BUREAU OF ENVIRONMENTAL REMEDIATION POLICY

MONITORED NATURAL ATTENUATION OF VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER

BER POLICY # BER-RS-042

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1. INTRODUCTION

Monitored Natural Attenuation (MNA) refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by more active methods (USEPA, 1999). These natural attenuation processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants. The Kansas Department of Health and Environment (KDHE) has established strong preference for remedial strategies that incorporate contaminant destruction as opposed to other non-destructive natural attenuation mechanisms, as such, MNA is not considered a presumptive remedy for any site.

This policy outlines: (1) the set of threshold conditions under which KDHE will consider MNA as a potential component of a site remedial strategy; (2) the data and information necessary to evaluate the potential effectiveness of natural attenuation processes before identifying or selecting MNA as a component of the overall site remedial strategy; and, (3) considerations for long-term performance evaluation monitoring of an MNA-based remedial strategy. The MNA screening and evaluation process is intended to proceed concurrently with site investigation and remedial alternative evaluations conducted under state cleanup programs such as the Voluntary Cleanup and Property Redevelopment Program or State Cooperative Program. Accordingly, the data collected to support the MNA screening and evaluation should be considered during the scoping of initial site investigation activities (i.e., development of the investigation work plan) and expanded as necessary to complete the assessment. The intent to proceed with MNA screening and evaluation should be identified as early in the process as possible to avoid or limit potential delays from completing the MNA assessment. Substantive findings of various assessment phases should be thoroughly documented either as components of other project deliverables (e.g., remedial investigation report, feasibility study, etc.) or as standalone documents.

The predominant focus of this policy is on dissolved-phase volatile organic compounds (VOCs) in saturated porous media at sites with active source control in place or where source materials have been depleted. This policy does not treat contamination in the vadose zone, sites with

active, uncontrolled sources, non-aqueous phase liquids (NAPL), or highly heterogeneous settings, such as karst or fractured rock. Although some of the principles outlined in this policy may be applicable to these conditions, care must be taken to ensure that all potential exposure and migration pathways are addressed through the MNA evaluation and remedial action objectives are attained through subsequent performance monitoring efforts.

Users of this policy should also become familiar with various KDHE and EPA guidance pertaining to cleanup standards, MNA, and various state programs for site remediation as listed in the *references* section below.

2. Threshold Conditions for Screening MNA

Before proceeding with a costly and time consuming MNA Evaluation as discussed in Section 3 of this policy, an MNA Threshold Screening should be completed to distinguish early in the process (e.g., the investigation work plan or report) whether further consideration of MNA as a component of the overall remedial strategy is warranted. The Threshold Screening should evaluate the MNA-based remedial strategy using current and anticipated future site conditions (including institutional controls, where applicable) based on the following criteria: (1) Known or Potential Human Health or Ecological Risks; (2) Known or Potential Environmental Risks; and (3) Nature, Extent and Magnitude of Contamination subject to MNA.

Known or Potential Human Health or Ecological Risks

In order for KDHE to consider MNA as a potentially viable component of a remedial strategy, sufficient data must be presented to document that an MNA-based remedial strategy will not result in unacceptable human health or ecological risks. This may be accomplished by identifying all relevant exposure pathways and receptors and discussing at length whether, based on current and anticipated future site conditions, the various exposure pathways are complete. *For instance, is groundwater that is to be subject to MNA currently impacting or threatening to impact water supply wells, indoor air (via vapor intrusion), wetlands, or other potential human or ecological receptors?* A finding that an MNA-based remedial strategy could pose a threat to human or ecological receptors under current and anticipated future site conditions will preclude further consideration of MNA as a viable alternative.

Known or Potential Threats to the Environment

KDHE presumptively considers all groundwater in the State to be a potential future source of drinking water and, accordingly, expects contaminated groundwater to be restored to allow for this unrestricted use. KDHE will not consider an MNA-based remedial strategy if under the MNA scenario the groundwater contaminant plume will continue to expand (vertically or horizontally) or if the groundwater plume impacts surface waters or other environmental media.

Nature, Extent, and Magnitude of Contamination

To justify further evaluation, all contaminants present at a site that represent an actual or potential threat to human health or the environment must be amenable to MNA. In many cases,

mixtures of contaminants are released to the environment; while some contaminants (i.e., 1,1,1-trichlroethane) may be effectively mitigated by natural attenuation processes, others, such as the solvent stabilizer 1,4-dioxane, may not be. KDHE will not consider an MNA-based remedial strategy unless all contaminants that represent a potential threat are amenable to MNA.

MNA is best suited for sites where existing monitoring data indicate that the groundwater contaminant plume is stable or contracting. KDHE will not consider an MNA-based remedial strategy if the data indicate the plume is expanding or resulting in cross-media transfer of contaminants.

Finally, although KDHE may, in rare cases, consider an MNA-based approach for sites with very high contaminant concentrations in groundwater, KDHE believes that, in most cases, these sites are better managed using active remedial approaches. KDHE anticipates that the Agency will most commonly incorporate MNA as a final 'polishing' phase, where appropriate, of the overall remedial strategy following active remedial action or at sites with relatively low contaminant concentrations.

3. MNA Evaluation Process

Once sufficient documentation is provided to satisfy the threshold evaluation criteria specified in Section 2, the next step to assess the viability of an MNA-based remedial strategy is the MNA Evaluation. To initiate this process, an MNA Evaluation Work Plan that: (1) summarizes the MNA Threshold Evaluation; (2) presents a three-dimensional conceptual site model, including migration and fate of contamination relative to possible receptors and the geologic, hydrogeologic, biologic, geochemical and anthropogenic factors that affect contaminant distribution; (3) a thorough discussion of migration pathways, site hydrogeology, and any source control or other ongoing remedial actions; (3) presents a summary of historical groundwater data from relevant sampling points; and, (4) provides sampling and analytical protocol to satisfy the MNA Evaluation Criteria below (including any necessary supporting documentation such as an updated field sampling plan, quality assurance project plan, and/or health and safety plan). The MNA Evaluation should follow the general framework established in *Technical Protocol for evaluating natural Attenuation of Chlorinated Solvents in Ground Water* (EPA, 1998). The MNA Evaluation Work Plan may be combined with another project deliverable (e.g., investigation work plan, etc.) or submitted as a stand-alone document.

Geochemistry, Microbiology, and Contaminant Hydrogeology

Natural attenuation processes are affected by the natural and anthropogenic geochemistry of the aquifer matrix and groundwater as well as the microbes that are established in the aquifer system. The additional site characterization data summarized below are based on the assumption that the three-dimensional boundaries of the contaminant plume have been fully characterized prior to beginning the MNA Evaluation; therefore, the list only includes the additional data that may be needed to facilitate a MNA evaluation. In all cases, it is imperative to coordinate with KDHE throughout the MNA Evaluation process to help focus the MNA sampling program to ensure that the necessary data are collected and to avoid collecting unnecessary data. Rationale for collecting these additional data is presented in EPA, 1998.

Aquifer matrix characterization: Sufficient data should be collected to define the location, distribution, concentration, and total mass of contaminants sorbed to soils or present as NAPL to account for diffusive flux. In addition, aquifer matrix samples from a background location should be submitted for analysis of total organic carbon to support sorption and solute-retardation calculations.

Groundwater characterization: Sufficient data should be collected to define the location, distribution, concentration, and total mass of contaminants in groundwater with comparisons to their solubility in water to evaluate the potential presence of NAPL or emulsions. In addition, samples should be analyzed for the relevant geochemical or biogeochemical indicator parameters for evaluating natural attenuation based on the criteria presented in EPA 1998 and Navy 1998 during one or more sampling events. These may include dissolved oxygen, nitrate, iron (II), soluble manganese (II), sulfate, hydrogen sulfide, methane, ethane, ethene, total organic carbon, dissolved inorganic carbon, alkalinity, oxidation-reduction potential, dissolved hydrogen, pH, temperature, conductivity, and/or chloride. Scoring and mapping of indicator parameter results may be performed as described in EPA 1998.

Aquifer characterization: Typically, sufficient aquifer characterization data are collected during a site investigation to evaluate contaminant fate and transport as needed for an MNA Evaluation. At a minimum, site-specific hydraulic gradient and conductivity must be determined to help determine the rate and direction of contaminant migration. Long-term monitoring data may satisfy these requirements. Quantitative modeling may be necessary in some cases to support the MNA evaluation. It is also important to characterize any potential seasonal variations in the groundwater flow direction. There are many processes that can cause an apparent reduction in contaminant mass (e.g., dilution, retardation by sorption, and dispersion, among others). The effects of these processes should be accounted for in the MNA evaluation.

Biodegradation Rates: Once confirmed that biodegradation is occurring, biodegradation rates should be estimated based on site contaminants of concern using literature values or, preferably, site-specific data. It may be necessary to explicitly demonstrate that microorganisms capable of degrading contaminants are present at a site through a microcosm study.

Contaminant Fate and Transport: In some cases, it may be possible to determine qualitatively whether natural attenuation processes are sufficient to achieve remediation goals by evaluating contaminant concentration trends, migration rates, and the presence/effectiveness of biological activity and/or source control. Other times, it may be necessary to use analytical models to evaluate whether natural attenuation processes will be able to achieve remediation goals.

Timeframe for Remediation

Based on the data collected to support the MNA assessment and existing source control mechanisms, the estimated timeframe for achieving cleanup goals must be determined. This timeframe will be compared with the timeframes for active remedial alternatives, as part of the evaluation of remedial alternatives phase, to determine whether the timeframe is reasonable and appropriate for a given site.

Potential for Adverse Interactions of Source Control or other Active Remedial Actions on Natural Attenuation Processes

In some cases, existing or planned source control actions could adversely affect the effectiveness of natural attenuation processes outside of the source treatment zone (e.g., air sparging groundwater contaminated with chlorinated solvents). Sufficient data should be provided to address potential effects of source control efforts on natural attenuation processes.

Potential for Accumulation of Toxic and/or Mobile Degradation Products

Under some circumstances, more toxic and/or mobile degradation products may accumulate as primary contaminants are degraded. The potential for this to occur should be identified in the MNA Evaluation and evaluated as a component of the performance monitoring program. Accumulation of degradation products may trigger contingency implementation

The findings of the MNA Evaluation should be thoroughly documented in an MNA Evaluation Report, which may be combined with another project deliverable (e.g., investigation report or feasibility study) or submitted as a stand-alone document.

4. Performance Evaluation Monitoring of MNA-based Remedy

The long term performance evaluation monitoring associated with MNA-based remedies is commonly more involved than performance evaluation monitoring activities associated with active groundwater remediation activities. This is because any number of potential changes in site conditions could have a significant effect on the performance of the MNA-based remedy. For instance, as oxygen is depleted as a fuel release is degraded, the rate of degradation of the remaining fuel-related constituents may decrease to the point that the natural attenuation processes are not sufficient to address the residual contamination. These changes must be evaluated on a regular basis to ensure that the MNA-based remedy can still achieve its performance objectives. Additionally, based on site-specific conditions, some areas of a site may not be able to support natural attenuation processes that are effective elsewhere. General goals of the MNA performance evaluation monitoring program as provided in *Performance Monitoring of MNA Remedies for VOCs in Groundwater* (EPA 2004) include:

- Demonstrate that natural attenuation is occurring according to expectations;
- Detect changes in environmental conditions that may reduce the efficacy of any of the natural attenuation processes;
- Identify any potentially toxic and/or mobile transformation products;
- Verify that the plume is not expanding downgradient, laterally or vertically;
- Verify no unacceptable impacts to downgradient receptors;
- Detect new releases of contaminants;
- Demonstrate the efficacy of institutional controls; and,
- Verify attainment of remediation objectives.

These goals should be incorporated in the MNA Performance Evaluation Monitoring Work Plan

and subsequent reporting efforts. Although the performance evaluation monitoring program will vary on a case-by-case basis, some common elements and considerations are identified below. In all cases, the MNA performance evaluation monitoring should continue until the requirements of KDHE's Reclassification Plan are achieved or other active remedial actions are taken. Additional information regarding performance monitoring of MNA-based remedies is available in EPA 2004.

Conceptual Site Model: The MNA evaluation monitoring program should include periodic updates to the conceptual site model including any new geological or hydrogeological information collected, contaminant distribution, migration and fate, geochemistry, and/or changes to potential receptors or other site conditions.

Monitoring Network, Parameters, and Frequency: The MNA performance evaluation monitoring program should identify and provide justification for the proposed monitoring locations, parameters, and frequency. Monitoring locations should be sufficient to evaluate the performance of the MNA-based remedy based on site-specific hydrogeology and geochemistry. This includes, at a minimum, sample locations near the source areas, fringe portions of the plume, at or downgradient of the plume boundaries (i.e., compliance points), and background locations. Additional sample locations may be necessary in areas where natural attenuation processes appear to be less effective. Sample locations should be constructed with comparable screen intervals and be sufficient to identify changes in three-dimensional plume boundaries.

Monitoring parameters should include all site contaminants of concern as well as degradation products and select geochemical and biogeochemical indicator parameters determined on a site-specific basis. The need for additional indicator parameter analyses should be determined based on MNA performance evaluation monitoring data and other site conditions.

Groundwater samples should be collected at a frequency appropriate to detect changes in three-dimensional plume orientation, provide timely warning to potential receptors, detect geochemical or biogeochemical changes that could affect natural attenuation processes and support evaluation of MNA performance relative to remediation objectives. Typically more frequent monitoring will be required up front to evaluate potential seasonal or other cyclic changes in site conditions or if conditions suggest that natural attenuation processes are not as effective as originally anticipated. Not all wells must be sampled at the same frequency for all parameters of interest. The precise monitoring frequency will be determined on a site-by-site basis.

Institutional Control Reviews: The MNA performance evaluation monitoring program should evaluate the effectiveness of any existing institutional controls to ensure that the MNA-based remedy is protective of current and future receptors.

5. Other Considerations

This policy presents KDHE's general approach for evaluating the potential effectiveness of MNA as a remedy at most sites in Kansas. However, no two sites are exactly the same and as such, site-specific considerations will govern the overall screening, evaluation and implementation of a MNA-based remedial approach. Parties considering evaluation of a MNA-

based remedial approach should confer with KDHE as early in the site characterization process as possible to help focus the extent of any additional work necessary to facilitate the MNA evaluation process. Reclassification of sites with MNA-based remedies is subject to KDHE's Reclassification Policy (BER-RS-024).

6. REFERENCES

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