Monitored Natural Recovery and Enhanced Monitored Natural Recovery

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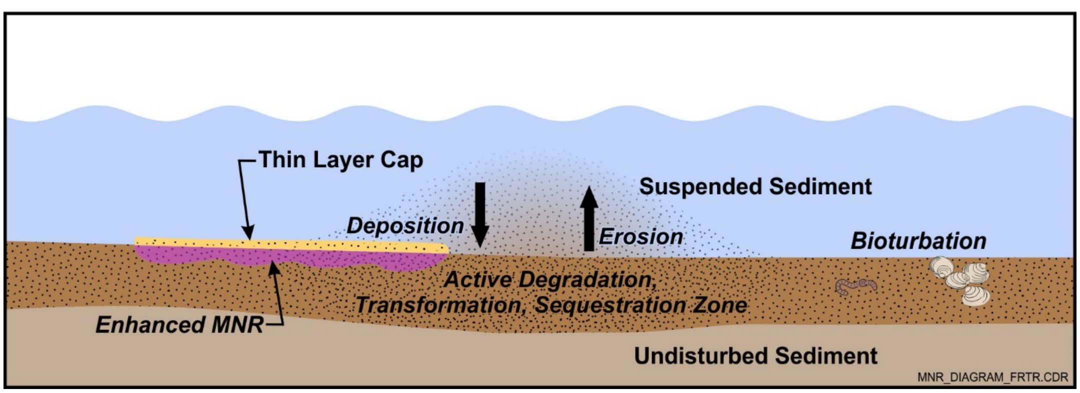
Schematic



Schematic of Monitored Natural Recovery and Enhanced Monitored Natural Recovery Processes

Introduction

Monitored natural recovery (MNR) is a remediation approach for contaminated sediments that relies on naturally-occurring physical, chemical, and biological processes to contain, destroy, or reduce the bioavailability and/or toxicity of contaminants. Recovery over time is monitored to verify that it progresses at the expected rate. Typically, recovery includes some of the following processes: the deposition of clean sediment over the contaminated material, chemical transformation and biodegradation of contaminants, and sediment mixing and dispersion.

MNR combined with engineering measures is referred to as EMNR. It includes the placement of a thin layer of granular material or a sediment amendment to accelerate natural recovery processes. The result is reduced ecological and human health risks from exposure to contaminated sediments, and a gradual decrease in contaminant concentrations in the surface sediment to levels below remediation goals. MNR and EMNR are different from sediment capping in that they gradually reduce the concentration of contaminants of concern (COCs) in surface sediment over time, whereas the objective of capping is to provide an immediate barrier to prevent exposure to the COCs in surface sediment. Furthermore, MNR/EMNR takes years to decades to achieve isolation through the gradual accumulation of cleaner sediment, whereas capping achieves isolation immediately.

Other Technology Names

Thin-layer capping (EMNR)

Description

MNR and EMNR are remediation approaches used for contaminated sediments, either alone or in combination with other sediment remediation technologies such as dredging, sediment capping, or sediment capping with amendments. MNR relies on naturally-occurring processes to reduce ecological and human health risks to acceptable levels over time. EMNR can be used when natural recovery processes alone are insufficient to reduce risks within an acceptable timeframe. With EMNR, recovery rates are accelerated by engineering means, for example, by adding a thin layer of clean sediment (typically less than 1 foot) or a flow control structure that enhances sediment deposition in certain areas of a site. A thin-layer cap is intended to immediately reduce contaminant concentrations in surface sediment and accelerate the process of natural burial through sediment deposition; however, thin-layer caps are not intended to completely isolate the affected sediment, as in a conventional isolation capping remedy (ITRC, 2014). EMNR may also include addition of an amendment such as activated carbon to help sequester organic contaminants such as polychlorinated biphenyls (PCBs).

Natural recovery processes generally include the following (ITRC, 2014):

- **Physical processes**: situations when the primary process responsible for MNR and/or EMNR is physical. Deposition of cleaner suspended sediment particles that gradually bury and isolate the contamination is often involved, reducing exposure to surface water and aquatic biota over a period of years to decades. Other natural physical processes that can reduce surface sediment concentrations over time include sediment resuspension and transport (from tide, current and wave activity and/or propeller scour) and bioturbation (which mixes newly-deposited clean sediment with contaminated sediment).
- **Chemical processes**: chemical reactions such as sequestration or transformation immobilize contaminants or convert them to less toxic forms. For example, potentially toxic hexavalent chromium can be converted to relatively non-toxic trivalent chromium under reducing conditions. Some contaminant transformations can lead to the formation of more toxic constituents or can be reversed if environmental conditions change, so all contaminant fate processes should be well understood.
- **Biological processes**: microbial processes that degrade/transform contaminants over time and change their bioavailability and toxicity characteristics.

An MNR or EMNR remedy typically includes the following components (EPA, 2005 and 2014; ESTCP, 2009; ITRC, 2014):

- **Site characterization**: investigating the site and developing a detailed conceptual site model (CSM) that identifies and characterizes the natural processes affecting the transport, fate, and bioavailability of contaminants.
- **Source control**: reducing or eliminating major ongoing sources of contamination to the water body so that natural recovery can occur.
- **MNR lines of evidence**: establishing multiple lines of evidence based on field and laboratory studies, literature reviews, and modeling to demonstrate that natural recovery is occurring and to estimate recovery rates.

- **Modeling**: developing and applying predictive tools (e.g., a computer model or extrapolation of empirical data) to predict the natural recovery trajectory and estimate the time required to achieve remedial action objectives (RAOs).
- **Source control**: reducing or eliminating major ongoing sources of contamination to the water body so that natural recovery can occur.
- **Long-term monitoring**: developing and implementing a monitoring program based on the previously-established lines of evidence to verify natural recovery rates and monitor progress towards achieving RAOs.

Institutional controls (e.g., fish consumption advisories) may be implemented in conjunction with MNR or EMNR until concentrations of contaminants have been reduced to levels that no longer pose a risk to human health or the environment. If MNR or EMNR does not progress as expected and/or does not achieve the expected risk reduction goals, then the responsible parties may need to take additional actions to accelerate the recovery rate through EMNR or to implement an alternative remediation approach such as dredging, sediment capping, or capping with amendments.

Development Status and Availability

The following checklist provides a summary of the development and implementation status of MNR and EMNR:

☐ At the laboratory/bench scale and shows promise

☐ In pilot studies

☒ At full scale

☒ To remediate an entire site (source in vadose zone)

☐ To remediate a source only

☒ As part of a technology train

☒ As the final remedy at multiple sites

☒ To successfully attain cleanup goals in multiple sites

MNR and EMNR are available through the following vendors:

☒ Commercially available nationwide

☐ Commercially available through limited vendors because of licensing or specialized equipment

☒ Research organizations and academia

Applicability

Contaminant Class Applicability Rating for MNR and EMNR

(Rating codes: ● Demonstrated Effectiveness, ◐ Limited Effectiveness, ○ No Demonstrated Effectiveness,
I/D Insufficient Data, N/A Not Applicable)

Nonhalogenated VOC	Halogenated VOC	Nonhalogenated SVOC	Halogenated SVOC	Fuels	Inorganics	Radionuclides	Munitions	Emerging Contaminants
●	●	●	●	●	●	●	●	I/D

Sediment site conditions that are conducive to the successful application of an MNR or EMNR approach include (EPA, 2005):

- The anticipated future use of the water body is compatible with natural recovery; for example, MNR or EMNR may not be appropriate if future navigational dredging or marine construction is planned.
- The water body has a relatively high sediment deposition rate; for example, due to a heavy sediment load from a river discharge point.
- Natural recovery processes are likely to reduce risks to acceptable levels in a reasonable timeframe.
- Human, aquatic biota, and/or wildlife exposure to contaminants is expected to be low or can be limited using institutional controls during the recovery period.

- The sediment bed is reasonably stable and is likely to remain so.
- Contaminant concentrations in surface sediment and biota already show declining trends.
- Contaminant concentrations are relatively low and cover large areas.
- The contaminants tend to biodegrade or transform to lower toxicity forms, or do not readily bioaccumulate.

MNR or EMNR may be desirable in areas with sensitive habitats, or where the benefits of habitat preservation outweigh the benefits of removing or capping the contamination (ITRC, 2014). Under the appropriate site conditions, MNR and EMNR have a low implementation risk and high level of effectiveness and permanence.

Cost

MNR and EMNR are generally considered relatively low-cost remediation approaches compared to dredging, sediment capping, and capping with amendments. Site characterization and long-term monitoring costs are likely to be higher for MNR than for dredging or capping projects; however, MNR typically has no construction costs. Major cost drivers include:

Upfront Costs

- Site characterization and modeling efforts to develop the MNR lines of evidence and predict the time required to achieve RAOs (ITRC, 2014).
- Costs for engineering controls (e.g., thin layer cover) if EMNR is applied.
- Amendments, if added, if EMNR is applied.
- Development and implementation of institutional controls.

Operation and Maintenance Costs

- Long-term monitoring (ITRC, 2014).

The bullet above highlights the major cost dependency specific to MNR and EMNR. Click here for a general discussion on costing which includes definitions and repetitive costs for remediation technologies. A project-specific cost estimate can be developed in consultation with a subject matter expert, or obtained using an integrated cost-estimating application such as RACER®.

Duration

MNR and EMNR tends to be a long-duration remedy requiring several years to reach protectiveness and longer to monitor for long-term protectiveness. A site-specific long-term monitoring plan documents the scope and frequency of the field activities needed to assess progress towards achieving RAOs through MNR or EMNR. Monitoring generally is performed more frequently during the early stage of a monitoring program, and then as sufficient time series data become available that demonstrate natural recovery is proceeding as expected, the monitoring frequency can be reduced. In general, monitoring should be continued until stability and permanence of the remedy can be verified, or that objectives have been met (ITRC,2014). Once remedial goals are met, monitoring might be reduced to low-frequency, disturbance-based monitoring (ASTM, 2018). Oftentimes, for mature programs, monitoring can be reduced to every five years until the point in time when RAOs are predicted to be achieved is commonly proposed. Reviews could be conducted once every five years, corresponding to each five-year monitoring event, which is consistent with requirements for five-year reviews.

Implementability Considerations

MNR and EMNR are not viable remedies in cases where natural processes are unlikely to reduce ecological and human health risks to acceptable levels in a reasonable timeframe (for example, at sites with low sediment accumulation rates or low degradation rates). Other factors that may limit the applicability or effectiveness of MNR or EMNR include:

- MNR or EMNR are not appropriate where imminent and substantial site risks are present.
- MNR or EMNR may be perceived as a "do nothing" approach; stakeholder and public education and a robust monitoring program are critical to facilitating acceptance of an MNR or EMNR remedy.
- The models and data used to predict natural recovery rates are not precise; therefore, the estimates of the time required to achieve RAOs are uncertain. The timeframe for achieving RAOs should be presented as a range rather than as a specific point in time to account for these uncertainties.
- A longer timeframe most likely will be required to achieve RAOs compared to active remediation approaches.
- Long-term monitoring is required to verify that RAOs are met.

- Contaminated sediments are left in place and sediment disturbance could result in increased risks. MMR and EMNR are not applicable at sites where disturbances are likely or where natural scouring may occur.
- Intermediate degradation products may be more mobile and toxic than the original contaminant.
- Institutional controls may be required.
- Existing beneficial ecological services of the contaminated site are preserved, and perhaps improved, during the remediation timeframe. These are usually lost or diminished during more invasive approaches such as capping or dredging.

Resources

American Society of Testing and Materials (ASTM). Standard Guide for Sediment Corrective Action — Monitoring (2018).
This guide discusses practices for monitoring before, during and after sediment remediation activities.

Environmental Protection Agency (EPA). CLU-IN Sediments Issue Area Web Page
This Web page provides links to sediment-related guidance and documents.

EPA. Contaminated Sediments in Superfund - Guidance Documents, Fact Sheets and Policies Web Page
This Web page presents links to the EPA guidance documents, fact sheets and policies relating to contaminated sediments at Superfund sites.

EPA. Superfund Sediment Resource Center Web Page
This Web page provides assistance on technical issues related to cleanup of sediments.

EPA. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (2005) (PDF) (236 pp, 2.81 MB)
The guidance is designed to assist sediment site managers by providing a thorough overview of methods that can be used to reduce risk caused by contaminated sediment. Chapter 4 addresses Monitored Natural Recovery.

EPA. Superfund Remedy Report (2013) (PDF) (44 pp, 1.45 MB)
This is a report formulated by the EPA providing information and analyses on remedies selected to address contamination at Superfund sites. The report

specifically lists new and innovative treatment technologies including MNR and EMNR.

EPA. **Technical Resource Document on Monitored Natural Recovery (2014) (PDF)** (251 pp, 3.18 MB)
This technical resource document is designed to complement Chapter 4 on MNR in EPA's 2005 *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* by providing detailed information on field-scale methodologies and approaches that can be used to measure or predict natural processes that contribute to receptor risk reduction at contaminated sediment sites.

Environmental Security Technology Certification Program (ESTCP). **Monitored Natural Recovery at Contaminated Sediment Sites (2009) (PDF)** (276 pp, 4.45 MB)
This document provides a technical guide for project managers and management teams evaluating and implementing MNR at contaminated sediment sites. It is primarily intended to support environmental restoration at DoD sites; however, many aspects of the document can be useful for other government organizations, potentially responsible parties, communities, and stakeholders involved in management of sediment cleanup.

Interstate Technology and Regulatory Council (ITRC). **Contaminated Sediments Remediation: Remedy Selection for Contaminated Sediments (2014) (PDF)** (236 pp, 2.81 MB)
This Web page provides a remedy selection framework to help project managers evaluate remedial technologies and develop remedial alternatives (often composed of multiple technologies) based on site-specific data.