PUMP-AND-TREAT SYSTEMS ARE A FACT OF LIFE – HOW DO WE OPTIMIZE THEIR EFFECTIVENESS?

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Background

Restoration of contaminated groundwater is one of the primary objectives of the Superfund and RCRA corrective action programs. The Superfund and RCRA programs share the common purposes of protecting human health and the environment from contaminated groundwaters, and restoring those waters to a quality consistent with their current or reasonably expected future uses.

Extraction of groundwater from the subsurface by means of wells, trenches, or other engineered technology, followed by *ex-situ* treatment of the extracted water to remove, destroy, or neutralize dissolved contaminants (i.e., groundwater "pump-and-treat"), is one of the most widely used groundwater remediation technologies, and is applied at about three-quarters of the Superfund sites where groundwater is contaminated, and at most sites where cleanup is required under RCRA or state regulations. Although the effectiveness of pump-and-treat systems has been questioned, this approach remains a common component of most groundwater remediation efforts after more than two decades of use.

Introduction

Optimization of a groundwater pump-and-treat system typically begins with a review of the remedy decision documents, system design criteria, historical operating information, and the conceptual hydrogeologic model upon which the remedy selection and design were based. Identification and evaluation of remedial action objectives (RAOs) established for the system is particularly critical, as RAOs typically are used by regulatory personnel as performance metrics, against which the effectiveness of the groundwater-extraction remedy is judged. A series of analyses then is completed, using qualitative and quantitative approaches, to evaluate the system in its current operational mode and configuration, and to develop recommendations for optimization of the extraction, treatment, and/or disposal components of the system.

Focus

Recommendations for optimizing groundwater pump-and-treat can range from simple (e.g., valve adjustments) to complex (e.g., reconfiguration or removal from service of some or all of the components of the system). In this session, we will accomplish the following:

1. Identify and answer key questions that RPMs should be asking their O&M contractors in order to assess current groundwater pump-and-treat system performance relative to RAOs;
2. Discuss the relevance of the conceptual site model (CSM) in selection and design of an appropriate remedy, and in evaluating and optimizing existing remedies;
3. Present recommendations regarding basis-of-design for pump-and-treat systems, techniques for analyzing system performance, and optimization implementation strategies, that can provide a defensible basis for system modifications, in order to increase the effectiveness and efficiency of pump-and-treat systems; and
4. Provide insight and examples on how to successfully negotiate remedy changes with regulators and other interested stakeholders.

Section 1—Key Questions to Ask During Initial Phase of Evaluation

Operations and maintenance (O&M) contractors tend to be comfortable with the status quo (i.e., continued operation of the existing system without any changes) unless provided other motivation. The RPM plays a key role in the attitude of the contractor. Suggested questions include the following:

1. Discuss progress towards meeting the RAOs and any changes to the timeframe.
2. Does the CSM appear to be complete, comprehensive, and correct? What unknowns remain?
3. Is the system being properly maintained? What is the up-time for the system? What is the contractor doing to reduce their costs?
4. Is the contractor capable of providing recommendations regarding potential improvements to the existing system? Can the contractor implement those recommendations and track the results?
5. How much contaminant mass has been removed, and how much mass remains? How much of the remaining mass is recoverable using the existing system?
6. How has the cost per pound of contaminant removed changed over time?
7. What masses of priority pollutants and greenhouse gases are being produced? How does this compare to the amount of contaminants removed?

Section 2—Evaluating the Conceptual Site Model

Determining realistic objectives and restoration timeframes for a pump-and-treat system (or any remedial technology) requires a degree of site characterization sufficient to define the complexity of the hydrogeologic setting, the subsurface distribution of contaminants, and the extent to which contaminants interact with subsurface media via the above mechanisms/processes. Such information makes it possible for the system operator to assess whether conditions at a particular site will result in tailing and rebound, and to evaluate the extent to which these conditions are likely to increase the time needed to attain cleanup standards.

The hydrogeologic conceptual model of a site describes the groundwater and surface-water systems at the site, the relationships among the systems, and their spatial and temporal evolution. A hydrogeologic CSM is a comprehensive summary of site conditions, and should not be confused with the diagrammatic conceptual exposure models commonly used in risk assessments to summarize completed contaminant migration/receptor exposure pathways. At a minimum, an adequate hydrogeologic CSM should incorporate the following information:

- A description of general regional and local geology, including lithology, stratigraphy, structure, and geologic history;
- Identification of principal hydrogeologic units;
- The hydraulic properties of the different hydrogeologic units;
- The elevation and configuration of the potentiometric surface(s);
- Surface drainage configurations, and hydrologic boundaries;
- Surface-water and groundwater interactions;
- Source(s) of contaminants;
- Direction(s) and rate(s) of contaminant migration;
- Biogeochemical processes controlling contaminant fate; and
- Locations of receptor exposure points and potential exposure pathways.

The CSM provides the basis for understanding the occurrence and movement of contaminants at the site, and incorporates and organizes the geologic and hydrologic information into a framework that can be used to guide site investigations and subsequent remediation activities. Without an adequate conceptual understanding of the hydrogeologic framework and the relationships among the components of the hydrologic system, subsequent investigation activities will not generate conclusions that can be used with any confidence to make remedial decisions. In addition, the CSM provides the technical foundation for evaluating the performance of any remedial actions (including groundwater pump-and-treat systems), and for identifying appropriate remedial approaches for final implementation.

A CSM represents a set of statements of fact and hypotheses regarding the conditions and processes that are active at the site; and improved understanding of conditions and refinement of hypotheses resulting from additional information cause the CSM to evolve as characterization and remediation activities progress. Sufficient data should be collected, compiled, and interpreted prior to remedy selection and design, thereby generating a CSM that will be adequate for use in this selection. However, some potentially-important information always will remain unknown at the time a remedy is selected and implemented. In fact, operation of a remedial system can provide unique opportunities for collecting additional information to be incorporated into the CSM. In order to optimize any remedy, the CSM must be updated and refined as new data are gathered, so that appropriate changes to the remedy can identified and implemented. Updating the CSM is essential to effective system optimization.

Key questions to be addressed in using the CSM to select optimal remedies, or to optimize existing remedies, include:

- How much understanding is needed before proceeding with remediation?
- Do the data that have been collected during installation, operation, and monitoring of the selected remedy support or contradict the primary elements of the CSM?

Section 3—Optimizing the System

Ultimately, the effectiveness of any remediation system (including groundwater pump-and-treat systems) is judged by evaluating the degree to which it achieves its objectives. The efficiency of the system is considered to be optimal if it is effectively achieving its objectives at the lowest total cost, and/or in the shortest period of time. In general, two primary remediation objectives are associated with conventional groundwater extraction (i.e., pump-and-treat) systems: removing contaminant mass from the subsurface, and establishing or maintaining hydraulic control of groundwater movement to restrict or prevent continued migration of dissolved contaminants in groundwater. The effectiveness of a groundwater extraction system, and of the individual wells in the system, can be evaluated qualitatively and/or quantitatively in terms of the two complementary objectives – mass removal and plume containment. Although incremental improvements in the effectiveness and efficiency of a groundwater extraction system may be achieved through changes in well placement or depth intervals of extraction, the opportunities to optimize an operating groundwater extraction system must be addressed in terms of the physics of the system and the nature and distribution of contaminants in groundwater.

Possible recommendations for optimizing a groundwater pump-and-treat system may include:

- Reducing the number of groundwater extraction wells;
- Increasing the number of groundwater extraction wells;
- Changing the locations or extraction rates of operating wells;
- “Cycling” the extraction system;
- Changing the technology used for post-extraction treatment and/or disposal of water; and
- Selecting and implementing a more effective alternative remedy.

Section 4—Negotiating Changes to a Remedy

Both the Superfund response action and RCRA corrective action programs have been evolving over the past decade, primarily in response to direct reform efforts and maturing programmatic experience. All of the Superfund and RCRA reforms completed to date have been intended to accomplish various goals, ranging from national programmatic changes to changes affecting individual sites at every stage of the cleanup and enforcement processes. In general, all of the Superfund and RCRA reforms are intended to foster faster, more efficient, and results-based approaches to corrective action. To accomplish this, USEPA has encouraged the regulatory community to:

- Provide tailored oversight;
- Use holistic approaches (e.g., facility-wide corrective action measures);
- Exercise procedural flexibility (e.g., emphasize results over mechanistic process steps);
- Set performance standards (e.g., define cleanup expectations early); and

- Target data collection (e.g., characterization plans based on site-specific data-needs analysis rather than presumptive requirements).

The Superfund and RCRA reforms also have resulted in the development of clarifying technical guidance materials designed to review relevant policies and expectations involved in cleanup decisions. Emphasis has been placed on corrective-action development and design, treatment of principal threats, preference for permanence, establishment of cleanup levels, use of alternate cleanup levels, and establishing the degree to which corrective actions must protect human health and the environment.

The flexible cleanup paradigm encouraged by the Superfund and RCRA reforms represents a significant opportunity for negotiating changes to proposed or operational remedies, because rather than focusing on procedures and mechanistic approaches to cleanup that may not be justified given specific site conditions (e.g., groundwater pump-and-treat systems), the regulatory reforms encourage the regulatory community to implement creative and possibly unique solutions to environmental restoration problems.

Of particular relevance to optimization efforts are recent guidance documents developed by USEPA related to selecting and/or updating remedies where significant new scientific information, technological advancements, or other considerations will allow the current level of protectiveness of human health and the environment to be achieved in a more cost-effective manner. Related reforms address the question of when changes in a remedy may be warranted and appropriate. The latter initiative generally applies to issued RODs, although the technical basis of these changes could be equally important during the pre-decision phases as well. The objectives of these reforms are consistent with the intent of system optimization: improving the cost-effectiveness of site remediation while ensuring reliable short- and long-term protection of human health and the environment.

Recent experience suggests that implementation of the “Core Team” approach to remedy selection and operational oversight — which generally can be described as a formalized, consensus-based process in which those parties with decision-making authority work together to reach agreement on key remediation decisions — is critical to effectively incorporating the information generated by a remedy evaluation into the development of remedial decisions, which are integrated with and supportive of clear, long-term exit strategies. The Core Team (i.e., the facility operator or responsible party, the PRP’s consultant, and the appropriate regulatory agency[ies]) is responsible and accountable for identifying site problems and sufficiently defining them to ensure that appropriate remedial measures are selected and implemented. However, working together as a team does not change the roles or responsibilities of the agency representatives; rather, the strength of the Core Team approach is improved communication among all involved stakeholders so that regulators can more effectively oversee remedial progress. An effective Core Team approach requires that each Team member be provided an opportunity to express his or her views or concerns (e.g., perceptions of risk, questions about data interpretations). The objective is to narrow the planning process to the important issues and concerns that must be clearly addressed to support a defensible remedial strategy, including system optimization or selection of an alternative remedy, if appropriate, and identifying the basis for system shutoff.