GEI Consultants

Geotechnical
Environmental and
Water Resources
Ecological

The GEI

MGP Reporter

A Publication of GEI Consultants | Serving the Utility Industry Since 1995 | Fall 2010

Stuck in the Mud: Multiple Causes of Ecological Risk in Sediment

By Bob Gensemer, Kim Bradley, Carrie Claytor, GEI Consultants, Inc.

Many former MGP sites are located on waterways. As a result, stream and lake/reservoir sediments adjacent to these MGP sites may be contaminated with tars and tar-related chemicals such as polycyclic aromatic hydrocarbons (PAHs). PAHs may pose unacceptable risks to human health or the aquatic environment and may require some kind of remedial action to remove or mitigate the risk.

Assessment of potential ecological risk to benthic organisms inhabiting these sediments is often necessary to determine risk-based remedial cleanup goals. In some cases, these ecological risk assessments (ERAs) can be relatively straightforward, focusing only on the visual presence of tar or sheen in sediment cores or on PAH concentrations linked to unacceptable risk thresholds. However, ERAs can also be complicated by the presence of other contaminants, and/or the presence of multiple physical stressors not related to former MGP operations. These complications can arise for several reasons:

- The site is located near an urban waterway with many other active or historical industries and their impacts, including metals, pesticides, or PCBs.
- The urban waterway has been highly modified by input of organic matter or fine particulates from surface runoff or combined sewer overflows (CSOs).
- The urban waterway has been highly modified with respect to biological habitat, resulting from channelization, bulkheading, dredging for shipping, or development.
- The sediments and overlying waters are low in dissolved oxygen (DO) or contain elevated levels of ammonia or sulfides.

Standard ERA Methods

ERAs conducted during sediment remedial investigations typically use standard methods describing the general types of studies needed to complete the assessment. The USEPA and other federal agencies have developed guidance for con-

continued on page 2

What's News

Page 2

Feature Article: Stuck in the Mud (Continued)

Page 3

Editorial: Regulations

Page 4

Feature Article: Stuck in the Mud (Continued)

Page 5

Newsbriefs and Web Watch

Stuck in the Mud (continued from page 1)

ducting ERAs to improve the quality and consistency of these assessments across all regulatory programs. Many state governments have adopted the USEPA guidelines and incorporated them into state-specific approaches for sites that are not under federal jurisdiction (e.g., CERCLA, or "Superfund").

The basic structure of the ERA process incorporates two major phases:

- A Screening Level Ecological Risk Assessment (SLERA) identifies ecological exposure pathways and often entails an initial quantitative screening to determine if potential risk to organisms of concern (also termed "receptors") exists.
- A Baseline Ecological Risk Assessment (BERA) is performed if the SLERA indicates potentially complete exposure pathways exist to ecological receptors or if contaminant concentrations exceed screening-level risk thresholds. A more robust and site-specific evaluation is then performed to identify whether risks to ecological receptors exist, and if so, what cleanup goals could be derived to mitigate or eliminate this risk.

A SLERA for sediment investigations typically screens bulk sediment contaminant concentrations against generic benchmarks derived for protection of benthic organisms. For marine environments these typically include effects range low (ERL) and effects range median (ERM) benchmark values, and for freshwater sediments these typically include threshold effect concentrations (TEC) and probable effect concentrations (PEC). In both cases if contaminant concentrations are below the lowest benchmark (ERL or TEC) then ecological risk is unlikely; if concentrations exceed the highest benchmark (ERM or PEC) then ecological risk is more likely. However, these thresholds are conservative, based on "consensus" evaluations of data from multiple, often unrelated sites, and, therefore, cannot account for complex local environmental conditions. Therefore, it's possible that risk is absent even if sediment contaminant concentrations exceed screening-level benchmarks. Under these circumstances a site-specific BERA is often needed.

A typical BERA consists of studies designed to empirically confirm the potential for ecological risk at a particular location. If conducted properly, a BERA can also evaluate the influence of local conditions (physical, chemical, or biological) that can either diminish or enhance the toxicity of sediment contaminants. There is no "one size fits all" approach, but most BERAs for sediment investigations include some kind of toxicity testing with benthic organisms or a survey of the kinds and numbers of benthic organisms living in or on the sediments at a site.

Sediment toxicity testing is performed to evaluate the toxicity of sediments collected from the site on laboratory organisms using standard testing protocols. These tests are widely used and are a reliable means of confirming whether sediments are actually toxic, rather than relying on the generic screening level thresholds used in the SLERA. However, toxicity tests alone do not identify the contaminant or condition that causes toxicity in a particular sediment sample. Even if a sediment sample contains elevated PAH concentrations, for example, the real cause of toxicity may be the presence of contaminant mixtures, sediment characteristics (e.g., percent fines), or harmful concentrations of dissolved oxygen or ammonia.

Therefore, if toxicity is observed in the tests, benthic community surveys are also often conducted to evaluate the numbers and types of invertebrate organisms living on or in sediments at the site. This is done because the "structure" of the invertebrate community (i.e., relative composition of different invertebrate species) can be diagnostic of adverse ecological impacts for certain types of contaminants. However, like sediment toxicity testing, benthic community structure can be strongly influenced by poor habitat conditions owing to sediment characteristics, low levels of dissolved oxygen, etc.

Regulations driving site remediation can, unfortunately, restrict the kinds of approaches one may be able to select for conducting ERAs and evaluating the role of multiple stressors.

In summary, these "standard" BERA approaches tend to focus on evaluating the risks of individual chemical contaminants in isolation from other physical or environmental stressors which can cause adverse effects every bit as severe as those from chemical contaminants. BERAs for MGP sediment investigations should, therefore, consider using one or more specialized tools for evaluating the relative effects of "multiple stressors" rather than relying on the standard BERA approaches outlined above. Some of these specialized approaches are summarized below.

Toxicity Identification Evaluations (TIEs)

Sediment TIEs investigate which chemical or physical factors are most likely responsible for observed toxicity. They can also be used to evaluate potential confounding factors such as ammonia, which can be as or more toxic than chemical contaminants such as PAHs. Sediment TIE studies consist of a series of sediment manipulations (e.g., chemical amendments) that are designed to identify, by process of elimination, the toxicity of classes of chemical stressors including cationic metals (e.g., lead, cadmium), non-polar organic toxicants (e.g., PAHs or PCBs), and ammonia. The applicability and effectiveness of the sediment TIE methodology at contaminated sites (including Superfund Sites) is well-documented.

continued on page 4

Editorial

Regulations – Or No Good Deed Goes Unpunished – The Next Generation

By Steve Canton, Certified Senior Ecologist/VP, GEI Consultants, Inc.

As a practicing scientist with an ecological background, I'm generally focused on identifying the "drivers" controlling ecological communities. To do so, I always remember that ecology is defined as the interaction of biological communities with their environment. This means the entire environment, not just "Clean Water Act" standards-based environments or "CERCLA" legacy contaminant-based environments. Pristine mountain streams and not so pristine urban waterways have the same thing in common – no single stressor or family of stressors drives the system. In fact, it is the combination of flow regime, sediment particle size, water quality, physical habitat, dissolved oxygen, ionic composition, and even biological interactions that is responsible for the structure of biological communities at any site.

This makes perfect sense, to ecologists (and maybe even enlightened engineers) – we wouldn't expect anything different. And given this knowledge that all parameters are important to the structure of ecological communities, we naturally look at site remediation differently. We look to fix what is wrong. This is where regulations can get in the way.

The Clean Water Act focuses on known and promulgated water quality standards – leaving potential impacts of habitat, sediment contamination, or even nuisance species out of the picture. CERCLA focuses on legacy chemical contaminants – often in sediment – but does not and cannot address water quality impacts from sources regulated under the Clean Water Act. Neither regulatory scheme addresses non-chemical stressors, like channelization or flow modification.

Why does this matter? Assume you're working on an urban waterway with multiple PRPs, multiple permitted discharges, and a long history of channel and flow modification. Objective multi-stressor analyses indicate that the primary limiting factors for your biological communities turn out to be a combination of water quality impacts from stormwater discharges and lack of suitable habitat. However, legacy contaminants from your site are also present in the sediments. CERCLA forces remediation based strictly on sediment removal – which according to the "ecological evaluation" may not actually result in any benefits to the environment! Now it's true that during evaluation of the feasibility options, we can try to balance these non-CERCLA stressors' impacts when selecting preferred remedial alternatives, but those alternatives will still be focused on CERCLA stressors – not stressors that might be more important and that will remain – with the same negative impact – after remediation. This is even more problematic when multi-stressor analysis identifies non-CERCLA stressors, and also points to contaminants from non-client PRPs!

Is there an answer? Under the current multi-agency (and "within-agency") regulatory framework, I'm not sure there is. This isn't just unfortunate, it feels almost criminal when strict conformance with regulations may force remediation that does not actually address the problem.

MGP Reporter

GEI Consultants, Inc.
455 Winding Brook Dr., Suite 201
Glastonbury, CT 06033
phone (860) 368-5300
fax (860) 368-5307
www.geiconsultants.com

Stuck in the Mud (continued from page 2)

Contaminant Bioavailability Assessments

The toxicity of most chemical contaminants, including PAHs, can be affected by the presence of factors that diminish toxicity by limiting the availability of the contaminant to the organism (termed "bioavailability"). Contaminant bioavailability has been widely studied, particularly for PAHs and metals, and several USEPA-approved methodologies for assessing bioavailability have been developed.

One common factor that reduces the toxicity of PAHs and metals is organic carbon. Organic carbon can be naturally present in sediments and surface water (primarily from weathered or decayed organic matter like leaves). It can also be artificially introduced as a result of discharges from wastewater discharges or CSO input. Either in dissolved or particulate form, organic carbon can bind to PAHs and metals, rendering them less bioavailable and, as a result, less toxic. Relatively high concentrations of PAHs in bulk sediments thus may have limited ecological risk because of their reduced bioavailability due to high concentrations of organic carbon.

Most bioavailability studies for sediments are based on the well-confirmed premise that benthic organisms are primarily exposed to contaminants in sediment porewater, rather than the sediment itself. Therefore, any factor—such as organic carbon—that can reduce the bioavailable fraction of contaminant porewater concentrations will reduce bioavailability. Many techniques have been developed for measuring or predicting the bioavailable fraction of contaminants in porewater such as simultaneous extracted metal/acid volatile sulfide (SEM/AVS) for metals and solid-phase micro-extraction (SPME) analysis for PAHs.

Statistical Analysis of Multiple Stressors on Benthic Communities

The types and numbers of benthic invertebrate species sometimes vary in predictable ways with particular stressors such as sediment characteristics, water quality, chemical contaminants, etc. Statistical tools can be applied to determine which factors or chemicals other than PAHs are limiting the abundance or diversity of benthic communities.

Collectively, these statistical tools are termed "multivariate" statistics because they simultaneously evaluate quantitative relationships between benthic community structure and multiple environmental characteristics such as a chemical contaminants, bioavailability factors, or even non-chemical stressors such as habitat quality. While multivariate tools cannot by themselves prove which factor or group of factors is the most likely cause of biological impacts, they can help identify the presence of confounding factors which can be evaluated, if necessary, by additional study.

Three statistical approaches that have been used to identify relationships between environmental and biological variables include:

- Principle Component Analysis - a procedure used to identify groups of chemical, physical, or biological variables that tend to increase or decrease in value together in the same samples. This analysis helps find parameters that are related to each other – or "move together" in the environment. It can also be used to show that parameters are not related, thus potentially useful for removing potential stressors from future analyses.
- All Possible Regressions Analysis - looks at all numeric relationships between a single biological response variable with many chemical or physical variables which may be responsible for causing the biological response. This analysis ultimately identifies the best single variable or subset of variables that best explain the biological or ecological response of interest.
- Chi-squared Automatic Interaction Detector (CHAID) - evaluates contingent relationships between a biological response variable and several stressor variables. CHAID selects a subset of stressor variables that best predicts the biological response of interest and presents these variables in a decision tree leading to groupings of the stressor variables that best predict the biological response variable. This test provides a unique evaluation of potential relationships between biological variables and different abiotic variables where each level of relationship is "contingent" on the strength of the prior relationship. When combined with the two previous parametric analyses, these three analyses can be used to develop prioritized listings of key stressor variables that best explain variability in the benthic community.

Regulatory Acceptance

While the tools and approaches described here have achieved broad scientific acceptance, careful planning and communication is needed to ensure any approach will be accepted by regulators or other stakeholders. Regulations driving site remediation can, unfortunately, restrict the kinds of approaches one may be able to select for conducting ERAs and evaluating the role of multiple stressors. For example, CERCLA does not generally allow for the evaluation of stressors other than chemical contaminants during the remedial investigation phase. Instead, physical or habitat stressors can be incorporated into the feasibility study by "balancing" the risks from chemical contamination with these other stressors in selecting the final preferred remedial alternative. However, the presence of stressors other than chemical contaminants can still confound evaluation of traditional ERA endpoints such as benthic toxicity and so need to be incorporated into the remedial investigation phase. This is crucially important for remedial investigations to ensure that remedial designs are focused on the specific factors driving ecological risk at the site and lead to the desired goal of reducing or eliminating those risks. Otherwise, significant resources could be expended on a remedial action that does not achieve the desired result.

For additional information on this topic, please contact Bob Gensemer at bgensemer@geiconsultants.com.

Newsbriefs

Cleanup Plan for Ashland, Wisconsin former MGP site

On September 30, 2010, US EPA Region 5 Superfund Division Issued a Record of Decision (ROD) for Cleanup of Contaminated Sediments in Lake Superior at the Ashland/Northern State Power Site in Ashland, Wisconsin.

The Site consists of a former manufactured gas plant (MGP) that is owned by Northern States Power (d/b/a Xcel Energy), a railroad corridor, a city-owned park and approximately 16 acres of Chequamegon Bay in Lake Superior. The Site consists of soils, sediments, and groundwater contaminated by polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs).

The selected remedy was estimated to cost between $83-$97 million, will serve as the final cleanup action for the Site, and consists of the following key components:

- removal and treatment or off-site disposal of contaminated soil, groundwater and sediment, including all NAPL;
- engineered surface and vertical barriers to contain contaminated groundwater;
- groundwater extraction for hydraulic control and restoration, with possible in-situ treatment of groundwater;
- long-term groundwater and sediment monitoring; and
- institutional controls to limit future site use to prevent exposure to hazardous substances that will remain at the Site after construction of the remedy is complete.

The ROD is available at: http://www.epa.gov/region5/sites/ashland/pdfs/ashland_rod_201009.pdf

Additional information about the site is available at: http://www.epa.gov/R5Super/npl/wisconsin/WISFN0507952.htm

Web Watch

Refreshing Perspective

MGP practitioners spend a lot of time reading about the negative impacts and potential risks of coal tar in the environment. Therefore, the information found about coal tar at the wiseGEEK website was strangely refreshing. GEI does not endorse the site or its information. However, we think our readers might also find the info um, well.......... different? Check it out at http://www.wisegeek.com/what-is-coal-tar.htm

Tar Wash

Most of us already know that coal tar is used in shampoos to treat scalp conditions. At least one user of coal tar shampoo is passionate about the matter. See http://www.psorsite.com/coaltar.html

GEI Consultants