SUBMISSION INSTRUCTIONS NO. 21

GROUNDWATER MONITORING PROGRAMS AT REGULATED LANDFILLS UNDERGOING Monitored Natural Attenuation (MNA)-BASED CORRECTIVE ACTION

Developed by

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Office of Waste Permitting
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v. 08/23/04

1.0 APPLICABILITY OF INSTRUCTIONS

These instructions are applicable to all solid waste facilities conducting groundwater monitoring under the requirements contained in the Virginia Solid Waste Management Regulations (VSWMR), promulgated by the Virginia Waste Management Board, December 21, 1988, as amended.

2.0 INTENT OF INSTRUCTIONS

These instructions have been developed to assist the Permittee in developing a monitoring well network and groundwater sampling program supportive of the implementation of a Monitored Natural Attenuation (MNA)-based Corrective Action Program (CAP), and which provides the type of data needed to measure the performance of the natural attenuation process in the aquifer.

The content of these instructions has been modeled, in part, after several existing references listed at the end of this document. It is important to note that other data or reporting requirements contained in the sources listed, which are not applicable to the contaminant types expected to be associated with solid waste landfills, have not been made part of these instructions.

These instructions have been developed as guidance, not a rule. They have not gone through public comment. They may be altered to fit facility-specific conditions where needed. The Department understands the importance of site-specific considerations and technical details in defining the final content of an MNA-based Corrective Action Monitoring Plan (CAMP), and has developed these submission instructions as an outline of the minimum technical content to be addressed within an MNA-based CAMP.

3.0 BENEFITS OF INSTRUCTIONS

The Department believes these submission guidelines will:

- provide the minimum technical information expected of an MNA-based CAMP,
- expedite internal Department review time, and
- assist the regulated community with preparing technically complete documents.

4.0 BACKGROUND INFORMATION

Definition

Natural attenuation is a process within the aquifer media that acts without human intervention to reduce the mass, volume, and concentration of contaminants via: chemical or biologic destruction, physical dispersion, dilution, adsorption, or volatilization.

The last four mechanisms are non-destructive attenuation avenues and are applicable to Presumptive Remedies (discussed in a separate Submission Instruction). The use of measurable natural chemical or biologic mechanisms is commonly referred to as MNA. The NRC (2000) specifically noted that MNA should never be considered a Presumptive Remedy.

EPA (1997) defined MNA as an acceptable Corrective Action method as long as a Permittee can design a monitoring program that has the ability to measure and demonstrate that chemical or biologic mechanisms are taking place in the aquifer. NRC

(2000) stated that the MNA monitoring program must have the ability to show the contaminant mass is being destroyed, not simply diluted or adsorbed to the aquifer matrix.

While MNA has been shown to be effective in reducing contaminant levels on many sites, Wiedemeier (1999) noted that there had been no cases where MNA alone has been successful in meeting groundwater clean-up goals. Therefore, the success of MNA hinges greatly on whether or not it is augmented by other source controls such as a impermeable landfill cover, leachate collection, landfill gas collection and treatment, enhanced bio-remediation or other types of contaminant source reduction.

Feasibility Considerations
(Off-Site Impact)

MNA may not be applicable or adequate at every landfill, which proposes its use under the Corrective Action Program. If off-site plume migration is identified, or on-site receptors are present (including surface waters), MNA may not be appropriate unless a successful risk assessment has been completed. The facility must prove that MNA has the ability to satisfy the performance criteria under ***9 VAC 20-80-310.B.3.***

(Monitoring Requirements)

An MNA groundwater network involves measuring additional parameters or indicators and has strict requirements regarding design, sampling frequency, and sample constituent lists. MNA may require significant modifications to a facility's existing (pre-CAP) monitoring well network.

(Performance Criteria)

MNA has strict periodic performance review requirements that are discussed in detail in a separate section below.

Application

The applicability of MNA on any site will be considered using the below-listed technical factors at a minimum:

1] Evidence already indicates there's a reduction in contaminant concentrations along flow paths - *historical data + Nature and Extent Study (NES) results* (EPA 1999)

2] Contaminant reduction is supported by chemical/geochemical data or a microbiological survey - *NES results* (EPA 1999)

3] Evidence indicates the plume is NOT expanding - *historical data + NES results* (EPA 2001)

4] Evidence indicates there are NO current on-site or off-site receptors (i.e., surface water, wetlands, supply wells) - *NES results* (EPA 1998)

5] Reduction rates are sufficient to bring contamination levels below the GPS within a reasonable timeframe – *Assessment of Corrective Measures (ACM) modeling* (EPA, 2001)

6] Clean-up timeframe is comparable to active remediation - *ACM* (EPA, 1990)

7] All source areas on site are capped with an impermeable cover, as defined by EPA (EPA, 2001)

8] The application of MNA on site will not conflict with any provision of State Water Law (62.1-44.5) or State Water Regulation (9 VAC 25-26-20; 25-31-50; 25-32-30)

9] Using MNA for impacted, off-site areas is technically supportable. The Department has no Regulatory authority to require that any impacted off-site (third-party) landowner accept application of an MNA-based clean-up approach to address the off-site contamination.

10] Site geology / aquifer conditions allow for a definition of the groundwater flow field

Regarding item 2 above, Wiedemeier et al. (1998) noted that the microcosm study is only a strict requirement when geochemical data are insufficient to document the MNA process.

Regarding item 5 above, neither EPA nor the VSWMR have defined "reasonable" timeframe. Since all groundwater in the Commonwealth is considered by the Department to be a potential source of drinking water, restoration of the aquifer should proceed at a pace quick enough to be comparable with other, more active restoration remedies such as groundwater pump & treat, enhanced bioremediation, groundwater extraction systems, etc. In addition, for facilities in the Post-closure monitoring period, Corrective Action must be successfully completed prior to any decision to allow the termination of Post-closure requirements.

Regarding item 7 above, while neither EPA guidance (1999 & 2001) nor the VSWMR restrict the application of MNA on sites without full containment (impermeable cap) over all the source areas, EPA (1999) and Wiedemeier et al. (1999) have documented that the effectiveness of MNA may be negatively impacted if a site does not have containment over all potential source areas (including unregulated areas) that may be adding contaminant mass to the aquifer system.

Regarding item 9 above, the Department does not have the authority to force any impacted, off-site landowner to accept the use of MNA on any impacted off-site property. Application of MNA as a form of Corrective Action on properties with off-site plume is allowable under EPA guidance (1999), but only when supported by the results of a full risk assessment, and the technical investigation.

Regarding item 10 above, EPA (1998) noted that the proper siting of wells is of a greater concern at MNA sites when compared to sites undergoing a different form of Corrective Action. Wiedemeier (1999) has noted that in cases where the groundwater flow field can not be determined with certainty (e.g., fractured bedrock, karst), the accurate evaluation of the performance of MNA can be difficult to complete. In cases such as these, the number of wells needed as part of the remedy will be greater than that for more isotropic aquifers, thus adding additional long-term sampling and analytical costs that may outweigh the cost savings when compared to another more active clean-up remedy.

Well Network

For the purposes of MNA applied to Corrective Action Plans designed under ***9 VAC 20-80-310***, three separate well classifications will be required as part of the MNA-based CAMP:

1] Compliance wells (including site background)
2] Performance wells (to prove MNA is working successfully on site), and
3] Sentinel wells (to monitor for plume movement toward receptors or property boundaries).

Following EPA guidance (1998), these wells must have the ability to provide data on both the vertical and horizontal extent of the groundwater impact. NRC (2000) has noted that at least one nested well pair should be installed in the middle of the groundwater plume.

Regarding item 1 above, compliance wells are not strictly part of an MNA network as defined by Wiedemeier (1999) or the EPA, but they are included in the Corrective Action network because of requirements of ***9 VAC 20-80-310.A.2***.

Regarding item 2 above, these wells must be demonstrated to be installed in the interior of the plume and along distinct flow paths downgradient from the Groundwater Protection Standards (GPS)-exceeding compliance well. The intent, following the discussion of Wiedemeier (1999), is to monitor a "specific" slug of groundwater over time and distance as it moves from a compliance well through one or more performance wells. If a performance well is not installed along a discreet flow path downgradient from an exceeding well, the sampling results may show the effects of plume dispersion and dilution and not chemical or biologic attenuation. The linear (downgradient) distance between the compliance well and a performance well should be no more than an estimated 5-year groundwater travel time distance (derived from the EPA's 5-year periodic NPL remedy review process), or other timeframe supported by site-specific conditions.

Following the methodology of Wiedemeier (1999) and Wiedemeier et al. (1999), the Permittee should prove each well proposed for use as a performance well actually resides in the plume of contamination by sampling each proposed performance well for the contaminant(s) of concern, and in cases where those constituents are below the limits of detection (LOD), the following MNA fingerprint compounds:

1] **dissolved oxygen** (concentration levels below background may be indicative of aerobic respiration).
2] **nitrate** (concentration levels below background may be indicative of anaerobic biodegradation via dentrification process).
3] **sulfate** (concentration levels below background may be indicative of sulfate reduction).
4] **Fe (II)** (concentration levels of the soluble form of iron above background may be indicative of anaerobic biodegradation).
5] **methane** (concentration levels above background may be indicative of methanogenesis).
6] **chloride** or **alkalinity** (concentration levels above background may be indicative of a release of carbon dioxide or chloride as end products of the biodegradation of petroleum or chlorinated hydrocarbons).

The resulting fingerprint data should be compared to the results of sampling of the site background wells. Wiedemeier (1999) has demonstrated that there should be a marked difference in the concentrations of these fingerprint compounds in the background well vs. the performance wells, if the performance wells are accurately positioned to reside within the groundwater plume. This sampling effort should be completed during the initial Corrective Action sampling event.

Regarding item 3 above, this well type is correlative to the "Point of Action" wells defined by Wiedemeier (1999). For the purposes of the VSWMR, the sentinel well is defined as a well that is positioned outside the leading edge or lateral sides of the groundwater plume in a location that can act as a sensor to detect plume movement toward a receptor (seep, spring, wetlands, surface water body, irrigation well, agricultural well, potable well, etc.) or a property boundary. As a guide, the lateral spacing between sentinel wells should be no more than 500 feet, and the distance between the sentinel well and the receptor should be no less than 50 feet. The location of the sentinel wells (outside the plume) can be verified using the fingerprint compounds listed above.

Sampling Frequency

The sampling frequency requirements concerning evaluating the effectiveness of MNA are separate from the sampling requirements called for under the VSWMR regarding routine compliance monitoring. The statistical method may dictate that groundwater sampling be conducted temporarily at a frequency greater than that which would otherwise be required by the VSWMR.

EPA (1998) has indicated that groundwater should be sampled at a quarterly frequency once Corrective Action has begun. Quarterly sampling should continue until such time as there are sufficient data collected to perform a Corrective Action Site Evaluation (CASE).

Most statistical-trend or regression analysis requires a minimum of 10 independent data points before a valid statistical conclusion can be reached. If the Corrective Action Plan sets a 3 year CASE submission timeframe, quarterly sampling would be required during the first 2 years of the Corrective Action program in order to collect 10 data points within 3 calendar years. If a 4-year CASE study submission timeframe is required, quarterly sampling would be required during the first year of the Corrective Action program in order to collect 10 data points within 4 calendar years. If a 5-year CASE study submission timeframe is required, quarterly sampling would not be required in order to collect 10 data points within 5 calendar years.

The frequency of the CASE report submissions will be established in the facility's Permit and will be based on site specific data including estimated groundwater flow rate, proximity of the plume to receptors, and presence or absence of off-site impact. Once sufficient data has been collected to perform CASE statistics, the groundwater sampling requirements of ***9 VAC 20-80-310.A.2.b*** and ***310.C.1.a.(2) and (3)*** would be applicable for future sampling events.

Sampling Constituents

Sampling of compliance wells shall continue under the respective monitoring program (Assessment or Phase 2) during the Corrective Action process. Regarding the performance and sentinel wells, the VSWMR requirements are applicable and EPA guidance should be considered.

9 VAC 20-80-310.A.2 requires that, while a facility is in the Corrective Action program, the Permittee must continue to meet the applicable requirements of ***9 VAC 20-80-300*** (Assessment or Phase II programs). With regard to 9 VAC 20-80-310.C.1.a(2), EPA (1998) and Wiedemeier (1999) have documented that the following constituents should be monitored in order to document the performance of the MNA process.

This MNA performance list includes:

1] dissolved oxygen
2] nitrate
3] Fe (II)
4] sulfate
5] methane
6] chloride
7] alkalinity
8] oxidation reduction potential
9] conductivity
10] temperature
11] ethane
12] ethene

These 12 constituents should be sampled for at a minimum at each performance well and at the site background well(s) each time groundwater is sampled during the Corrective Action program. If a Permittee believes that one or more of the performance list constituents is not applicable to the site contaminants of concern (e.g., site is characterized by solely aerobic vs. anaerobic degradation), the Permittee may request a site-specific list of MNA performance constituent(s).

Regarding sentinel wells, the monitoring requirements are for contaminants of concern (or their metabolic breakdown products) as suggested under EPA guidance (i.e., GPS-exceeding constituents of concern and their related breakdown products).

Based on the purpose of sentinel wells, the 12 constituents noted above, or the site-specific MNA performance constituents, if different, should be sampled for at least on an annual basis to detect plume movement toward any receptors or property boundaries.

Interpretation of data and design of CASE Reports

The intent of the Corrective Action Site Evaluation (CASE) report is to document, on a periodic basis (timeframe to be established in the facility's Permit), the performance of the MNA program on site. EPA guidance (1999 & 2001) requires a minimum of three demonstrations:

1] proof that there is a <u>statistical</u> reduction in contaminant concentrations along distinct flow paths

2] a demonstration that contaminant reduction is driven by <u>chemical</u> or <u>biologic</u> attenuation of the contaminant(s) of concern

3] sampling data that proves the plume has <u>stabilized</u> in horizontal and vertical extent

Regarding item 1 above, using data obtained during the Corrective Action program, the Permittee should construct two-dimensional, time-specific, constituent-specific, bar graphs with a vertical axis showing constituent concentration, and a horizontal axis scaled to show linear (ground) distance along the flow path.

Regarding item 2 above, using data obtained during the Corrective Action program, the Permittee should construct constituent-specific (including each of the MNA performance sampling constituents) trend or regression analyses (Wilcoxon rank – sum test, Spearmans's test, or Mann-kendall test) with a normal or semi-log vertical axis showing constituent concentration, and a normal horizontal axis scaled to represent the dates sampling events took place during the 3-, 4-, or 5-year CASE reporting period. Facilities that have pre-Corrective Action program sampling data may voluntarily add this data to the analysis for reference. Additionally, the Permittee may choose to graphically represent the MNA performance constituent data on multi-axis SEQUENCE-redux radial diagrams (plotted against data obtained from site background, and each performance well's historical data).

Regarding item 3 above, using data obtained during the Corrective Action program, the Permittee should construct two-dimensional, time-specific, constituent-specific, plume delineation maps showing both the horizontal and vertical extent of the groundwater plume, and noting whether or not the margins of the plume have expanded or decreased since initiating Corrective Action.

5.0 REPORT FORMAT

The MNA-based CAMP will be submitted as part of the Corrective Action Plan documentation, and shall be an attachment to the facility's Permit. The CAMP should be a stand-alone technical document, certified by a qualified groundwater professional. For the sake of consistency and to ensure an expeditious review, the information (technical content) of the CAMP should be arranged in the order presented within these submission instructions as outlined in Table C of these instructions.

The sections listed herein shall be considered standard technical content. Please note that submissions that do not provide the standard technical content outlined here may be judged incomplete during technical review.

The Department notes that there may be some site-specific instances where a facility's technical data may require additional information beyond that listed in these submission instructions as a means of more fully characterizing the technical data available and conclusions derived thereof. These instructions set no limit on the number or content of additional report sections as long as the information included directly pertains to that required of an MNA-based CAMP.

The administrative and technical content expected for each section of the CAMP is briefly described on the following pages.

Cover Page – Provide the following information:

- Landfill Name
- Landfill location
- DEQ Permit #
- Name & Address of the Consultant
- Name & Address of the Permittee

- Report Date

Signature Page – This page should contain the signature & seal of a qualified groundwater professional certifying the content of the CAMP.

Table of Contents – Specify the order and organization of the report sections as outlined in Attachment C of these instructions.

Introduction – States, in general terms, that the actions described in the CAMP are designed to meet the requirements of ***9 VAC 20-80-300; 310.A.2***; and ***310.C.1.a***.

The Permittee should indicate the CAMP was submitted in a format consistent with these submission instructions and applicable reference(s) in the VSWMR. The report should describe any limitations (company specific language), as well as definitions for any technical or laboratory terminology used in the report. The report shall describe the QA/QC procedures used during ASD sampling if applicable.

Technical Content – The technical content of the Corrective Action CAMP shall include that specified under the Department's **Submission Instructions #12** augmented by the information discussed above. Specifically, the MNA-based CAMP shall include a fully defined monitoring network, including well identification, well classification, well sampling constituent listing and sampling frequency description. The CAMP shall state the type of analytical methods used (including those for the MNA performance constituent list), laboratory limits of detection (LOD) and quantitation (LOQ) and a notation that the methods used meet or exceed those listed in SW-846 as updated [***9 VAC 20-80-300***]. The CAMP shall describe (in general detail) the materials/information that shall be included in the periodic CASE reports. The CAMP shall identify a neutral location in which copies of the Corrective Action related site documents will be stored for public review.

Figures – Provide at a minimum copies of the:

- USGS 7 ½-minute topographic map - showing the site location
- Site Plan - to include topographic contours, permanent structures, surface water features, a bar scale, north arrow, facility boundary, waste management unit boundary, and all monitoring wells or sampling points relevant to the MNA-based CAP.
- Recent Potentiometric map
- Optional figures - may include copies of published geologic maps, US Department of Agriculture soils maps, geologic cross-sections, etc.

Appendices – Provide at a minimum, copies of the following:

- Boring logs for all Corrective Action monitoring program wells/borings
- Sample Field Sampling Sheets
- Sample Chain of Custody Records
- Copy of off-site access agreement (if applicable)

6.0 SUBMISSION TIMELINES

The current VSWMR do not specifically list a submission timeframe for the MNA-based CAMP. However, ***9 VAC 20-80-310.C.1.a*** requires that a CAMP must be ready for

implementation at the time of Corrective Action initiation. Therefore, the facility should develop and submit the CAMP at the same time it submits the MNA-based proposed Corrective Action Plan.

7.0 DEPARTMENT REVIEW PROCESS

9 VAC 20-80-310.B.7 requires the Director to issue a decision on the merits of the proposed Corrective Action. Since the CAMP is based on the proposed clean-up remedy, the Department will undertake a technical review of the content of the CAMP to ensure it meets the requirements included in this Submission Instruction. Revisions to the CAMP based on the Department's technical comments will be requested concurrent with revisions to the corrective action plan (CAP).

ATTACHMENTS

A - REFERENCE LISTING

Environmental Protection Agency, 1998, Monitored Natural Attenuation for Groundwater EPA/625/K-98/001.

Environmental Protection Agency, 1999, Use of Monitored Natural Attenuation at Superfund, RCRA, Corrective Action and Underground Storage Tank Sites OSWER Policy Directive 9200.4-17P.

Environmental Protection Agency, 2001, Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action EPA/530/R-01/015.

National Research Council (Committee on Intrinsic Remediation), 2000, Natural Attenuation for Groundwater Remediation, National Academy Press, 274p.

Wiedemeier, T. H., 1999, Designing Monitoring Programs to evaluate the performance of natural attenuation, in: Alleman, B. C., and Leeson, A., Natural Attenuation of Chlorinated Solvents, Petroleum Hydrocarbons, and Other Organic Compounds, Battle Press, pp313-323.

Wiedemeier, T. H., Rifai, H. S., Newell, C. J., and Wilson, J. T., 1999, Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface, John Wiley & Sons, 617p.

B – SAMPLE MNA DECISION CHECKLISTS

Applicability of MNA on site?

1] Are all source areas on site capped with an impermeable (as defined by EPA) cover? If no, then performance of the MNA may be adversely affected.

2] Does site groundwater data already indicate there's a reduction in contaminant concentrations along flow paths? If no, then plume may still be expanding at a rate faster than which can be chemically or biologically attenuated.

3] Does site groundwater data indicate the plume is stable in both vertical and horizontal extent? If no, see 2] above

4] Did the ACM/Pilot Study contain chemical/geochemical data or a microbiological survey proving attenuation is taking place? If no, data may not be present which will be adequate justification to propose MNA as a form of Corrective Action.

5] Does site evidence indicate there are on-site or off-site sensitive receptors (i.e., surface water, wetlands, supply wells) immediately downgradient of the plume? If yes, a risk assessment showing no unacceptable impact to sensitive receptors and a correctly designed monitoring network would be required prior to approval of MNA-based Corrective Action.

6] Are calculated attenuation rates high enough to bring exceeding levels to GPS in a reasonable timeframe compared to active remedies? If no, use of MNA as a stand alone Corrective Action may not be appropriate.

Accurate development of an MNA monitoring network on site?

1] Does the facility define each function of the monitoring wells on site? If no, further description is needed.

2] Is there at least one nested well in the core of the plume? If no, additional wells will be required to meet EPA guidance requirements.

3] Can the GPS-exceeding and performance well(s) be proven to be on distinct flowpaths, with at least one flowpath being in the center of the plume? If no, additional wells will be needed.

4] Is the linear spacing between flowpath exceeding and performance wells appropriate for the groundwater flow rate calculated for the site? If no, additional wells will be needed.

5] Have the performance wells (in cases where GPS-exceeding compound(s) are non-detect) been tested for the 6 MNA-fingerprint signature constituents? If no, testing should be undertaken as soon as possible.

6] Are Sentinel Wells located appropriately at each receptor? If no, additional wells will be required.

7] Is the lateral spacing between Sentinel Wells no greater than 500' and the distance to the receptor no less than 50'? If no, wells to close the spacing will be required.

- Note that if the answer to any question is no, the modification to the network may be placed in the facility-specific Corrective Action Permit module.

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