A NATIONAL OVERVIEW OF MONITORED NATURAL ATTENUATION AND ENHANCED ATTENUATION—RESULTS OF AN INTERSTATE TECHNOLOGY REGULATORY COUNCIL SURVEY

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ABSTRACT: To facilitate an understanding of key issues related to approving monitored natural attenuation (MNA) as a stand-alone remedy or as a component of a larger remedy for a chlorinated solvent site, the Interstate Technology & Regulatory Council (ITRC) Enhanced Attenuation: Chlorinated Organics (EACO) Team conducted a survey of state regulators from state environmental remediation programs. The 2005 survey was designed to evaluate factors involved in decisions on the acceptability of MNA and to determine interest in new concepts to facilitate transition from initial treatment methods to MNA. Respondents included 38 regulators from different environmental programs in 30 states. Data were collected on the respondents' programs, number of sites they had regulated that incorporate MNA, factors contributing to approval/disapproval of MNA, and the protocols/guidance used in making those determinations. Respondents were also queried on their support of and interest in enhanced attenuation (EA) technologies. Survey results indicated that most states dealing with chlorinated solvent sites accept MNA as a viable remediation technology. Generally, state regulators use U.S. Environmental Protection Agency (EPA) protocols or similar state protocols when evaluating MNA proposals. Models are frequently used and considered to be useful, and simple models appear to be more accepted than more complex models. The response was generally positive to the use of EA as a transitional remedial approach and the use of mass balance and flux measurements as tools to scientifically evaluate these alternative remedial approaches.

INTRODUCTION

Although regulators have generally accepted MNA as a viable remediation technology for highly degradable petroleum contamination, the national use and acceptance of MNA for chlorinated solvents is less clear. As in the case with any remedy acceptance, regulatory approval is necessary for MNA to be implemented. The acceptability of MNA by state regulators is typically based on (1) their experience with chlorinated solvent sites, (2) their experience with the use MNA, (3) whether the state has protocols in place for evaluating MNA proposals, and (4) their understanding of these protocols in evaluating the effectiveness of MNA at a particular site.

To obtain a better understanding of the overall experience and acceptance that state regulators have with MNA at sites where chlorinated solvents are impacting groundwater, the EACO Team surveyed state regulators. The survey was constructed to obtain a general idea of regulatory acceptability of MNA for chlorinated solvent sites. Its objective was to secure responses from regulators representing a broad spectrum of regulatory programs that deal with chlorinated solvent sites by querying the regulators on how many chlorinated solvent sites their programs oversee along with the number of MNA proposals submitted and approved for these sites. The survey was also designed to determine which protocols are currently being used by state regulators for the evaluation of MNA proposals, whether models are accepted, and if so, the usefulness and types of models used. The final section of the survey asked about different types of innovative technologies classified as EA technologies and the potential acceptability of these technologies by the regulators.

SURVEY STRUCTURE

The survey comprised 122 questions, either multiple choice or text answers. Questions were categorized by topic and divided into five sections. The first section determined which states and regulatory programs were responding to the survey. The second section aimed to better understand which programs within the state regulatory agencies are accepting MNA as part of a larger remedy or as a sole remedy for chlorinated solvent plumes. The third survey section asked about the tools and policies state regulators are using to evaluate the acceptability of MNA for chlorinated solvent plumes. The fourth section focused on the importance of data and modeling tools. The last section introduced the concepts of mass balance and EA, provided a list of different remedial technologies classified as EA, gauged the general level of support for these concepts, and asked which of these technologies regulators would support as part of a remedial action.

DATA-COLLECTION METHODS

A Web-based survey was published on the ITRC Web site May to September 2005. Requests to complete the survey were submitted to 44 ITRC state point-of-contacts (POCs, i.e., liaisons between state regulatory agencies and ITRC) across the United States. The POCs were asked to have representatives within their regulatory agencies that dealt with the remediation of chlorinated solvent plumes respond to the survey. Respondents were asked to complete the online survey and were told that it would take approximately one hour to complete. All survey responses were compiled in an online database. Not all respondents answered all questions.

EVALUATION OF SURVEY RESULTS

Respondent Demographics and Regulatory Program Jurisdictions. Members of the ITRC EACO team evaluated the survey results. Thirty-nine responses were received from regulators from 31 different states, as shown in Figure 1. One response and the corresponding state was discounted since the respondent represented a program associated with no chlorinated solvent sites. Of the 38 remaining respondents, 32 worked in programs with statewide jurisdiction, one had jurisdiction over a region within a state, and two performed regulatory oversight of specific U.S. Department of Energy facilities in their states.

FIGURE 1. States represented in survey response (darkened).

(Four did not respond to this question.) The respondents represented multiple programs within their states, including Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) programs, dry cleaner, brownfield and voluntary cleanup programs, and other state and federal programs. Figure 2 depicts the number of programs represented.

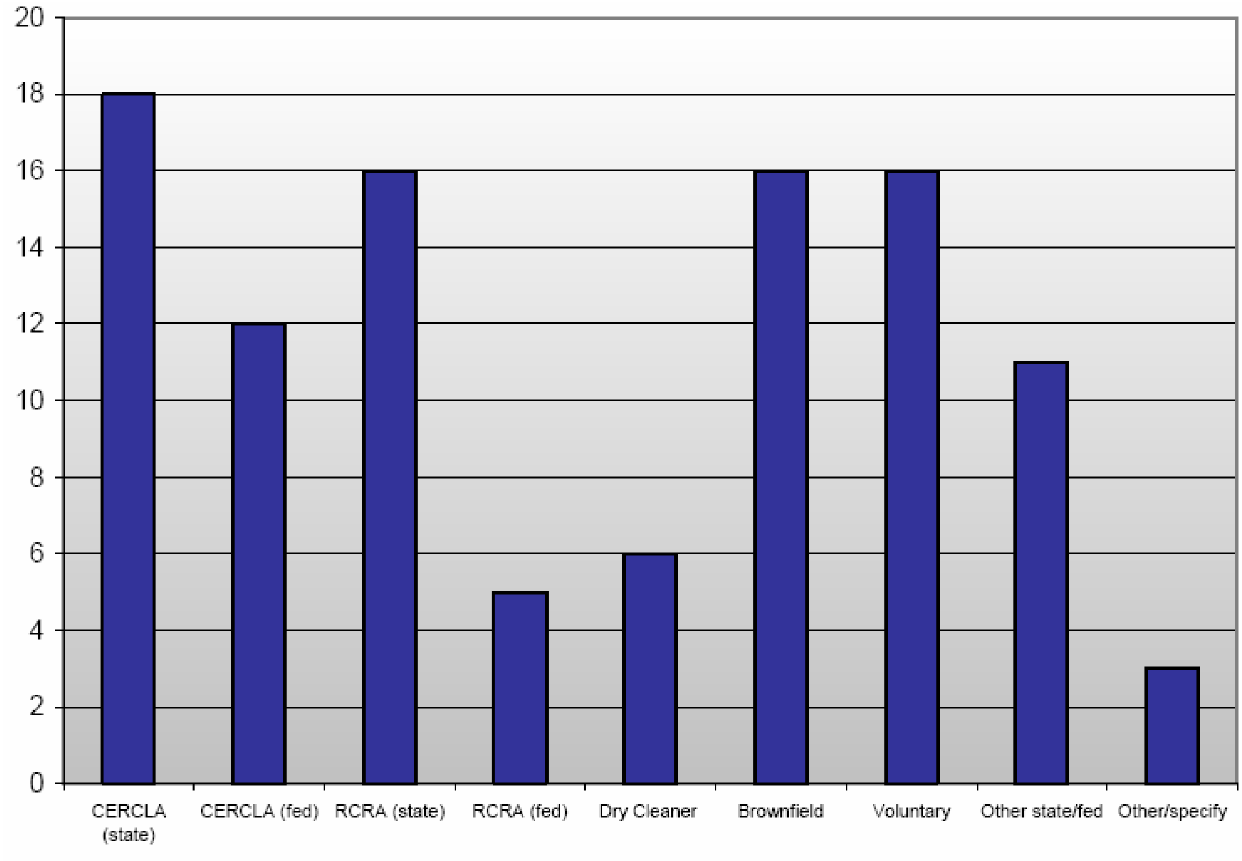


FIGURE 2. Breakdown of regulatory programs represented in the survey.

General Experience with MNA within Each Program Jurisdiction. This section of the survey elicited information related to both experience with and approval/disapproval of MNA for chlorinated solvent plumes. Due to the design of the survey, all programs represented should have had some experience with chlorinated solvent groundwater contamination. Fifteen respondents indicated that their programs had 1–50 chlorinated sites within the programs, 16 indicated that their programs dealt with 51–200 sites, and five respondents replied that their programs had more than 200 sites where chlorinated solvents were present.

Of the 38 respondents, five indicated that the programs they represented have not approved MNA for chlorinated solvent sites. Of these, two indicated that MNA was not a currently accepted remedial technology within their programs, and the other three noted rationales comparable to the responses from the other respondents as reasons for not approving MNA. It is important to note that three of these five respondents had not received any MNA proposals and that the other two had received fewer than five such proposals.

Of the 33 respondents that indicated MNA had been approved for at least one site within their programs, seven respondents had received fewer than five MNA proposals, the majority (16) had received 5–24 MNA proposals, two had received 25–45, and seven had received more than 45 such proposals (one respondent did not answer this question). Evaluation of this data indicates that an increasing approval rate for MNA proposals has a strong correlation with the number of MNA proposals received by a regulatory program. It is interesting to note that most of the MNA proposals submitted were in combination with active treatment systems and that MNA was seldom proposed along with a passive treatment technology such as a permeable reactive barrier, although we did not collect information on how many passive treatments technologies are being proposed.

Of the MNA proposals that had been approved, 15 respondents indicated that none of the sites in their programs had gone through completion. Nine of the respondents replied that fewer than 10% of the sites had gone through to completion, three indicated that 10%–60% had gone through completion, and only one indicated that more than 60% had been completed. This result indicates that, although a significant number of MNA remedies have been implemented, it may be premature to evaluate their success in providing a path to reach remedial goals.

MNA Protocols, Policies, or Guidelines. The EACO Team survey included a series of 12 questions that asked regulators to identify state-specific protocols, policies, or guidelines for using MNA to remediate sites with chlorinated solvent contamination in groundwater. The vast majority of respondents indicated that their states rely on either the EPA protocol for evaluating MNA at chlorinated solvent sites (EPA 1998), the EPA OSWER Directive (EPA 1999), or state protocols, policies, or guidelines that are based primarily on the EPA protocol or OSWER Directive. A majority of the respondents also indicated that site-specific calculations are very important to the approval of MNA at chlorinated solvent sites. Of the 30 states covered in the EACO survey, 15 were reported to have state-specific MNA protocols, policies, or guidelines. In most of these states, MNA policies are generally based on the use of MNA at petroleum hydrocarbon sites, although some states are developing specific documents relating to the use of MNA at chlorinated solvent sites.

Issues Affecting the Approval of MNA. MNA is being approved by regulators and used as a groundwater remedy on a regular basis through out the United States. However, five of the 38 respondents indicated that MNA has not been approved for chlorinated sites within their programs; two of these indicated that MNA is still incompatible with current state policies. Other reasons MNA approvals had not been granted, according to these five respondents, were that sites were being effectively treated by other means or that there was still a lack of confidence in the MNA process. Respondents who indicated that an MNA proposal had been approved within their program were asked a series of questions about the factors important in evaluating a proposal. According to the responses, significant reasons for not approving MNA were (1) the groundwater plume was impacting a receptor, such as a drinking water well; (2) the plume was determined to be expanding; (3) the contaminated sites were already being effectively treated using other methods; (4) site-specific conditions were not favorable; (5) the proposal was incomplete or of poor quality; and (6) the MNA proposal did not contain an appropriate timeframe to reach regulatory goals.

Use and Importance of Data and Modeling Tools in MNA Decision Making. Characterization and monitoring are key components in determining whether natural attenuation processes are contributing to the remediation of a contaminant plume. EPA's technical protocol for evaluating natural attenuation of chlorinated solvents in groundwater (EPA 1998) provides guidance based on the three lines of evidence for characterizing sites: (1) groundwater and/or soil chemistry data that demonstrate clear and meaningful decreasing concentration trends over time, (2) hydrogeologic and geochemical data that can be used to indirectly demonstrate natural attenuation processes active at the site along with reduction rates, and (3) data from field microcosm studies. The survey asked respondents to qualify the relative usefulness of collecting characterization data in accordance with these different lines of evidence in evaluating the approval of an MNA remedy. The results, as shown in Figure 3, indicated that parameters identified as the first line of evidence by EPA are considered the most useful collected data. The collection and usefulness of the second and third line of evidence data is more variable.

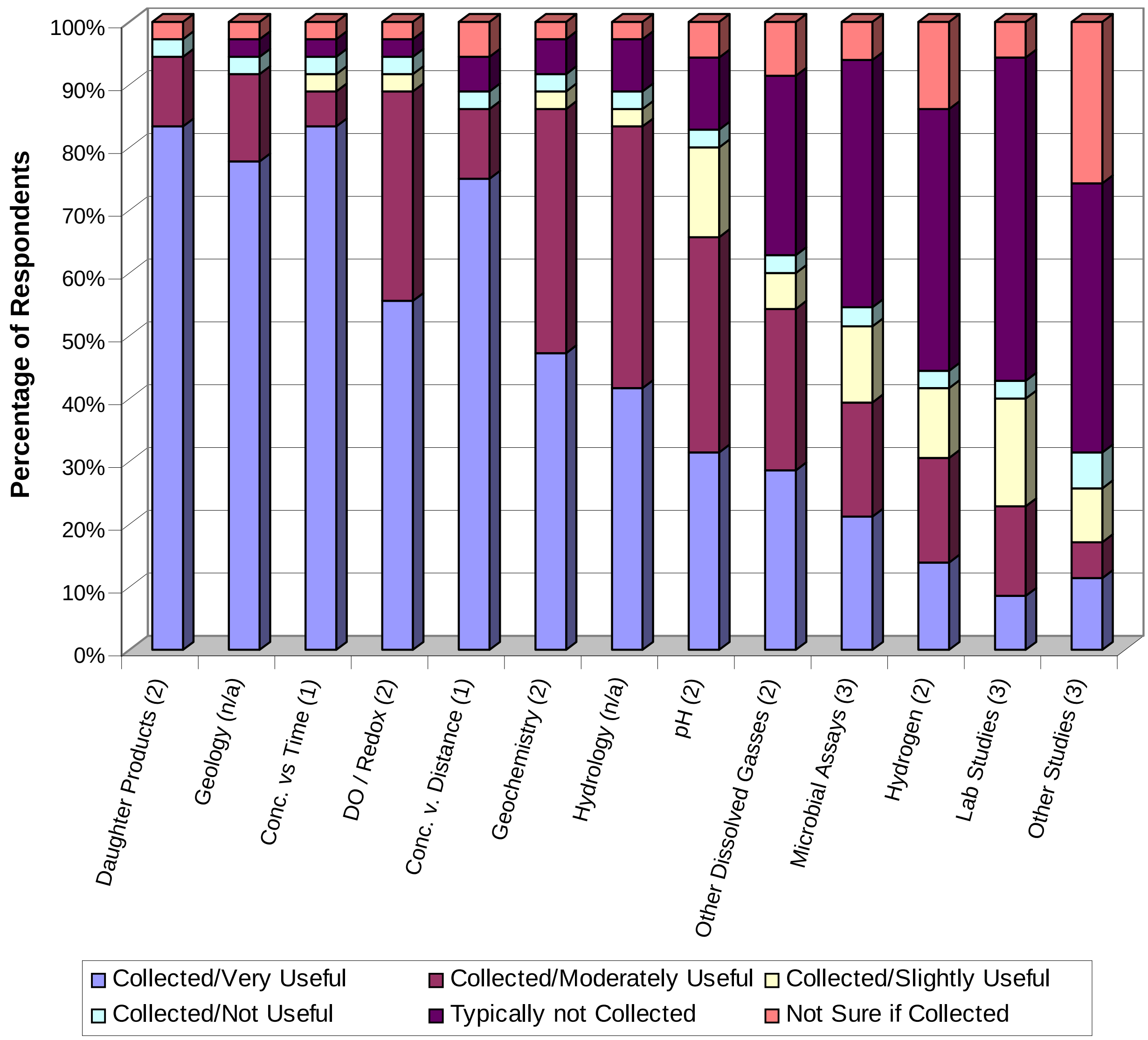


FIGURE 3. Use and importance of data collected for MNA decision making.

Interestingly, only 44% of the respondents characterized geochemical measurements as being very useful when evaluating the efficacy of MNA for chlorinated solvent sites. This is a surprisingly low portion, given the importance of this information in evaluating natural attenuation of chlorinated solvents. Also surprising was the relatively low number of respondents who characterized hydrology (e.g. pumping tests and slug tests) as being very useful, given the importance of groundwater velocity and travel time to the determination of risk to downgradient receptors. It should be noted that all categories of data were identified by at least one respondent as useful.

One possible interpretation of this information is that, for sites where reductive dechlorination is not the predominant attenuation mechanism, it is recognized that other types of data must be collected to evaluate the potential of MNA as a remedy. For example, pH is an important parameter to measure to determine whether hydrolysis of carbon tetrachloride is an attenuation mechanism, as the pH of the groundwater is a controlling factor. Another possible interpretation of this same information, in conjunction with the variability in use of data from the second and third lines of evidence data types, is the lack of user knowledge related to interpreting this data for making decisions on the robustness of various attenuation mechanisms.

Upon collecting and analyzing site-specific data for MNA remedies, models can be generated as part of the evaluation process. These models range from a simple conceptual model to a complex numerical model with degradation reactions. The survey asked, “How often are different model types used and how important are they in supporting the decision to implement MNA as a remedy?” Forty-two percent of the respondents indicated that models are used often, 24% found them to be very useful, and half (50%) believe models are moderately useful. Respondents were asked to evaluate both use and importance of approximately a half-dozen model types. The results, presented in Figure 4, indicate that simpler conceptual models tended to be used more and were of greater importance in supporting decision-making than were analytical or numerical transport models such as BIOCHLOR or RT3D. However, the results indicated that all methods are used and deemed as having importance. One possible interpretation is that regulators perceive models used in decision making that are based on observed data such as chemical concentrations as having more credibility than models based on estimated input parameters (e.g. groundwater velocity, biodegradation rates, dispersion, retardation, etc.).

Interest in Future Research and Policy Development Related to MNA and EA. Research teams continue to develop new tools and processes to improve technical abilities to address characterization and monitoring, as well as remediation, of chlorinated solvent–contaminated sites. From a purely technical perspective, these new developments are viable; however, there may be regulatory and/or nontechnical roadblocks to implementing these new tools and processes. Several questions were asked of the respondents to identify technical concepts related to MNA and EA where development efforts would be supported. Supported areas are as follows:

1. mass balance evaluation for the purposes of
    - evaluating contaminant mass loading versus the system’s natural attenuation capacity
    - facilitating selection of source treatment type and duration
    - determining when to terminate active treatment and transition to MNA or EA

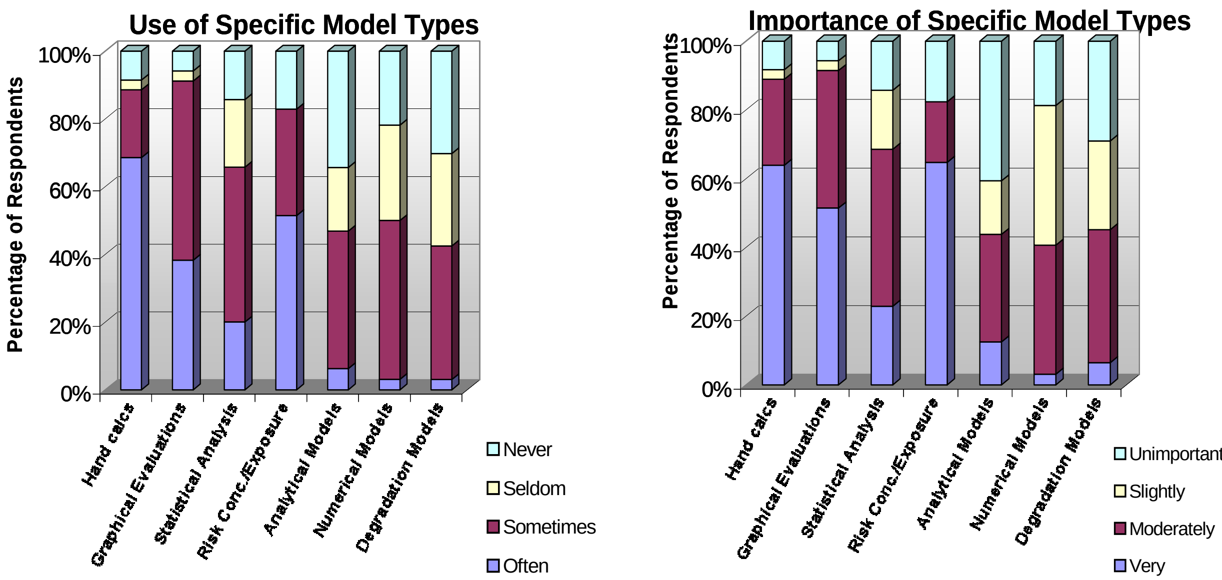
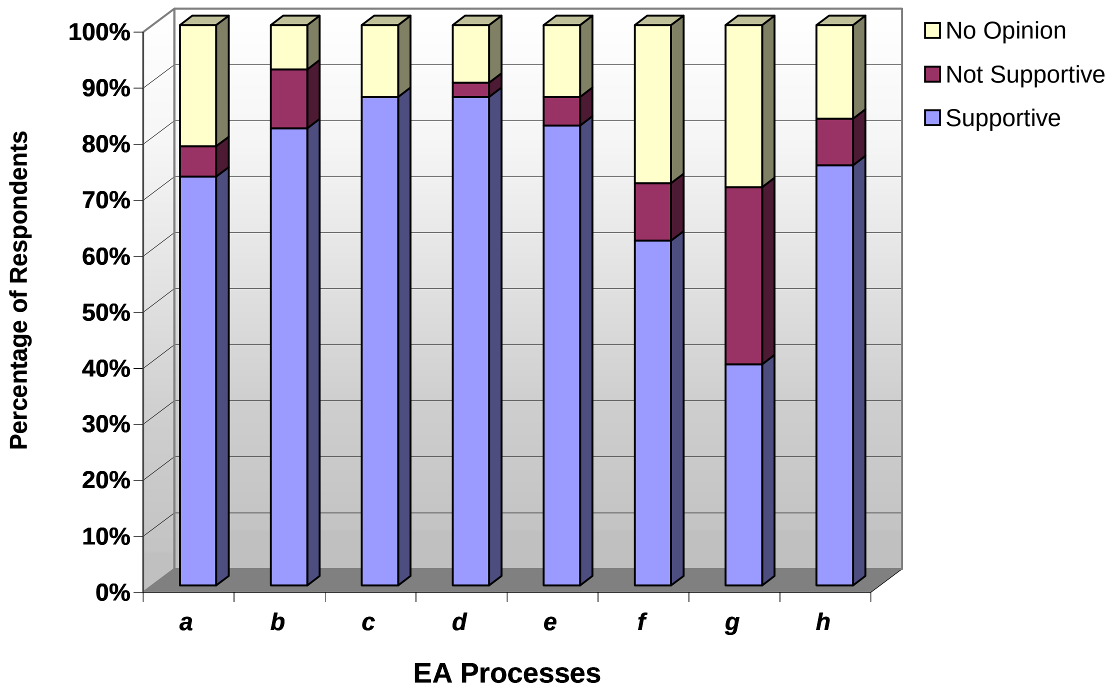


FIGURE 4. The extent to which specific model types are used and their relative importance in the decision-making process to implement MNA.

2. developing EA, a transitioning strategy between the initial remedy and MNA that will provide a mechanism for meeting remediation goals in an acceptable timeframe
3. developing protocols that separate characterization into two stages, with a separate early screening characterization phase
4. developing protocols that separate monitoring into two stages, with a separate long-term monitoring phase

Mass Balance—Contaminant levels have traditionally been measured as concentration, mass/volume. In addition, cleanup goals are typically defined as concentrations. One approach to calculating a mass balance is to evaluate the loading and attenuation capacity in terms of flux, mass/time. Respondents were asked to identify their level of support for the use of flux measurements. Approximately two-thirds of the respondents supported the idea of using both flux and concentration measurements. Interestingly, approximately one-third of the respondents supported the idea of measuring flux instead of concentration.

Enhanced Attenuation—EA is a new strategy that provides a transition between initial remedies and MNA. EA encourages the use of "active" treatments designed to produce sustainable attenuation processes while minimizing the duration of the active component of the remedy. Respondents were asked to identify their level of support for enhancing different processes in either the source, plume or discharge areas of a plume. As shown in Figure 5, the regulators were supportive of enhancements to the majority of the processes. The greatest level of support was for enhancements to the source and plume areas (Figure 5, from left, the first five enhancements on the horizontal axis). Interestingly, one-third of the respondents supported the idea of volatilization of chlorinated solvents from wetlands or surface water. One possible interpretation of this result would be that, while not widely accepted, the inclusion of volatilization as an attenuation process in the remediation of a chlorinated solvent–contaminated site will be on a case-by-case basis.



NOTE: (a) Reduce contaminant release rate from source using long-lived sustainable removal treatments
(b) Physical modifications to source and/or plume area to reduce water flow
(c) Biostimulation in the plume area
(d) Bioaugmentation in the plume area
(e) Permeable reactive barrier in the plume area
(f) Degradation in expanded/constructed wetlands
(g) Volatilization from wetlands or surface water
(h) Phytoremediation in the plume discharge zone

FIGURE 5. Level of support for enhanced attenuation processes that address source, plume, and distal plume areas.

CONCLUSIONS

Several significant points can be concluded from this survey. Protocols generally used by regulatory programs in most states for the evaluation of MNA at chlorinated solvent sites are either the EPA protocols or policies based on those protocols, along with site-specific calculations. The more experience a state program has with chlorinated solvent sites and MNA proposals, the more amenable it is to accepting this technology as a viable remedial alternative. The major reasons for a program's rejecting an MNA proposal were either because either a receptor was impacted or a plume was expanding.

Based on the responses received with regard to the use and usefulness of models, it seems that the regulatory community in general accepts simple conceptual models but is less accepting of the use of analytical or numerical transport models. Though EA is a new concept, the survey respondents were receptive to the development of this concept. Those technologies that support EA in the source and plume areas were most supported; technologies that support EA in plume discharge areas were less supported. This result may tie with the finding that one reason to not approve MNA is impact to receptors. Finally, there appears to be wide support for including flux measurements and a mass balance approach with the more traditional evaluation methodologies.

In general, regulators support the implementation of MNA at chlorinated solvent sites, depending on site-specific information: risk impacts, source zone remediation, etc. However, the success of MNA as a remedial action is undecided, as the majority of sites where it has been implemented have not reached their remedial goals.

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