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Design Guidance for Encapsulation Cells

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Introduction

The purpose of this document is to serve as a guide to the suitability, selection, design, and construction of encapsulation cells containing contaminated soil, sediment, and/or waste material as part of a state-lead removal or remedial action under the direction of the Kansas Department of Health and Environment (KDHE) - Bureau of Environmental Remediation (BER). This document is intended to serve as a reference; it does not supplant other state regulations or policies pertaining to the various activities discussed herein. Additionally, this guidance document is not intended to address solid or hazardous waste disposal regulated by KDHE – Bureau of Waste Management (BWM). As noted in this document, there will be close coordination between BER and BWM for issues regarding waste disposal activities at contaminated sites.

Encapsulating contaminated material can be an effective technology for isolating contaminants and may be a suitable alternative for protecting human health and the environment when removal and off-site disposal may not be cost-effective and/or practical. Primary objectives for the design and construction of an encapsulation cell include:

- Preventing direct contact with contaminated media.
- Minimizing infiltration so that leachate is not generated or is limited.
- Achieving long-term performance so that encapsulation cells maintain their integrity over time without need for extensive maintenance.
- Considering future land use and redevelopment options while maintaining the integrity and effectiveness of the encapsulation cell.

Factors to Consider When Selecting an Encapsulation Cell

Multiple factors should be considered in the selection, planning, and design of an encapsulation cell because every situation is unique. Some factors to consider include:

- **Type of Contamination:** Understanding the physical and chemical properties of the contaminant, including its methods of transport and mobility through various materials, will assist in determining whether an encapsulation cell will be effective. Some contaminant materials may require pre-treatment to reduce toxicity, leachability, or to solidify/stabilize the material before placement in an encapsulation cell. Certain contaminants may also be toxic to various plant species which could negatively impact vegetation cover. Impacted media that is classified as hazardous is addressed under RCRA Subtitle C and should be coordinated with the KDHE Bureau of Waste Management.

- **Gas and Vapor Release Potential:** Contaminated environmental media containing organic materials or volatile organic compounds may produce gases or vapors. A vapor barrier or vents within the encapsulation cell may be necessary to control off-gassing, along with air monitoring.

- **Property Owners Preference and Land Use:** The proximity of sensitive receptors and high traffic areas versus low traffic areas should be considered in the design. Designing the encapsulation cell around the land's current and potential future uses is a critical way to optimize the cover's life expectancy.

- **Site Lithology:** Site lithology affects the mobility and migration potential of contamination and the degree of infiltration control that may be necessary. For example, clay materials are more conducive to preventing migration or infiltration than sandy environments. Sites with shallow groundwater have a higher potential for impact through water infiltration and thus are less favorable for below-grade encapsulation.

- **Climatic Conditions:** The climatic conditions such as annual precipitation, maximum and minimum temperature, relative humidity, and daily wind run should be evaluated to determine the types of design features needed for meeting Remedial Action Objectives (RAOs). Areas with low rainfall and high evapotranspiration rates may support an evapotranspiration cover design, while areas subjected to larger amounts of seasonal rainfall will have a greater concern for storm water drainage and erosion. A site that is subjected to larger amounts of seasonal rainfall should consider a soil or composite cover Site frost penetration depth should also be taken into consideration when selecting the cover design type.

- **Long-Term Physical Stability:** Instability may result from subsidence and may damage the cover, increasing infiltration and erosion issues. Instability can be caused by factors such as: biodegradation, varying moisture content in different areas in the cap, frost penetration depth, seismic activity, and naturally-occurring biotic intrusion (burrowing animals and plant roots).

- **Topography:** The suitability of using uneven terrain, depressions, ravines or low lying areas for the encapsulation cell should be considered in the design. The buffer zone between natural bodies of water and encapsulation cells should be maximized whenever possible. In most cases, encapsulation cells should not be located within the 100-year flood elevation.

Types of Covers

The selection of the type of cover for the encapsulation cell should be based on the purpose of the cover and the RAOs. A variety of cover designs commonly used for encapsulation cells include, but are not limited to soil, evapotranspiration, single, and composite covers. They are described in more detail below:

Soil Cover: The use of a native soil cover may be appropriate when surface water infiltration and leachate generation are not controlling factors. This particular cover type is typically composed of multiple layers of low permeability, topsoil, and readily available site soils with varying thicknesses to minimize infiltration, promote total water holding capacity, and/or protect from freeze and thaw effects.

Evapotranspiration (ET) Cover: An ET cover is a type of soil cover that consists of a vegetated soil layer with sufficient thickness to hold annual precipitation until it is removed by the evapotranspiration processes. ET covers are designed to control water infiltration by balancing the water storage capacity of the soils and the ability of the plants and atmosphere to extract the water stored in the soil. ET covers are generally used in arid or semi-arid climates where clay or other barrier layers may exhibit a potential for desiccation and cracking. The design of the ET cover will require an understanding of the plant growth and properties, water storage capacity of the soil, ET rates, and climatic conditions.

Single Barrier: A single barrier cover is primarily used to reduce storm water infiltration, prevent direct human contact, control erosion and/or enhance future use by increasing the load bearing capacity. Materials commonly used include but are not limited to gravels, asphalt and concrete placed on well-compacted gravel or clay sub-base. These barrier layers are low permeability layers that reduce surface water infiltration into the underlying waste material.

Composite Cover: A composite cover design is selected when the primary remedial objective is to prevent infiltration through the consolidated material when groundwater is present at the site. A composite cover typically consists of a combination of a geotextile fabric, a synthetic geomembrane, or geomembrane composite clay (GCL), or permeable (clay) layer overlain by a drainage layer, and a final layer with vegetation. Composite covers are the most effective covers in restricting infiltration.

Engineering Considerations for Encapsulation Cell Design

The broad spectrum of possible site conditions and variety of contaminated material types preclude the establishment of a prescriptive design process. Applicable state solid waste regulations (specifically K.A.R. 28-29-121(g) and 28-29-304(g)) and best engineering and management practices should be used as guidance in encapsulation cell designs. Site-specific RAOs should be used by the design engineer to determine the specific components of the encapsulation cell design. The following guidelines should be considered for the design:

Project Plans and Specifications: A complete set of project construction plans and specifications for the encapsulation cell design are to be submitted for review and approval by BER. Refer to the Kansas State Board of Technical Professions K.A. R. 66-6-1(b) for professional seal requirements.

Soil covers: EPA Subtitle D or State compliant soil covers should consist of a minimum of eighteen (18) inches of compacted soil having a permeability of 1×10^{-5} centimeters per second or less (i.e. low permeably layer) and a minimum of six (6) inches of topsoil (i.e. final protective layer). K.A.R. 28-29-121 (g)(2) requires the thickness of the final protective layer to be at least as thick as the site frost depth which in Kansas is twelve (12) inches or more; therefore, the minimum total soil cover thickness should be a minimum of thirty (30) inches. A soil cover design should be based on meeting the RAOs, minimizing long-term maintenance of the project, and maximizing the growth and sustainability of vegetation on the cap.

Borrow Sites: Soil testing is recommended to determine the suitability of potential on-site or off-site borrow soils for use as low permeable layers and final covers supporting vegetation. Low permeability soil candidates are analyzed most commonly for permeability, moisture content and soil density by a competent geotechnical soil testing firm. In addition, a Proctor or Modified Proctor Test is performed on a particular soil to determine the ideal amount of moisture to achieve maximum density for development of compaction specifications. Refer to #BER-RS-048 *Consideration and Selection of Borrow Sites*, and K.A.R 28-29-121(e) and (g). Borrow soil to be used as the final cover (topsoil) should have an appropriate amount of organic material and fertilizer content to support vegetation.

Compaction Specifications and Testing: Soil testing, as discussed above, will assist in determining the compaction specifications for achieving the desired level of infiltration control. When compaction is an important factor in achieving the stated permeability, both the placement and compaction methods should be specified along with field testing methods and frequencies to verify that adequate compaction has been achieved. The soil cover specifications should include the height of lifts and types of equipment to be used in the construction of the cover components. In-situ field testing of individual compacted soil lifts should be conducted to verify compliance with compaction specifications prior to continuing soil cover construction activities. Type B or C compaction standards from the *Standard Specifications for State Road and Bridge Construction, Kansas Department of Transportation 1990* can be considered in circumstances when compaction is not a critical factor in achieving the required cover permeability standard.

Site-Specific Water Balance: Long-term cover performance can be tied to moisture content. Water balance should be calculated using average annual data collected for precipitation, evaporation, soil water storage, and drainage.

Erosion and Surface Water Drainage Controls: Steeper slopes (see Slope Stability below) on the encapsulation cell provide greater potential for erosion due to increased storm water runoff velocity. Matting, terraces, or riprap should be considered where erosion may be more difficult to control. Final surface contours, storm water runoff controls, side slopes and perimeter drainage details should be provided in design documents and drawings.

Slope Stability: The ideal slopes for the encapsulation cell should be determined from a stability analysis. Generally, side slopes should be no steeper than a ratio of 3.5:1 horizontal to vertical to prevent soil instability, erosion concerns, and to facilitate mowing. Where possible, KDHE prefers side slopes ranging between 5:1 to 7:1 horizontal to vertical, with appropriate Best Management Practices, such as constructed swales, terracing, and surface water let-down structures to minimize the potential for erosion. The effects of saturation should also be evaluated and measures taken to address the loss of shear strength that occurs. Applicable NRCS guidance should be followed when determining ideal slopes for an encapsulation cell.

Vegetative Cover: Vegetative covers minimize erosion by protecting against rill erosion, wind, gullying and surface water runoff scouring. Plant species should be selected that are most suited to naturally thrive in the environment while taking into account density, growing season, and root depth. The best type of soil cover vegetation in Kansas is usually some type of grass species that is dense and establishes quickly. Vegetation on an encapsulation cell should have root depths that are deep enough to ensure a good stand but not penetrate the low permeability layer. Native grasses have a tendency to root deeper. The growing season of the vegetation should be considered in scheduling construction so that re-vegetation activities can occur during the growing season. If the ideal planting time for the selected seed mixture was missed, it may be necessary to include an annual species (i.e. rye, wheat, etc.) to achieve a temporary grass stand until the next germination period. The final soil layer must have sufficient nutrient and organic content. Local Kansas State University Cooperative Extension Service county agents or staff of the United States Department of Agriculture (USDA) Soil Conservation Services should be consulted for recommendations as to types of grass species and tips for establishment. Additionally, the re-vegetation requirements described in the Construction Stormwater Permit should be followed.

Groundwater Protection/Monitoring – The need for a low permeability bottom liner, leachate collection system and/or comprehensive groundwater monitoring network will depend on whether there is a usable source of groundwater underlying the site and the degree of impact by contaminants. The amount of leachate generated can be controlled by the type of cover selected. The groundwater monitoring system should consist of a minimum of three monitoring wells with one up-gradient and down gradient well completed within the interval of groundwater impact. Refer to #BER-RS-045.

Operation and Maintenance Issues

The primary goal of an Operation and Maintenance (O&M) Plan is to protect the integrity of the cover in an effort to prevent uncontrolled human and environmental exposures to contaminated materials. An O&M Plan should be prepared during the encapsulation cell design phase and submitted to BER for approval.

At sites where an encapsulation cell is implemented as part of the final remedy, an Environmental Use Control (EUC) Agreement with the BER ensures there are institutional and administrative controls to limit and/or prevent future exposures. An EUC serves as a legal mechanism to enforce restrictions, prohibitions, and conditions of the land. EUC restrictions may include preventing disturbance of encapsulated areas, drilling of water wells, and providing notification during excavation activities, utility installation or repairs. For properties with an encapsulation cell containing concentrations of contaminants above the residential Risk-Based Standards for Kansas (RSK) threshold, an EUC should be applied to ensure adequate protection of human health and the environment. The O&M Plan may be included with the EUC Agreement.

The O&M Plan should address the following objectives and activities:

Periodic Inspections: In order to monitor the stability and integrity of the selected cover and its effectiveness in meeting the RAOs, periodic inspections should be conducted. The frequency of inspections will be based on the cover material and design. Inspections should include the following components:

- Review sampling records for compliance with discharge permits and deviations.
- Observe site conditions such as drainage, erosion, and vegetation establishment.
- Evaluate institutional controls such as fencing and site access points.

Environmental Monitoring: A monitoring program should be designed based on site-specific conditions and nearby receptors to evaluate the performance of the remedial action. This may include leachate, surface water, groundwater, sediment, etc. Environmental monitoring should follow the inspection schedule for the encapsulation cell.

Routine Maintenance and Repairs: In order to maintain the integrity of the encapsulation cell, repairs may be necessary to improve erosion controls, drainage systems, roads, fencing, and vegetation. Evidence of stressed vegetation may require reseeding and an evaluation of maintenance procedures. Additional controls may be needed to reduce or eliminate leachate. Vegetation height and woody plant invasion can be controlled by periodic mowing, or burning in order to inhibit degradation of the cover and maintain the desired vegetative species.

Reporting Requirements: Reporting requirements are determined on a programmatic and site-specific basis and should be specified in the O&M Plan. An EUC Agreement with BER will have specific requirements that may include routine reports on site activities.

Other Regulatory Considerations

When designing, constructing, and maintaining an encapsulation cell, other regulatory concerns need to be evaluated with respect to potential applicable or relevant and appropriate requirements (ARARs).

- **Storm Water Pollution Prevention Plans – KDHE Bureau of Water**
- **State Hazardous Waste Regulations – KDHE Bureau of Waste Management**
- **Disposal of Solid Waste or Special Waste – KDHE Bureau of Waste Management**
- **Heritage and Archeological concerns – Kansas Historical Society, Kansas Historical Preservation Office**
- **State and Federal Endangered Species – United States Fish and Wildlife Service and Kansas Department of Wildlife, Parks, and Tourism**
- **Off-Site Transportation – Federal Hazardous Materials Transportation Laws and Kansas Department of Transportation**
- **404 Wetlands Permitting – US Army Corps of Engineers**

Remedial actions may be subject to other ARARs besides those listed above. Refer to #BER-RS-015 *Potential ARARs* for additional information.

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