THE HAZARDOUS WASTE REMEDIATION MARKET: INNOVATIVE TECHNOLOGICAL DEVELOPMENT and THE GROWING INVOLVEMENT OF THE CONSTRUCTION INDUSTRY

by

Andrew J. Hoffman

B.S. Chemical Engineering, University of Massachusetts, Amherst
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Signature of Author ______________________________
Department of Civil Engineering
August 15, 1991

Certified by ______________________________
Fred Moavenzadeh
Director, Center for Construction Research and Education
Thesis Supervisor

Accepted by ______________________________
Eduardo Kausel
Chairman, Departmental Committee on Graduate Students

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ABSTRACT

The cleanup of hazardous waste disposal sites is a pressing national crisis due to the slow implementation of the cleanup of hazardous waste disposal sites under the ten year old Superfund program. However, implementation of the Superfund represents a growing market of enormous proportions for engineering and consulting firms through the emergence of new markets within DOE, DOD and others. Actual remediation construction work is only now beginning to materialize on a large scale, thus attracting a new player to the market: the construction industry.

The first part of this thesis analyzes the role that construction firms will play in the hazardous waste remediation market. They offer construction management skills that are far more experienced than what is presently available through traditional environmental contractors and consultants. As they assimilate into the market, they can be expected to create a more competitive environment for established environmental firms but, will also be required to alter their own organizations in order to continue to compete. As the market becomes more competitive, remediation technologies that offer economic savings to the client will find an increasing market share. Bioremediation and in-situ vitrification offer great potential as economical and technically effective technologies for future remediation projects.

The second part of this thesis analyzes the obstacles and incentives to innovation in hazardous waste remediation technologies today. The need exists at this time for new technologies that are quicker, less costly, and provide more permanent destruction of toxics than are presently available. However, lack of pollution insurance, lack of available financing, and a cumbersome regulatory process increases the financial risks to the technology developer and, thus, tends to stifle innovation. Technology innovators are facing an uncertain regulatory and financial future as they bring their systems to the market. The EPA programs designed to ease these obstacles such as SITE, ATTIC and the new Indemnification Program are in place but are not producing effective results.

Existing remediation technologies are not as technically advanced or economically efficient as the market requires. Furthermore, new and innovative technologies are not entering the market as rapidly as is needed. When rating the criteria that make their technologies attractive to potential clients, vendors listed the applicability to certain wastes and capability of meeting EPA standards as the most important. High speed and low cost were not highly considered. In other words, they were more concerned with satisfying regulatory demands than market demands. Although this is, in part, due to the infancy of the market, it also underscores the dominating influence that the government has on the market and the extent of research.

In order for the EPA to promote technological development, it need not spend more money promoting research. It must strive to withdraw its regulatory influence on the technical aspects of the cleanup process and allow market forces to drive innovation. The EPA should take steps to eliminate the barriers between the technology vendor and the client, and therefore, the economic profits.

To do this, the EPA should set firm and reasonable standards to which sites must be cleaned up. Then, it should streamline the remediation process so as to allow the responsible parties the latitude to choose whichever technology they feel will best allow them to achieve that standard. It should develop an efficient process for determining who the responsible parties are. And finally, it should develop an effective technology transfer program to accelerate the spread of information about the variety of remediation technologies that are now available as well as those that will become available in the future. In essence, the answer to promoting technological development is less, not more government intervention.

Thesis Supervisor: Dr. Fred Moavenzadeh

Title: Director, Center for Construction Research and Education

Foreword

". . . It is not true that 'nature knows best.' It often creates ecosystems that are inefficient, wasteful, and destructive. . . . The reciprocal interplay between humankind and the earth can result in a true symbiosis. . . . Symbiotic relationships mean creative partnerships. The earth is to be seen neither as an ecosystem to be preserved unchanged nor as a quarry for selfish and short-range economic reasons, but as a garden to be cultivated for the development of its own potentialities of the human adventure. The goal of the relationship is not the status quo, but the emergence of new phenomena and new values. Millennia of experience show that by entering into a symbiotic relationship with nature, humankind can invent and generate futures not predictable from the deterministic order of things, and thus can engage in a continuous process of creation." [1]

Rene Dubos

First Tyler Ecology Symposium, April 6, 1976

[1]"Symbiosis Between the Earth and Humankind", *Science,* August 6, 1976, p. 461-462.

Rene Dubos presented his vision of a new balance between humans and nature at the dawn of today's world environmental movement. In 1976, business and industry were popularly viewed as villains, caring more about profits than the environment. Pollution was viewed as an externality which could not be controlled through regular market mechanisms. And, government was beginning to rely on command and control regulations to force polluters to act responsibly towards the environment.

Today, fifteen years later, a symbiotic relationship between humans and the environment can be seen, not as an idealistic dream, but as a conceivable reality. This reality will come to pass in what I believe is the only way possible: through market system mechanisms. That is, the market will demand environmentally responsible products and processes, whether through regulatory mandates or consumer expectations, and industry should soon realize that environmentalism can be an opportunity to increase market share and profits rather than an obstacle to economic growth.

In the coming decade, attention to protecting the environment can be viewed as good business sense. Although initial implementation of environmental controls are costly, companies should realize that waste minimization and pollution prevention will increase profitability by reducing the expenses of collection, transportation, and disposal of hazardous chemical and gaseous wastes. Additional profits can be realized by reducing the liability risks from accidental releases of these wastes.

In a more proactive step, companies can begin to alter their processes and products to become more environmentally responsible. Environmentalism will offer a completely new dimension to measuring how we define "a better mousetrap" in the marketplace of the coming decade. Environmentally efficient products and processes can be more efficient in raw material and power usage and therefore more profitable.

For example, in the 1970s, the big three American auto makers responded to EPA air emission standards with the catalytic converter, a technologically short-sighted, $600.00, end-of-the-pipe device. Consumers reduced exhaust emissions but realized no real improvement in the overall product. Japanese and European auto makers, on the other hand, were more far-sighted. They developed more efficient motors that minimized both exhaust emissions and fuel consumption. Consumers paid more but received a better product for their money.

As corporate environmentalism grows, technology will be developed to meet the new market demands. Advanced techniques for pollution control, recycling, clean energy production, balanced use of raw materials, and the clean-up of past pollution mistakes will offer huge rewards to the technology developer. Scientists and engineers are fully capable of tackling the obstacles to environmental symbiosis. All that is necessary for them to begin is industry's realization of the economic opportunities in protecting the environment.

Corporate environmentalism is only the tip of the ever-growing iceberg of environmental social awareness in this country. Society is changing in many ways that reflect a new way of thinking and acting. The changes can be seen in the fundamental social fabric of private citizens. Many towns have embraced trash separation requirements for household garbage; household hazardous waste collection days have proven huge successes;[2] the town of Brookline Massachusetts is considering a referendum before the voters to

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[2] "Waste Drive So Successful Some are Turned Away", *The Boston Globe,* June 9, 1991, p. 30.

require that all household garbage be thrown out in special bags, the cost of which is included in the bag; consumers have pressured McDonalds to offer their products in biodegradable packages. Other producers are following suit by trying to appeal to customers through "green" products. ARCO has recently announced the development of a new blend of gasoline that will cut toxic auto emissions by nearly 50%.[3] Discussions of the permanence of disposable diapers, the effects of ozone depletion, and the causes of acid rain are commonplace. In 1991, the Presbyterian Church decided to place environmental concerns into the church canon, thus making it a sin to "threaten death to the planet entrusted to our care."[4] These changes illustrate the extent and permanence of environmental awareness in our society.

Fifteen years is a remarkably short time for such dramatic changes in the thought and behavior patterns of a society. One undeniably important force in this change has been the creation of the Comprehensive Response, Compensation, and Liability Act (CERCLA) or Superfund. Although far from achieving its initial objective of cleaning up what was originally perceived to be a small number of abandoned hazardous waste sites, Superfund's impact has been profound on other levels. No other single force has been so controversial and, therefore, able to attract the attention of everyone from corporate CEOs to private citizens. Other statutes such as the Resource Conservation and Recovery Act (RCRA), Clean Air Act, and Clean Water Act have set the guidelines by which corporations must act, but Superfund has served to change the behavior of almost every sector of society, making all aware of the effects and the penalties (both environmental and financial) of

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[3]"Gee, Your Car Smells Terrific", *Time*, July 22, 1991, p. 48.
[4]"Presbyterians Ratify Teaching on Sex, Ecology", *The Boston Globe*, June 9, 1991, p. 4.

careless disregard for our environment. In economic terms, the Superfund program has "internalized the externalities."[5] Insurance companies, bonding companies, bankers, real estate developers, chemical companies, oil companies, contractors, engineers, gas station owners, and private citizens have all felt the far reaching impact of the Superfund act. As a result, they have been shocked into an awareness of the importance of thinking environmentally.

Society is being directed irreversibly toward environmental awareness. There will be a total and fundamental alteration in the way that today's young and thus, future generations, will perceive their place in the ecosystem. The thinking of the "disposable society" will vanish in a world that is moving towards a symbiotic relationship between humans and the environment. The market system will reflect this change, and as a result, industry, once blamed as the source of the problem, can provide the solution. But it must first perceive these changes as opportunities for increased profits rather than a source of economic burden. The minimization and control of pollution will reduce costs for pollution producers. New market opportunities will open up for both environmentally responsible products and service industries. Companies that adopt environmentalism into their corporate agenda will have a competitive advantage which will be increasingly important in the 1990's and beyond. In the end, this will prove beneficial to business, society, and the planet. Dubos' dream of symbiosis will become a reality.

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[5]"Interview of Mr Ira Leighton, Chief, CT Waste Management Branch, US EPA Region I", *CONSTRUCTION, MIT Center for Construction Research and Education,* Spring, 1991, p. 14.

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Contents

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Glossary

Abbreviations/Acronyms

ARAR	Applicable or Relevant and Appropriate Requirements
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
HSWA	Hazardous and Solid Waste Amendments to RCRA
LDR	Land Disposal Restrictions
LUST	Leaking Underground Storage Tank
NPL	National Priority List
PA/SI	Preliminary Assessment/Site Investigation
PRP	Potentially Responsible Party
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design/Remedial Action
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager
SARA	Superfund Amendments and Reauthorization Act to CERCLA
SQG	Small Quantity Generator
UST	Underground Storage Tank

Definitions

ARAR	Applicable or Relevant and Appropriate Requirements. ARARs include the federal standards and more stringent state standards that are legally applicable or relevant and appropriate under the circumstances.
Chlorinated Hydrocarbons	Organic compounds containing chlorine. These compounds are generally more difficult to break down and more toxic than ordinary hydrocarbons.
Cleanup	Actions taken to deal with a release or threat of a hazardous substance that could affect people or the environment. Cleanup is sometimes used interchangeably with the terms remedial action, removal action, remediation, or corrective action
Deep-Well Injection	A method of disposing of hazardous waste by injecting the wastes through a well thousands of feet below the surface. It is typically performed in areas with very low groundwater tables.
Dioxin	The trade name for the highly toxic defoliant 2, 4, 5-trichlorophenoxy-acetic acid, one of the compounds in Agent Orange.
Inorganic Compounds	Chemical compounds that do not contain compounds. Inorganic hazardous wastes generally refer to substances containing heavy metals: Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, or Silver.
HRS	Hazard Ranking System. The method EPA uses to rank the hazard from a Superfund site in order to determine if should be listed on the National Priority List.
NPL	National Priority List. A list of sites designated as needing long-term remedial cleanup.

Organic Compound	Chemical compounds containing Carbon. These compounds are generally volatile and combustible.
PCB	Poly-Chlorinated Bi-Phenyl. PCBs are a family of 209 different compounds produced by the direct chlorination of bi-phenyl. PCBs are extremely difficult to destroy and are considered to be highly toxic. Their production is now banned under TSCA.
PA/SI	Preliminary Assessment/Site Investigation. The collection of historical data (PA) and information from a Superfund site (SI) to determine the extent and severity of the hazards. The purpose is to gather information necessary to score the site for the Hazard Ranking System.
PRP	Potentially Responsible Party. Those identified by EPA as potentially liable under CERCLA for cleanup costs. PRPs may include generators and present or former owners/operators of certain facilities or real property where hazardous wastes have been stored, treated, or disposed of, as well as those who accepted hazardous waste for transport and selected the facility.
Remedial Action	Actual construction and implementation of a Superfund remedial design that results in a site cleanup.
Remedial Design	A phase of remedial action that follows the ROD, remedial investigation/feasibility study (RI/FS) and includes development of engineering drawings and specifications for a site cleanup.
Remediation	See Cleanup.
RI/FS	Remedial Investigation/Feasibility Study. Extensive technical study conducted by the government or the PRPs to investigate the scope of contamination (RI) and determine the remedial alternatives (FS) which may be implemented at a Superfund site.

ROD	Record of Decision. Published by the government after completion of the RI/FS, the ROD identifies the remediation method for implementation at a Superfund site.
SQG	Small Quantity Generator. A generator of more than 100 kilograms and less than 1,000 kilograms of hazardous waste per month. SQGs are regulated by a less stringent set of standards than full generators.
Surface Impoundment	A natural or man-made depression which is used to hold an accumulation of liquid wastes. Examples include holding, storage, settling, and aeration pits, ponds and lagoons.

Chapter 1 - *Introduction*

The cleanup of hazardous waste disposal sites is a growing market of enormous proportions for engineering and contracting firms in this country. The Superfund (CERCLA) program has listed 1246 sites on it's National Priority List.[6] That does not include the 26,000 sites listed on EPA's Hazardous Ranking System.[7] The General Accounting Office estimates that this list could grow to 368,000 sites if a more comprehensive inventory is taken.[8] Add to that the growing list of State Superfund cleanups, DOE, DOD, private party cleanups (those initiated both by Superfund and state real estate development cleanup laws such as Mass. 21E and NJ ECRA), leaking underground storage tanks and RCRA Corrective Action cleanups. The numbers are overwhelming. New and growing market opportunities exist for those presently in the remediation field and those who choose to enter it in the future.

The pace and cost of past cleanups under the Superfund program has been less than impressive. Individual site cleanups can take as long as 13

[6]U.S. EPA Office of Solid Waste and Emergency Response, *Superfund: Environmental Progress*,(Washington D.C., Government Printing Office, 1990) p. 2.
[7]"Real Property", *ABA Journal*, November 1, 1987, p. 67.
[8]*Ibid*.

years and cost an average of $20 to $30 million[9]. Early cleanups relied heavily on such simple techniques as: in-place containment and cap, which leaves a ticking time-bomb on the site; and removal of wastes and contaminated soils to an off-site landfill, which only moves the contamination from one site to another. Later cleanups relied heavily on incineration, which some would argue simply shifts the problem from one media (solid/liquid) to another (gas).

Given the cost and time statistics, coupled with the 1988 RCRA "land-ban" of specific hazardous wastes and the 1986 Superfund SARA amendment's clear preference for treatment technologies over disposal practices, the need for quicker, less costly and more permanent treatment technologies is a paramount need to the nation as a whole. However, serious obstacles exist to the development and commercialization of new remediation technologies. These obstacles are serious enough to thwart technology development by placing the innovative company at great risk both financially and legally.

This thesis will analyze the hazardous waste remediation market and provide insights into where it is going. It will also analyze the research and development market environment in order to identify the obstacles to innovation and the appropriateness of existing and potential government responses to alleviate them.

Chapter 2 provides the background to the hazardous waste remediation problem in this country. It addresses the nature of the hazardous waste site, the laws and statutes that exist to facilitate their cleanup, and an in-depth analysis of the available and innovative technologies for remediating them.

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[9]"Cleaning Up, Lucrative Markets Abound in Environmental Services", *Chemicalweek*, October 11, 1989, p. 21

Chapter 3 analyzes the scope of the hazardous waste remediation market. What is the size of this market? What are its various business service segments? How have these companies competed in the past? How are they competing now? How will they compete in the future? What impact will the answers to these questions will have on the technology developer? Specific attention in this chapter is given to analyzing the growing involvement of the construction industry in the hazardous waste remediation market.

Chapter 4 analyzes the incentives and disincentives to the development and commercialization of innovative technologies. Is adequate funding, insurance and bonding available to the technology innovator? Can the innovator get his technology from the prototype stage to becoming an accepted technology by government and private parties at an acceptable financial risk? Are government programs designed for the promotion of new technologies effective?

Chapter 5 discusses the results of a survey conducted of companies performing research and development in hazardous waste remediation technologies, regarding such issues as the obstacles to development of their product, the effectiveness of government programs, and the projected markets for their services.

Chapter 6 analyzes what more the government could do to promote technological development of hazardous waste remediation technologies. Tax incentives, research funding and consortia encouragement are all possible approaches to providing more proactive support of research and development. But, do these traditional methods really attack the core of the problem?

Finally, **Chapter 7** concludes with the purpose of this thesis. To identify: what the past and present dynamics of the hazardous waste remediation market are; where new technologies for hazardous waste remediation are coming from; what the primary obstacles and incentives to development and commercialization of these technologies are; and, finally, what steps government and business might take to enhance increased development and commercialization of new technologies.

Method of Approach

The content of this thesis was developed through an extensive literature search utilizing databases at the Massachusetts Institute of Technology, Harvard University, EPA Region 1, NTIS, Hollis, and the Boston Public Library system. The information gathered formed the baseline for a survey of companies performing research and development in hazardous waste remediation technologies. The results of this survey (which is enclosed in Appendix A, with its results in Appendix B) are used to enhance the arguments presented. Finally, the thesis draws on over two dozen interviews with government, business and trade association representatives.

Chapter 2 - *The Superfund Cleanup Process*

This chapter serves to acquaint the reader with the legal and technical background necessary for understanding how and why hazardous waste sites are remediated (or cleaned up). A glossary of acronyms, terms and definitions that may be helpful while reading this thesis precedes Chapter One.

Early Environmental Regulation

The U.S. government's first attempt at addressing the problem of managing hazardous waste was the Solid Waste Disposal Act (SWDA) of 1965. This act required safeguards and encouraged sound methods for the disposal of hazardous waste. The SWDA was amended in 1970 by the Resource Conservation Act (RCA) which was again amended in 1976 by what we now know as the Resource Conservation and Recovery Act (RCRA). Other regulations related to the objectives of RCRA are: the Clean Water Act (CWA) which provides for the regulation of discharges of toxic and hazardous substances into the nation's waterways; the Toxic Substances Control Act (TSCA) which makes it EPA's task to identify and control dangerous chemical products; and, the Clean Air Act (CAA) which provides for the regulation of discharges of airborne contaminants from stationary and non-stationary sources.

The Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) was signed into law in 1976 as an amendment to the Solid Waste Disposal Act. The most important mission of RCRA was to establish "cradle-to-grave" management and tracking of hazardous waste from generator, to transporter to treatment, storage or disposal unit (TSD). Other aspects of RCRA include the permitting of TSDs, transporters and generators and regular enforcement to insure proper adherence to federal statutes. RCRA was amended in 1984 with the Hazardous and Solid Waste Amendments (HSWA). These amendments, among other things, restricted land disposal of certain hazardous wastes, regulated underground storage tanks (USTs) and established guidelines for corrective action. Under the corrective action provision, RCRA regulates the cleanup of contamination much like the Comprehensive Response, Compensation, and Liability Act (CERCLA). However, RCRA concentrates on active, regulated facilities while CERCLA focuses on inactive or uncontrolled sites.

The Comprehensive Response, Compensation and Liability Act

Responding to a growing realization that regulations must be broadened to cover the remediation of "abandoned" hazardous waste sites the Comprehensive Response, Compensation, and Liability Act (CERCLA) -- commonly known as the Superfund -- was passed into law in December, 1980. It was the result of a national outcry to incidents such as Love Canal, Valley of the Drums, and Times Beach. At the time, the problem was thought to be a relatively small one. A 1979 EPA study concluded that there were between

1,200-2,000 sites which could potentially cause serious problems to human health and the environment. The initial cost estimates were between $3.6-44 billion[10]

CERCLA was intended to act as a catalyst for the cleanup of the nations hazardous waste dumpsites. The program's objectives were:

- To develop comprehensive procedures for setting priorities for cleaning up the nations worst sites.
- To make those responsible for the contamination pay for the cleanup.
- To set up a Hazardous Waste Trust Fund with the twofold function of providing funds for performing remedial responses to emergency spills and providing for the cleanup of existing sites when responsible parties were unknown or unwilling to pay. Those that were unwilling to pay would presumably be forced to pay through ensuing court action. The trust fund, or the Superfund, would be funded through taxes on crude oil and forty two (42) different commercial chemicals.

Another important aspect of the program was (and still is) a reliance on the private sector to perform these cleanups. Since EPA was providing the legal requirement that PRPs (Potentially Responsible Parties) perform these cleanups, it was assumed that the market sector would fill the void and provide the necessary technical skills to undertake the task. Unfortunately, the technological infrastructure for this type of work was virtually nonexistent. Early cleanup technologies were fairly primitive and short sited. According to Ira Leighton of EPA Region 1, "The program moved very quickly into the remediation of hazardous waste sites without the benefit of a

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[10]*Hazardous Waste Market - Handling, Storage and Disposal* (New York, New York, Frost and Sullivan, Inc., January, 1981) p. 24.

long history of science and technology to support the implementation of the program."[11]

An EPA review of the first three years of initial remedial action cleanup work showed that removal of the wastes from the site, and subsequent placement in an off-site landfill, was the most commonly implemented remedial technique (used at 41% of the site cleanups).[12] Another widely used site remediation technique (at 17% of the sites) was capping, grading, and revegetation.[13] This method was intended to contain the contamination from any further migration.

CERCLA spent $1.6 billion in its first five years. Much of this money was spent on identifying the extent of the problem, initiating emergency and remedial cleanups on any imminent hazards, and beginning the process of cleanup at the growing National Priority List (NPL) of sites. This first 5 years saw $600 million spent on private party cleanup agreements, 580 removal actions started by EPA at NPL sites, 470 completed Remedial Investigations/Feasibility Studies (RI/FSs), and 200 lawsuits filed by the government.[14] Despite this level of activity, EPA considered only 10 sites dangerous enough to be cleaned.[15]

As a result, Congress demanded more, faster, and better cleanup action at NPL sites. Toward that end, the Superfund Amendments and Reauthorization Act (SARA) was signed into law on October 17, 1986. SARA was a 5 year extension and expansion of CERCLA including a fund extension

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[11]"Interview of Mr Ira Leighton, Chief, CT Waste Management Branch, US EPA Region I", *CONSTRUCTION, MIT Center for Construction Research and Education*, Spring, 1991, p. 14.
[12] U.S. EPA Office of Emergency and Remedial Response, *Summary Report: Remedial Response at Hazardous Waste Sites* (Washington D.C.: Government Printing Office, 1984), p. 18.
[13]*Ibid*.
[14]Sidley & Austin, *Superfund Handbook: A Guide to Managing Responses to Toxic Releases Under Superfund*, (Acton, Mass., ENSR Corporation, 1989), p. 13.
[15]*Ibid*.

of $8.5 billion which was funded, as before, through a tax on crude oil and chemical feedstocks. SARA added structure to the program by creating mandatory deadlines for the cleanup process, accelerating enforcement actions, and increasing public and state involvement.

One of the changes that SARA enacted was the required development of stringent cleanup standards with a preference for permanent solutions that significantly reduce waste volume, toxicity, or mobility and that encourage alternatives to land disposal. Again as before, the technological infrastructure was still emerging and was not fully capable of responding to this new emphasis. Because of SARA, 1986 saw an increase in the use of standard treatment technologies such as incineration and in-situ (taking place at the site) solidification/ stabilization as well as a slow increase in the use of innovative technologies in EPA Records of Decision (RODs).

TABLE 2.1
ROD Treatment Technologies[16]

Year	Incineration	Solidification/ Stabilization	Innovative Technologies	Total RODs
1982	0	1	0	1
1983	0	0	0	0
1984	3	1	1	5
1985	7	2	6	15
1986	12	9	9	30
1987	13	9	10	32
1988	26	18	32	76
1989	30	18	52	100

The Hazardous Waste Site

The hazardous waste site is a tract of land that has been contaminated by a waste material that is listed as a hazardous waste under the Resource

[16]U.S. EPA Office of Emergency and Remedial Response, *ROD Annual Report: FY 1989* (U.S. Government Printing Office), p. 19.

Conservation and Recovery Act, 40 CFR Part 261. Wastes may be considered hazardous by explicit inclusion in the Part 261 list of over 500 chemical compounds or by exhibiting one of four characteristics of a hazardous waste: ignitability, corrosivity, reactivity or toxicity. Part 261 identifies tests that must be used to label a waste as characteristically hazardous.

Hazardous waste sites can be the result of past disposal practices such as surface impoundments or landfills for hazardous waste or can be the result of a past or present day accidental spill. A hazardous waste site can also be the result of a leaking underground storage tank. The most prominent source of this type of contamination is a gas station. However, a buried home heating oil tank can also become a source of contamination.

Until the 1970s, the standard practice for hazardous waste disposal was underground burial. Figures 1 and 2 illustrate this practice in New England in the 1970s. Perhaps the most prominent hazardous waste site in history was the Love Canal hazardous waste site. It was a hazardous waste dump for 25 years for Hooker Chemical Corp. in Niagara, New York. An entire community had to be evacuated after it was discovered that the buried wastes had contaminated the drinking water supply and in certain spots had begun to re-emerge at the surface. In response to Love Canal, Rachel Carson wrote the book *The Silent Spring* which is considered by many to have initiated the environmental movement in this country.

Another highly visible site was the Times Beach Missouri site where the residents of an entire town were relocated by EPA after it was determined that the oil used as a street dust suppressant was a waste product from the local chemical plant and was laced with a highly toxic carcinogen, dioxin.

The way that a hazardous waste site manifests itself is multi-faceted. Contaminants may be divided into categories: inorganics, metals, volatile organic compounds, non-volatile organic compounds, and halogenated compounds. They may exist in the soils and/or the groundwater. Soil contaminants usually are less mobile than groundwater contaminants because groundwater will move, dilute, and disperse contaminants. Therefore, groundwater contamination complicates a hazardous waste site cleanup considerably. Within the groundwater layer, liquid contaminants may become stratified. There may be a layer of liquids that do not mix with water and will float on top of the groundwater table. These are called Light Non-Aqueous Phase Liquids (LNAPLs). Likewise, there may exist liquids that do not mix with water and sink below the groundwater table. These are called Dense Non-Aqueous Phase Liquids (DNAPLs). Finally, contaminants may exist in the damp soils between the groundwater and the soil layers called the unsaturated zone. Each of these areas of contamination requires different response techniques.

Because groundwater movement will depend upon the media in which it exists, soil stratifications become critical to the identification and remediation of site contamination. Soils will flow quickly through sand and slowly, if at all, through clay. Fractured bedrock poses unique uncertainties to the waste site since flow through this media is unpredictable and difficult to analyze. Soil borings and groundwater monitoring wells are used to determine the subsurface geology and groundwater flow direction of a site in order to characterize groundwater and contaminant movements. However,

Figure 2.1 - Historic Hazardous Waste Disposal Practices, circa 1970.

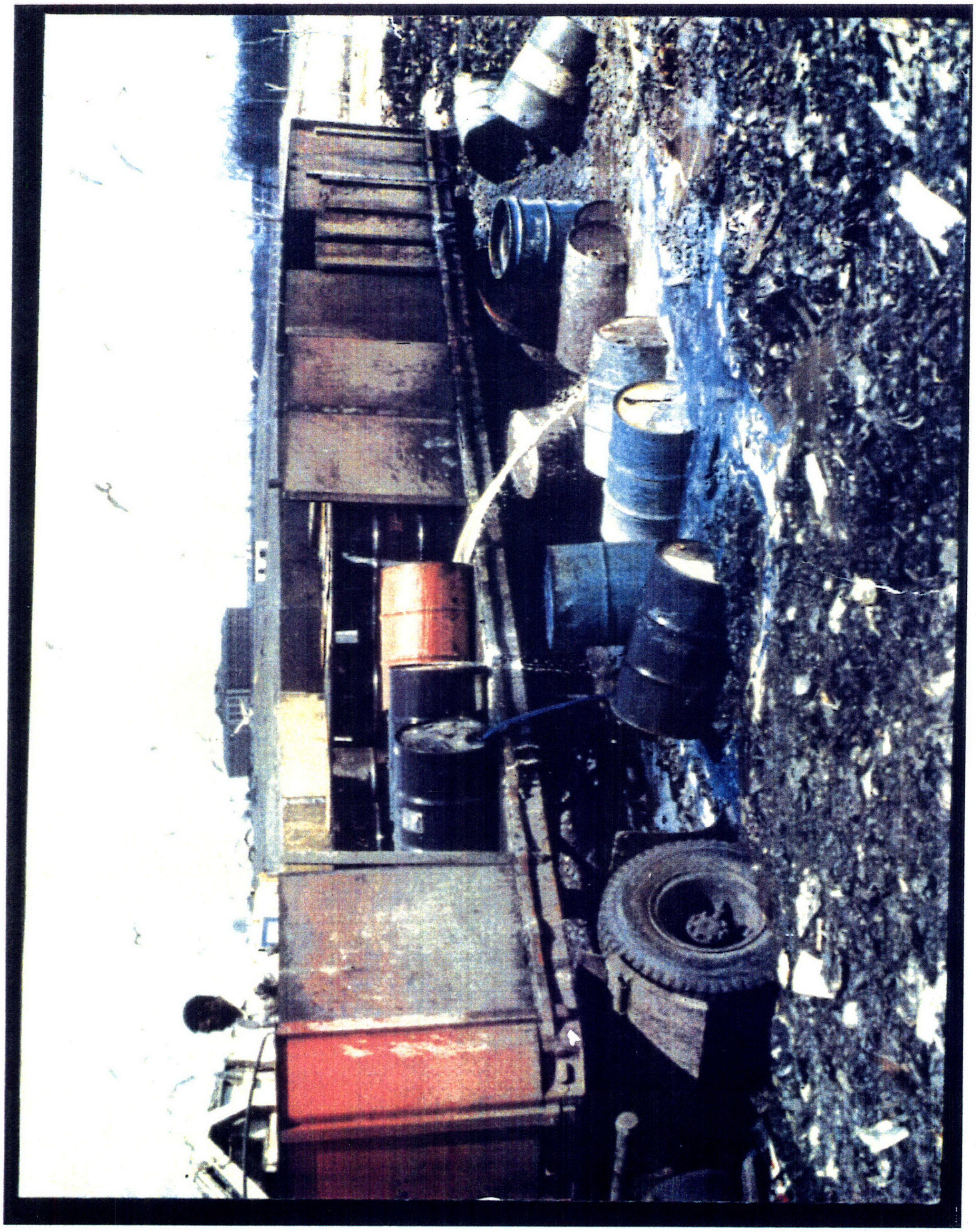

Figure 2.2 - Historic Hazardous Waste Disposal Practices, circa 1970.

the introduction of multiple-drilled holes or groundwater monitoring wells may also provide a channel through which contaminants may pass through an impervious layer and continue to spread, thus, exacerbating the contamination problem.

The Superfund Remediation Process

Upon discovery of a potential hazardous waste site, EPA conducts studies to determine its degree of hazard to the public or the environment. A Preliminary Assessment (PA) and a Site Investigation (SI) are conducted which combine a historical literature search and a field study of the site. If the site warrants further investigation, it is placed on the Hazard Ranking System and assigned a ranking against other sites in the country. If it is deemed a significant threat to human health and the environment, it is placed on the National Priority List.

Once on the National Priority List (NPL) a definitive set of steps move it towards eventual cleanup. An NPL site first undergoes an intensive site investigation called a Remedial Investigation (RI) followed by an analysis of the potential options for remediation called the Feasibility Study (FS). EPA selects one of the proposed remediation methods and officially documents it in the Record of Decision (ROD). The ROD clearly sets forth the work's cleanup goals (ie. cubic yards of soil to be removed, cleanup standards to be met).

Next, engineers develop a detailed design for the construction phase of the cleanup called the Remedial Design (RD). Actual implementation of this plan is called the Remedial Action (RA).

Ultimately a site will be removed from the Hazard Ranking System and the National Priority List, but this will not happen until after years of site monitoring to determine that the cleanup process was successful. EPA is the controlling agent throughout this entire process, however, private contractors and consultants perform the work under government or private contract.

Technologies for Superfund Cleanups

According to Walter Kovalick, Director of EPA's Technology Innovation Office, *available* technologies are those which are fully proven and in routine commercial use so that sufficient cost and performance data exists.[17] Conversely, *innovative* technologies are those for which performance information is incomplete. Extensive field testing is required for innovative technologies before they may be considered for use on a Superfund site.

Remediation technologies must address both soil and groundwater contamination (if present) and can be performed in one of three basic formats: in-situ, prepared bed or in-tank reactor. **In-situ** systems involve treating contaminated soils or groundwater where they lie directly in the site. No excavation is necessary. **Prepared bed** systems involve either (1) the physical removal of contaminated soil from it's original site to a newly prepared area which has been designed to enhance treatment and/or prevent transport of contaminants from the site, or (2) movement of the contaminated soil from the site to a storage area while the original area is prepared for use, after which the soil is returned to the site and treatment takes place. This format is not appropriate for groundwater treatment. **In-tank** systems involve removal of contaminated soil or groundwater for treatment in an enclosed

[17]Technology Incubation Workgroup Minutes, The Hotel Washington, Washington, D.C., October 16, 1990, p. 2.

reactor which utilizes batch, complete mix or plug flow systems.[18] When this format is used for treating contaminated groundwater it is commonly referred to as **pump and treat.**

To date 210 different technologies have been specified in EPA Record of Decisions.[19]: They can be classified into 5 basic categories: thermal treatment, solidification/stabilization, physical separation, chemical treatment and biodegradation.

1. Thermal Treatment can be divided into two categories: high temperature and low temperature. **High temperature** thermal treatment uses temperatures between 2,500-3,000°F to destroy or break down hazardous wastes into other compounds. Most thermal destruction technologies require that the hazardous material be batch or continuously fed into a reaction chamber under controlled conditions. Complete combustion of a hazardous waste produces CO_2, H_2O vapor, SO_2, NO_x, HCl gases and ash. However, incomplete combustion of hazardous waste constituents can result in the formation of other possibly toxic by-products. EPA requires that commercial incinerators perform with a 99.9999% destruction efficiency for the principle hazardous constituents.

High temperature thermal treatment includes **incineration, pyrolysis, wet oxidation** and **vitrification**. Incineration is a process that destroys combustible constituents at temperatures exceeding 2,200°F.. Pyrolysis decomposes organics in an oxygen deficient atmosphere. Wet oxidation employs high temperature and pressure in a water solution or suspension to

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[18]"Soil Remediation Techniques at Uncontrolled Hazardous Waste Sites: A Critical Review", *The Journal of Air Waste Management Association*, May, 1990, p. 706.
[19]*Ibid.*, p. 15-16.

destroy organics. Vitrification is a high temperature treatment that destroys organics and immobilizes inorganics in a glass melt.

High temperature thermal treatment is most suitable for organic wastes and is EPA's treatment method of choice for more toxic compounds such as dioxin and poly-chlorinated bi-phenyls (PCBs). Inorganics will be condensed and removed in the ash. Long term liability is eliminated through incineration as wastes are destroyed.

High temperature thermal treatment is usually very expensive because the waste material rarely has a BTU content high enough to sustain combustion. A supplementary fuel such as natural gas, oil or coal is necessary for complete destruction of the waste.

Flue gases from most thermal processes must be treated before emission to the atmosphere. This secondary treatment is usually a series of scrubbers or filters. Thus, high temperature thermal treatment creates hazardous waste in the form of combustion ash, scrubber liquid and filter dust which must be either landfilled or treated again. Due to insecurities over long-term emission quality and the creation of these additional wastes, incineration technology is the focus of intense public opposition and permitting difficulties.

In this country, thermal treatment can be performed at a fixed treatment site or in a mobile unit that is erected at the contaminated site. In Europe, ocean burning on incinerator ships has been in practice since 1969. The fostering concept behind burning at sea is that the main air pollutant emitted from the combustion of chlorinated materials, hydrochloric acid, would be absorbed by the seawater via droplets generated by the ocean's humidity.[20]

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[20]Bruce W. Piasecki and Gary A. Davis, *America's Future in Toxic Waste Management,* (Westport, CT., Greenwood Press, 1987) p. 68.

This practice has not gained acceptance in this country and is becoming increasingly less popular abroad.

The most common "available" technology for high temperature thermal treatment is the **rotary kiln incinerator**. This system feeds contaminated soils continuously into a reaction chamber (rotary kiln) where internal temperatures vaporize the hazardous constituents. Immediately following the kiln is an afterburner that completes the destruction of residual contaminants.

One thermal treatment technology, vitrification, can be performed in-situ[21]. Developed by Battelle Pacific Northwest Laboratory under a grant from the Department of Energy, **in-situ vitrification** (ISV) involves placing electrodes in the ground around the contaminated soil and passing an electrical current between the electrodes, thus melting the soil and surrounding rock. The soil, reaching temperatures as high as 4,000°F, destroys organic constituents (including PCBs) by pyrolysis. Inorganic pollutants are trapped within the resulting vitrified mass, which has the properties of glass. This process requires that a vapor collection system be installed over the site to capture any organic or inorganic airborne bi-products. Presently, Battelle subsidiary Geosafe Corp. (Kirkland, Washington) is the only company licensed by DOE to utilize this "innovative" technology.

Low Temperature thermal treatment utilizes temperatures between 200-900°F to essentially separate organic contaminants from soils, sludges and other solid media through evaporation. No incineration or pyrolysis takes place. Chemical oxidation and reactions are not encouraged and no combustion bi-products are formed. The organic constituents are removed as

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[21]"New Ways to Clean Up Toxic Wastes", *The Futurist*, July-August, 1986, p. 37.

a condensed high BTU liquid which must be destroyed in a permitted incinerator. Because of lower temperatures and gas flow rates, this process is less expensive than incineration. Chemical Waste Management Inc. (Oak Brook, Illinois) has developed the "innovative" X*TRAX™ system which utilizes low temperature thermal treatment in a mobile reactor vessel.

Low temperature thermal treatment has in-situ capabilities as well. Toxic Treatments, Inc. (San Francisco, California) has developed an "innovative" system that involves injecting air at 300°F and 250 psig and steam at 450°F and 450 psig through rotating cutter blades that are drilled into the contaminated site. The steam heats the soil causing the organic constituents to vaporize. The steam and air carry the stripped contaminants through a collection system above the blades to the surface where they are removed from the exhaust stream by condensation. The contaminants are then removed from the water by distillation.

2. Solidification/Stabilization techniques facilitate a chemical or physical reduction of the mobility of hazardous constituents without destroying them. This can be performed in-situ, in tanks, or in containers. Implementation generally requires extensive material handling and mixing. Consequently, true in-situ applications are limited. However, all treatment may be conducted on site. Solidification/stabilization is relatively inexpensive in relation to other technologies but is less permanent.

Solidification generally produces a durable monolithic block. **Stabilization** involves the addition and mixing of materials that limit the solubility or mobility of the waste constituents even though the physical characteristics of the waste may be unchanged. The treated waste has higher strength, lower permeability and lower leachability than the untreated waste.

Solidification/Stabilization is most suited to inorganic wastes containing heavy metals. Organic compounds may interfere with the setting action or leach out of the treated waste over a period of time. The attractiveness of this technology is the short term effectiveness of containing wastes from migrating. It is particularly useful at sites with limited space or needing emergency actions to alter the form of the waste into a more easily transportable form.

The disadvantages include: the weight and volume of the waste material increase by as much as 2 times thereby increasing handling costs; contaminant leaching occurs over the long term due to the porosity of the resultant solid mass; and, the technology requires considerable materials handling and controlled mixing.

"Available" technologies include include primarily three systems. **Cement based solidification** chemically or physically seals the waste in a portland cement based matrix. This technology neutralizes and seals acids, handles strong oxidizers and solidifies many toxic metals by forming insoluble carbonates and hydroxides due to the high pH of cements It is generally considered unacceptable for organics. **Pozzolanic Stabilization** binds waste in a siliceous and lime matrix similar to the portland cement process. **Thermoplastic binding** seals waste in a matrix such as asphalt. This is particularly useful for waste containing limited concentrations of petroleum oils. However, organic solvents, strong oxidizers and thermally unstable wastes tend to break down the matrix.

Recently, three "innovative" technologies have been developed. **Glassification** combines the waste stream with molten glass. The resultant solid glass-like residue and the treatment applicability are much like that of in-situ vitrification. **Ion exchange** substitutes innocuous ions from a binding material, typically clay, for contaminant ions from the waste stream. **Microencapsulation** is a molecular level treatment approach utilizing calcium-alumino-silicate compounds to solidify, fixate, and encapsulate hazardous waste.

3. **Physical separation** techniques separate hazardous constituents from the carrier soil and each other through various methods such as volatilization, adsorption, extraction, or filtration but do not alter their chemical structure. **In-Situ vacuum/vapor extraction** is used to remove organic compounds from the soil by applying a vacuum through production wells, forcing VOCs (Volatile Organic Compounds) in the soil to diffuse into the production wells. A similar system involves forcing air into injection wells and withdrawing air and VOCs through extraction wells. This treatment method can also be performed ex-situ. **Soil aeration** is the process of excavating and aerating soils in a mill or drum causing VOCs to volatize. They are subsequently collected and treated.

Soil washing extracts contaminants from excavated soil using a liquid medium such as water, organic solvents, water/chelating agents, water/surfactants, acids or bases. **Soil flushing** is applied in-situ using an injection/recirculation system. In both systems, the washing solution is treated for removal of the contaminants via a conventional treatment system.

Chemical extraction processes are used to separate contaminated soil and sludge into their respective phase fractions: organics, water and particulate solids. Types of solvent extraction include B.E.S.T., which uses a secondary or tertiary amine as the solvent, and critical fluid, which uses liquified gases (ie. carbon dioxide or propane) at high pressure.

Freeze Technologies Corporation (Raleigh, North Carolina) has developed an "innovative" technology that physically separates wastes by freezing them. **Freeze separation** operates on the principle that when water freezes, the crystal structure that forms naturally excludes contaminants from the matrix thereby allowing them to be collected. In the freeze crystallization process, refrigerant is injected directly into the excavated soil in a reaction chamber causing a temperature drop until a phase change occurs from liquid to solid. Crystals of solute and solvent are separated from each other by gravity and melted in a heat pump.

M.I.T. researchers are working on a system which utilizes **electroosmosis** to remediate contaminated sites. This technique works under the principle that contaminated groundwater can be made to flow through saturated clay upon application of an electric field. Two electrodes are placed in the saturated zone of the contaminated soil and a current is induced. The liquid will then flow from the anode (positive) to the cathode (negative). Clean purge water is added at the anode site and contaminated water is collected at the cathode site for removal and treatment. This technique is still in the experimental stage but offers advantages over traditional groundwater pumping methods since the flow direction and distribution is very uniform and controllable.[22]

Physical separation techniques can be viewed primarily as a method for separating and condensing hazardous contaminants. The resultant waste streams must be treated for detoxification or destruction before their final disposition. Therefore, These techniques must always be used in series with other treatment techniques.

[22]"Electroosmosis Decontamination of Hazardous Waste Sites", *Chemical Processing,* November, 1990, p. 12

4. Chemical treatment techniques destroy or detoxify hazardous constituents through the use of a chemical oxidation and reduction reactions. **Oxidation** reactions are generally applied to waste streams contaminated with organics because heavy metals (with the exception of arsenic) are more mobile at higher oxidation states. This process is carried out by adding oxidizing agents, such as ozone or hydrogen peroxide to the soil in a reactor vessel. In-situ applications are difficult to control due to the non-uniformity of soil particles. Phenols, aldehydes and certain sulfur containing organic compounds are highly reactive while halogenated hydrocarbons and benzene are relatively impossible to break down through this method.

Chemical **reduction** of soil contaminants has more limited applications than oxidation. However, soils contaminated with chlorinated hydrocarbons and certain heavy metals are receptive to reducing agents.

Contaminants are usually completely destroyed in chemical treatment, however, if only partial degradation takes place, the resultant compounds could be more toxic than the original feed.

Ultrox International (Santa Ana, California) has developed an "innovative" system which utilizes ultraviolet radiation in combination with the oxidizing agents ozone and hydrogen peroxide to destroy organic compounds, particularly chlorinated hydrocarbons, in water.

5. Biodegradation/Land Application. Biodegradation uses bacteria, fungi and/or micro-organisms to detoxify organic matter. There are several types of applications including composting, in-situ, solid phase, and slurry phase which may occur in aerobic (with oxygen) or anaerobic (without oxygen) conditions. The process is highly sensitive to environmental conditions such as temperature, pH, light, contaminant concentration, and micro-organism concentration.

Bioremediation is generally very slow. Some sites may take as long as long as 10 years to remediate. The process will only work under very controlled conditions. The technique usually involves extracting native organisms from the contaminated site, testing them to determine which is most applicable to the waste present, colonizing them to increase the population and, finally, readmitting them to the site. Some genetic engineering is under way to develop more effective strains for particular waste streams but is still experimental.

Bioremediation was tested successfully by the EPA following the *Exxon Valdez* catastrophe. Phosphate and nitrogen fertilizers were added to the contaminated Alaskan shoreline to increase the number of native oil-degrading microbes from 30-fold to 100-fold. The microbes "eat" the oil and produce carbon dioxide and water. Within three weeks, the fertilized areas had shown dramatic decreases in the level of oil contamination.[23]

Bioremediation is even claimed to be capable of destroying PCBs and dioxin. Extensive research in this area is being conducted at General Electric's Corporate Research and Development Laboratory at Schenectady, New York. GE is awaiting approval from EPA to employ their aerobic and anaerobic microbes on their PCB contaminated Superfund sites in California, Massachusetts, and New York.

The advantages to bioremediation are dramatic. It could cost less than $100 per ton compared to such techniques as incineration that may cost as much as $1,000 per ton.[24] The technology can be employed in a variety of in-situ conditions: soil, groundwater, lake, or river. However, regulators are wary of the drawbacks. It is a very lengthy process from initiation through

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[23]"Alaska Spill Creates Giant Laboratory", *ENR*, August 3, 1989, p. 33.
[24]"The Tiniest Toxic Avengers", *Business Week*, June 4, 1990, p. 96.

completion, and, it is extremely difficult to verify complete detoxification of wastes under in-situ applications.

Innovative technologies are gaining slow acceptance and are gradually producing results in the Superfund program. A new report by the EPA shows that new technologies are now in use or specified in 37% of Superfund site cleanup plans issued between 1982 and 1989.[25] Few innovative technologies, however, have yet to make their way through the cleanup pipeline. Only 6 cleanups have been completed using the new approaches.[26]

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[25]U.S. EPA Office of Solid Waste and Emergency Response, *Innovative Treatment Technologies: Semi-Annual Status Report*, (Washington D.C., Government Printing Office)
[26]"Technologies Gain Slow Nod", *ENR*, March 11, 1991, p. 15.

Chapter 3 -
The Hazardous Waste Remediation Market

History of the Market

In 1981, the first firms to capitalize on the $400-600 million hazardous waste market were solid waste disposal firms since hazardous waste was originally treated in the same fashion as solid waste. The extent of services was primarily that of hazardous waste handling, transportation and disposal. Disposal was carried out either through landfilling, deep-well injection or incineration. A 1981 Frost and Sullivan business report cited 7 companies as being responsible for 40-60% of the hazardous waste management business in 1980[27].

[27] *Hazardous Waste Market - Handling, Storage & Disposal* (New York, New York: Frost and Sullivan, Inc., January, 1981) page 135.

TABLE 3.1
Top 7 Hazardous Waste Management Firm Sales
(in 1980 dollars, millions)

	1979 Total Sales	1979 Haz Waste	1980 Total Sales	1980 Haz. Waste
Waste Management, Inc.	382	50	500-550	100
Rollins Env. Svcs.	322	23	400-425	40
Browning-Ferris Ind.	457	25	560-600	40
SCA Services	210	10-15	250-275	30
Cecos International	30	10	75	30
IT Corp.	37	2-3	45	5
Chem-Nuclear	NA	NA	40	2
TOTAL	1,438	120-125	1870-2010	247

During the 1980s, Superfund created opportunities for a wider range of hazardous waste service industries. In particular, geotechnical and engineering design firms experienced rapid growth to meet the demand for consulting services in the remediation field. By 1984, 37 engineering firms had focussed their corporate strategies towards this market[28]

The present day realities of the growth of this market have far exceeded the expectations. In 1981, Frost and Sullivan, realizing that remediation would add considerably to the hazardous waste market, predicted that the market would increase to roughly $2.5 billion by 1990. In actuality, the hazardous waste market has increased to $11.5 billion[29] in 1990 and is expected to continue it's upward trend to $15 billion by 1992 and $23.5 billion by 1996[30]. This can be attributed to the initial underestimation of the number

[28]*Hazardous Waste Management Markets* (New York, New York, Frost and Sullivan, Inc., September, 1984, vol. 2) p. 166.
[29]"What's News in Environmental Health", *Journal of Environmental Health*, July/August, 1990, p. 6.
[30]*Ibid.*

of sites needing remediation and underestimating the costs associated with each cleanup.

The players in this field have also experienced dramatic changes. The 1980s were marked by a large number of new entrants, primarily in the remediation field, and extensive reorganization and consolidation among the major environmental players. The most significant player in the field is Waste Management Inc (WMI). When Waste Management went public in 1971, its value was $20 million. Today, it is $19 billion.[31] . WMI posted revenues in 1989 of $4.5 billion[32]. Chemical Waste Management is now the subsidiary of WMI that deals exclusively with chemical wastes. CWM is a full service hazardous waste management firm, providing consulting and analysis, on-site remediation, transportation and disposal. It posted 1989 revenues of $891 million.[33] These figures are at least three times that of the nearest competitor.

Of the other original 7 waste management firms in 1980: Browning-Ferris Industries disbanded its chemical waste operations in June, 1990 following extensive litigation, unsuccessful landfill projects and other problems[34]; Cecos International has become a subsidiary of BFI with 1989 posted revenues of $75 million; Chem Nuclear has become a subsidiary of CWM with 1989 posted revenues of $50 million; Rollins Environmental Services has remained in the waste disposal business but has not become involved in remediation services. 1989 revenues reached $162 million.

IT Corp. has risen to become an important player in the hazardous waste field. In fiscal 1986 and 1987, IT began a campaign of buying up smaller

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31 "Tough Target", *The Wall Street Journal*, May 1, 1991, p. A1.
32 Waste Management Inc., Annual Report, Oak Brook, Illinois, 1989, p. 2.
33 Chemical Waste Management, Inc., Annual Report, Oak Brook, Illinois, 1989, p. 1.
34 "BFI's Stumbles Prove Costly", *ENR*, January 28, 1991, p. 24.

businesses. In 1987, amid extensive regulatory problems with its landfill sites, IT sold off its disposal business. In 1989, the company posted revenues of $264 million.[35].

All of these companies share a market that demands a wide variety of services. Theses services can be broken down into 6 primary areas.

TABLE 3.2[36]
Hazardous Waste Market Breakdown

Service	Percentage	$ Value
Remediation	55.6%	$6.5 billion
Disposal	15.5%	$1.8 billion
Small Quantity Generator Services	13.1%	$1.5 billion
Nuclear Waste	6.5%	$750 million
Hazardous Waste Treatment	4.4 %	$500 million
Technical & Analytic Services	3.9%	$450 million
TOTAL		$11.5 billion

Size of the Market

The remediation services market has proven to be the most lucrative. The markets for these services can be broken down into 8 primary markets: Federal EPA, State EPA, DOE, DOD, Private Party Cleanup, RCRA Corrective Action, Real Estate Development Cleanup, and Leaking Underground Storage Tanks (LUST).

Federal EPA. 1246[37] Sites have been listed on the EPA National Priority List (NPL). Another 26,000 sites[38] have been identified as being of less potential danger and have been placed on the Hazardous Ranking System (HRS). The General Accounting Office estimates that this list could grow to

[35]IT Corp., Annual Report, Torrance California, 1990, p. 2.
[36]*Ibid.*
[37]U.S. EPA Office of Solid Waste and Emergency Response, *Superfund: Environmental Progress*, (Washington D.C., Government Printing Office, 1990) p. 2
[38]"Real Property", *ABA Journal*, November 1, 1987, p. 67.

368,000 sites if a more comprehensive inventory is taken.[39] Costs of individual site cleanups range from tens of thousands of dollars to millions depending upon the extent of contamination. The largest Superfund settlement to date, at the Rocky Mountain Arsenal, is expected to be in excess of $1 billion, with the U.S. Army and Shell Oil Company paying for the cleanup[40]. Individual site cleanups cost an average of $20-30 million[41]. Current estimates by the Office of Technology Assessment of the costs to clean up the EPA NPL sites alone stand at more than $500 billion over the next fifty years[42].

State EPA. As of September 1989 thirty seven states had full fund and enforcement capabilities in a hazardous waste cleanup statute and seven states had limited fund capabilities which allow them to provide emergency responses. The states have collectively identified approximately 50,000 sites which may pose some threat to human health and the environment. Of this number 28,192 may require some form of cleanup action and 6,169 sites have so far been designated as priorities.

As of September 1989 the total amount of money available for state Superfund cleanups was $415 million. An additional $1.9 billion has been authorized in bonds for four states, New York, New Jersey, Massachusetts, and Michigan.[43].

Department of Energy. In June 1990, DOE published its "Environmental Restoration and Waste Management Five Year Plan" for fiscal years 1992-1996. The plan identifies 3,700 potential release sites at 500 facilities, with an

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[39]*Ibid.*
[40]*Hazardous Waste Market Report,* (Lexington, MA, Con Solve, Inc. 1991) p.16.
[41]"Cleaning Up, Lucrative Markets Abound in Environmental Services", *Chemicalweek,* October 11, 1989, p. 21.
[42]"Cleaning Up", *The Atlantic,* October, 1990, p. 48.
[43]Con Solve, p. 17.

additional 5,000 "vicinity properties" which may also be affected by their proximity to DOE facilities. There are presently 17 DOE facilities on EPA's National Priority List. The DOE plan presents the following expenditures:

TABLE 3.3[44]
DOE Expenditures 1991-1995

Year	$ in millions
1991	$4,440
1992	$5,967
1993	$6,414
1994	$6,800
1995	$6,372
TOTAL	$30 billion

Of these costs, 35% will be spent on environmental remediation. The other 65% will be spent on waste operations management improvements, technology development, education, and community relations. James Watkins, Secretary of Energy has stated that DOE may eventually spend $150 billion to achieve its goal of cleaning up all of its contaminated waste sites and bringing its aging facilities into full environmental compliance by 2019.

Department of Defense. The Defense Environmental Restoration Program was established in 1984 to facilitate the cleanup of DOD hazardous waste sites. DOD has identified 14,401 sites at 1,579 active installations and 7,118 formerly used properties which may require some form of remediation[45]. There are 96 DOD sites on the EPA NPL list.

DOD spent $600 million on cleanups in 1990. Funding for remediation could reach $1.1 billion in 1991 and Secretary of Defense, Dick Cheney, has

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[44]U.S. Dept. of Energy, *Environmental Restoration and Waste Management, Five Year Plan, 1992-1996,* (Washington D.C., Government Printing Office, June, 1990) p. 9.
[45]Con Solve, p. 19.

suggested that complete environmental restoration may cost more than $14 billion.[46]

Private Party Cleanup. Nationwide over 60% of the response actions at NPL sites in 1989 were conducted by potentially responsible parties (PRPs)[47]. These are cleanup actions that were initiated by EPA action. But the extent of private cleanups goes beyond that. Clean Sites Inc., a non-profit organization based in Alexandria Virginia, has found a strong interest among private parties to facilitate cleanups before EPA gets involved. Proceeding without EPA intervention can greatly increase the speed of a cleanup. However, this can also increase the risks since EPA may, at a later date, review the cleanup procedure and require further remediation.

RCRA Corrective Action. Corrective action under RCRA is essentially a program for cleaning up hazardous waste sites at operating facilities regulated under RCRA. These facilities fall outside the boundaries of CERCLA since they are not abandoned or closed. Approximately 5,700 facilities are currently regulated under RCRA. These facilities may have as many as 80,000 separate locations where hazardous waste disposal/treatment activities formerly took place. Estimates of the total cleanup cost to industry for corrective action ranges from $7-42 billion.[48]

Real Estate Development. States have now begun to develop new laws that require parties to undertake environmental audits at the time when: a property is sold; a business changes ownership; a company merges with another; a company goes bankrupt; an industrial lease expires; or the cessation of operations by an industrial establishment. An environmental

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[46]*Ibid.*
[47]Interview, March 21, 1991.
[48]Con Solve p. 7.

audit is similar to a Superfund Preliminary Assessment/Site Investigation (PA/SI) which is intended to identify contamination or potential releases of contamination at a property. The first of its kind, New Jersey's Environmental Cleanup Responsibility Act[49] or ECRA has been nicknamed the Environmental Contractors Retirement Act because of it's huge profit potential. Other states such as California, Delaware, Maryland, Michigan, New Hampshire, Pennsylvania, Massachusetts, Connecticut, Iowa , Illinois and Missouri have bills that closely follow the New Jersey law.

Leaking Underground Storage Tanks. Subtitle I of the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA requires strict regulation by EPA and the states of underground tanks that store hazardous substances. EPA estimates that there are approximately two million petroleum underground storage tanks at 70,000 facilities subject to subtitle I and 50,000 hazardous substance USTs at 30,000 facilities that are subject to the Corrective Action provisions. Based on this data, and the expected life expectancy of a tank to be 15 years, EPA estimates that 20% of these tanks are currently leaking.

In 1986, the HSWA originally provided a fund of $500 million to be used by states to clean up leaking underground storage tanks. The fund is financed by a 0.1 cent per gallon tax on motor fuels. The Office of Management and Budget predicts that this tax will raise $600 million through 1995.[50] This money will be used by states to identify, test and cleanup leaking underground tanks when responsible parties are unable to pay.

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[49]N.J.S.A. 13:1K-6, et seq., (1983)
[50]Con Solve p. 13.

Hazardous Waste Services

The types of services that environmental consultants and contractors offer can be broken up into thirteen categories within the remediation field. They are as follows:

TABLE 3.4
Remediation Services

Well Drilling and Soil Sampling
Sampling and Analysis Services
Geotechnical Services
Engineering Design Services
Construction Management
Excavation
Underground Tank Testing
Underground Tank Removal
Underground Tank Installation
On Site Remediation Technology Vendor
Hazardous Waste Transportation
Off Site Disposal Services
Off Site Treatment Services

Well drilling and soil sampling firms are involved with the actual installation of groundwater monitoring wells and collecting soil boring data to characterize the subsurface geology and groundwater flow in a hazardous waste site. The actual location and depth of these wells as well as the interpretation of the data is usually dictated and performed by an geotechnical engineering consultant. These firms often do similar work in preparation of constructing building foundations.

Sampling and analysis services are provided by a laboratory that verifies that samples were collected properly and analyzes the chemical constituents present.

Geotechnical and engineering design services are often, but not always, performed by the same types of engineering firms. The required specialties for each service are different. Geotechnical engineers comprise geologists, hydrogeologists and civil engineers. Engineering design services comprise civil, chemical and mechanical engineers.

Construction management services can be offered by environmental contractors, environmental consultants and construction firms.

Excavation services are offered by construction companies who are familiar with specific requirements of hazardous waste work such as decontamination of men and equipment, sensitivity to the nature and mobility of solid, liquid and air-borne wastes, and the proper handling and disposal of these wastes.

Underground tank testing can be performed by an EPA certified company but must be performed using only EPA approved testing methods. To date, the Hunter Leak Locator® and the Heath Petro-Tite Tank Tester® are two predominantly used methods. They work by overfilling the tank and measuring any change in the hydraulic head above the tank. Pneumatic testing is not allowed.

Underground tank removal and replacement are generally performed by the same firm since switching contractors mid way-through excavation would not be efficient. Tank removal can only be performed by an EPA registered contractor since the retired tank must be disposed of as a hazardous waste. Tank installation has become a complex field with the introduction of such elaborate options as cathodic protection of steel tanks, secondary containment systems and leak detection systems complete with monitoring wells.

On-site remediation technology vendors are firms such as those described in this thesis. Generally, these technologies are mobile and services are performed on the hazardous waste site. These companies may choose to perform direct contracting and construction management services or the may choose to simply provide the equipment and technical support to a contractor on a subcontract basis.

Hazardous waste transportation can be performed in rucks, trains or barges. Waste haulers must be licenced with the EPA and adhere to strict manifest and pollution prevention requirements.

Off Site disposal services constitute primarily landfills and deep well injection sites to which the wastes must be transported. These services are offered by only a few large firms who already have these sites built. Siting of new facilities is becoming increasingly difficult.

Off-site treatment services constitute primarily incineration and also involve transportation of the wastes. Like disposal, off-site treatment is a very difficult field to enter at this time due to intense siting difficulties.

Some companies, such as Chemical Waste Management perform essentially all of these services. They have capitalized extensively in areas of off-site disposal and treatment which are very difficult market sectors to enter at this time. The RCRA "land ban" makes it extremely difficult to site new landfills and public opposition can so fierce that locating any kind of permanent facility may be nearly impossible. For example, Clean Harbors Inc. spent $13-14 million over a period of years trying to site a hazardous waste incinerator in Braintree, Mass. only to have the permit denied under intense public opposition. Their stock value plummeted from 25 to 4 $^7/_8$. Now Clean Harbors has focussed on smaller markets such as underground tank testing, removal, replacement, treatment and disposal.

The Construction Industry and Remediation

An area of growing interest to environmental contractors and construction companies in particular is that of providing construction management services. *Engineering News Record* has estimated that 4% of the $204.5 billion world construction market is in hazardous waste.[51] This market has withstood the damage that the rest of the construction market has faced from the recession of 1990-91. Construction spending in hazardous waste can be expected to increase.

Due to the slow nature of the EPA Superfund process, actual construction work is beginning to emerge in large amounts. For the past 10 years EPA, through it's contractors, has been performing extensive studies at NPL sites to determine the extent of contamination, the responsible party liability and the appropriate cleanup response. Now, having completed the initial developmental stages of the cleanup process, EPA is moving more towards the physical implementation of remedial action plans as dictated by the Record of Decisions (RODs). Since 1982, 580 RODs have been signed. The numbers have been growing steadily year by year.

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[51]"Industry Optimistic Despite Setbacks", *ENR*, May 27, 1991, p. 35.

TABLE 3.5[52]
Number and Value of RODs Signed per Year

Year	0-$10 M	$10-20M	$20-30M	+$30M	Total
1982	4	0	0	0	4
1983	12	1	0	0	13
1984	33	3	2	0	38
1985	50	9	4	3	69
1986	56	13	6	8	83
1987	59	6	5	5	77
1988	118	15	14	6	153
1989	100	20	7	19	143
TOTAL	422	67	38	41	580

There is a great deal of work now coming out of the pipe line and companies are gearing up to capture it. Thomas Thurston, Program Manager for Sverdrup Environmental, a newly formed subsidiary of the construction firm, Sverdrup Corp. feels that "construction companies will push the environmental heavy-weights out of the market."[53]. He believes that environmental consulting firms have become complacent by charging high fees for exhaustive studies and environmental contracting firms are ill-equipped for the project management requirements of a construction project. "They are not results oriented like a construction company." Furthermore, he does not see the risks to this market to be any greater than that of other Sverdrup fields such as bridge and tunnel building The Sverdrup 5 year action plan for Hazardous waste Remediation sums it up:

"Scientific and engineering organizations which dominated the market by performing investigations and design studies in the 1980's are typically not as well equipped as Sverdrup to meet the action phases of remedial cleanup

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[52]U.S. EPA Office of Emergency and Remedial Response, *ROD Annual Report: FY 1989* (U.S. Government Printing Office).p. 29.
[53]Interview, March 29, 1991.

and construction expected in the 1990s"..."The market which was previously dominated by investigation and design studies with little actual implementation has undergone its natural progression by shifting to a program of action with needs in the actual remedial cleanup and construction of sites."

The report goes on to point out that the PRPs responsible for financing the ReSolve Superfund site in Dartmouth Mass. replaced the ENSR Project Manager with someone with more construction management experience. Therefore, Sverdrup concluded, "ENSR (second in hazardous waste billing according to *Engineering News Record*) is still viewed by the ReSolve Executive Committee as being institutionally inexperienced in managing the action phases of such projects because the company has no history in the scheduling or management of large and complex public works construction projects".

Micheal Skriba, Technical Director of the Environmental Services Unit for construction giant, Flour Daniel Inc. agrees[54]. Although he does not think that construction companies will push environmental contractors out of the business, he does feel that they will dominate and the environmental firms will subcontract to them. He feels so sure of this prediction that he left environmental division of Westinghouse to join Flour Daniel.

One construction company, Summit Constructors, Inc took its experience in water and wastewater facilities applied it to the environmental cleanup of groundwater. "This year has been our best year yet, with an expected $100 million in revenue," says Vice President Walter J. Bacer. The company plans to add 80 more people to its 400 person staff.[55]

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[54]Interview, April 22, 1991.

[55]"Industry Optimistic Despite Setbacks", *ENR*, May 27, 1991, p. 35.

These predictions may be overlooking several critical factors. First, environmental heavy weights such as IT Corp., Chemical Waste Management Inc and O.H. Materials are firmly committed and capitalized to this field. They are vertically integrated and may be better able to undercut the bid of a construction manager who must subcontract all construction portions of the project.

Second, the risks in the hazardous waste remediation market may be more of a concern than that of a bridge or tunnel construction project. Granted, as Mr. Thurston states "if a bridge collapses, people die just as in hazardous waste liabilities"[56] , that statement is ignoring the intangible and latent nature of hazardous waste injuries and claims. Exposure to harmful chemicals do not manifest themselves in health hazards for years or even decades. One might argue that a bridge collapse such as the section of I-95 in Greenwich, CT. offers the same latent risk. However, the damages by such an incident are finite and tangible. Damages resulting from hazardous waste exposure are difficult to identify, let alone quantify. Cancer, or the potential of getting cancer has unlimited potential value in a courtroom, whether the risk is medically (real) or psychologically (perceived) supported. Despite their downplaying the risks, both Sverdrup and Fluor Daniel executives are concerned, as evidenced by each company's decision to separate itself from the hazardous waste organizations by making them autonomous companies.

Third, public opposition in construction projects is not often as volatile and costly as that in the hazardous waste business. For example, CSX Transportation of Jacksonville, Fla. cleaned up a contaminated site in Freeland, Michigan after a train car carrying acrylic acid derailed. The

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[56]Interview, March 29, 1991.

contaminated soil was loaded into train cars and sent to be landfilled. In the process, members of Greenpeace and other environmental groups bird-dogged the train and at one point even chained themselves to it. The controversy scared off four landfill operators from accepting the waste, so the train cars have been roaming the country looking for a disposal site. Throughout this time, CSX is paying for transportation costs. To make matters worse, the company recently was fined $21,975 by the South Carolina DEP for leaks from the train cars.[57].

Fourth, the hazardous waste field may be more restrictively regulated and litigious than other construction fields. Mr. Thurston feels that Sverdrup's use of the law department as merely a support group makes the company better able to work efficiently. Is that the best approach for this field? Environmental heavyweight, Waste Management Inc. maintains its competitive edge by employing 80 lawyers, a legal army that it terms the largest private environmental practice in the country. Furthermore, the company has paid fines and related settlements exceeding $50 million.[58] Some critics charge the company with a cavalier attitude towards such fines which are small compared to the company's huge profits. Ironically the company enjoys the publicity of the fines. They feel that such actions only serve to make the business less attractive to competitors.[59]

Finally, the project management organization within a construction firm may be too burdensome for the needs of a hazardous waste construction project. The procurement and coordination needs, for example, are not nearly so complex as those for an office high rise or power plant. That is what

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[57]"Contaminated Cargo", *Time*, May 6, 1991, p. 25.
[58]"Tough Target", *The Wall Street Journal*, May 1, 1991, p. A11.
[59]*Ibid.*

Jeffrey Lawson, Principal of Environmental Protection Control Inc, Grafton Mass. is counting on. His firm is offering construction management services in the hazardous waste remediation field based on the premise that management needs are considerably less than for other fields. He feels that one project manager could successfully oversee a site cleanup essentially single-handed[60]. He feels that construction companies carry too much overhead and are too bureaucratic to deal economically with the hazardous waste remediation field.

There is no doubt that construction companies will alter the dynamics of the hazardous waste remediation field. They will increase the competitive nature of the market and, in the early stages out bid the traditional environmental firms. However, established environmental firms such as OH Materials, IT Corp, and CWM are financially and organizationally committed to this field and will not be knocked out of the business as some have suggested. They will be forced to refine their organizations and develop (or obtain) project management skills that will help them to compete more successfully. Construction companies may also find that they must refine their organizations to be better suited to remediation work. Remediation work holds different risks and skills than traditional construction projects. The ultimate result will be a healthy dose of competition and an overall improvement in the services being offered. The construction companies will not, however, dominate the field. They will spread the market out among more players.

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[60]Interview, June 23, 1991.

Consolidation among firms can also be expected. Construction firms with little technical understanding of hazardous waste remediation will either absorb or develop strategic alliances with engineering firms experienced in the market. In order to develop more competitive bids they may also try to vertically integrate or develop strategic partnering with firms in testing and analysis, well installation, technology development, treatment, transportation and disposal.

A more competitive field should have an impact on all facets of the market including remediation technology vendors. As the need for more economically competitive bids develops, the need for more economically competitive technologies will also develop. This may tend to change the dynamics of the research and development environment from one that is now in its early stages of trying to perfect the technology, to one that will be focussed more on improving service, cost and speed.

Chapter 4 - *Incentives and Obstacles To Technological Innovation*

Risks to the Remediation Technology Developer

The hazardous waste remediation contractor faces many risks when considering development of an innovative treatment technology. These risks can be grouped into four categories: liability, financial, business and market risks.

Liability Risks associated with hazardous waste remediation work arise out of the potential for accidental releases of hazardous substances during the remediation process. For example, O.H. Materials was sued for an accidental release of an acid cloud during the cleanup of the Drake Chemicals site in Lock Haven, Pennsylvania on March 23, 1982. Payment totalled $133,296.27.[61] Persons injured by hazardous chemicals can potentially seek common law remedies through four legal actions: trespass, nuisance, negligence, and strict liability. These remedies are referred to as toxic torts.

Trespass action may be brought by a plaintiff who owns a parcel of land that has been physically invaded by some substance so as to injure the rights of the landowner. This action has been used successfully to recover damages

[61]U.S. EPA , *Supporting Background Document for Proposed Response Action Contractor Indemnification Guidelines*,(McLean, VA, PRC Environmental, 1989) p.4-82.

in these following examples: the airborne emission of microscopic flouride compounds which entered the property of the plaintiff (*Martin v. Reynolds Metal Co.*); the flow of leachate from a buried dump site (*Curry Coal Co. v. Arnoni Co.*) and damage to trees from power plant emissions (*Stacy v. Arnoni Co.*).[62]

Nuisance action is used to defend the right to use one's property free from disturbance or interference from activities carried on by others on another property. The most common remedy obtained in a nuisance suit is the abatement of the nuisance. For example, nuisance has been used to stop a disposal company from further disposal of hazardous waste in a municipal landfill (*Village of Wilsonville v. SCA Services*).[63]

In a *negligence* action, the plaintiff must show that the defendant was obligated to conform to a specific standard of due care, that the defendant failed to so act, that an injury occurred, and that the lack of due care was the proximate cause of the injury. These cases are most successful when the temporal delay between a chemical release and the injury is brief. Another barrier to recovery has been the plaintiff's burden of establishing the defendant's lack of proper care.

Strict liability is considered to be the most viable theory for plaintiffs. There are several formulations of strict liability. The first formulation holds a party strictly liable for damages caused by a "nonnatural" use of land. In *Rylands v. Fletcher* the court found the defendant liable for the escape of water impounded on his land into a neighbor's mineshaft, even though the defendant was not found to be negligent. A second formulation holds

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[62]Martin T. Katzman, *Chemical Catastrophes* (Homewood, Illinois: Richard D. Irwin, Inc., 1985). p. 21.
[63]*Ibid.* p. 22.

defendants strictly liable for injuries caused by "ultrahazardous" activities. A third formulation determines strict liability by analyzing six factors: high degree of risk, likelihood of great harm, inability of third parties to protect themselves by reasonable care, uncommon usage, appropriateness of location and value to community versus risk of harm.[64]

An important aspect of the liability risks that make this industry different than other high risk construction activities such as bridge or tunnel building is the long term, latent aspect of the injuries. Medical injuries such as a preponderance of cancer or leukemia in a specific geographic location take a long time to develop. Therefore, remediation contractors may be exposed to risk long after their work is completed. Furthermore, even if the injury is detected early, the scope of the injury and the subsequent award size is extremely vague and open to subjective reasoning by the courts. This may leave contractors open to unlimited liabilities.

Another important aspect of the liability risks associated with Superfund cleanups is the risk of individual liability in the case of damages resulting from the release of a hazardous substance. Courts have held corporate employees, officers, directors, and shareholders directly liable for their hazardous waste management practices.

Financial Risks to the technology developer manifest themselves in several ways. The most obvious are the financial risks due to a lawsuit judgement as stated above. Such a judgement could easily bankrupt a small firm and risk severe damage to a large firm. One such example of a large firm who feared these risks is Phillips Petroleum. Phillips established a subsidiary called Incinitrol (Denver) to provide incineration services to outside clients.

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[64]*Ibid*. p. 25.

The project had been developed for two years when the board of directors decided to shut it down. Barbara Price Thurman, manager/corporate safety and environment states that the reason for the shutdown was a fear that the "corporate veil" theory would not hold. "Is it worth placing everything at risk?"[65] The Phillips board of directors decided that the answer was no!

Another financial risk to technology development is the extreme capital intensity of the field. The high research and development/process equipment development costs coupled with the long period of market entry make this a high financial risk market. Vincent Fitzpatrick, research engineer for technology vendor Geosafe (Kirkland, WA.) states that the fabrication costs for their in-situ vitrification equipment cost $2.5 million.[66]_This does not include the cost of research and development that was performed by Batelle Institute under funding from the DOE. Time periods for industry and regulatory acceptance of the new technology can be as long as 4 years. Then, time periods between issuance of an EPA ROD (and signing of a cleanup contract) and the actual remediation completion can be as long as 8 years. Given this lengthy period between technology development and full payment of services, a company that uses lending institutions to finance operations will face enormous and unpredictable interest costs. According G. Mead Wyman, General Partner, Hambrecht & Quist Venture Partners "a number of entrepreneurial firms with applicable cleanup technology have been stalled in the takeoff stage for periods ranging up to several years. The time required to penetrate the market must be conservatively estimated.

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[65]"Hazardous Waste: Faced with Dwindling Choices, Companies Must Seek New Ways To Manage It", *Chemicalweek*, August 23, 1989, p. 18.
[66]Interview, March 8,1991.

Demonstration and proof of a technology's efficacy often is a major, time-consuming step in entrepreneurial business development"[67].

Business Risks to this market segment are not altogether different than business risks to other innovative technology markets. The technology developer must make an in-depth analysis. Will the technology work? Will it maintain the safety of the workers and the local residents? Will there be a market for the technology? Will it be a technology of choice by industry and regulatory officials? Will it perform its function and assure an acceptable profit for the company? The need clearly exists for improved technologies and the market is still new, so the business risks for a carefully designed technology may be considered to be no different than those for any other business venture.

Market Risks are unusual for hazardous waste remediation. The market is driven primarily by federal and, to a lesser extent state regulation, as well as industry and public opinion. Regulations have been changing steadily for the past ten years. For example, if a firm invested heavily in perfecting cap and containment technologies in the early 80's, the SARA amendments effectively eliminated that company's market segment. If a company invested heavily in incineration technologies in the late 80's, it is probably watching its market segment dry up as the siting of commercial incinerator facilities becomes increasingly impossible. Another concern resulting from unsteady regulations is the possibility that regulations and technology might change and leave companies liable for what they thought they had cleaned up already.

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[67]"Industrial Waste Management", *TechLaw Update*, Third Quarter, 1990., p. 1.

On the flip side, the universe of hazardous waste remediation opportunities is growing every day. The increase in the NPL list, DOD sites, DOE sites, leaking underground storage tanks, and RCRA corrective action sites provides more market opportunities for the remediation contractor. New technologies that cost effectively remediate these sites offer tremendous economic rewards to the technology developer. Bioremediation is perhaps the hottest field today in that regard. What must be understood is that the market is ever changing. It may be starting to reach a balanced state, but the technology developer must stay in tune to future alterations in the cleanup strategy of the federal government and subsequently PRPs and State agencies.

The final market risk facing the innovative technology firm is a dynamic competitive industry structure. The market is fragmented with many small, mid-size and large firms. On the level of new entrants to this market, the market is highly competitive with many small firms seeking subcontractor relationships with larger contracting companies. The larger, established firms dominate the business and the smaller firms will find that they must rely on these heavy-weights for entry into the larger markets. Inability to establish industry ties will leave the technology developer competing for very small projects.

Institutional Obstacles to Remediation Technology Development

Institutional obstacles to innovative technology development fall into four categories: inability to obtain pollution insurance, inability to obtain bonding, inability to obtain financing, and EPA programmatic obstacles to development.

Pollution Insurance. The hazardous waste contractors insurance program could include as many as eight insurance coverage parts[68]. *Commercial General Liability Insurance* is the litigation coverage purchased by all businesses. Of specific importance to hazardous waste contractors are the exclusions that eliminate coverage for claims arising out of pollution, claims arising from operations at a hazardous waste site, claims arising out of the maintenance, operation and use of an automobile, claims that arise out of injuries to the insured's employees, and claims that arise out of a professional error, act or omission. To fill these gaps in coverage, the purchase of separate insurance coverages is necessary. *Contractors Pollution Liability* (CPL) coverage is in response to the pollution exclusion in the General Policy. The CPL policy has its roots in the Environmental Impairment Liability (EIL) policy, but amends the coverage to more closely reflect the exposures of the contracting firm. *Architects and Engineers Errors and Omissions* (E&O) policy coverage has been necessitated by the design errors exclusion in the General policy. However, if a hazardous waste contractor wants this type of coverage to cover pollution claims, the E&O policy must be amended by a *Specialty Environmental Engineers Errors and Omissions Policy*. Other possible coverages include *Asbestos Abatement Liability, Asbestos Consultant's Errors and Omissions, Commercial Automobile Liability,* and *Worker's Compensation Insurance.* (Some underwriters will surcharge their premiums when adding pollution coverage to the Auto policy.) Finally, some underwriters are introducing *Specialty Policy* forms that combine pollution coverages with either Professional Liability or General Liability coverage.

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[68]David J. Dybdahl, "An Integrated Risk Financing Approach to Remedial Action Contracting" (Caroon and Black Environmental Insurance Services, 1990) p. 3.

Just because these policies exist, it is not correct to assume that they are readily available to the hazardous waste contractor. A 1988 General Accounting Office report stated that "the number of insurers writing pollution insurance, the number of policies written, and the total pollution liability coverage decreased dramatically from a 1984 peak. Simultaneously, the average premium for the insurance increased to as much as 11 times its 1982 level. Insurance contracts become more limited in their coverage and in some cases provide no real protection to operators from financial losses arising out of pollution damage."[69] Many policies that are written today are "claims made" policies. This means that claims can only be made during the term of the policy. This offers no protection for the contractor who is hit with a claim after completion of the project as is most often the case. However, David Dybdahl of Caroon and Black Environmental Insurance Services believes that the pollution insurance market has been improving since that 1988 report. He states that "anyone who can't get insurance is dealing with an incompetent broker."[70]

However, in todays market many hazardous waste contractors are choosing to self-insure their practices through a captive insurance company, a self insurance association with other contractors or simply a financial trust fund. Another common practice for the contractor is to set up a separate subsidiary for its hazardous waste operations. Any liabilities that this subsidiary faces would hopefully be diverted from the parent company which would be hide "behind the corporate veil". Mr. Dybdahl states that "the issue

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[69]U.S. General Accounting Office, *Hazardous Waste: The Cost and Availability of Pollution Insurance*, (Washington D. C., Government Printing Office, 1988) p. 3.
[70]Interview, March 22, 1991.

of liability and insurance becomes one of the more significant barriers to entry (for the environmental engineering and contracting firm)".[71]

Dybdahl feels that there are three reasons why insurance companies are uneasy about getting involved in the pollution industry. First, environmental claims need not prove a cause and effect relationship between the event and the damage. This thought is supported by the courts interpretation of strict liability. Second, plaintiffs can "sue for the moon" based on unspecified or fear of future damages. Third, the courts appear to have shifted the burden of proof onto the contractor to prove that he/she was not responsible for the third party injuries.

Insurance companies ,may have a fourth reason for avoiding claims. An insurance company can become liable for pollution claims under CERCLA. According to a recent jury verdict in Denver, Colorado, The Hartford Accident and Indemnity Co. was required to pay investigation and cleanup costs associated with groundwater contamination at the Broderick Wood Products site. The court chose to overrule the pollution exclusion in the CGL policy . This case set a precedent with the verdict rendered in favor of the insured.[72]

Bonding. Bonding companies are equally uneasy about becoming involved in the hazardous waste services market. Tom Young, bond manager for Aetna Casualty and Surety Company states that "most sureties will not bond a contractor who is exposed to hazardous waste, particularly Superfund."[73] He feels that courts are unreasonably holding contractors and sureties responsible above and beyond the terms of the contract, even if

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[71]Dybdahl, p. 9.
[72]"Insurance Liability For Pollution Claims", *TechLaw Update*, Third Quarter, 1990, p. 4.
[73]Interview, March 29, 1991.

claims turn up years after the cleanup is completed. Bill VerPlanck, of the Surety Association of New England agrees, "bond companies are reluctant to get involved. Some do it, but only if there is a 'hold harmless' clause that indemnifies the bond company from any work beyond the scope of the contract."[74] Both Aetna and the Surety Association are actively pushing EPA to create a hold harmless indemnification clause in Superfund with clear indemnification limits for surety bond holders. They are also assisting EPA in properly analyzing and improving the insurance market in hazardous waste contracting. Only with all the possible risk management mechanisms in place, does Aetna feel that a bonding company can begin to accept its portion of the risk.

Financing. "Wall street likes what it sees" claims one headline in *Chemicalweek*.[75] "The U.S. Environmental market is a good investment with tremendous potential for growth" says Paul Zofnass, head of the environmental advisory group of Oppenheimer & Co.[76] Wall Street analysts have taken strong notice of the growth in the environmental engineering and contracting markets. The number of interested investors has prompted the an outpouring of public offerings, including those of environmental funds run by Openheimer Global, Fidelity, Freedom, Merrill Lynch, New Alternative, Progressive and SFT. These funds tend to focus on the large environmental firms, particularly those that operate landfills and collect household trash and other nonhazardous garbage. One company that seems to be on everyone's portfolio is Waste Management, Inc. WMI had $4.5 billion in 1989 sales resulting from everything from trash pickup to

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[74]Interview, April 2, 1991.
[75]"Wall Street Likes What It Sees", *Chemicalweek*, October 11, 1989, p. 25.
[76]"Cleaning Up", *The Atlantic*, October, 1990, p. 46.

incineration to asbestos removal. WMI stock recently traded at 33 1/2 which is 25 times earnings. Furthermore, the company has been compounding its earnings at a better than 25% annual rate over the past decade.[77]

The market is not as aggressive for smaller companies. Lawrence Greenberg, manager of the Fidelity Select Environmental Services Portfolio says that he is leery of small hazardous waste companies.[78] He cites as one of his reasons his losing experience with investments in Clean Harbors. Their stock went from 25 to 4 7/8 during their failed attempt to build a hazardous waste incinerator in Braintree, Mass. He goes on to say that a wise investor would stay away from most initial public offerings. He feels that "companies are coming public earlier. The longer the fad is in place, the less the quality names are coming up."[79]

The market also seems to have an uneasiness about investing in companies that perform research and development in hazardous waste. "Major companies and venture capitalists are nervous about possibly being held liable for any environmental damage that occurs from the use of a new process" states Oppenheimer's Paul Zofnass.[80] One venture capital firm, Hambrecht & Quist (San Francisco) has organized the Environmental Technology Fund (ENF). The fund invests in start-up and developmental phase companies pursuing a variety of environmental products, technologies and services. However, to date the fund has no investments in companies that perform hazardous waste remediation work. Instead the fund has invested in three companies focussing on recycling technologies for the semiconductor, metal plating and plastics industries.

77"Some Waste Stocks Aren't Trash", Forbes, October 15, 1990, p. 226.
78*Ibid.*
79*Ibid.*
80"Cleaning Up", p. 50.

Lending institutions are also wary of becoming involved with companies that perform hazardous waste cleanups. David Floreen, Senior V.P. of the Mass. Bankers Assoc. sees some lenders finding the market to be too good to pass up. However, he also feels that these institutions will temper their enthusiasm with the unstated liabilities that these firms face. If a firm is hit with a major lawsuit, will they be able to pay off their loan? He feels that the odds of that happening right now are just too great. Furthermore, if a bank chooses to manage a long term bailout of the troubled firm and assumes any kind of management control to accomplish this, he feels that the liberal interpretation by the courts of what constitutes an owner/operator may classify the bank as a PRP.[81]

Sometimes, the cleanup costs can exceed the value of the land. Recently a Texas bank disavowed a foreclosure on an oil refinery site after learning that it might become liable for its cleanup under CERCLA.[82]

EPA Institutional Obstacles. The government itself can be one of the main barriers to commercialization of innovative technologies. Superfund project managers must develop records of decision (RODs) that will stand the test of engineering review, public scrutiny, regulatory requirements and even court verified legality. According to Section 121 of CERCLA, the remedial action must comply with all applicable or relevant and appropriate Federal and State requirements (ARARs), be cost effective, and utilize permanent solutions and alternative treatment technologies to the maximum extent possible. Most of all, the technology must work. This tends to create an environment that will make the ROD process risk-averse and therefore biased away from innovative technologies. The ROD must promote a

[81] Interview, April 5, 1991.
[82] "Real Property", *ABA Journal*, November 1, 1987, p. 69.

technology that is effective the first time. The ramifications of using innovative methods for hazardous waste cleanups are much more significant than those compared to, for example, a wastewater treatment plant. In addition to lost time and potential exposures to contaminants, failure can increase costs, both because the work must be done over and the cleanup may be complicated by the overall effects of the failed technology. Dave Webster, Chief of EPAs Region 1 Maine, N.H., Vt., Waste Management Branch explains, "PRPs and even DOE and DOD can stick their neck out on a technology that may or may not work, but EPA is under incredible scrutiny and cannot take that chance." [83]

There are programmatic obstacles as well as institutional ones. The Resource Conservation and Recovery Act *(RCRA) "land-ban"* is one. Under this provision of RCRA Hazardous and Solid Waste Amendments of 1986 (HSWA), hazardous waste is banned from land disposal unless the waste meets specified treatment standards set by EPA. These treatment standards can fall into three categories: concentration levels; specified technologies; or a total ban from land disposal. Therefore, if a Superfund cleanup involves excavation of the soil, followed by treatment and replacement of the soil on-site, the ROD must satisfy the requirements of the land ban.

The concentration levels are based on Best Demonstrated Available Technology (BDAT) for the waste. Innovative technologies, such as biological treatment, soil washing and solidification will, in many cases not be able to achieve these levels.[84] In other cases, even if the technology is able to meet the concentration limit, it may not be appropriate by definition, either due to

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[83]Interview, April 11, 1991.

[84]U.S. EPA, *A Management Review of the Superfund Program*, (Washington D.C., Government Printing Office, 1990) p. 4-7.

a total ban limitation or the required use of another specified technology. For instance, bioremediation is not listed as a RCRA technology.

This would suggest that any in-situ technology that would leave the soils in place while removing the contaminants would be strongly preferred to avoid the requirements of the land-ban. But in-situ solutions have strong verification problems. EPA decision makers may be unwilling to choose a technology that may leave a small overlooked "hot-spot" of contamination that could later be detected by any concerned citizen with a shovel.

The EPA is seeking ways to get around these obstacles. A recently published "Superfund LDR Guides #6A and 6B" provide information to EPA decision makers on how to obtain Treatability Variances from the land ban for remedial and removal actions.

Another policy that can act as an obstacle to the use of innovative technologies is the *cost recovery provisions* of SARA. It is the objective of EPA to fund site cleanups when responsible parties are unwilling to initiate the cleanup and then recover the costs after cleanup is completed. If EPA utilizes a technology that fails or costs more than projected, then PRPs can argue in court that EPA is not entitled to full cost recovery.

Procurement procedures for innovative technologies within EPA can impede the selection of innovative technologies. One constraint is the provision of the Federal Acquisition Regulations (FAR) that prohibits contractors from preparing plans and specifications, and implementing construction at the same jobsite. If an innovative technology is being marketed by a single firm or small group of firms, a contractor may be unwilling to perform a treatability test during the RI/FS since that will preclude him/her from actually implementing the cleanup.

A related contracting constraint relates to the *sole source procurement* process, which can often be a slow and uncertain process. If only one company can perform the cleanup procedure specified in the ROD, then EPA must justify this open-bidding restriction. Dave Webster of EPA Region 1 says he gets around that by writing RODs with enough care so as to be general enough that several technologies could possibly meet the requirement.

Another constraint is an Agency policy that restricts a contractor from working for both the EPA and the PRP on the same site. At many sites EPA enters into a cooperative agreement with the PRP to divide up the work. If the same contractor cannot be used by both EPA and the PRP and the technology is proprietary, then there will undoubtedly be problems.

EPA Programs for the Enhancement of Technological Development

EPA has instituted several programs to enhance technology development in hazardous remediation technology.

ATTIC Program. The Alternative Treatment Technology Information Center (ATTIC) is an automated database that is accessible to site managers in the Federal, State and private sector through both a system operator or an online computer system. The database became operational in May 1989 and is designed to provide the most up-to-date information available on alternative and innovative technologies for hazardous waste treatment.

The program has been fairly quiet in its first two years of operation. Ira Leighton, EPA Region 1 Chief , CT. Waste Management Branch, says that his staff rarely uses ATTIC. If they need information, they most commonly use the SITE reports.[85]

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[85]Interview, March 21, 1991

SITE Program. The Superfund Innovative Technology Evaluation (SITE) program is designed to promote the development and use of innovative technologies to clean up Superfund sites throughout the country. The program is primarily an opportunity for EPA to verify the effectiveness of the new technique. Contractors pay for the operation and test runs of their equipment. EPA pays for and assumes complete control of all testing and analysis procedures. The program has five components.

The *Emerging Technologies* program is the first step in evaluating a new technology. In this step, the technology is subjected to a combination of bench and pilot scale testing under controlled conditions. Furthermore, through this program EPA will make up to $150,000 per year, for up to 2 years, available to emerging technology companies for assistance in whatever area of development is needed. The only stipulation of this "cooperative agreement" is that the company supply matching funds. For this contribution, EPA has the right to input technical direction, but is not entitled to any of the rights to the resulting technology. [86]

If bench and pilot tests are encouraging, the technology moves into the *Demonstration* program. (Technologies may also skip the Emerging Technologies Program and move directly into the Demonstration program if they choose to the initial bench and pilot scale testing themselves and the results are encouraging.) In this program, the technology is field tested on hazardous waste materials. Engineering and cost data are collected to determine if the technology is applicable for site clean-ups. The Emerging Technologies and Demonstration program are the prime focus of the SITE program.

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[86]Interview, Kim Kreighton, EPA Risk Reduction Lab, April 25, 1991.

The information from each of these steps is collected in an overall report and distributed to the user community through the *Technology Transfer* program. The *Measurement and Monitoring Technologies Development Program* explores new and innovative technologies for assessing the nature and extent of contamination as well as evaluating cleanup levels at Superfund sites.

Criticisms of the SITE program are consistently along the same lines. The demonstration program is too long and too costly. According to Walter Kovalick, director of EPA's Technology Innovation Office "the SITE program expenses are often so great that only the largest companies can participate."[87] Robert Olexsey, director of the SITE technology demonstration division states that the combined EPA and contractor costs for a single technology demonstration program can run from $600,000 to $1.5 million.[88] James J. Malot, president of technology vendor Terra Vac, states that " If we had waited for the SITE results to promote and implement our technology, Tera Vac would either be bankrupt or substantially behind our competitors in experience".[89] Terra Vac officials also contend that the that the $250,000 cost of participating in SITE, over the 4 year evaluation period, far exceeded the budgeted $60,000.[90]

Heather Ford, Vice President of technology vendor, SBP Technologies, Inc., adds that "although SITE is improving communication, technology results from the SITE program just die." The technology transfer program "is

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[87] "Fear of Trying", *Civil Engineering*, April 1991, p. 54.
[88] *Ibid.*, p. 52.
[89] "Toxics R & D: A Brave New World", *ENR*, August 3, 1989, p. 34.
[90] *Ibid.*

currently ineffective for getting the word out to prospective clients and government officials."[91]

Innovative Treatment Technologies: Semi-Annual Status Report. The Technology Innovation Office was established in April 1991. As part of its function, the office will produce semi-annual reports that (1) track the progress of innovative technology use; (2) to provide market information to technology vendors; and (3) to facilitate communication among innovative technology users. The first report came out January 1991.

Proposed Indemnification of Contractors. The EPA has published proposed guidelines in the Federal Register[92] to offer indemnification to response action contractors (RACs) for negligent releases arising from response action activities at sites on the National Priority List and at sites of removal actions. Under the this proposal, EPA will apply a strict underwriting program to its Superfund RACs and develop an award-fee plan that rewards contractors based on their performance. This program is intended to be an interim vehicle to assure that the Superfund program remain operative during the present pollution insurance crisis. It is based on the assumption that the crisis is due to an industry cycle involving cash flow and investment income. Under this view, the cycle will right itself and begin to provide pollution insurance coverage in the future.

This theory has drawn considerable criticism. The American Insurance Association and Aetna Casualty and Surety Company believe that the insurance crisis is due to: the disparate estimates of clean-up costs; the absence of any actuarial basis for apportioning potential liability; divergent and inconsistent judicial interpretations of policy provisions; retroactively created

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[91]Interview, April 23, 1991.
[92]Federal Register, Vol. 54, No. 209, October 31, 1989.

liability on past occurrence policies that could not be so changed; and the unavailability of reinsurance for those same reasons.[93]

Furthermore, the program does not offer relief to any contractors working outside the realm of the Superfund program. Cleanups initiated by PRPs, DOE or DOD will leave contractors with the same problem.

Federal Technology Transfer Act. The Federal Technology Transfer Act of 1986 allows federal labs to enter into Cooperative Research and Development Agreements (CRADAs) with industry to hasten the process of getting discoveries out of the labs and into the marketplace. This act has been used by a number of technology developers including SBP Technologies. For this support, the government retains the rights to the patent of the new development. Heather Ford explains that "the government gives us a 17 year exclusive right to the technology and we give back a portion of the profits each time it is used."[94]

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[93]Aetna Casualty and Surety Company, *Comments of the Aetna Casualty and Surety Company Submitted to the United States EPA Regarding the Proposed Section 119 Guidance Document* , January 29, 1990.
[94]Interview, April 23, 1991.

Chapter 5 - *Survey Results*

A four page survey was sent to 96 companies performing research and development on hazardous waste remediation technologies. Responses were received from 21 companies, who were collectively developing over 27 technologies. The survey form and the tabulated results are attached to this report in Appendices 1 and 2 respectively. The following is a summary of the survey results.

Of the technologies being reported, 18 were still in the SITE program, 4 were complete and 3 were never in it.

7 companies reported being able to obtain both pollution insurance and bonding. 1 was unable and 12 did not need it.

When asked to rate the obstacles to both development and commercialization of innovative technologies, the following order was reported starting with the most serious obstacle and ending with the least serious.

TABLE 5.1
Most Serious Obstacles to Innovation

Development	*Commercialization*
EPA Superfund Cleanup Process	Financial Risks
Financial Risks	EPA Superfund Cleanup Process
Financing Availability	Financing Availability
Uncertainty of EPA Standards	Permitting
Permitting	Liability Risks
Insurance Availability	Uncertainty of EPA Standards
Engineering Difficulties	SITE Program Approval
Liability Risks	Insurance Availability
Bond Availability	Engineering Difficulties
SITE Program Approval	Bonding Availability

What is particularly interesting about these lists is that the top three obstacles in each category are the same and deal with EPA approval and the risks of obtaining and losing money. These issues are related since a lengthy Superfund process can prolong high interest rate costs if loans have been used for technology development. Money seems to be the driving force in technology development. The technical difficulties of developing a new technology were considered to be relatively minor in both cases. One respondent added another obstacle to both development and commercialization as patent infringement.

When asked to rate the effectiveness of the various EPA programs intended to provide incentives for innovative research, most companies felt that they were not qualified to comment on the ATTIC program, the Federal Technology Transfer Act, the Technology Innovation Office hazardous waste market reports or the proposed indemnification program. Interviews with technology developers revealed that many companies are not aware and do not use these services. Most companies commented on the Demonstration and Technology Transfer programs. The results, in order of most to least effective, are as follows:

TABLE 5.2
Effectiveness of EPA Programs for Promoting Innovation

Development	*Commercialization*
Proposed Indemnification Program	Proposed Indemnification Program
SITE Demonstration Program	Federal Technology Transfer Act
ATTIC Program	ATTIC Program
Federal Technology Transfer Act	SITE Demonstration Program
SITE Technology Transfer Program	TIO Hazardous Waste Market Reports
TIO Hazardous Waste Market Reports	SITE Technology Transfer Program

When asked to rank the attractiveness of the various markets as to size of market, profit potential, and ease of entry into that market, the ranking from most to least attractive is as follows:

TABLE 5.3
Attractiveness of Remediation Markets

Size of Market	*Profit Potential*	*Ease of Entry*
Federal Superfund	Federal Superfund	LUST
Private Party Clean-ups	Private Party Clean-ups	Private Party Clean-ups
DOD	RCRA Corrective Actions	RCRA Corrective Actions
RCRA Corrective Action	Haz Waste Contractors	Haz Waste Contractors
Haz Waste Contractors	Real Estate Clean-ups	State Superfund
DOE	DOD	Real Estate Clean-ups
State Superfund	State Superfund	Federal Superfund
LUST	DOE	DOD
Real Estate Clean-ups	LUST	DOE

Federal Superfund was viewed by technology developers as having the most profit potential yet the market is not viewed as easily accessible.

Conversely, LUST was viewed as unprofitable but easily entered. Finally, contrary to the statistics mentioned in chapter 2, technology developers do not see DOD and DOE clean-ups to be very attractive markets. Both of these markets have yet to fully develop into full scale remediation work. As they do in the coming decade, technology vendors will become increasingly aware of their potential profits.

Technology developers viewed construction companies to be a new and growing force in the hazardous waste market. When asked to rate their confidence in Environmental Contractors (ie. CWM, OH Materials, IT Corp.), Environmental Engineers (ie. CDM, R.F. Weston, Dames & Moore) and Construction Companies (ie. Sverdrup, Bechtel, Fluor Daniel, ICF Kaiser) as to their ability to obtain contracts now and in the future, confidence in construction companies increased for the future while confidence in the other players remained constant.

Technology developers feel that direct contract bids will be the best ways to promote their technology. The ranking from most attractive to least is as follows:

TABLE 5.4
Favored Promotion Methods:

Direct Contract Bids to Clients
SITE Program
Sales Calls to Consultants
ATTIC Program
Trade Shows
Send Info. Directly to EPA RPMs
Sales Calls to Contractors
Trade Journals

It is interesting to note that, although the SITE (Technology Transfer) program was rated highly by vendors for technology promotion, few of those surveyed have actually used it. 18 of the 25 technologies responding are still in the SITE (Demonstration or Emerging Technology) program and have not yet reached the Technology Transfer program, and 3 were never in SITE. This suggests that expectations are high among vendors that EPA will successfully promote their technologies.

Bioremediation, followed by Solidification/Stabilization, and Incineration are considered by most technology developers to be the most important technologies for the future of hazardous waste remediation. In-Situ-Vitrification, Bioremediation, Proper Combinations of Technologies (linking two or more technologies together), and Genetic Engineering are considered to be the most overlooked technologies.

Comparing the list of technologies of the future with the list of technologies which the respondents feel are their most important competitors today reveals that innovative technologies have still not become widely accepted in the market.and that clean-ups still rely heavily on the most primitive methods. The ranking of the major present day technologies, from most predominant to least are as follows:

TABLE 5.5
Major Competitive Remediation Technologies

Incineration
Landfilling
Bioremediation
Vitrification
Carbon Adsorption
Solidification/Stabilization

Most companies performed all levels of research for their technology in-house. The only two areas of research that some did not perform were: basic scientific research (performed by 80% of the respondents) and commercial application (performed by 61% of the respondents).

90% of the respondents had no objection to EPA funding research in hazardous waste remediation technologies.

When asked to rate the criteria that make each company's technology more attractive than the competitors, its ability to meet EPA standards and its applicability to specific waste types were most important. In-situ capability was least important and low cost was in the middle. The ranking from most to least important is as follows:

TABLE 5.6
Important Criteria that Increase the Attractiveness of Vendor's Technology

Capability of Meeting EPA Cleanup Standards
Applicability to Specific Waste Types
Certainty of Results
Permanent Detoxification of Waste
Capability of Exceeding EPA Standards
Return of Site to Commercial Usefulness
Low Cost
Low Potential for Public Opposition
Beneficial Reuse of Waste
High Speed
Established Track Record
In-Situ Capabilities

The relative unimportance of high speed and low cost suggests that technology developers do not believe that they must compete vigorously with other vendors. In fact, 76% of the respondents described themselves as being in a niche market. Only 69% felt that the market was competitive.

83% of the technologies had markets outside the hazardous waste remediation field, primarily in the chemical processing field.

81% of the respondents intend to contract their services as a commercial enterprise.

73% will or have obtained a patent for their technology.

59% will licence their technology to other contractors.

2 companies will focus their marketing efforts regionally within the U.S. The rest will market throughout the entire U.S. 83% will market in Canada. 75% will market in Europe and 54% will market in the Pacific Rim.

Finally, when asked to rate the factors that affect the competitiveness of the field, threat of entry and buyer power were rated high, availability of substitutes was moderate and supplier power was low.

The results of this survey reveal that the development of innovative hazardous waste remediation technologies is still in its early stages and, perhaps, more concerned with satisfying government regulation than the client's economic needs. Most innovators feel that they are moving into a niche market. This suggests that vendors do not forsee strong competition for their services.

Incineration and landfilling are still seen as the key technologies for present day hazardous waste remediation. Although they are favored by regulatory officials and some PRPs for certain wastes, markets for both of these technologies can be expected to diminish over the next decade. The land disposal restrictions in the Hazardous and Solid Waste Amendments to RCRA put severe limitations on the further use of landfills for hazardous waste. Existing landfills have maximum volume limits and new landfills must be equipped with extensive liner and leachate collection systems. That is, of course, if they can be built at all. Public opposition to both landfill siting is extraordinary. The NIMBY (Not In My Backyard) movement is rapidly being replaced by the NOPE (Not On Planet Earth) movement.

Incinerators offer the attractiveness of a permanent solution to hazardous wastes and thereby minimizing liability risk. However, new technologies, such as bioremediation and chemical treatment, are offering equally permanent solutions without the drawbacks. The long term quality of stack emissions from incinerators is drawing sharp criticisms from citizen groups causing siting problems equal to those of landfills. Furthermore, incinerators create toxic waste in the form of ash, scrubber liquid and filter dust. Finally, incinerators are an extremely expensive solution when compared to other innovative technologies.

Bioremediation is viewed as the most important technology of the future yet it is also viewed as the most under utilized. This innovative technology must undergo more testing before it will see extensive use. It offers benefits of low cost, in-situ capabilities, and an ability to destroy strong compounds such as PCBs and dioxin. Its drawbacks include an inability to verify cleanup when used under in-situ conditions and the need for a severely controlled environment. It will take time and engineering data to gain full confidence in this technology.

In-situ vitrification also offers great potential for future hazardous waste site cleanups. It can be performed in-situ and virtually assures the detoxification of organic wastes and binding the of inorganic wastes.

Proper combinations of technologies is also seen as important in the future. Examples of technology trains may include soil venting or liquid extraction followed by bioremediation or chemical treatment. Since many technologies serve to separate hazardous constituents, technology trains which seek to recycle or re-use the chemicals removed from the ground would be most advantageous from an economic and environmental point of view.

Chapter 6 - *What More Could Government Do To Promote Innovative Technological Development?*

Present Political Climate for Government Support of Commercial Research

In 1980, the Reagan administration focussed its efforts on reducing the size and scope of the federal government and, in particular, its influence over business and industry. This translated into a laissez-faire attitude towards government intervention in the market place. Industrial policy -- the idea of using government power and taxpayer money to stimulate key industries through support of commercial research -- became anathema.

The Bush administration has continued this hands-off approach to the market place. In his presidential campaign, Bush derided industrial policy as "picking winners and losers."[95] Within the administration, the strongest opposition to federal support of commercial research is believed to come from three powerful people: Richard Darman, head of the White House Office of Management and Budget; John Sununu, the President's Chief of Staff; and Micheal Boskin, chairman of the Council of Economic Advisors.[96]

[95]"Washington Policy on R&D Proving Divisive Issue", *Congressional Quarterly Weekly Report,* May 13, 1989, p. 1108.
[96]"Congress Presses Bush to Provide Strong Support for Commercial Development of Technologies", *The Chronicle of Higher Education,* July 5, 1990, p. A19.

Recently, however, due to growing foreign competition to U.S. industry and increasing foreign government support of that industry, industrial policy is gaining acceptance. Paul Tsongas, a 1992 presidential candidate, charges that the Republican mania for free markets is dangerously out of date. Today, foreign governments keenly nourish their own private industries. "American companies," says Tsongas, "need the U.S. government as a full partner"[97] .

Administration members are split. Some argue that the U.S. must find some way to spur technology development if American business is to compete with their foreign counterparts. Others fear that government support of commercial research would lead to federal interference in the free market system. In a March, 1990 speech, Bush softened his views by pledging to work with industry to promote "pre-competitive" work on "generic technologies that support our economic competitiveness and our national security."[98]

Translated, "generic" refers to technologies that could have broad applications across a number of industries. "Pre-competitive" means that the federal government would not be part of a program to develop a specific commercial product or manufacturing process for a particular industry or company.

The term "national security" is also one which must be defined. In the past, this term has been viewed in purely military terms. However, national security has increasingly been used to describe economic security and the

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[97]"It's Tsongas With a T", *Time*, June 24, 1991, p. 19
[98]*Ibid.*

promotion of advanced commercial technologies necessary for maintaining the competitive status of U.S. industry.[99]

Why Should the Government Support Hazardous Waste Remediation Technology Research

Government support for the development of innovative technologies for hazardous waste remediation is an issue that poses unique questions. Is the development of these technologies strictly the responsibility of industry? Past hazardous waste sites were created through actions which, at the time, were legal and ethical given the level of understanding of their effects. Therefore, how can industry be held completely liable for the expenses of both the cleanup and the development of the technologies for its implementation? Is the cleanup of abandoned hazardous waste sites not a public good for which the government must bear some responsibility?

Is it efficient to require that innovative companies assume all of the risks to develop technologies for a market that is finite? The Superfund is, by nature, a temporary program which will eventually be replaced by responsible waste handling practices as regulated under RCRA. This fact will serve to minimize the number of industries, their level of assumed financial risk in developing new technologies and, the rate at which they will be developed. Wouldn't the rapid development of hazardous waste remediation technologies improve the competitiveness of American industry against foreign competition? Hazardous waste site cleanups create a tremendous financial burden on domestic industries which affects their ability to compete with foreign competitors who are not subject to similar regulations in their

[99]"Technology and Competitiveness: The New Policy Frontier", *Foreign Affairs*, Spring, 1990, p. 116.

own countries. Cost efficient technologies will minimize that burden and improve competitive stature. Would it not be best for the country as a whole if the objectives of the Superfund program were completed? To this end, government should do more to assist in the rapid development of efficient cleanup methods. The question is, how best to do it?

Traditional Methods of Government Support for Technological Research

The federal government has many tools at its disposal for promoting innovative technological development. The most immediate way in which government can influence the market is the **tax incentive**. Tax incentives can speed the adoption rate of new technologies by lowering the overall implementation cost to the user and, therefore, lowering the financial risk. Incentives can be offered directly to the innovator of the technology. For example, since 1981 the federal government has allowed industry a 20% research and development tax credit. Tax incentives may also be offered directly to the end-user of the new technology. For example, tax credits could be offered to hazardous waste site owners on the funds spent to remediate their sites. This would help to increase the rate at which sites are cleaned up in this country without biasing the market towards any specific technologies. However, if the government wanted to focus efforts on specific types of technologies, it could offer greater tax credits for monies spent on technologies that are, for example, performed in-situ, result in complete detoxification of the wastes, or create a beneficial re-use of the wastes. This latter example is contrary to the present administration's policy of not picking winners and losers and could result in unfair bias toward specific existing technologies. Future innovations would be faced with even greater barriers to entry than already exist. This would be best avoided.

Other, less used, methods of support include: the use of national laboratories for private research; funding of industrial research either directly or through universities; and encouraging consortia which bring industry, government, and university researchers together to explore specific scientific research.

Researchers at **national laboratories** can become involved in commercial technology development in primarily two ways. Under the Stevenson-Wydler Technology Innovation Act of 1980, federal laboratories are encouraged to find commercial applications of their work. Previous to that Act, a great deal of useful technology was being developed for the government but was just sitting on the shelf. Under the Federal Technology Transfer Act of 1986, industry and government researchers are allowed to collaborate on technology development. Through these two Acts, the work of some of the 700 federal laboratories could be directed toward developing new remediation technologies. One federal laboratory, EPAs research facility in Cincinnati, Ohio is already involved in remediation technology development through the SITE program.

Research centers created specifically to combine government, industry, and university resources have also proliferated over the years. Around the country, there are 18 federally funded Engineering Research Centers, 11 Science and Technology Centers, three "Hollings Centers" -- named after Senator Ernest Hollings, D - S.C. -- devoted to technology transfer in manufacturing and various other government sponsored ventures. More are on the way. The 29 engineering and science centers together cost the federal government $60.6 million in fiscal 1989, of which $7.5 million went to the Hollings Centers.[100]

The federal government can fund industrial research either directly or through universities. Direct funding for hazardous waste remediation technologies is unlikely since this method of support is used almost exclusively for military contractors. Funding, however, of industrial research at universities is a viable option. A 1982 NSF survey identified that industry benefitted from university research relations through: access to students and professors; access to technology for problem-solving or obtaining state-of-the-art information; prestige; economical use of resources; support of technical excellence; and proximity and access to university facilities. University researchers benefitted from industry research relations through: access to scientific and technical areas where industry has special expertise; the opportunity to expose students to practical problems; the use of ear-marked government funds; and potential employment for graduates.[101]

There are critics to the use of academic institutions for industrial research. A report by the Organization for Economic Cooperation and Development (OECD) states that industrial research at the university level is more practical, short-term, and commercial in its orientation. It warns that the industrialization of research threatens the accessibility of research results. As a result, this "compromises the primary function of academic institutions...to serve the broad public interest."[102]

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100 "Washington Policy on R&D Proving Divisive Issue", *Congressional Quarterly Weekly Report*, May 13, 1989, p. 1109

101 Albert N. Link et al., *Cooperative Research and Development: The Industry University Government Relationship*, (Norwell, Massachusetts, Kluwer Academic Publishers, 1989) p. 44.

102 "Dangers of Industrial Domination of Academic Research", *Nature*, September 29, 1988, p. 388.

Finally, government can promote development of innovative remediation technologies through encouraging consortia. These cooperative ventures can include industry, government and academic researchers. The benefits include a significant reduction in the time and cost of capital-intensive and multi-disciplinary research. Since the passage of the 1984 National Cooperative Research Act (NCRA) which encourages collaboration by shielding such ventures from antitrust litigation, more than 173 consortia have registered with the U.S. Department of Commerce.[103]

Overseas, government sponsored, and often orchestrated, consortia have proven successful. The Espirit, Eureka and Airbus programs in Europe and Japan's Erato, MITI, and Monbusho programs are all examples that have proved successful in developing key sectors for foreign competitors.[104]

The past level of U.S. government involvement in these cooperative agreements has been as low as easing antitrust restrictions, to as high as contributing financial assistance to the endeavor. Federal involvement in the semiconductor consortium, Sematech, amounted to contributing half of the entire $200 million price tag. This funding came from the Defense Advanced Research Projects Agency (DARPA) which feared that weak U.S. industries threatened national security. DARPA has also provided $30 million over three years for HDTV research. The Commerce Department has also initiated its Advanced Technology Program which will distribute $10 million to fund future industry led consortia.

Critics contend that consortia have, as yet, been ineffective in promoting technological competitiveness. They feel that declining competitiveness of

[103] "Hard Lessons in Cooperative Research", *Issues in Science and Technology*, Spring, 1991, p. 44.
[104] "High Tech Patriotism", *Omni*, April, 1991, p. 10.

many U.S. industries is not due to deficiencies in basic research but to an inefficiency in transferring technology to the marketplace. Videocassette recorders, semiconductors, and televisions are all examples of markets in which U.S. scientists pioneered technological breakthroughs only to have foreign competitors dominate the market through better and faster entry. This inefficiency will only be exacerbated by the formation of a consortium since competitors cannot really cooperate at a level of research so close to the marketing of the final product.[105]

The development of new, remediation technologies, unfortunately, needs assistance in this technology transfer stage. The basic scientific research for bioremediation, vitrification, and other technologies is well under way. The necessary step is now to help these technologies toward full market use by developing field application and engineering data to verify their reliability and improve their efficiency. Given this need, relative to past experience, the formation of a consortia to promote remediation technology development would not be appropriate.

How the EPA Should Best Promote Hazardous Waste Remediation Technology Development

Milton Friedman wrote that "the role of government is to do something that the market cannot do for itself, namely, to determine, arbitrate, and enforce the rules of the game.[106] " Some might argue that the government already fulfilled its role of determining the rules of the game by requiring that owners of hazardous waste sites clean them up. However, the rules need more refinement. Through real market dynamics, this cleanup requirement

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[105] *Ibid.*

[106] Dorfman and Dorfman, *Economics of the Environment,* (W.W. Norton, 1972) p. 202.

should create a market which will provide the necessary profit incentive for industry to assume the risk of developing new and innovative technologies. This is not happening to the degree that it should.

As the exorbitant cost and excessive time frame for present-day cleanups illustrate, available technologies are not as technically advanced or economically efficient as the market requires. Furthermore, new and innovative technologies are not entering the market as rapidly as is needed. If the present system remains unchanged, future improvements and refinements of these new systems can be expected to be equally as slow. By the time these technologies reach full market maturity, industry and the taxpayer will have spent hundreds of billions of dollars cleaning sites using established but antiquated methods while more effective technologies struggle to enter the market.

The most convenient response to solving this problem is to speed up the engineering and field tests of new technologies through increases in public or private funding. However, government or industry should avoid intervention in the market-place through deciding which technologies receive funding. This holds the danger of investing time and effort pursuing the merits of a select group of technologies. Other potentially better systems will be passed by -- to the detriment of all concerned. The most effective way to identify and promote innovative technologies is through the free market system. Technologies that satisfy market demands such as low cost, high speed, and minimization of liability through complete detoxification of wastes will be quickly promoted above those that do not. Presently, EPA involvement in the cleanup process tends to nullify this process.

EPA is too engrained in the technical aspects of the cleanup process in this country, so as to cloud the picture of what the true rewards are to contractors and technology vendors. The market is ill-defined and unclear due to the dominating effect of the fluctuating nature of the Superfund program. Vendors surveyed in this report, cited the Superfund cleanup process and the uncertainty of future EPA standards as obstacles of greater concern than insurance and bonding availability. If the full extent of the potential profits were clearly visible and obtainable, industry would be eager to initiate research and venture capitalists would be eager to fund research. At present, this is not so.

Despite the magnitude of the potential work offered by DOE, DOD and EPA, contractors are still unsure of the market. Vendors, surveyed, perceive these three key markets to be the most difficult to enter. Furthermore, they perceive the profit potential of DOE and DOD work to be relatively low. Contractors fear that the program is not stable enough to insure a definite future. According to a 1991 *ENR* article, "even with the potential of environmental work, many firms are taking a cautious approach to the market."[107]

When rating the criteria that make their technologies attractive to potential clients, vendors listed the applicability to certain wastes and the capability of meeting EPA standards as most important. High speed and low cost were not highly considered. In other words, vendors were more concerned with satisfying regulatory demands than market demands. Although this is, in part, due to the infancy of the market, it also underscores the dominating influence that the government has on the market and the extent of research. Unlike market-driven research, technology vendors who choose to overcome the uncertainties of research and development in pursuit

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[107]"Industry Optimistic Despite Setbacks", *ENR*, May 27, 1991, p. 35.

of remediation profits do so without a clear idea of the risks that are involved. They are dealing with a market that is regulation-driven rather than market-driven, and, has elements of risk which are based not upon the predictable demands of site owners but upon the presently unpredictable cleanup process that dominates the market.

Everett Rogers identifies five characteristics of innovation that will affect rate of entry to the market: relative advantage, compatibility, complexity, trialability, and observability. Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes. Compatibility is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential users. Complexity is the degree to which an innovation is perceived as relatively difficult to understand or use. Trialability is the degree to which an innovation may be experimented with on a limited basis. And, observability is the degree to which the results of an innovation are visible to others.[108]

Each of these aspects affecting innovation diffusion are based upon the perception of innovation by the potential user. In many ways, EPA is presently integrated with, or, has actually become the potential user, thereby influencing each of the five characteristics and, ultimately, the rate of entry of new technologies. In most cases, this influence has been a hindrance.

For example, **relative advantage,** and to a lesser extent, **complexity and trialability** are subjective determinations based on varying sets of criteria. Government is concerned with technologies that will create the least amount of public opposition, will guarantee successful remediation of the site, and will allow rapid collection of the costs from PRPs. This approach can be

[108] Everett M. Rogers, *Diffusion of Innovations*, (New York, New York, The Free Press, 1983) p.238.

summed up as extremely conservative. Site owners are concerned with the cost and pace of the cleanup, the extent of liability that the cleanup creates, and the effectiveness of the technology. Site owners would be more willing to risk trying a new technology that, for example, had only a 90% chance of complete success, if that risk was adequately offset by a potential cost savings.

As Friedman said, government's role is to define the rules of the game. However, it must not become a active player in the game. Under the present system, EPA is just that. EPA project managers have tremendous influence over picking the most effective technologies by writing the Record of Decision. If government were to leave that decision completely up to the market by allowing those who are responsible for the clean-up choose which cleanup method is best, technologies would be developed and promoted on the merits that satisfy market demands.

EPA influences the determination of **compatibility** by setting the standards to which technologies must comply. Very often these standards, as stated in the Record of Decision, are inconsistent or vaguely defined making the market, itself, uncertain. If the market is filled with a high degree of uncertainty, the innovator must cope with even greater uncertainty. The innovator must understand not only his or her own problems but also the problems of the site owners or contractors who will use the technology and the problems of the government officials who will set the cleanup policies. Both of these parties will affect the future success of the new technology. As a result, the value of compatibility cannot be easily defined, forcing potential users to choose the most conservative technology available. Today, that technology is usually incineration. Innovative technologies will be passed by.

Observability is affected by whatever method the technology vendor utilizes for marketing as well as the efforts of EPA to inform its project managers and PRPs of new technologies. EPAs efforts under the SITE Technology Transfer Program and ATTIC program have been less than successful (see Chapter 4 - EPA Programs for Enhancing Technological Development). Technology vendors must promote their technologies themselves. Most of those surveyed preferred contacting environmental consultants directly. However, direct marketing is only partially successful at improving observability due to its biased nature. Improvements in EPAs technology transfer programs would be instrumental in promoting the diffusion of innovation.

In order for the EPA to promote technological development, it need not spend more money promoting research. It must strive to withdraw its regulatory influence on the technical aspects of the cleanup process and allow market forces to drive innovation.

Government should restrict its involvement in the hazardous waste remediation market to performing those tasks that the market cannot do for itself. Namely, to enforce the initiation of site cleanups, set firm and reasonable standards to which cleanups must comply, mediate the dispute resolution process of determining who is responsible for the funding, and act as a source of unbiased information on the technical aspects of the variety of remediation technologies available.

EPA should take steps to eliminate the barriers between the technology vendor and the client and, therefore, the economic profits. It must set firm and reasonable standards to which sites must be cleaned up. Then it must streamline the remediation process to allow the responsible parties the latitude to choose whichever technology they feel will best allow them to achieve that standard. It must develop an efficient process for identifying the responsible parties. Finally, it must develop an effective technology transfer program to accelerate the spread of information about the variety of remediation technologies that are now available as well as those that will become available in the future. In essence, the answer to promoting technological development is less, not more, government intervention.

Chapter 7 - *Conclusions*

The Hazardous Waste Remediation Market

The hazardous waste remediation market is growing rapidly in this country. The market originated in 1980 with the passage of the Comprehensive Environmental Response and Liability Act (CERCLA). By 1990, the remediation portion of the $11.5 billion hazardous waste market stands at $6.5 billion. It is expected to double by 1996 and the potential for more increases exist. The EPA Superfund program still offers the most revenue potential for private industry, but the Department of Energy and, to a lesser extent, the Department of Defense are prepared to spend enormous sums of money to remediate their respective hazardous (and radioactive) waste contaminated sites. The RCRA Corrective Action, Real Estate Development Clean-up and Leaking Underground Storage Tank markets have not fully materialized in comparison to EPA, DOE. and DOD, but their profit potential is still significant. While this appears true on paper, technology vendors still do not see the potential of these markets. As the DOE and DOD remediation programs develop in the coming years, the market opportunities they offer will become evident.

Due to the slow nature of site studies and remediation plan development under the Superfund program, actual construction work is only now beginning to emerge in large amounts. Since 1982, 580 Record of Decisions (RODs) have been signed. 296 have been signed in 1988 and 1989 alone. This can be attributed to site cleanups finally emerging from the Superfund pipeline. Mandatory cleanup deadlines under SARA have also sped up the process. Therefore, the field of remediation construction services can be expected to grow into an extremely lucrative market.

Contractors in this field originated in the solid waste disposal field. Waste Management Inc.(WMI) and IT Corporation are the only two of the original field of hazardous waste contractors in 1980 who still have any significant portion of the market. Engineering consults branched into environmental work during the 1980s, capitalizing on their geotechnical and design capabilities for performing assessments and designing remediation projects.

Construction companies are now beginning to gear up to compete in this market. Since they are already prepared to provide sophisticated construction management services, many believe that they will dominate. Heads of the Sverdrup Environmental and Fluor Daniel Environmental groups concur that traditional environmental consultants and contractors are ill-prepared to compete with the project management organizations that construction companies possess. Technology vendors agreed. Among those surveyed, confidence ratings of the construction industry's ability to obtain remediation work in the future increased while the same ratings for traditional environmental firms remained constant.

Others may disagree. First, environmental contractors such as Chemical Waste Management are vertically integrated throughout the entire chain of remediation services. This allows them a tremendous source of competitive advantage. Second, the liability and financial risks in the remediation field may be considerably different than those in traditional construction fields. To minimize corporate exposure to liability, Sverdup and Fluor Daniel have separated their hazardous waste organizations from the parent group in an effort to hide behind the "corporate veil". Third, public opposition to hazardous waste work is much more volatile than opposition to traditional construction projects. Public relations surprises may stall a construction company's progress if it is ill-prepared to deal with them. Fourth, the hazardous waste field may be more restrictively regulated and litigious than traditional construction work. This may necessitate larger and different legal, government, and community relations staffs than construction companies may presently possess. Finally, the project management organization of a construction company may be too bureaucratic and carry too much overhead for hazardous waste remediation work. The management requirements for site remediation are clearly less complex than those for constructing traditional construction projects such as power plants or high rises.

There is no doubt that construction companies will alter the dynamics of the hazardous waste remediation field. They will increase the competitive nature of the market and, in the early stages, out bid the traditional environmental firms. However, established environmental firms such as OH Materials, IT Corp, and CWM are financially and organizationally committed to this field and will not be knocked out of the business as some have suggested. They will be forced to refine their organizations and develop (or obtain) project management skills that will help them to compete more successfully. Construction companies may also find that they must refine their organizations to be better suited to remediation work.

The ultimate result will be a healthy dose of competition and an overall improvement in the services being offered. The construction companies will not, however, dominate the field. They will spread the market out among more players. Consolidation among firms can also be expected. Construction firms with little technical understanding of hazardous waste remediation will either absorb or develop strategic alliances with engineering firms experienced in the market. In order to develop more competitive bids they may also try to vertically integrate or develop strategic partnering with firms in testing and analysis, well installation, technology development, treatment, transportation and disposal.

A more competitive field will have an impact on all facets of the market including remediation technology vendors. As the need for more economically competitive bids develops, the need for more economically competitive technologies should also develop. This may tend to change the dynamics of the research and development environment from one that is now in its early stages of trying to perfect the technology to one that will be focussed more on improving service, cost, and speed.

Commercialization of Innovative Remediation Technologies

Remediation technology vendors also have some interesting market challenges ahead as they attempt to develop and promote their individual technologies. Due to the inherently slow pace and high costs of present technologies, coupled with the RCRA "land-ban" and the SARA amendment's clear preference for treatment technologies over disposal practices, the need exists for quicker, less costly, and more permanent treatment technologies than presently exist

Given this, it is surprising to find that 76% of technology vendors surveyed in this report felt that they were in a niche market and only 69% felt that the market was competitive. When rating the factors that made their technology more attractive than their competitor, capability of meeting EPA standards and applicability to specific waste types were most important. Low cost was seventh on a list of eleven, high speed was ninth, and in-situ capabilities were last.

This suggests that the development of innovative hazardous waste remediation technologies is still in its early stages. Innovators are concerned primarily with developing technologies that will work on specific types of waste rather than developing a technology that will save the client money or increase marketability. Although this is, in part, due to the infancy of the market, it also underscores the extent to which regulatory forces rather than market forces dominate this market. Under to the present system, technology vendors are required to satisfy regulatory rather than PRP requirements. These two are not always the same.

The development and commercialization market that presently exists may tend to stifle innovation. Technology vendors surveyed felt that technological innovation was not the primary impediment to commercial development. Rather, the availability of financing and the financial risk were foremost on their minds. The lengthy Superfund process was listed as inflaming the problem.

Progress of EPA Programs for Enhancing Technological Development

EPA programs to promote innovation in the field were viewed with mixed feelings. Technology vendors seemed to be relatively unfamiliar with the ATTIC program, the Technology Innovation Office Hazardous Waste Market Reports and the Federal Technology Transfer Act. In fact, Region 1 EPA RPMs do not even use the ATTIC reports to any appreciable extent. They rely more heavily on SITE Demonstration program technology profiles. Vendors were not happy with the Technology Transfer Program which is intended to provide publicity for their technology.

Rather than rely on the Technology Transfer program to promote their technologies, vendors view direct bids to potential clients and providing technology information to consultants as the best way to promote their technologies.

Bioremediation was viewed as both the most overlooked technology at present and the most important technology of the future of hazardous waste remediation. However, incineration and landfilling are still viewed as the two major competing technologies for technology vendors.

In closing the loop between present EPA programs for promoting the hazardous waste remediation market for research and the realities of their success, several areas need to be addressed. First, the criteria behind which technology vendors focus the effort of their technology development represents a contradiction between the stated and actual objectives of Superfund policy. EPA needs fast, inexpensive and in-situ technologies. Bioremediation offers low-cost, in-situ, and permanent destruction of wastes but EPA is hesitant to promote it until more data is available. In-situ vitrification also offers in-situ and permanent destruction or binding of wastes. However, at this time, incineration and landfilling continue to be lucrative markets for environmental firms regardless of their contrast to good hazardous waste management sense. Fortunately, markets for these technologies can be expected to diminish in the coming decade due to increasing public opposition to their use, and regulations and permitting obstacles which are making them increasingly difficult to implement.

Second, EPA's efforts to promote research through the SITE program are only partially successful. The demonstration program, although lengthy, appears to be satisfying a need for objective qualifying of a technology's validity. However, the program dies there. The Technology Transfer program is largely unsuccessful at circulating the word about new technologies. Another program, ATTIC, also designed for technology transfer, also appears to be ineffective. Technology vendors seem unaware that it exists, and EPA project managers do not use it.

EPA must develop a better system for publicizing these technologies once they have been approved. One possible solution, rather than the myriad of programs that presently exist, is to focus on a single source of technical information that is readily available to any interested party. For example, an 800 hotline much like the RCRA/Superfund hotline that exists today would be a useful tool. The RCRA/Superfund hotline handled 89,000 calls in 1987[109]. The largest percentage of calls were from hazardous waste generators in areas where Superfund sites exist. It is used extensively by EPA and State environmental officials as well as members of the general public. A separate hotline for innovative technologies would be instrumental in providing easily accessible information to any interested parties.

Third, EPAs indemnification program does not really solve the present lack of pollution insurance to hazardous waste contractors. First, it only offers a temporary solution to Superfund cleanups and not to cleanups initiated outside the program (ie. PRPs). Second, replacement of the insurance underwriting capabilities of this country will not draw the insurance market back into the field. Insurance companies need a clear

[109] *Hazardous Materials/Water Resources Newsletter*, Sierra Club, June, 1987.

definition of the limits of liability under damage claims related to hazardous waste accidents so as to prepare appropriate actuarial data on which to base their underwriting practices. If this is done, insurance companies, followed by bonding companies can be expected to start to reenter the market. Simple replacement of the insurance market is not the answer. A prime example of the pitfalls of attempting to replace the insurance industry is the costs facing the Federal Deposit Insurance Company (FDIC) as it tries to bail out the present savings and loan crisis.

How Can EPA Promote Innovative Technological Development in the Future

In order to promote the commercialization of innovative remediation technologies in keeping with this country's long-term environmental goals , EPA need not spend more money promoting research. It must, instead, begin to withdraw itself from the technical aspects of the cleanup process and allow the free market system to identify and promote those technologies that best satisfy both EPA standards and the financial and technical needs of the hazardous waste site owner.

Available technologies are not as technically advanced or economically efficient as the market requires. Furthermore, new and innovative technologies are not entering the market as rapidly as is needed. If the present system remains unchanged, future improvements and refinements of these new systems can be expected to be equally slow. By the time these technologies reach full market maturity, industry and the taxpayer will have spent hundreds of billions of dollars cleaning sites using established methods which may not actually be the best available.

When rating the criteria that make their technologies attractive to potential clients, vendors listed the applicability to certain wastes and capability of meeting EPA standards as the most important. High speed and low cost were not highly considered. In other words, they were more concerned with satisfying regulatory demands than market demands. Although this is, in part, due to the infancy of the market, it also underscores the dominating influence that the government has on the market and the extent of research. Unlike market-driven research, technology vendors who choose to overcome the uncertainties of research and development in pursuit of remediation profits do so without a clear idea of the risks that are involved. They are dealing with a market that is regulation-driven rather than market-driven, and, thus, has elements of risk which are based not upon the predictable demands of site owners but upon the presently unpredictable cleanup process that dominates the market.

EPA is too engrained in the process of cleaning up the hazardous waste sites in this country, so as to cloud the picture of what the true rewards are to contractors and technology vendors. The market, at present, is ill-defined and un-clear because of the dominating effect of the Superfund program which is often in a state of flux. If the full extent of the potential profits were clearly visible, industry would be eager to initiate research and venture capitalists would be eager to fund research.

EPA should restrict its involvement to performing those tasks which the market cannot do for itself. Namely, to enforce the initiation of site cleanups, set firm and reasonable standards to which cleanups must comply, mediate the dispute resolution process to determine who is responsible for the costs, and act as a source of unbiased information on technical aspects of the variety of remediation technologies available.

Provided that EPA establishes the rules of the game properly, the free-market system can effectively undertake the hazardous waste site clean up process in this country and promote new and innovative technologies for its implementation. What is needed is less, not more, government intervention.

List of Interviewees

Daniel Abromovitz, Manager, Environmental Technology Program
General Electric Corp., Schenectady, New York

Frank Coffman, Vice President, Government Programs
IT Corp., Knoxville, Tennessee

Jack Curtain, President
National Association of Surety Bond Issues, Environmental Issues Committee, Cambridge, Massachusetts

David Dybdahl, MBA, ARM, CPCU
Carroon and Black Environmental Insurance Services, Madison, Wisconsin

Vincent Fitzpatrick, Program Manager
Geosafe Corp., Kirkland, Washington

Heather Ford, Vice President
SBP Technologies Inc., Hamilton, Massachusetts

David Flanagan,
Association of General Contractors, Boston, Massachusetts

David Floreen, Senior Vice President
Massachusetts Bankers Association, Boston, Massachusetts

Mark Johnson, Policy Analyst
PRC Environmental Management, Maclean, Virginia

Kim Kreighton, Environmental Engineer
U.S. EPA Risk Reduction Engineering Lab, Cincinnati, Ohio

Jeffrey Lawson, Principal
Environmental Protection Control, Grafton, Massachusetts

Ira Leighton, Chief, CT. Waste Management Branch
U.S. EPA Region 1, Boston, Massachusetts

Bill Macelroy, Insurance Underwriter
American International Group, New York, New York

Micheal C. Skriba, Technical Director
Environmental Services Business Unit
Flour Daniel, Inc., Irvine, California

Thomas Thurston, Program Manager, Hazardous Waste
Sverdrup Environmental, Boston, Mass.

Bill VerPlanck, President
Surety Association of New England, Manchester, New Hampshire

David Webster, Chief, Maine, NH, Vt Waste Regulation Section
U.S. EPA Region 1, Boston, Massachusetts

Tom Young, Assistant Bond Manager
AETNA Casualty and Surety Co., Quincy, Massachusetts

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APPENDIX 1
Survey Form

Date: April 29, 1991

To: Innovative firms in hazardous waste remediation.

From: Andy Hoffman, Candidate for MS in Civil Engineering

Enclosed with this letter is a survey which is being sent to you and over 80 other companies that perform research and development in hazardous waste remediation technologies. Your involvement in this survey is requested as part of the development of a graduate thesis at M.I.T. Your assistance is greatly appreciated and will be kept completely confidential.

The survey is divided into 2 parts. Part I covers more general information about your company and its objectives and insights. Part II is more specific to each of the technologies that your company is developing. Two copies of Part II are enclosed. Please make more copies if your company is developing more than two technologies. If you are uncomfortable answering any questions on this survey, please omit the answer and continue on.

Also included with this letter is a permission request to contact you at a later date if I have further questions. If you have no objections to a telephone interview, please complete and return the approval sheet with the survey.

You are requested to complete this survey and return it in the enclosed envelope by **May 22, 1991**. If you would like to add any of your own thoughts on the points raised, please add them on separate sheets. I would be very interested in reading them.

If you have any questions, please contact Andy Hoffman at (617) 253-3880/office or (617) 864-5019/home and answering machine. Thank you for your assistance.

An explanation of the thesis purpose and objectives follows.

Purpose

The cleanup of hazardous waste disposal sites is a growing market of enormous proportions for engineering and contracting firms in this country. The Superfund (CERCLA) program has listed 1246 sites on it's National Priority List. The Office of Technology Assessment estimates that it will cost $50 billion over the next 50 years to clean up these sites. That does not include the 26,000 sites listed on EPA's Hazardous Ranking System which the General Accounting Office estimates could grow to 368,000 sites if a more comprehensive inventory is taken. Add to that the growing list of DOE, DOD, private party cleanups (those initiated both by Superfund and state real estate development cleanup laws such as MA. 21E or N.J. ECRA), leaking underground storage tanks and RCRA Corrective Action cleanups and the numbers are overwhelming.

The historic pace and cost of cleanups under the Superfund program has been less than impressive. Individual site cleanups can take as long as 13 years and cost an average of $20 to $30 million. In it's first five years, the Superfund program completed cleanups at only 10 sites. Early cleanups relied heavily on such simple techniques as: in-place containment and cap, which leaves a ticking time-bomb on the site;and removal of wastes and contaminated soils to an off-site landfill, which only moves the contamination from one site to another. Later technologies would include incineration, which some would argue simply shifts the problem from one media to another.

The SARA (Superfund Amendments and Reauthorization Act of 1986) provision of Superfund outlined clear new objectives for the program. Among them, SARA requires that remedial actions must comply with all applicable or relevant and appropriate Federal and State requirements (ARARs), is cost effective, and utilizes permanent solutions and alternative treatment technologies to the maximum extent possible. SARA also requires a significant increase in the pace of cleanups by the Superfund program.

The most significant ARAR that impacts cleanups is the "land-ban" provision of the RCRA (Resource Conservation and Recovery Act) amendments of 1986. Under the land-ban, any hazardous waste that is to be placed in the ground must comply with specific concentration or technology standards. Therefore, any remedial action that involves the excavation, treatment and replacement of contaminated soil or groundwater must comply with the strict standards of the land-ban.

All of these regulatory requirements add up to a clear preference for new treatment technologies that are (1) cost effective, (2) utilize permanent solutions (ie. detoxification, destruction, etc.), (3) involve in-situ treatment methods rather than removal and replacement of contaminated materials and (4) are conducive to a series of treatments.

The purpose of this thesis will be to identify where these technologies will come from and what incentives or assistance the government/EPA should provide to facilitate their (1) development and (2) commercialization.

Objectives

The objectives of the thesis focus on three central questions:

1. What are the incentives and obstacles to (1) research and development and (2) commercialization of innovative hazardous waste remediation technologies today?
2. What alteration in governmental approaches to the market system would promote further development and commercialization on innovative treatment technologies?
3. What are the areas of research and development that are presently being performed by the private sector?, and
4. Is there a need for government/EPA performed or funded basic research to promote further development?

Again, thank you for your time and assistance. I look forward to receiving your response.

You may contact me again

Name of company ____

Address of company ______________________________________

____

Name of parent company ____________________________________

Name and title of respondent ________________________________

Phone Number ____

Best times to call ____

Hazardous Waste Remediation Technology Survey: Part I

Center for Construction Research and Education
Massachusetts Institute of Technology

1. When was your company formed?
   before 1970___1970-1980___1980-1985___1985-1989___after 1989___

2. How large is your company?
   Gross revenues: $0___$0-1 mill.___$1-10mill.___$10-100mill.___>$100mill.___.
   # of employees: 0-10___, 10-100___, 100-1000___, >1000___.

3. Has your company been able to obtain pollution insurance? yes___ no___not needed___
   If Yes,What are your coverage limits (per occurrence)?
   $0-1 mill.___$1-3 mill.___$3-5 mill.___$5-10 mill.___>$10 mill.___
   What are your annual insurance premiums?
   $0-100K___$100K-500K___$500K-1 mill.___$1 - 5 mill.___.
   Is the policy a claims made policy? yes___ no___.
   If No, Is your company using:
   Self-insurance___ Captive insurance co.___ Risk Retention Pool___.

4. Has your company been able to obtain bonding?
   yes___ no___ not needed___ self-bonded___.

5. What has been the source of financing for your R&D effort?
   Bank loans___Stock sales___Venture capitalists___Company equity___.

6. What has been your total R&D expenditure?
   $0-500K___$500K-1 mill.___$1-5 mill.___$5-10 mill.___$10-20 mill.___>$20 mill.___
   Over what time period?
   0-1 yrs___1-2 yrs___2-3 yrs___3-5 yrs___5-10 yrs___>10 yrs___.

7. How do you rate these as obstacles to the development and commercialization of your technology?
   (1=serious obstacle, 10=not an obstacle, 0=do not know)
   EPA SITE program approval.................. Development___Commercialization___
   EPA Superfund cleanup process............... Development___Commercialization___
   Uncertainty in EPA standards (market risks).. Development___Commercialization___
   Liability risks.................................... Development___Commercialization___
   Financial risks.................................... Development___Commercialization___
   Insurance availability............................ Development___Commercialization___
   Bonding availability............................. Development___Commercialization___
   Financing availability............................ Development___Commercialization___
   Engineering difficulties.......................... Development___Commercialization___
   Permitting.. Development___Commercialization___
   Other ____

8. How do you view the effectiveness of EPAs incentives to development & commercialization?
   (1=ineffective, 10=extremely effective, 0=do not know)

   SITE demonstration program................... Development___Commercialization___
   SITE technology transfer program............. Development___Commercialization___
   Proposed indemnification program............. Development___Commercialization___
   ATTIC program.................................. Development___Commercialization___
   Technology Innovation Office hazardous waste market reports...........................
   .... Development___Commercialization___
   Federal Technology Transfer Act.............. Development___Commercialization___

9. How do you rank the attractiveness of each of these markets for your company?
(1=unattractive, 10=extremely attractive, 0=do not know)

	Size of market	Profit potential	Ease of Entry
Federal Superfund	___	___	___
State Superfund	___	___	___
DOE	___	___	___
DOD	___	___	___
Private party clean-ups	___	___	___
Leaking underground storage tanks	___	___	___
RCRA corrective actions	___	___	___
Real estate development cleanups	___	___	___
Hazardous waste contractors	___	___	___

10. How do you rate your confidence in the various types of contractors ability to obtain and complete cleanup contracts?
(1=no confidence, 10=complete confidence, 0=do not know)

	Obtain jobs		Complete jobs	
	now	in future	now	in future
Construction Cos. (ie, Sverdrup, Bechtel, Flour Daniel, ICF Kaiser)	___	___	___	___
Environmental Contractors (ie, CWM, OH Materials, IT Corp.)	___	___	___	___
Environmental Engineers (ie, CDM, R.F. Weston, Dames & Moore)	___	___	___	___

11. How do you rate the following methods for promoting your technology?
(1=unimportant, 10=very important, 0=do not know)

Advertisements in trade journals___
Sales calls to contractors___consultants___
SITE program___
ATTIC program___
Trade shows___
Direct contract bids to clients (ie PRP)___
Send info. directly to EPA RPMs___

12. What do you see as the three most important technologies for the future of hazardous waste remediation?
1.___________________ 2.___________________ 3. ___________________

13. What three technologies do you see as being overlooked as potential sources of future remediation technologies?
1.___________________ 2.___________________ 3. ___________________

14. Would you be opposed to seeing EPA fund research in hazardous waste remediation technologies? yes___ no___

15. How many technologies is your company developing at this time?
1___,2___,3___,4___,5___,6___,7___,8___,9___,10___,>10___.

16. How many technologies has your company developed successfully in the past?
0___,1___,2___,3___,4___,5___,6___,7___,8___,9___,10___,>10___.

17. How many technologies has your company been unsuccessful with in the past?
0___,1___,2___,3___,4___,5___,6___,7___,8___,9___,10___,>10___.

Part II

For each of the technologies your company is developing, answer the following questions

18. What is the name of the technology? ____________________

19. To what waste(s) type is the technology applicable? ____________________
____

20. What is the expected size of the market for the technology?
$0-1 mill.___$1-10 mill.___$10-100 mill.___$100-1000 mill.___>$1 bill.___

21. Does this technology have applications in other markets? If so, what market?
____

22. How much money has your company invested on R&D developing this product/process?
$0-500K___$500K-1 mill.___$1-3 mill.___$3-5 mill.___>$5 mill.___

23. How much money has been invested in the SITE program by your company?
$0-100K___$100-250K___$250-500K___$500K-1 mill.___>$1 mill.___

24. How much money has been invested in the SITE program by EPA?
Demonstration program:
$0-100K___$100-250K___$250-500K___$500K-1 mill.___>$1 mill.___
Emerging technology program:
$0-50K___$50-100K___$100-150K___>$150K___

25. How much time has been invested on R&D developing this product/process?
0-6 mos___6 mos-1 yr___1-2 yrs___2-3 yrs___3-5 yrs___>5 yrs___

26. How much of this time has been invested in the SITE program?
0-6 mos___6 mos-1 yr___1-1.5 yrs___1.5-2 yrs___2-4 yrs____>4 yrs___

27.What were/are your expected costs for the SITE program?
$0-100K___$100-250K___$250-500K___$500K-1 mill.___>$1 mill.___

28. What was/is your expected time investment for the SITE program?
0-6 mos___6 mos-1 yr___1-2 yrs___2-3 yrs___3-5 yrs___>5 yrs___

29. At what stage is your technology in the SITE program?
Emerging Technologies program___Demonstration program___
Technology Transfer program___Complete___

30. Is this technology being developed for use on your company's or your parent company's own superfund site? yes ___, no ___.

31. Does your company intend to contract out the services of this new technology?
yes___ no___.

32. Does your company intend to patent this technology? yes ___, no ___.

33. Does your company intend to licence this technology to other contractors?
yes___no___

34. In what regions do you plan to market your technology?
US: SE___NE___SW___NW___Central___,Canada___,Europe___,Pacific Rim___.

35. What levels of research did your company perform in-house? If it was not performed in-house, where was it performed and by-whom? Did you buy (B) or licence (L) the rights?

	In-house (check item)	Not In-house, By whom.	Acquired rights? (B or L)
Product/process definition	_____	_____________	______
Basic scientific research	_____	_____________	______
Market evaluation	_____	_____________	______
Product/process design	_____	_____________	______
Product/process engineering	_____	_____________	______
Product/process development	_____	_____________	______
Field testing & implementation	_____	_____________	______
Commercial application	_____	_____________	______

36. How do you rank the factors that will make your technology more attractive to potential clients than other technologies?
(1=not important, 10=very important, 0=do not know)

Applicability to specific waste type(s)___
Capability of meeting EPA standards___
Capability of exceeding EPA standards___
In-situ capabilities___
Low potential for public opposition___
Established track record___
Low cost___
High speed___
Certainty of results___
Permanent detoxification of waste___
Beneficial reuse of waste or other by-product___
Return of site to commercial usefulness___

37. Do you see your company as a niche market player? yes___no___

38. What technologies do you consider to be the major competitors to your technology?
1st____________________ 2nd___________________ 3rd ____________________

39. What companies do you consider to be the major competitors to your company?
1st____________________ 2nd___________________ 3rd ____________________

40. Do you consider the market for your technology to be highly competitive? yes___no___

41. Please rate the following factors as to their effect on the competitiveness of your market.
(1=no effect, 10=strong effect, 0=do not know)

Power of suppliers of materials/labor to affect the costs or feasibility of your technology___
Power of buyers to bargain down your price or choose an alternative technology___
Threat of entry of new technologies___
Availability of substitutes to your technology___
Industry rivalry for market share___

APPENDIX 2
Survey Results

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Co. Formed																						
<1970	4				1										1				1	1		
1970-1980	6						1	1		1			1				1				1	
1980-1985	4					1					1			1		1						
1985-1989	6	1	1	1					1									1				1
>1989	0																					
2. Co. Size																						
$0	2					1												1				
$0-1 mil.	5	1		1			1	1				1										
$1-10 mil.	5		1						1		1			1		1						
$10-100 mil.	5									1			1						1	1		1
>$100 mil.	4				1										1		1				1	
employees:																						
0-10	4	1				1		1				1										
10-100	2						1							1								
100-1000	5		1								1		1						1	1		
>1000	4				1										1		1				1	
3. Insurance																						
yes	7			1			1			1			1				1				1	1
no	1	1																				
not needed	12		1		1	1		1	1		1	1		1		1		1	1	1		
limits:																						
$0-1 mil.	2		1				1															
$1-3 mil.	1																1					
$3-5 mil.	2									1												1
$5-10 mil.	0																					
>$10 mil.	1																				1	

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
premiums:																						
$0-100K	1						1															
$100-500K	3		1														1					1
$500K-1 mil.	1									1												
$1-5 mil.	1																				1	
claims made?																						
yes	3		1							1							1					
no	1																				1	
Self-insured?	2							1													1	
Captive-ins?	1																				1	
Risk Retention	1																				1	
Indemnification	1		1																			
4. Bonding																						
yes	5		1	1						1							1					1
no	1	1																				
not needed	12				1	1	1	1	1		1	1		1		1		1	1	1		
self-bonded	1																				1	
5. Financing																						
Bank Loans	3									1				1				1				
Stock Sales	2									1				1								
Venture Cap.	1											1										
Company Equ.	12	1	1			1	1	1		1			1		1			1		1	1	1
Bank Guaranty	1			1																		
Research Grants	5							1	1		1			1					1			
Working Capital	1																1					

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
6. R&D Exp.																*	*					
$0-500K	4		1			1	1															1
$500K-1mil.	1	1																				
$1-5 mil.	7							1		1		1	1		1			1		1		
$5-10 mil.	0																					
$10-20 mil.	3			1							1			1								
>$20 mil.	3				1														1		1	
time:																						
0-1 yrs	0																					
1-2 yrs.	1						1															
2-3 yrs.	4	1				1			1			1										
3-5 yrs.	5		1					1		1	1							1				
5-10 yrs.	4			1									1	1							1	
>10 yrs.	2				1														1			
7. Dev. Obst.																						
SITE Program	150	1	10	8	10	7	10	10	10	8	7		10		10	10	5	10		9	5	10
Superfund pro	65	1	8	9	1	7	10		3	3	2		3			10				4	4	
EPA Standards	95	1	8	7.5	10	3	10		1	8	1		8	10	5	10	3	1		5	2	1
Liab. Risk	120	9	10	3.5		10	10	10	5	5	5		10	10	10		3	1		9	9	
Fin. Risk	76	1	3	4.5		4	10	10	1	4	5		5	10	10		1	1		3	2	1
Ins. Avail.	99	3	9	5		3	10			10	5		10	10	10		3	1		10	10	
Bond. Avail.	94		10	7		1	10			10			10	10	10		5	1		10	10	
Financ. Avail.	88	1	2	4		1	10	10	5	7	2		7	5	10		5	1		8	10	
Eng. Diff.	123	9	8	6	10	7	1	10	5	10	4		10	9	8		3	10		3	8	2
Permitting	100		8	8	10	2	10	5	3	10	6		10	8	7	5	3			2	2	1
atent Infringement	5		5																			

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Comm. Obst.																						
SITE Program	79	1	9		10	5	1		8	5	3		5			10	5			9	8	
Superfund pro	33	1	5		1	2			3	3	2		2			10				2	2	
EPA Standards	70	1	8		10	1			1	8	1		5	4	8	10	3	1		5	3	1
Liab. Risk	62	5	7			2	1	1	5	5	3		6	3	3		3	1		9	8	
Fin. Risk	41	1	2			3	1	1	1	2	5		5	8	5		1	1		2	2	1
Ins. Avail.	67	3	8			3				10	5		8	7			3	1		9	10	
Bond. Avail.	65	1	8			2				10			8	10			5	1		10	10	
Financ. Avail.	49	1	1			1	1	1	5	5	1		7	5			5	1		5	10	
Eng. Diff.	118	9	5		10	4	10	10	5	10	7		8	10	5		3	10		3	7	2
Permitting	51		8		10	2				7	3		1	5	2	5	3			1	3	1
atent Infringement	3		3																			
8. EPA Dev.																						
Demonstration	101	3	1		10	10	10	10	8	5	3			4	10	1	3	10		3	2	8
Tech Transfer	58	3	1		10	10			8	4	2			4		1	3			4	3	5
Indem	22					8				8	4										2	
ATTIC	23				10	5															3	5
Haz Waste Rep.	19	2				5											3				4	5
Tech Tran Act	24					7					4					1	3				9	
EPA Comm.																						
Demonstration	79	1	2		10	10	10			3	2	8	5	1	7	1	5			3	3	8
Tech Transfer	52	1	1		10	8	1			2	2	2	5	1		1	5			5	3	5
Indem	33					8	10			8	6										1	
ATTIC	29				10		10					1									3	5
Haz Waste Rep.	36	2				8	10					1	3				3				4	5
Tech Tran Act	33					10					6	8				1	3				5	

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
9. Market Att.																						
Size																						
Fed Superfund	168	5	9	9.5	10	10	10	10	1	10	9	10	10	7	8	10	6	10		6	7	10
State Superfund	95	2	4	8.5	10	7	1			5		10	5	7	10		7			5	6	7
DOE	121	8	5	10	1	1	10		1	8	9	10		10		6	6	10		9	8	9
DOD	124	8	8	10	1	8	10		1	8	8	10		10			6	10		10	7	9
Private Party	136	8	9	8.5		8	10	10	1	10	5	10	10	8	10		9			1	9	9
LUST	93		5			1	10	10		8	7	6	3	10		10	9	1		1	5	7
RCRA	127	8	6	8		7		10	1	10	3	10	8	8		10	8	10		5	7	8
Real Estate	64	1	3			1	1	10		8	7	8					5	10		1	3	6
Contractors	131	5	1	9	10	10	10	10		6	3		5	5	8	10	4	10		10	8	7
Profit																						
Fed Superfund	127	10	10	8	10	7		10		5	2	6	10		8	10	5	10		6	5	5
State Superfund	71	5	5	8	10	1				5		5	5		8		6			6	5	2
DOE	74	10	3	8	1	1	10			5	1	5		7			3	10		6	4	
DOD	71	10	4	8	1	5				5	3	5		7			3	10		6	4	
Private Party	108	5	7	8		6	10	5		6	5	8	7	7	10		8				8	8
LUST	61		3			1		5		4	6	8		10		10	7	1			2	4
RCRA	90	5	7	8		1				6	1	8	7	5		10	6	10			8	8
Real Estate	77	3	9			1	1	10		5	7	8		5			5	10			8	5
Contractors	111	3	5	8	10	10	10			5	5		5	5	7	10	4	10		6	8	
Ease of Entry																						
Fed Superfund	59	1	3	5	1	6				10	3	5	1		2	1	4			4	8	5
State Superfund	54	1	2	6	1	6				5		5	1		2	1	7			4	8	5
DOE	45	2	1	7	1	1				5	2	5		7		1	2			6	5	
DOD	49	2	2	6	1	1				5	3	5		7		1	2			6	8	
Private Party	72	2	7	6		6				3	5	7	3	5	5	1	8			1	8	5
LUST	56		9			1				6	4	7				1	8	1		1	8	10
RCRA	62	2	7	6		2				3	6	7	5			1	5			2	8	8
Real Estate	47	2	6			2				4	4	7				1	7			1	8	5
Contractors	64	5	6	5	1	10				3	3		3	5	7	1	6			6	3	

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
10. Confidence																						
Obtain Now																						
Const. Cos.	115	10	4	9	10	6	10	10		6	4	6	10	5		1	7			6	5	6
Env. Conts.	143	10	7	9	10	10	10	10	5	7	7	6	10	6		6	8			5	9	8
Env. Eng.	130	10	3	9	10	7	10	10	2	3	8	10	10	6		6	8			4	8	6
Obtain Future																						
Const. Cos.	120	10	7	9	10	6	10	10		7	3	6	10	5			8			8	7	4
Env. Conts.	129	10	7	8	10	10		10	5	8	8	6	10	6			8			6	9	8
Env. Eng.	125	10	4	8	10	10	10	10	2	4	6	10	10	6			8			4	8	5
Complete Now																						
Const. Cos.	106	10	2	10		4	10	5		4	7	9	10	4		1	9			5	9	7
Env. Conts.	114	10	2	9	10	3		5	5	5	4	10	10	5		6	6			7	9	8
Env. Eng.	95	10	1	9	1	7		2	2	3	5	10	10	5		6	7			3	9	5
Complete Future																						
Const. Cos.	108	10	5	10		5	10	5		4	8	9	7	4			9			6	9	7
Env. Conts.	115	10	5	10	10	8		5	5	5	5	10	7	5			6			8	9	7
Env. Eng.	90	10	3	10	1	8		2	2	3	5	10	7	5			7			3	9	5
11. Promotion																						
Trade Journals	69	8	1		1	2	1		5	8	2	5	1	8	2	10	3			4	6	2
Contractor Calls	79	8	2	8	1	4	10		6	2	2	10	8	3		3	2			8	2	
Consultant Calls	90	8	9	8	1	10	10			8	3	10	8	1		3	2			4	2	3
SITE	133	10	3	8	10	10	10	10	6	2	4	5	6	5	10	8	4	10		6	3	3
ATTIC	28				10	7						5					4				2	
Trade Shows	85	8	6	8	10	8	1		3	4	3	3	6			5	4			8	3	5
Contract bids	140	3	10			10	10	10	3	5	6	10	8	10	3	6	8	10	10	2	8	8
Info to EPA	72	1	1	8	1	6		5	5	1	5	10				6	4	10		2	3	4
PR	8			8																		

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
12. Important Tec																						
Bioremediation	10	1			1	1	1			1		1	1				1			1		1
Solid/Stab.	8	1	1	1	1					1		1	1								1	
Vitrification	2	1		1																		
Vacuum Extraction	2		1																		1	
Incineration	7		1	1			1					1		1						1		1
Soil Washing	3				1			1	1													
UV Oxidation	2						1							1								
Secure Landfill	1							1														
Solvent Extraction	2							1					1									
Low Temp Thermal	1																				1	
Bio Polymer Drains	1									1												
13. Overlooked																						
Bioremediation	2	1															1					
Proper Combinations	2		1									1										
In-Situ Metal Fix.	1		1																			
Electro Mag. Rad.	1						1															
Genetic Engineering	2						1					1										
In Situ Soil Washing	1											1										
Toxicity Removal	1											1										
Large Scale Fixation	1											1										
Solar	1												1									
Vitrification	3												1								1	1
Membranes	1													1								
Landfilling	1																					1
Solid/Stab.	2																				1	1
14. EPA Fund Res																						
yes	2		1																	1		
no	18	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
15. # Pres. dev																						
1	5			1		1							1		1							1
2	5	1					1							1		1				1		
3	4				1			1	1	1												
4	0																					
5	3		1								1	1										
6	0																					
7	0																					
8	0																					
9	0																					
10	0																					
>10	2																1				1	
16. # Past succ.																						
0	6					1	1	1				1			1	1						
1	7			1	1				1				1	1						1		1
2	3	1	1								1											
3	1																				1	
4	0																					
5	1									1												
6	0																					
7	0																					
8	0																					
9	0																					
10	0																					
>10	1																1					

	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
17. # Past Unsu																						
0	16	1	1	1	1		1	1	1	1		1	1	1	1	1	1			1		1
1	1					1																
2	0																					
3	0																					
4	0																					
5	1										1											
6	0																					
7	0																					
8	0																					
9	0																					
10	0																					
>10	1																				1	
	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14
19. Technology																						
Bio Remediation	3			1														1				
Solid/Stab	3				1														1			
Vacuum Extraction	1					1																
Spray Aeration	1						1															
Vitrification	2							1														1
Micro Filtration	1								1													
Electro Coagulation	1									1												
Photochemical Oxidation	1										1											
Incineration	1											1										
Soil Washing	1												1									
Water Purification	1													1								
Plasma Centrifigal Furnace	1																					
Soil Mixing	1															1						
Low Temp Thermal	1																					
20. Market Size																						
$0-1 mill.	1								1													
$1-10 mill.	0																					
$10-100 mill.	5									1		1				1						1
$100-1000 mill.	11				1		1	1			1				1			1		1		
>$1 bill.	9			1		1							1	1			1				1	
21. Other Market																						
yes	19				1		1	1		1	1	1	1	1	1	1		1		1	1	
no	4			1		1			1													
22. Cost of R&D																						
$0-500K	9					1	1		1	1		1			1		1					1
$500K-1 mill.	6			1	1						1		1	1								
$1-3 mill.	4															1					1	
$3-5 mill.	5																	1	1	1		
>$5 mill.	2							1														

15A	15B	17	18	19	20A	20B	21
							1
					1		
				1			
						1	
			1				
		1		1	1	1	
1	1						1
		1	1	1	1	1	1
	1						
	1						
1							
		1			1		
			1	1			
						1	

	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14
23. Cost of SITE																						
$0-100K	17			1	1		1		1	1		1		1	1		1		1	1	1	
$100-250K	6										1		1			1						1
$250K-500K	1					1																
$500K-1 mill.	0																					
>1 mill.	2																	1				
24. EPA SITE Cost																						
Demonstration																						
$0-100K	10			1	1		1			1	1	1									1	
$100-250K	3															1	1					1
$250K-500K	3												1		1							
$500K-1 mill.	2																	1				
>1 mill.	2					1			1													
Emerging Technology																						
$0-50K	9			1	1		1					1		1							1	
$50-100K	0																					
$100-150K	5									1			1				1			1		1
>$150K	3										1				1							
25. R&D Time																						
0-6 mos	0																					
6 mos-1 yr	2													1		1						
1-2 yrs	5									1		1			1							1
2-3 yrs	5			1	1		1											1				
3-5 yrs	7					1							1				1				1	
>5 yrs	7							1	1		1								1	1		

15A	15B	17	18	19	20A	20B	21
1	1				1	1	1
		1	1				
				1			
	1	1			1		
1							
				1			
	1				1	1	
			1				
	1						
		1					
1				1		1	
			1		1		

	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14
26. SITE Time																						
0-6 mos	7						1					1									1	1
6 mos-1 yr	5												1	1				1	1			
1-1.5 yr	4			1						1						1				1		
1.5-2 yr	5				1						1				1		1					
2-4 yr	5					1		1	1													
>4 yr	0																					
27. Expected SITE Cost																						
$0-100K	10					1	1		1			1		1		1			1	1	1	
$100K-250K	2														1							
$250K-500K	8			1	1					1	1		1									1
$500K-1 mill.	2																1					
>$1 mill.	2																	1				
28. Expected SITE Time																						
0-6 mos	4						1												1		1	
6 mos-1 yr	2					1										1						
1-2 yrs	8			1	1				1	1								1		1		1
2-3 yrs	6										1	1					1					
3-5 yrs	4							1					1	1								
>5 yrs	0																					
29. SITE Stage																						
Emerging Technology	12			1	1					1	1		1	1	1					1		1
Demonstration	6							1	1								1	1				
Technology Transfer	0																					
Complete	4					1										1			1			
Not Applicable	3						1														1	
30. For Cos Own Sites																						
yes	1								1													
no	25			1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1

15A	15B	17	18	19	20A	20B	21
	1	1			1		
			1				
1							
				1		1	
	1						
						1	
1			1				
		1					
				1			
	1						
		1					
1			1	1			
						1	
1		1	1				
				1		1	
							1
	1						
1	1	1	1	1		1	1

	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14
31. Contract Out Service																						
yes	21			1	1	1	1	1		1	1	1	1	1	1	1	1	1	1			
no	5								1											1	1	1
32. Will Obtain Patent																						
yes	17									1	1	1	1	1	1		1		1	1	1	1
no	7			1	1		1		1							1		1				
patented	2					1		1														
33. Will Licence Out																						
yes	16					1	1			1			1	1	1		1		1	1	1	1
no	11			1	1			1	1		1	1				1		1				
34. Market Regions																						
SE US	23			1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	
NE US	24			1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	
SW US	23			1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	
NW US	23			1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	
Central US	24			1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
Canada	20			1	1	1		1	1		1	1	1	1		1		1	1	1	1	
Europe	18			1	1	1		1			1	1	1	1				1	1	1	1	
Pacific Rim	13			1	1	1	1	1					1	1				1			1	
EEC	1							1														
35. In House R&D																						
Product definition	23			1	1	1	0		1	0	1	1	1	1	1	1		1	1	1	1	1
Basic Scientific Research	20			1	1	1	0		1	1	1	1	1	1	0	0		1	0	1	1	0
Market Evaluation	24			1	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	1
Product Design	23			1	1	1	1		1	1	1	1	1	1	1	1		0	1	1	1	1
Product Engineering	22			1	1	1	1		1	0	1	1	1	1	1	1		1	1	1	1	1
Product Development	24			1	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1	1
Field Testing	19			1	1	1	1		1	1	0	0	1	1	0	1		1	1	1	1	0
Commercial Application	15			1	1	1	1		1	1	0	0	1	1	0	0		1	1	1	1	0

15A	15B	17	18	19	20A	20B	21
1	1	1	1			1	1
				1			
1	1	1		1		1	1
			1				
1	1	1	1	1			
					1	1	1
1	1	1		1		1	1
1	1	1	1	1		1	1
1	1	1		1		1	1
1	1	1		1		1	1
1	1	1		1		1	1
1	1	1		1		1	1
1	1	1	1	1		1	
1		1		1		1	
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	0	1	1	1	1
1	1	1	0	1	1	1	1
1	1	1	0	1		1	1
1	1	1	0	1	1	1	1
1	1	1	0		1	1	1
0	0	0	0		1	1	1

	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14
36. Unique Tech Aspects																						
Waste Applicability	192	8.73	10.00	10	10	10	10	10	10	1	10	10			5			10	10	8	7	10
Meets EPA Standards	230	9.58	10.00	10	10	8	10	10	10	10	10	10	10	10	10			10	10	10	8	10
Exceeds EPA Standards	195	8.48	10.00	8	10	2	2		10	10	10	10	10	10	10			10	7	10	8	10
In-Situ	128	6.10	8.00	10	10	8	1	10	1	8	1	1	10	10	6			10		10	10	
Low Public Opposition	161	7.32	9.00	8	10	9	2	9	1	1	10	1	10	10	6			9		8	10	9
Established Track Record	137	6.23	7.50	2	10	9	9	1	10	1	10	10	5	5	10			8	10	2	1	4
Low Cost	173	7.86	9.00	7	5	9	10	7	10	10	10	10	10	10	6				8	5	5	3
High Speed	103	6.44	6.00	5	10	3	2	6		5			10	10	6				8			3
Certainty of Results	192	8.73	10.00	10	10	3	8	10	10	10	10		10	10	10				8	5	5	9
Permanent Detoxification	208	8.67	10.00	10	10	8	9	10	10	6	10	10	10	10	8			10	8	1	1	10
Beneficial Reuse	149	6.77	7.50	10	5	1	8		1	10		1	5	5	6			1	8	10	10	10
Return of Site to Usefulness	161	8.05	10.00	10	10	9	2	10	1	10	10	1	10	10	8			10	8			
37. Co. In Niche Market																						
yes	19			1	1	1	1			1	1	1			1	1			1	1	1	1
no	6							1	1				1	1								

15A	15B	17	18	19	20A	20B	21
10	10	10	8	10		8	5
10	10	10	8	8		10	8
10	10	10	6	4		10	8
10		1	1	1		1	8
10	10		5	10		7	6
		10	3	2		8	7
10	10		10	1		9	8
	10		10	2		5	8
10	10	10	8	8		10	8
10	10	10	8	10		10	9
10	10	10	6	5		10	7
10		10	10	5		10	7
1	1	1	1	1			1
					1	1	

	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14
38. Tech. Competitors																						
Incineration	11			1	1			1				1							1	1		1
Land Farming	1			1																		
Stab/Solid	2				1			1														
Soil Venting	1					1																
Excavation	1					1																
BioRemediation	4					1																
Packed Towers	1						1															
Vitrification	3							1														1
Chemical Addition	1									1												
UV Oxidation	1										1											
Carbon Adsorption	3										1									1	1	
Landfilling	5												1	1					1			
Ion Exchange	1													1								
Extraction	1																		1			
Soil Washing	2																					
39. Co. Competitors																						
Geo-Con	1				1																	
EM Seiko	1				1																	
Midwest Water Resources	1					1																
Dames & Mooore	1					1																
Groundwater Tech	2					1	1															
IT Corp.	2						1															
Ultrox	1										1											
Calgon	1										1											
Chemical Waste Management	2											1										
Westinghouse	1																					
40. Is Market Competitive																						
yes	16					1	1	1	1	1		1				1			1	1	1	
no	7			1	1						1		1	1								1

15A	15B	17	18	19	20A	20B	21
				1	1	1	1
			1		1	1	
					1		
			1		1		
					1	1	
							1
							1
				1			
1	1		1	1		1	1
		1					

	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14
41. Competitive Factors																						
Supplier Power	89	3.87	3.00	10	1	8	3	2	1	5	10	1			4	5			10	1	4	3
Buyer Power	122	5.30	7.00	7	5	7	9	3	1	1	1	10			8	5			10	8	7	7
Threat of Entry	120	6.00	7.00	10	10	2	2	3	10	5					8	5			6	8	7	1
Substitutes	123	5.35	5.00	5	5	7	10	1	10	5		10	1	1	8	5			8	4	6	1
Industry Rivalry	137	5.96	7.00	5	10	8	1	3	10	7	10	10			3	5			8	1	2	7
	Total	Average	Mean	1A	1B	2A	2B	3	4	5	6A	6B	7A	7B	8	9	10	11	12	13A	13B	14

15A	15B	17	18	19	20A	20B	21
1	1	1	2	4	3	3	6
1	1	1	2	10	8	3	7
8	8		4	2	7	7	7
4	3		2	8	8	4	7
4	6	1	8	8	8	5	7
15A	15B	17	18	19	20A	20B	21