221

6. C. R. Ferguson
   Texaco Inc.
   March Point
   Anacortes, WA 98221

APPENDIX B

GENERATORS OF ICW SURVEYED USING TREATMENT TECHNOLOGY OTHER THAN LAND APPLICATION

Region 1

1. The Manager
American Cyanamid
1937 West Main St.
Stamford, CT 06902

2. The Manager
Belding Chemical Industries
Route 12
Grosvenordale, CT 06246

3. The Manager
Carpenter Technology Corp.
837 Seaview Ave.
Bridgeport, CT 06607

4. The Manager
Exide Corp.
2190 Post Rd.
Fairfield, CT 06430

5. The Manager
CMC New Departure Hyatt Bearings Bristol
780 James P. Casey Rd.
Bristol, CT 06010

6. The Manager
Naugatuck Chemical Div.
Uniroyal, Inc.
Elm Street
Naugatuck, CT 06770

7. The Manager
Porters Grove Metal Recovery Co.
1558 Barnum Ave.
Middletown, CT 06457

8. The Manager
Raybestos Manhattan Co.
Stratford Plant
75 East Main St.
Stratford, CT 06497

9. The Manager
American Hoechst Corp.
289 North Main St.
Leominster, CT 01453

10. The Manager
Boston Edison LST/New Boston Station
776 Summer St.
Boston, MA 02191

Region 1 (cont'd)

11. The Manager
Chemical Waste Mgt. of MA Inc.
10 Mercer Rd.
Natick, MA 01760

12. The Manager
Graph Coat Inc.
75 Whiting Farms Rd.
Holyoke, MA 01040

13. The Manager
North East Solvents Reclamation Corp.
300 Canal St.
Lawrence, MA 02184

14. The Manager
Recycling Industries Inc.
385 Quincy Ave.
Braintree, MA 02184

15. The Manager
Riverside Station
Water Street
Holyoke, MA 01040

16. The Manager
Service Chemical Corp.
221 Sutton St.
North Andover, MA 01845

17. The Manager
Thiokol/Ventron Div.
154 Andover St.
Danvers, MA 01923

18. The Manager
Western Mass. Electric Co.
West Springfield Sta.
15 Agawan Ave.
West Springfield, MA 01089

19. The Manager
Crago Co. Inc.
Libby Hill Rd.
Gray, Maine 04039

20. The Manager
Jet Line Services
106 Main St.
South Portland, ME 04106

Region 1 (cont'd)

21. The Manager
Maine Yankee Atomic Power Station
Bailey Point Ferry Rd.
Wiscasset, ME 04578

22. The Manager
Scott Paper Co.
Rte #201
Skowhegan, ME 04976

23. The Manager
Beede Waste Oil Corp.
Kelly Rd.
Plaistow, NH 03865

24. The Manager
General Electric Co.
130 Main St.
Somerworth, NH 03878

25. The Manager
American Hoechst Corp.
129 Quiknick St.
Coventry, MA 02815

26. The Manager
Bradford Dyeing Corp.
17½ Bowling Lane
Bradford, MA 02891

27. The Manager
Corning Glass Works
1193 Broad St.
Central Falls, MA 02863

28. The Manager
International Business Machines
Maple St/River Rd
Essex Junction, VT 05452

29. The Manager
Vermont Yankee Nuclear Power Station
Governor Hunt Rd.
Vernon, VT 05354

Region 2

1. John Leuzarder, V. Pres.
   Adv. Envi. Technology Corp.
   Goldmine Rd.
   Mt. Olive, NJ 07828

2. David Gaydos, Process Engr.
   Air Products and Chemicals, Inc.
   172 Baekeland Ave.
   Middlesex, NJ 08846

3. Edward O'Connor, V. Pres.
   Alliance Chemical
   33 Avenue P
   Newark, NJ 07114

4. Wayne Fennimore
   BFI Chemical Services Inc.
   Frontage Indust. Park Bldg D-1
   Westville, NJ 08093

5. William Sessler, Plant Engr.
   Dart Industries Inc.
   Woodfern Rd.
   Neshanic Station, NJ 08853

6. John R. Marshall, Env. Coord.
   DuPont E.I. DeNemours & Co.
   Washington Rd.
   Parlin, MJ 08859

7. L. Makfinsky, Mgr.
   Ethyl Corp., Bromine Chemicals Div.
   880 Main St.
   Sayreville, NJ 08872

8. Steve Rice, Env. Engr.
   Exxon Research & Engr. Co.
   US Route 22 East, Clinton TWP
   Annandale, NJ 08801

9. The Manager
   Fairmont Chemical Co.
   117 Blanchard St.
   Newark, NJ 07105

10. David Hersey, Plant Supt.
    GMI Electronics Inc.
    20 Washington Ave.
    Plainfield, NJ 07060

Region 2 (cont'd)

11. Mitchell Becker, Asst. Vice Pres.
Halcon Research and Development Corp.
1 Phillips Parkway
Montvale, NJ 07645

12. James Armstrong, Plant Engr.
Hunt Philip A Chemical Corp.
Roosevelt Place
Palisades Park, NJ 07650

13. Edward Smith, Plant Manager
Interstab Chemical Inc.
500 Hersey Ave.
New Brunswick, NJ 08903

14. H. Decker, Mgr.
Kearney Generating Station
Foot of Hackensack Ave.
Kearney, NJ 07032

15. Tom Puchalski, Mgr.
Merck and Co., Inc.
126 E. Lincoln Ave.
Rahway, NJ 07065

16. S. J. Gold
Mobil Chemical/Chemical Coatings Div.
Rte #27 & Vineyard Rd.
Edison, NJ 08818

17. Fred Cassaday, Plant Mgr.
National Can Corp.
Route 287 at Rondolphville Rd.
Piscataway, NJ 08854

18. John Wentz, Director
Natl. Smelting of New Jersey Inc.
Penus Grove, Pedricktown Rd.
Pedricktown, NJ 08067

19. The Manager
NL Chemicals
Chevalier Ave.
Sayreville, NJ 08872

20. Edward O'Connor, V. Pres-
Pfister Chemical Inc.
Foot of Linden Ave.
Ridgefield, NJ 07657

Region 2 (cont'd)

21. Gerald E. Jordan, Tech. Mgr.
Rollins Env. Services, Inc.
Route 322
Bridgeport, NJ 08014

22. Plant Manager
Southern California Chemical Co. Inc.
Foot of E22 St.
Bayonne, NJ 07002

23. A. R. Brubaker
Tech. Info. Systems Div., American Hoech
50 Meister Ave.
Branchburg TWP, NJ 08876

24. Charles Much, Mgr.
The Sherwin Williams Co.
Industrial Ave.
Perth Amboy, NJ 08863

25. Thomas Marshall, Plant Mgr.
Union Carbide Corp.
100 Normandy Dr.
Piscataway, NJ 08805

26. Director, Safety and Environment
Bausch & Lomb Inc. Optics Center
1400 N. Goodman St.
Rochester, NY 14602

27. A. Filiaci, Director
U.S. Metal Refining
400 Middlesex Ave.
Carteret, NJ 07008

28. Arlene Hendrickson, Env. Engr.
Ashland Chemicsl
South Street
Rensselaer, NY 12144

29. The Manager
Buffalo Color
340 Elk St.
Buffalo, NY 14210

30. John F. Dugan
Cecos International Inc.
56th St. & Pine Ave.
Niagara Falls, NY 14302

Region 2 (cont'd)

31. The Manager
Diaz Chemical Corp.
40 Jackson St.
Holley, NY 14470

32. Director of Engineering
Empire Cheese Corp.
Jordan Rd.
Hart Lot, NY 13705

33. Edward Urbanic, Corp. Engr.
Frontier Bindery Corp.
1144 Military Rd.
Kenmore, NY 14217

34. Plant Engineer
General Electric
Beekman Ave.
North Tarrytown, NY 10591

35. The Assistant Director
Grumman Aerospace
South Oyster Bay Rd.
Bethpage, NY 11714

36. The Supervisor
Hooker Chemicals & Plastics Corp.
4700 Hyde Park Blvd.
Niagara Falls, NY 14305

37. Dominic Casale, Env. Engr.
IBM Corp.
1701 North Street
Endicott, NY 13760

38. Israel Gajer
Jameco Industries Inc.
248 Wyandanch Ave.
Wyandanch, NY 11798

39. Gregory Smith, Tech. Supt.
Mobil Chemical Co. Plastics-Macedon Pkg.
Route 31
Macedon, NY 14502

40. The Plant Manager
Pennwalt Corp. Homer Plant
43 James St.
Homer, NY 13077

Region 2 (cont'd)

41. Joseph Dowling, Tech. Mgr.
Refined Syrups and Sugars Inc.
1 Federal St.
Onkers, NY 10702

42. Paul Letki, Env. Mgr.
SCA Chemical Waste Services
1550 Balmer Rd.
Model City, NY 14109

43. Robert Wills, Env. Engr.
Specialty Metals Div/Crucible Inc.
State Fair Blvd.
Geddes, NY 13209

44. The Manager
Three Star Anodizing Corp.
1 East Main St.
Beacon, NY 12508

45. Frank Lequerica, V. Pres.
Cyanamid Agricultural De Puerto Rico
Km 47.3 Route 2
Manati, Puerto Rico 00701

46. Jose Solero, Mfg. Engr.
General Electric Gepol Inc.
Rt. 129 Km 41.0
Zeno G. Industrial Park
Arecibo, Puerto Rico 00612

47. The Director
Municipal Dump of Ponce
#500 Municipal Rd., La Cotorr
Ponce, Puerto Rico 00731

48. The Manager
Searle & Co.
State Road No. 189 Km. 2
Caguas, Puerto Rico 00625

49. Luis Oyole Rivera
Union Carbide Caribe, Inc.
Road 127
Penuelas, Puerto Rico 00724

Region 3

1. The Manager
   U.S. Bureau of Engraving & Printing
   14th and C Streets, S.W.
   Washington, DC 20228

2. The manager
   Ametec Inc., Haveg Div.
   900 Grenback Rd.
   Wilmington, DE 19808

3. ICI Americans Inc. Atlas Paint
   Cherry Lane
   New Castle, DE 19720

4. The Manager
   Baltimore Gas & Electric
   P.O. Box 1475
   Baltimore, MD 21203

5. The Manager
   Chem-Clear of Baltimore Inc.
   1910 Russel St.
   Baltimore, MD 21230

6. The Manager
   Dutch Boy Paints Coatings Group
   2325 Hollins Ferry Rd.
   Baltimore, MD 21230

7. The Manager
   FMC Corp., Agricultural Chem Group
   P.O. Box 1616
   Baltimore, MD 21203

8. The Manager
   Naval Ordnance Station
   Route 210
   Indian Head, MD 20640

9. The Manager
   PEPCO, Morgantown Generating Sta.
   1900 Pennsylvania Ave, N.W.
   Washington, DC 20068

10. The Manager
    Tenneco Chemicals Inc. Chestertown Plant
    P.O. Box 120
    Chestertown, MD 21620

Region 3 (cont'd)

11. The Manager
U.S. Andrews AFB
1185 Civil Engineering GP/DEV
Andrews AFB, DC 20331

12. The Manager
Vulcan Materials Co.
2415 Grays Rd.
Baltimore, MD 21219

13. The Manager
Allied Chamicals, Baker & Adamson Works
Route 13
Marcus Hook, PA 19061

14. The Manager
Allied Table & Conduit Corp.
11350 Norcom Rd.
Philadelphia, PA 19154

15. The Manager
Amchen Products Inc.
300 Brookside Ave.
Ambler, PA 19002

16. The Manager
Allion Chemical Co. Inc.
P.O. Box 114
Folcroft, PA 19032

17. The Manager

Mt. Vernon St.
Lock Haven, PA 17745

18. The Manager
American Inks & Coatings Corp.
P.O. Box 803
Valley Forge, PA 19481

19. The Manager
Arco Chemical Co. Res. & Engr. Center
3801 West Chester Pike
Newton Square, PA 19073

20. The Manager
Atlas Powder Co.
Tamaqua, PA 18252

Region 3 (cont'd)

21. The Manager
Berkeley Products Co. Inc.
405 S. 7th St.
Akron, PA 17501

22. The Manager
Bethlehem Steel Corp, Johnstown Plant
119 Walnut St.
Johnstown, PA 15907

23. The Manager
Betz Laboratories
4636 Somerton Rd.
Trevose, PA 19047

24. The Manager
Boeing Vertol Co.
P.O. Box 16858
Philadelphia, PA 19142

25. The Manager
Cabot Berylco Industries Inc.
P.O. Box 1296
Reading, PA 19603

26. The Manager
Carpenter Technology Corp.
P.O. Box 662
Reading, PA 19603

27. The Manager
Chemical Clear Inc.
Jeffrey St. & Delaware Ave.
Chester, PA 19013

28. The Manager
Congoleum Corp.
Ridge Road
Marcus Hook, PA 19061

29. The Manager
Conversion Systems
Box 340
Honey Hook, PA 19344

30. The Manager
Dana Corp., Parish Div.
P.O. Box 1422
Reading, PA 19603

Region 3 (cont'd)

31. The Manager
Electronic Mfg. & Precision Assembly Inc.
9 Queen Anne Court
Laughorne, PA 19047

32. The Manager
GTE Products
Hawes St.
Towanda, PA 18848

33. The Manager
Gilbert Spruance Co.
Richmond and Tioga Sts.
Philadelphia, PA 19134

34. The Manager
Gulf Oil Co., U.S. Philadelphia Refinery
P.O. Box 7408
Philadelphia, PA 19101

35. The Manager
Hammerhill Paper Co.
P.O. Box 1440
Erie, PA 16533

36. The Manager
International Metals Reclamation Co.
P.O. Box 720
Ellwood City, PA 16117

37. The Manager
Koppers Co. Inc., Bridgeville Plant
P.O. Box 219
Bridgeville, PA 15017

38. The Manager
Lanchester Corp. Stabilized Disposal Site
P.O. Box 490
Honey Brook, PA 19344

39. The Manager
Mallinckrodt Inc.
Calsicat Div.
1707 Gaskell Ave.
Erie, PA 16503

40. The Manager
Merck & Co. Inc., Merck Chemical Div.
P.O. Box 196
Denville, PA 17821

Region 3 (cont'd)

41. The Manager
Mill Service Inc., Yukon Plant
1815 Washington Rd.
Pittsburg, PA 15241

42. The Manager
Municipal & Industrial Disposal Co.
P.O. Box 119
Clairton, PA 15025

43. The Manager
Penn Rare Metals, Cabot Berylco Inc.
Beaver Run Rd.
Revere, PA 18953

44. The Manager
Rohna & Haas Del Val Inc. Bristol Plant
P.O. Box 219
Bristol, PA 19007

45. The Manager
Smith Kline & French Labs
709 Swedeland Rd.
Swedeland, PA 19479

46. The Manager
Technographics Fitchburg Coated Products Inc.
P.O. Box 1106
Scranton, PA 18501

47. The Manager
U.S. Steel Corp., Clairton, Wks.
415 Fourth Ave.
McKeesport, PA 15132

48. The Manager
Vulcan Materials Co.
4100 Grand Ave.
Pittsburgh, PA 15225

49. The Manager
Waste Concersion Inc.
2869 Sandstone Dr.
Hatfield, PA 19440

50. The Manager
Westinghouse Air Brake Div.
P.O. Box 99
Wilmerding, PA 15148

Region 3 (cont'd)

51. The Manager
Witco Chemical Corp.
3300 W. 4th St.
Trainer, PA 19043

52. The Manager
DuPont De Nemours E.I. Co.
P.O. Box 4000
Front Royal, VA 22630

53. The Manager
Hercules Inc., Hopewell Plant
P.O. Box 271
Hopewell, VA 23860

54. The Manager
Mobay Chemical Corp.
P.O. Box 367
Damascus, VA 24236

55. The Manager
Radford Army Ammunition Plant
State Route 114
Radford, VA 24141

56. The Manager
Union Camp Corp.
Bleached Paper & Board
P.O. Box 178
Franklin, VA 23851

57. The Manager
Borg-Warner Chemicals Weston Plant #2
P.O. Box 816
Morgantown, WV 26505

58. The Manager
E.I. duPont DeNemours Parkersburg
P.O. Box 1217
Parkersburg, WV 26101

59. The Manager
Fike Chemicals
P.O. Box 546
Nitro, WV 25143

60. The Manager
FMC Corp., Organic Chem. Div.
P.O. Box 547
Nitro, WV 25143

61. The Manager
LCP Chemical Corp
South Plant
P.O. Drawer J
Moundsville, WV 26041

62. The Manager
Sharon Steel Corp.
Fairmont Coke Works
P.O. Box 291
Sharon, PA 16146

63. The Manager

P.O. Box 8004
South Charlestown, WV
25303

Region 4

1. Corina Byron, Env. Supervisor
   Alabama Power Co/Gaston Steam Plant
   P.O. Drawer B
   Wilsonville, AL 35186

2. Arlene Hendrickson
   Ashland Chemical Co.
   P.O. Box 7368
   Mobile, AL 36607

3. Steven Erickson, Mgr.
   Cheesebrough - Ponds Inc.
   P.O. Box 1348
   Huntsville, AL 35807

4. LaVern Heble, Mgr.
   Diamond Shamrock Corp.
   P.O. Box 1000
   Sheffield, AL 35660

5. Robert Milk, Mechanical Engr.
   Goodyear Tire & Rubber Co.
   P.O. Box 952
   Scottsboro, AL 35768

6. Sidney Foster, Mgr.
   Kerr-McGee Chemical Corp.
   P.O. Box 629
   Theodore, AL 36590

7. Mike Sappington, V. Pres.
   Sanders Lead Co., Inc.
   Henderson Rd.
   Troy, AL 36081

8. George Lessley, Plant Mgr.
   Stauffer Chemical Co.
   P.O. Box 32
   Bucks, AL 36512

9. Mohamed T. El-Ashry
   TVA Widows Creek Steam Plant
   Natural Resources Bldg.
   Norris, TN 37828

10. Tennimon Oakland, Mgr.
    Walverine/UOP Div.
    P.O. 2202
    Decatur, AL 35602

Region 4 (cont'd)

11. John Mueller, Plant Mgr.
Anheuser-Busch Inc.
P.O. Box 18017 AMF
Jacksonville, FL 32218

12. Whit Hudson, Mgr.
Chemical Waste Mgt.
2700 N.W. 48th St.
Pompano Beach, FL 33067

13. H.E. Sanders, Mgr.
Florida P & L
Ft. Lauderdale Plant
P.O. Box 8248
Ft. Lauderdale, FL 33310

14. C.M. Wethy, Mgr.
Florida P & L
St. Lucie Plant
P.O. Box 128
Ft. Pierce, FL 33450

15. John May, V. Pres.
Holly Hill Fruit Product Co. Sprayfield
P.O. Box 708
Davenport, FL 33837

16. William Bader, Mgr.
Jones Chemicals Inc.
P.O. Box 6067
Ft. Lauderdale, FL 33310

17. Frank Bartnick, Mgr.
RCA Corp. Solid State Div.
3900 RCA Blvd.
Palm Beach Gardens, FL 33408

18. Enrique Arias
Sugar Cane Growers Coop of Florida
P.O. Box 666
Belle Grade, FL 33430

Region 6

1. John B. Manning III
   Allied Chemical Corp., Helena Works
   AR Hwy 20 South
   Helena, AR 72342

2. Wayne Sickels, Technical Mgr.
   Energy Systems Co.
   American Rd.
   El Dorado, LA 71730

3. Ray Wilson, V. Pres.
   Maybelline Co.
   I-40 and Galloway Junction
   North Little Rock, AR 72117

4. John Garrison
   Monsanto Co., Inc.
   Hwy 7 North
   El Dorado, LA 71730

5. J.L. Echhoff, Mgr.
   Teletype Corp.
   8000 Interstate 30
   Little Rock, AR 72209

6. Joe Porter, Env. Engr.
   Vertac Chemical Corp.
   Hwy 242 South
   West Helena, AR 72390

7. Paul Michael, Env. Mgr.
   American Hoechst Corp.
   11911 Scenic Hwy
   Baton Rouge, LA 70807

8. Austin Arabie, Site Mgr.
   Browning-Ferris Ind. Chem. Services
   Hwy 37 Willow Springs Rd.
   Westlake, LA 70669

9. A.M. Fry, Env. Engr.
   Chevron Chem. Co.
   LA Hwy 23
   Belle Chase, LA 70037

10. M.L. Spence, Tech. Supt.
    Copolymer Rubber & Chem. Corp.
    Hwy 1
    Addis, LA 70710

Region 6 (cont'd)

11. M.M. Koenecke, Plant Mgr.
Ethyl Plant
Gulf States Rd.
Baton Rouge, LA 70821

12. Sheryl Brocato
Gulf States Utilities Co.
Nelson Station
Myrtle Spring Rd.
Westlake, LA 70669

13. J.H. Lashover, Chief Env. Engr.
Kaiser Aluminum & Chem. Co.
U.S. 61 Airline Hwy
Gramercy, LA 70052

14. Charles Keffer, Env. Supt.
Monsanto Co.
River Road
Luling, LA 70070

15. Dr. W.F. Snyder, Tech. Mgr.
Rollins Environmental Services
13351 Secnic Hwy
Baton Rouge, LA 70807

16. W.L. Caughman, Mgr.
Shell Oil Co. Refinery
River Td.
Merco, LA 70079

17. P.F. Normand
Union Carbide Corp. EOG Div.
Hwy 19 River Rd.
Hahnville, LA 70057

18. J.F. Baechtel, Mgr.
General Electric Co.
336 Woodward S.E.
Albuquerque, NM 87102

19. Dennis Murphey, Env. Supervisor
Agrico Chemical Co.
West of Verdigres
Catoosa, OK 74015

20. George O'Brien, Refinery Mgr.
Conoco Inc., Ponca City
1000 S. Pine
Ponca City, OK 74601

Region 6 (cont'd)

21. Steve Burford, Env. Engr.
Halliburton Services
Osage Rd.
Duncan, OK 73536

22. B.F. Ballard, Director
Phillips Research Center
94E PRC
Bartlesville, OK 74004

23. J.C. Wagner, Plant Mgr.
Air Products & Chemicals Co.
Rt. 1 10202 Strang Rd.
La Porte, TX 77571

24. Everett Nicoson, Mgr.
Advanced Micro Devices
5204 E. Ben White Blvd.
Austin, TX 78760

25. Philip Morris, Sr., Env. Engr.
American Hoechst Corp. Bayport
12212 Port Rd.
Addison, TX 75001

26. F.F. McKay, Mgr.
Arco Chemical Co.
8280 Sheldon Rd.
Channelview, TX 77530

27. R.H. Young, Env. Mgt. Mgr.
Bell Helicopter Textron
600 E. Hurst Rd.
Ft. Worth, TX 76053

28. B.F. Ballard, Director
Borger Refinery & NGL Process Center
State Hwy Spur 119
Phillips, TX 79007

29. Charles H. Neeley
Campbell Soup (Texas) Inc.
500 N. Loop 286
Paris, TX 75460

30. Robert Stubbeman, Mgr.
Celanese Chemical Co., Inc.
1901 Clarkwood Rd.
Corpus Christi, TX 78409

Region 6 (cont'd)

31. M.H. Davis, Mgr.
Champion Chemicals Inc.
115 Proctor
Odessa, TX 79763

32. Norb Bolda, General Mgr.
Chemical Waste Mgt. Inc.
Hwy 73
Port Arthur, TX 77640

33. Windle Taylor, Env. Engr.
Coastal States Petroleum Co.
1300 Cantwell Dr.
Corpus Christi, TX 78407

34. Harril Eastus, Mgr.
Dallas Morning News
Young & Houston Streets
Dallas, TX 75202

35. Arthur Meyer, Mgr.
Denka Chemical Corp.
8701 Park Place Blvd.
Houston, TX 77017

36. Jeffrey Leed, Mgr.
Dixie Metals Co.
3030 McGowan
Dallas, TX 75216

37. Richard Tavelli, Analyst
DSI Terminals Inc.
404 Holley St.
Quintana Townsite, TX 77541

38. Charles Evans, Env. Coord.
E.I. Dupont De Nemours & Co.
Hwy 361
Ingleside, TX 78362

39. V.P. Piskura, Jr.
Empak Inc. Deer Park
2759 Battleground Rd.
Deer Park, TX 77536

40. Marvin Chlapek, Env. Coord.
Exxon Chemical Baytown Olefins Plant
3525 Decker Dr.
Baytown, TX 77520

Region 6 (cont'd)

41. G.S. Hsieh, Env. Coord.
GAF Corp. Texas City
State Hwy 146
Texas City, TX 77590

42. Ronald Miller, Plant Mgr.
GM Assembly Div.
Arlington Plant
2525 E. Abram
Arlington, TX 76010

43. Larry Goza, Quality Control Supt.
General Cynamics-Abilene Facility
300 Wall St.
Abilene, TX 79604

44. James Pearson, Plant Mgr.
Goodyear Tire & Rubber Co.
13441 Bay Area Blvd.
La Porte, TX 77571

45. Carter Hart, Tech. Supv.
Gulf Oil Co.-Dawson Terminal
State Hwy 31 East
Dawson, TX 76679

46. Kathleen H. Anglin
Hercules Inc.
1101 Johnson Dr.
McGregor, TX 76657

47. W.F. McGuire, Mgr.
Houston Light & Power
Hwy 146 North of San Leon
Baycliff, TX 77518

48. Jeffrey Jones, Plant Mgr.
Jones Chemicals, Inc.
1777 Haden Rd.
Houston, TX 77015

49. Benjamin Renzo, Mgr.
Lonza Inc.
9700 Bayport Blvd.
Pasadena, TX 77507

50. A.E. Kelly, V. Pres.
Mission Petroleum Carriers, Inc.
8434 Mosley St.
Houston, TX 77075

Region 6 (cont'd)

51. P.B. Mullin, Env. Supt.
Mobil Chemical Co.
GSU County Rd.
Beaumont, TX 77704

52. Bill Morries, Plant Mgr.
National Can Corp.
8800 South Freeway
Fort Worth, TX 76134

53. Louis Leuthyold
Oakite Products Inc.
10100 Hirsch Rd.
Houston, TX 77016

54. Larry Burrell
Paktank Corp. Galena Park Terminal
1500 Clinton Dr.
Galena Park, TX 77547

55. Robert Laither, Plant Mgr.
Pennwalt Corp.
2231 Haden
Houston, TX 77015

56. Robert Reddin, Superv.
Reichhold Chemical Inc.
1503 Haden Road
Houston, TX 77015

57. J. Venable, Mgr.
Rohn and Haas Texas, Inc.
La Porte Hwy 225
Deer Park, TX 77536

58. Henry Blank
Standard Industries
Nelson Rd. at Reliable Drive
San Antonio, TX 78227

59. Michael Sikirica, Plant Mgr.
Stauffer Chemical Co.
8615 Manchester Blvd.
Houston, TX 77012

60. J.E. Langford, Mgr.
Tenneco Chemicals Inc.
Pasadena Site
4403 La Porte Rd.
Pasadena, TX 77501

Region 6 (cont'd)

61. G.R. Coker, Mgr.
Texaco, Inc.
6500 Trowbridge
El Paso, TX 79905

62. R.S. Beard, Supt.
Texas Elec. SVC Co.
6604 E. Rosedale St.
Fort Worth, TX 76112

63. Dominic Campe, Facilities Engr.
Texas Instruments Inc.
Hwy 75 South
Sherman, TX 75090

64. John Leverton
Union Carbide Corp.
Hwy 1765
Texas City, TX 77590

65. G. L. Phillips, Mgr.
Vulcan Materials Co.
East County Road
Denver City, TX 79323

Region 7

1. Leonard Reggit, Chief
   Amana Refrigeration Inc.
   Main At.
   Amana, IA 52203

2. Robert Schuler, Process Engineer
   Chemplex Co.
   P.O. Box 819
   Clinton, IA 52732

3. Don Evans, Env. Control Supt.
   Monsanto Co.
   P.O. Box 473
   Muscatine, IA 52761

4. Kent Houser
   Abbott Laboratories
   P.O. Box 12291
   Wichita, KS 67277

5. R.R. Williams, Plant Engr.
   General Motors Corp.
   GMAD Fairfax Plant
   100 Kindelberger Rd.
   Kansas City, KS 66115

6. James Turrentine, Env. Coord.
   Sunflower Army Ammunition Plant
   P.O. Box 640
   De Soto, KS 66018

7. John Lamkin, Stup.
   American Oil Co., Sugar Creek Refinery
   P.O. Box 8507
   Sugar Creek, MO 64054

8. Brad Willett, Env. Engr.
   American Cyanimid Co., Hannibal Plant
   Box 817
   Hannibal, MO 63401

9. The Manager
   Hercules Inc.
   P.O. Box 717
   Carthage, MO 64836

10. J.V. Weatherspoon, Mgr.
    Lake City Army Ammunition Plant
    P.O. Box 717
    Carthage, MO 64836

Region 7 (cont'd)

11. J. V. Weatherspoon, Mgr.
Lake City Army Ammunition Plant
P.O. Box 169
Independence, MO 64050

12. John Lawson, Mgr.
Mobay Chemical Corp., SG Chemical Div.
P.O. Box 4913
Kansas City, MO 64120

13. Louis Dellorco, Director
Ralston Purina Health Industries Plant
13001 St. Charles Rock Rd.
Bridgeton, MO 63044

14. Charles Reilly, Mgr.
Schuylkill Metals Corp.
P.O. Box 36
Forest City, MO 64451

15. Alan B. Staples, Env. Engr.
3M Company, T&CG
P.O. Box 327
Nevada, MO 64722

16. John Cooper, Env. Mgr.
Nebraska Public Power District
P.O. Box 499
Columbus, NE 68601

17. James Stolmeier, Env. Coordinator
Caterpillar Tractor Co.
P.O. Box 2790
Davenport, IA 52808

18. Robert Aaron, Plant Mgr.
GNB Betteries
P.O. Box 209
Leavenworth, KS 66048

19. Gary Mason, Mgr.
Vulcan Chemicals Co.
P.O. Box 12283
Wichita, KS 67277

20. Albert Dillis, Engr.
Union Carbide Corp., Maryville Plant
P.O. Box 280
Maryville, MO 64428

Region 7 (cont'd)

21. The Manager
McDonnell Douglas Corp., St. Louis Tract.
P.O. Box 516, Dept. 191C
St. Louis, MO 63166

22. Wallace Rasch, Research Engr.
Annheuser-Busch Inc.
721 Pestalozzi
St. Louis, MO 63118

23. Ronald Vorthmann, Plant Engr.
Sperry Vickers
6600 N. 72nd St.
Omaha, NE 68122

Region 8

1. The Manager
   Adolph Coors Co.
   8714 Hwy 60
   Johnstown, CO 80534

2. The Manager
   Allied Chemical Corp., Denver Works
   1271 West Bayand Ave.
   Denver, CO 80209

3. The Manager
   Ashland Chemical Co.
   3350 South Zuni
   Sheridan, CO 80110

4. The Manager
   Balcom Chemicals Inc.
   P.O. Box 1286
   Greeley, CO 80632

5. The Manager
   Beech Aircraft Corp.
   P.O. Box 9631
   Boulder, CO 80301

6. The Manager
   Colorado Yampa Coal Co., Middle Creek
   P.O. Box 774228
   Steamboat Springs, CO 80477

7. The Manager
   Conoco Inc.
   5801 Brighton Blvd.
   Commerce City, CO 80022

8. The Manager
   Coors Container Co.
   Mail #334
   Golden, CO 80401

9. The Manager
   Denver, Arapahoe Chemical Waste Process Facility
   P.O. Box 440865
   Aurora, CO 80044

10. The Manager
    Gary Refining Co.
    Rural Area
    Fruita, CO 81521

Region 8 (cont'd)

11. Gates Rubber Co.
P.O. Box 5887
Denver, CO 80217

12. The Manager
Honeywell Inc.
1150 E. Cheyenne Mountain Blvd.
Colorado Springs, CO 80906

13. Komac Paint Inc.
1275 Osage St.
Denver, CO 80201

14. McKesson Chemical Co.
5400 Monroe
Commerce City, CO 80022

15. Moly Corp. Inc, Union Oil Co.
P.O. Box 607
Louviers, CO 80131

16. Mountain Chemical Inc.
16035 W. 4th Ave.
Golden, CO 80401

17. NCR Microelectronics
1635 Aeroplaza
Colorado Springs, CO 80916

18. Oil & Solvent Process Co.
P.O. Box 360
Commerce City, CO 80037

19. Platte Chemical Co.
P.O. Box 667
Greeley, CO 80631

20. Shattuck Chemical Co.
1805 S. Bonnock St.
Denver, CO 80223

21. Storage Technology Corp.
2270 S. 88th St. MD N5
Louisville, CO 80027

22. Syntex Chemicals Inc.
2075 N. 55th St.
Boulder, CO 80301

Region 8 (cont'd)

23. Thompson-Hayward Chemical Co.
P.O. Box 7427 Park Hill Station
Denver, CO 80207

24. Allen-Bradley
P.O. Box 1906
Bozeman, MT 59715

25. AT&T-Fallow
P.O. Box 7810
San Francisco, CA 94120

26. Carl Weissman & Sons Inc.
P.O. Box 1204
Great Falls, MT 59415

27. Conoco Bozeman Terminal
318 Griffin Dr.
Bozeman, MT 59715

28. Exxon Billings Refinery
P.O. Box 1163
Billings, MT 59103

29. Exxon Pipeline Co., Montana System
P.O. Box 2220
Houston, TX 77001

30. Great Western Chemical Co.
2000 Boulder Ave.
Helena, MT 59624

31. Malstrom Air Force Base
341 CSG/CC
Malstrom AFB, MT 59402

32. Ranzoil Inc.
2207 Central Ave., Suite 302
Billings, MT 59102

33. US DOEHot Springs Substation
P.O. Box 491
Vancouver, WA 89666

34. Amoco Oil Co.
P.O. Box 1247
Jamestown, ND 58401

35. General Electric Co.
1810 40th Ave., S.E.
Mandan, ND 58554

Region 8 (cont'd)

36. The Commander
Minot Air Force Base
91 CSG/CC
Minot AFB, ND 58705

37. 3M Wahpeton Mag A/V & Telecom
2200 North 3M Drove
Wahpeton, ND 58075

38. Hardcastle Transfer
202 10th Ave. East
Mobridge, SD 57601

39. Midtex Division, Midland Corp.
121 Airport Dr.
Watertown, SD 57201

40. Robert Short & Sons Const.
1115 5th St.
Strugis, SD 57785

41. 3M Brookings Medical Products Div.
P.O. Box 33331
St. Paul, MN 55133

42. American Plating & Bumper
1621 Beck St.
Salt Lake City, UT 84116

43. Chevron USA Inc., Milford Bulk Plant
P.O. Box 599
Denver, CO 80201

44. Chicago Bridge & Iron Co.
P.O. Box 599
Denver, CO 80201

45. Crysen Refining
P.O. Box 251
Woods Cross, UT 84087

46. National Semiconductor Corp.
3333 West 9000 South
West Jordan, UT 84084

47. Scientific Products Div. of AHSC
2177 West Custer Rd.
Salt Lake City, UT 84125

48. Syro Steel
Box 835
Centerville, UT 84014

49. Sinclair Oil Corp.
P.O. Box 277
Sinclair, WY 82334

50. Conoco Rock Sptings Terminal
Box 429
Rock Springs, WY 82901

51. Amoco Oil Co., Casper
P.O. Box 160
Casper, WY 82602

52. Syro Steel Corp., Geneva Works
P.O. Blx 510
Provo, UT 84603

53. General Electric Co.
P.O. Box 2559
Casper, WY 82602

Region 9

1. David Anderson
   Ashland Chemical Co.
   P.O. Box 1209
   Mesa, AZ 85201

2. McKesson Chemical Co.
   P.O. Box 14799
   Phoenix, AZ 85063

3. The Director, Environmental Affairs
   Aerojet-General Corp.
   P.O. Box 13222
   Sacramento, CA 95813

4. Advanced Micro Devices Inc/
   901 Thompson Place M/S 8
   Sunnyvale, CA 94086

5. The Environmental Engr.
   Ashland Chemical Co.
   10505 S. Painter Ave.
   Santa Fe Springs, CA 90670

6. The Vice President, Production
   Betz Laboratories
   4636 Somerton Rd.
   Trevose, PA 19047

7. Chief Engineer
   BKK Corp.
   San Diego Transfer Sta.
   2550 237th St.
   Torrance, CA 90505

8. The Environmental Engineer
   Chevron Chemical Co.
   Ortho Division
   940 Hensley St.
   Richmond, CA 94804

9. Crowley Environmental Services Corp.
   1453 Harbour Way South
   Richmond, CA 90731

10. Dow Chemical-Torrance Plant
    306 Crenshaw Blvd.
    Torrance, CA 90503

Region 9 (cont'd)

11. EPC Eastside Disposal Farm
3040 19th St, Suite 10
Bakersfield, CA 93301

12. Fairchild Hazardous Waste Storage Facility
101 Bernal Rd.
San Jose, CA 95119

13. Ferro Corp.
Productol Chem. Div.
10051 Romandel Ave.
Santa Fe Springs, CA 90670

14. The Vice President
Forward Disposal Site
P.O. Box 6567
Stockton, CA 95206

15. Francis Plating of Oakland Inc.
785 7th St.
Oakland, CA 94607

16. General Battery Corp.
P.O. Box 1262
Reading, PA 19603

17. Golden Eagle Refining Co., Inc.
P.O. Box 4886
Carson, CA 90749

18. Great Western Chemical Co.
860 Wharf St.
Richmond, CA 94804

19. Hunt Phillip A Chemical Corp.
4265 Charter St.
Los Angeles, CA 90058

20. David Bauer, Vice President
IT Corp. Baker Factory
336 W. Anaheim St.
Wilmington, CA 90744

21. Mobil Oil Corp.
3700 W. 190th St.
Torrance, CA 90509

22. Northrop Corp. Aircraft Div.
3901 W. Broadway
Hawthorne, CA 90250

Region 9 (cont'd)

23. The Director
Oil & Solvent Process Co.
P.O. Box 907
Azuza, CA 91782

24. Pacific Oasis
14700 Downey
Paramount, CA 90723

25. Petroleum Waste Inc.
P.O. Box 3366
Bakersfield, CA 93385

26. Prestolite Battery Div. of Eltra Corp.
P.O. Box 3067
Visalia, CA 93277

27. Rio Bravo Refining Co.
2323 E Street
Bakersfield, CA 93301

28. Rockwell International Corp.
6633 Canoga Park
Canoga Park, CA 91304

29. Shell Oil Co.
Martinize Mfg. Complex
P.O. Box 711
Martinez, CA 94553

30. Signetics Corp.
811 E. ARques Ave.
Sunnyville, CA 94086

31. Solvent Service Co., Inc.
1021 Berryessa Rd.
San Jose, CA 95133

32. The Administrator
Southern California Waste Reduction
P.O. Box 1063
Sun Valley, CA 91352

33. Standard T. Chem. Co. Inc.
3016 Alvarado St.
San Leandro, CA 94577

34. Stauffer Chemical Co.
100 Mococo Rd.
Martinez, CA 94553

Region 9 (cont'd)

35. Texaco USA
P.O. Box 817
Wilmington, CA 90748

36. Union Oil Co. of California
San Francisco RDF
County Road
Rodeo, CA 94572

37. Varian Assoc. EIMAC Div.
301 Industrial Way
San Carlos, CA 94070

38. West Contra Costa Co. Sanitary Landfill
205 41st St.
Richmond, CA 94805

39. Witco Chem. Corp.
Golden Bear Div.
P.O. Box 5446
Carson, CA 90744

40. Zoecon Corp. Chem. Div.
1990 Bay Rd.
East Palo Alto, CA 94303

41. Unitek Env. Services Inc.
91-125 Kaomi Loop
Ewa Beach, HI 96706

42. Kerr McGee Chem. Corp.
P.O. Box 55
Henderson, NV 89015

43. Montrose Chem. Corp. of California
P.O. Box 37
Henderson, NV 89015

44. Titanium Metals Corp. of America Timet
P.O. Box 2128
Henderson, NV 89015

45. Tyoby Electronics
P.O. Box 664
Carson City, NV 89701

Region 10

1. Shawn Moore, General Mgr.
   AM Test Inc.
   4900 9th Ave., N.W.
   Seattle, WA 98107

2. Allied Chemical Corp., Hedges Works
   P.O. Box 6447
   Kennewick, WA 99336

3. Alumax Irrigation Products
   TA Box 3107
   Spokane, WA 99220

4. B & H Body Shop Inc.
   P.O. Box 6127
   Bellevue, WA 98008

5. Big Bend Fertilizers
   1276 Halyard Dr.
   West Sacramento, CA 95651

6. Boeing Co. Development Center
   Box 3999, Mail Stop 89-13
   Seattle, WA 98124

7. Boeing Kent Space Center
   P.O. Box 3707
   Seattle, WA 98124

8. Brea Agricultural Service, Toppenish
   1276 Halyard Dr.
   West Sacramento, CA 95651

9. Burlington Northern Inc., Hillyard Shop
   Box 6218
   Spokane, WA 99207

10. C & D Batteries Div.
    960 Industry Dr.
    Seattle, WA 98188

11. Cenex Trucking Terminal
    Box 1200
    Pasco, WA 99301

12. Chemcentral/Seattle
    7601 South 190th St.
    Kent, WA 98031

Region 10 (cont'd)

13. Colfax Orange Supply Inc.
P.O. Box 526
Colfax, WA 99111

14. Continental Can Co., USA Plant 466
Rt. 4, Grant Co.
Airport Bldg. 5825
Moses Lake, WA 98837

15. Daniel Boone Paint Co. Inc.
P.O. Box 9240
Seattle, WA 98109

16. Deer Park Co. Pacific N.W.
Room 1501, 1600 Bell Plaza
Seattle, WA 98191

17. DuPont Repeater Bldg, Pacific N.W. Bell
Room 1501, 1600 Bell Plaza
Seattle, WS 98327

18. Elenbaas Co. Inc.
P.O. Box 38
Sumas, WA 98295

19. Exotic Metals Forming Co.
P.O. Box 46406
Seattle, WA 98146

20. Farwest Pint Mfg. Co.
P.O. Box 68782
Tukwila, WA 98168

21. Fiber Resin Supply Co.
366 W. Nickerson St.
Seattle, WA 98119

22. Fibrex Corp.
Box 428
Burlington, WA 98233

23. Frontier Hard Chrome
113 Y St.
Vancouver, WA 98661

24. General Electric Co.
N. 3919 Sullivan Rd.
Spokane, WA 99216

25. Georgia Pacific, Bio Treatment Lagoon
P.O. Box 1236
Bellingham, WA 98227

Region 10 (cont'd)

26. Graham Steel Corp.
P.O. Box 658
Kirkland, WA 98033

27. Great Western Chemical Co. of Washington
6900 Fox Avenue
Seattle, WA 98108

28. Hansen Machine Corp.
712 S. Portland St.
Seattle, WA 98108

29. Harbor Island Plant, Shell Oil Co.
P.O. Box 3947
Seattle, WA 98124

30. Hewlett Packard
1620 Signal Dr., TAF C-34
Spokane, WA 99220

31. Honeywell, Inc.
5303 Shilshole Ave., N.W.
Seattle, WA 98107

32. Industrial Finishers Unlimited, Inc.
22631 88th Ave., South
Kent, WA 98031

33. Industrial Plating Corp.
2411 6th Ave., South
Seattle, WA 98134

34. Intalco Aluminum Corp.
P.O. Box 937
Ferndale, WA 98248

35. International Paper Co. Wood Products
P.O. Box 579
Longview, WA 98632

36. Jones Chemical Inc.
100 Sunny Sol Blvd.
Caledonia, NY 14423

37. Kaiser Aluminum & Chemical Corp., Mead Plant
P.O. Box 6217
Spokane, WA 99207

38. Lilyblad Petroleum Inc.
P.O. Box 1381
Tacoma, WA 98401

Region 10 (cont'd)

39. Long Painting Co.
Box C81435
Seattle, WA 98108

40. M & M Finisher
16600 Pacific Hwy 80
Seattle, WA 98188

41. McKesson Chemical Co.
702 3rd St.,S.W.
Aubutn, WA 98002

42. Metal Technical Plating
15327 N.E. 92nd St.
Redmond, WA 98052

43. Mobil Oil Corp.
10 Box 8
Ferndale, WA 98248

44. National Can Corp.
2601 N.W. Lower River Td.
Vancouver, WA 98660

45. Naval Undersea Warfare Engineering Sta.
Code 073
Keyport, WA 98345

46. Northwest Plating Co., Inc.
825 S. Dakota
Seattle, WA 98108

47. Nulife Fertilizers Hygrade Food Products
P.O. Box 883
Tacoma, WA 98421

48. Occidental Chemical Corp.
P.O. Box 2157
Tacoma, WA 98401

49. Pacific Circuits Inc.
3830 148th Ave., N.E.
Redmond, WA 98052

50. Pacific Wood Treating Corp.
111 W. Division
Ridgefield, WA 98642

51. Terry Eggen, Production Mgr.
Pacific Woodworks, Inc.
2138 Humboldt St.
Bellingham, WA 98225

Region 10 (cont'd)

52. Parker Paint Mfg. Co., Inc.
P.O. Box 11047
Tacoma, WA 98411

53. Phillips Pacific Chamical Co.
104D Phillips Bldg.
Bartlesville, OK 74004

54. Robert Walker,
Vice President OPS & Engr.
P.O. Box 1482
Tacoma, WA 98421

55. Alan M. Park, Jr., General Mgr.
Rudd Paint & Varnish Co., Inc.
1608 15th Ave., West
Seattle, WA 98119

56. Donald W. Lilly
United Paint Mfg. Co.
P.O. Box 369
Greenacres, WA 99016

57. M. F. Calloway
Virgin Chemical Inc.
P.O. Box 10
Kalama, WA 98625

58. Greg Barnette, Mgr.
Wolfkill Feed & Fertilizer Corp.
P.O. Box 406
Lyden, WA 98264

APPENDIX C

SURVEY FORMS USED

Date _____

File No. _____

SURVEY OF CORROSIVE AND IGNITABLE WASTE

1. Name of Company: _____
   Address: _____
   _____ Tel.No. ( )
   Name of Contact Person: _____ Tel.No. ( )

2. Nature of corrosive waste: (check one or more)
   ____Sludge ____Slurry ____Aqueous ____Solid ____Others
   Nature of ignitable waste:
   ____Sludge ____Slurry ____Aqueous ____Solid ____Others

3. Composition of the Waste:
   Corrosive Waste; ___consistent ___variable ___highly variable
   Ignitable Waste; ___consistent ___variable ___highly variable

4. Is the waste generated from batch or continuous type processes? ___Yes ___No

5. Are all of the waste generated combined before disposal? ___Yes ___No

6. If not, what kinds of wastes are separated? _____
   _____
   _____

   Is corrosive waste pretreated before disposal? ____Yes ___No
   Ignitable Waste? ____Yes ____No

7. If yes to question 6, what are the methods of pretreatment for corrosive waste?
   ___Chemical ___Ponding
   ___Carbon Absorption/Adsorption ___Dilution
   ___Flocculation ___Bio-oxidation
   ___Neutralization ___Others _____

   For ignitable waste _____
   _____

8. What is the pH range of your corrosive waste?
   _____ <2 ___>2 ___ 2-6 ____7-12

9. What is the flash point of your ignitable waste?
   _____ $\leq 60^{\circ}C$ ($140^{\circ}F$) _____ $> 60^{\circ}C$ ($140^{\circ}F$)

10. What is the alcohol content of your ignitable waste?
    ___less than 24% by volume ____more than 24% by volume

11. Did you previously have a land application facility? ___Yes ___No
    If yes, why was land application discontinued? _____
    _____
    _____

12. What was the nature of the waste that was previously land applied?
_____

13. Was Land Application considered for disposal of corrosive/ignitable waste? ___Yes ___No

14. Factors considered for not considering Land application:
___Land Availability
___Economics
___Contamination of Groundwater
___Regulations/Federal Constrainst
___Others (Name them) _____
_____

15. Do you think that land application is a viable means of disposal of corrosive/ignitable waste? ___Yes ___No
If answer is no, why?_____
_____
_____

16. Are you willing to participate in a feasibility study for land application to be conducted at the University of Oklahoma in the future? ___Yes ___No
If answer is no, why?_____
_____
_____

17. Do you have a Part A and/or Part B permit/application to manage, handle and dispose of hazardous waste? ___Yes ___No

18. Volume of corrosive waste produced annually _____metric tons/year
Volume of ignitable waste produced annually _____metric tons/year

19. Current methods of disposal of waste: (check one or more)
___Landfill
___Lagoon/Pond
___Incineration
___Contracted out
___Land application
___Others _____

20. If waste is pretreated before disposal, how is the final sludge/effluent disposed of? _____
_____
_____

**** Your participation in this survey is highly appreciated. Thank you!

File No._____

Date _____

SURVEY FOR LAND APPLICATION OF CORROSIVE/IGNITABLE WASTES

1. Name of Company:_____
2. Address: _____

_____Tel.No._____

Name of Contact Person:_____Tel. No._____

2. Do you have a Part A or Part B application/Permit to operate/handle/dispose of hazardous waste? ____Yes _____NO

If No, do you have an interim permit? _____YES _____NO

3. Do you have a land application facility? _____YES _____NO

If YES, what is the total land area of your land application site?_____acres

4. Are operating records available for those land application facilities identified? _____YES _____NO

5. Is the land treatable waste generated from batch or continuous type processes? _____YES _____NO

6. Is the composition of the waste __consistent __variable __highly variable

Is it, __solid __liquid __semi-solid __sludge

7. Do you combine all your waste before disposal? _____YES _____NO

If no, what kinds of wastes are separated? _____

_____

8. How often is the waste applied to the land?

___Daily ___Weekly ___ Monthly ___Yearly ___Others_____

9. What would you consider are the land limiting constituents of your waste?

____Metals ____Acids/Bases ___Organics ___Inorganics

____PCB's ___Cyanide ___Others_____

10. Are wastes pretreated or conditioned in any manner prior to land application?

_____YES _____NO

If Yes, what are the pretreatment methods used?

___Neutralization _____Flocculation _____Dilution

___Chemical Treatment ___Physical treatment (aeration, settling, etc.)

___ Others _____

11. What is the pH range of your corrosive waste?

____ < 2 ___ > 2 _____2-6 _____7-12

12. What is the flash point of your ignitable waste?
    _____ 60°C (140°F) _____60°C (140°F)
13. What is the alcohohol content of your waste?
    ___less than 24% by volume ___more than 24% by volume
14. Is the soil in the land treatment area conditioned? ___Yes _____No
    If Yes, (check one or more) which of the following are used?
    ____Fertilizer _____Lime _____Others
15. Were there any wastes previously land treated that are no longer treated in this manner? _____Yes _____No. If yes, what was the waste land treated and why was this practice discontinued?_____
    _____
    _____
16. Is an unsaturated zone monitoring plan available? _____YES _____No
    If not why?_____
    _____
17. Are analytical results available for unsaturated zone monitoring?
    ____Yes ___No
18. Do you think that land application of corrosive/ignitable waste is a viable means of disposing of this kind of waste? _____YES ____NO
    If NO, Why?_____
    _____
    _____
19. If land application of corrosive/ignitable waste was discontinued, why?

    _____ Land Availability
    _____ Economics
    _____ Government Regulations
    _____ Pollution of Ground Water
    _____ Others

20. What is the total volume of the waste that is land applied?
    Total volume: _____Metric tons/year
    Corrosive waste (D002) _____Metric tons/year
    Ignitable waste (D001) _____Metric tons/year
21. Are you willing to participate in a feasibility study on land application of corrosive/ignitable waste in collaboration with the University of Oklahoma? _____Yes _____No
    If No, why? _____
    _____

APPENDIX D

INDUSTRIAL PROCESS AND WASTE CHARACTERIZATION

This portion of the report deals with process descriptions and waste stream characterization of ICW to enhance understanding of the source and nature of ICW in selected industries.

Table D.1. Major National Industrial ICW Waste Generators, Estimated Production and Hazardous Waste Quantities.

	Industry	Estimated Production (Million Metric Tons/Year)	Hazardous Waste Generated (Metric Tons/Year)	Reference
1.	Petroleum Refining	1.1×10^6	53,739	USDA, Census of Manufactures, 1981.
2.	Paint Industry	4.0	105,000	USEPA, 1976
3.	Citrus Processing	14.2	-	NTIS, 1978
4.	Pharmaceutical Industry	1.6	78,995	USEPA, SW-508, 1976 Arthur D. Little Inc. estimates
5.	Fertilizer Industry	14.2	-	Battelle Memorail Institute, 12020 FPD 09/71, Sept. 1971.
6.	Pulp and Paper Industry		1050×10^9	FWPCA Publication no. IWP-3
7.	Steel Industry	60	212×10^5	Battacharya, S. IIT Research Inst. July 1979
8.	Soap and Detergent	-	29	USEPA-600/2-78/140a 1978

Table D.1 (con't)

Industry	Estimated Production (Million Metric Tons/Year)	Hazardous Waste Generated (Metric Tons/Year)	Reference
9. Textile Mills	36.4	4.7×10^9	USDA, Census of Manufac. NTIS, 1978.
10. Inorganic Chemicals			
a. Titanium Dioxide	0.3	60,000 m^3/day	USEPA-uuo/1-79/007, 1979
b. Hydrofluoric Acid	0.3	2,350 m^3/day	USEPA-UUO/1-79/048-D Dec. 1979.
11. Explosives and Munitions Industry	1.9	21,500	USEPA, 1980.

PETROLEUM REFINING

There were a total of 120 firms operating 297 refineries processing 19.37 billion barrels of crude oil on a daily basis (Table D.1). Figure D.1 is the flow diagram for a typical complete refinery.

The waste stream produced by each refinery is dependent on the type of processes employed and the variety of products produced. Estimates of waste generation rate and characteristics may therefore be liberal or conservative depending on the category of the facility used for characterization.

In general, the major sources of ICW are storage tank drainoffs, crude desalting and distillation, thermal and catalytic cracking processes, and solvent refining. Two significant general waste streams are the surfidic sour waters (containing H_2S/NH_3), sulfidic spent caustics, sour water steam stripper, phenolic sour waters (H_2S/NH_3 and phenols), phelolic spent caustics and water after scrubs, following caustic-scrubs. Figure D.2 presents the different waste streams generated in an oil refinery and in-plant pretreatment methods.

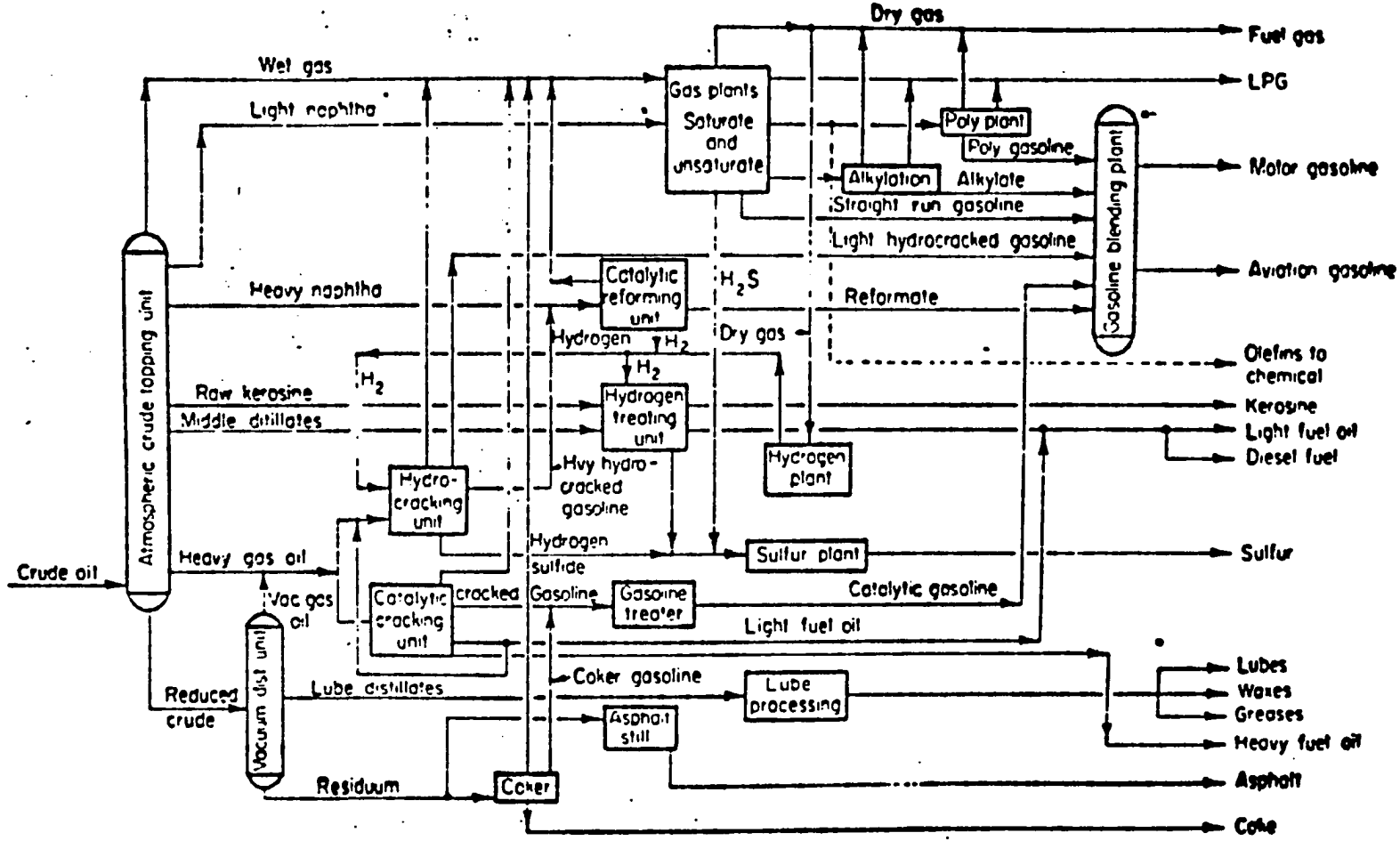
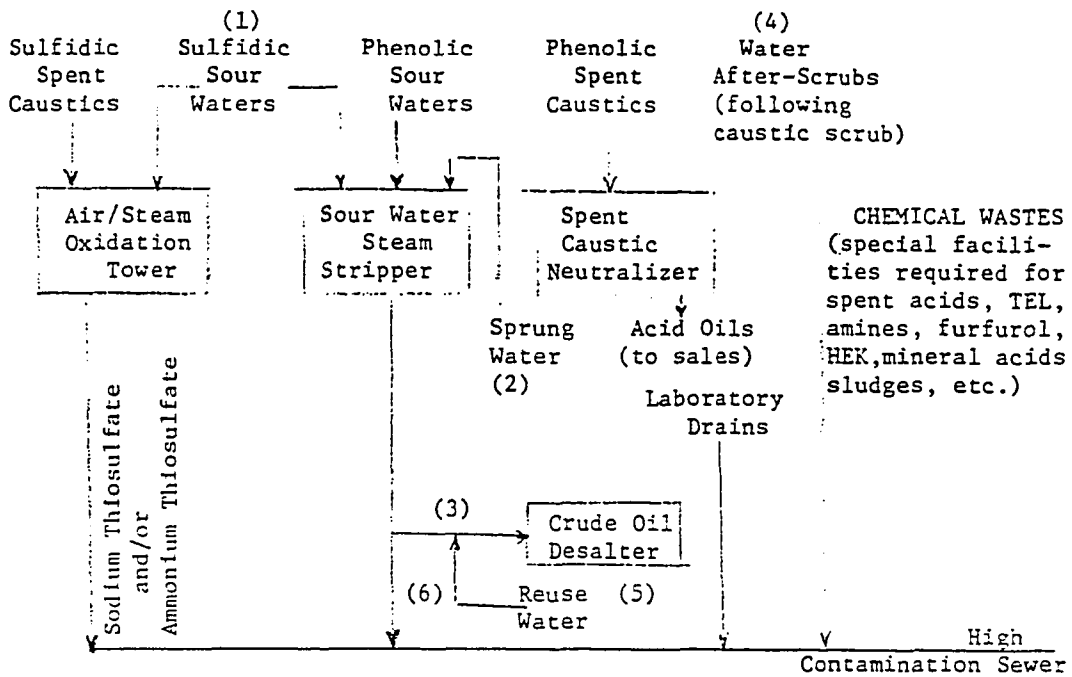


Figure D.1. Processing Plan for Typical Complete Refinery.

Source: USEPA-600/2-83-101, Feb. 1983 (45)



(1) Usually steam stripped. If no phenols or oil present, may be oxidized.
(2) Will contain about 3000 ppm st.H_2S, 8000 ppm wt. phenol, and 15-30 wt. % sodium salts. High salt content may cause problems in steam stripper.
(3) Stripper removes about 98% of H_2S, 95% of NH_3 and 20% of phenols. pH of stripped water will be about 9-10. With some crudes residual NH_3 may require acid neutralization to pH 6.8-7.0 to avoid formation of salts in desalter.
(4) May require acid neutralization if caustic carryover is excessive.
(5) Desalter removes most of the phenols and H_2S from water. This stream will contain 0-10 ppm wt. H_2S, 10-15 ppm wt. phenols, 100-300 wt. oil, 50-500 ppm wt. BOD.
(6) H_2S content about 10-150 ppm wt. and NH_3 content about 50-500 ppm wt. pH about 9-10. Will also contain phenols.

Figure D.2 In-plant pretreatment of high contamination waste streams.

Source: Beychok, M.R. "Trends in treating petroleum refining wastes," Industrial Process Design for Water Pollution Control, AICHE Workshop, vol. 2, p. 56, April 1969.(48)

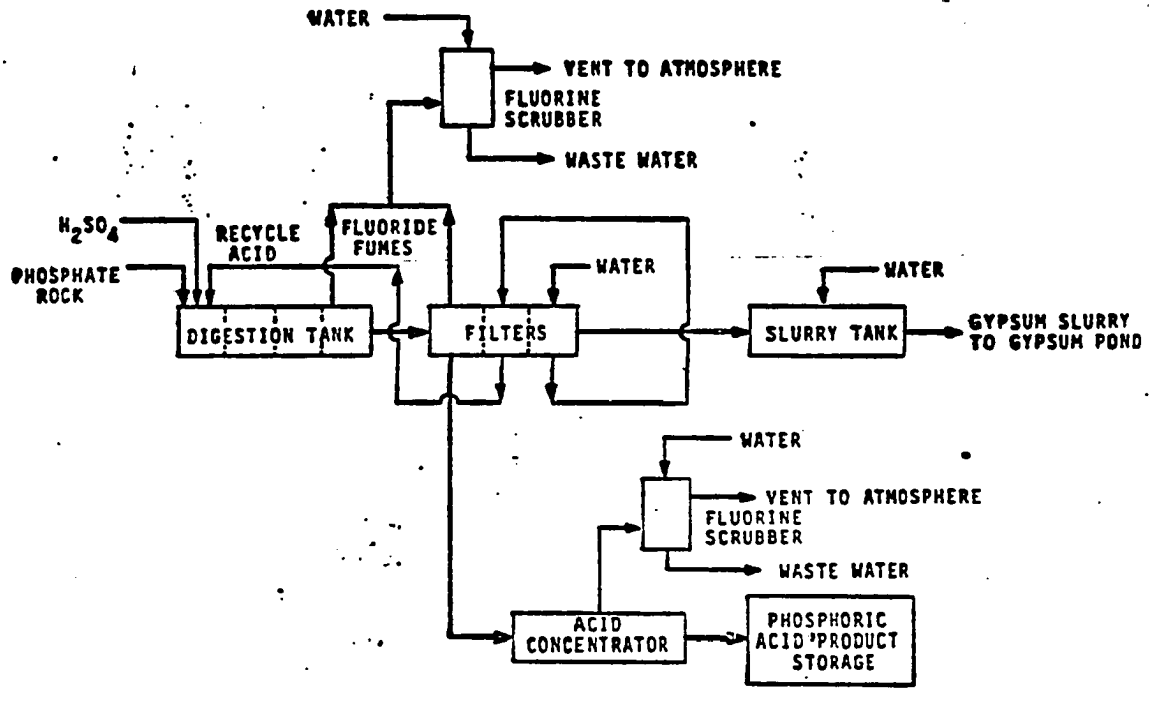


Figure 5.3. Wet Process Phosphoric Acid Flowsheet.

Source: Battelle Memorial Institute, USEPA-12121 FPD 09/71, U.S. Government Printing Office, September 1971, p. 33. (49)

2. FERTILIZER INDUSTRY

The fertilizer industry produces several types of fertilizer, principally classified as nitrogen or phosphorus production facilities. Nitrogen fertilizer processes include those that produce anhydrous ammonia, ammonia nitrate, ammonia sulfate or urea. Phosphate fertilizer processes include normal superphosphate, triple superphosphate, ammonium phosphates and ammoniated superphosphates.

It is in the phosphate fertilizer industry where ICW is generated in significant volumes. The total production of phosphate fertilizer in 1971 was 14.2×10^6 short tons. The flow chart for phosphate fertilizer production is shown in Figure D.3. ICW is generated in the wet sulfuric acid treatment of phosphate rock. The wet process is the principal method used to produce phosphoric acid and the waste stream may consist of gypsum slurry, off-gas scrubber liquor, acid sludge, and steam condensate. 30-32 percent phosphoric and waste is discharged as a slurry to a gypsum pond. Typical composition of the gypsum pond water are as follows:

Contaminant	Concentration, mg/ℓ
P_2O_5	6,000 - 12,000
Fluoride	3,000 - 5,000
Sulfate	2,000 - 4,000
Calcium	350 - 1,200
Ammonia	0 - 100
Nitrate	0 - 100
pH	1.0 - 1.5

3. CITRUS PROCESSING INDUSTRY

The total production of the citrus processing industry in 1978 was 14.2×10^6 metric tons. A typical citrus processing plant flow diagram is shown in Figure D .4.

Inplant waste stream characteristics that generate ICW are spend caustic solutions used to clean equipment and holding tanks.

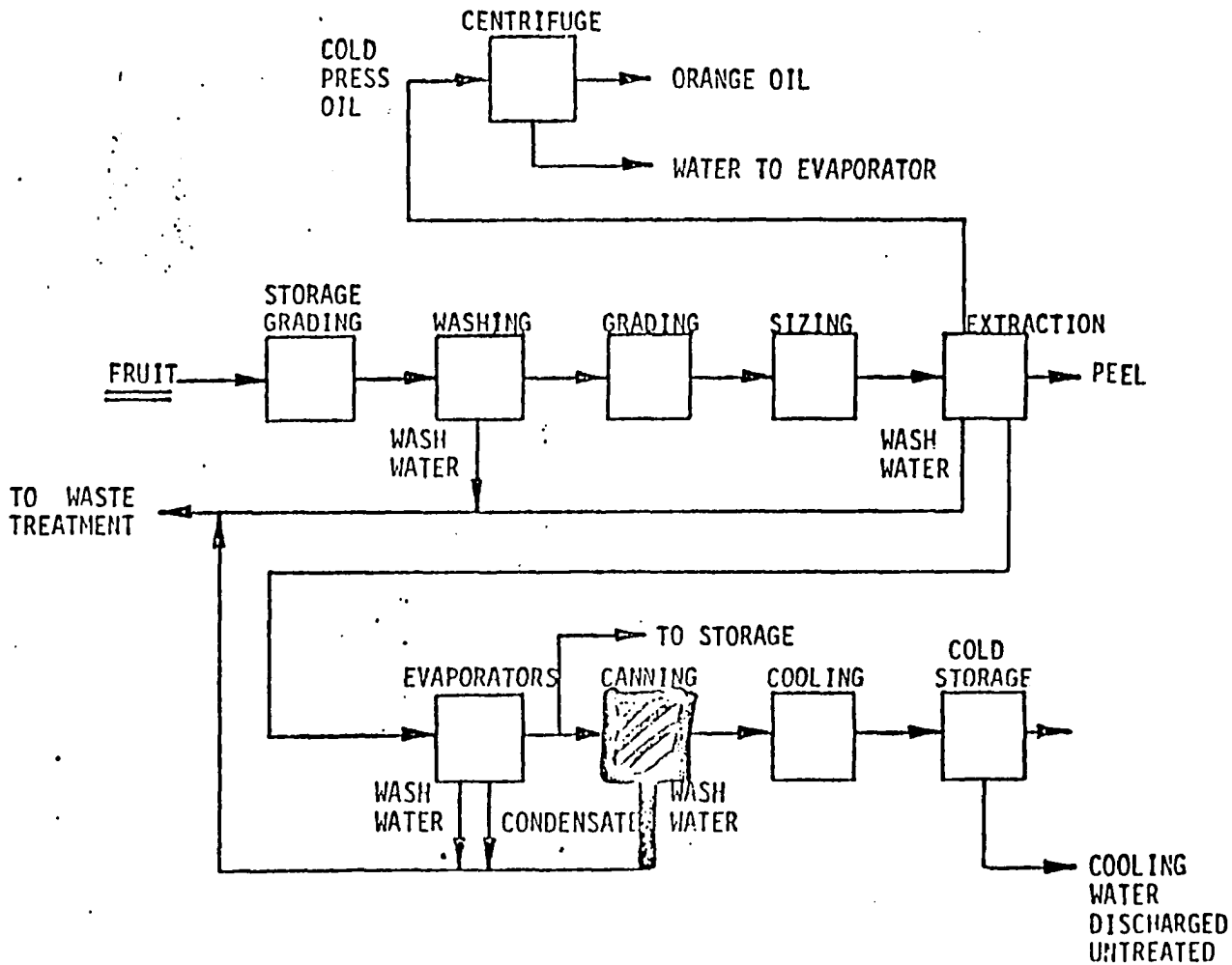


Figure D.4 Process flow diagram (continued on next page)

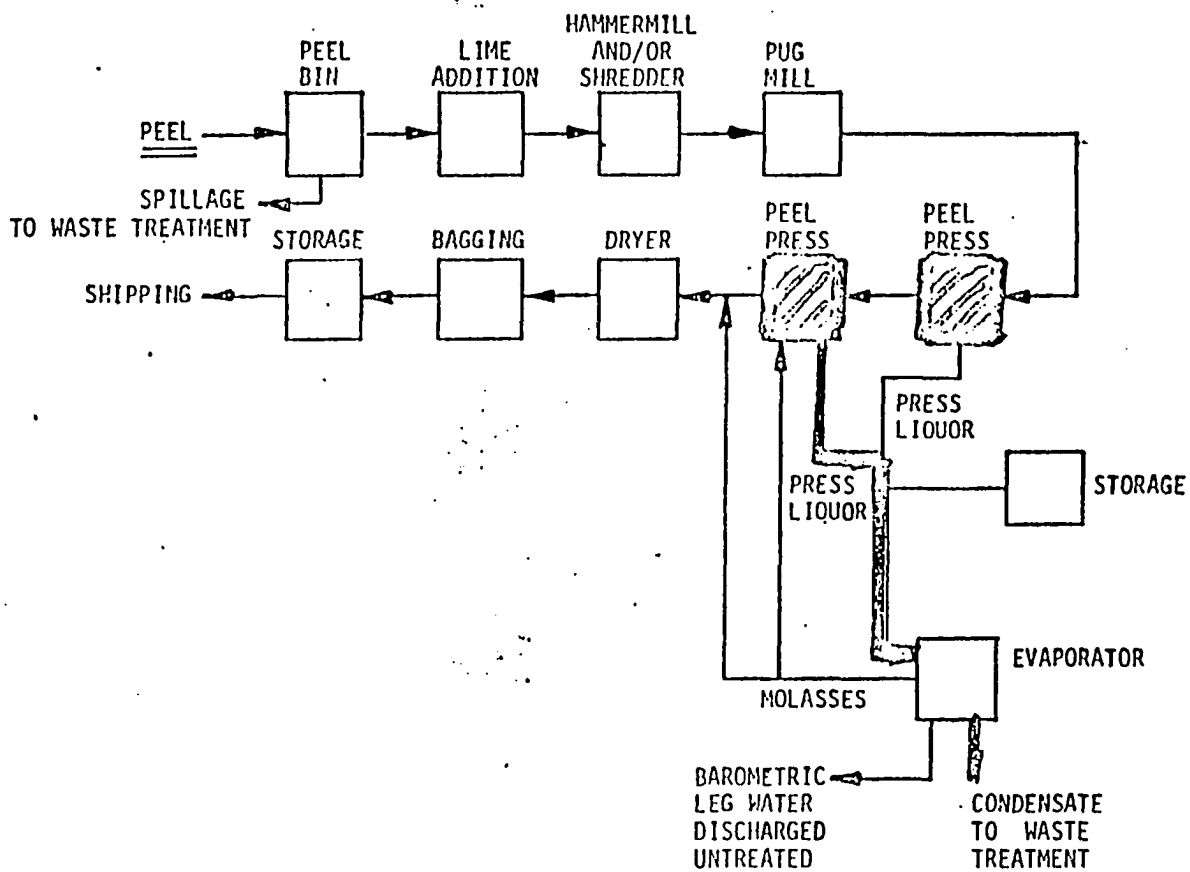


Figure D.4. .(CONTINUED)
PROCESS FLOW DIAGRAM

Source: EPA, Complete mix activated sludge treatment of citrus process wastes, 1971, p.36. (50)

4. TEXTILE MILL INDUSTRY

Total production for the textile mill industry in 1978 was 36.4 M metric tons. 64 percent of the total production in this industry generates potentially hazardous waste. The following process categories are potential generators of ICW:

Wool fabric dyeing and finishing

Woven fabric dyeing and finishing

Knit fabric dyeing and finishing

Carpet mills

Stock and yary dyeing and finishing.

Tables D.2 and D.3 present the characteristics of wastewaters by pH from cotton and wool manufacturing processes. Scouring, mercerizing, bleaching and dyeing all yield caustic waste streams with pH ranging from 6 to 12.

TABLE D.2 . **CHARACTERISTICS OF WASTEWATER BY pH FROM WOOL WET PROCESSES**

PROCESS	CHARACTERISTICS	pH UNIT	WATER USE GALLONS 1000 LB. PRODUCT	REFERENCE
SCOURING				
Soap-Alkali Method	High Alkalinity Resulted From Hot Alkali Soap	9.5 — 10.5	5,500 — 12,000	5
Detergent - N_2SO_4 Method	Natural to High Alkaline	6.4 — 9.1	5,500 — 12,000	5
WASHING AFTER FULLING	High Alkalinity Resulted From Soap and Detergent Solution	9.0 — 10.7	40,000 — 100,000	5
NEUTRALIZATION AFTER CARBONIZING				
First Running Rinse	Acid pH Resulted From Sulfuric Acid	1.9 — 2.4	N/I	5
Fast Soda Ash Rinse	Alkaline pH Resulted from Soda Ash	7.9 — 9.0	N/I	5
	Total Process	N/I	12,500 — 15,700	5
BLEACHING	Neutral	6.0	300 — 2,680	5
DYEING				
Acetic Acid Used	Acid pH to Neutral Resulted from Acid Used	4.8 — 8.4	N/I	5
Ammonia Sulfate Used	Neutral	5.0 — 8.3	N/I	5
	Average Process	N/I	1,900 - 2,680	

N/I No Information Available

TABLE D.3 . **CHARACTERISTICS OF WASTEWATER BY pH FROM COTTON FABRIC MANUFACTURING PROCESSES**

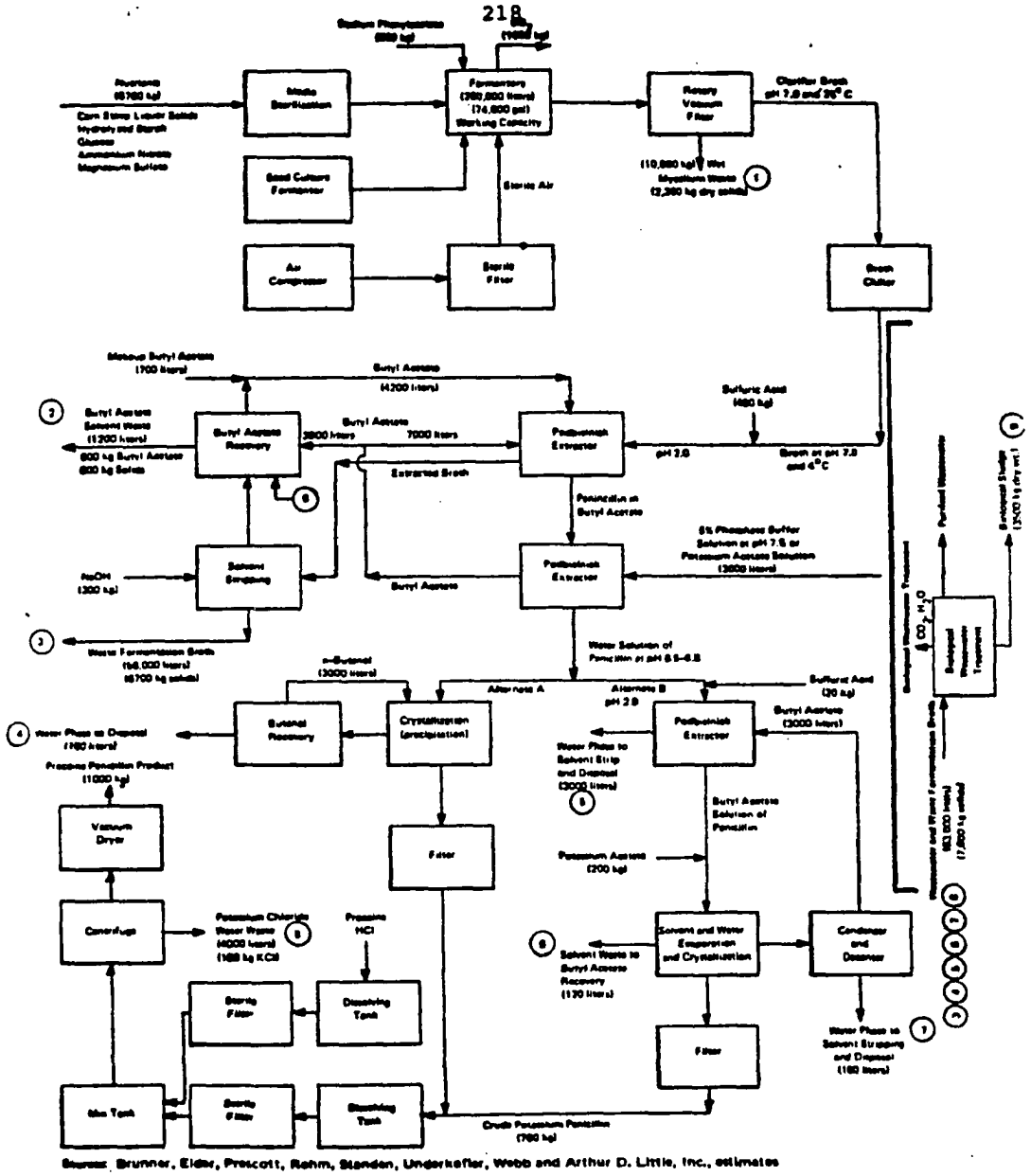
PROCESS	CHARACTERISTIC	pH UNIT	WATER USE GALLONS 1000 LB PRODUCT	REFERENCE
SLASHING	Neutral	7.0 - 9.5	60 - 940	7
DESIZING:	Neutral Except Acid Starch Which is Low pH (1-2) Resulted From Solution of Sulfuric Acid	6 - 8	1,500	8
SCOURING	High Alkalinity Resulted from Hot Alkaline Detergents or Soap Solutions	12.5	3,000	8
MERCERIZING	High Alkalinity Resulted from 15 to 30 Percent Solution of Sodium Hydroxide Used in Process	12.0	2,000	8
BLEACHING	Alkaline pH Resulted from Bleaching Solutions	8 - 12	2,000 - 10,000	8
DYEING	Neutral to Alkaline pH Resulted from Dye Used Except Developed Dyeing Which is Low pH (1-2) Due to Sulfuric Acid Solution Used in Dyeing Process	6 - 12	5,000 - 30,000	8
PRINTING	Neutral to High Alkaline	6 - 11	1,500 - 4,000	8
FINISHING	Neutral	6 - 8	1,500	8

Source: USEPA-625/7-77/002, October, 1978.(51)

PHARMACEUTICAL INDUSTRY

The subcategories of concern in terms of ICW generation are the organic and inorganic medicinal chemicals. There are a wide variety of solvents used: benzene, toluene and other similar ring type compounds such as xylene, cyclohexane and pyridine. Essentially all production plants operate solvent recovery facilities that purify contaminated solvent reuse. The final wastes are anhydrous organic compounds which are withdrawn from the base of distillation columns or are residues from solvent extraction operations. Most often they are thick, tarry residues which are very difficult to treat because it is so highly variable. They may contain acids, bases, cyanides, solvents and metals. The pH is extremely variable, pH 1-11.

Figure B.8 is a presentative process for antibiotic production. The final waste effluents from the different manufacturing processes are treated in a biological wastewater treatment plant.



Sources: Brunner, Elder, Prescott, Rehm, Standen, Underkofler, Webb and Arthur D. Little, Inc., estimates

Figure D.5. Representative Process for Antibiotic Production (Procaine Penicillin G).

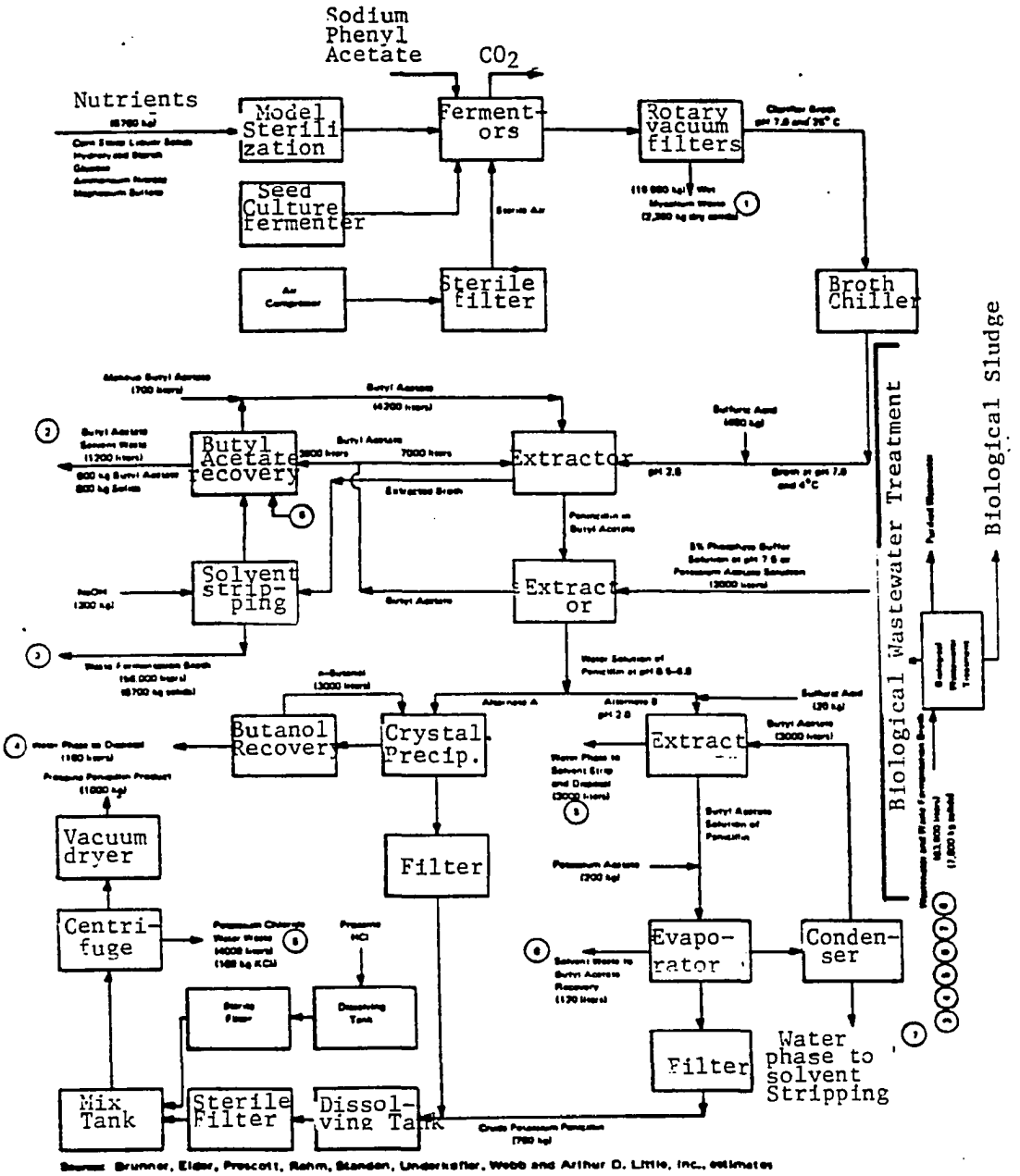


Figure D.5 Representative process for antibiotic production.

5. STEEL INDUSTRY

The iron and steel industry pickles about 60 million tons of steel products every year resulting in the generation of about 1 billion gallons of pickle liquor volume.

A typical steel plant would include the processes shown in Figure D.6. Pickling is the removal of scale through use of acid solutions. This is performed in various ways: batch, semicontinuous or continuous operations. In any case, the steel to be descaled is first immersed in an acid bath for some suitable time and then removed and subsequently washed with water to remove residual acid.

The steel pickling process generates wastes from three distinct sources:

1. waste pickle liquor,
2. rinse water from washing acid drag-out from pickling baths, and
3. acidified water generated in cleaning acid vapors from pickling baths.

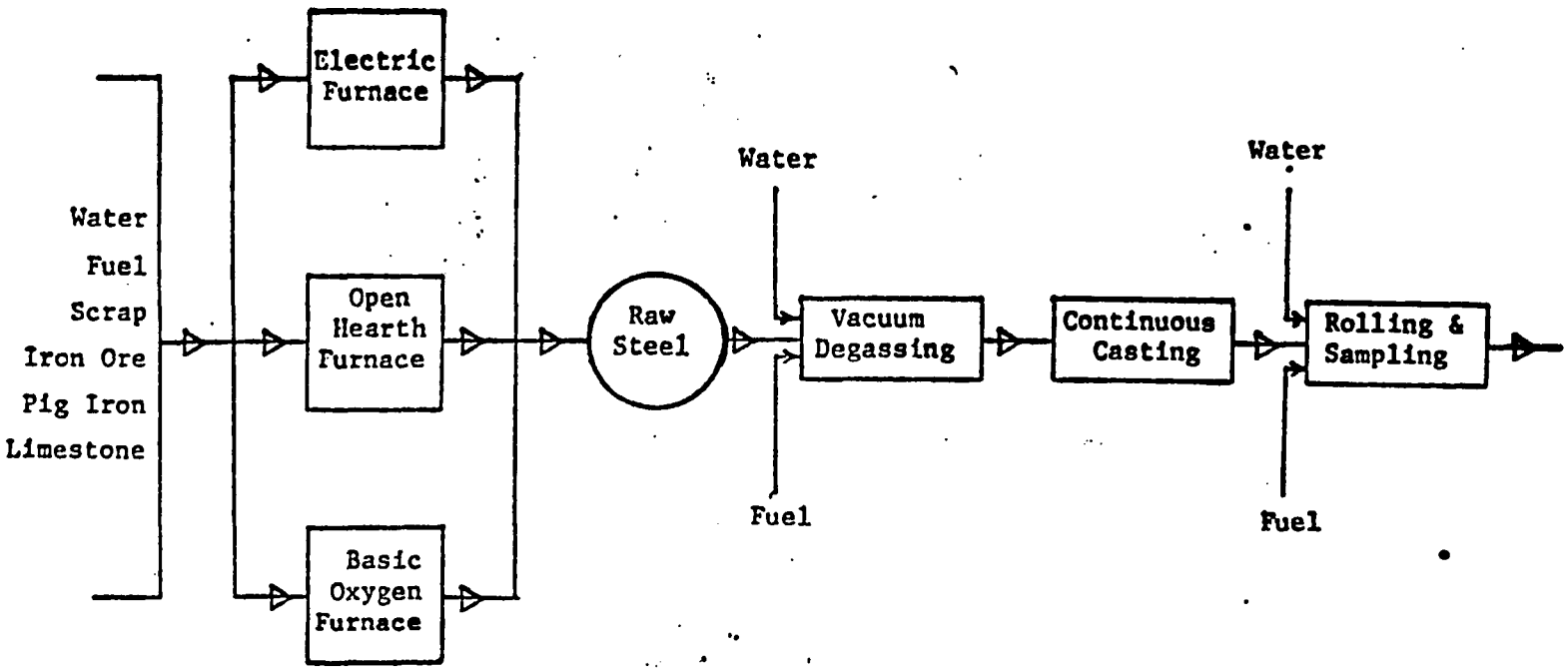


Figure D.6. Process Flow Sheet for Steel Production.

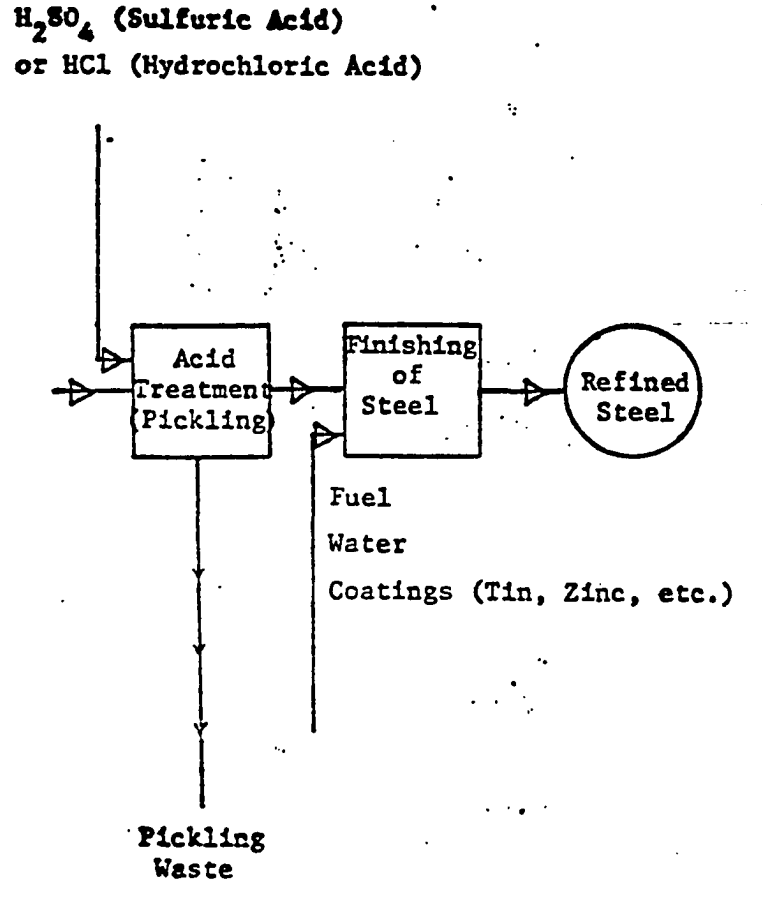


Figure D.6 (con't)

Source: Battacharya, S. "Steel Industry Pickling Waste and its Impact on the Environment." IIT Research Institute, Chicago, IL, July 1979, p. 48.(52)

CYCLIC CRUDE AND CYCLIC INTERMEDIATES

The principal products produced in the cyclic crude and cyclic intermediates industries are coal tar, benzene, toluene, xylene, napthalene and creosote oil. (Figure D.7).

The liquid effluents coming from plants in which coal tar is distilled contain coal tar hydrocarbons, and a variety of spent organic or inorganic chemicals used at various points in the processing sequence to condition cooling water, promote catalysts, improve product separation, or otherwise facilitate theconduct of a particular operation. The composition of the resultant effluents are process, and sometimes even site-dependent, and therefore more research is needed to determine the required disposal technology. The pollution abatement technologies currently being used are electrostatic precipitators for suspended solids or particulates, scrubbers for gaseous pollutants such as SO_x and NO_x which are emitted in large volumes from carbonization, gasification and liquefaction processes. Low concentrations of H_2S are incinerated.

Liquid effluents are temporarily contained in a waste treatment pond from which appropriately clarified water is eventually either recycled to the plant or released into a natural water course. Pond sludges are disposed of by landfilling. The process flow diagram for high temperature tar from hard coal is presented in Figure D.7.

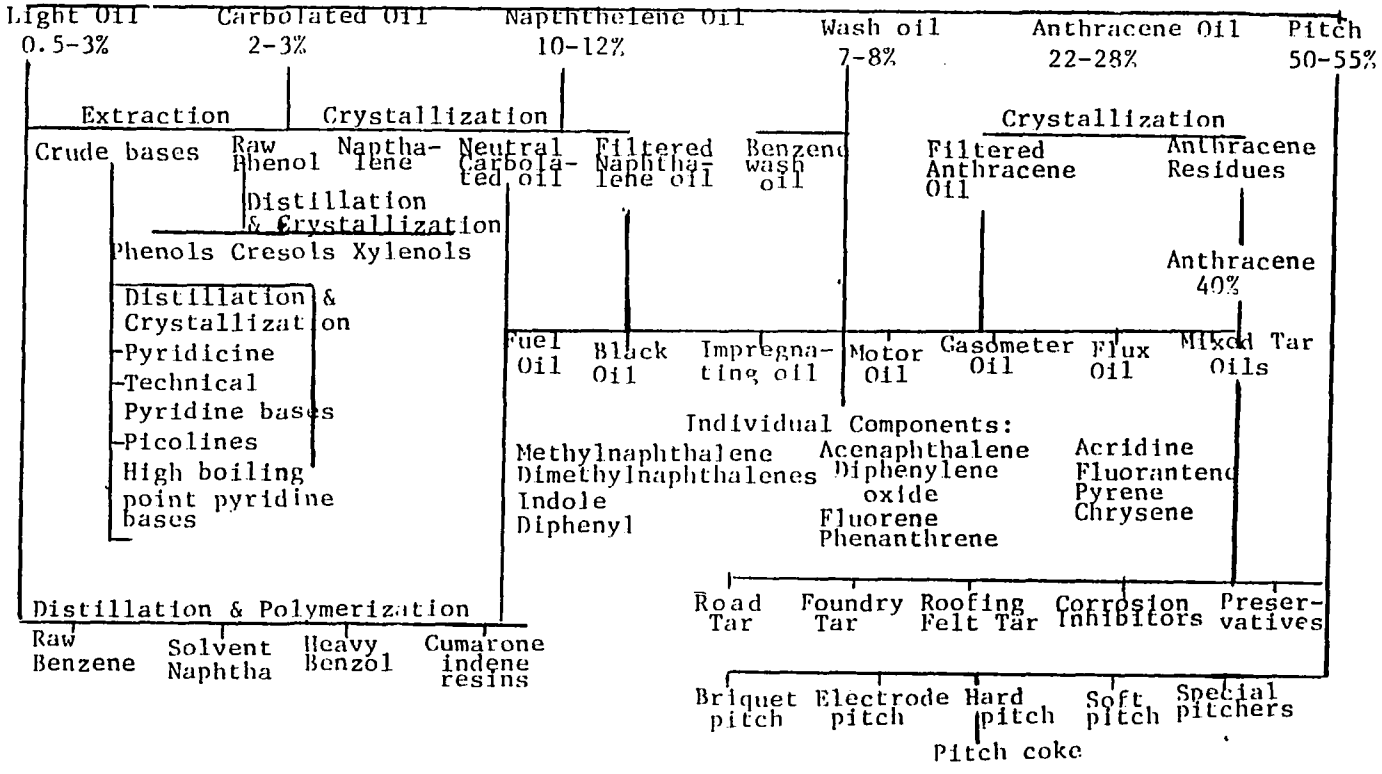


Figure D..7 Processing of high temperature tar from hard coal.

INORGANIC CHEMICALS INDUSTRY

The inorganic chemical industry generates a variety of waste products from a total of sixty-three subcategories of inorganic chemicals.

There are two industries that are significant from the D002 waste point of view that have potential for land treatment. These are: 1) titanium dioxide (sulfate process), and 2) hydrofluoric acid. The total production rate in the titanium dioxide industry is approximately 259 million kg/yr with an average waste flow range of 60,000 cubic meters/day.

The general process flow diagram for production of titanium dioxide by sulfate process is shown in Figure D.8 . The flow diagram shows that a strong acid waste stream is produced after water is added to titanyl sulfate solution after removal of copperas, whereby sulfuric acid and the hydrate of titanium dioxide are formed. The concentration of sulfuric acid varies from 15 to 30 percent as H_2SO_4. A part of the acid is returned to the process and the rest is sent to a treatment facility. Other waste streams which may be acidic are the weak acid waste streams from the washing of titanium dioxide hydrate precipitate and scrubber waste water resulting from the scrubbing of vapors emitted during the drying of the ore, during digestion and during kiln drying. The scrubber water contains titanium dioxide particulate, acid mist, sulfur trioxide and sulfur dioxide.

The production rate for hydrofluoric acid is 261 million kg/year. The average waste water flow range is 2,350 cubic meters/day.

Waste sources from this industry are gypsum solids, drip acid which contains high boiling compounds consisting of complex fluorides, especially fluorosulfuric acid, and small amounts of hydrofluoric acid, sulfuric acid and water, and scrubber waste water.

The final fate of gypsum solids are in settling/ storage gypsum ponds, after neutralization with lime. Other waste streams such as drip acid, noncontact cooling water, scrubber waste water and distillation wastes are treated in waste water treatment plants.

The general process flow diagram for hydrofluiric acid manufacture is presented in Figure D .9.

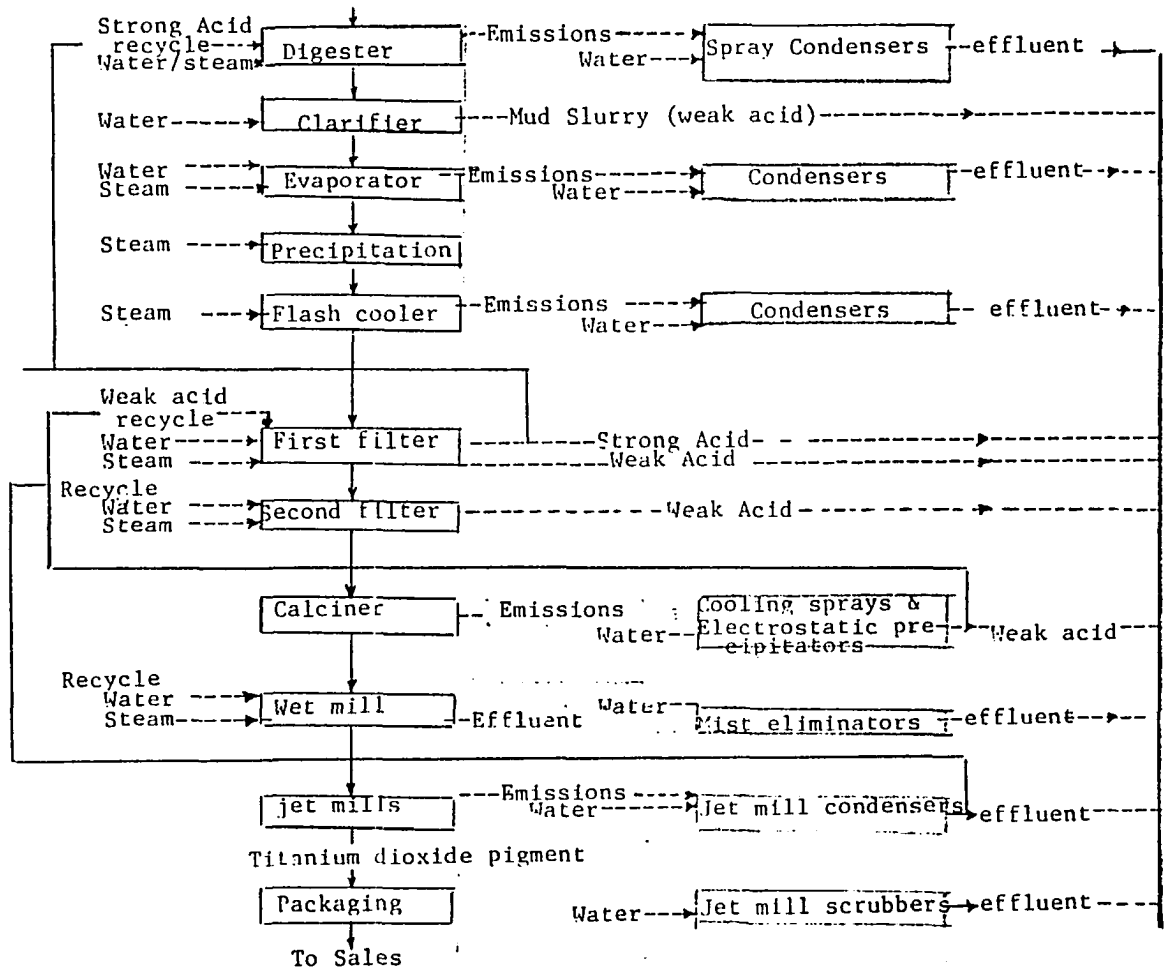


Figure D.8 General Process flow diagram for production of titanium dioxide by sulfate process. (Source: EPA UUO/1-79/007

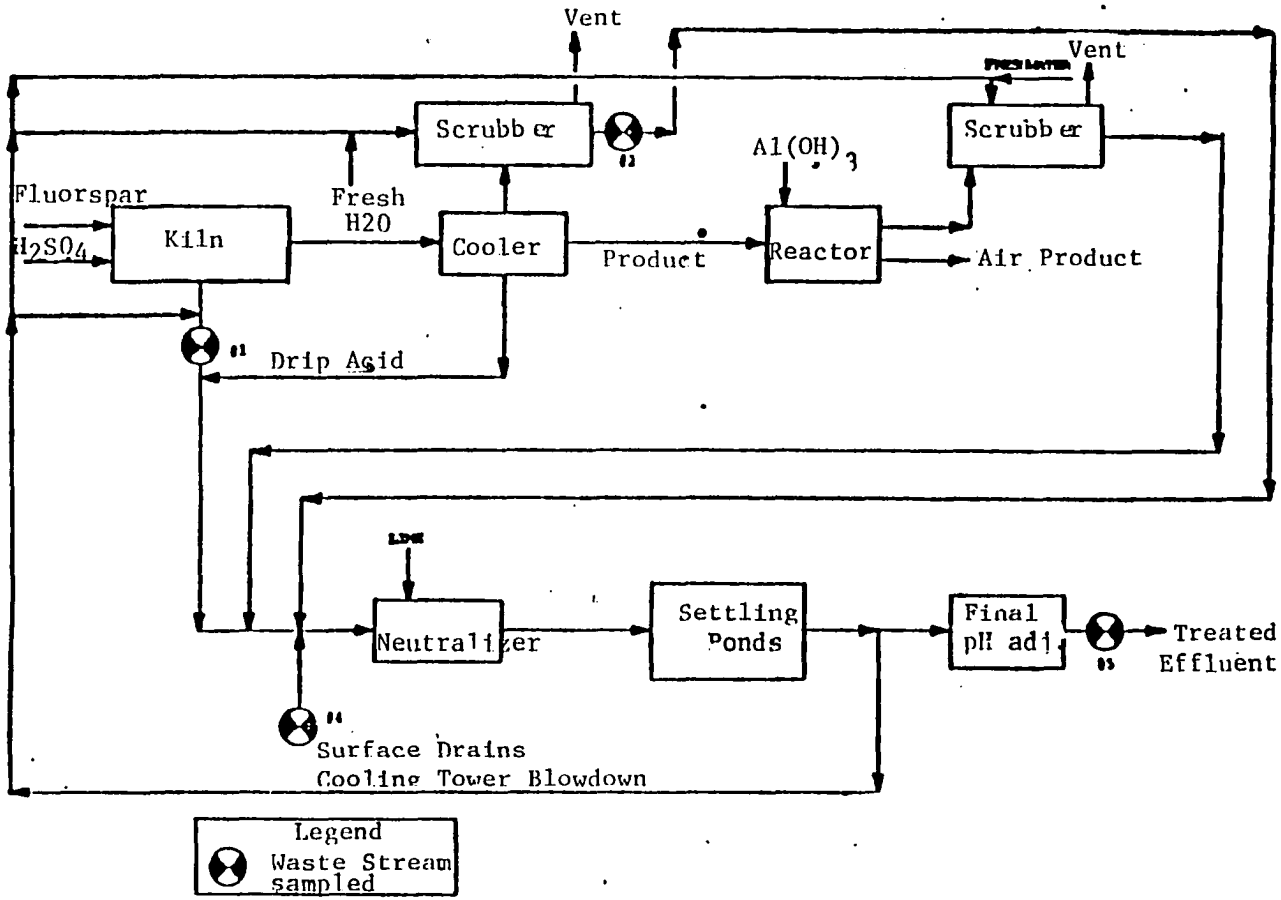


Figure D.9 General process flow diagram, hydrofluoric acid manufacture.
Source, EPA UUO/1-79/007.

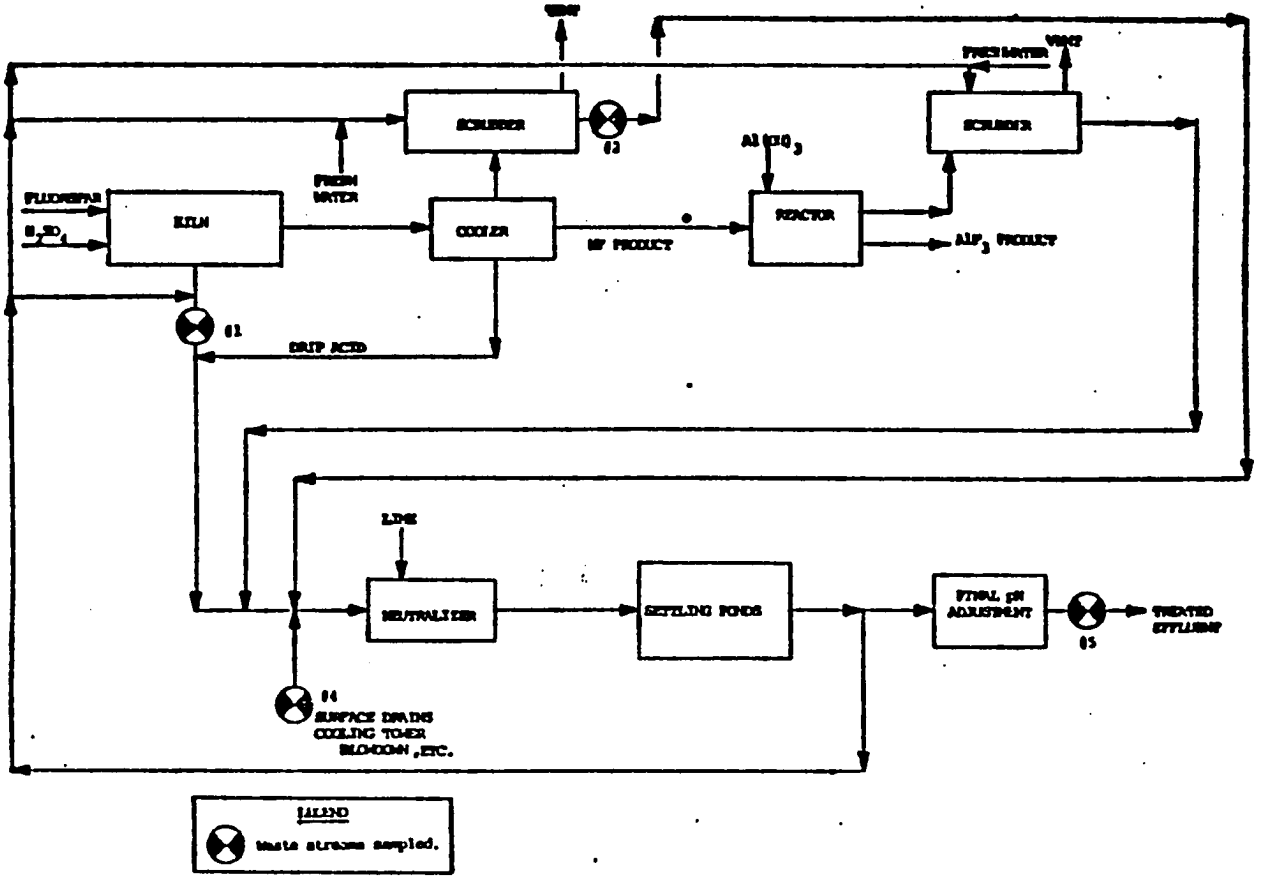


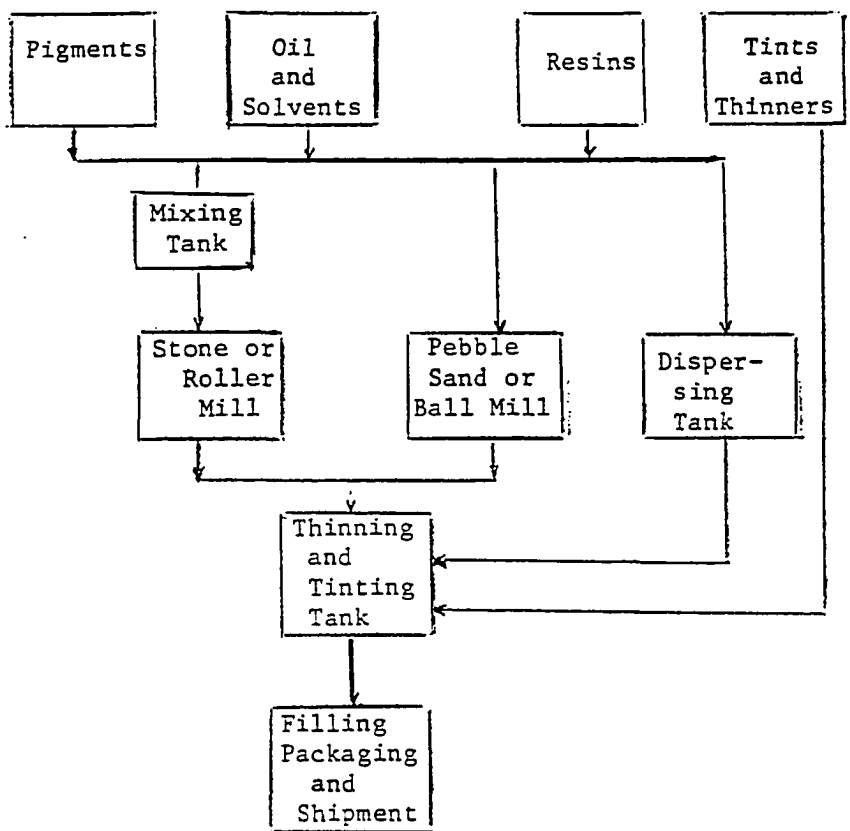
Figure D.9. General process flow diagram, Hydrofluoric acid manufacture. Source, EPA UUO/1-79/007.

CHEMICALS AND ALLIED PRODUCTS

The industries under this category are gum and wood chemicals manufacturing, soap and detergent manufacturing, explosives industry, synthetic fiber indystry, pesticide chemicals manufacture, synthetic polymers, plastics and resins industry, paint formulating and ink formulating industries.

All of these industries generate different quantities of ICW. The industry that generates ignitable waste which has potential for land application is the paint industry. The other industries have volatile organics in their waste streams but land treatment does not look like a viable alternative because the volumes generated are relatively low.

The total production in the paint industry is approximately 1 billion gallons/year. (Table D.1).



Source: EPA-UUO/1-79/048-D, December 1979.

Figure D .10 Flow diagram of manufacturing process for solvent-base paints.

APPENDIX E

PROCEDURES AND METHODS FOR MICROBIOLOGICAL AND CHEMICAL ANALYSES OF SOIL SAMPLES

GC ANALYSES - SOLVENT RECOVERY WASTE, BASE/NEUTRAL FRACTION

D A T A A C Q U I S I T I O N VERSION 1.1 18-May-84

load/store Method : METHOD.M

Description : SRS

last modified By : EM

Tune file : *ATUNE.U

Quant. file :

Lib search file : POLLUTE.L

Acquisition mode : SCAN

Inlet : GC

Use a softkey, abbrev., or press any key.
Prep to |Edit Acq |Edit Temp|Edit Run |
D A T A A C Q U I S I T I O N 5 Oct 84 3:02 pm METHOD.M

Data file : KWBROWN.D

Words available in file are 384384

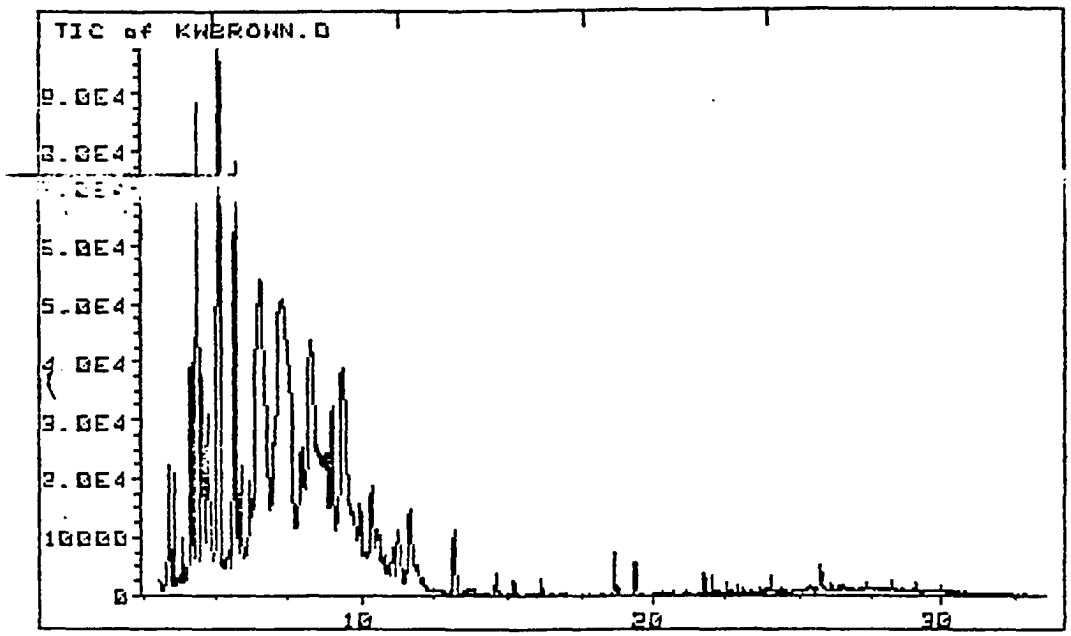
Operator : HEM

sample Name : SRS

misc. Info : 1.6 µl Base/Neut. fr.

ZONE ACTUAL SETPOINT ZONE ACTUAL SETPOINT

eady to inject



Library Search Results

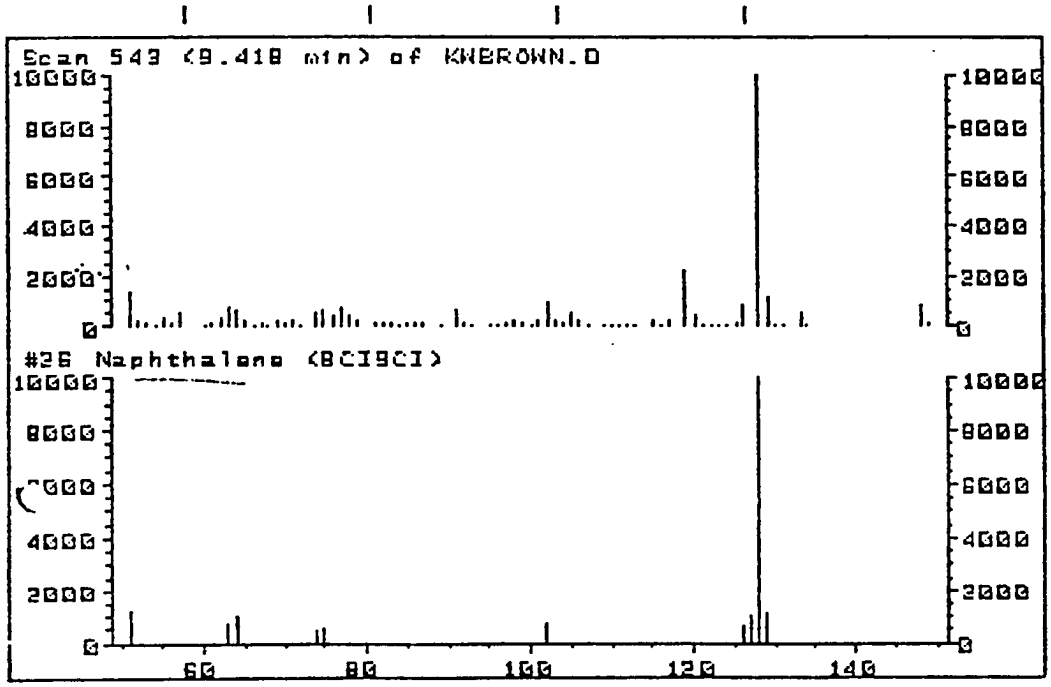
Scan 543 (9.418 min) of KWBROWN.D
KWBROWN.D

Library file: POLLUTE.L
Library name: PRIORITY POLLUTANTS

	match quality (0 to 10000)	library entry number
1:	9561	26
2:	7686	27
3:	1590	45
4:	1236	41
5:	1130	25
6:	964	72
7:	835	71
8:	814	67
9:	633	46
10:	565	62

T: Scan 446 (8.272 min) of KW
Z: TIC of KWBROWN.D
Y: Set of 3 MS

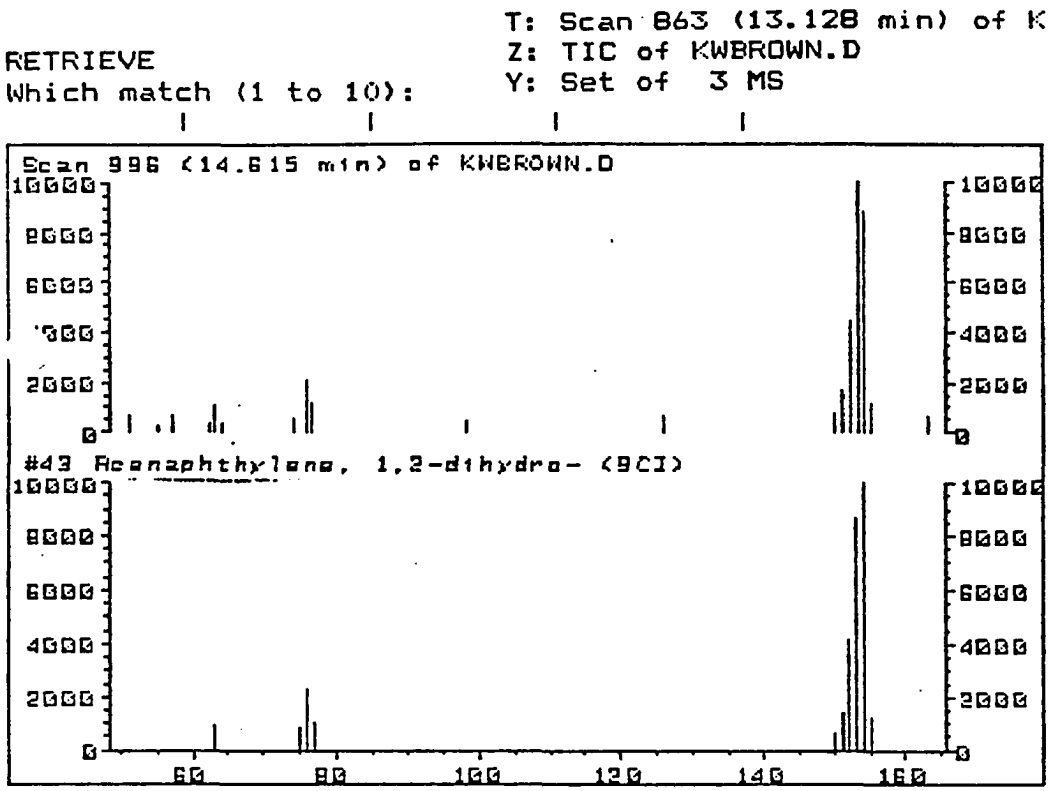
RETRIEVE
Which match (1 to 10):



Scan 996 (14.615 min) of KWBROWN.D
KWBROWN.D

Library file: POLLUTE.L
Library name: PRIORITY POLLUTANTS

	match quality (0 to 10000)	library entry number
1:	9857	43
2:	4337	42
3:	3178	59
4:	1362	108
5:	866	60
6:	819	95
7:	740	53
8:	732	74
9:	624	25
10:	463	52



Library Search Results

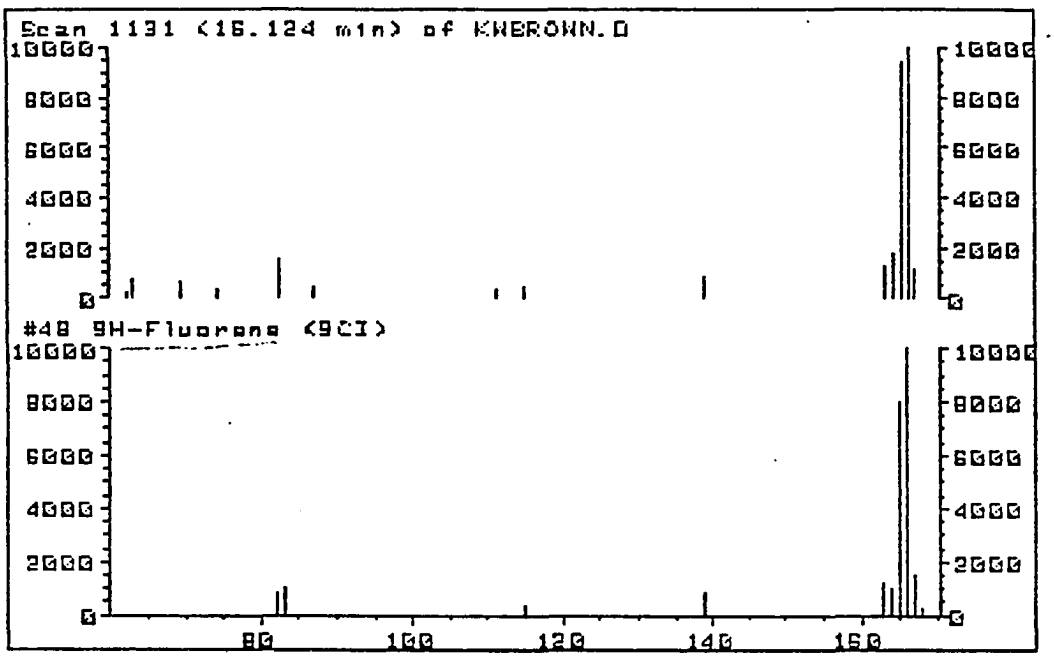
Scan 1131 (16.124 min) of KWBROWN.D
KWBROWN.D

Library file: POLLUTE.L
Library name: PRIORITY POLLUTANTS

	match quality (0 to 10000)	library entry number
1:	9884	48
2:	5660	55
3:	4983	56
4:	4857	47
7:	1948	94
8:	1837	71
9:	1338	46
10:	997	33

RETRIEVE
(ich match (1 to 10):

T: Scan 1047 (15.188 min) of
Z: TIC of KWBROWN.D
Y: Set of 3 MS



Library Search Results

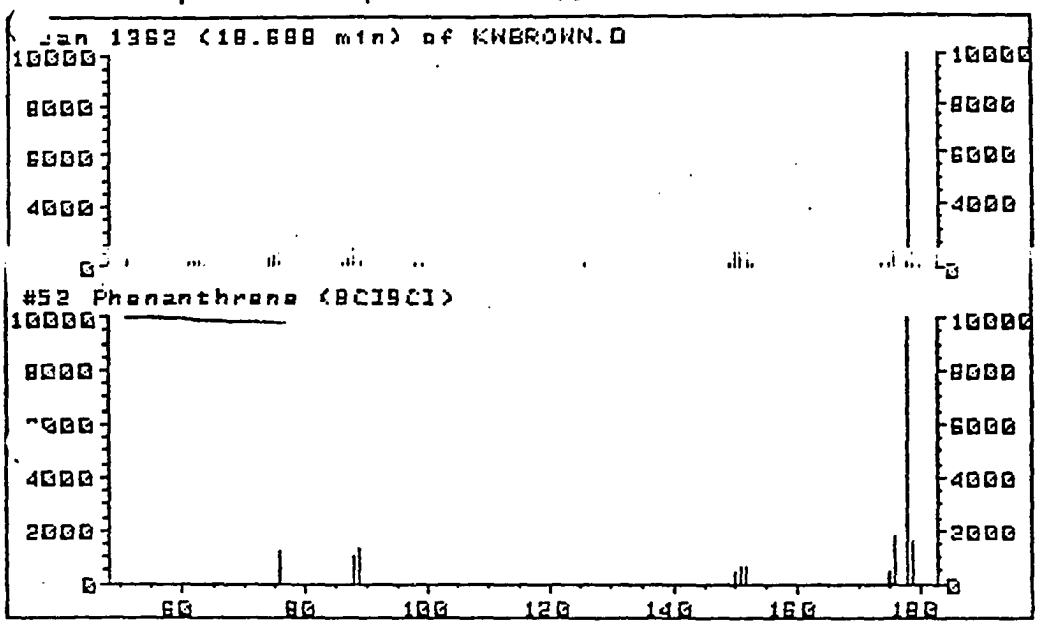
Scan 1362 (18.688 min) of KWBROWN.D
KWBROWN.D

Library file: POLLUTE.L
Library name: PRIORITY POLLUTANTS

	match quality (0 to 10000)	library entry number
1:	9969	52
2:	6589	53
3:	1347	42
4:	854	92
5:	760	68
6:	550	43
7:	530	108
8:	402	55
9:	326	91
10:	282	56

RETRIEVE
Which match (1 to 10):

T: Scan 1429 (19.438 min) of
Z: TIC of KWBROWN.D
Y: Set of 3 MS



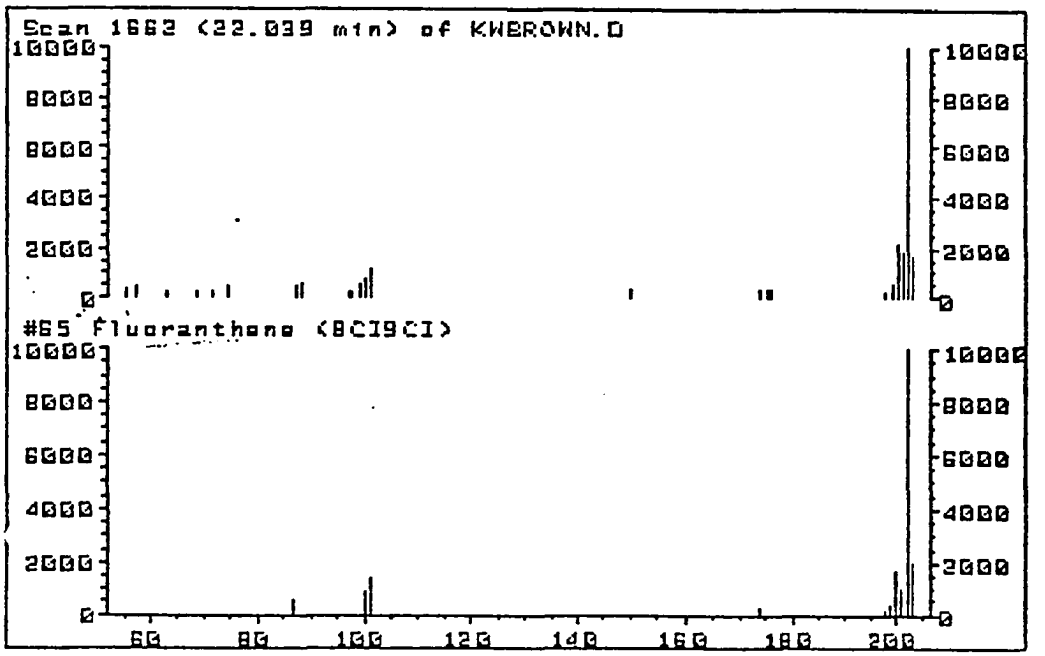
Library Search Results

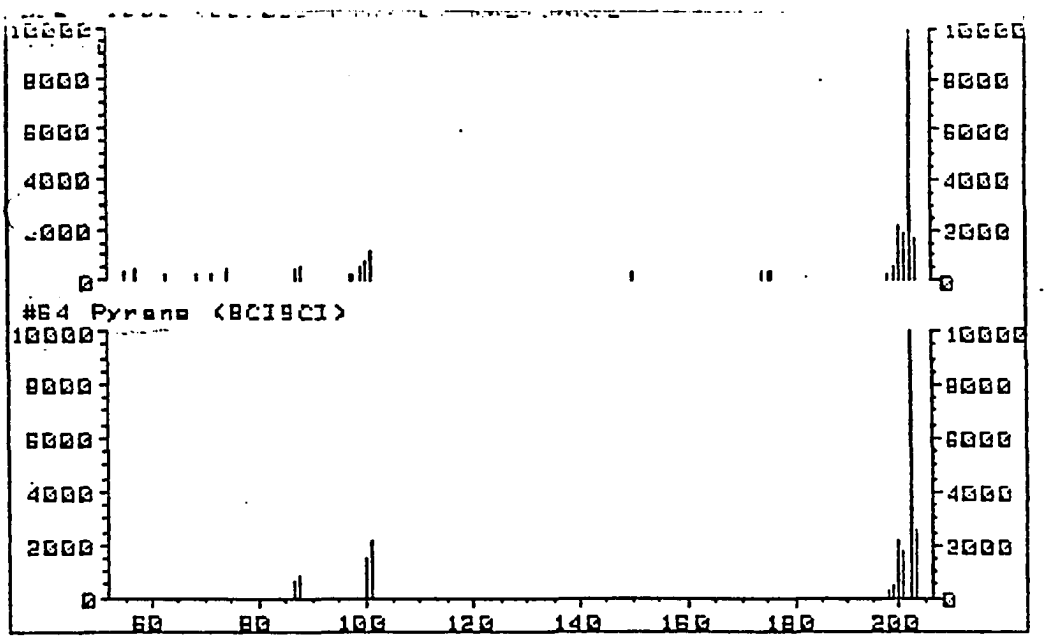
Scan 1662 (22.039 min) of KWBROWN.D
KWBROWN.D

Library file: POLLUTE.L
Library name: PRIORITY POLLUTANTS

	match quality (0 to 10000)	library entry number
1:	9920	65
2:	9834	64
3:	1656	71
4:	1532	79
5:	861	32
6:	530	96
7:	454	61
8:	236	95
9:	130	23
10:	129	73

RETRIEVE
Which match (1 to 10):
T: Scan 1641 (21.806 min) of
Z: TIC of KWBROWN.D
Y: Set of 3 MS





Library Search Results

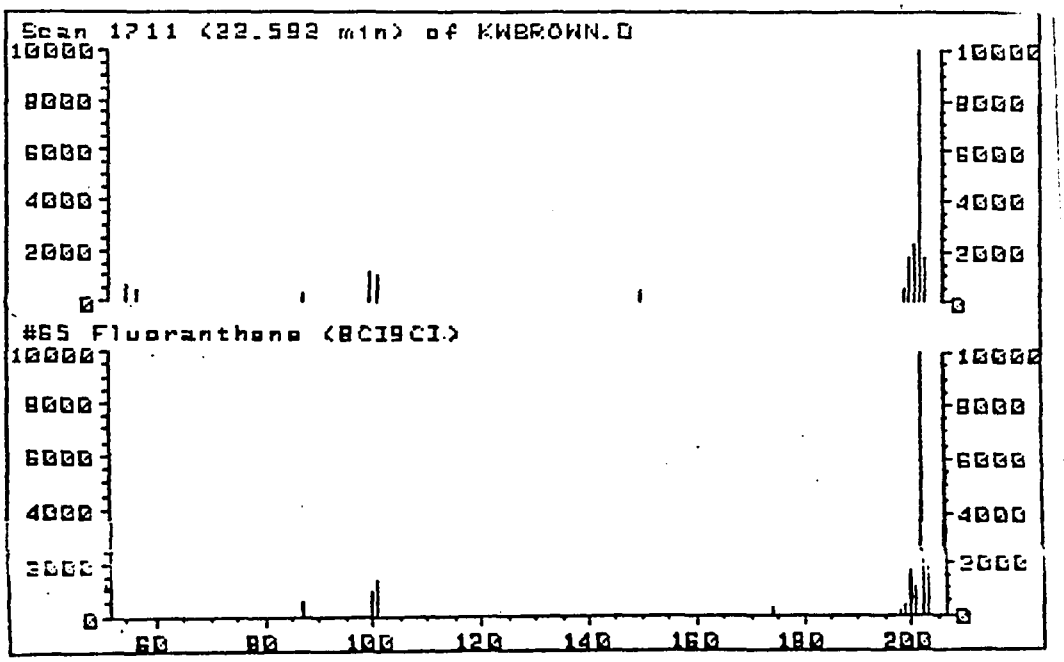
Scan 1711 (22.592 min) of KWBROWN.D
KWBROWN.D

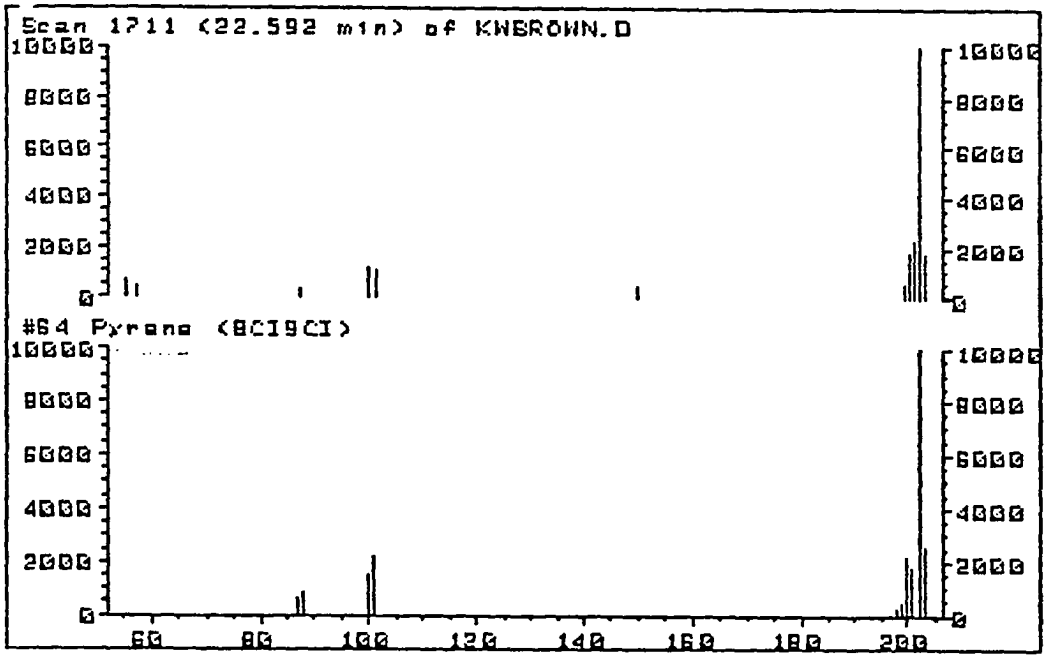
Library file: POLLUTE.L
Library name: PRIORITY POLLUTANTS

	match quality (0 to 10000)	library entry number
1:	9894	65
2:	9841	64
3:	1891	71
4:	1476	79
5:	809	96
6:	768	32
7:	354	61
8:	215	23
9:	210	95
10:	174	109

RETRIEVE
Which match (1 to 10):

T: Scan 1662 (22.039 min) of
Z: TIC of KWBROWN.D
Y: Set of 3 MS




Scan 1711 (22.592 min) of KWBROWN.D
10000
8000
6000
4000
2000
0
#64 Pyrene (8CI9CI)
60
80
100
120
140
160
180
200

GC ANALYSES - SOLVENT RECOVERY WASTE, ACID FRACTION

Library Search Results

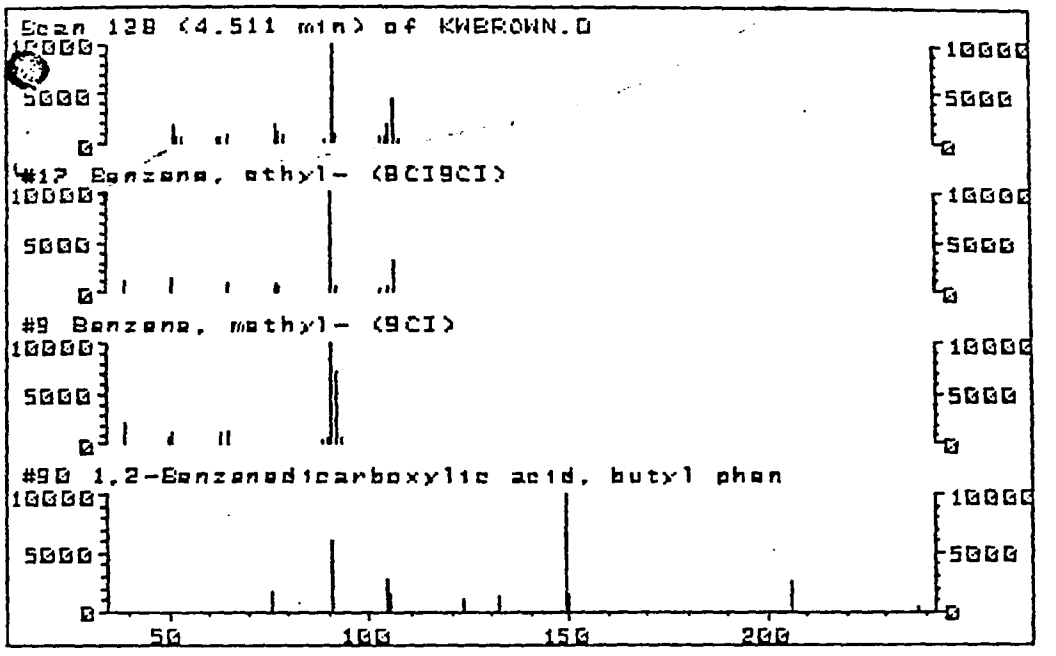
Scan 128 (4.511 min) of KWBROWN.D
KWBROWN.D

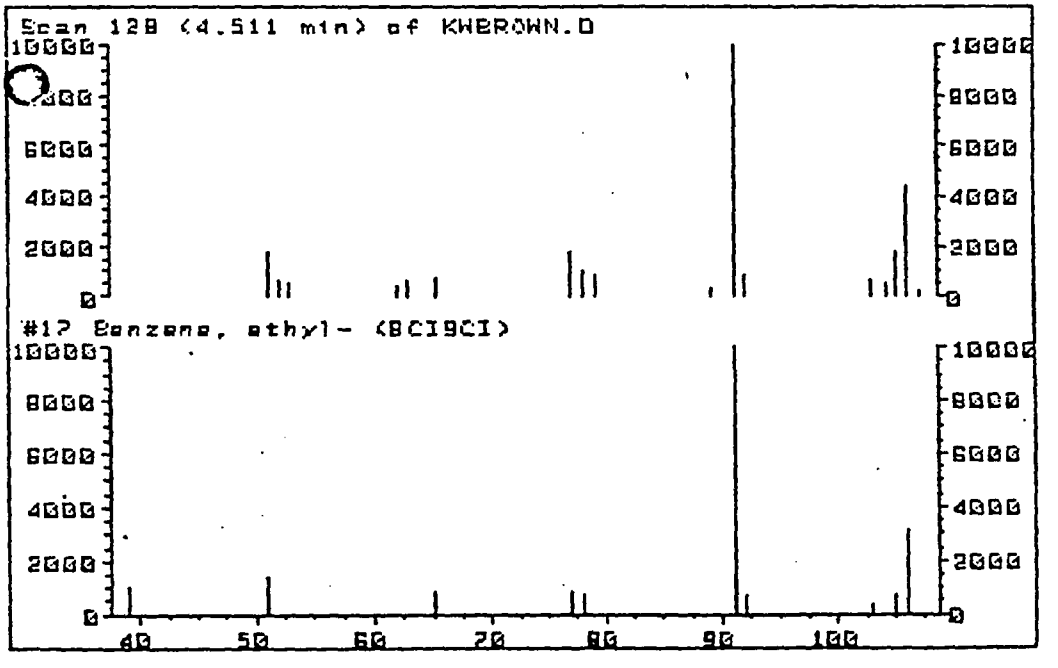
Library file: POLLUTE.L
Library name: PRIORITY POLLUTANTS

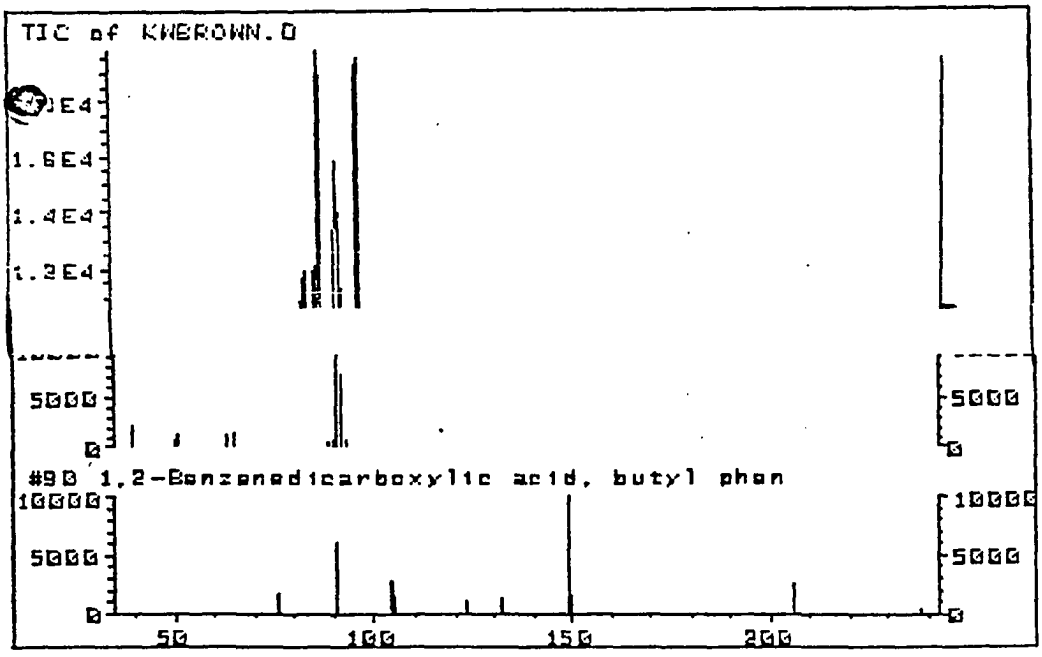
	match quality (0 to 10000)	library entry number
1:	9749	17
2:	7407	9
3:	4441	90
4:	2629	95
5:	1975	25
6:	1855	56
7:	1692	59
8:	1598	24
9:	1544	33
10:	1522	72

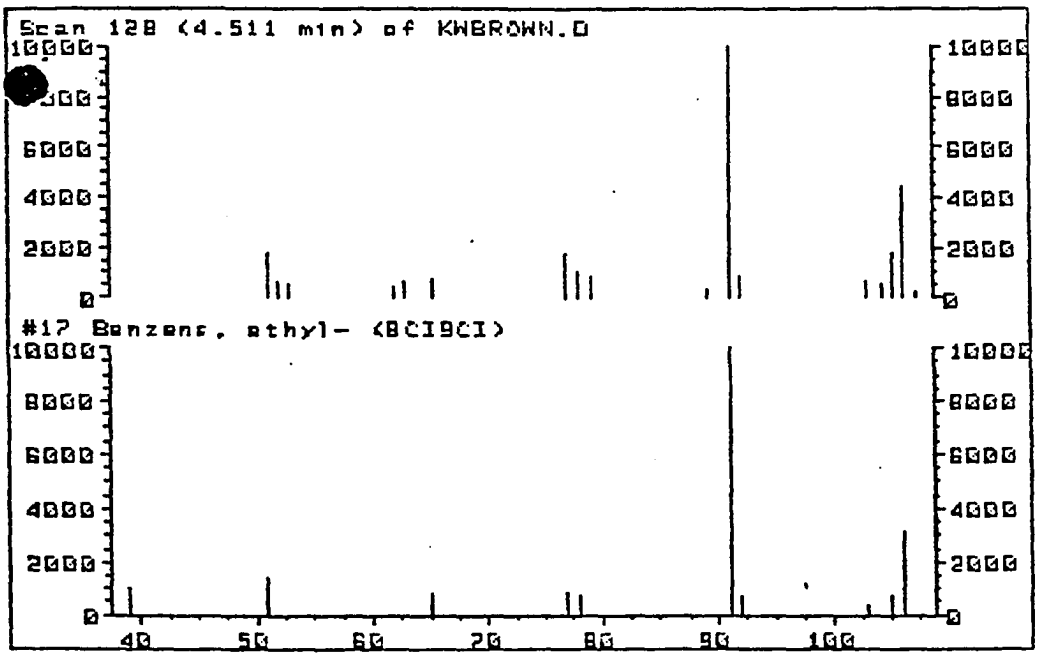
RETRIEVE
Which match (1 to 10):

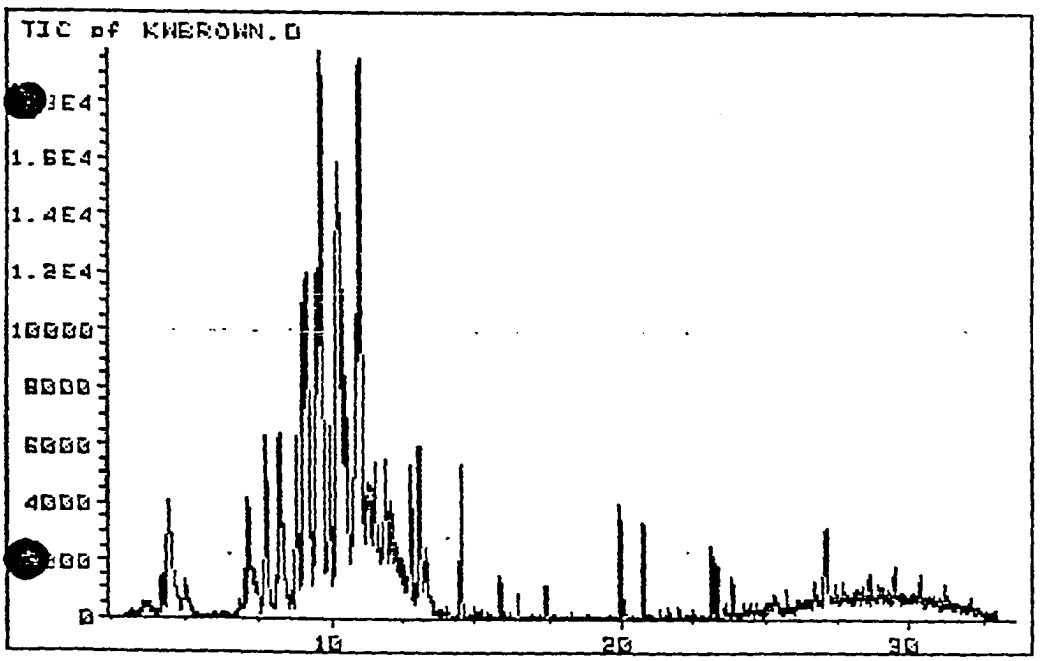
T: Scan 124 (4.465 min) of KW
Z: TIC of KWBROWN.D
Y: Set of 3 MS






TIC of KWBROWN.D
1.6E4
1.4E4
1.2E4
5000
0
#90 1,2-Benzenedicarboxylic acid, butyl phen
10000
5000
0
50
100
150
200


Scan 128 (4.511 min) of KWBROWN.D
10000
8000
6000
4000
2000
0
#17 Benzene, ethyl- (8CI9CI)
40
50
60
70
80
90
100


TIC of KWBROWN.D
1.6E4
1.4E4
1.2E4
10000
8000
6000
4000
0
10
20
30

NITRATE DETERMINATION
(colorimetrically with nitrophenoldisulfonic acid)

The phenoldisulfonic acid method for nitrates depends upon the nitration position of 6 of 2, 4-phenoldisulfonic acid in fuming H_2SO_4:

$$C_6H_3OH(HSO_3)_2 + HNO_3 \longrightarrow C_6H_2OH(HSO_3)_2NO_2 + H_2O$$

The nitrate solution is dried out previous to determination since the reaction must be effected in the virtual absence of water. The product behaves as a nitrophenolic type indicator with C-Y-Y reaction, that is, is colorless in acid and yellow when neutralized or in alkaline solution. A hydroxide such as KOH or NH_4OH is therefore employed to shift the pH to the yellow range for the colorimetric determination.

APPARATUS--

Needed apparatus includes a torsion balance, a 500-ml extraction bottle and tight-fitting rubber stopper, an 18-cm filter paper and funnel, 8 cm evaporating dishes, 3 by 70 mm glass stirring rods, a 3-ml pipet with its tip cut off to deliver rapidly, volumetric pipet, colorimeter tubes with 40-ml calibration marks (or Nessler tubes), and a colorimeter with 420-mu light maximum.

REAGENTS --

Needed reagents (all tested to be nitrate-free) include 6 N NH_4OH, $Ca(OH)_2$, $MgCO_3$ activatec charcoal (GElf or Darco G 60), approximately 1 N $CuSO_4$ (125 gm of $CuSO_4 \cdot 5H_2$) per liter, and the following special reagents.

1. Phenol 2, 4-Disulphonic Acid. Twenty five gm of pure phenol (crystal white in color) is dissolved in 150 ml of concentrated H_2SO_4. Then 75 ml of fuming H_2SO_4 is added. This solution is mixed and heated by placing the flask in boiling water for 2 hours. The resulting phenoldisulfonic acid, $C_6H_3OH(HSO_3)_2$, solution is stored in a brown bottle. Caution: This reagent is highly corrosive.

2. Standard Nitrate Solution. Exactly 0.7221 gm of pure dry KNO_3 is dissolved in water and the solution is diluted to exactly 1 liter, giving 0.1 mg N per ml, or 100 ppm stock solution. This stock solution is then diluted, 20 ml to 200 ml in a volumetric flask. This latter solution contains 0.01 mg N per ml, or 10 ppm. Aliquots (2, 5, 10 and 15 ml) of the 10 ppm N standard nitrate solution are placed in separate 8-cm porcelain evaporating dishes and evaporated to dryness on the steam bath in an atmosphere free from HNO_3 fumes. Color development follows.

3. Nitrate Extraction Solution. This is prepared by mixing 200 ml of 1 N $CuSO_4$ solution and 1 liter of 0.6 per cent Ag_2SO_4 solution and diluted to 10 liters with H_2O. The Ag_2SO_4 is equivalent to 338 ppm Cl^- present in 50 gm soil, or 0.03 per cent Cl^-. If 10 ppm of Cl^- is present in soil, the Ag_2SO_4 may be omitted from the extraction solution. If more than 0.03 per cent Cl^- is present, as in acid

soils, 2.25 gm of powdered Ag_2SO_4 salt for each 1 per cent Cl^- present is mixed with the soil prior to extraction, or the Cl^- in the soil is determined and a Cl^- correction factor is established by addition of Cl^- to a standard nitrate series.

PROCEDURE--

1. Soil Sampling and Preparation. Composite soil samples are obtained freshly from the field or pot. The soil is mixed thoroughly by passing it rhough a 6-mm sieve. Clayey soils that have dried and contain hard granules are pulverized to pass a 2-mm sieve, to facilitate complete wetting of the sample by the extractant in the time allowed.

2. Extraction of Nitrate from the Soil. Fifty gm of soil (25 gm peat) is weighed out and placed in a 500-ml wide mouthed bottle, and 250 ml of extraction solution is added. (At the same time, a 25 gm sample is weighed out for moisture determination). The suspension is shaken for 10 minutes and then 0.4 gm $Ca(OH)_2$ is added. This is followed by 5 minutes further shaking and the addition of 1 gm of $MgCO_3$. These 2 reagents precipitate the copper and silver and clarify the suspension. The suspension is filtered in a dry filter paper, and the first 20 ml of filtrate discarded. A 10-ml portion of the clear filtrate is pipetted into an 8-cm evaporating dish and evaporated to dryness in an atmosphere free of HNO_3 fumes. Color development follows.

3. Development of the Nitrophenoldisulfonic Color. The 8-cm evaporating dishes are allowed to cool, and 3 ml of phenoldisulfonic acid is added rapidly directly in the center of each. The dish is

rotated to effect contact with all of the residual salt, and the reagent is allowed to act for 10 minutes. Then 15 ml of cold water is added, and the solution is stirred with a glass rod until all the residue is in solution. After the dishes are cool, 6 N NH_4OH is added slowly until the solution is distinctly alkaline as indicated by the development of a yellow color, then 3 ml more is added. The standard series is diluted to 100 ml and contains 0.2, 0.5, 1 and 1.5 ppm of nitrate nitrogen. Soils extract is usually diluted to 100 ml. Runoff nitrate is conveniently diluted to 40 ml in calibrated tubes.

4. The transmission percentage of the nitrate solutions is read in a colorimeter with 420 mu light maximum. Alternately, the color may be evaluated by visual comparison to the standard solution by means of Nessler tubes.

5. Preparation of the Standard Colorimetric Curve. A calibration curve is plotted from the standard nitrates on semilogarithmic paper, the log scale being employed for the transmission percentage readings. This curve is usually not exactly linear, and thus it is best to refer to the graph to determine the nitrate concentration in the test sample.

6. Calculation of Results. The results are reported in parts of N (nitrate form) per million parts of oven-dry soil. The concentration of the nitrate test solution is ppm N is obtained from the standard curve. Then the calculation is as follows:

ppm N in soil = ppm N in test soln X Aliquot dilution X soil dilution
(nitrate form)

$$= \text{ppm N in test soln.} \times \frac{\text{ml final color vol.}}{\text{ml aliquot evaporated}} \times \frac{\text{ml extraction solution}}{\text{gm O.D. soil extracted}}$$

$$= \text{ppm N in test soln.} \times \frac{100}{10} \times \frac{250 + \text{ml } H_2O}{50 - \text{ml } H_2O}$$

PHOSPHORUS DETERMINATION

This method has been used as an index of available P in soils. The combination of HCl abd NH_4F is designed to remove easily acid-soluble forms of P, largely calcium phosphates, and a portion of the aluminum and iron phosphates. The NH_4F dissolves aluminum and iron phosphates by its complex ion formation with these metal ions in acid solution. In general, this method has been most successful on acid soils.

REAGENTS--

1. Ammonium fluoride (NH_4F), 1 N: Dissolve 37 gm of NH_4F in distilled water, and dilute the solution to 1 liter. Store this solution in a polyethylene bottle.

2. Hydrochloric Acid (HCl), 0.5 N: Dilute 20.2 ml of concentrated HCl to a volume of 500 ml with distilled water.

3. Extracting Solution. Add 15 ml of 1.0 N NH_4F and 25 ml of 0.5 N HCl to 460 ml. of distilled water. This gives a solution 0.03 N in NH_4F and 0.025 N in HCl. It will keep in glass more than 1 year.

4. Stannous Chloride ($SnCl_2.2H_2O$), stock solution. Dissolve 10 g. of reagent grade $SnCl_2.2H_2O$), in 25 ml concentrated HCl. Keep the solution in a black, glass-stoppered bottle, and prepare a fresh solution every 6 weeks. Store the solution in a refrigerator in a polyethylene bottle to lengthen the life of the reagent.

5. Ammonium molybdate $(NH_4)_6Mo_7O_4.4H_2$). Dissolve 15 gm of reagent-grade $(NH_4)_6Mo_7O_{24}.4H_2O$ in 350 ml of distilled water. Add 350 ml of 10 N HCl to the flask slowly, with stirring. Cool the contents to

room temperature, and add water to obtain a volume of 1 liter. Store the solution in a black, glass-stoppered bottle. Prepare a fresh solution every 2 months.

6. Stannous Chloride, dilute solution. Mix 1 ml of $SnCl_2$ stock solution with 333 ml of water. Make a fresh solution every 2 hours as needed.

PROCEDURE--

Weigh 1 gm of soil into an extraction bottle or tube, and add 7 ml of the extracting solution. Shake the container 1 minute, and filter the contents through Whatman no. 42 paper. If the filtrate is not clear, pour the solution back through the filter. To 2 ml of the filtrate, add 5 ml of distilled water. Add 2 ml of the ammonium molybdate solution, and mix the contents well. Add 1 ml of the $SnCl_2$ dilute solution, and mix the solution again. After 5 or 6 minutes and before 20 minutes, measure the color photometrically using 660 mu incident light.

Prepare a standard curve including the 2 ml of extracting solution in the range of 0.1 to 1 ug of P per ml. Plot the transmittances of the standards against the ug of P per ml. on semilogarithmic graph paper.

Calculate the concentration of extractable phosphorus as follows:

ppm of P in soil = ppm P in solution X 35

The soil test values are interpreted in general as follows: less than 3 ppm, very low; 3 to 7 ppm, low; 7 to 20 ppm, medium; and greater than 20 ppm, very high.

MICROBIOLOGICAL TECHNIQUES

I. Nutrient Agar

Peptone	5 g
Beef Extract	3 g
Agar	15.0 g
Distilled Water	1 L

Sterilize in an autoclave at standard temperature and pressure for 30 minutes. pH should be approximately 6.8 after sterilization.

II. Standard Plate Count for Soil Samples

The Standard Plate Count procedure provides a standardized means of determining the density of aerobic and facultative anaerobic heterotrophic bacteria in soil samples.

A. Melting Medium - Melt sterile solid agar medium in boiling water or by exposure to flowing steam in a partially closed container. Discard melted agar that contains precipitate. Maintain melted medium in a water bath between 44 ^{o}C and 46^{o}C until used.

B. Sample Dilution - Select the dilutions so that the total number of colonies on a plate will be between 20 and 200.

C. Pouring Plates: Limit the number of samples to be plated in any one series so that no more than 20 minutes (preferably 10 minutes) elapse between dilution of the first sample and pouring of the last plate in the series. Pour at least 10 to 12 ml liguefied medium at 44 to 46°C into each dish by gently lifting cover just high enough to pour. As each plate is poured mix melted medium thoroughly with test portions in a petri dish, taking care not to splash mixture over the edge , or rotating and tilting. Let plates solidify (within 10 minutes) on a level surface. After medium solidifies, invert plates and incubate at room temperature for 48 ± 3 hr.

D. Sterility Counts - Check sterility of medium and dilution water blanks by pouring control plates for each series of samples.

E. Counting and Recording - Count all colonies on selected plates promptly after incubation. If counting must be delayed temporarily, store plates at 5 to 10 °C for no more than 24 hr. Compute bacterial count per gram by multiplying average number of colonies per plate by the dilution used.

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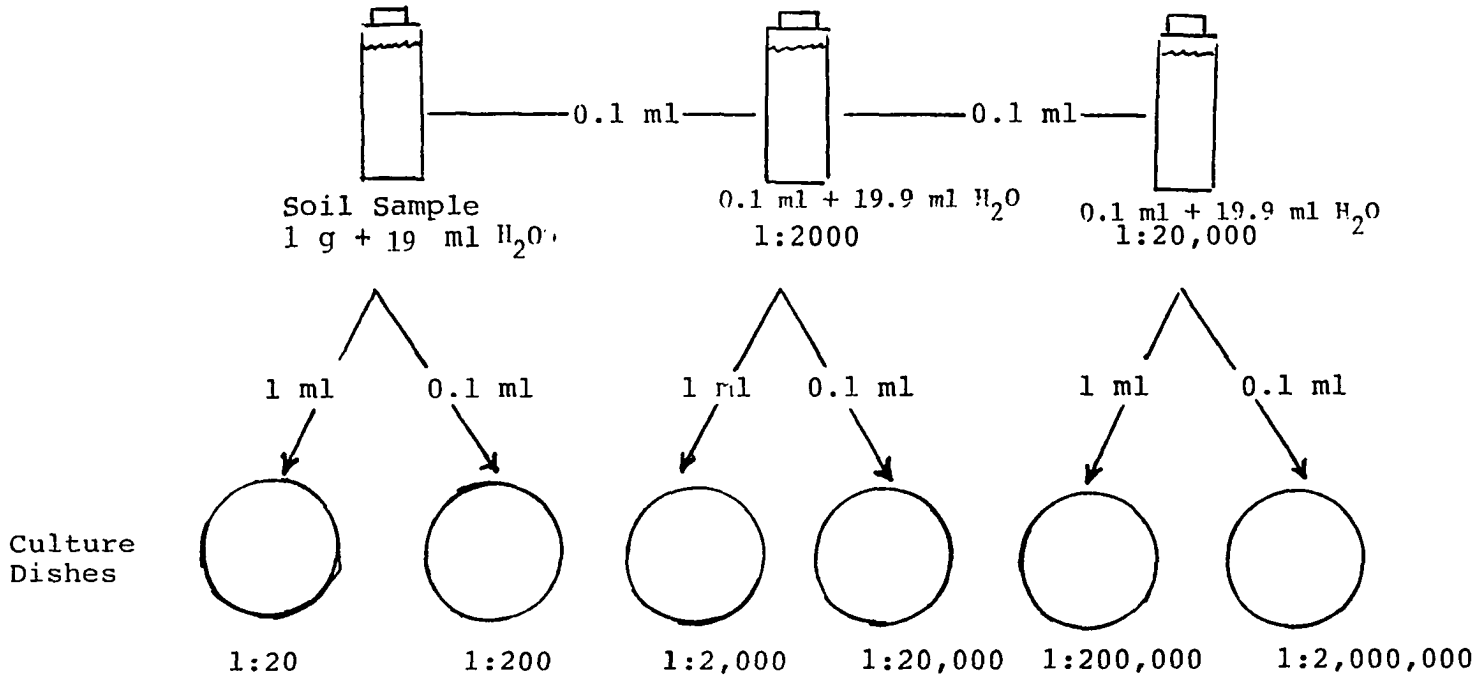

Figure D.11 Standard Plating Technique used for soil samples.