



Monitored Natural Attenuation (MNA)

An Online Continuing Education Course for Engineers

Course Number: EN-4004

Credit: 4 Hours / 4 PDH / 4 CPD

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Overview

The term “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 other more active methods. Long-term performance monitoring is a fundamental component of an MNA remedy, hence the emphasis on “monitoring” in the term “monitored natural attenuation”. Other terms associated with natural attenuation in the literature include “intrinsic remediation”, “intrinsic bioremediation”, “passive bioremediation”, “natural recovery”, and “natural assimilation”. Note, however, that none of these are necessarily equivalent to MNA.

MNA is often dubbed “passive” remediation because natural attenuation processes occur without human intervention to a varying degree at all sites. It should be understood, however, that this does not imply that these processes necessarily will be effective at all sites in meeting remediation objectives within a reasonable time frame. This course describes the various chemical and environmental factors that influence the rate of natural attenuation processes. Because of complex interrelationships and the variability of cleanup standards from state-to-state and site-to-site, this course does not provide specific numerical thresholds to determine whether MNA will be effective.

The fact that some natural attenuation processes are occurring does not preclude the use of “active” remediation or the application of enhancers of biological activity (*e.g.*, electron acceptors, nutrients, and electron donors)¹. In fact, MNA will typically be used in conjunction with, or as a follow-up to, active remediation measures, and typically only after source control measures have been implemented. For example, following source control measures², natural attenuation may be sufficiently effective to achieve remediation objectives without the aid of other (active) remedial measures, although this must be conclusively demonstrated by long-term performance monitoring. More typically, active remedial measures (*e.g.*, SVE, air-sparging) will be applied in areas with high concentrations of contaminants (*i.e.*, source areas) while MNA is employed for the dilute contaminant plume. In any case, MNA should be used very cautiously as

¹ However, by definition, a remedy that includes the introduction of an enhancer of any type is no longer considered to be “natural” attenuation.

² Note that MNA may be an appropriate remediation option only after separate phase product has been removed to the maximum extent practicable from the subsurface as required under 40 CFR 280.64.

the sole remedy at any given site since there is no immediate backup (although there should be contingency plans in place) should MNA fail to meet remediation objectives.

EPA does not consider MNA to be a “presumptive” or “default” remedy - it is merely one option that should be evaluated with other applicable remedies. EPA does not view MNA to be a “no action” or “walk away” approach, but rather considers it to be an alternative means of achieving remediation objectives that may be appropriate for specific, well-documented site circumstances where its use meets the applicable statutory and regulatory requirements. As there is often a variety of methods available for achieving remediation objectives at any given site, MNA may be evaluated and compared to other viable remediation methods (including innovative technologies) during the study phases leading to the selection of a remedy. As with any other remedial alternative, MNA should be selected only where it meets all relevant remedy selection criteria, and where it will meet site remediation objectives within a time frame that is reasonable compared to that offered by other methods. Exhibit 1 provides a summary of the advantages and disadvantages of using monitored natural attenuation as a remedial option for petroleum-contaminated soils and groundwater.

Natural Attenuation Processes

Natural attenuation processes include a variety of physical, chemical, and biological processes that, under favorable conditions, reduce the mass, toxicity, mobility, volume, and/or concentration of contaminants in soil and/or groundwater. Processes that result only in reducing the concentration of a contaminant are termed “nondestructive” and include hydrodynamic dispersion, sorption and volatilization. Other processes, such as biodegradation and abiotic degradation (*e.g.*, hydrolysis), result in an actual reduction in the mass of contaminants and are termed “destructive” (Weidemeier, *et. al.*, 1999). For petroleum hydrocarbons, biodegradation is the most important (and preferred) attenuation mechanism since it is the only natural process that results in actual reduction in the mass of petroleum hydrocarbon contamination. Aerobic biodegradation consumes available oxygen resulting in anaerobic conditions in the core of the plume and a zone of oxygen depletion along the outer margins. As illustrated by Exhibit 2, the anaerobic zone is typically more extensive than the aerobic zone due to the rapid depletion of oxygen, the low rate of oxygen replacement, and the abundance of anaerobic electron acceptors³ relative to dissolved oxygen (Weidemeier, *et. al.*, 1999). For this reason, anaerobic biodegradation is typically the dominant process. For both aerobic and anaerobic processes, the rate of contaminant degradation is limited by the rate of supply of the electron acceptor not the rate of utilization of the electron acceptor by the microorganisms. If there is a sufficient supply of the electron acceptor, the rate of metabolism does not make any practical difference in the length of time required to achieve remediation objectives.

³ Anaerobic electron acceptors include nitrate, sulfate, ferric iron, manganese, and carbon dioxide. For aerobic respiration the electron acceptor is oxygen.

Corrective Action Plan (CAP)

The key components of a corrective action plan (CAP) that proposes MNA as a remediation alternative are:

- documentation of adequate source control,
- comprehensive site characterization (as reflected in a detailed conceptual site model),
- evaluation of time frame for meeting remediation objectives,
- long-term performance monitoring, and
- a contingency plan(s).

This course is intended to be an aide in evaluating a CAP that proposes MNA as a remedial option for petroleum-contaminated soil and groundwater. Note that a state may have specific requirements that are not addressed in this course.

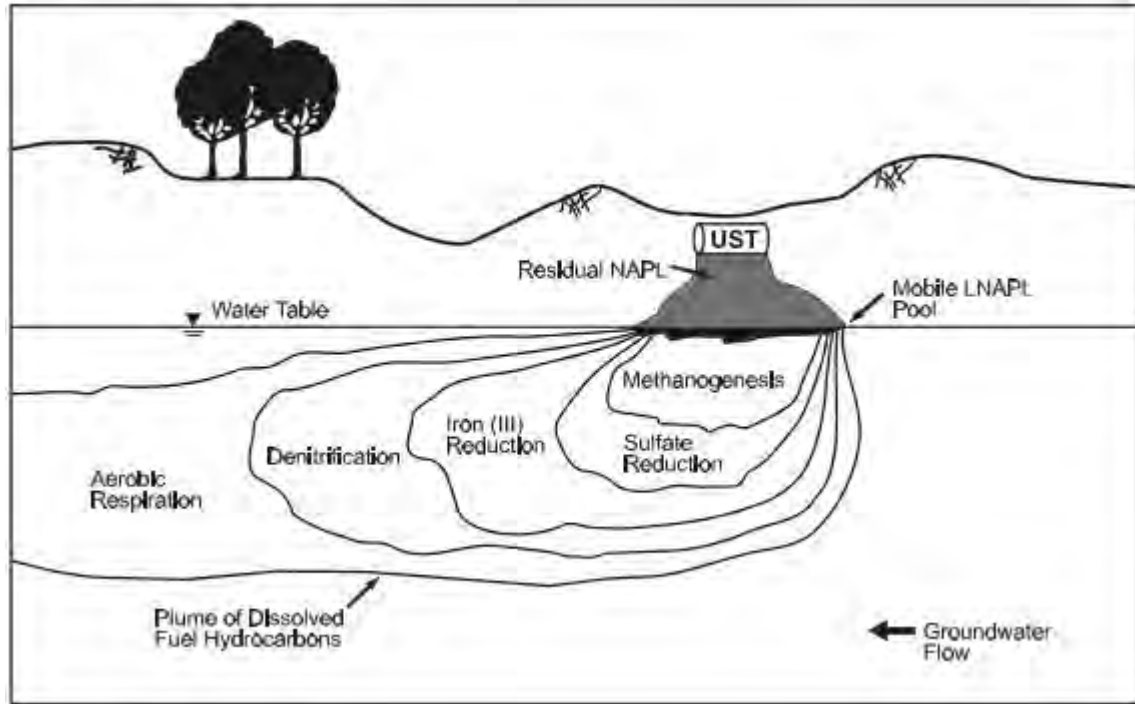
The evaluation process is presented in the four steps described below. A series of checklists have also been provided at the end of this course. They can be used as tools to evaluate the completeness of the CAP and to help focus attention on areas where additional information may be needed.

- **Step 1: *An initial screening of monitored natural attenuation applicability.*** This initial step is comprised of several relatively easily answered questions which should allow for a quick decision on whether MNA is even potentially applicable.
- **Step 2: *A detailed evaluation of monitored natural attenuation effectiveness.*** This step provides further criteria to confirm whether monitored natural attenuation is likely to be effective. To complete this evaluation, you will need to review monitoring data, chemical and physical parameters of the petroleum constituents, and site conditions. You will then need to determine whether site and constituent characteristics are such that monitored natural attenuation will likely result in adequate reductions of contaminant concentrations.
- **Step 3: *An evaluation of monitoring plan.*** Once it has been determined that MNA has the potential to be effective, the adequacy of the proposed long-term performance monitoring schedule must be evaluated.
- **Step 4: *An evaluation of the contingency plan.*** If monitoring indicates that MNA does not appear to be effective in meeting remediation objectives in a reasonable time frame, a more aggressive remediation technology will need to be implemented.

Exhibit 1

Advantages And Disadvantages Of Monitored Natural Attenuation	
Advantages	Disadvantages
<ul style="list-style-type: none"> ▪ Overall costs may be lower. ▪ Minimal disturbance to the site operations. ▪ Potential use below buildings and other areas that cannot be excavated. ▪ Does not generate remediation wastes. However, be aware of risks from methane produced during natural biodegradation of petroleum hydrocarbons. ▪ Reduced potential for cross-media transfer of contaminants commonly associated with <i>ex-situ</i> treatment. ▪ Reduced risk of human exposure to contaminants near the source area. ▪ Natural biodegradation may result in the complete destruction of contaminants <i>in-situ</i>. ▪ May be used in conjunction with, or as follow-up to, active remedial measures. 	<ul style="list-style-type: none"> ▪ Much less effective where TPH concentrations in soil are high (> 20,000 to 25,000 mg/kg). Not suitable in the presence of free product. ▪ Not suitable when contamination has impacted a receptor (e.g., impacted ground water supply well, vapors in a building). ▪ Despite predictions that the contaminants are stationary, some migration of contaminants may occur. Not suitable if receptors might be affected. ▪ Longer periods of time may be required to mitigate contamination (especially true for heavier petroleum products). ▪ May fail to achieve the desired cleanup levels within a reasonable length of time (and an engineered remedy should instead be selected). ▪ Site characterization will necessarily be more detailed, and may include additional parameters. Site characterization will be more costly. ▪ Institutional controls may be necessary to ensure long term protectiveness. ▪ Performance monitoring will generally require more monitoring locations. Monitoring will extend over a longer period of time. ▪ It may be necessary to implement contingency measures. If so, this may increase overall cost of remediation. ▪ May be accompanied by changes in groundwater geochemistry that can mobilize other contaminants.

Exhibit 2 Conceptualization of Electron Acceptor Zones in the Subsurface



(Adapted from Wiedemeier *et al.*, 1999. NOTE: Due to the presence of the mobile NAPL pool—“free product”—the site depicted in Exhibit 2 above would not be an appropriate candidate for MNA. After the free product has been removed from the subsurface to the maximum extent practicable, then the site may be evaluated as to whether it would be an appropriate candidate for MNA.)

Initial Screening of Monitored Natural Attenuation Applicability

The policies and regulations of your state determine whether MNA will be allowed as a treatment option. As the first step in the screening process, determine if your state allows the use of MNA as a remedial option. For example, MNA may not be allowed if the contaminant mass is large enough that groundwater impacts are likely (or have already occurred), or if sampling indicates the presence of free product, or an existing contaminant plume isn't shrinking, or if there are potential receptors located nearby. Also, be aware that it is possible that while allowing MNA as a remedial option, your state may have requirements that are more stringent than those described in this course.

Although the specific screening criteria for both contaminated soil and groundwater might be expected to be very different due to the characteristics of the impacted media, they are quite similar. For both media the criteria focus on two elements: (1) source longevity and (2) potential receptor impacts. Source longevity influences not only the time to achieve remediation objectives but also the potential for groundwater contamination and plume migration. Receptors

may be impacted through direct contact with source materials (such as residual soil contamination or free product), or through ingestion of dissolved- phase contaminants or inhalation of vapor-phase contaminants. The objective of the initial screening is to determine how long the source is likely to persist, and whether there are likely to be impacts to receptors during this time. The following section will provide guidance on how these criteria should be evaluated for either contaminated soil or contaminated groundwater. Exhibit 3 is a flow chart that can serve as a roadmap for the initial screening evaluation process. If results of the initial screening indicate that MNA is not likely to be effective, then other more aggressive measures (for example excavation of contaminated soil, or pump-and-treat for groundwater) should be employed.

Contaminant Transport and Fate

The most commonly encountered fuels, gasoline, diesel fuel, kerosene, heating oils, and other petroleum products are a mixture often containing hundreds of different chemical constituents. The characteristics of individual contaminants are a function of their chemical and physical properties.

Each fuel constituent will migrate through the subsurface in different ways, depending on its chemical and physical characteristics. Consequently, the fate of a contaminant is highly variable. For example, a portion of the benzene in gasoline will volatilize and enter the vapor phase, the majority of the benzene mass will stay in the liquid phase, and the remaining portion will dissolve into either soil moisture or groundwater.

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