Design Considerations for In Situ Chemical Oxidation

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1.0 PURPOSE

Most in situ remediation systems including in situ chemical oxidation (ISCO) are less mature than ex situ remediation systems (e.g., pump and treat) and other conventional environmental systems (e.g., wastewater treatment systems); therefore, design information, formats, and standards for in situ remediation systems are generally not as readily available or as consistent. The lack of available standards causes the design submittals for in situ remediation systems to vary widely from one project to another.

The purpose of this course is to provide a framework for design and planning of ISCO systems. The document provides a summary of best practices for ISCO design, tips for appropriate quality assurance and quality control (QA/QC) measures, and a listing of available standards and references.

This course incorporates lessons learned from a multitude of hazardous waste sites on the design, implementation, and performance of ISCO. The information provided here can be readily incorporated into a design format suitable to the scope of the project.

2.0 REMEDIAL DESIGN DOCUMENTS

Remedial design documents should comprise the following components, at a minimum:

- **Basis of Design**: Conceptual site model (CSM), rationale for the design, calculations to support the design, and a description of the design
- **Drawings**: Detailed drawings to describe (prescriptive or performance-based) how to construct, operate, and maintain the system
- **Specifications**: Details of performance-based specifications on how to construct, operate, and maintain the system
- **QA/QC Plans**: Project-specific Contractor Quality Control (CQC) Plan with QA/QC provisions for monitoring construction (if required by the contract and as necessary to convey design-specific requirements [see Section 4])
- **Monitoring Plans:** Details of process and performance monitoring plans, including locations, monitoring parameters, sampling frequency (see Section 4.4).
- **Schedule and Milestones**: Remedial designs are typically performed in several phases. The first phase is the conceptual design (10 to 15% design). The conceptual design provides basic information about the project and includes the conceptual site plan and other preliminary drawings (see Section 5.0). The second set of design submittals (35 to 50% design) should convey the complete design, but in a preliminary manner. All necessary drawings should be included, but are not finalized and might not include all of the details necessary for implementation of the design. However, although all of the details may not be included, many times for environmental projects, the level of detail included in the 35 to 50% design package is sufficient for project execution. The 90 to 100% design consists of a very detailed design package, which could be required for very complex projects and would include all of the necessary details required for execution. The final 100% design package consists of submittal and acceptance of all reviewed and previously approved drawings and design elements.
- **Cost Estimate:** In some cases, a construction cost estimate is included with +/- 10% accuracy for bidding purposes.

Because of the simple nature of in situ remediation systems, remedial design submittals can be streamlined. However, regardless of the streamlining effort, the submittals should contain the design components discussed above. Streamlining efforts could be performed in the following ways:

- **Work Plan Approach**. This approach involves combining all components of the design submittals into a work plan format and submitting the work plan for client and regulatory agency approval in a three-phase review process: draft review, draft-final review, and final submittal. In some cases, if required, the draft review, draft-final review, and final submittal could correspond to the 15% to 35% design, which is equivalent to the conceptual design, 50% to 60%

design, which is equivalent to the preliminary design submittal, and the 90 to 100%, which is equivalent to the final design. For some contracts, it may be appropriate for a single contractor to develop the design from the concept through a more detailed level, which is a common element of a performance-based design contract. However, in other cases, it may be appropriate for one contractor to develop the conceptual design and a second contractor to finalize the design and implement it. For example, many times, the Comprehensive Long-Term Environmental Action contractor prepares the conceptual design that is used to bid the project and the Remedial Action Contract (RAC) contractor refines and finalizes the design after project award.

- **Design-Build Approach**. This involves a design-build approach, which is less prescriptive, but contains appropriate performance-based language and combines design drawings and specifications. A design-build approach is appropriate when site uncertainties necessitate that the design evolve during the course of the contract even after construction has commenced. These uncertainties can include gaps in site characterization data or using a treatment train approach (for which accurate design of the secondary or tertiary remedy is not possible until the primary remedy has been implemented). The objective of the design-build approach is to avoid prescriptive requirements that limit the range of options available to the remediation contractor. The frequency and level of internal design reviews are at the discretion of the client within the limits set forth in Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), and other state orders or permits. If a design-build contract is competitively bid, the award can be made based on a “Best Value” evaluation as opposed to “Lowest Price” to account for the fact that the proposed approaches could vary substantially due to site uncertainties. Evaluation criteria should include both technical understanding of the work and price. Technical understanding of the work may be demonstrated through various metrics including, but not necessarily limited to, experience with the proposed remedy, experience at the site or sites having similar conditions, and use of innovative technical approaches. As a result, it is necessary that proposal reviewers also have a detailed understanding of the site and the technologies that are proposed.

3.0 KEY CSM ELEMENTS

The CSM summarizes site conditions, the distribution, concentration, and fate and transport of contaminants of concern (COCs), potential receptors and exposure pathways, and land use data available for a given site. The CSM is a living model. It is developed based on data from the first investigation performed at the site and is continually updated throughout the lifecycle of the project to reflect new information as it becomes available. It must be reviewed, updated, and incorporated into each stage of the remedial design as the design progresses. In some cases, remedies fail because of an incomplete or improper CSM and/or failure to integrate the information presented in the CSM into the design of the remedy. This section provides an overview of key CSM elements needed to adequately describe the site and common pitfalls in site characterization that can lead to suboptimal designs of ISCO treatment systems.

3.1 Key CSM Elements and Potential Impacts to ISCO Designs

It is important to have a thorough understanding of the CSM when designing and applying ISCO treatment technologies. A detailed understanding of geochemical and lithologic characteristics of the site, flow and mass transport, and transformation and retardation of contaminants and the proposed oxidants is required to ensure adequate distribution and contact of the oxidant with the COCs. Failure to address these components in the design can have a negative impact on technology performance. Specifically, a CSM should take into consideration the site-specific factors listed in Table 1.

Several of these elements can have a significant impact on ISCO design and successful introduction and distribution of ISCO reagents into the subsurface (see Table 2).

Table 1. Key CSM Elements for ISCO Applications

CSM Element	Description
Nature and extent of contamination	Several factors help to determine the horizontal and vertical locations to introduce oxidants as follows: • Age and origin of COCs, COC physical and chemical properties (e.g., organic carbon-water partition coefficient [Koc], solubility) • Mass of COCs, horizontal and vertical distribution of COCs, and heterogeneity of COC distribution • Presence and distribution of non-aqueous phase liquids (NAPLs) – smear zone vs. clay lens
Human and ecological health risks	• Risks presented by COCs, as well as risks associated with the introduction and persistence of the oxidants (which can influence treatment endpoints, number of applications required, etc.)
Fate and transport of the COCs	• Determine how it impacts the location of injections, concentrations of oxidants, flowrates, and method of introduction into the aquifer
Site-specific infrastructure and characteristics	Several factors influence injection locations and overall strategy as follows: • Consider urban vs. rural environment • Presence of buildings and utilities • Proximity to nearby receptors • Current and future land use