Waste Management Control Strategies for Landfills

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ABSTRACT

The U. S. Environmental Protection Agency through its research and field experiences has developed control strategies for hazardous and municipal solid waste landfills. These control strategies include liner and cover systems. The liner systems include double liners for hazardous waste and a single composite liner for municipal solid waste. The purpose of each individual component will be discussed with options for using natural in-situ materials or geosynthetics. Although natural soils are used as various components, emphasis has been placed on the use of geosynthetics, including geomembranes, geonets, geotextiles, and plastic pipes. Cover systems for both hazardous and municipal waste facilities are based on a multiplayer design. The multiplayer component characteristics, including performance, thickness and material type will be discussed. These designs include both natural soils and geosynthetics.

It has been demonstrated with field data that the development of construction quality control/quality assurance will improve the performance of the disposal facility. Current programs and techniques used in the United States will be discussed.

Information on design and construction has been assembled into technical resource and guidance documents. The documents present summaries of state-of-the-art technologies and evaluation techniques determined by the Agency to constitute good engineering designs, practices, and procedures.

INTRODUCTION

Waste is generated at all levels of society. This waste may be either industry related or municipally generated. Both types of wastes may contain a variety of potential pollutants. In the United States, these wastes are managed by landfills, surface impoundments and waste piles. The U. S. Environmental Protection Agency (USEPA) through its research and field experiences has developed control strategies to prevent potential pollutants from escaping into the environment.

The control strategies for waste management facilities include liner and cover systems. These systems are designed for long-term performance. In addition, for those containment systems for hazardous and toxic wastes, redundancy is designed into the containment systems to help ensure against major releases to the environment.

Field experience has clearly demonstrated that the development of construction quality control and quality assurance programs will improve the waste management facility performance.

THE BEGINNING

The Agency first got involved with landfill design when people were asking about the validity of the "7 day beaker" test. A sample of liquid leachate was collected and specimens of various liner materials were immersed in it. After seven days, tests were used to detect any material changes. If no changes appeared, then the material was thought to be acceptable.

A research project was initiated to determine if the method was accurate or whether a new method was needed. The concepts of this program were expanded using hazardous waste. The results of these initial research projects were later incorporated into Methods 9090 and 9100.

During the early period, the U. S. Congress challenged the Agency to develop rules and regulations that would meet three objectives. The first was to be protective of human health and the environment. The second was to be flexible so as to not stifle innovative designs and the third was to allow individual states the latitude to develop state specific regulations.

There was a lot of work to be accomplished in a short period of time. The geosynthetic industry, as we know it today, did not exist. Research quickly was put together with input from a variety of industry and academia. The arguments between natural soils and geosynthetics surfaced and had to be resolved. People had to be trained, materials had to be developed, laboratory tests had to be developed that would explain the field conditions and methods had to be developed that would ensure that what was designed could, in fact, be placed in the field.

BOTTOM CONTAINMENT DESIGNS

The basic bottom liner design, for hazardous waste landfills, is two or more liners with a leachate collection system above and between the liners. The redundancy aspect of the design is that if the top liner does not perform as designed, then the second leachate collection system will alert appropriate personnel while corrective actions are implemented. The bottom liner in the design is assumed to contain the waste until the corrective action is in place. The design was reviewed and modeled in saturated and unsaturated hydraulic flow conditions. The result of these studies is the current recommended design of a double liner which has a bottom composite liner and a top geomembrane, Figure 1. The composite bottom liner is one that consists of a geomembrane in intimate contact with a compacted, low permeability natural soil. The composite liner design has been determined to be more hydraulically efficient than the geomembrane or natural soil liner working independently.

Liner Systems for Hazardous Wastes

The liner system currently being used by most hazardous waste management facilities incorporate in descending order a filer layer, followed by a primary leachate collection and removal system (LCRS), a primary geomembrane, a leak detection, collection and removal system (LCDRS), and a composite liner above the native soil foundation (EPA, 1987). The composite liner is defined as a geomembrane and a compacted, low hydraulic conductivity ($k \leq 1 \times 10^{-7}$ cm/sec) natural soil.

In bottom liner systems for construction and field seaming purposes, the geomembrane is to be at least 0.75 mm (30 mils) thick or 1.12 mm (45 mils) thick if left exposed to the elements for more than 30 days. These thicknesses may not be suitable for all geomembrane materials. The required geomembrane thickness will depend on the site-specific design, installation/construction concerns, seam ability, and long-term durability.

Liner Systems for Municipal Solid Waste

Liner systems for municipal solid wastes may have different designs based on site specific considerations including geology, hydrology and climatic conditions. Two basic approaches are used in the United States. The first is a generic design. This design has a composite liner system that is designed and constructed to maintain less than 30 cm (12 inches) depth of leachate over the liner collection systems to ensure that the concentration values of selected chemicals will not be exceeded at some point on the owner/operator's property. The second approach based on performance consists of liners and leachate.

Generic Design: A composite liner is shown schematically in Figure 2 and is defined as consisting of two components; the upper component is a geomembrane with a minimum of 0.75 mm (30 mil) thickness, the lower component consists of at least a 60 cm (24 inches) layer of compacted soil with a hydraulic conductivity less than or equal to a 1×10^{-7} cm/sec. The required geomembrane thickness will depend on the site-specific design, installation/construction concerns, seam ability and long-term durability. The geomembrane must be installed in direct and uniform contact with the compacted soil component so as to minimize the migration of leachate through potential defects in the geomembrane. A leachate collection and removal system (LCRS) should be located immediately above the composite liner to control the level of leachate on the liner.

Performance Based Design: The second design allows the owner/operator of the proposed municipal solid waste landfill (MSWLF) to demonstrate that the design is protective of human health and the environment with respect to ground water quality down gradient from the landfill. The nature of the demonstration is essentially an assessment of the landfill leachate characteristics, the potential for leakage from the landfill of the leachate to ground water and an assessment of the anticipated fate and transport of those constituents to the proposed point of compliance at the facility. Inherent to the type of approach, is the need to obtain sufficient site-specific data to adequately characterize the existing ground water quality, the pre-existing ground water regime (flow direction, horizontal and vertical gradients, hydraulic conductivity, specific yield and aquifer thickness). The assessment should consider the effects construction of the MSWLF may have on the groundwater system. The major consideration here, for shallow groundwater systems, is the local capturing of precipitation that normally would have infiltrated as a source of groundwater recharge. As assessment of leakage from the proposed liner and leachate collection design should be based on empirical data from other existing operational facilities of similar design that have the capability of leak detection monitoring. In lieu of the existence or availability of such information, analytical approaches based on conservative assumptions may need to be conducted to estimate anticipated leakage rates. Given known source concentrations, groundwater and soil parameters, and the hydraulic gradients, a simple and hopefully conservative assessment of down gradient concentration at specific times and distances from the source can be conducted. Either one dimensional or two dimensional advection/dispersion containment transport methods may be used. The analysis should be performed by qualified professionals and may entail hypothetical computer simulations of groundwater flow and transport.

TOP COVER SYSTEM DESIGNS

Proper closure is essential to complete a landfill. Research has established minimum requirements needed to meet the stringent, necessary, closure criteria for both hazardous and nonhazardous waste landfills in the United States. In designing the landfill cover, the objective is to limit the infiltration of water to the waste so as to limit creation of leachate that might possibly escape to groundwater sources.

The cover system must be devised at the time the site is selected and the plan and design of the landfill containment structure is chosen. The location, the availability of low-hydraulic conductivy soil, the stockpiling of good topsoil, the availability and use of geosynthetics to improve performance of the cover system, the height restrictions to provide stable slopes, and the use of the site after the post closure care period are typical considerations. The goals of the cover systems are to minimize further maintenance and to protect human health and the environment.

Cover System for Hazardous Wastes

The closure of a hazardous waste landfill will normally have as its main criteria the minimization of moisture into the facility. Allowing moisture into a hazardous waste facility will subject the waste to leaching of potentially toxic pollutants into the leachate.

Minimizing leachates in a closed waste management unit required that liquids be kept out and that the leachate that does exist be detected collected and removed. Where the waste is above the groundwater zone, a properly designed and maintained cover can prevent (for practical purposes) water from entering the landfill and, thus, minimize the formation of leachate.

The current recommended design, Figure 3, is a multilayered system consisting of, from bottom to top:

- A Low-Hydraulic Conductivity Geomembrane/Soil Layer: A 60 cm (24 inch) layer of compacted natural or amended soil with a hydraulic conductivity of 1 x 10^{-7} cm/sec in intimate contact with a minimum of 0.5 mm (20 mil) geomembrane liner.
- A Drainage Layer: A minimum 30 cm (12 inch) soil layer having a minimum hydraulic conductivity of 1 x 10^{-2} cm/sec, or a layer of geosyntetic material having the same hydraulic characteristics.
- A Top, Vegetation/Soil Layer: A top layer with vegetation (or an armored top surface) and a minimum of 60 cm (24 inch) of soil graded at a slope between 3 and 5 percent.

Because the design of the final cover must consider the site, the weather, the character of the waste, and other site-specific conditions, these minimum recommendations may be altered. Design innovation is encouraged to meet the site-specific criteria. For example, in extremely arid regions, a gravel top surface might compensate for reduced vegetation, or the middle drainage layer might be expendable. Where burrowing animals might damage the geomembrane/low permeability soil layer, a biotic barrier layer of large-sized cobbles may be needed above it. Where the type of waste may create gases, soil or geosynthetic vent structures would need to be included.

Cover Systems for Nonhazardous Waste

The cover system in nonhazardous waste landfills will be a function of the bottom liner system and the liquids management strategy for the specific site. If the bottom liner system contains a geomembrane, then the cover system should contain a geomembrane to prevent the “bathtub” effect. Likewise, if the bottom liner system is a natural soil liner, then the cover system barrier should be hydraulically equivalent to or less permeable than the bottom liner system. A geomembrane used in the cover will prevent the infiltration of moisture to the waste below and may contribute to the collection of waste decomposition gases, therefore, necessitating a gas collection layer.

There are at least two options to consider under a liquids management strategy, mummification and recirculation. In the mummification approach, the cover system is designed, constructed and maintained to prevent moisture infiltration to the waste below. The waste will eventually approach and remain in a state of “mummification” until the cover system is breached and moisture enters the landfill. A continual maintenance program is necessary to maintain the cover system in a state of good repair so that the waste does not decompose to generate leachate and gas.

The recirculation concept results in the rapid physical, chemical and biological stabilization of the waste. To accomplish this, a moisture balance is maintained within the landfill that will accelerate these stabilization processes. This approach requires geomembranes in both the bottom and top control systems to prevent leachate from getting out and excess moisture from getting in. In addition, the system needs a leachate collection and removal system on the bottom and a leachate injection system on the top, maintenance of this system for a number of years (depending on the size of the facility), and a gas collection system to remove the waste decomposition gases. In a modern landfill facility, all of these elements, except the leachate injection system, would probably be available. The benefit of this approach is that, after stabilization, the facility should not require further maintenance. A more important advantage is that the decomposed and stabilized waste may be removed and used like compost, the plastics and metals could be recycled, and the site used again. If properly planned and operated in the manner, few landfill cells could serve much of a community's waste management needs for many years.

In nonhazardous municipal solid waste landfills natural soils have been used for daily and final covers. However, the use of manmade materials such as foams, recycled paper mixed with polymers, geosynthetics, etc., are gaining popularity for use as daily cover soils. When using natural soils as either the daily or final cover material, it is sometimes necessary to consider different material characteristics to satisfy set-specific criteria. A matrix of soil characteristics can be developed to provide information on which soil or combination of soils will be the most beneficial.

Health considerations demand the evaluation of each soil type to minimize vector breeding areas and attractiveness to animals. The soil should minimize moisture infiltration (best accomplished by fine grain soils) while allowing gas movement (coarse grain soils are best). This desired combination of seemingly opposite soil properties suggests a layered system. The soil should also minimize fire potential.

Aesthetic considerations include minimizing blowing of paper and other waste, controlling odors and providing a sightly appearance. All landfill operators strive to be good neighbors and these considerations are very important for community relations.

The landfill site may be used for a variety of activities after closure. For this reason, cover soils should minimize settlement and subsidence, maximize compaction, assist vehicle support and movement, allow for equipment workability under all weather conditions, and allow healthy vegetation to grow. The future use of the site should be considered at the initial landfill design stages so that appropriate end use design features can be incorporated into the cover during the active life of the facility.

DISCUSSION ON GEOSYNTHETIC CLAY LINERS

In those situations where natural clay is in short supply or where construction time is very short, the designer may want to consider using geosynthetics clay liners (GCLs). GCLs are manufactured by placing geotextiles on either side of a layer of bentonite or gluing bentonite to a geomembrane. Their hydraulic performance can be on the order of 10^{-7} to 10^{-10} cm/sec depending on the applied normal stress. The material comes in a roll to the job site which allows for each installation. No seaming has to occur as overlays of 7-15 cm are the normal installation.

In the United States, GCLs are used extensively in landfill covers and to some extent on sidewalls of disposal facilities. Their use on replacement of the bottom compacted natural clay has not been sufficiently investigated for attenuation properties to warrant their use in this critical area.

Equivalency of GCLs to compacted clays has been researched by many universities and consultant firms. The research topics included hydraulic issues, physical/mechanical issues and construction issues. The issues of concern remaining include absorption capacity, breakthrough time, puncture resistance and internal slope stability.

CONSTRUCTION QUALITY CONTROL AND QUALITY ASSURANCE

Field data studies have clearly indicated that with the development of a construction quality control/quality assurance (CQA/CQC) program that the performance of the waste management facility will improve over a facility constructed with a good CQA/CQC program.

CQA consists of a series of planned observations and tests required to insure that the final product (the waste management facility) will meet the project specifications.

CQA is a management tool and the plans, specifications, observations and test are all used to provide a quantitative means of acceptance of the final product.

CQC consists of a series of actions which provide a continuing means of measuring and controlling the characteristics of the product in order to meet the specifications of the finished product. CQC is the production tool that is employed by the manufacturer of materials and contractor installing the materials at the site.

The CQA/CQC plans are implemented through inspection activities which include visual observations, field testing and measurements, laboratory testing and the evaluation of the test data. The inspection activities are typically concerned with three separate functions:

- Quality control inspection by the <u>manufacturer</u> provides a real time measure of the quality of the product and the conformance with the project plans and specifications. Typically the manufacturer will provide the CQC test results and a certification of the conformance of the product with the project plans and specification for the manufactured merials.

- Quality control inspection by the <u>contractor</u> provides a real time measure of the quality of construction and conformance with the project plans and specifications. This allows the contractor to correct the construction process if the quality of the product is not meeting the specification and plans. CQC is performed independently of the CQA plan.

- Quality assurance testing by the owner (acceptance inspection) performed by the owner usually through the third party testing firm, provides a measure of the quality of the final product and the conformance with the project plans and specifications. Due to the size and costs of a typical construction project, rejection of the project at completion would be costly to all parties. Consequently, this testing takes place through the construction process. This allows deficiencies to be found and corrected before they become too large and costly.

The CQA/CQC plan will require the development of the following key terms:

- **Responsibility and Authority**-The responsibility and authority of organization and personnel involved in permitting, (if necessary), designing and constructing the facility should be described in the CQA/CQC plans.

- **Personnel Qualifications**-The qualifications of the CQA officers and supporting CQA inspection personnel should be presented in the CQA/CQC plans.

- **Inspection Activities**-The observations and tests that will be used to ensure that the construction or installation meets or exceeds all design criteria, plans and specifications for each component should be described in the CQA/CQC plans.

- **Sampling Strategies**-The sampling activities, sample size, methods for determining sample locations, frequency of sampling, acceptance and rejection criteria, and methods for ensuring that corrective measures are implemented should be presented in the CQA/CQC plans.

- **Documentation**-Reporting requirements for CQA actives should be described in detail in the CQA/CQC plans.

Preconstruction meetings will be necessary to identify all key factors and their authority. This meeting should also develop a complete understanding of the intent of the above criteria. Discussion on specific issues should be finalized before construction begins so as not to delay the overall construction process.

TECHNICAL GUIDANCE DOCUMENTS

The U. S. Environmental Protection Agency, in support of hazardous and non hazardous waste management facilities, developed three types of documents. The intent of these documents was to assist designers of facilities and reviewers of permits for these facilities. One document, the permit guidance manual, addresses the type of information required for a permit. The other two document, the Technical Resource Documents (TRDs), and the Technical Guidance Document, contain information useful to designers.

The Technical Resource Documents (TRDs) present summaries of state-of-the-art technologies and evaluation techniques determined by the Agency to constitute good engineering designs, practices, and procedures. They describe current technologies and methods for waste facilities, or for evaluating the performance of a facility design. Although emphasis is given to hazardous waste facilities, the information presented in these TRDs may be used for designing and operating nonhazardous waste treatment, storage and disposal facilities.

The Technical Guidance Documents present design and operating parameters or design evaluation techniques that, if followed, would demonstrate compliance with the United States regulations.

In addition to the documents described above, the Agency presented detailed seminars through the U. S. Seminar publications, developed from these forums, provided additional information useful to designers, operators, and owners of waste management facilities.

The seminars could not nave been as successful as they were without the input of others. Industry provided actual designs from which people could learn how to do it and how not to do it. Specific examples of failures and solutions to those failures were used to demonstrate techniques and the thinking input to design work. Academia provided input to laboratory techniques with hands on approaches, test methods and field experiences.

Foreign countries, such as Germany, England, Australia, and Hong Kong, China provided critiques and solutions to unique problems that were starting to surface in the United States. There were many discussions on designs and material usage that benefited all.

SUMMARY

Management of hazardous waste and nonhazardous waste requires the development of liner and cover systems that will minimize the release of potential pollutants to the environment. These systems, as designed and constructed in the United States, contain combinations of geosynthetics and natural soil materials. These designs have been generally described.

To insure that the facilities are constructed as designed, the development of a CQA/CQC plan is recommended. Specific objectives, as well as, key elements of the plan have been provided.

Finally, the technical knowledge gathered from laboratory and field experiences and discussion with other countries, was presented in seminars and technical manuals.

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