REACTIVE MATERIAL MAT FOR IN-SITU CAPPING OF CONTAMINATED SEDIMENT

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ABSTRACT:

Environmental dredging can create challenges, such as, finding available space to construct confined disposal facilities and dealing with residual contaminants. In-situ capping (either in place of dredging or for capping residual contaminants) can be limited by concerns regarding navigation, uniform cap placement, biointrusion and geotechnical stability. A potential solution for many in-situ capping concerns is the use of a reactive material mat. A reactive material cap could greatly reduce the thickness required for the cap compared to conventional sand caps. Various reactive materials (e.g., activated carbon, apatite, organoclay, zeolite, zero-valent iron) are used for wastewater and groundwater treatment and may be applicable to in-situ capping. Production processes have been developed to manufacture reactive material filled geotextile mats. The added functions of the geotextiles provide several advantages for reactive material mat over loose placement of reactive materials. A coke-filled geotextile mat was constructed for the Anacostia River Demonstration Project and successfully deployed. Other deployment methods have also been used for installing geosynthetics in waterways from shoreline and would be applicable to a reactive material mat.

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Reactive Material Mat for In Situ Capping of Contaminated Sediment

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ABSTRACT: Environmental dredging can create challenges, such as, finding available space to construct confined disposal facilities and dealing with residual contaminants. In situ capping (either in place of dredging or for capping residual contaminants) can be limited by concerns regarding navigation, uniform cap placement, biointrusion and geotechnical stability. A potential solution for many in situ capping concerns is the use of a reactive material mat. A reactive material cap could greatly reduce the thickness required for the cap compared to a conventional sand cap. Various reactive materials (e.g., activated carbon, apatite, organoclay, zeolite, zero-valent iron) are used for wastewater and groundwater treatment and may be applicable to in situ capping. Production processes have been developed to manufacture reactive material filled geotextile mats. The added functions of the geotextiles provide several advantages for reactive material mat over loose placement of reactive materials. A coke-filled geotextile mat was manufactured for the Anacostia River Demonstration Project and successfully deployed. Other deployment methods have also been used for installing geosynthetics in waterways from shore and would be applicable for installing reactive material mats.

INTRODUCTION

Dredging has evolved into a highly technical process drawing from some of the latest technology. The methods of navigational dredging range from clamshell buckets to sophisticated hydraulic dredges. More recently, these techniques have evolved into the processes used for environmental dredging applications.

High concentrations of certain contaminants in sediments pose human heath and ecological risks. Dredging of contaminated sediment provides a method of removal of these contaminants of concern (COC). One of the most obvious benefits of environmental dredging is the fact the contaminated sediments are permanently removed from the waterbody. These sediments are typically disposed of in an upland containment facility or landfill. In some cases disposal of contaminants may not be permitted or the costs to transport them to a permitted facility may be very high. Alternate uses for the contaminated sediments may be considered and may help to reduce or eliminate risks. The cost of these alternate treatment and use methods must be evaluated against other permitable disposal options.

Of paramount concern when dredging is the ability of the process to remove the COCs to a level that is below the regulated concentration. Although dredging techniques have been demonstrated to reduce sediment contaminant concentrations, it appears that these techniques can result in residual contamination. This residual contamination may be the result of re-suspension of contaminants into the water column or sloughing of adjacent materials into the dredged areas. Concern over these residual concentrations may lead to subsequent passes or other means to minimize risk from the residuals.

The impacts of the cleanup activity to the surrounding area need to be evaluated regarding the impact of the operation or long-term disturbance of an area. A dredging operation will typically require some sort of sediment dewatering process. After removal of the solids, the associated water may have to be treated before it can be discharged back into the waterway. Because of these facts a dredging operation typically requires onshore support facilities. Construction of these facilities will likely impact the area surrounding the dredged area.

An alternate solution to dredging contaminated sediments is to cap them in place. In situ sediment caps are typically designed to take into consideration stabilization and physical isolation of the sediments as well as contaminant transport mechanisms (Palermo et al,. 1998). To accomplish this, computer modeling is relied upon.

Due to a limited set of information on many mechanical processes that can affect the long-term stability of the cap some uncertainty exists over this issue. Concerns exist over the effects of ice heaving, currents, tides, wave action, propeller and thruster wash on the cap. Caps may be limited to areas where concerns over these erosional forces may not exist. Alternatively, these concerns are typically addressed by increasing the cap thickness to the point that it exceeds the thickness of material that may be affected by such forces. Additional research in this area may provide a more clear understanding of these forces on a cap design. Another alternative is to include a component in the cap design that would act to minimize the effect of these erosional forces.

A proper cap design should take into account the indigenous benthic community. To do so means to properly address the potential for biointrusion into the contaminated sediment. This is typically done by increasing the overall cap thickness to the point that it exceeds the depth of penetration of the local benthos. Another approach is to block bio-intrusion with some other layer in the cap design.

Construction processes have evolved to allow an accurate placement of the cover materials in a traditional sand cap. Although these processes have advanced, an allowance in the cap design is typically made to account for the spatial variability of the cover material placement. Once again this allowance usually entails adding more material to account for the variability of placement. Methods of ensuring uniform placement of materials are needed.

With all of the variability in the conditions which a cap may be in service, comes a degree of uncertainty. This uncertainty is typically compensated for by adding more and more material to the cap design. For this reason cap designs may become impractical in water depths that do not even exceed the total cap thickness. Clearly, the impact to navigability must be assessed when evaluating whether a cap design is practical. From a practical point, if a thin cap can be designed that provides as good or better performance than a traditional sand cap, then the capping alternative may become a practical solution for a wider range of applications.

Despite the variability in cap designs based on the range of considerations herein, in situ capping whether traditional or thin cap design does offer some inherent advantages over dredging. First, the cost to cap is typically only 30 percent of the cost to dredge and dispose (Evison et al., 2004).

In addition to the cost advantage, typically a remediation of contaminated sediment can be completed faster by in situ capping than by dredging. This may be of significance to a heavily navigated area or an area where recreational use needs to be restored rapidly.

Finally, the impact to surrounding area may be of importance. In an urban setting the shoreline may not be conducive to the operation of a dewatering facility. Or, the impact of having sustained dredging operations to the area may be financially significant. These impacts are generally less if capping is chosen as the remedial option.

INNOVATIVE METHOD

A system has been devised that encapsulates reactive materials within a geotextile composite that can be easily deployed as an in situ capping material over sediments.

Various reactive materials (e.g., activated carbon, apatite, organoclay, zeolite, zero-valent iron) are used for water, wastewater and groundwater treatment and can be applied to in situ capping. Activated carbon is a widely used adsorptive media for water treatment removal of phenol, halogenated compounds and pesticides (Thomas and Crittenden, 1998). Apatite, $Ca_{10}(PO_4)_6(OH,F)_2$, is a commercially available mineral that has been shown to be effective at sequestration of Pb. Apatite removes contaminants from water through three mechanisms: ion exchange, isomorphic substitution and precipitation (Gardner and Stern, 2004).

Organoclays are surface-modified clays. The production of organoclays replaces the surface cation of bentonite or hectorite clay with an organic molecule. Quaternary amines based upon tallow are the most commonly used organic compound. The resulting organoclay is oleophilic, hydrophobic and permeable. A properly compounded organoclay will exhibit minimal swelling upon organic adsorption and maintain high permeability. Several manufacturing quality control tests have been developed using x-ray diffraction and thermogravimetric analysis to assure proper compounding. Organoclays are proven to be effective adsorbents for insoluble and partially insoluble compounds. In treatment of produced water from offshore crude oil production organoclays have removed polyaromatic hydrocarbons to non-detect levels (Darlington 2002). Because of their high capacity for organics (up to 1:1 on a per weight basis) organoclay can be more cost effective than activated carbon.

Zeolites are porous crystalline aluminosilicates. Both natural and synthetic zeolites are used commercially for their adsorption, ion exchange, molecular sieve and catalytic properties. Zeolites are used in water treatment for removal of nitrates and metals such as Pb, Zn, and Cu (Thomas and Crittenden, 1998). Zero-valent iron, Fe(0), is a strong reductant and has been used successfully in permeable reactive barriers for the dechlorination of chlorinated hydrocarbons and the reductive precipitation of chromate (Cr^{+6} as CrO_4^{-2}) (Powell 2002). Reductive precipitation involves the transfer of electrons from Fe(0) to the hexavalent chromium and transforming the chromium to a less soluble form, $Cr(OH)_3$.

Geotextiles are textiles that are manufactured with synthetic fibers into flexible, porous fabrics. Since they are not manufactured with natural fibers, such as cotton, there is no concern with biodegradation. Geotextiles have varying properties based upon the type of polymer, the type of fiber and fabric style. The four main functions of geotextiles are separation, reinforcement, filtration and drainage. Geotextiles have been used in civil engineering, and particularly coastal work, for decades. Some of the earliest uses of geotextile were in the late 1950s behind precast concrete seawalls and under large riprap. (Koerner, 1998).

Composition. Reactive material mats have been constructed by CETCO using two methods. The first method is by needlepunching. This method has been used since the late 1980s to manufacture geosynthetic clay liners. In the needlepunching operation a layer of geotextile, either woven or nonwoven, is fed onto the line. A hopper disperses an even layer of the reactive material onto the geotextile. A top nonwoven geotextile is then unrolled on top of the reactive material. The material is then fed through a loom where nonwoven fibers are needlepunched through the reactive material and into the lower geotextile. Typical thickness of the needlepunched mat is 6 mm. The reactive mat is rolled onto a core tube and then wrapped in a polyethylene bag.

The second method is a laminating method (Figure 1). This method allows a higher mass per unit area than needlepunching and the ability to use abrasive reactive materials that cannot be needlepunched. In the laminating method a nonwoven core is bonded either by needlepunching or adhesive to a geotextile. The bonded material is then fed core side up through the line. Reactive material is fed onto the core from a hopper. The core has an apparent opening size (AOS) that is larger than the maximum particle size of the reactive material. The reactive material is worked into the core openings by suction and/or vibration. A cap geotextile is then bonded to the top of the core by heat or adhesive. Typical thickness of the laminated mat is 11 mm. The reactive mat is rolled onto a core tube and then wrapped in a polyethylene bag.

Certain reactive materials, such as activated carbon, are buoyant. The reactive mat may be engineered with a geotextile with a high specific gravity and/or a fraction of sand mixed with the reactive material to counteract the buoyancy.

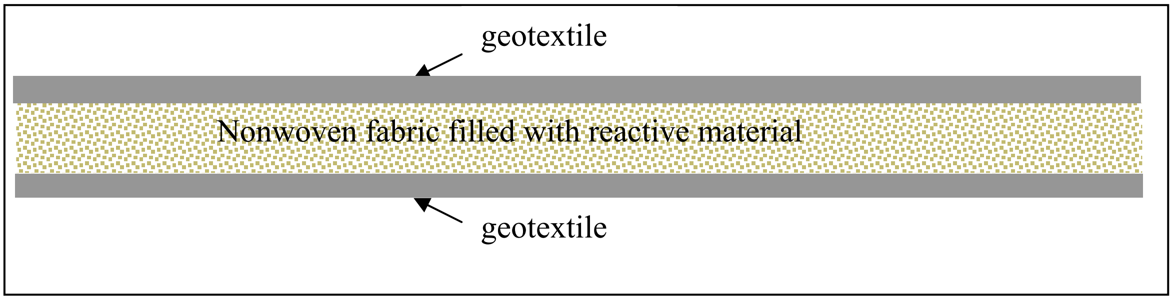

FIGURE 1. Cross section of laminated reactive core mat.

Benefits. An advantage of a reactive cap over a sand cap is reduced cap thickness. Lab column testing and modeling illustrate that a thin layer of highly adsorptive material such as activated carbon can have over 100 times the adsorption capacity for PCBs as sand or organically-rich soil containing 3.8% carbon fraction (Murphy and Lowry, 2004). Project specific conditions and adsorptive material properties will affect results. However, a 10 mm thick reactive mat can theoretically replace 1 m of sand or soil. This can help maintain navigable depths and flow capacity of waterways.

One factor with using reactive materials is their cost. By constructing a mat encapsulating the reactive materials within geotextiles they can be used in a controlled and potentially cost-effective manner. The reactive mat also combines the benefits of reactive materials and geotextiles.

The U.S. EPA program on Assessment and Remediation of Contaminated Sediments (ARCS) has developed guidance on the design of in situ caps that includes laboratory tests and models of the following key processes; advective/diffusive contaminant flux, bioturbation, consolidation and erosion. The potential functions of geotextiles in in situ cap designs include: 1) providing a bioturbation barrier, 2) preventing mixing of cap materials with underlying sediments, 3) reducing contaminant flux, 4) promoting uniform consolidation, 5) stabilizing the cap, and 6) reducing erosion of the capping materials (Palermo et al., 1998). Since the reactive mat is constructed with two geotextiles the composite mat can be designed to perform multiple cap functions.

Hampton et al. (2002) showed that geotextiles can greatly reduce movement of benthic invertebrates in sediments. As previously stated, a geotextile with a proper AOS can contain the cap material and prevent mixing into the underlying sediments. The permittivity of the geotextiles can reduce contaminant flux and/or promote uniform flow during consolidation. The multiaxial tensile strength of the geotextiles can provide stabilization to the cap. At the Anacostia River Demonstration Project the reactive mat was installed over sediments with an undisturbed shear strength of 12.3 psf (at 2 foot depth) per field vane shear ASTM D2573 test results. The geotextile, along with appropriate armoring, can help reduce erosion of the capping material.

Deployment. Reactive material mats may be deployed in a number of ways. The Anacostia demonstration project is considered to be a successful demonstration of a barge-based deployment technique (Figure 2). For this project a coke-filled Reactive Core Mat™ (RCM) was manufactured. A barge mounted crane was used to position the rolls and unroll the RCM underwater. The mats were first submerged to allow them to absorb water and displace entrained air. Then the rolls were positioned 18 inches above the river bottom and anchored with sand at one end. The crane was able to swing across the area to be capped and unroll the mat as it went. The installation was assisted and coordinated by having a diver in radio communication with the crane operator.

FIGURE 2. Reactive material mat being deployed at the Anacostia River Demonstration Project, Washington DC.

Land-based deployment techniques may also be used to deploy RCM. Rolls may be positioned on shore suspended by a spreader bar system with a clamp connected to the leading edge of the roll. The material is then pulled off of the roll using a winch that is either mounted on a barge or on the opposite side of the waterway.

Deployment techniques may take advantage of temporary buoyancy before the mat absorbs water and displaces air to allow the material to "float" into position and subsequently sink as they take on water. It is likely that as the RCM technology develops, the methods of deployment will also evolve.

CONCLUSION

The environmental remediation community is seeking innovative methods to remediate contaminated sediments. Reactive materials and geotextiles have been used extensively in civil engineering for water treatment and coastal applications, respectively. A reactive material mat combines the benefits of reactive materials and geotextiles in addressing concerns with in situ capping.

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