Examples of Approved Groundwater Corrective Measures For Solid Waste Management Facilities

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DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION

Constructed Wetlands

Constructed wetlands are wetlands built to treat contaminated water. They have four key components:

- Soil and drainage materials (such as pipes and gravel)
- Water
- Plants (both above and below the water)
- Micro-organisms.

Constructed wetlands purify the water that flows through them. Compared to conventional treatment methods, they tend to be simple, inexpensive, and environmentally friendly. Constructed wetlands mimic natural wetlands and marshes by mechanically filtering, chemically transforming, and biologically consuming potential pollutants in the wastewater stream. Constructed wetlands also provide food and habitat for wildlife and create pleasant landscapes. Constructed wetlands differ from natural wetlands in several ways:

- They remain constant in size
- They are not directly connected with groundwater
- They accommodate greater volumes of sediment
- They more quickly develop the desired diversity of plants and associated organisms.

Constructed wetlands are of two basic types: subsurface-flow and surface-flow wetlands. Subsurface-flow wetlands can be further classified as horizontal flow and vertical flow constructed wetlands. Subsurface-flow wetlands move effluent through a gravel or sand medium on which plants are rooted; surface-flow wetlands move effluent above the soil in a planted marsh or swamp, and thus can be supported by a wider variety of soil types including bay mud and other silty clays. In subsurface-flow systems, the effluent may move either horizontally, parallel to the surface, or vertically, from the planted layer down through the substrate and out. Subsurface horizontal-flow wetlands are less hospitable to mosquitoes, whose populations can be a problem in constructed wetlands (carnivorous plants have been used to address this problem). Subsurface-flow systems have the advantage of requiring less land area for water treatment, but are not generally as suitable for wildlife habitat as are surface-flow constructed wetlands.

Monitored Natural Attenuation (MNA)

Monitored natural attenuation (MNA) is the sum of natural processes that leads to the decreasing of contaminant concentrations in groundwater over time. The primary objective of MNA is to demonstrate that natural processes will reduce contaminant concentrations in groundwater to levels below regulatory standards before a point of compliance is reached. MNA as a remedial alternative is highly dependent on a good understanding of localized hydrogeologic conditions and may require considerable information and monitoring over an extended period of time. Please refer to the Environmental Protection Agency (EPA) MNA guidance documents on the EPA's website: www.epa.gov.

There are certain site specific conditions that can limit the effectiveness of MNA. If any of the following conditions are present, MNA cannot be utilized as the sole remedy to address groundwater contamination:

- An advancing groundwater plume indicates that the natural attenuation capacity of the system is unable to control the migration of contaminants.
- The contaminated media is difficult to assess as in some bedrock aquifers.
- Contaminant concentrations exceed groundwater standards established in 15A NCAC 02L .0202 beyond the relevant point of compliance.
- Points of exposure other than the property boundary are currently impacted.
- Mobile free product is present at the site, and no remedial method addressing the free product removal has been proposed.
- One or more of the other four exposure pathways (Subsurface Soil Leachate to Groundwater, Surficial Soil, Groundwater to Indoor Air Inhalation and Soil Vapor to Indoor Air Inhalation) exists at the site, and no active remediation method has been proposed to eliminate them.
- Contaminants are present which do not readily biodegrade.
- Fractured bedrock contamination.
- Contamination that has impacted receptors or creates an imminent threat to receptors (e.g.,drinking water wells, surface water, other environmental receptors)
- Source water protection areas.
- Well head protection areas.

Monitoring Well Network

An initial period of monitoring of an approved monitoring well network is needed to establish the effectiveness of MNA as a remedial option. An approved monitoring well network shall be sampled for all MNA performance parameters on a semiannual basis for at least two calendar years (four semiannual sampling events) to establish baseline trends. The groundwater monitoring well network shall consist of compliance wells, performance wells, and sentinel wells. The performance wells are used to prove the MNA is working at the landfill, and the sentinel wells are used to monitor the plume movement toward adjacent properties and receptors. The groundwater monitoring well network shall have the ability to provide data on the horizontal and vertical extents of the groundwater plume.

MNA Performance Parameters

The MNA performance parameters provide insight into the microbial and biogeochemical reactions and processes that are occurring within the subsurface. As a result, the baseline sampling shall include the following MNA performance parameters:

- Dissolved Oxygen
- Nitrate
- Iron
- Sulfate
- Sulfide
- Methane
- Ethene, Ethane
- ORP
- TOC/BOD/COD
- CO_2
- Alkalinity
- Chloride
- Hydrogen
- Volatile Fatty Acids
- pH
- Temperature
- Conductivity
- Turbidity

All of the above MNA performance parameters should be sampled at each background monitoring well, all performance monitoring wells, and all sentinel monitoring wells. An EPA approved MNA screening model shall be performed during each semiannual baseline event and submitted with the facility's semiannual groundwater monitoring report. The screening model must include the ability to measure mass flux.

After the completion of the baseline sampling events, the MNA performance parameters may be re-evaluated to determine if the sampling frequency may decrease for a specific MNA performance parameter or if a specific MNA performance parameter may be removed from the corrective action sampling program based upon its technical relevance (example anaerobic conditions instead of aerobic conditions). It is necessary to determine after the baseline sampling events, which reactions and processes are driving the subsurface biogeochemistry. A mass balance assessment must also be completed. There must be balance between source loading and plume attenuation capacity. Any changes to the MNA performance parameter list must be approved by the Solid Waste Section.

MNA Effectiveness

Pursuant to EPA guidance documents, MNA is effective based upon the following technical and scientific demonstrations:

1. The reduction of the contaminant concentrations is caused by chemical or biological attenuation of the contaminant;
2. The sampling analytical results show that the plume has stabilized horizontally and

vertically in size and is not migrating; and

3. A statistical reduction in the contaminant concentrations along specific flow paths can be shown.

Plume stability (chemical, biological, and physical) must be determined in evaluating trends along specific flow lines within the contaminant plume and along the contaminant plume boundary. The interpretation of the MNA performance parameter data and the technical evaluation of MNA as a remedy at the facility shall be presented in a comprehensive MNA Corrective Action Evaluation Report at least once every five calendar years. The initial MNA Corrective Action Evaluation Report required for submission coincides with the minimum number of independent sampling data points required for most statistical or regression analyses. In the five calendar years, ten MNA sampling events should have been conducted, and the MNA Corrective Action Evaluation Report shall include interpretations of the three technical and scientific demonstrations above. It is important to note that site specific conditions may require additional technical information to obtain a better characterization of the processes occurring at the facility.

After the baseline sampling events have been completed, an EPA approved MNA screening model is required at least annually to simulate the groundwater remediation at the facility and determine the mass flux and mass balance.

In addition, institutional controls (land use restrictions) will be imposed as part of MNA. The land use restrictions will be imposed on the permitted facility and any buffer that has been acquired to help ensure that the migration of groundwater (and landfill gas) from the landfill is confined to property owned and controlled by the responsible party.

Corrective Action Contingency

The approved MNA program shall include a contingency plan with a list of triggering events and established responses to those triggering events. If MNA is not performing in accordance with the objectives set forth in the approved Corrective Action Plan (CAP) after the first five consecutive calendar years, the contingency plan must be implemented immediately. If contaminants migrate off site, active remediation shall be initiated and adjacent property owners notified. Also, if the contingency plan is found not to be effective at the facility, then the public participation process pursuant to 15A NCAC 13B .1635 may be required and a new CAP shall be submitted for approval.

Uncertainty associated with estimated rates of attenuation over extended periods of time is a major consideration with MNA. Hydrologic and geochemical conditions amenable to MNA can change due to (1) natural or anthropogenic causes, and (2) changes in the mobility of a plume over time. MNA should not be considered a presumptive remedy, but should be evaluated along with active remediation options to restore groundwater to its designated beneficial use considering cost, technical practicability, remedial objectives, and protection of human health and the environment

Suggested Readings

- EPA OSWER Directive 9200.4-17P Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites, dated April 21, 1999.

• Monitored Natural Attenuation of Petroleum Hydrocarbons, U.S. EPA Remedial Technology Fact Sheet dated May 1999.

• Monitored Natural Attenuation of Chlorinated Solvents, U.S. EPA Remedial Technology Fact Sheet dated May 1999.

• Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action, Section 11, Monitored Natural Attenuation, U.S. EPA, September 2001.

• Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water, EPA/600/R-98/128, September 1998.

Enhanced Bioremediation With Hydrogen Release Compound (HRC)

A hydrogen release compound (HRC) is a controlled release, electron donor material, that when hydrated is specifically designed to produce a controlled release of lactic acid. The newly available lactic acid is critical for the production of hydrogen to fuel anaerobic biodegradation processes in soil and groundwater. Hydrogen is the key ingredient in the anaerobic contaminant degrading process known as reductive dechlorination. Reductive dechlorination is the mechanism by which chlorinated compounds are biodegraded into less harmful constituents such as ethene and ethane. HRC can be used to degrade a range of chlorinated compounds including: degreasing agents (PCE, TCE, TCA and their breakdown products), carbon tetrachloride, chloroform, methylene chloride, certain pesticides/herbicides, perchlorate, nitrate, nitroaromatic explosives and dyes, chlorofluorocarbons, certain metals and radionuclides. HRC is typically applied using direct-injection techniques. This process enables the viscous HRC material to be pressure injected into the zone of contamination and moved out into the aquifer media. Once in the subsurface, HRC can reside within the soil matrix fueling reductive dechlorination and promoting reducing aquifer conditions for periods of up to 24 months or longer through the controlled release of lactic acid and subsequent hydrogen production.

UV Oxidation

UV oxidation is a destruction process that oxidizes organic and explosive constituents in wastewater by the addition of strong oxidizers and irradiation with UV light. Oxidation of target contaminants is caused by direct reaction with the oxidizers, UV photolysis, and through the synergistic action of UV light, in combination with ozone (O_3) and/or hydrogen peroxide (H_2O_2). If complete mineralization is achieved, the final products of oxidation are carbon dioxide, water, and salts. The main advantage of UV oxidation is that it is a destruction process, as opposed to air stripping or carbon adsorption, for which contaminants are extracted and concentrated in a separate phase. UV oxidation processes can be configured in batch or continuous flow modes, depending on the throughput under consideration.

The UV oxidation process is general done with low pressure lamps operating at 65 watts of electricity for ozone systems and lamps operating at 15kW to 60kW for hydrogen peroxide systems.

Costs generally range in price per 1,000 liters. Factors that influence the cost of implementing UV/oxidation include:

- Types and concentration of contaminants (as they affect oxidizer selection, oxidizer

dosage, UV light intensity, and treatment time)
- Degree of contaminant destruction required
- Desired water flow rates
- Requirements for pretreatment and/or post-treatment

Air Stripping

Air stripping is a full-scale technology in which volatile organics are partitioned from groundwater by greatly increasing the surface area of the contaminated water exposed to air. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.

Air stripping involves the mass transfer of volatile contaminants from water to air. For groundwater remediation, this process is typically conducted in a packed tower or an aeration tank. The typical packed tower air stripper includes a spray nozzle at the top of the tower to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect decontaminated water. Auxiliary equipment that can be added to the basic air stripper includes an air heater to improve removal efficiencies; automated control systems with sump level switches and safety features, such as differential pressure monitors, high sump level switches, and explosion-proof components; and air emission control and treatment systems, such as activated carbon units, catalytic oxidizers, or thermal oxidizers. Packed tower air strippers are installed either as permanent installations on concrete pads or on a skid or a trailer.

Aeration tanks strip volatile compounds by bubbling air into a tank through which contaminated water flows. A forced air blower and a distribution manifold are designed to ensure air-water contact without the need for any packing materials. The baffles and multiple units ensure adequate residence time for stripping to occur. The discharge air from aeration tanks can be treated using the same technology as for packed tower air discharge treatment.

Air strippers can be operated continuously or in a batch mode where the air stripper is intermittently fed from a collection tank. The batch mode ensures consistent air stripper performance and greater energy efficiency than continuously operated units because mixing in the storage tanks eliminates any inconsistencies in feed water composition.

The eventual duration of cleanup using an air stripping system may be tens of years and depends on the capture of the entire plume from the groundwater.

Phytoremediation

Phytoremediation is a process that uses plants to remove, transfer, stabilize, or destroy contaminants in soil, sediment, and groundwater. The mechanisms of phytoremediation include enhanced rhizosphere biodegradation (takes place in soil or groundwater immediately surrounding plant roots), phytoextraction (also known as phytoaccumulation, the uptake of contaminants by plant roots and the translocation/accumulation of contaminants into plant shoots and leaves), phytodegradation (metabolism of contaminants within plant tissues), and phytostabilization (production of chemical compounds by plants to immobilize contaminants at the interface of roots and soil). Phytoremediation applies to all biological, chemical, and physical processes that are influenced by plants (including the rhizosphere) and that aid in cleanup of the contaminated substances. Plants can be used in site remediation, both through the mineralization of toxic organic compounds and through the accumulation and concentration of heavy metals and other inorganic compounds from soil into aboveground shoots. Phytoremediation may be applied in situ or ex situ, to soils, sludges, sediments, other solids, or groundwater. It is clean, efficient,inexpensive and non-environmentally disruptive.

Please Note:
Other effective remedies may include:

- Treatment Walls
- Barriers
- Surfactants / Cosolvents
- Hydraulic and Pneumatic Fracturing
- Thermal Enhancement
- In Situ Oxidation
- Electrokinetics
- Chemical Treatment
- Other Innovative Technologies