

Appendix I

Municipal Solid Waste (MSW) Landfill Closure and Postclosure Issues¹

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Typically, landfill developers, whether public or private, and some regulatory agencies allow the postclosure period for a proposed landfill, landfill expansion and/or landfill closure to potentially be limited to 30 years, where only minimal postclosure funding is required to be developed during the active life of the landfill. Little or no consideration is given to the fact that the wastes in a US EPA Subtitle D “dry tomb” landfill will remain a threat to generate leachate that can pollute groundwater well beyond the 30-year postclosure period. In fact, the wastes in the closed landfill will be a threat, effectively, forever. Further, the ultimate failure of the plastic sheeting liner, and the inherent permeability of the compacted clay liner that underlies the plastic sheeting liner, which together make up the single composite liner that is required as the minimum design for Subtitle D landfills, are not taken into consideration in determining the duration of the postclosure period and its associated funding.

The US EPA (1991) RCRA Subtitle D regulations governing municipal solid waste disposal by landfilling (PART 258—CRITERIA FOR MUNICIPAL SOLID WASTE LANDFILLS Subpart F—Closure and Post-closure Care § 258.61 Post-closure care requirements) states,

“(a) Following closure of each MSWLF unit, the owner or operator must conduct post-closure care. Post-closure care must be conducted for 30 years, except as provided under paragraph (b) of this section, and consist of at least the following:

(1) Maintaining the integrity and effectiveness of any final cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and runoff from eroding or otherwise damaging the final cover;

(2) Maintaining and operating the leachate collection system in accordance with the requirements in § 258.40, if applicable. The Director of an approved State may allow the owner or operator to stop managing leachate if the owner or operator demonstrates that leachate no longer poses a threat to human health and the environment;

(3) Monitoring the ground water in accordance with the requirements of subpart E of this part and maintaining the ground-water monitoring system, if applicable; and

(4) Maintaining and operating the gas monitoring system in accordance with the requirements of § 258.23.

(b) The length of the post-closure care period may be:

(1) Decreased by the Director of an approved State if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Director of an approved State; or

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(2) Increased by the Director of an approved State if the Director of an approved State determines that the lengthened period is necessary to protect human health and the environment.”

It is the last paragraph of the regulation (b-2) that is of concern to private and public landfill owners, where the US EPA Regional Director and state agencies that administer the state's landfilling regulations can extend the postclosure care period beyond the minimum 30 years specified in RCRA and Subtitle D. Extending the postclosure period beyond 30 years after closure would increase the financial obligation of the landfill owner during the time when the landfill is not generating income. In addition to the continued monitoring and maintenance beyond the initial 30-year postclosure period specified in the postclosure requirements presented above, extending the financial obligation beyond 30 years could lead to the need to begin to fund “Superfund”-like groundwater remediation programs associated with the ultimate failure of the landfill liner system.

As discussed by Lee and Jones-Lee (2004a, 2005), in a properly constructed landfill liner system, where the initial placement of wastes does not puncture the plastic sheeting portion of the liner, the liner system should not start to fail until after 30 or more years. Failure of the liner system means that it fails to continue to collect all of the leachate and transport it to a sump where it can be removed. Leachate that penetrates the failed liner system can begin to pollute the groundwater system below the landfill. Included as part of Lee and Jones-Lee's (2005) assessment is the inherent unreliability of groundwater monitoring that is based on monitoring wells placed along the point of compliance for groundwater monitoring. The initial pollution of groundwater can readily pass between these widely spaced monitoring wells and fail to be detected. This can lead to situations where the liner failure and its associated groundwater pollution is first detected in an offsite production well(s).

Some states, such as California, have established more definitive regulations governing landfill postclosure requirements. The California State Water Resources Control Board Chapter 15 (now Title 27) regulations also have a Performance Standard, which specifies that the liner system used for a particular landfill must be able to achieve the protection of groundwater quality from impaired use by landfill leachate for **as long as the wastes in the landfill will be a threat** (Title 27, California Code of Regulations sections 20330 and 20950) (SWRCB 2005).

The State of Pennsylvania Title 25, Code Chapters 271 and 273 (DEP 2005) establish landfill solid waste management regulations, including requirements for landfilling of municipal solid wastes. These regulations do not limit the postclosure period to 30 years or any other period. A landfill owner is obligated to provide landfill monitoring and maintenance for as long as the wastes in the landfill are a threat. The landfill owner is obligated to remediate any groundwater pollution that results from the landfill.

Dry Tomb Landfilling is Fundamentally Flawed

As was discussed at the time the dry tomb landfilling approach was adopted (prior to the adoption of Subtitle D regulations), this approach requires funding for landfill postclosure monitoring, maintenance and groundwater remediation, forever. It has been well recognized for over 20 years (see Lee and Jones 1991, 1992, 1993; Lee 2003) that the 30-year minimum

postclosure funding specified in RCRA and in Subtitle D was one of the most significant errors made by Congress in developing the current landfilling regulations. Those who advised Congress on this issue did not understand or reliably consider the processes that take place in landfills which control releases of hazardous/deleterious waste components from a closed landfill. As discussed by Lee and Jones-Lee (2005) non-dry-tomb landfills (conventional sanitary landfills), where moisture is allowed to penetrate through the cover and interact with the wastes, are threats to cause groundwater pollution for hundreds to thousands of years. However, a dry tomb landfill will, through leachate and gas releases, be a threat to public health and the environment forever. This threat mandates that funding be available to address all plausible worst case landfill containment system and groundwater monitoring system failures during the infinite period of time that the wastes in the landfill can be a threat.

Unreliable Groundwater Monitoring

While those who develop minimum-design Subtitle D landfills will save some funds in the construction of the landfill, these funds will have to be spent many times over in remediation of polluted groundwater when the unreliable groundwater monitoring systems (which are being proposed by landfill developers, supported by their consultants and approved by regulatory agencies) fail to detect leachate-polluted groundwater at the point of compliance for groundwater monitoring before widespread groundwater pollution occurs on adjacent properties. These issues were discussed by Cherry (1990) and others (Lee and Jones-Lee 1998).

ISSUES RELATED TO THE CLOSURE OF MSW LANDFILLS

Listed and briefly discussed below are issues that need to be considered in developing a landfill closure plan that will be protective of public health and the environment for as long as the wastes in the landfill will be a threat.

Recognize that the Landfilled Wastes will be a Threat Forever

Some of the waste components, such as heavy metals and salts, and some organics will not decompose in a dry tomb landfill. The closure plan must take this situation into account and prepare for it.

Landfill Liner Integrity Issues

There is a finite period of time during which the plastic sheeting in a composite liner can be expected to function as designed in collecting leachate and thereby preventing it from polluting groundwater. In time, the minimum US EPA Subtitle D composite liner will fail, and groundwater pollution by the landfill will occur.

Long-Term Functioning of the Leachate Collection and Removal System. The leachate collection system that is installed at Subtitle D landfills can initially be effective in collecting leachate generated in the landfill. However, over time the leachate collection and removal system will fail to function as designed due to deterioration of the plastic sheeting layer in the composite liner. Leachate will pass through holes in the plastic sheeting and then penetrate through the underlying clay layer in the composite liner. It is not possible to repair the landfill liner system and the associated leachate collection and removal system, because they are buried under the wastes. If failure of the leachate collection and removal system is properly

monitored/detected, action can be taken to repair the areas of the landfill cover that are allowing moisture to pass through the cover to generate leachate.

Expected Performance of the Landfill Cover

A properly constructed and maintained landfill cover that includes a plastic sheeting layer can be effective in preventing moisture from entering the landfill and therefore keep the wastes dry. When dry, the wastes do not generate leachate or landfill gas. In a dry tomb type landfill, drying out of the wastes leads to a dormant period with respect to landfill gas and leachate generation. However, the integrity of the low-permeability layer of the cover is subject to many stresses; eventually, it deteriorates and allows moisture to enter the wastes, which allows the renewed generation of leachate and landfill gas. This can occur a short time after landfill closure, or be postponed for decades after landfill closure.

A reliable landfill closure plan for a landfill must include monitoring of leachate and landfill gas generation for as long as the wastes in the landfill have the potential to generate leachate and gas when moisture is introduced into the wastes. Continued leachate and/or landfill gas generation after the landfill is closed is an indication that the landfill cover is not preventing water from entering the landfill. The landfill cover must be routinely inspected for areas of stressed vegetation, which is indicative of landfill gas migration through the cover. Renewed landfill gas and/or leachate generation after a dormant period of little or no leachate generation is an indication that water is entering the landfill. Under those conditions, the landfill owner must be required to locate the area of the cover that is no longer preventing moisture from entering the landfill, and repair the low-permeability layer of that area of the cover. This process will have to be repeated as needed for as long as the wastes in the landfill are a threat.

Recognize that the low-permeability layer of the landfill cover will need to be periodically evaluated for deterioration that will lead to its failure to prevent moisture from entering the wastes and generating leachate. It will be necessary to develop an approach to repair the low-permeability layer of the cover when it becomes evident that a closed part of the landfill is generating leachate and landfill gas at a rate well above that which would be expected for a landfill with a properly functioning low-permeability cover. The typical landfill postclosure funding does not include the funds needed to locate and repair the landfill cover low permeability plastic sheeting layer.

Reliability of Groundwater Monitoring

The geology/hydrogeology of the area under and near some landfills is complex. Because of fractured rock or sandy lens aquifer systems underlying some landfills, it is difficult, if not impossible, to use vertical monitoring wells at the point of compliance for groundwater monitoring of the landfill to reliably monitor groundwater pollution associated with the initial failure of the composite liner. Typically, landfill permitting agencies allow a highly arbitrary approach to determining the number of monitoring wells that are to be placed along the point of compliance for groundwater monitoring. As part of permitting a landfill, the landfill owner should conduct a quantitative assessment of the number and locations of groundwater monitoring wells that would be needed to reliably detect leachate-polluted groundwater when it first reaches the point of compliance for groundwater monitoring which occurs from liner leaks at any location in the landfill liner system.

Recognize that the Groundwater Monitoring System is Unreliable for Detecting Leachate-Polluted Groundwater. An evaluation should be made of the flow path(s), migration rates, and possible attenuation for leachate pollution of groundwater that could be generated from liner leakage from any location in the landfill footprint, including side slopes. Additional monitoring wells will likely be needed to properly monitor leachate pollution of groundwater. In making the groundwater pollution potential evaluation, the worst case from a pollution potential perspective is the one that should be considered, such as the highest recorded groundwater velocity, least dilution/attenuation.

Similar problems exist with respect to reliably monitoring landfill gas migration at the edge of the landfill property. The closure of the landfill should include a comprehensive review of the adequacy of the existing groundwater and gas monitoring systems. The geology/hydrogeology of the landfill area should be sufficiently well delineated so that it is possible to determine whether the existing monitoring well array has a high probability (95%) of detecting leachate-polluted groundwater and landfill gas migration at the location of the monitoring wells.

Yearly monitoring of all downgradient public and private domestic and agricultural wells that are potentially impacted by leachate-polluted groundwater is recommended as an additional safeguard to protect the health of those most likely impacted by leachate-polluted groundwater that is not detected by the groundwater monitoring systems that are allowed at Subtitle D landfills. Further, a procedure should be developed that will ensure that the landfill owner will incorporate new monitoring parameters as new but long-standing unrecognized pollutants are discovered in municipal solid waste and industrial nonhazardous waste streams.

Landfill Gas Emissions

Landfill gas emissions are a significant threat to cause explosions and to present a health threat to those in the sphere of influence of the landfill. As part of developing the final closure plan for a landfill, there will be need to gain better control of both landfill gas generation, through controlling the water that enters the landfill through the cover, and the offsite migration of landfill gas. There is need to evaluate if landfill gas will be detected by the current gas migration monitoring system. There is also need every five years to reevaluate if those most likely impacted by inadequately controlled landfill gas emissions are experiencing elevated landfill gas concentrations in their area.

Consider the potential of landfill gas pollution of groundwater. Of particular concern in monitoring for potential impacts of landfill gas migration is the potential for such migration to cause groundwater pollution in areas upgradient of the direction of groundwater flow. Such pollution can readily occur and thereby make upgradient monitoring wells unreliable for establishing the background concentrations of constituents derived from landfill gas.

Periodically evaluate the rate of landfill gas releases through the cover. Every five years an evaluation should be conducted of landfill gas mass flux rates through the cover, with particular attention given to areas of the landfill cover where the vegetation has been damaged/killed. These areas are an indication that the plastic sheeting layer of the cover needs repair. They also indicate that the landfill gas collection system is not working adequately and needs repair.

Landfill Postclosure Issues

There are several important landfill closure issues that need to be addressed pertinent to long-term funding of postclosure care. These include,

- The regulatory agency should clarify its current approach of requiring that landfill owners provide assured funding for as long as the wastes in the landfill are a threat to produce leachate and/or landfill gas.
- The regulatory agency needs to define how it ensures that funds will be available from the landfill owner to perform postclosure monitoring and maintenance (including replacement of the landfill cover) and for groundwater pollution remediation for as long as the wastes in the landfill will be a threat.
- What are the conditions under which a regulatory agency might relieve the landfill owner of further postclosure care responsibility for landfill monitoring, maintenance and groundwater remediation?
- How will the needed postclosure care be funded and implemented if/when a private landfill owner is no longer able to provide the needed funding?

Establish a reliable funding mechanism for ad infinitum postclosure care. Since many of the MSW waste components will forever be a threat to generate leachate that can pollute groundwater, there is need to establish a funding mechanism to support *ad infinitum* postclosure monitoring, maintenance and eventually, for many landfills, remediation of polluted groundwater. What assurance is available to ensure that the owner of the landfill will provide funding for postclosure activities if the owner files for bankruptcy?

Recognize that the regulatory agencies may not be adequately funded to properly oversee the postclosure activities at the landfill. The landfill owner should be responsible for conducting the postclosure activities of monitoring and maintenance. The regulatory agency should be responsible for overseeing the adequacy of postclosure care provided by the landfill owner. In order to address these situations, a third party (independent) oversight monitoring committee/program should be funded by the landfill owner. This third-party monitoring should be developed in such a way that the landfill owner cannot control the third-party review of the adequacy of postclosure activities. Those concerned about the impact of the landfill should be responsible for organizing the third-party monitoring committee. Those conducting the monitoring should report to this committee and the regulatory agencies.

Bioreactor Landfill Operation

The conversion of a dry tomb landfill to a bioreactor landfill could potentially reduce the magnitude of the long-term threat of releases from the landfill. A change in regulations may be required to permit this change in mode of operation for a landfill. Consideration should be given to the potential for increased groundwater pollution associated with operating a minimum-design Subtitle D landfill, with its inherently unreliable groundwater monitoring, as a bioreactor landfill.

Attempts to Limit Landfill Owner's Period of Liability

With municipal solid waste landfills developed under Subtitle D regulations beginning to be closed, efforts are being made by members of the community of landfill owners and their

consultants to try to convince the regulatory agencies and the federal Congress that these landfills can be closed, where the landfill owners would be relieved of the long-term financial obligations associated with postclosure monitoring, maintenance and groundwater remediation of the closed landfill. GeoSyntec (2003a,b) made a presentation and developed a report that provides unreliable, technically invalid, and for some landfill closure/postclosure issues, distorted information in support of relieving landfill owners from the responsibility of implementing postclosure activities to ensure to a high degree of reliability that the closed landfill will not at some time in the future (during the time that the MSW in the landfill will be a threat) cause groundwater pollution and experience uncontrolled landfill gas releases that are a threat to public health and the environment in the vicinity of the landfill.

GeoSyntec is a geotechnical consulting firm that specializes in assisting landfill developers with gaining permits to develop landfills and landfill expansions, and assisting with closure and postclosure issues. GeoSyntec has made unreliable statements, such as that it is possible to predict, based on landfill monitoring records, the period of time that a minimum-design Subtitle D landfill will be a threat to cause groundwater pollution by landfill leachate that has passed through the bottom liner and/or to emit landfill gas through the cover that will be a threat to public health, safety and the environment. Further, GeoSyntec (2003b) has stated in a report to the California Integrated Waste Management Board that there is no need to make it explicitly clear that the current RCRA Subtitle D postclosure funding obligation extends for the period that the waste components and their transformation products that are present in a landfill will be a threat to generate leachate and landfill gas. Lee (2004a,b) commented on the inadequate and unreliable information provided by GeoSyntec in their reports to the California Integrated Waste Management Board.

As discussed by Lee and Jones-Lee (1995a,b; 2005), for planning purposes, the period of postclosure care for a Subtitle D “dry tomb” is forever, since some of the components in MSW will remain a threat forever. In a “dry tomb” type landfill (which was adopted by the US EPA first for hazardous waste landfills in the early 1980s and for MSW in the early 1990s), so long as the wastes are kept dry after closure of the landfill, the waste components do not degrade, decompose, or leach hazardous and/or deleterious components. Moisture (water) in contact with the MSW waste components is essential for degradation and leaching processes that can eliminate the essentially infinite threat to public health and groundwater quality.

A similar presentation to that of GeoSyntec on this issue was made by Caldwell (2004) of Waste Management, Inc., to the California Integrated Waste Management Board in December 2004. As discussed by Lee and Jones-Lee (2004b) in their comments on the Caldwell presentation, it is inappropriate to assume normal processes that occur in a classical sanitary landfill will occur in a Subtitle D dry tomb landfill. While the normal process of landfill gas formation in the unlined sanitary landfill is somewhat predictable, the processes that govern landfill gas and leachate formation in a dry tomb landfill are dependent on the amount of moisture that enters the landfill through the low-permeability cover. If the cover is effective in greatly restricting the amount of moisture (water) that enters the landfill, landfill gas and leachate generation will greatly slow down and can even stop. Under these conditions, the landfill will enter a dormant period with little or no landfill gas and leachate formation. These issues have been reviewed by Lee and Jones-Lee (1999).

The key to keeping a dry tomb landfill dry is the integrity of the plastic sheeting layer in the landfill cover. Normally this cover liner is buried below several feet of a top soil and drainage layer. The deterioration of the plastic sheeting liner in the cover that enables moisture to enter into the landfill in sufficient amounts to generate landfill gas and leachate is not predictable or readily measured by the approaches being used today. The dormant period of a dry tomb landfill will last until the integrity of the cover is breached and moisture begins again to enter the wastes. At that time, landfill gas and leachate generation will begin again. If this situation occurs during the minimum 30-year postclosure period when there is landfill gas and leachate monitoring, the regulatory agency for the landfill could require that the landfill owner repair the cover. One of the issues that needs to be addressed is that the typical postclosure funding does not provide funds for plastic sheeting cover liner repair. This could be expensive since the area of deterioration of the buried plastic sheeting layer of the cover cannot be detected by a visual inspection.

Importance of Adequate Review of a Landfill's Closure Plan

As discussed herein, there are a number of important issues that those who are concerned about the long-term impacts of a landfill need to consider as part of reviewing the landfill's closure plan. This plan should adequately and reliably consider the variety of issues that will govern the impacts of the landfill on public health and the environment for as long as the wastes in the landfill will be a threat. Many of the key issues that need to be considered have been discussed in this review.

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