GUIDELINE 43 - ALTERNATIVE LINER DEMONSTRATIONS FOR SOLID WASTE MANAGEMENT FACILITIES

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Alternative designs for landfill and surface impoundment liners are allowed by state rule to allow design innovation and consideration of site-specific conditions. The design must ensure that the Maximum Contaminant Levels (MCLs) for the required groundwater monitoring parameters in North Dakota Administrative Code (NDAC) Chapter 33.1-20-03.1-13, also found in Table 1 are not exceeded in groundwater at the compliance boundary. The compliance boundary is normally located at the waste management unit boundary or, if approved by the Department, up to a maximum of 500 feet from the waste management unit boundary. The compliance boundary for a CCR unit is at the waste disposal boundary.

When evaluating an alternative design, owners/operators should consider at least three factors: (1) the hydrogeologic characteristics of the facility and surrounding land; (2) the climate of the area; and (3) the volume and physical and chemical composition of the leachate.

The performance and design standards for new municipal solid waste landfills and lateral expansion of municipal solid waste landfills (MSWLFs) are addressed in NDAC Chapter 33.1-20-06.1. The rule allows for the use of either a four-foot-thick compacted clay liner, a composite liner consisting of a minimum of two feet of compacted clay and a synthetic liner that is at least 60-mil thick, or another alternative design. Special waste landfills are allowed to use a four-foot-thick compacted clay liner if they will not receive any waste containing leachable organic compounds or TENORM waste. The liner requirement for a special waste landfill that will receive leachable organic compounds or TENORM waste is a composite liner consisting of a minimum of three feet of compacted clay and a synthetic liner that is at least 60-mil thick. CCR landfills and impoundments are not allowed to use a liner constructed only of compacted clay; they must use a composite liner equivalent to the MSWLF composite liner. Owners or operators proposing to use an alternative design must demonstrate the capability of maintaining contaminant concentrations below MCLs at the facility's relevant point of compliance.

I. Demonstration Requirements

The demonstration requirements apply to any municipal waste landfill, special waste landfill, or CCR unit designs proposing an alternative design other than the designs prescribed in the solid waste rules. The owner/operator must demonstrate to the Department that the design will not allow contamination of groundwater at the relevant point of compliance to exceed the established MCLs for the parameters listed in Table 1 as well as the standards identified in NDAC Section 33.1-20-13-03 and, if necessary, constituents in excess of any secondary maximum contaminant levels or in excess of any health advisories.

Any demonstration should consider an assessment of leachate quality and quantity, leachate leakage to the subsurface, and subsurface transport to the compliance boundary. These factors are governed by the waste characteristics, site hydrogeology, and climatic factors. The nature of the demonstration is essentially an assessment of the potential for leachate production and leakage from the landfill to groundwater and the anticipated fate and transport of constituents to the compliance boundary at the facility. Inherent to this type of approach is the need to evaluate leachate quality and quantity and obtain sufficient site-specific data to adequately characterize the existing groundwater quality and the existing groundwater flow regime (e.g., flow direction, horizontal and vertical gradients, hydraulic conductivity, stratigraphy, and aquifer thickness).

The assessment should be made of the effect the waste management facility construction will have on site hydrogeology. The assessment should focus on the reduced infiltration over the landfill area, increased infiltration from any ponds etc., and the effects of altered surface water runoff patterns. Changes in recharge and changes in surface water patterns resulting from landfill construction may affect upward groundwater gradients in some cases and result in changes in lateral flow direction in others.

II. Leachate Characterization

Leachate characterization should include an assessment of both the quantity and composition of leachate anticipated at the proposed facility. The demonstration should be supported with an historic evaluation of precipitation events and the likelihood for flooding of the unit through heavy rains, surface runoff, or high-water tables. The demonstration should evaluate whether constituents can be expected to be produced in concentrations greater than those discussed above. It is plausible that the toxicity of leachate from household wastes may be controlled, particularly if the area served by the unit has an effective toxic waste prevention and segregation program that prevents the disposal of wastes of concern as well as consumer goods containing significant quantities of the pesticides, herbicides, solvents, and metals.

When leachate constituents can be expected to exceed the established standards, then the demonstration should focus on developing a profile of leachate quality and production rates (volume) sufficient to be used in evaluating its fate and transport from point of release to the relevant point of compliance.

If leachate composition data that are representative of the proposed facility are not available, then leachate data with a similar expected composition should be presented. Landfill leachate composition is influenced by:

A. The annual precipitation infiltration and rate of leaching;

B. The type and relative amounts of materials in the waste stream; and

C. The age and the biological maturity of the landfill that may affect types of organic and inorganic acids generated, oxidation/reduction potential (Eh), and pH conditions.

If leachate composition data that are representative of the proposed facility are not available, then leachate data with a similar expected composition should be presented. Landfill leachate composition is influenced by:

Volumetric production rates of leachate are important in evaluating the fate and transport of the constituents listed in Table 1. Leachate production depends on rainfall incident to the unit, run-on, runoff, evapotranspiration, water table elevation relative to the bottom of the landfill, and prevention of liquid disposal at the site. Run-on, runoff, and water table factors can be eliminated traditionally through design and operational controls. Incident precipitation and evapotranspiration can be evaluated using the Hydrologic Evaluation of Landfill Performance (HELP) model or other more site-specific methods of estimating leachate production. It is reasonable to expect that leachate production may assume seasonal cyclical characteristics of low and high flows.

Once leachate composition and production have been estimated, it is possible to predict the fate and transport of contaminants at the compliance boundary. Alternately, the demonstration could take the following approach:

A. Use the maximum allowable contaminant concentrations at the relevant point of compliance;

B. Back-calculate point of leakage (e.g., the landfill liner); and

C. Project the appropriate combination of concentration and leachate volumes that, if not exceeded, would not cause the maximum allowable contaminant concentration values to be exceeded at the compliance boundary.

This latter approach should provide the planner with information needed to define the performance standard of an alternate design for the active life of the unit. Once the municipal solid waste landfill unit is closed, leachate volume and concentration can be expected to decrease over time assuming the final cover is intact. Therefore, the combination of leachate volume and leachate concentration controlling the assessment can be expected to change during the active life of the unit.

III. Leakage Assessment

An assessment of leakage, the volumetric release of leachate from the proposed alternative design, should be based on analytical approaches supported by empirical data from other existing operational facilities of similar design, particularly those that have leak detection monitoring (see USEPA, 1990b). In lieu of the existence of availability of such information, conservative analytical assumptions may need to be made to estimate anticipated leakage rates.

The transport of fluids and waste constituents through geomembranes differs in principle from transport through soil liner materials. Transport through geomembranes where tears, punctures, imperfections, or seam failures are not involved, is dominated by molecular diffusion. Diffusion occurs in response to a concentration gradient and is governed by a relationship known as Fick's first law. Diffusion rates in membranes are very low in comparison to hydraulic flow rates in soil liners, including compacted clays. In synthetic liners, the factor that most influences liner performance is penetration of the liner, including imperfect seams or pinholes, which can allow leachate to pass through the membrane (USEPA, 1989a).

The dominant mode of leachate transport through the liner components is flow through holes and penetrations of the geomembrane and Darcian flow through soil components. Synthetic bentonite mats, which have been used successfully in composite liner designs, may be considered to limit the transport of fluids through diffusion due to their low hydraulic conductivities, i.e., 1 x 10-9 cm/sec reported by manufacturers.

Several researchers have studied the flow of fluids through imperfections in single geomembrane and composite liner systems. For empirical data and analytical methodologies, the reader is referred to literature by Jayawickrama et al. (1988), Kastman (1984), Haxo (1983), Haxo et al. (1984), Radian (1987), Giroud and Bonaparte (1989 [Parts I and II]), and Giroud et al. (1989). Leakage assessments also may be conducted by use of the HELP model (USEPA 2020). Version 4.0 of the model includes an updated method to assess leakage that is based on recent research and data conducted by Giroud and Bonaparte. For more information see the HELP website at
https://www.epa.gov/land-research/hydrologic-evaluation-landfill-performance-help-model.

IV. Leachate Migration in the Subsurface

Leachate that leaks from a landfill will migrate through the subsurface. Flow and transport in the subsurface typically occurs through the unsaturated zone, to the water table and into the saturated zone. However, in some instances, the water table may be located immediately below the landfill, so that only saturated flow and transport away from the landfill need to be considered. Similarly, leachate migration may occur only in the vadose zone where groundwater is located well below the landfill. Once below the water table, the leachate constituents are transported through the saturated zone to a point of discharge (i.e., a pumping well, a stream, a lake, etc.).

The migration of leachate and leachate constituents in the subsurface depends on factors such as the volume of the liquid component of the waste, the chemical and physical properties of the leachate constituents, the loading rate, the climate, and the chemical and physical properties of the subsurface (saturated and unsaturated zones). A number of physical, chemical, and biological processes influence migration. Because of complex interactions between these processes, specific contaminants may be transported through the subsurface at different rates. Certain processes result in the attenuation and degradation of contaminants. The degree of attenuation is dependent on the time that the contaminant is in contact with the subsurface material, the physical and chemical characteristics of the subsurface material, the distance which the contaminant has traveled, and the volume and characteristics of the leachate.

V. Leachate Migration in the Subsurface

After defining the hydrogeologic characteristics of the site, the nature of leakage, and leachate concentrations, it may be appropriate to develop a mathematical model to describe and simulate the expected fate and transport of the contaminants to the unit's compliance boundary. Solute transport and groundwater modeling efforts should be conducted by a qualified groundwater scientist. It is necessary to address many factors when selecting and applying a model to a site. Travers and Sharp-Hansen (1991) provide a thorough review of these issues. The text provided below in subsection F is excerpted from their report.

VI. Overview of the Modeling Process

A number of factors can influence leachate migration from solid waste management facilities. These include, but are not limited to, climatic effects, the hydrogeological setting, and the nature of the disposed waste. Each facility is different, and no one generic model will be appropriate in all situations.

To develop a model for a site, the modeling needs and the objectives of the study should be determined first. Next, it will be necessary to collect data for characterizing the hydrological, geological, chemical, and biological conditions present in the system. These data are used to assist in the development of a conceptual model of the system, including spatial and temporal characteristics and boundary conditions. The conceptual model and data are then used to select a mathematical model that accurately represents the conceptual model. The model selected should have been tested and evaluated by qualified investigators, should adequately simulate the significant processes present in the actual system, and should be consistent with the complexity of the study area, amount of available data, and objectives of the study.

Three basic decisions are required when selecting a model for soil and groundwater contamination (Boutwell et al., 1986). First, the necessity for a model should be determined. Not all studies require the use of a mathematical model. This decision should be made at the beginning of the study since modeling requires a substantial amount of resources and effort. Next, the level of modeling required for a specific study should be determined. Boutwell et al.

(1986) classify models into Level I (simple/analytical) and Level II (complex/numerical) models. Finally, the model capabilities which will be necessary for representing a particular system should be considered. Several models may be equally suitable for a particular study: conversely, a suitable model may not be available to simulate a given system. In some cases, it may be necessary to link or couple two or more computer codes to accurately represent the processes at the site. In the section which follows, specific issues which should be considered when developing a scenario and selecting a model(s) will be described.

Because all models are a simplified representation of the real system, no model will ever reproduce the exact characteristics of a site. Errors are introduced because of: (1) assumptions and simplifications; (2) a lack of data; and (3) a poor understanding of some processes influencing the fate and transport of contaminants. Therefore, model results should always be interpreted as estimates of groundwater flow and contaminant transport. Bond and Hwang (1988) recommend that models be used for comparing various cases or scenarios, since all cases are subject to the same limitations and simplifications.

The quality of model results can depend to a large extent on the experience and judgement of the modeler, and on the quality of the data used to develop model input. The process of applying the model may delineate data deficiencies which may require additional data collection. The model results should be calibrated to obtain the best fit to the observed data. After that, the accuracy of the results which are obtained from the mathematical model should be validated. Model validation, which is the comparison of model results with numerical data independently derived from experiments or observations of the environment, is a critical aspect of model application, and is particularly important for site-specific studies.

Several recent reports present detailed discussions of the issues surrounding model selection, application, and validation. Donigian and Rao (1990) address each of these issues and present several considerations for developing a generalized framework for model validation. EPA's Exposure Assessment Group has developed suggested definitions and guidance on model validation (Versar Inc., 1987). A recent report by the National Resource Council (1989) discusses the issues related to model application and validation and provides recommendations for the proper use of groundwater models. Weaver et al. (1989) discuss considerations for selection and field validation of mathematical models.

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Table 1. Full List of Parameters for Assessing Groundwater Quality at ND Landfills - 07/2020

Appendix I to NDAC Section 33.1-20-13-05 – List of Hazardous Inorganic and Organic Constituents can be found at: https://ndlegis.gov/information/acdata/pdf/33.1-20-13.pdf

a. Parameters measured in the field:

(1) Appearance (including color, foaming, and odor)
(2) pH[1]
(3) Specific conductance[2]
(4) Temperature
(5) Water elevation[3]

b. General geochemical parameters:

(1) Ammonia nitrogen
(2) Total hardness
(3) Iron
(4) Calcium
(5) Magnesium
(6) Manganese
(7) Potassium
(8) Total alkalinity
(9) Bicarbonate
(10) Carbonate
(11) Chloride
(12) Fluoride
(13) Nitrate + Nitrite, as N
(14) Total phosphorus
(15) Sulfate
(16) Sodium
(17) Total dissolved solids (TDS)
(18) Total suspended solids (TSS)
(19) Cation/anion balance

c. Heavy metals:

Group A:
(1) Arsenic
(2) Barium
(3) Cadmium
(4) Chromium
(5) Lead
(6) Mercury
(7) Selenium
(8) Silver

Group B:
(9) Antimony
(10) Beryllium
(11) Cobalt
(12) Copper
(13) Nickel
(14) Thallium
(15) Vanadium
(16) Zinc

d. Total organic carbon (TOC)

e. Chemical oxygen demand (COD)

f. Naturally occurring radionuclides:

(1) Radon
(2) Radium
(3) Uranium

g. Volatile organic compounds, both halogenated and nonhalogenated:

Halogenated:

Acrylonitrile	1,1-Dichloroethylene
Allyl chloride	1,2-Dichloropropane
Bromochloromethane	cis-1,3-Dichloropropene
Bromodichloromethane	cis-1,2-Dichloroethylene
Bromoform	trans-1,2-Dichloroethylene
Bromomethane	trans-1,3-Dichloropropene
Carbon disulfide	trans-1,4-Dichloro-2-butene
Carbon tetrachloride	Dichlorofluoromethane
Chlorobenzene	Dichloromethane (methylene chloride)
(monochlorobenzene)	1,3-Dichloropropene
Chlorodibromomethane	2,3-Dichloro-1-propene
Chloroethane	Pentachloroethane
Chloroform	1,1,1,2-Tetrachloroethane
Chloromethane	1,1,2,2-Tetrachloroethane
Dibromomethane	Tetrachloroethylene
1,2-Dibromo-3-chloropropane	1,1,1-Trichloroethane
1,2-Dibromoethane	1,1,2-Trichloroethane
Dichloroacetonitrile	Trichloroethylene
1,2-Dichlorobenzene	Trichlorofluoromethane
1,3-Dichlorobenzene	1,2,3-Trichloropropane
1,4-Dichlorobenzene	1,1,2-Trichlorotrifluoroethane
Dichlorodifluoromethane	Vinyl acetate
1,1-Dichloroethane	Vinyl chloride
1,2-Dichloroethane	

Nonhalogenated:

Acetone	Methyl isobutyl ketone
Benzene	Pyrene
Cumene	Styrene
Ethylbenzene	Tetrahydrofuran
Ethyl ether	Toluene
Methyl butyl ketone	m-Xylene
Methyl ethyl ketone	o-Xylene
Methyl iodide	p-Xylene

h. Pesticides:

Aldrin	Endrin
Chlordane	Heptachlor
Chloroform	Lindane
4,4 DDT	Methyl bromide
Dibenzofuran	Methyl methacrylate
Dieldrin	Methylene bromide
Dimethoate	Naphthalene
Endosulfan	Parathion

[1] Two measurements: in field, and immediately upon sample's arrival in laboratory.
[2] As measured in field.
[3] As measured to the nearest 0.01 foot in field before pumping or bailing.