# PASSIVE REMEDIATION AND OPTIMIZED MONITORING

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## ABSTRACT

In recent years, perceptions of the environmental industry's ability to remediate large and/or complex groundwater plumes have changed markedly. Pump-and-treat remedies were once universally presumed to be capable of returning contaminated aquifers to beneficial use within a reasonable time frame. However, three decades of pump-and-treat operations have shown that, although these systems can remove significant quantities of contaminants, this approach often fails to return contaminated aquifers to beneficial use in the expected time frame. In many cases, contaminants remain in groundwater at levels above Maximum Contaminant Levels (MCL) even after many years of pump-and-treat remediation.

Other remedies developed after pump-and-treat were anticipated to be the "silver bullet" of remediation. Unfortunately, results similar to pump-and-treat remedies were seen only after several years of operation. It was found that remediation rates, though often rapid in the early years, decreased as MCLs were approached. It now appears that many sites, particularly those with recalcitrant contaminants present as dense non-aqueous phase liquids (DNAPL) and complex geology, may require many decades or even centuries to reach closure. As a result, long-term, low-cost, and low-maintenance remedial strategies are needed to provide a means to ensure that remedial goals are achieved at these sites.

Dynamac Corporation is currently developing an approach called Passive Remediation and Optimized Monitoring (PROM) as a sustainable solution to the economic challenges posed by legacy sites. This two-component approach first analyzes the environmental challenges posed by the site and selects remedies with the lowest long-term operation and maintenance (O&M) costs. This remedy selection primarily focuses on passive, low O&M technologies such as phytoremediation, monitored natural attenuation, impermeable caps, barrier walls, and permeable reactive barriers. Multiple remedies may be implemented simultaneously to achieve site-specific goals. Once the appropriate remedial approach has been selected, the historical dataset is statistically analyzed to determine temporal and spatial variations in measured parameters. Temporal analyses are used to determine the appropriate sampling frequency, while spatial variations are analyzed to segregate the plume into representative units in order to determine sampling locations. The results of these analyses are used to construct a matrix that indicates the parameters that require measurement, which wells should be measured, and how often the parameters should be measured. Case studies, system approach, and logic will be presented.

## INTRODUCTION

Long-term costs for groundwater remediation projects are growing, persistent, and not fully predicable for both publicly and privately financed cleanup projects. The main components of these costs are long-term monitoring and O&M . The cost for each of these components has far exceeded initial expectations and projections.

This paper reports the results from the application of passive remediation and optimized monitoring at sites throughout the United States. Methodologies and case studies from the United States Environmental Protection Agency (EPA), the Department of Defense (DoD), the Department of Energy (DOE), and the private sector are presented.

The experience of the DoD and others shows that annual savings of about 30% can be achieved after a systematic review of installed remedial systems.

## REMEDIAL SYSTEM OPERATION AND MONITORING

In 2004, the EPA defined monitoring as:

“…*collection and analysis of data (chemical, physical, and/or biological) over a sufficient period of time and frequency to determine the status and/or trend in one or more environmental parameters or characteristics…related to the management objectives for the site in question*.”

Long-term monitoring programs are often crafted from pre-existing site characterization networks. These site characterization networks were designed to define the nature and extent of the problem, often when very little was known about the site’s history and environmental problems. Consequently, they are often ill suited to the task of monitoring the effectiveness of a remedial system. Challenges include:

- Despite diligent expansive data collection and analysis efforts, long-term monitoring programs fail to answer the most basic question: *Is the remedy effective and protective?*
- Long-term monitoring programs can also yield too much information, far more than is needed to make decisions about the effectiveness of the remedial operation and the need for its continuance.

Optimization of long-term monitoring seeks to achieve monitoring objectives with an appropriate level of effort. Optimization can reduce costs and protect against potential impacts to the public and the environment. The opportunity to achieve cost reduction and public protection increase as the remedy advances and monitoring results become more stable and more predictable; and the spatial extent of the contamination subsides. Monitoring frequency, locations, and analytical requirements can be diminished and restructured to maintain an adequate understanding of site conditions and support decision-making while reducing costs.

In addition to monitoring costs, routine O&M also generates significant costs. These include management, oversight, operations labor, maintenance labor, electricity and other utilities, supplies, equipment, and fees. Initial remedies are often active and aggressive. They focus on source control, removal, and remediation. As these initial measures gain success, passive remedies emphasizing maintenance and control can be appropriate and far more cost-effective.

## OPTIMIZATION TECHNIQUES AND RESULTS FOR REMEDIAL SYSTEMS

Over the past few years, many Federal agencies have worked to reduce their remediation and monitoring costs. In many cases, they have developed protocols and procedures for optimizing long-term remediation and monitoring.  For example:

- The Air Force Center for Environmental Excellence (AFCEE) and the Defense Logistics Agency (DLA) have developed "Remedial Process Optimization" [2].
- AFCEE developed Monitoring and Remediation Optimization System (MAROS) software, which is a decision support tool based on statistical methods applied to site-specific data that accounts for relevant current and historical site data as well as hydrogeologic factors (e.g., seepage velocity) and the location of potential receptors (e.g., wells, discharge points, or property boundaries). Based on this site-specific information the software suggests an optimization plan for the current monitoring system in order to efficiently achieve the termination of the monitoring program. Thus, MAROS provides site managers with a strategy for formulating appropriate long-term groundwater monitoring programs that can be implemented at lower costs.
- The DOE developed technical guidance for long-term monitoring of natural attenuation remedies [3].
- The U.S. Army Corps of Engineers (USACE) developed the remedial system evaluation protocol [4].
- The U.S. Navy formalized its guidance for optimizing remedial operations [5].
- Most recently (August, 2004), the EPA issued its "Action Plan for Ground Water Remedy Optimization" [6], which will "fully integrate optimization into the Superfund cleanup process."

While they vary in form and approach, all of these systems share some common objectives including identification, review and evaluation of:

- Protection of human health and the environment;
- Site-specific O&M cost drivers;
- Contaminant distribution;
- Regulatory drivers;
- Monitoring program (location, frequency, analytes, analytical methods);
- Accelerated site transfer or closure; and
- Closure strategy and plans.

What have all of these efforts accomplished? Do they result in cost savings? Can they be applied to private sector sites or do they work only for Federal cleanups? Dynamac participated in two recent EPA studies to help answer these questions.

The first study, completed in November 2002, evaluated pump-and-treat remedies at Superfund-financed sites [7]. In this study, 20 Superfund-lead pump-and-treat sites were evaluated with the purpose of providing recommendations to improve remedy effectiveness, reduce remedy costs, improve technical operations and achieve site closeout. Each site was evaluated using the USACE Remediation System Evaluation (RSE) procedure.

The RSE process is a comprehensive expert evaluation of an operating remediation system. The RSE process includes reviewing site data, visiting the site for one to two days, submitting a draft report for review by the site managers, and finalizing that report considering the comments from the review. For each site evaluated, the RSE team is composed of senior process engineers, senior hydrogeologists, EPA and state Remedial Project Managers (RPM), and site contractors. Each team evaluates the following items:

- System goals,
- Site conceptual model,
- Extraction well network,
- Above-ground treatment system,
- Groundwater and treatment process monitoring,
- System effectiveness with respect to protection of human health and the environment,
- Data management, and
- Costs.

During the site visit, the RSE team tours the facility and surrounding area and interviews the site managers, contractors, and key regulators, including both the EPA and State regulators. Next, the RSE team develops a report documenting their findings and presents recommendations to improve the remedy. The recommendations typically fall into the following categories:

- Improve system effectiveness (i.e., the ability to meet stated objectives of protecting human health and the environment);
- Reduce life-cycle O&M costs;
- Technical improvement; and
- Improve the likelihood of site closeout.

The most common cost reduction recommendations were:

- Reduce groundwater or process treatment monitoring,
- Replace existing treatment components with more efficient units or technologies,
- Simplify existing system and/or remove unnecessary treatment components,
- Consider alternate discharge options for treated groundwater,
- Reduce labor costs, and
- Reduce oversight or project management costs.

The 20 sites evaluated had annual O&M costs ranging from under $100,000 per year to approximately $3.4 million per year. The total annual O&M cost for these 20 sites is approximately $13.3 million per year. Cost saving opportunities were found at 17 of the 20 sites. The estimated capital cost for implementing all of these recommendations was $3.5 million, but annual cost savings would be approximately $5.1 million. This is a 38% decrease in annual O&M costs. Such savings over a long time period are very significant. EPA's second study, completed in September 2004, looked at optimization efforts at five RCRA corrective action facilities [8]. These pump-and-treat sites were evaluated with the purpose of providing recommendations to improve remedy effectives, reduce remedy costs, improve technical operations and achieve site closeout. The study's method and approach closely followed the approach used by the EPA at the Superfund-lead sites [7]. These evaluated sites were all privately funded. Even so, the RSE process revealed significant opportunities for cost savings: implementation of all recommendations would reduce O&M costs by 21%. The types of cost savings identified were very similar to those found for the Superfund-lead sites.

The EPA has also looked for methods to optimize remediation of radionuclides, including an extensive study of biological remediation for radionuclides [9]. In addition, the EPA is working on additional guidance documents on Monitored Natural Attenuation, which include the following:

- **Site Characterization For Monitored Natural Attenuation**, which will describe site characterization data, methods, and study designs used to characterize natural attenuation processes.
- **Monitored Natural Attenuation of Inorganics**, which will be similar to the MNA Directive [10], but specifically tailored to inorganics including radioactive contaminants.

In addition, the EPA recently published guidance on long-term monitoring for remedies using monitored natural attenuation [11], which provides guidance on the types of data required to evaluate and quantify the effects of the natural attenuation processes at a site. It also provides guidance on obtaining necessary data in a scientifically defensible manner.

## CONCLUSION

Federal agencies continue to seek methods to optimize their long-term remedial obligations and costs. It is noteworthy that the EPA itself is adopting optimization methods at the sites where it is responsible for cleanup. The goal is to reduce long-term monitoring and remedial costs and accelerate site closeout while meeting site cleanup objectives. The major categories for potential cost savings are optimized monitoring, O&M changes, using more “passive” remedial technology methods, and developing strategies to accelerate site closeout.

Long-term monitoring programs are often crafted from pre-existing site characterization networks. These site characterization networks were designed to define the nature and extent of the problem, often when very little was known about the site’s history and environmental problems. Consequently, these networks are often ill suited to the long-term monitoring task at a significantly, but incompletely, remediated site. In such cases, optimization of a long-term monitoring program can provide significant benefits, due to the typically long time periods before monitoring can be discontinued.

Optimization of O&M can also yield significant cost savings. These can arise from reductions in labor, utilities, management, oversight, and the use of remedial technologies better suited to the final stages of site remediation (e.g., bioremediation and monitored natural attenuation).

Passive remediation and optimized monitoring are proven, technically feasible, and readily available. Furthermore, they are accepted by regulators, used by regulators, and offer significant cost savings.

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