INTERSTATE TECHNOLOGY & REGULATORY COUNCIL

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INTERSTATE TECHNOLOGY & REGULATORY COUNCIL

GENERAL PROTOCOL

FOR

DEMONSTRATION

OF

IN SITU BIOREMEDIATION TECHNOLOGIES

previously released as

Protocol Binder and Resource Document
of ITRC's
In Situ Bioremediation
Technology Specific Task Group

- Revised FINAL -

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Prepared by
The Interstate Technology and Regulatory Cooperation Work Group
InSitu Bioremediation Work Team

ABOUT ITRC

Established in 1995, the Interstate Technology & Regulatory Council (ITRC) is a state-led, national coalition of personnel from the environmental regulatory agencies of some 40 states and the District of Columbia; three federal agencies; tribes; and public and industry stakeholders. The organization is devoted to reducing barriers to, and speeding interstate deployment of, better, more cost-effective, innovative environmental techniques. ITRC operates as a committee of the Environmental Research Institute of the States (ERIS), a Section 501(c)(3) public charity that supports the Environmental Council of the States (ECOS) through its educational and research activities aimed at improving the environment in the United States and providing a forum for state environmental policy makers. More information about ITRC and its available products and services can be found on the Internet at **www.itrcweb.org.**

DISCLAIMER

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EXECUTIVE SUMMARY

In situ technologies rely on the capabilities of indigenous or introduced microorganisms to degrade, destroy or otherwise alter objectionable chemicals in soils or ground water. These technologies can be applied to soils or deep sediments and in arid or wet regions. *In situ* bioremediation is a class of technologies as variable as the subsurface itself. The In Situ Bioremediation Technology Specific Task Group (ISB Group), a subgroup of the ITRC, recognized that given appropriate conditions, *in situ* technologies can remediate contaminants more cost effectively than conventional technologies.
The ISB Group developed a General Protocol and Outline for the general class of *in situ* bioremediation technologies plus conducted detailed literature reviews of technology-specific protocols for "Natural Attenuation" and "Bioventing" of petroleum hydrocarbons. These protocols have been developed by Federal agencies, contractors and industry. The use of this document is intended to offer the proponent of the demonstration multi-state and tribal (regulatory) acceptance of the data generated during the demonstration project. It also offers an early opportunity for tribal and stakeholders to understand the intent of the demonstration and discuss their concerns and sensitivities with the proponent before the demonstration is in its final design.

The ISB Group knows, through experience, that acceptance of a technology by multiple states and state agencies, tribes (as regulators or stakeholders), and local communities requires an organized collective process. In the "General Protocol" the ISB Group defined categories of responsibilities for participants in a multi-state demonstration. These participants might include the state or tribal regulatory agency hosting the demonstration, other states interested in the technology, the proponent, other tribal governments and stakeholders. Each have identified responsibilities during three phases of the technology demonstration process. Phase One identifies the specific parties by name, Phase Two designs the demonstration and Phase Three implements the demonstration and reports the results. These responsibilities are clearly defined in Table 1 of the General Protocol.

The "General Outline" to the General Protocol contains the essential elements of an *in situ* bioremediation (ISB) demonstration. It provides guidance to the proponent during the development of the initial demonstration proposal. While following this guidance, the proponent of the demonstration project should include enough detail that the states or tribal regulatory agency (host and participating) can identify; the applicable regulatory requirements for the project, the innovative nature of the project, and the advantage this project might have over other conventional technologies. It should also contain enough information so that stakeholders, tribal governments and states can identify any sensitivities they may have with this technology.

The ISB Group is comprised of representatives from 15 states, the Federal government, industry, and representatives from an environmental and other non-profit groups. Members of the larger ITRC working group, which include community and tribal representatives, offered comments and guidance throughout the development of the General Protocol. Thus, the "Protocol Binder and Resource Document" reflects the input of many sectors of our society interested in site cleanup.

Through its collective experience, and depth of representation, the ISB Group found several issues pertinent to *in situ* bioremediation. These issues, as summarized by the ISB Group, are as follows.

- ♦ Cleanup levels, and the approaches used by various jurisdictions to derive those numerical criteria, vary among state and federal agencies. Although a single set of concentration based cleanup levels cannot be developed to apply to all jurisdictions, it is recommended that a work group be established to formulate policy recommendations for changes that encourage consistency in approach, if not numerical criteria.

- ♦ Factors beyond the jurisdiction of the state regulatory agencies often dictate the type of remedial technology that is deployed. These factors include addressing the concerns of participants in real estate transactions and the financial institutions lending on such transactions and the public's opposition and fear of a technology. These pressures often discourage the deployment of cost-effective techniques and technologies, particularly natural attenuation and bioventing, and thus reduce the potential market for affordable remedial measures. The governors need to consider means of addressing the concerns of these non-regulatory entities in order to broaden market acceptance of many affordable remedial options, as well as encourage the free market to continue to develop remediation techniques and technologies.

- ♦ Natural attenuation for petroleum hydrocarbons, particularly benzene, toluene, ethyl benzene and xylene, is well demonstrated as a remedial option for groundwater. Governors should require that for all sites where remediation is deemed necessary, particularly fuel tank sites, the appropriate agencies should evaluate natural attenuation as a remedy, referencing their agencies to consider the ITRC work-product concerning this topic and the various technical guidance documents and references now available in the literature.

- ♦ Bioventing is a cost-effective *in situ* technology which reduces petroleum hydrocarbon contamination by accelerating natural biological conversion processes. Where remediation of soils is deemed necessary, particularly for leaking underground fuel sites overseen by state agencies, the use of bioventing should be encouraged as a remedial measure.

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GENERAL PROTOCOL FOR DEMONSTRATION OF IN SITU BIOREMEDIATION TECHNOLOGIES

1.0 INTRODUCTION

In February of 1995 the Interstate Technology and Regulatory Cooperation (ITRC) Work Group chose to focus on *in situ* bioremediation (ISB) technologies. The purpose was to review the existing use of ISB technologies, identify barriers to their effective use and recommend actions which, if implemented, will promote multi-state acceptance[1] of data obtained during the demonstration[2]. By promoting state agency, federal agency, industry, user, tribal and stakeholder cooperation, the ISB group set out to develop products, processes and recommendations which would accelerate the safe and effective development and deployment of site cleanup technologies using ISB techniques which are as good or better and cost less than conventional technologies.

2.0 GENERAL PROTOCOL

2.1 Notes to the Reader

The discovery, characterization and remediation of contaminated sites have historically created explosive growth and development of remediation programs in government and industry. As an increasing share of the total expenditure in this field shifts from discovery and characterization to remediation attention has focused on documenting the cost and performance of conventional site cleanup technologies. This activity has demonstrated a broadly recognized need for innovation in the environmental technology field from state and federal government, technology users, technology vendors, tribal government and the public. The collective desire is, through innovation, to develop and demonstrate new environmental technologies that perform as well or better and cost less.

This document was developed by members of the Interstate Technology and Regulatory Cooperation (ITRC) Work Group. The membership of the workgroup includes:

- Representatives of state and Federal environmental regulatory agencies
- Representatives of Federal agencies
- Public Representative
- Tribal Representatives

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[1]Acceptance for this application is defined as "States will accept the results of the demonstration as if they had overseen the demonstration themselves".

[2]In the context of this document, the term "demonstration" refers to field scale deployment of an *in situ* bioremediation technique or technology to show (demonstrate and validate) the performance of that technique or technology. Full-scale application of *in situ* technique or technology may in fact be used to measure, record and document performance. The central element of a demonstration is the determination of performance.

- Members of Industry

The ITRC believes that the field of *in situ* bioremediation has the potential of providing cost-effective cleanups for a variety of waste sites. Therefore, for this and other reasons, *in situ* bioremediation was deemed of high interest to members of the ITRC.

This ITRC product facilitates the demonstration of *in situ* bioremediation (ISB) technologies through cooperative mechanisms among participating states and stakeholders. It captures not only the technical elements of ISB but also the general thinking and experience of members of many state regulatory agencies. As the format and approach of this document are somewhat unique and different from other publications found in the field of site remediation.

ISB technologies have long been recognized to offer efficient, cost effective remedial alternatives. A vast amount of research is being sponsored and conducted in this area by universities, research institutes and private industry. Advances in this field have been observed even during the compilation of this document. While the ITRC fully expects changes to result from new technology and new science, we offer this protocol as a framework which can accept new technologies for demonstration.

ISB offers a number of challenges not apparent in other conventional cleanup technologies. Because the active process relies on microorganisms and the natural properties of the subsurface, longer times are often required to observe measurable changes when compared with technologies which employ physical/chemical/thermal processes. The challenges of obtaining meaningful process and performance data are compounded by obtaining representative samples from a heterogeneous system. Lastly, because these technologies are not contained in the formal sense, the flow of mass and energy through the system is far more complicated than with a contained system such as an above ground system. The group recognizes these issues will be apparent in virtually every ISB technique or technology. Therefore we hope the reader will view these issues as challenges for the future rather than obstacles from the past.

As a reader of this document, bear in mind the challenges and opportunities in this field. This is not a prescriptive document, but rather a descriptive process which will accommodate site specific and community specific considerations in the demonstration and use of ISB. This binder also carries with it technology specific position papers supporting the appropriate consideration of intrinsic bioremediation and bioventing. These position papers also contain references to other documents which characterize the performance of these techniques. We encourage readers to make this material available to their colleagues as a resource document.

2.2 Purpose and Scope of this Document

The purpose of the General Protocol is to provide guiding principles and a standard approach for conducting safe and appropriate demonstrations of *in situ* bioremediation techniques to foster interstate acceptance of the test results from a variety of *in situ* bio demonstrations. This document emphasizes the establishment of objectives, criteria and measures so that work plans can be designed consistent with those measures, and results can be verified.

This document presents an outline containing the essential elements the proponent of an *in situ* demonstration must address when initiating a demonstration. The outline represents a compilation of concerns gathered by the ITRC states.

A process is also presented which defines the parties responsible for verifying demonstration results and transferring those results to other states for acceptance.

In addition, as a guide to the proponent, ITRC has included examples of recommended technology-specific protocols which have been developed by industry and tested in field applications. The technology-specific protocols for bioventing and natural attenuation (presented in Appendices A and B, respectively) have been evaluated by members of the ISB Group. Use of these protocols will increase the likelihood that the essential information required by the states has been included in the design of the demonstration and test plan.

2.3 General Outline

The essential elements of a ISB demonstration proposal are contained in the General Outline section of this document. This provides guidance to the proponent during development of the initial proposal for a demonstration. The proposal should contain enough detail so that the other parties can identify the applicable regulatory requirements for the project, the innovative nature and scope of the project, the advantage this technology might have over conventional technologies and the sensitivities the participants might have with this technology.

2.4 Responsibilities of the Parties

Many "parties" need to voluntarily accept responsibility during the implementation of a General Protocol based demonstration. These include Host States[3], Participating States[4], Proponents[5], Tribes

[3] The State which receives the demonstration proposal and oversees the implementation.

[4] States which are projected to receive an application to use the successfully demonstrated technology in their state in the future.

[5] The company or organization (public or private) submitting a proposal to the host state to conduct a

and Community/Other Public Stakeholders. In some cases, Tribes with regulatory authority may act as host or participating states in this process. The responsibilities of each party are discussed below in phases of a demonstration program.

The responsibilities of each of the parties is discussed in the following sections and summarized in Table 1. What follows is not a prescription, rather it describes a process to fulfill individual responsibilities in a collective manner.

demonstration.

Table 1-1 - "Responsible Parties"

"X" indicates party responsible for activity

	Responsibilities	Host State	Participating States	Tribal Regulatory Agency	Proponent	Community /Public Stakeholder
PHASE ONE	Select target states for demonstration				X	
	Notify contact agency in each state				X	
	Identify intra-state authorities applicable to this demonstration	X	X	X		
	Identify other stakeholders	X	X	X	X	
PHASE TWO	Submit "Demonstration Proposal" based on general outline to the parties				X	
	Review the proposal for acceptability and application	X	X	X		X
	Identify applicable regulatory requirements for the demonstration	X	X	X		
	Identify concerns and sensitivities with demonstration				X	X
	Compile the applicable regulatory requirements, concerns and sensitivities from all participants	X				
	Define performance objectives for the demonstration	X	X	X	X	X
	Determine the format for data reporting	X	X	X	X	X

	Responsibilities	**Host State**	**Participating States**	**Tribal Regulatory Agency**	**Proponent**	**Community /Public Stakeholder**
	Define verification[6] criteria and measures	X	X	X	X	X
	Complete and submit demonstration work plan (based on technology-specific protocol or general outline)				X	
	Insure demo data collection follows "Guide to Documenting Cost and Performance for Remediation Projects", March 1995.	X				
	Issue permits and approvals	X				
PHASE THREE	Implement the demonstration				X	
	Oversee the demonstration	X				
	Provide report of demonstration results to the host state				X	
	Review report of results according to verification criteria and measures	X	X *As necessary	X *As necessary		X
	Issue letter of approval (Host State) and acceptance (Participating States &(or) Tribal Regulatory Agency) of results according to verification criteria and measures	X	X	X		

[6]Verification criteria and measures include, but are not limited to, achievement of predefined cleanup levels or specific performance standards which may vary among participating states.

Phase 1: Identification of the Parties

The first phase in the process describes the opportunity for the proponent to identify a host state in which to conduct a demonstration, and select those states where the technology could be transferred following successful demonstration. The host state will coordinate the activities of the participating states. Each participating state must identify and be responsible for any intra-state coordination steps necessary to fully evaluate a demonstration proposal.

The proponent, with the assistance of the host state, should also identify other stakeholders who may be impacted or have a stake in the outcome of the demonstration. Participating states should also identify interested community/public stakeholders to include in the review technology demonstration proposals.

Phase 2: Demonstration Design

The second phase of the process is the submission of the demonstration proposal, prepared by the proponent consistent with the General Outline. Upon receipt each state or tribal environmental agency will identify the applicable regulatory requirements for the technology demonstration. These will be compiled into a single document and provided to the proponent for use in developing the demonstration plan.

Community/public stakeholders in turn should identify any concerns or sensitivities they have with the demonstration proposal or technology and deliver these to the proponent.

This phase validates the common concerns and regulatory requirements among participating states as well as identifying unique concerns of one or more participating states or other stakeholders that may be incorporated in the demonstration in the host state. This will guide the development of the performance objectives for the demonstration

Once the performance objectives are established, the proponent and the states must establish verification criteria (see footnote in Table 1) and the verification measures for this demonstration. These are the elements which the host state will use to verify the performance of the technology and report that success to the other participating states.

Phase 3: Implementation and Reporting Results

Phase three of this process is the actual implementation of the demonstration plan. During this phase the host state is responsible for issuing any applicable permits or approvals from their agency(ies) and overseeing the demonstration. The proponent must collect and validate the results of the demonstration and submit those results to the host state for verification of the demonstration according to the predefined verification criteria and measures, and report those results to the other participating states.

The host state, in collaboration with participating states, will develop a summary evaluation describing the level of acceptance of the demonstrated technology based on the predefined verification criteria and measures.

3.0 GENERAL OUTLINE FOR IN SITU BIOREMEDIATION DEMONSTRATIONS

3.1 Outline Format

This General Outline contains the essential elements of a ISB demonstration proposal. It is intended to provide guidance to the proponent during development of the initial proposal for a demonstration. A proposal developed according to the outline should contain enough detail that the other parties can identify the applicable regulatory requirements for the project, the nature and scope of the project, the advantage this technology might have over conventional technologies and other sensitivities and concerns the participants might have with this technology. Expansion of the outline creates a site-specific work plan. Technology-specific information, as provided in the technology-specific protocol documents; (4.9)Bioventing Position Paper and (5.9)Natural Attenuation Position Paper, forms the basis for section IX, X, XI and XII of the following outline.

I. Executive Summary
This Section briefly describes the contents of the Test Plan and includes a general overview of the technology to be verified, a clear description of test objectives and their suitability, and a concise description of the test approach.

II. Table of Contents

III. List of Tables

IV. List of Figures

V. Acknowledgments/Disclaimers

VI. Introduction

VII. Background
This section describes the market need for an alternative technology.

VIII. Stakeholder (community/tribal) Involvement Plan

A. Describe Method(s) for identifying and contacting citizens concerned about technology development and application.

1. Applicable state public participation requirements.

B. Describe a process for collecting and addressing community concerns and issues with a demonstration. (e.g. Noise, Odor, Traffic, Dust)

IX. Technology Summary

A. Basic process description

1. Principles

a. Stimulation

b. Naturally occurring microorganisms
c. Aerobic or anaerobic

2. Implementation
    a. Air emissions
    b. Water reinjection
    c. Amendments-list chemicals and MSDS
    d. Delivery system
    e. Process monitoring
    f. Process containment
3. Site monitoring

B. Applicability to chemicals of concern
1. Expected reactions/pathways
    a. Degradeablity of the compound
2. Expected extent of mineralization/possible end products, by-products, products of incomplete degradation

C. History of application or previous testing results

This section summarizes any existing data (e.g., microcosm tests or other laboratory scale data) and explains how this data was used in developing test objectives and the test plan.

D. Cost and performance information

X. Suitability of the Site for ISB

A. Description of Site
1. History of the site
    a. Operations at the site and land use
    b. Disposal practices and waste types
2. Environmental setting/characteristics
    a. Soil types, particle size, moisture content
    b. Ground water
    c. Surface water
    d. Air
    e. Climatic conditions
3. Receptors

B. Existing condition(s) of the site
1. Characterization results-nature and extent of contaminants
2. Indigenous microorganism population & activity
3. Targeted chemicals
4. Medium to be treated
5. Source control/removal

C. Predicted condition during the test
1. Scope of demonstration
2. Targeted chemicals, amendments, by-products, end products, products of incomplete

3. Medium treated
4. Other media of interest

D. Predicted condition following test
   1. Targeted chemicals, amendments, by-products, end products, products of incomplete degradation
   2. Medium treated

E. Monitoring systems
   1. Soil
   2. Soil gas
   3. Ground water
   4. Surface Water
   5. Air

F. Other considerations
   1. Land Ownership Stability
   2. Institutional Controls
   3. Adjacent Ownership
      a. Land Use
      b. Uncontrolled Exposure

G. Site Protection
   1. Worker Health and Safety
   2. Public Health and Safety

XI. Demonstration Objectives

Determine the specific objectives of the demonstration (e.g. performance under specified conditions, address identified regulatory or stakeholder concerns, ability to meet established site cleanup standards from multiple states).

XII. Performance Objectives

A. Determining the mass destruction or reduction attributable to the technique or technology

B. Define criteria, measures, methods for evaluating performance (e. g. oxygen depletion, CO_2 increase, primary metabolite depletion, soil sample analytical confirmation)

XIII. Test Design

A. Controls and baseline measurements

Establish the effect of the technology by comparison of "with project" and "without project" conditions, often including the design and implementation of a suitable control or controls.

B. Description of the test region

C. Data Quality Assurance/Quality Control

D. Introduction of amendments
Explanation: Showing that amendments added, or alterations to the test region, reach targeted chemicals and cause an increase in the desired biochemical reactions (demonstrate cause and effect)
1. mode
2. amounts
3. rates

E. Process measurements
1. Injection rates
a. Electron acceptors (oxygen, etc)
b. Nutrients
c. Microbes
d. Cometabolites
2. Monitoring
a. Air emissions
b. Ground water
c. Fate and effect of amendments and byproducts
d. Respiration rates (oxygen and CO_2 levels)
e. Microbial Levels (Plate Counts, Most Probable Number Procedure, other)
f. Degradation by-products, end products
g. Targeted contaminants & levels

F. Engineering controls

G. Safety considerations
1. Conditions for shutdown

H. Contingency Plan

I. Analytic procedures and Data Quality Objectives
1. Published methodologies by recognized organizations
2. Modifications to published methods, provided modifications are completely documented
3.Unpublished methods which are scientifically valid and are fully described and documented in the demonstration plans

J. Health and Safety Plan

XIV. Final Report

This section should describe in detail how the results of the testing will be reported and presented. It should also follow the Federal Remediation Roundtable Guidance on Cost and Performance Reporting.

APPENDIX A

BIOVENTING POSITION PAPER
and
PROTOCOL

- Revised FINAL -
September 1, 1998
[Original Release - 06/18/96]

Prepared by
The Interstate Technology and Regulatory Cooperation Work Group
In Situ Bioremediation Work Team

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EXECUTIVE SUMMARY

Bioventing is a cost effective, *in situ* technology which reduces petroleum hydrocarbon contamination by accelerating natural biological conversion processes. There is increasing evidence of the successful performance of this technology.

Advantages of bioventing include:

- Because the remedy is implemented below ground, without requirements for excavation, risk to workers and residents from off-gas, re-entrainment of particulate matter, and on-site earthmoving equipment and off-site truck traffic is eliminated.
- It is more cost effective than many conventional technologies because cost associated with off-gas treatment and material handling are avoided.
- Site disruption is minimized.
- Bioventing technology potentially treats a wide range of hydrocarbons including semi-volatile constituents.

Evaluation of bioventing for other contaminants including chlorinated solvents through research and demonstration projects should be encouraged and supported.

APPENDIX A

BIOVENTING POSITION PAPER AND PROTOCOL

1.0 INTRODUCTION

In February of 1995 the Interstate Technology and Regulatory Cooperation (ITRC) Work Group chose to focus on In Situ Bioremediation (ISB) technologies. The purpose was to review the existing use of ISB technologies, identify barriers to their effective use and recommend actions which, if implemented, will promote multi-state acceptance of data obtained during the demonstration of these technologies. By promoting state agency, federal agency, industry, user, tribal and stakeholder cooperation, the task group set out to develop products, processes and recommendations which will accelerate the safe and effective development and deployment of site cleanup technologies using ISB techniques which are as good or better and cost less than conventional technologies.

As part of this process, it was decided that a Bioventing Position Paper should be created that would highlight the potential application of bioventing technology to state underground storage tank programs, promoting better and more economical management of contaminated sites. It is the Task Group's opinion that bioventing has been adequately demonstrated in soils, primarily by the Air Force, and is considered a viable, low cost remedial alternative as compared to the traditional methods of excavation or soil vapor extraction at sites with petroleum hydrocarbon contamination (i.e. jet fuel, gasoline, fuel oil, diesel).

Bioventing is defined as the use of induced low volume air movement through unsaturated soils, with or without nutrient addition, to reduce soil contamination through biodegradation. The vast majority of field applications to date have involved fuel hydrocarbon sites, but the full application of this technology has yet to be realized or adequately researched. Bioventing potentially may be effective for other contaminants including longer chain hydrocarbons found in soils at former manufactured gas plants (polycyclic aromatic hydrocarbons or PAH's).

Bioventing may involve the injection or extraction of air (containing 20% oxygen). If extraction is induced, using pressure differentials, the treatment zone will be smaller and off-gases will have to be considered for treatment, although it is possible to re-inject these gases for further biological treatment in the subsurface.

During scientific efficacy discussions examining this technology, the ISB Task Group identified the following barriers to bioventing which include:

- A lack of knowledge of bioventing technology by regulators and potential users (consultants and responsible parties).
- The successful initiation of bioventing at 125 sites by the Air Force and the supporting documentation has not been adequately distributed outside the Air Force to increase

knowledge and deepen the potential market for the technology. However, EPA and the Air Force have recently released to the public the *Principles and Practices Manual for Bioventing*.

- The EPA SITE program (Superfund Innovative Technology Evaluation) demonstrations and bioventing guidance documents have been published but lack adequate distribution similar to the Air Force initiatives as discussed above.
- Regulators and potential users of the technology may be prejudiced by the "bio-" in bioventing from past experiences with vendors with "black box" bioremediation schemes.
- Some components of petroleum hydrocarbons may be recalcitrant to bioremediation.

This document was created to address these barriers. The Bioventing Technology Protocol document (located in this Appendix) was developed to provide a framework for proposing bioventing technology in work plans presented to the regulatory community.

2.0 DISCUSSION

During the ISB Task Group discussions examining the question of "why this technology (bioventing) has not been accepted by consultants and/or the regulatory community", it was commonly agreed that this technology has a stigma of being associated with the "black box" type of technology. A discussion was held concerning the financial status of the various state underground tank funds. Two state funds, Kansas and South Dakota, have operated successful remedial programs and continue to remain solvent. It appears a common denominator for these funds is that each state encourages cost effective remedial technologies (such as bioventing) and cost control measures, which may include competitive bidding.

It is recognized by the ISB Task Group that depending on specific site conditions, the use of bioventing technology could result in substantial cost savings as compared to current traditional methods of contaminant source treatment. For example, at a small gasoline station site, it may be as effective in terms of protecting human health and the environment, and least expensive, to excavate 30 cubic yards of petroleum-contaminated soils for licensed landfill disposal or composting, fill the excavation with clean soil and monitor or otherwise close the site. But if the site was large, or excavation was impractical because of existing structures, or the contaminated vadose (unsaturated) zone was too thick to justify excavation, it may make sense to consider bioventing. Even if hydrocarbon concentrations were too high (toxic) to support microbe activity, soil vapor extraction could be sequenced to lower contaminant values below the toxic concentration of 30,000 parts per million, and then convert the SVE system to bioventing.

Costs can vary dramatically depending on site specific conditions. However costs from the Air Force have been estimated for bioventing at $2 to $60 per cubic yard ($60 for 500 cubic yards or less and $2 for sites greater than 20,000 cubic yards). Costs for an average bioventing site (Kansas) have been estimated at $125,000. Time frames at a biovent site have been estimated at two years or more using small blowers (low operating costs). Costs include early site characterization and respiration tests. The injection of air near structures (utilities, sewer lines and basements) may raise concerns regarding explosion risks. It may be prudent in the interest of safety to place extraction points nearby for some period of time to lower the risk of explosion or inhalation risk.

While one year results are available for the multi-site Air Force initiative, most of the 125 sites are still in operation. More complete cost and performance summaries are expected. Other concerns about the technology involve recalcitrant petroleum hydrocarbon products such as MTBE (methyl tertiary butyl ether). It is assumed, however that benzene drives the risk at petroleum hydrocarbon bioventing sites, just as benzo(a)pyrene drives the risk at semi-volatile sites such as coal gas plants and wood treatment facilities. There are also uncertainties concerning adequate site characterization (contaminant distribution and the capability of getting air to those contaminants).

When should the system be turned off? Risk-based cleanup criteria are being developed through the American Society for Testing Materials (ASTM) RBCA (Risk Based Corrective Action) effort and by the individual states. Another possibility as the number of applications of bioventing technology increase is to assign a stated operating time frame, such as two years, then turn a system off after soil sampling confirms that closure has been achieved. It has been pointed out that it may be less costly to operate a bioventing system for an additional year as opposed to spending significant analytical costs for soil sampling to determine if cleanup is complete enough for closure. Another designed "stop" technique involves measuring no significant rebound in contaminant levels after a sequence of system operation and shutdown, or rest periods. An additional method involves soil or soil gas measurements with shutoff levels equivalent to published values such as the EPA soil screening levels, or groundwater at Maximum Contaminant Level (MCL) concentrations in equilibrium with soil vapor using Henry's Law constants.

More work is being done on this problem at the current time. EPA and Air Force recommend operating bioventing until *in situ* respiration tests yield oxygen uptake rates not significantly greater than oxygen uptake rates measured in uncontaminated soil at the site. Cleanup must then be confirmed with soil sampling and analysis according to individual state requirements.

The heightened awareness of risk determination/reduction and the increased weighting of costs may drive decisions in the future, given the climate of reduced resources and federal devolvement to the states. Most of these decisions occur on a site by site basis. State tank programs have notice and public comment requirements where these issues can be discussed. The advantages to bioventing suggest that this technology should be well received.

The Air Force has estimated that it has 2,000 underground tank sites to cleanup. This number may be equivalent to an entire state's leaking underground tank inventory. The arrival of bioventing as a remedial alternative may be timely, with budget shortfalls (federal and state), regulatory devolvement to states, the culmination of Air Force demonstrations, the EPA SITE program results and the WGA DOIT efforts. As a caveat, each decision to use or not use bioventing has to be site specific. Bioventing cannot be a universal solution. As in the Air Force guidance documents, "No Action" (natural attenuation) may first be considered, then bioventing technology, followed by the consideration of other remedial alternatives.

Bioventing as a remedial alternative provides an opportunity in terms of promoting cost effective remediations, the saving of cleanup dollars, and making efficient use of limited funds. With wider deployment of bioventing, there may be more sites to move forward on while providing overall savings to already financially strapped (or worse) state tank funds.

The Air Force is demonstrating the efficacy of bioventing in nearly every western state and in every region of the country. The traditional excavation of contaminated soils may result in a future landfill liability. Bioventing offers low capital costs to design and install, low operation and maintenance costs, with permanent destruction of contaminants by bioremediation. The joint EPA/Air Force *Principles and Practices Manual for Bioventing* has just been released to the public and should prove useful for determining where and when bioventing technology can be utilized.

3.0 SUMMARY

It has been demonstrated at multiple sites that oxygen is being reduced in hydrocarbon-contaminated soils, and carbon dioxide is increased, indicating that aerobic microbial activity is occurring. Studies by the Air Force and others have shown that oxygen is the limiting factor. At most sites, no further enhancements or augmentation, such as nitrogen and phosphorous addition, are necessary to sustain microbial growth and activity except for replacing the oxygen consumed. The end products of biological degradation are water and carbon dioxide.

Bioventing has been demonstrated at sites with a wide range of soil types (sandy clay, silts and sands), soil pH (3 to 9), soil temperature (5 to 40 degrees Centigrade) and soil moisture. Aside from oxygen being the primary limiting factor, too much moisture may inhibit air flow and impact the efficiency of the system, while too little moisture may inhibit or otherwise reduce microbial activity. However the Air Force has documented few sites where high or low moisture precludes the use of bioventing. High concentrations of hydrocarbons (greater than 30,000 parts per million) may be toxic to organisms, as has been mentioned previously. However, the limited application of SVE should quickly lower the toxic concentrations and the system can subsequently be converted to bioventing. It should be emphasized that bioventing does not have to be excluded from consideration at a site based on perceived limitations. An inexpensive site-specific treatability test can be conducted which indicates whether the presence of injected air will stimulate aerobic biodegradation processes. The results of the test provide a clear indication of the feasibility of bioventing.

4.0 FINDINGS

- The use of bioventing technology should be encouraged as a means to remediate underground storage tank sites in a cost effective manner.
- The Air Force and EPA should continue the efforts to disseminate information about bioventing and bioventing demonstrations, including cost and performance data.

- State regulators should become better informed about bioventing, including its cost benefit, technology limitations and successful applications.
- Bioventing technical gatherings (seminars, conferences, etc.) should be expanded to enlarge the knowledge base, invite participation and improve communications concerning bioventing.
- Data from bioventing demonstrations should be released in a more timely manner. At the present time, peer review processes are causing delays approaching one year or more before data becomes available for wide review.
- Through the ITRC task group efforts it was observed that states such as Kansas and South Dakota are deploying bioventing successfully. Other states should consider including bioventing as a presumptive remedy for petroleum contamination in soils.

5.0 ITRC TECHNOLOGY SPECIFIC PROTOCOL FOR BIOVENTING

Objective of ITRC Bioventing Protocol

The objective of the ITRC Bioventing Protocol is to provide guidance for performing and documenting bioventing as a viable cleanup technology, in a manner which will encourage acceptance of the results by ITRC participating states.

Format

The format of this protocol is a framework designed to direct a user/vendor/consultant to those existing technical guidance documents which detail the requirements for completing a rigorous and scientifically valid demonstration of bioventing.

Initial Evaluation

For initial evaluation of the applicability of bioventing to a demonstration site, the following guidance document is recommended:

> *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites: A Guide For Corrective Action Plan Reviewers ("EPA GUIDE"),* Chapter III, Bioventing, EPA 510-F-94-003, October 1994.

Implementation

For the actual implementation of a bioventing system, the following guidance document is recommended:

> *Manual, Bioventing Principles and Practice, ("EPA MANUAL"), Volume II: Bioventing Design*, EPA/625/XXX/001, DRAFT September 1995.

6.0 OUTLINE FORMAT

The following is an outline of what a bioventing site work plan or report ideally should contain from a regulator/reviewer perspective:

Table of Contents

List of Tables

List of Figures

List of Acronyms (see Appendix C)

I. Introduction and Overview of Bioventing
(General description of bioventing technology.)
- Conventional Enhanced Biodegradation
- Bioventing Concept
- Applications and Limitations
- Example Sites and Results

II. Site Description
(Description of site location, history, and physical characteristics; see EPA 510-B-94-003.)
- Site Location and History
- Site Characteristics
  - Soil Geology
  - Intrinsic Permeability
  - Microbial Presence and Characterization
  - Nitrogen and Phosphate Availability
  - Soil pH
  - Moisture Content
  - Soil Temperature
  - Nutrient Concentrations
  - Depth to Groundwater

III. Site Contaminants and Characteristics
(Description of site contaminants and their physical characteristics; include vertical and horizontal distribution of contaminants; see EPA 510-B-94-003.)
- Chemical Structure
- Product Composition and Boiling Point
- Henry's Law Constants
- Vapor Pressure
- Concentration and Toxicity to Aerobic Bacteria
- Contaminant Distribution
  - Soil Samples (Number and rationale)
  - Soil Gas Samples (Number and rationale)
  - Sample Preservation and Analytical Methods

IV. Bioventing Design
(Description of site-specific bioventing design; include testing, system components, instruments, and controls; see EPA/625/XXX/001.)

- Air Permeability and *In Situ* Respiration Tests
- System Components
  - Extraction Wells, Air Injection Wells, and Monitoring Points
    - Location
    - Depth
    - Construction Details
    - Thermocouples
    - Design Radius of Influence
    - Vapor Treatment
    - Blower Selection
    - Site Construction Limitations
    - Surface Seals
  - Instruments, Controls, and Measurements
    - Oxygen and Carbon Dioxide
    - Hydrocarbon Concentrations
  - Helium Monitoring
  - Temperature Monitoring
  - Pressure/Vacuum Monitoring
  - Airflow
  - Analytical Methods
- Optional Bioventing Components

V. Investigation Derived Wastes (IDW) and Emissions
(Description of wastes and emissions produced as a result of site investigation; to include handling, disposal, and permitting requirements and procedures; see State contact for state-specific requirements.)

- Estimated Volume of IDW
- Handling and Disposal of Drill Cuttings
- Handling and Disposal of Drilling Decontamination Water
- Emissions Calculations
- Required Permits and Regulatory Approvals (Examples: Nutrient injection, air injection, or air emissions)

VI. System Operation and Monitoring
(Description of system operation parameters and progress monitoring; see EPA/625/XXX/001.)

- Pre-startup Modeling Parameters and Pore Volume Calculation
- Nutrient Formulation and Delivery Rate
- Biodegradation Rates
- Cleanup Criteria and Shutdown Parameters

Start-up Operations
Long-term Operations
Remedial Progress Monitoring

VII. Project and Monitoring Schedule

VIII. Reporting
(See State Contact for State-Specific Requirements)
Data Records and Quality Assurance
Computerized Data Format
Periodic Progress Reports
Site Reports
Exceptions to Protocol Procedures

IX. Post-Cleanup Assessment
(See State contact for state-specific requirements.)

X. Points of Contact
(*see Appendix D)

XI. References
(The outline was prepared based on the following primary documents, See *References*, Section 1.7)

7.0 REFERENCES

1) *Manual, Bioventing Principles and Practice, ("EPA MANUAL"), Volume II: Bioventing Design*, EPA/625/XXX/001, DRAFT September 1995.

2) *How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites: A Guide For Corrective Action Plan Reviewers ("EPA GUIDE")*, Chapter III, Bioventing, EPA 510-B-94-003, October 1994.

3) *Bioventing Pilot Test Work Plan for Building 406, Offutt AFB, Nebraska*, Engineering-Science, Inc., October 1993.

4) *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing*, Air Force Center for Environmental Excellence, May 1992.

5) *Hill AFB, Utah JP-4 Site (Building 914) Remediation*, Battelle, July 1991.

APPENDIX B

NATURAL ATTENUATION POSITION PAPER

- Revised FINAL -
September 1, 1998
[Original Release - O6/18/96]

Prepared by
The Interstate Technology and Regulatory Cooperation Work Group
In Situ Bioremediation Work Team

APPENDIX B
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EXECUTIVE SUMMARY

Natural attenuation occurs when physical, chemical and biological processes act to reduce the toxicity and mobility of subsurface contamination. Consideration of natural attenuation as a remedial option depends on:

- Adequate site characterization;
- A monitoring plan consistent with the level of knowledge regarding subsurface conditions at the site; and
- Evaluation of the contaminant source.

Several states have developed regulations and/or guidance regarding the evaluation and implementation of natural attenuation. Various entities have also developed natural attenuation protocols.

Natural attenuation for petroleum hydrocarbons, particularly BTEX, is well demonstrated. Natural attenuation for other contaminants, such as chlorinated solvents, has been demonstrated but not to the same degree as petroleum hydrocarbons.

With considerable cost savings compared to active remediation, natural attenuation allows for resources to be devoted to higher priority sites. However, natural attenuation possibly impacts property transfers because longer time frames are necessary to reach remedial objectives. Also, more extensive site characterization and monitoring may be required compared to conventional remedies due to liability concerns caused by the potential for plume migration beyond property boundaries or to sensitive receptors.

APPENDIX B

NATURAL ATTENUATION POSITION PAPER

1.0 INTRODUCTION

A recent National Research Council (National Research Council [NRC], 1994) study of groundwater cleanup alternatives confirmed what has been common knowledge within the regulatory community for years -- that the attainment of cleanup criteria with conventional pump and treat systems at many sites under the most favorable conditions can be expected to take decades. Five main reasons were cited for this:

- Physical heterogeneity of the subsurface
- NAPLs
- Contaminant diffusion into inaccessible regions
- Adherence of contaminants to subsurface materials
- Difficulties in characterizing the subsurface

Given the difficulties with conventional pump and treat technologies, the study recommended alternative groundwater treatment technologies to pump and treat. Along with physical containment and *in-situ* reactive barriers, natural attenuation was recognized as an alternative technology to pump and treat.

2.0 NATURAL ATTENUATION DEFINED

Natural attenuation is the biodegradation, diffusion, dilution, sorption, volatization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the environment. Natural attenuation implementation requires a competent team of environmental professionals with cross disciplinary expertise such as microbiology, computer modeling, hydrogeology, and engineering. Illustrating the complexity of natural attenuation, the Air Force Center for Environmental Excellence (AFCEE) Protocol outlines the steps of natural attenuation (Wiedmeier et al., 1995) as:

1) Review Existing Site Data
2) Develop Preliminary Conceptual Model and Assess Potential for Intrinsic Bioremediation
3) Perform Site Characterization in Support of Intrinsic Remediation
4) Refine Conceptual Model, Complete Pre-Modeling Calculations, and Document Indicators of Intrinsic Remediation
5) Model Intrinsic Remediation Using Numerical Models
6) Conduct an Exposure Assessment

7) Prepare a Long-Term Monitoring Plan
8) Conduct Regulatory Negotiations

3.0 GOAL OF THE DOCUMENT

In the past, the regulatory community has been slow to accept natural attenuation due to a faulty perception that natural attenuation equals no action.[1] Natural attenuation may involve intensive, long-term monitoring that can require more substantial site characterization and monitoring than other conventional remedial approaches (EPA/600/R-94/162,1994, p.7). Recognizing the growing regulatory acceptance of natural attenuation, the ITRC has performed a literature survey in order to learn more about the technology - i.e., operating histories, demonstrated successes, defined application protocols, and process limitations. The ITRC then developed a summary of the current status of natural attenuation regulatory acceptance at the state level, a list of agreed upon limitations to natural attenuation, and a set of findings on proper implementation of natural attenuation. The goals of this document are to:

- Inform ITRC member states of the growing movement towards natural attenuation on the state level.
- Develop a common understanding amongst ITRC member states about natural attenuation and convince states that natural attenuation does have merit as a remedial option.
- Identify rigorous and scientifically valid natural attenuation protocols, previously developed by various private and public sector entities.

4.0 NATURAL ATTENUATION REGULATORY ACCEPTANCE

4.1 States Allow For Natural Attenuation

A recent survey of states discovered that 37 state programs have no natural attenuation policies or guidelines but would consider natural attenuation. Eight state programs have informal natural attenuation policies or guidelines. Fourteen state programs have addressed natural attenuation implicitly in policies and guidelines. Two state programs have written policies and guidelines. Six state programs do not allow natural attenuation (Ritz, 1996, p.18). New Jersey Department of Environmental Protection has proposed new regulations to allow for natural attenuation under certain circumstances (New Jersey Department of Environmental Protection [NJDEP], 1996). Wisconsin has developed guidance focused on soil petroleum hydrocarbon contamination and site characterization and monitoring requirements (Wisconsin Department of Natural Resources [WI DNR], 1993). Florida has developed guidance that provides petroleum contaminant levels in the groundwater that allow for "monitoring only" or "no further action" alternatives (Florida Department

[1] Other more skeptical members of the regulatory community have sarcastically called natural attenuation a "put it on the back burner and we'll get to it later consequence of the bureaucratic overload" and "unprotective inaction" ("What About Natural Attenuation?", Gilberto Alvarez, *Lust Line Bulletin No. 22*).

of Environment Regulation [FLA DER],1990). South Carolina is currently developing guidance on natural attenuation as well (EPA/600/R-94/162, 1994, p.9).

4.2 AFCEE Prefers Natural Attenuation

The Air Force ranks natural attenuation as their preferred remedial alternative for petroleum hydrocarbons. In a guide for Air Force base managers, remedial technologies were ranked based upon 12 common Air Force Base contamination problems. For 10 of the 12 site contamination problem, natural attenuation was ranked as the number one preferred alternative. This means that Air Force Base Site Managers must first evaluate natural attenuation before any other alternative (Air Force Center for Environmental Excellence [AFCEE], 1994).

4.3 Natural Attenuation Appears Consistent with Risk Based Corrective Action (RBCA), which Is Being Considered by States

Presently, most states require cleanup of soil and groundwater based on generic criteria and regulatory requirements and little thought is given to site-specific factors which should determine cleanup criteria. In response to these concerns, ASTM has released the "Guide for Risk Based Corrective Action (RBCA) at Petroleum Release Sites." Under Tiers 1 and 2 of the ASTM program, if contaminant concentrations are found to exceed generic health based limits, site-specific remedial cleanup standards are calculated using screening-level analytical models for soil, groundwater, and air exposure pathways. Tier 3 involves detailed numerical modeling analyses and is only conducted if the site complexity or potential remediation cost warrant the additional time and expense required for further data collection and analyses (Gustafson - Shell Development Co., 1995).

RBCA was applied at two different AFCEE sites located at the Wurtsmith Air Force Base, in Michigan. At one site, where saturated soils and groundwater were contaminated by a release of heating fuel oil USTs, the measured concentration of chemicals of potential concern (COPCs) were below site specific, risk-based criteria and a recommendation of no further action was favorably received by Michigan regulators. At the other JP-4 fuel release site, data indicated that BTEX are biodegrading *in-situ* and a BIOPLUME II model predicted that COPCs will be degraded completely within 10 years. The remedy included land controls and long-term monitoring to confirm natural attenuation of COPC (Guest - Parsons Engineering Science Co., 1995).

Discussions with states regarding incorporation of RBCA into many state and local authority regulatory programs is currently ongoing. ASTM has initiated a RBCA Training Program. As of October 1995, ten states expressed interest in training or have scheduled training, 17 states in the middle of training, or have 13 states have completed training and are currently implementing RBCA (Lund - EPA, 1995). A report sponsored by the state of California has concluded that "the recently developed ASTM RBCA framework offers a promising tiered decision making approach to LUFT cleanups" (Rice et al.,1995).

5.0 NATURAL ATTENUATION PROCESS LIMITATIONS

The following conclusions are based upon a literature survey, conversations with state regulators, and correspondence with other natural attenuation experts.

5.1 Source Removal

High contaminant concentrations are lethal to microbes. Numerous protocol documents and studies recommend that natural attenuation should not be used where the contaminant source (free product, excessive soil concentrations, etc.) has not been abated [2,3,45] (EPA/510/F-95/003, May 1995, p.IX-

2 The guidance provides petroleum contaminant levels in the groundwater that allow for "monitoring only" or "no further action" alternatives. These levels can be considered if the contaminant source has been abated, free product is not present, excess soil contamination is not present, and groundwater contamination is not off-site of migrating vertically. (Florida Department of Environmental Regulation, *No Further Action and Monitoring Only Guidelines for Petroleum Contaminated Soil ("FLA DER Guidance")*, October 1990.)

7). In general, natural attenuation is generally not effective where the TPH levels greater than 20,000 mg/kg in the soil.[6] However, recent ISB group discussions indicate that the level of TPH which inhibits microbial degradation has been documented to be higher than 60,000 mg/kg.

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3 A recent AFCEE-sponsored review concluded that eight states - Delaware, District of Columbia, Florida, Iowa, Michigan, North Carolina, Ohio, and Wisconsin - allow for natural attenuation after (1) action has been taken to eliminate sources of contamination and (2) free product has been removed to the extent possible. *(Review of State Regulations Regarding Natural Attenuation as a Remedial Option,* MITRE Corporation.)

4 "Data demonstrated that if fuel hydrocarbon sources are significantly removed or reduced, plume will most likely heal themselves through passive remediation even if no active remediation is being performed." ("California Leaking Underground Fuel Tanks (LUFT) Historical Case Analysis", D. Rice, B. Dooher, S. Cullen. L. Everett. W. Kastenberg, R. Grose, M. Marino, submitted to the California State Water Resource Control Board and the Senate Bill 1764 LUFTS Advisory Committee, November 16, 1995.)

5 In this proposed regulatory change to allow for natural attenuation, “neither free nor residual product...in either the unsaturated or saturated zones” is allowed when implementing natural attenuation. (Site Remediation Program, Technical Requirements for Proposed Readoption with Amendment: NJAC 7:26E, authorized by Robert J. Shinn Jr., Commissioner, DEP, March 1996.)

6 The table below, found in the EPA document *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers,* lists site factors favoring natural attenuation. (*How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers ("EPA Guide")*, Chapter IX, Natural Attenuation, EPA 510-F-95-003, May 1995, p. IX-7.)

5.2 Site-Specific Factors

The Table (1.1 - Site-Specific Factors) found in the EPA Document *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tanks: A Guide for Corrective Action plan Reviewers,* lists site factors favoring natural attenuation (EPA/510/F-95/003, May 1995, p.IX-13).

Table 1-1 - Site-Specific Factors

Site Parameter	Site Condition
Soil Texture	Intrinsic Permeability > 10^{-8} cm^2
Adsorption Potential	Fraction of Organic Carbon (f_{oc}) > 2 percent
Groundwater Flow Rate	Contaminant Travel Time to Receptor > 2 years
Soil Aeration	Oxygen Content 2% (volume)
Groundwater Aeration	Dissolved Oxygen > 1 to 2 mg/L
Soil Moisture Content	40%< soil moisture content < 85% (of total water bearing capacity)
Soil pH	6 < pH <8
Precipitation	10 to 60 inches per year
Temperature	5 to 45 degrees C
Soil Nutrient Concentration	Carbon to nitrogen to phosphorus ratio = 100:10:1

5.3 Contaminant Type Issues

5.3.1 Petroleum Hydrocarbons Natural Attenuation Has Been Successfully Demonstrated

Overwhelming evidence exists that natural attenuation of petroleum contamination[7] occurs at sites. Many petroleum hydrocarbon site case studies are now available that clearly demonstrate the effectiveness of natural attenuation.

- A site in Traverse City, Michigan resulting from an estimated 25,000 gallons of aviator gasoline suggested that both aerobic and anaerobic intrinsic bioremediation can occur with groundwater contaminated by petroleum products (Wilson, 1994, p.94).
- AFCEE has demonstrated that the BTEX plume at Hill Air Force Base, where hydrogeological data indicate that groundwater is traveling about 1600 feet per year, has shrunk from 750 feet wide to 420 feet wide over a one year period due to aerobic and anaerobic natural attenuation (Wiedmeier et al., 1994).
- A Minnesota pipeline ruptured and released 1670 m^3 of crude oil in 1979. Data collected over an 8 year period indicate that 200 meters down gradient of the spill, the "geochemistry of the groundwater is virtually indistinguishable from that of native groundwater.... [which] attests to the efficiency of natural processes in removing/attenuating the oil-derived contaminants of primary concern at the site" (Eganhouse, 1994, p.111).
- After 6 month of monitoring a natural gas plant BTEX plume, the extent of groundwater contamination of the dissolved hydrocarbon plume was smaller by five orders of magnitude than expected if no natural attenuation was occurring. Although some oxygen flux occurs, the 90% of contaminant mass was biodegraded anaerobically with sulfate, as opposed to oxygen, the likely electron acceptor (Piontek, 1994, p.179).
- A study, which looked at 112 cases in Napa County, concluded that the annual rate of natural biodegradation of TPH-gasoline and TPH-diesel in groundwater was on average 50% and 60%, respectively, when concentrations were below 2,000 ppb (Lee, 1995).
- A recent controlled field experiment in Columbus Air Force Base, Mississippi is the "first field experiment to prove conclusively that hydrocarbon solute losses were due to chemical degradation rather than physical loss." The study involved the injection of several aromatic

7 In the case of petroleum fuels, natural attenuation (and other bioremediation) is commonly expressed in terms of the decrease or disappearance of components or fractions of the fuel which are presently of regulatory concern, as measured by one or several analytical methods. Disappearance of these components or fractions in no way constitutes evidence of complete mineralization of the fuel. [Conversations with Dr. Wolfgang Fuhs, CAL EPA]

hydrocarbons and a non-reactive tracer into an uncontaminated aquifer (Stauffer et al., 1994).

- A historical case study analysis pooled data from over 5700 eligible leaking underground fuel tank sites in California. The study concluded the following:
  - Plume lengths change slowly and tend to stabilize at relatively short distances from the fuel hydrocarbon (FHC) release.
  - Plume lengths rarely exceed 250 feet in length.
  - Benzene average concentrations tend to decrease much more rapidly than plume lengths.
  - Significant reduction in benzene concentrations can be achieved without active remediation (Rice et al., 1995).

5.3.2 MTBE Natural Attenuation Has Not Been Demonstrated (Davidson - Alpine Environmental Inc., 1996).

Methyl-Tert-Butyl Ether (MTBE), a gasoline additive used since the early 1980's, is highly mobile and soluble. An examination of 30 sites indicated that the MTBE plume was 1.5 to 2.0 times further out than the leading edge of the benzene plume. EPA considers MTBE a possible human carcinogen and draft EPA drinking water lifetime health advisory for MTBE falls into the range of 20 - 200 ppb.

Unlike other gasoline components, MTBE does not readily biodegrade. Bench scale tests indicate that after 232 days no measurable biodegradation of MTBE had been realized in an oxygen rich environment. Under a more realistic bench scale test with oxygen levels closer to actual subsurface conditions, no aerobic or anaerobic biodegradation could be measured after 420 days. An actual field test found that no biodegradation had occurred after 476 days in the groundwater of a sandy aquifer.

5.3.3 Chlorinated Solvent Natural Attenuation Has Been Demonstrated But to a Lesser Degree Than Petroleum Hydrocarbons

Natural attenuation of chlorinated solvent through anaerobic dechlorination commonly occurs at sites where co-contaminants are present as a primary substrate to support the energy needs and metabolic activities of transforming bacteria. The extent of biodegradation depends upon the relative concentration of substrate. Case studies, summarized below, illustrate that although PCE and TCE transformation to ethene occurs at many sites, transformations are often not complete (McCarty, 1994, p.135).

- A northern Toronto chemical transfer facility, where PCE contaminated the groundwater 10 years ago, reported evidence that PCE transformation to ethene and ethane was occurring with methanol and acetate as primary substrates. However, at some areas where high PCE was found, little ethene was found.
- A carpet-backing manufacturing plant in Hawkesbury, Ontario, with two separate waste lagoons that lead to PCE, TCE, and TCA groundwater plumes, had conditions conducive to cometabolism. Methanol and fatty acids, acting as primary substrates, and sulfate and iron,

acting as electron acceptors, were present in the groundwater. While good evidence for intrinsic biotransformation occurred at this site, ethene and ethane concentrations were very low compared to VC concentrations, suggesting that the chlorinated solvent hazard at the site still existed.

- A study of biotransformation at Picattiny Arsenal, NJ indicates that biodegradation is the main mechanism for which dissolved TCE leaves the groundwater system. However, TCE contaminant plume concentrations have changed little from September 1986 to 1991(Martin, 1994, p.143).

However, chlorinated solvent natural attenuation has been demonstrated to be effective. At the St. Joseph, Michigan Superfund site, TCE concentrations as high as 100 mg/L have been found degrading via anaerobic dechlorination fueled by waste leaching from a disposal lagoon, nearly complete conversion to methane has been observed. Chlorinated solvent levels have been reduced 24-fold at the site (McCarty, 1994, p.135). Natural attenuation has been accepted by the EPA and the Delaware Department of Natural Resources as the interim remedy for one of the target areas at Dover Air Force Base. Additionally, the US Air Force is developing a natural attenuation protocol for chlorinated solvents.

The Bioremediation of Chlorinated Solvents Work Group, one of the four Work Groups of the Remediation Technologies Development Forum (RTDF), was established in May 1993, when representatives from six companies (Dupont, Dow, GE, Monsanto, Zeneca, and Ciba-Geigy), the Environmental Protection Agency (EPA), Department of Energy (DOE), and the Air Force met in Wilmington, Delaware to discuss their mutual interest in *in situ* treatment of chlorinated solvents. The Work Group has drafted research plans and is currently evaluating two sites that may be appropriate for testing and evaluating *in situ* bioremediation processes, including natural attenuation.

5.4 Mathematical Models - Although Not Perfect, Appear Capable of Modeling Natural Attenuation of Groundwater

A number of biodegradation models, developed in the past ten years, are generally similar in their simulation of transport and biodegradation of a number of components in the groundwater. They differ in the mathematical biodegradation expressions and numerical procedures used to solve equation systems. Due to lack of biodegradation parameters, most models have resorted to first-order decay or instantaneous representation of the biodegradation process (Rifai, 1994, p.103). A case study at Hill Air Force Base indicates that a BTEX plume has reached a steady-state condition and is not migrating down gradient and that the BIOPLUME II model accurately predicted the migration and attenuation of the BTEX plume (Wiedmeier et al., 1994).

6.0 FINDINGS

The ITRC has determined the following regarding natural attenuation:

- State agencies need to participate in programs to educate regulators about the merits of natural attenuation.
- Source area removal/remediation should be thoroughly evaluated when implementing natural attenuation.
- Petroleum hydrocarbon natural attenuation has been shown to be operate successfully at many sites.
- MTBE, a highly soluble and mobile gasoline additive that is a possible human carcinogen, does not naturally attenuate.
- Chlorinated solvent natural attenuation has been demonstrated, but not to the same degree as petroleum hydrocarbons.
- Mathematical models, although not perfect, appear capable of modeling natural attenuation.
- To evaluate the appropriateness of natural attenuation for a site, ITRC refers the reader the use of guidance contained in *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers ("EPA Guide")*. An entire chapter of this document examines the suitability of the use of natural attenuation at a site by describing the site factors (soil texture, groundwater flow rate, soil PH, etc.) and chemical constituent factors (solubility, vapor pressure, etc.) that allow for the natural attenuation. An easy to follow checklist entitled "Can Natural Attenuation Be Used at This Site?" is included. Please note that the check list is not meant to preclude an engineer's best professional judgement. [Please see Appendix E, Attachment 1, p.IX 32-33]

- For natural attenuation implementation, ITRC refers the reader to the following protocols:
  - *Protocol for Monitoring Intrinsic Bioremediation in Groundwater ("Chevron Protocol")*, Funded by the Chevron Corporation, Tim Buscheck, Kirk O'Rielly, March 1995. [Please see Appendix E, Attachment 2] This brief guidance document recommends indicator parameters - dissolved oxygen, oxidation-reduction potential, pH, etc. - to be monitored for and provides a detailed description of the sampling and analysis protocols that should be followed for each indicator compound.
  - *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Ground Water, ("Air Force Protocol")*, 11/11/95, The Air Force Center for Environmental Excellence, written by Todd H. Wiedmeier, John T. Wilson, Ross N. Miller and Donald H. Kampbell. [Please see Appendix E, Attachment 3] This dense two volume guidance document offers a detailed natural attenuation methodology. Additionally, case studies at two AFCEE sites are provided.

- A number of state have prepared guidance regarding evaluation and implementation of natural attenuation. If attempting to develop state guidance regarding the regulatory limitations of natural attenuation, states should refer to the following guidance documents:
  - Wisconsin Department of Natural Resources, *Interim Guidance on Natural Attenuation, ("WI DNR Guidance")*, February 1993. The guidance focussed on soil contamination by petroleum hydrocarbons and on the requirements for site characterization and monitoring necessary to use this approach.
    [Please see Appendix E, Attachment 4]
  - Florida Department of Environmental Regulation, *No Further Action and Monitoring Only Guidelines for Petroleum Contaminated Soil ("FLA DER Guidance")*, October 1990. The guidance provides petroleum contaminant levels in the groundwater that allow for "monitoring only" or "no further action" alternatives. These levels can be considered if the contaminant source has been abated, free product is not present, excess soil contamination is not present, and groundwater contamination is not off-site of migrating vertically. [Please see Appendix E, Attachment 5]
  - New Jersey Department of Environmental Protection *Proposed Regulation N.J.A.C. 7:26E* The Department has specified requirements for remediation of site on which ground water contamination is present, but will be reduced through natural processes such as biodegradation, dispersion, and retardation, to levels below applicable standards before reaching receptors. I specifies when ground water may be “naturally” remediated and the minimum technical requirements for implementing a natural attenuation remediation. [Please see Appendix E, Attachment #6]

7.0 REFERENCES

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APPENDIX C

Referenced Documentation

APPENDIX C
Referenced Documentation

The following items are in relation to the Natural Attenuation Position Paper, located in Appendix B (with the exception of Attachment #7). These documents provide further insight into the uses of natural attenuation in relation to various environmental conditions/situations.

1.) Attachment/Reference #1: EPA Guide

U.S. EPA - Office of Underground Storage Tanks. (1995, June 13). How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers, ("EPA Guide").EPA510F95003.

2.) Attachment/Reference #2: Chevron Protocol

Buscheck, Tim.,O'Rielly, Kirk - Cheveron Corporation. (1995, March). Protocol for Monitoring Intrinsic Bioremediation in Groundwater, ("Cheveron Protocol").

3.) Attachment/Reference #3: Air Force Protocol

Wiedmeier, Todd H., Wilson, John T., Miller, Ross N., Kampbell, and Donald H. (1995, June). Technical Protocol for Implementing the Intrinsic Remediation with Long- Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater, Vol. II, ("Air Force Protocol"). ADA324247.

4.) Attachment/Reference #4: WI DNR Guidance

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6.) Attachment/Reference #6: NJ Guide

New Jersey Department of Environmental Protection, NJDEP. (1996, Mar.18). Site Remediation Program, Technical Requirements for Proposed Readoption with Amendment: NJAC 7:26E.

7.) Attatchment/Reference #7: AFCEE Document

Air Force Center For Enviornmental Excellence. (1995, June). Intrinsic Remediation Engineering Evaluation/Cost Analysis,(for UST Site 870).

These documents can be located via the Internet or by contacting the entity for which the document was prepared for or prepared by.

APPENDIX D

Acronyms

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Acronyms

APC -Air Pollution Control
ARAR -Applicable or Relevant and Appropriate Requirements
ASTM -American Society of Testing and Materials
BNA -Base/Neutral/Acid
CAMU -Corrective Action Management Unit
CERCLA -Comprehensive Environmental Response, Compensation and Liability Act
CEM -Continuous Emissions Monitor
CFR -Code of Federal Regulations
CLP -Contract Laboratory Program
CO -Carbon Monoxide
DCA -Dichloroethane
DCE -Dichloroethene
EPA -Environmental Protection Agency
GC/ECD -Gas Chromatography/Electron Capture Detector
GC/MS -Gas Chromatography/Mass Spectrometer
ITRC -Interstate Technology and Regulatory Cooperation (Work Group)
LEL -Lower Explosive Limit
LTTD -Low Temperature Thermal Desorption
NPL -National Priority List
OSHA -Occupational Safety and Health Administration
PAH -Polycyclic Aromatic Hydrocarbon
PCB -Polychlorinated Biphenyl
PIC -Products of Incomplete Combustion
POC -Point of Contact
POP -Proof of Process
POTW -Publicly Owned Treatment Works
QA/QC -Quality Assurance/Quality Control
RCRA -Resource Conservation and Recovery Act
TCE -Trichloroethylene
TDU -Thermal Desorption Unit
TPHC -Total Petroleum Hydrocarbons
TRPH -Total Recoverable Petroleum Hydrocarbons
TSD -Treatment, Storage and Disposal
VO -Volatile Organic
VOC -Volatile Organic Compound
TSCA -Toxic Substances Control Act

APPENDIX E

ITRC Contacts, Information and User Survey

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