Natural attenuation as a viable remediation method

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Keywords *Environment, Contamination, Groundwater, Regulations, Hazardous materials*

Abstract *This paper describes the concept of natural attenuation and its role as a remediation method. It contains examples illustrating the various modalities via which natural attenuation may assist in dealing with environmental contamination.*

Natural attenuation defined: what is it?

Natural attenuation has been referred to by the lay community as the "do nothing" remedy and by some community stakeholders as the "no action" approach. Yet precisely because extraction, treatment, and reinjection (ETR) systems have not consistently met performance goals (NRC, 1994), natural attenuation is being used more frequently at hazardous waste sites across the country. Although it is generally considered an automatic, or "natural" component of remediation activities at many sites, it is only within the last few years that natural attenuation has been applied as a purposive treatment strategy to be considered along with other human-engineered solutions.

The scientific literature describes natural attenuation using various terms including "intrinsic remediation", "intrinsic bioremediation", "passive bioremediation", "natural recovery" and "natural assimilation". The Environmental Protection Agency (EPA) describes natural attenuation as the method which allows natural processes to reduce and eliminate contamination, and notes that while natural attenuation is generally not a recognized remediation technology by itself, it does assist the process of degradation and decontamination to some degree at every site. In this sense, it is an approach that focuses on the confirmation and monitoring of natural remediation processes rather than relying totally on "engineered" technologies. Jim Woolford of the EPA has suggested that, "Under certain site conditions, and if properly documented, natural attenuation can be a viable option for remediation sites as a stand-alone option or in conjunction with other engineered remediation" (EPA, 1996).

Dr John Wilson of the EPA compares natural attenuation in groundwater to the flame of a candle. The source of the flame is the wax of the candle just as the source of the groundwater contamination is the concentrated solvents trapped in the soil. The flame appears steady because the wax is destroyed in the flame as fast as it is removed from the candle. In the same way, many groundwater plumes will reach "steady state" at some distance from the source of contamination, when biological processes will destroy contaminants as fast as

Environmental Management and Health, Vol. 12 No. 4, 2001, pp. 428-435. © MCB University Press, 0956-6163

they flow through the groundwater. Thus, just as the candle is consumed by the flame, the contaminants in the soil and groundwater can be attenuated through biodegradation and other natural processes (EPA, 1996).

More specifically, when chlorinated solvents such as trichloroethene (TCE) or perchloroethene (PCE) are spilled or leak into the soil or groundwater, several natural processes can occur to destroy or alter these chemicals. These processes include adsorption (which means to gather a gas, a liquid, or dissolved substance on a surface in a condensed layer), to soil particles, particles, biodegradation of contaminants, and dilution and dispersion in groundwater. Many contaminants are prevented from migrating off the site because they are adsorbed to soil particles. Although biodegradation does not occur at all chlorinated solvent sites, it can be an important process in destroying these contaminants. For example, although mobile and toxic fuel hydrocarbons are difficult to trap because of their mobility, they are among the contaminants most easily destroyed by biodegradation (EPA, 1966). Dilution and dispersion do not destroy contaminants, but can significantly reduce their potential risk at many sites.

Monitored natural attenuation (MNA) and the regulatory context

Federal agencies such as the EPA, the Department of Defense (DoD), and the Department of Energy (DoE) agree that despite the potential of natural attenuation as a "natural" technology for combatting pollution, it should be monitored. In November 1997, EPA issued a directive that outlined the use of monitored natural attenuation (EPA/OSWER, 1997). The EPA defines "monitored natural attenuation" (MNA) as the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remedial objectives within a timeframe that is reasonable compared to that offered by other more active methods. The agency maintains that natural attenuation is not a "no action" or "walk away" approach but "rather an alternative means of achieving remediation objectives that may be appropriate for a limited set of site circumstances where its use meets the applicable statutory and regulatory requirements" (EPA/OSWER, 1997).

In 1997, EPA issued a set of criteria that regulatory authorities must consider when determining whether monitored natural attenuation is an appropriate remedy for contaminated soil or groundwater at a given site:

- Can the contaminants present in the soil or groundwater be effectively remediated by natural attenuation processes?
- Do the results of natural attenuation present a greater risk than do the parent contaminants?
- What is the nature and distribution of sources of contamination, and have these sources been (or can these sources be) adequately controlled?
- Is the plume relatively stable or is it still migrating?

- What is the potential for environmental conditions to change over time?
- What is the likely impact of existing and proposed active remediation measures upon the monitored natural attenuation component of the remedy?
- Will drinking water supplies, other groundwater, surface waters, ecosystems, sediments, air, or other environmental resources be adversely affected?
- Is the estimated time frame of remediation reasonable compared to time frames required for other more active methods (including the anticipated effectiveness of various remedial approaches on different portions of the contaminated soil and/or groundwater)?
- What is the current and projected demand for the affected acquifer over the time period that the remedy will remain in effect (including the availability of other water supplies and the loss of availability of other groundwater resources due to contamination from other sources)?
- Can reliable site-specific vehicles for implementing institutional controls (i.e. zoning ordinances) responsible for their monitoring and enforcement be identified?

Within the regulatory context, EPA recognition of natural attenuation extends to sites regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), and underground storage tank (UST) regulations. For example, under the Superfund program, monitored natural attenuation has been selected as part of the cleanup methods at 73 groundwater contamination sites, but is the sole treatment option at only six of these sites. The sites include municipal and industrial landfills refineries and recycling facilities. Within EPA Region I, which covers New England, it is a component of the selected remedy at sites such as Fort Devens in Massachusetts and Savage Municipal Water Supply in New Hampshire (EPA, 1996). Moreover, natural attenuation must comply with state groundwater use classification and standards. In fact, demonstrating the effectiveness of remedies involving natural attenuation requires more thorough site characterization, detailed monitoring of the remedial progress, and contingency measures to ensure long-term reliability and protection of human health and the ecosystem.

Beyond the EPA's willingness to endorse MNA, there are only two states (North Carolina and New Jersey) with formal natural attenuation policies. However, almost 20 other states have expressed support for employing this form of pollution control and are currently in the process of developing appropriate state policies. The US military is also finding use for natural attenuation. The Army has developed a protocol for explosives remediation through natural attenuation, using the Environmental Security Technology

Certification Program and environmental restoration program funding. The natural attenuation process has been used at Sierra Army Depot, CA, Canal Creek at Aberdeen Proving Ground, MD, Seneca Army Depot, NY, and the Cornhusker Army Ammunition Plant, NB (AEP, 1998). The Air Force has monitored natural attenuation at over 40 Air Force sites, including the Hill Air Force Base in Utah and Patrick Air Force Base in Florida. Moreover, the United States Air Force Center for Environmental Excellence (AFCEE) developed a comprehensive technical protocol for the implementation of monitored natural attenuation (Wiedmeier *et al.*, 1995). The US Navy is presently conducting a study of the sediment of Pearl Harbor to evaluate the potential threat to human health and the environment from contaminants in harbor sediments. Monitored natural attenuation is being utilized as an integral part of the evaluation and potential cleanup strategy for this and other contaminated sites in Hawaii (NBPH, 1998a, b). Since 1996, the Navy has been working closely with various state and federal agencies regarding the sediment study. Information collected for the study is provided to health agencies such as the Hawaii State Department of Health and the EPA. The data are also provided to federal and state regulatory agencies and natural resource trustees such as the US Fish and Wildlife Service, the National Oceanic and Atmospheric Administration (NOAA), and the Hawaii State Department of Land and Natural Resources (DLNR) (NBPH, 1998b).

Natural attenuation: advantages and disadvantages

The 1997 EPA Directive cautions that monitored natural attenuation has several potential advantages and disadvantages, and its use should be carefully considered during site characterization and evaluation of remediation alternatives (EPA/OSWER, 1997). The potential advantages include:

- Generation of less volume of remediation wastes, reduced potential for cross-media transfer of contaminants commonly associated with conventional treatment, and reduced risk of human exposure to contaminated media.
- Less intrusion, as few surface structures are required.
- Potential for application to all or part of a given site, depending on site conditions and cleanup objectives.
- Use in conjunction with, or as a follow-up to, other (active) remedial measures.
- Lower overall remediation costs than those associated with active remediation.

The potential disadvantages of monitored natural attenuation include:

- Longer time frames may be required to achieve remediation objectives, compared to active remediation.

- Site characterization may be more complex and costly.
- Toxicity of transformation products may exceed that of the parent compound.
- Long-term monitoring will generally be necessary.
- Institutional controls may be necessary to ensure long-term protection.
- Potential exists for continued contamination migration, and/or cross-media transfer of contaminants.
- Hydrologic and geochemical conditions amedable to natural attenuation are likely to change over time and could result in renewed mobility of previously stabilized contaminants, adversely affecting remedial effectiveness.
- More extensive education and outreach efforts may be required in order to gain public acceptance.

Where and when is natural attenuation more appropriate?

To determine how well natural attenuation will work and how long it will take requires a detailed study of the contaminated site. The community and those conducting the study need to know whether natural attenuation, or any proposed remedy, will reduce the contaminant concentrations in the soil and water to legally acceptable levels within a reasonable time.

Because the ability of natural attenuation to be an effective cleanup method depends on a variety of conditions, the site needs to be well-characterized to determine the extent to which natural attenuation is occurring or will occur. Sites where the soil contains high levels of natural organic matter, such as swampy areas or former marshlands, generally provide conditions that enhance the prospect for successful natural attenuation. Certain geological formations such as fractured bedrock aquifers or limestone areas are less likely candidates for natural attenuation because these environments often have a wide variety of soil types that cause unpredictable groundwater flow and make the containment of contamination difficult.

In September of 1998, at a forum in San Francisco on natural attenuation sponsored by the Center for Public Environmental Oversight (CPEO), the EPA, and DOD there seemed to be a general consensus among the EPA, other federal agencies (e.g. DOD, DOE), scientific experts, and "community stakeholders" on the following items related to the use of natural attenuation. The consensus reflects the main aspects of the EPA's policy position on when and where monitored natural attenuation may be appropriate.

- Natural attenuation should be monitored.
- "Monitored" natural attenuation (MNA or MoNA) should require standards and provide measurement against established standards over time as the natural attenuation process takes place.

- Some natural attenuation processes are more effective than others with regard to water contaminants, soil contaminants, etc. and are site specific.
- A combination of natural attenuation, once monitored and measured against standards, and conventional intervention of scientific and technological remedial action may be the most cost effective and short-term method to closure at many identified contaminated sites.
- Each site would still require a risk assessment before concluding that MNA would be allowed alone or in combination with conventional intervention remedies.
- MNA should always be considered as an alternative to the conventional methods of remediation.

Moreover, there was general consensus that natural attenuation is most appropriate when the following conditions exist (Prizzia and Yuen, 1998):

- When samples taken from existing sites prior to remedial action reveal high levels of natural attenuation microbes (e.g. contaminated water).
- When and where scientific evidence and data support recommendations for MNA at a site, rather than just fiscal considerations.
- When and where existing conditions at a site replicate previous MNA sites which were successfully closed with less risk, shorter time frame, and more efficiency than conventional remediation methods.

Predicting, measuring, and verifying the effectiveness of monitored natural attenuation

The issues of predictability and verification of the effectiveness of monitored natural attenuation were also debated at the September 1998 forum in San Francisco. However, there was general consensus that the following concerns should be included in any measure of effectiveness of monitored natural attenuation (Prizzia and Yuen, 1998):

(1) MNA must be evaluated as an alternative method like any other proposed remedy utilizing EPA criteria.

(2) It is necessary to define what is meant by success (e.g. as in a successful clean-up or closure). Because natural attenuation is usually a long process there is a need for reassessment of performance goals every five years.

(3) Among the most important performance goals should be reducing the health risk of those people in the vicinity of the site (e.g. those in charge of the site clean-up must keep their "eye on the ball" and the overall mission of the clean-up).

(4) Other areas of consideration for effective MNA:

- Have the right data been collected? (e.g. samples of natural attenuation microbes at contaminated site).
- Is the level of analysis appropriate?
- Has all the cost of MNA been included?
- Has the range of costs and solutions been carefully considered?
- What is a reasonable time frame?
- Does long-term monitoring work and what is involved?
- Is MNA fair or equitable?
- In addition to institutional controls, what additional controls are needed for a longer time frame of MNA?
- What do community "stakeholders" think? (e.g. impact survey).
- What steps have been taken to insure community involvement at the start and to keep the community involved in the process to closure?

Conclusion

Natural attenuation is non-invasive, and unlike many elaborate mechanical site cleanup techniques, while natural attenuation is working below ground, the land surface above ground may continue to be used. Natural attenuation can be less costly than other active engineered treatment options, especially those available for groundwater, and requires no energy source or special equipment. However, even advocates of natural attenuation recognize that while progress has been made in understanding the underlying processes of natural attenuation and in assessing the efficacy of this remedial alternative, there are clear limitations. Advocates of natural attenuation are likely correct to note that failure to include it as a legitimate and regularly considered method or remediation risks the:

> . . . continue[d] . . . waste of millions of taxpayer dollars . . . on remediation efforts that are not necessary, not likely to succeed, or may, in fact, inhibit naturally-occurring mechanisms of natural attenuation (Wiedemeier and Pound, 1996).

References

AEP (1998), Raymond J. Fatz Congressional Testimony before Senate Armed Services Committee, 105th Congress, FY 99 Military Construction: the Army Environmental Program, March.

EPA (1996), *A Citizens Guide to Monitored Natural Attenuation*, October, US EPA, Washington, DC.

EPA/OSWER (1997), *Directive 9200.4-17, Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites*, November, US EPA, Office of Solid Waste & Emergency Response, Washington, DC.

National Research Council (1994), *Alternatives for Groundwater Cleanup*, US EPS, Academic Press, Washington, DC.

NBPH (1998a), Phase 2, *Remedial Investigation Ewa Junction Fuel Drumming Facility FISC*, Pearl Harbor, Hawaii, Naval Base Pearl Harbor (NBPH), February.

NBPH (1998b), *Pearl Harbor Sediment Study/Fish Advisory Fact Sheet*, Naval Base Pearl Harbor (NBPH), August.

Prizzia, R. and Yuen, D. (1998), *Report on National Stakeholder's Forum on Monitored Natural Attenuation*, Pearl Harbor Complex Restoration Advisory Board (RAB), September.

Wiedemeier, T.H. and Pound, M.J. (1996), "Group III Communications, soil and groundwater cleanup: natural attenuation can be an option for chlorinated solvents", Web site: http://www.sgcleanup.com/bio/pound.html

Wiedemeier, T.H., Wilson, J.T., Kampbell, D.H., Miller, R.N. and Hansen, J.E. (1995), *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*, Air Force Center for Environmental Excellence, Vols. I and II, November.

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2. Paul F. Hudak. 2012. Natural attenuation with varying degrees of aquifer heterogeneity: Implications for groundwater monitoring. *Remediation Journal* **22**:4, 93-98. [CrossRef]