Protocol for In-Situ Bioremediation of Chlorinated Solvents Using Edible Oil

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Module 1: Using the Edible Oil Process

Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the physical and chemical differences between chlorinated aliphatic hydrocarbons (CAHs) and petroleum contaminants to determine appropriate remediation strategies.
- **Select** the appropriate edible oil application configuration (Source Area vs. Biobarrier) based on site-specific remedial objectives and hydrogeological constraints.
- **Identify** the primary biochemical and abiotic pathways, including reductive dechlorination and sequestration, involved in the degradation of chlorinated solvents.

Executive Summary: The edible oil process is a flexible, long-lasting technology designed to stimulate the in situ anaerobic bioremediation of chlorinated solvents and other anaerobically degradable contaminants. By providing a slow-release source of molecular hydrogen and organic acids, edible oil supports reductive dechlorination over several years with a single injection. The process can be implemented using pure oil for source area sequestration and flow control, or as oil-in-water emulsions for expansive plume treatment in biobarriers.

Introduction

Management of groundwater contaminated with **chlorinated solvents** is one of the Department of Defense's (DoD's) greatest environmental challenges. Chlorinated solvents are widely used for cleaning and degreasing across military and commercial sectors. Due to their physical and chemical properties, they are relatively recalcitrant in the subsurface and more difficult to access than petroleum, oil, and lubricant (POL) sites.

When released as a **dense non-aqueous phase liquid (DNAPL)**, the density of the solvent relative to water leads to complex distributions in both vadose and saturated zones. Unlike POL contaminants, which are naturally occurring and degradable under various conditions, chlorinated solvents are oxidized man-made compounds that primarily require **reductive processes** under anaerobic conditions for degradation. Consequently, in situ treatment requires a sophisticated approach to reagent delivery and subsurface geochemical manipulation.

Intended Use of This Document

This protocol assists base managers and project engineers in:

1. **Determining** if the edible oil process is appropriate for a specific site.
2. **Designing** and implementing an engineered edible oil system.
3. **Evaluating** and optimizing remedial performance over time.

While specifically discussing chlorinated compounds, the procedures are applicable to other contaminants subject to anaerobic biodegradation, such as **nitrates, perchlorate, and explosives (RDX or TNT)**.

Following the Edible Oil Process

The implementation of this technology follows a structured "Road Map" (see Figure 1.1). The process moves from preliminary screening (Section 2) to pilot testing (Section 3), followed by full-scale design (Section 4) and field implementation (Section 5).

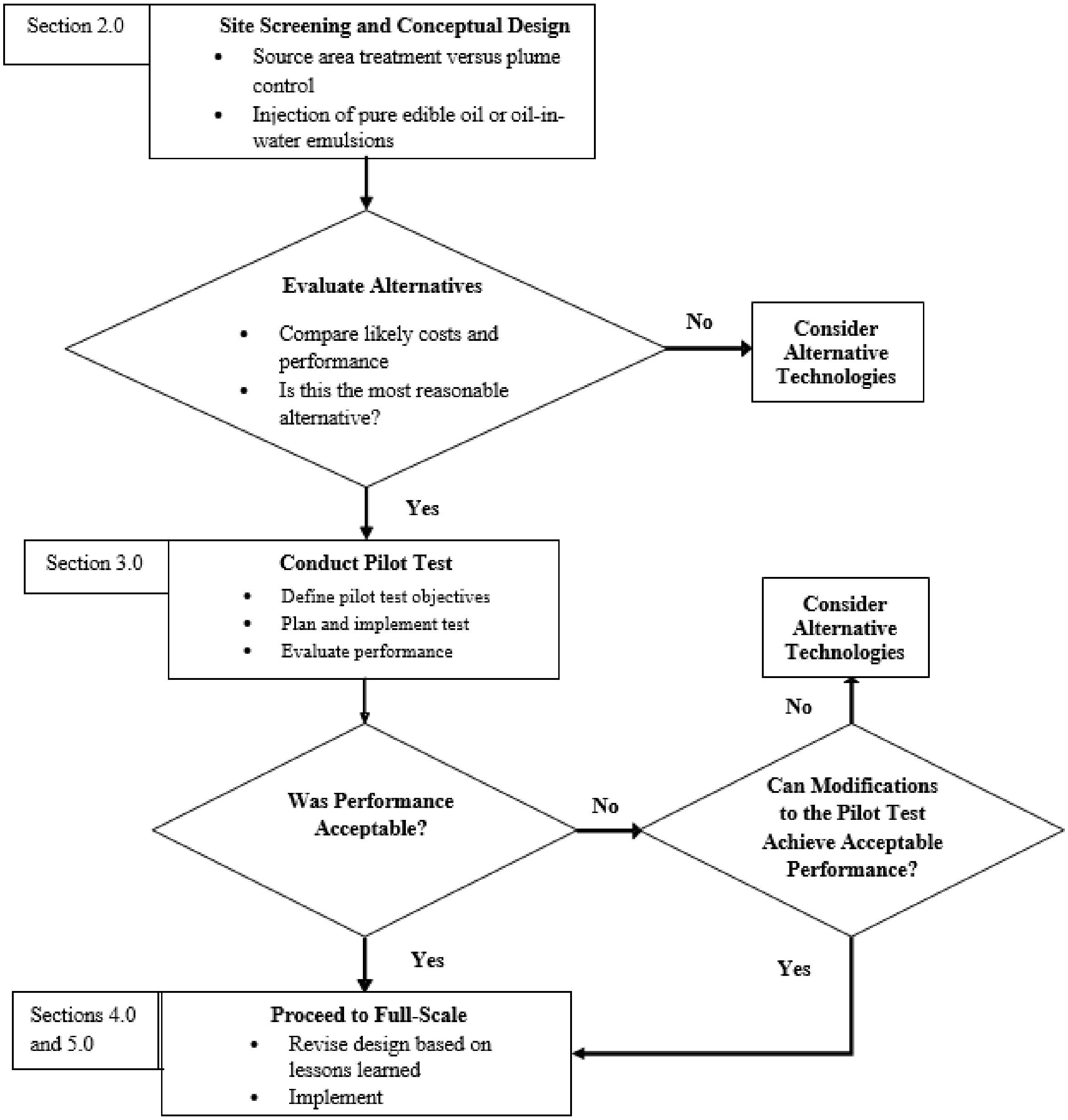

Figure 1.1: Road Map for Implementation of the Edible Oil Process

Defining Remedial Objectives

The edible oil process can be deployed in various configurations depending on the desired outcome. System objectives may include:

- **Destruction** of contaminant mass in source zones.
- **Reduction** of concentrations in a dissolved plume.
- **Control** of dissolved plume migration (containment).
- **Enhancement** of ongoing natural attenuation.
- **Polishing** step after aggressive remedies like thermal desorption.

⚠ **Safety Constraint:** Achievement of drinking water Maximum Contaminant Levels (MCLs) may not be possible at all sites. Risk-based remedial goals should be evaluated, especially in complex DNAPL source zones where mass transfer limitations exist.

Enhanced Anaerobic Bioremediation of Chlorinated Solvents

The most common contaminants addressed are **chlorinated aliphatic hydrocarbons (CAHs)**, including PCE, TCE, 1,1,1-TCA, and carbon tetrachloride. More highly chlorinated CAHs are more oxidized and thus more susceptible to anaerobic reductive degradation.

Biochemical Mechanisms

- **Reductive Dechlorination:** Microorganisms replace chlorine atoms with hydrogen. The sequence for ethenes is: **PCE -> TCE -> DCE -> VC -> Ethene**.
- **Cometabolism:** CAHs are reduced by enzymes produced during the metabolism of another compound without yielding energy to the microbe.
- **Anaerobic Oxidation:** Less chlorinated CAHs (e.g., VC) are directly oxidized to carbon dioxide and water under iron- or manganese-reducing conditions.
- **Biogeochemical Reduction:** The creation of an anaerobic environment facilitates the formation of reactive minerals (e.g., iron-monosulfides) that abiotically degrade CAHs.

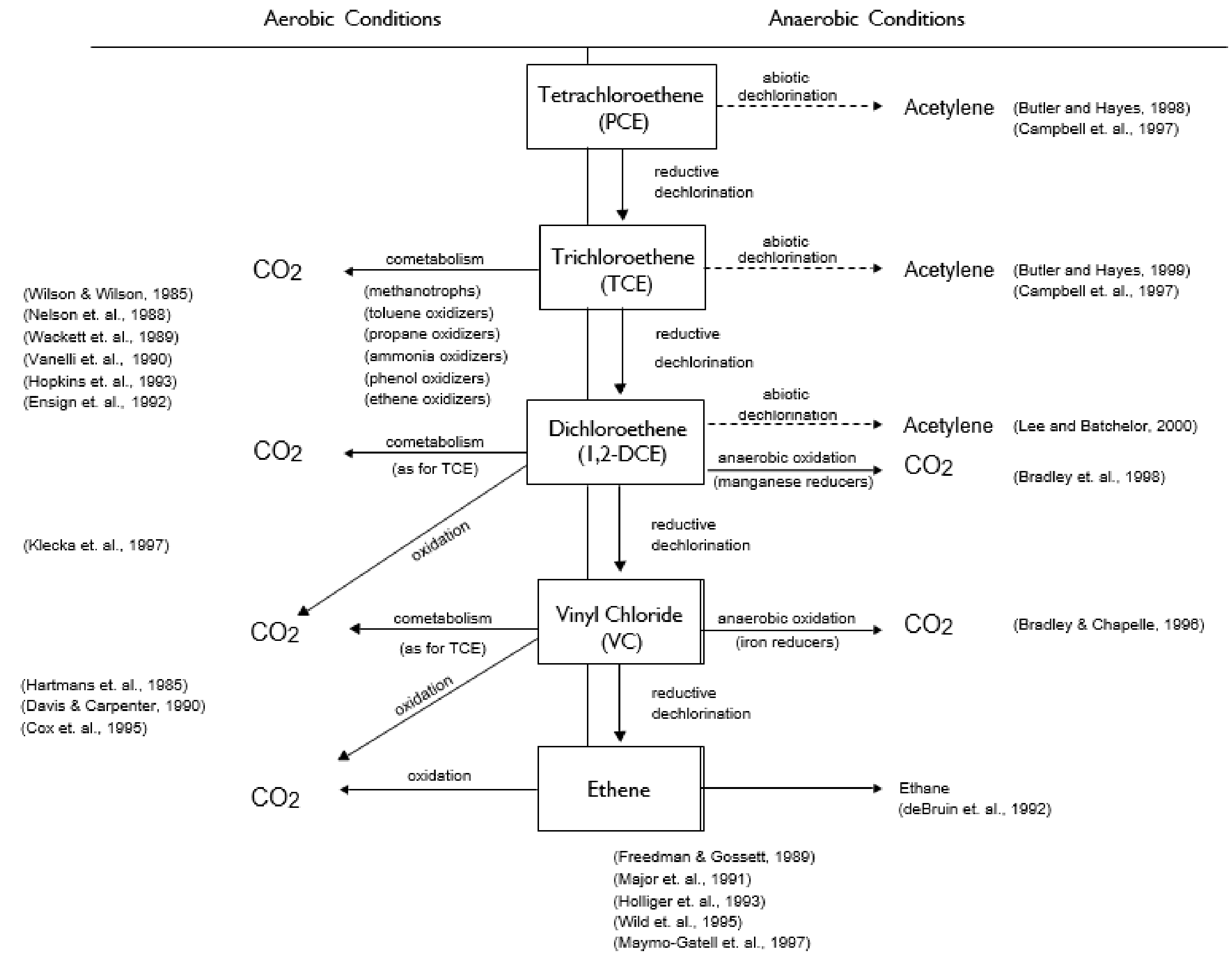

Figure 1.2: Pathways for the Degradation of Chlorinated Ethenes

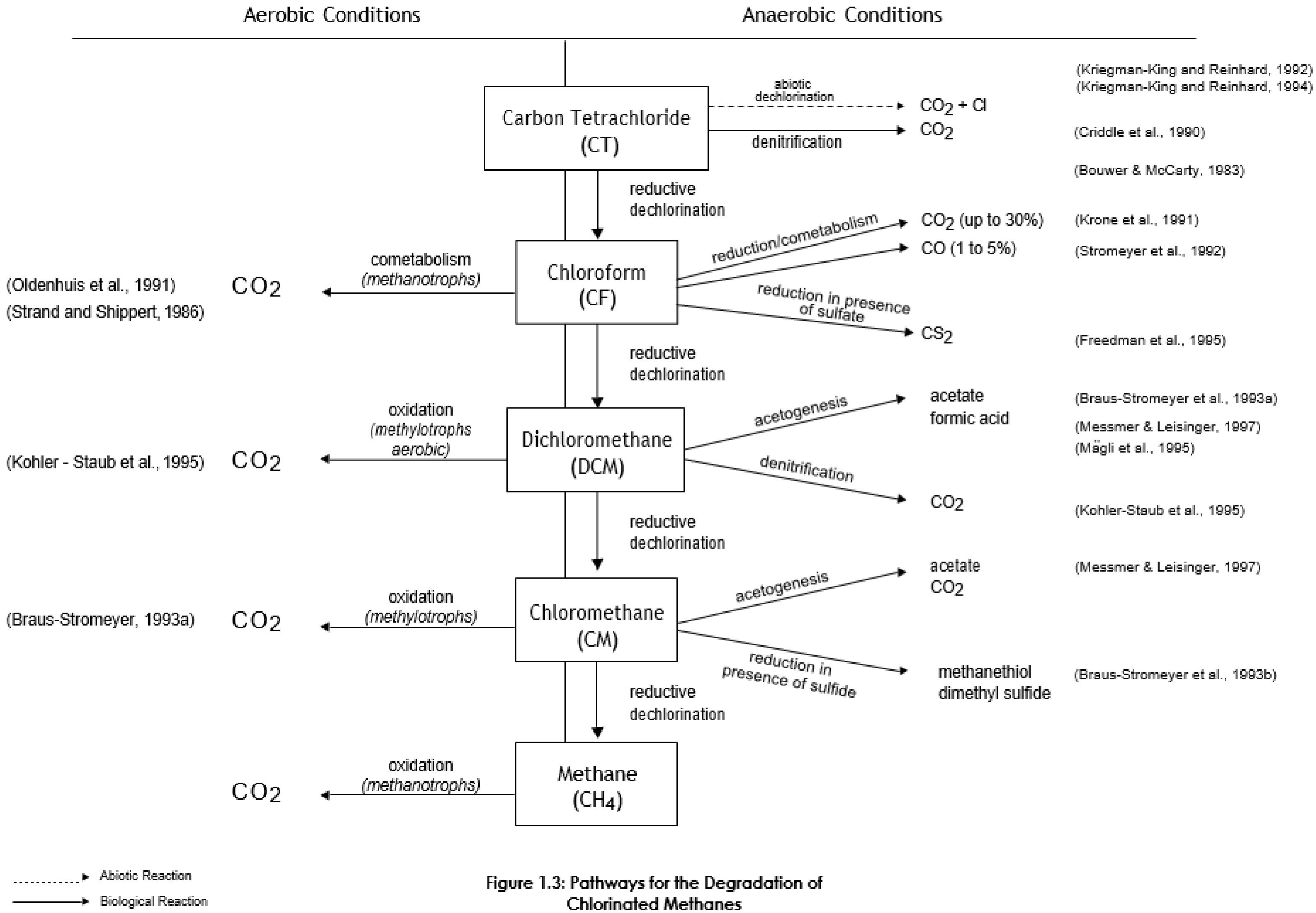

Figure 1.3: Pathways for the Degradation of Chlorinated Methanes