Use of Amendments for In Situ Remediation of Sediment

An Online Continuing Education Course for Engineers

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Use of Amendments for In Situ Remediation of Sediment

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1. Introduction

The in situ sequestering or destruction of contaminants has the potential to reduce risks at Superfund sites. These technologies have successfully treated groundwater contamination, but only recently have technologies been developed to treat contaminated sediments. These technologies, referred to as amendments when applied to sediment remediation, are generally placed into or onto the sediment surface layer, into a sand cap, or within a geotextile mat. They can be used as a single remedial approach or in combination with other remedies. The most common amendments, such as activated carbon, Organoclay™, and apatite, are specialized materials that decrease contaminant bioavailability by sorption. Other amendments being considered promote the degradation of contaminants. The appropriate use of these amendments has much potential to limit exposure to contaminants and, thus, to reduce risks.

Historically, most sediment remedies have included dredging or excavation as a significant component of the remedy. They also typically rely on MNR to achieve long-term risk reduction, even when not explicitly stated as part of the remedy. Recently, more sites are considering combination remedies where MNR, capping, and dredging are being concurrently selected, depending on conditions in different areas of the sites. Capping leaves contamination in place and is generally intended to isolate the contaminants of concern (COCs). Although traditional sand caps have effectively contained the COCs and prevented exposure of the benthic and pelagic communities, their large thickness can reduce the hydraulic capacity, flood storage, and depth of the water body. They may also be compromised by physical disturbances, gas ebullition (the transportation of contaminants via entrapment in migrating gas bubbles), non-aqueous phase liquid (NAPL) transport, or groundwater advection.

The use of amendments to reduce bioavailability of contaminants by sorption or promote the degradation of the contaminants is a relatively new option for in situ sediment remediation. This innovative technology is being developed and implemented to improve the risk reduction and cost-effectiveness of remedies at sediment sites. Amended caps have the potential to reduce the thickness of traditional caps and to improve their resistance to erosional events and advective transport of COCs by ebullition, NAPL, or groundwater flow. Amendments applied directly to the contaminated sediment may be particularly useful in areas where MNR, caps, or dredging are not likely to be effective in reducing risks.

This course will introduce the most promising amendments for in situ remediation of sediments and summarize some of the information on contaminated sediment sites that have already employed these amendments. The course provides information on the state of the practice of the use of amendments for in situ remediation of contaminated sediments, as well as three case studies where these amendments have been used. This course also focuses on the use of amendments either by themselves or in conjunction with a conventional isolation cap or a thin layer cap and EMNR. The amendments discussed are designed to treat hydrophobic organic contaminants, metals, or both. Some of these amendments may also be effective in reducing risks from NAPL. Amendments for hydrophilic organics (for example: PCE, BTEX, or munitions) are not discussed in this course. In situ technologies, such as in situ chemical oxidation and permeable reactive barriers, are well established for treating groundwater and well documented elsewhere. Additionally, there is less research on the effectiveness of using sediment amendments to remediate such hydrophilic organic contaminants. Information on types of amendments, placement methods, design considerations, modeling, monitoring, performance, and cost are included below. The appendix contains a list of sediment sites where amendments have been used as part of a remedy or as pilot studies, a brief description of the site remedies, and monitoring results.

2. Overview of Amendments for Sediments

Amendments can be introduced in sediments either as part of a cap, or directly into or onto the existing sediment. These two approaches are discussed separately below:

Amended caps. Where conditions preclude the use of a conventional cap, amendments show promise, especially for hydrophobic organic contaminants (HOCs): polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins/furans, and chlorinated pesticides. For example, the addition of amendments to a cap can increase the cap's effectiveness by 1 to 2 orders of magnitude, as described in more detail later in this report. Amendments may also better achieve design objectives, such as maintaining navigation depths, because these approaches do not reduce water depths the way thicker, conventional caps do. Amended caps work primarily by retarding contaminant transport through the cap and acting as a barrier between the contaminated sediment and the new benthic layer, thus preventing exposure of the benthic and pelagic communities to the contaminants. Amendments can be introduced to a capping layer in a geotextile mat or added to capping materials before or during placement of caps.

Direct sediment amendments. The primary exposure pathway for hydrophobic and bioaccumulative pollutants often involves bioaccumulation in the benthic infauna and subsequent transfer into the aquatic food web. Direct amendment of surficial sediment with sorbents can reduce pollutant bioavailability to the food chain and flux of pollutants into the water column. Amendments can be spread on the surface of the contaminated sediment as a thin layer, intended to be mixed with the sediments through natural processes, or mixed into the surface using equipment similar to a rototiller. The intent in direct application is to change the native sediment geochemistry to reduce contaminant bioavailability without creating a new surface layer or cap. Figure 1 shows examples of various placement methods.

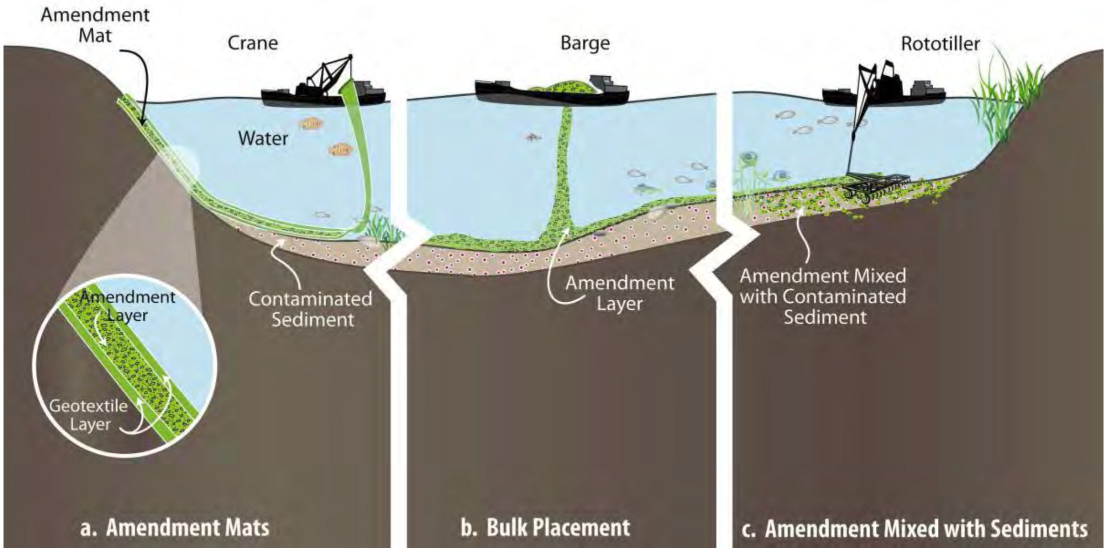


Figure 1: Placement Methods for Sediment Amendments

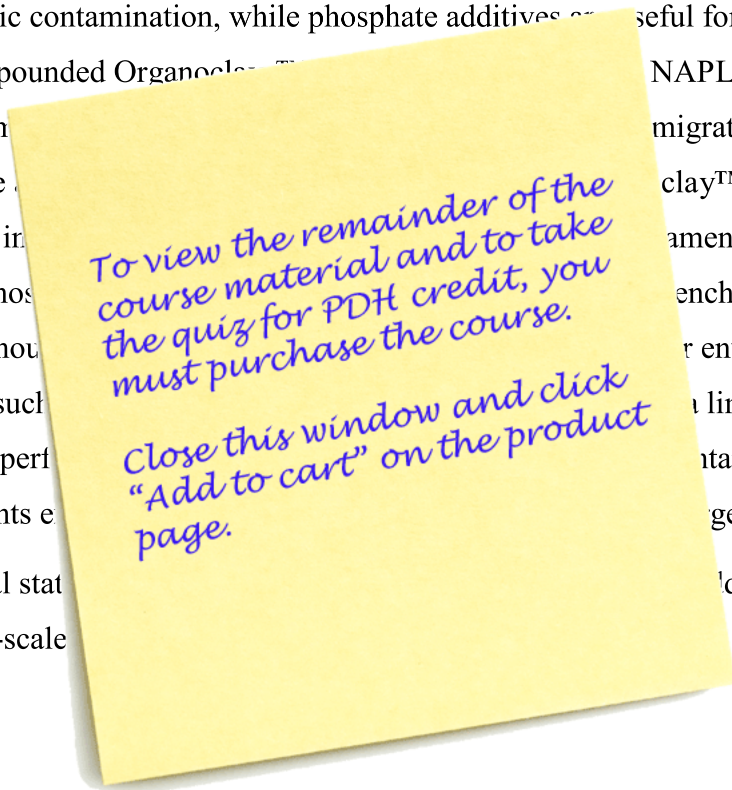
While amendments show promise, there are concerns and uncertainties that may limit their use in some site conditions. One current concern with using bulk amendments is the difficulty in placing some of these materials accurately in a dynamic, aqueous environment as a result of their potential for entrainment and movement within the water column. The unknown treatment capacity of some amendments, whether applied in bulk or in a mat, may also be a concern, particularly with respect to multiple contaminants and interactions with the natural system. As with other remedial alternatives (such as capping and dredging), the long-term permanence of amendments and their ability to retain contaminants over time are not well understood. Although laboratory tests and models can predict short- and long-term performance, there are few field applications currently in place to evaluate the effectiveness of amendments and to validate the models used. The success of in situ amendments also depends on the level of contamination in new sediment deposits that may form over time. Thus, ongoing source control is critical for the success of any in situ remedy. Additional field applications will increase the understanding of this technology and the key factors affecting its long-term effectiveness.

Currently, most of the amendment applications have been laboratory or pilot-scale (small scale, intended as a test or demonstration of effectiveness) research projects; there are a small number of sites where amendments have been used as demonstration projects or full scale in the field.

Site-specific information is provided in the course where available

3. Amendment Materials

The type of amendment used is dictated by the type of contamination, sediment characteristics, and site conditions. Activated carbon and other carbonaceous amendments are appropriate for sorbing organic contamination, while phosphate additives ar... seful for binding metals. Properly compounded Organocl... NAPL while maintaining sufficient perm... migration. The effectiveness of some of the ... clay™, has been demonstrated in ... amendments, such as zero valent iron, phos... ench-scale or pilot-testing phase. Even thou... r environmental applications, such ... limited number of projects and available perf... ntaminated sediments. Table 1 presents e... geted, and the developmental stat... ditional information about the full-scale



[1] For this course, the term "treatment technology" refers to any unit operation or series of unit operations that alters the composition or behavior of a hazardous substance, pollutant, or contaminant through chemical, biological, or physical means so as to reduce toxicity, mobility, or volume of the contaminated materials being treated.