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Project Summary

Avoiding Failure of Leachate Collection and Cap Drainage Systems

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Failure, caused by a variety of mechanisms, is common to drainage systems of all kinds. Leachate collection and cap drainage systems, which remove excess liquid from hazardous waste land disposal facilities, are no exception. Failure of these systems, however, may be a greater cause for concern than failure, for example, of agricultural drainage systems. This is especially true for leachate collection systems at hazardous waste disposal facilities. Undetected failures may cause leachate to build up on top of the liner. This can lead to failure of the liner system and contamination of groundwater. Furthermore, failures which are detected may be difficult to repair, and replacement is no longer a simple last resort since excavation of hazardous wastes would be required. Information is presented on those mechanisms which may cause leachate collection and cap drainage systems failure. Furthermore, information on design, construction, inspection, and maintenance for these systems is presented in order to minimize the potential of failure. Techniques to repair a failed system are also described.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The document summarized here was written to provide general guidance to design engineers, facility operators, and state and Federal regulatory officials. The document is not a comprehensive design and operations manual for leachate collection and cap drainage systems. Rather, it summarizes current knowledge and experience regarding potential failure mechanisms and presents information on factors to consider in design, construction, inspection, maintenance and repair of such systems. Detailed design and operation plans for leachate collection and cap drainage systems at a specific facility should be prepared by a qualified design engineer based on site-specific conditions.

Emphasis is placed throughout the document on avoiding failure of leachate collection systems at hazardous waste facilities. Most of the information presented for leachate collection systems can also be applied to cap drainage systems, since the basic components of the two systems are similar. Failure of cap drainage systems, however, is less critical than failure of leachate collection systems since the cap drainage system is accessible and therefore can be more readily maintained or repaired. Cap drainage systems are discussed separately in this document only when the information presented is significantly different from the discussion of leachate collection systems.

Failure Mechanisms

Leachate collection and cap drainage systems can fail or clog through a variety of physical, chemical, biological, and biochemical mechanisms. Some of

the most common failure mechanisms are those which lead to system clogging. Clogging is defined as the physical buildup of material in the collection pipe, drainage layer, or filter layer to the extent that leachate flow is significantly restricted. Other failure mechanisms which do not involve clogging include differential settling and deterioration of the collection pipe because of chemical attack or corrosion. Failure may also occur because the design capacity is exceeded. In this case liquid is not adequately removed from the system, even though system components may not be physically blocked.

As a first step in this project, confirmation testing was conducted to verify that the failure mechanisms described above are indeed possible for leachate collection and cap drainage systems. A three-step approach was utilized to confirm the failure mechanisms:

Step 1: Confirmation by experience;
Step 2: Confirmation by first principles;
Step 3: Confirmation by laboratory investigation.

The results of the three-step confirmation testing process indicate that all the failure mechanisms should be considered in the design, construction and operation of leachate collection and cap drainage systems.

Design

Leachate collection and cap drainage systems must be designed to meet legislated and regulatory performance standards and design specifications. For example, a leachate collection system must be designed to ensure that the leachate depth over the liner does not exceed 30 cm (1 foot). In order to meet this requirement, as well as other requirements specified in the regulations, the design must address the various components of the leachate collection or cap drainage system. These components include the drainage layer, collection pipe network, filter layer, and associated appurtenances (e.g., sumps, pumps, manholes).

Drainage layers generally consist of granular soils such as coarse sand which provide sufficient hydraulic conductivity for leachate flow and at the same time protect the underlying synthetic liner. The particle-size distribution of the drainage layer must be selected to allow liquid transport, prevent puncture of the underlying synthetic liner, and minimize migration of filter layer materials into the drainage layer. Increasingly, geotextiles are being proposed and used as a substitute for granular material in portions or all of the drainage layer. Geotextile materials include needlepunched, non-woven polypropylene or polyester fabric and polyethylene grids. Combinations of these materials may also be used, for example, placing a grid between two layers of geotextile fabric.

The collection pipe network of a leachate collection system drains, collects and transports leachate through the drainage layer to a collection sump where it is removed for treatment or disposal. The pipes also serve as drains within the drainage layer to minimize mounding of leachate in the layer. In a cap drainage system, pipes are used to collect and transport water from the drainage layer to surface drainage facilities. Pipes used to collect and convey leachate must be structurally able to withstand the loading of the overlying filter and drainage layers, wastes, cap materials, and vehicular traffic that may move over the disposal cell. These pipes must be sized and spaced to remove liquid from the drainage layer without causing any significant backup. In a leachate collection system, the collection pipes must be designed to carry the leachate without allowing more than 30 cm (1 ft) of leachate buildup within the drainage layer.

The filter layer is used above the drainage layer in both leachate collection and cap drainage systems to trap fines and prevent waste and other solid materials from entering the drainage layer while allowing the passage of liquid. Information regarding physical characteristics of the fines and the anticipated loading rates is needed to formulate design criteria for constructing a filter that will continue to function through the design life of the drainage system. Typically, filter layers may either be granular or a geotextile. Granular filters consist of a soil layer of combination of soild layers having a coarser gradation in the direction of seepage. Geotextiles may also be used as filters and are either woven or non-woven. Woven geotextiles are similar to screens which have uniform sized openings whereas the non-woven variety consists of fibers placed in a random orientation. Both types can be made with high permeability relative to most soils while having an opening or mesh size sufficiently small to prevent soil particle movement.

Appurtenances associated with leachate collection systems include sumps, pumps, manholes, discharge lines, and liquid-level monitors. All of these items are important factors in ensuring the performance of leachate collection and cap drainage systems and should be designed in accordance with established engineering practice and where applicable, manufacturers' specifications.

Construction

Construction of leachate collection and cap drainage systems must be performed in accordance with the design specifications. If specific design procedures are identified in the bid package, then the construction contractor must follow these procedures. Where performance standards alone are specified, then the construction contractor is allowed flexibility in meeting that standard.

In order to ensure that the construction of the leachate collection or cap drainage system is proceeding in accordance with the design, the hazardous waste land disposal facility owner may employ the design engineer, or an independent party, to monitor and report on the quality of construction. Such activities do not guarantee that the facility will not fail. Rather, construction quality assurance is a tool to ensure, with a reasonable degree of certainty, that the completed systems meet or exceed the specified design.

Construction quality assurance (CQA) serves to detect variations from design, and to provide for suitable corrective measures before wastes are accepted at the facility. Without proper construction quality assurance, problems with the leachate collection or cap drainage system that are caused by construction may not be discovered until the system fails during operation.

A Construction Quality Assurance Plan is the written document describing the specific approach to be followed in attaining and maintaining consistently high quality in the construction of a hazardous waste disposal facility so that the completed facility meets or exceeds the specified design. While the overall content of the CQA plan will depend on the site-specific nature of the proposed facility, specific elements that may be included in the plan are:

- *Responsibility and Authority*—The responsibility and authority of all organizations and key personnel involved in permitting, designing, and

constructing the hazardous waste land disposal facility should be described fully in the plan.

- *CQA Personnel Qualifications*—The qualifications of the CQA officer and supporting inspection personnel should be presented in the plan to demonstrate that they possess the training and experience necessary to fulfill their identified responsibilities.
- *Inspection Activities*—The observations and tests that will be used to monitor the installation of the leachate collection system should be summarized in the plan.
- *Sampling Requirements*—The sampling activities, sample size, sample locations, frequency of testing, acceptance and rejection criteria, and plans for implementing corrective measures as addressed in the project specifications should be presented in the plan.
- *Documentation*—Reporting requirements for sampling activities should be described in detail in the plan. This should include such items as daily summary reports, inspection data sheets, problem identification and corrective measures reports, block evaluation reports, design acceptance reports, and final documentation. Provisions for the final storage of all records also should be presented in the plan.

Inspection

Leachate collection and cap drainage systems must be inspected to ensure that the constructed system continues to operate according to design specifications. Undetected failure of drainage-system components can lead to buildup of excess liquid over the liner, liner failure, and/or contamination of groundwater. Inspections serve to discover failed components of the system as well as to determine where failure mechanisms are active. In addition, inspection of the drainage system can be useful in discovering problems with other components of the disposal facility, especially the liner. Reduced outflow from the drainage system, for example, may indicate a variety of problems with the drainage system or a leaky liner.

Federal regulations under the Resource Conservation and Recovery Act require the leachate collection systems to be inspected. While in operation, a landfill, for example, "must be inspected weekly and after storms to detect evidence of the presence of leachate in the proper functioning of leachate collection and removal systems, where present."

There are no similar Federal requirements for inspection of cap drainage systems at closed facilities, although the "integrity and effectiveness of the final cover" must be maintained. This implies the need for inspection to make sure that the cap drainage system is functioning as intended.

State regulatory agencies may make requirements for inspecting leachate collection or cap drainage systems in addition to the Federal requirements. Requirements vary from state to state, and often from facility to facility within a state. The Wisconsin Department of Natural Resources (WIDNR), for example, does not have a standard set of requirements for the inspection of leachate collection systems. Typical requirements, based on WIDNR permit approvals and conversations with WIDNR staff include:

- cleaning the collection pipe after construction and after the first lift of waste is placed to verify continuity of the lines (conducted with Department representative present);
- field-checking collection pipe for clogging at least annually;
- daily recording of leachate levels in leachate collection tanks;
- quarterly recording of levels in leachate-level wells installed at site closure.

Inspections required at the Federal and state levels are intended to provide enough information to the regulatory agencies to ensure that the leachate collection or cap drainage system is performing adequately. They also provide the facility owner with performance data. Guidance on how to conduct the required inspections, however, is generally not given; it is left up to the facility owner to specify in the permit application how the requirements will be met.

Two types of inspection procedures may be used. The first, Regular or Periodic Inspections, includes visual inspection, monitoring leachate level over the liner, indicators of system failure or clogging, and direct inspection methods. The second section, Special Inspections, includes cleaning to verify the continuity of system construction and after the first lift of waste is placed, and methods to locate and diagnose leachate collection system problems.

Maintenance

Maintenance of leachate collection and cap drainage systems is needed to ensure that liquid will be effectively removed from over the liner throughout the lifetime (and post-closure care period) of the facility. There has been little experience, however, with maintenance of these systems. Typically, collection pipes are maintained only when problems are noted; that is, maintenance techniques are used as repair measures rather than for system maintenance.

The notion that the need for preventive maintenance is obviated by the ability to repair these systems seems shortsighted for at least two reasons. First, historical evidence indicates that drainage systems of all types require preventive maintenance to operate at maximum efficiency and to prolong service life. Second, some failure mechanisms may be extremely difficult to stop once the pipe is clogged. New iron deposits, for example, may be easily removed by preventive maintenance techniques even though the effect of the deposit may not yet be noticeable. However, mature deposits which do affect leachate flow may be extremely difficult, if not impossible, to remove by standard maintenance or repair methods.

The basic objectives of a maintenance program are:

- to keep the system operating near maximum efficiency;
- to obtain the longest operating life of the system; and
- to accomplish the above two objectives at minimum cost.

Underground drainage systems, in general, require minimal maintenance. The amount of maintenance required for a leachate collection or cap drainage system will vary depending on design, construction quality, operating procedures, and leachate characteristics (quantity and quality). Collection pipes, for example, may need to be cleaned several times a year if the leachate has a high sediment load or if the system is highly susceptible to other forms of clogging. Alternatively, annual cleaning may only be a safety measure at facilities where clogging mechanisms are not active. At all facilities, regular maintenance of mechanical equipment (e.g., pumps) is required. Further research is needed to determine the cost-effectiveness of preventive maintenance in meeting the above objectives.

Mechanical and hydraulic methods for cleaning collection pipes are discussed in this section. These techniques were developed for maintenance of

sewer pipes. Experience with these techniques for leachate collection system maintenance is limited. Two major constraints on using these techniques for leachate collection systems are more limited access (e.g., risers used instead of manholes, manholes surrounded by waste) and the use of plastic pipe.

Operator safety is also of great concern for leachate collection system maintenance because of the potentially hazardous nature of the leachate.

Repair

Leachate collection and cap drainage systems must be repaired when failure mechanism systems malfunction or fail. Failure occurs when the system becomes unable to remove leachate (ore precipitation) and allows liquid to accumulate over the liner. Maintenance procedures are used to address failure mechanisms before actual failure of the system occurs. Repair procedures are used to correct the problem after it occurs, thus allowing liquid to be removed from over the liner.

Leachate collection and cap drainage systems can fail as a result of problems in the collection pipe, filter layer, drainage layer and other system components, including sumps and pumps. Problems with components of the system that are buried under the waste are of particular concern since access to these components is difficult. Evidence of system failure includes:

- no flow out of the system when flow is expected;
- high leachate levels in portions of the facility; and
- leachate ponding or seepage at the surface of the waste mass (or cap).

A variety of repair options are available to correct problems with failed leachate collection or cap drainage systems. Maintenance techniques can be used as repair methods primarily for clogged collection pipe. Chemical methods may also be useful to remove (dissolve) material clogging a collection pipe and may be applicable to address clogging of the drainage or filter layer. Finally, the failed portion of the system can be replaced with a new system.

Selection of the appropriate repair option depends on a number of factors. Location of the problem influences the choice considerably. Some repair options, for example, are applicable only to the collection pipe and would not be of use for a clogged drainage layer. The type and extent of the problem are also important. Clogging of the drainage layer around the collection pipe might be addressed by chemical methods while chemical methods would not be applicable to extensive clogging of the drainage or filter layer away from the pipe. Also, the physical and chemical characteristics of the clogging material are important in determining the effectiveness of a repair option. In general, maintenance techniques and chemical methods are applicable to problems in and around the immediate area of the collection pipe, and replacement techniques are required for problems away from the pipe area.

Landfill design and waste characteristics must also be considered in selecting the appropriate repair option. Maintenance techniques, for example, may not be the best option for a clogged collection pipe if access to the pipe was not provided in the landfill design. Similarly, excavation and replacement may depend on the number of lifts of waste which have been placed and how "dangerous" those wastes are (e.g., explosive, reactive, volatile, unknown composition).

In some cases, the effect of leachate collection system failure can be eliminated by significantly reducing leachate generation. This would be accomplished, for example, by closing the site with a final cover to control the water balance at the site. Decreasing the quantity of precipitation and groundwater flow, and increasing runoff, surface storage and evapotranspiration can also be used to reduce the quantity of water available for leachate generation at the site.

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The complete report, entitled "Avoiding Failure of Leachate Collection and Cap Drainage Systems," (Order No. PB 86-208 733/AS; Cost: $16.95, subject to change) will be available only from:
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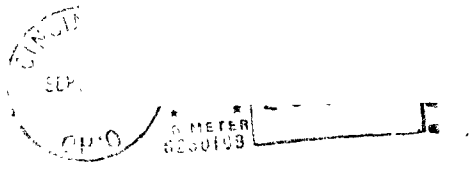

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