

## Cost of Groundwater Quality Protection in MSW Landfilling<sup>1</sup>

G. Fred Lee, Ph.D., P.E., D.E.E. and Anne Jones-Lee, Ph.D.  
President Vice-President

G. Fred Lee & Associates  
El Macero, CA 95618  
<https://www.gfredlee.com>

August, 1996

In October 1991 the US EPA (1991) promulgated the RCRA Subtitle D regulations which required that all municipal landfills meet certain prescriptive standards for groundwater and environmental protection from pollution by contaminants in municipal solid waste (MSW). Many US states are in the process of updating their municipal solid waste landfilling regulations to comply with the US EPA Subtitle D requirements. In 1991 the US EPA formally adopted the "dry tomb" landfilling approach as national policy in which there is an attempt to isolate MSW in a plastic sheeting and soil-lined "tomb" where attempts are made to prevent moisture from entering the landfill and generating leachate and, for any leachate that is generated, is to be collected and removed from the landfill in a leachate removal and collection system. After October 9, 1993 all MSW landfills will have to have a single composite liner, a leachate collection and removal system, a groundwater quality-based liner leakage detection system, a low permeability cover installed at the time of closure, a landfill gas collection and management system, and a 30-year post-closure care period in which funds are available to cover leachate collection and removal, groundwater monitoring and minimal cover maintenance.

### Expected Performance of Subtitle D Landfills

A review of the expected performance of the minimum prescriptive standards set forth in Subtitle D shows that a single composite liner for a landfill will not prevent leachate contamination of groundwaters for as long as MSW components represent a threat. As discussed by Jones-Lee and Lee (1993), there are a wide variety of organic and inorganic chemicals in conventional MSW that can dissolve in water to create MSW leachate (garbage juice) that will be a threat to groundwater quality forever.

A composite liner composed of plastic sheeting overlying two feet of clay of the type allowed by the US EPA Subtitle D may, with poor quality construction, leak leachate at a significant rate shortly after being placed in operation. This means that part of the leachate that is generated in the landfill will pass through the liner system, and therefore will not be collected in the leachate collection and removal system. Lee and Jones (1991) and Lee and Jones-Lee (1993a) reviewed the information available on the performance of landfill liners of the type being used today to prevent MSW leachate from passing through the liner and polluting groundwater. They point out that even if high-quality construction is achieved at the time that the liner is constructed, there may be significant problems with liner rupture when the landfill is placed in operation due to

---

<sup>1</sup> Report of G. Fred Lee & Associates, El Macero, CA

Copies of many of the authors' cited papers and reports, as well as additional and more reports and publications on these and related topics are available on the authors' website at <https://www.gfredlee.com>

inadequate separation between the liner components and the lower layer of the wastes in which waste components can puncture holes in the liner. Further, over time the expected performance of the plastic sheeting (flexible membrane liner) and the compacted soil layer will deteriorate from that achieved at the time of construction, allowing increased amounts of leachate to pass through the liner rather than being collected in the leachate collection and removal system above the liner. The US EPA Solid Waste Disposal Criteria (August 30, 1988a) stated:

*"First, even the best liner and leachate collection system will ultimately fail due to natural deterioration, and recent improvements in MSWLF (municipal solid waste landfill) containment technologies suggest that releases may be delayed by many decades at some landfills."*

The US EPA Criteria for Municipal Solid Waste Landfills (July 1988b) stated:

*"Once the unit is closed, the bottom layer of the landfill will deteriorate over time and, consequently, will not prevent leachate transport out of the unit."*

Lee and Jones-Lee (1993a,b) have reviewed the needed and expected performance of landfill covers for lined "dry tomb" landfills of the type allowed under Subtitle D. These low permeability covers can reduce the rate of moisture entering the landfill at the time of landfill closure and cover construction, but over time the low permeability properties of these covers will deteriorate to the point where they are largely ineffective in preventing moisture from entering the landfill and generating leachate.

As discussed by Lee and Jones-Lee (1992)(1993c), the post-closure care funding of cover maintenance that is typically proposed to be made available at the time of landfill closure will not be adequate to maintain the cover's low permeability properties during the 30-year post-closure period, much less for as long as the wastes represent a threat, i.e. ad infinitum.

The groundwater monitoring approach adopted by the US EPA involving the use of vertical monitoring wells spaced from hundreds to a thousand or so feet apart located at no more than 150 meters from the downgradient edge of the waste management unit have a very low probability of detecting leachate-polluted groundwater before widespread pollution occurs. The US EPA's Subtitle D groundwater monitoring system is designed for unlined landfills which would leak leachate essentially at all locations under the landfill. Lined landfills will leak from small areas and produce fingers of leachate- contaminated groundwater of no more than a few meters wide at the point of groundwater monitoring. The groundwater monitoring wells used have zones of capture of groundwater around the well of about one foot. Therefore, as discussed by Lee and Jones-Lee (1993d), the US EPA's approach towards monitoring MSW liner leakage is a flawed technology that will not protect groundwater from pollution by landfill leachate. Lee and Jones-Lee (1993d) have discussed the inadequacies of the US EPA Subtitle D groundwater monitoring approach in protecting groundwater from MSW leachate pollution before widespread groundwater pollution occurs.

It is therefore evident that the US EPA Subtitle D minimum prescriptive landfill requirements will not be protective of groundwater quality from MSW leachate pollution for as long as the

wastes represent a threat. At best, Subtitle D landfills will postpone groundwater pollution by a few decades. It is reasonable to ask why did the US EPA not adopt more appropriate MSW landfill minimum liner prescriptive standards. Basically, the reason was a perceived "excessive" cost. During the late 1980s and during 1991-1992 significant confrontations were experienced between those within the US EPA who wanted to develop more protective approaches for MSW management than those proposed in August 1988. However, the Bush administration Office of Manpower and Budget (OMB) blocked the development of the more protective MSW landfill liner design. It was claimed that OMB representatives asserted that the more protective MSW landfill requirements were not cost-effective in preventing new cancer cases in the US. It was reported that OMB opposed any groundwater monitoring at MSW landfills because of this low cost-effectiveness.

This situation typifies the problems that exist in the US with RCRA where the focus of solid waste management is the prevention of cancer in drinking water rather than groundwater quality protection. Jones-Lee and Lee (1993) discuss the highly inappropriate approach used by the US EPA in implementing RCRA where RCRA will allow groundwater pollution by conventional and non-conventional pollutants which are not suspected carcinogens. A groundwater could be rendered totally unusable for domestic purposes by MSW leachate, yet under RCRA requirements, the pollution of the groundwater can not be prevented.

#### Cost of MSW Management Under Subtitle D

The US EPA (1991) presented extensive discussions on the cost of MSW management where the agency claims that the implementation of the Subtitle D requirements would by "best estimate scenario" cost the average household in the US from \$2 to \$4/year above what they have been paying for classical sanitary landfilling of the waste in an unlined landfill where no groundwater monitoring is practiced. If it is assumed that each person generates about one ton of municipal solid waste per year and the average household has three people, this translates to a 0.3 cent/person/day increase in the cost of MSW management under Subtitle D requirements. Typically today the tipping fees for municipal solid waste management average about \$20 to \$50/ton or \$20 to \$50/year/person. If the tipping fees are \$36.50/ton, the cost for classical sanitary landfilling of MSW is 10 cents/person/day. This means that the implementation of the Subtitle D requirements represents an additional 0.3 cent/person/day when the disposal fees cost on the order of 10 cents/person/day. It is the authors' experience that an additional 12-15 cents/person/day is charged for garbage collection and transport to the landfill or solid waste management unit. Clearly the implementation of the US EPA Subtitle D requirements involving a single composite liner, a groundwater quality based liner leakage detection system, the installation of a low permeability cover at the time of landfill closure, provisions for control of landfill gas emissions, and 30 years of minimal post-closure care cover maintenance and groundwater monitoring did not represent a significant increase in the cost of MSW management from what the public has been paying for MSW disposal in a classical, unlined sanitary landfill.

There are several aspects of the US EPA's Subtitle D cost figures which cause them to be significantly low compared to the real cost of implementing Subtitle D. The US EPA only included 30 years of minimal post-closure cover maintenance and groundwater monitoring. No funds are set aside for post-closure care activities beyond 30 years and for the inevitable

groundwater pollution that will almost certainly occur at every Subtitle D landfill. The true cost of implementing Subtitle D requirements will be far greater than 0.3 cent/person/day estimated by the US EPA.

In a series of June 1993 hearings for the state of California Water Resources Control Board representatives of various political jurisdictions claimed that the landfill tipping fees would have to increase from \$20 to \$30/ton to \$70 to \$80/ton in order to implement Subtitle D requirements at their classical sanitary landfill. According to the information provided the increase in cost would not be 0.3 cent/person/day but would be on the order of 3 cents/person/day, i.e. a factor of 10 higher than that estimated by the US EPA. This difference is not related to funding more appropriate provisions for landfill cover maintenance or maintenance beyond the 30-year post-closure care period mandated by Subtitle D. The differences are due to a difference between what consulting firms indicate will be the increased cost in the liner system, groundwater monitoring, landfill closure, etc. compared to the costs projected by the US EPA. At this point the authors are not in a position to comment on whether the US EPA values are a factor of 10 low compared to the amount that various political jurisdictions consulting firms have estimated would be the costs in implementing Subtitle D requirements for their landfills. It is important to note that one political jurisdiction in California which had a number of very small landfills that managed waste for a sparsely populated rural area claimed that the cost to implement Subtitle D for such landfills was on the order of 15 cents/person/day above what had been spent in the past for an unlined landfills.

#### Cost of Groundwater Quality Protection

As discussed above, at best Subtitle D landfills will only postpone groundwater pollution; they will not necessarily prevent it. Lee and Jones-Lee (1993f) have discussed the approach they feel states should follow in implementing Subtitle D requirements where in addition to the US EPA required single composite liner, another composite liner and leak detection layer would be constructed below the Subtitle D single composite liner. The lower composite liner and leak detection layer would constitute a full landfill area pan lysimeter leak detection system. If it is assumed that the cost of this additional composite liner and leak detection system is \$5/ft<sup>2</sup>, it is estimated that the additional cost to the average waste contributor to a landfill would be on the order of 3 cents/person/day. This assumes a "standard" geometry for the landfill and the amount of liner that each person who contributes to the landfill can claim as their own. While these costs would vary depending on landfill design, size, filling rate, etc., the cost/person/day will not be significantly different from those estimated.

Lee and Jones-Lee (1993f) indicate that on the order of \$2/ft<sup>2</sup> would need to be spent in developing a landfill cover that has in it a potentially highly reliable leak detection system. At \$2/ft<sup>2</sup> it is estimated that the person/day cost for the cover of an "average" landfill is about 2 cents/person/day. Therefore, for about 5 cents/person/day more than the minimum Subtitle D prescriptive standards it would be possible to construct a double composite lined landfill with a low permeability cover that incorporates a double FML with leak detection between the two FML's in the cover. It is important to emphasize that these costs are above the Subtitle D requirements as well as the classical sanitary landfill tipping fees and the cost of solid waste collection and transportation. The total cost for a double composite lined "dry tomb" landfill

would likely be on the order of 30 cents/person/day in which only about 5 cents/person/day is associated with the increased cost of the additional groundwater quality protection associated with the double composite liner - liner leak detection system and a leak detection system in the landfill cover.

A significant part of the post-closure care costs associated with MSW "dry tomb" landfills is the cost of cover maintenance. Today landfill applicants are being required to set aside a very small amount of funds (typically a few thousand dollars/year) for landfill cover maintenance during the 30-year post-closure care period. As discussed by Lee and Jones-Lee (1993c) "dry tomb" landfills of the type developed under Subtitle D will require post-closure care cover maintenance forever, not just for 30 years. Further, they point out that the typical approach that is proposed by landfill applicants today of using a bulldozer or a shovel to fill any major cracks in the cover that are visible to someone walking across the surface will not address the significant problems that will occur in the low permeability layer of a "dry tomb" landfill cover. These covers will have several feet of material, such as a drainage layer and topsoil, above the low permeability layer. The desiccation cracks, cracks that develop around gas vents, differential settling caused cracks, etc. that will occur in the low permeability layer of "dry tomb" landfills will not be visible to those who walk across the surface of the landfill. The net result will be that rather than "kicking" some dirt into the cracks that are visible in the topsoil layer as is now typically proposed by landfill applicants for post-closure care cover maintenance, it will be necessary to periodically replace the cover, or at least large sections of it. This periodic replacement will have to take place forever. The authors estimate that rather than spend a few thousand dollars/year in landfill cover maintenance, it will likely require \$1 million/year or more to properly maintain a landfill cover for "dry tomb" landfills of the type that can be permitted under Subtitle D.

As discussed by Lee and Jones-Lee (1993f) the burial of MSW in "dry tomb" landfills, including those that practice leachate recycle as a method of leachate disposal, should be looked upon as temporary storage of municipal solid waste. Eventually the wastes will likely have to be exhumed, treated, with the treated residues deposited in an appropriate landfill. This exhumation (landfill mining) can be readily accomplished today at costs of \$5 to \$15/ton (see Lee and Jones 1990). If the wastes are not exhumed, eventually when cover maintenance becomes inadequate, it will be necessary to use large amounts of funds to clean up contaminated groundwaters associated with even double composite lined landfill failure. This means that a large amount of contingency funds must be set aside to either exhume and treat the wastes or to clean up contaminated groundwaters.

#### Funding Long-term Postclosure Care For "Dry Tomb" Landfills

It is evident that large amounts of post-closure care funds will be needed for "dry tomb" landfills, including those that practice leachate recycle if groundwater pollution is to be prevented. The authors believe that the best way to generate these funds is through an increase in the garbage disposal fees paid by those who contribute waste to the landfill. It has been found that for a moderate sized landfill of 100 acres or so in area that is active for about 20 years, that if each person in the half million people who contribute waste to that landfill would contribute 1 cent/person/day to a dedicated trust fund, that a sufficient trust fund would be developed that

would generate \$1 million/year interest for landfill cover maintenance, etc. and there would be a contingency fund of about \$250 million for waste exhumation. This would be a perpetual fund which assumes that the rate of interest generated would be twice that of inflation. While each landfill would have to develop its own post-closure care funding trust fund estimate of funding needs, they would not likely be significantly different than 1 cent or so/person/day.

#### Alternative Solid Waste Management Landfilling Approaches

Lee and Jones-Lee (1993e) have discussed an alternative approach to the "dry tomb" landfill, where utilizing a wet cell fermentation and leaching approach, it is possible to produce through in situ treatment of the wastes, waste residues that will not be longterm threats to groundwater quality. They recommend a combination of landfill leachate recycle followed by clean water washing of the shredded MSW to convert those components of the waste that are fermentable to produce methane and carbon dioxide. The fermentation step is to be followed by clean water washing of the garbage to leach those components that could be present in leachate that could lead to groundwater pollution when the landfill liner system failed to prevent significant leachate migration through it.

The costs of the liner system for the wet cell fermentation leaching approach is about the same as for a double composite "dry tomb" landfill. A considerably less expensive cover can be placed on a wet cell landfill since there would be no need to try to maintain a low permeability layer in the cover. Further the cost of the ad infinitum very expensive cover maintenance would not occur with the wet cell fermentation leaching landfill. There would be a significant increase in the cost of leachate treatment in the wet cell approach, however leachate generation would be under control conditions during the period when the liner system would still be expected to be effective in collecting leachate. The leachate treatment cost under these conditions would be far less than the cost associated with the attempts to clean up contaminated groundwaters that will likely occur from Subtitle D landfills.

#### Conclusion

In order to develop a significantly more reliable MSW management in a "dry tomb" landfill on the order of 9 to 10 cents/person/day above that being paid for the Subtitle D landfill will be needed. When considered in light of the value of groundwater resources to future generations and the amount of disposable income that most individuals have for the purchase of nonessential items, it is clear that the US population can readily afford to develop appropriately designed, constructed, operated and closed landfills that have adequate post-closure care provisions to protect groundwaters from leachate pollution. It is also clear that those who claim that it is too expensive to implement proper Subtitle D landfilling requirements have not reliably presented the true cost. It is possible to readily implement Subtitle D requirements, and most importantly, go far beyond the minimum Subtitle D requirements without "breaking the bank." Clearly future generations are entitled to have this generation spend 10 cents or so/day more for their garbage disposal in order to develop a far more reliable approach for municipal solid waste management than will be achieved by the US EPA's minimum prescriptive standards set forth in the Subtitle D regulations.

## References

- Jones-Lee, A., and Lee, G. F., "Groundwater Pollution by Municipal Landfills: Leachate Composition, Detection and Water Quality Significance," Proceedings of Sardinia '93 IV International Landfill Symposium, Sardinia, Italy, October (1993).
- Lee, G. F., and Jones, R. A., "Use of Landfill Mining in Solid Waste Management," Proc. Water Quality Management of Landfills, Water Pollution Control Federation, Chicago, IL, July (1990).
- Lee, G. F., and Jones, R. A., "Landfills and Ground-water Quality," guest editorial, J. Ground Water 29:482-486 (1991).
- Lee, G. F., and Jones-Lee, A., "Municipal Landfill Post-Closure Care Funding: The 30-Year Post-Closure Care Myth," report, G. Fred Lee & Associates, El Macero, CA (1992).
- Lee, G. F., and Jones, R. A., "Municipal Solid Waste Management in Lined, 'Dry Tomb' Landfills: A Technologically Flawed Approach for Protection of Groundwater Quality," short course notes for American Society of Civil Engineers short course, New York City and Atlanta, GA, January (1993a).
- Lee, G. F., and Jones-Lee, A., "Excerpts from 'Municipal Solid Waste Management: Long-Term Public Health and Environmental Protection,'" Report of G. Fred Lee & Associates, El Macero, CA and short course notes, Landfills and Groundwater Quality short course, University of California, Riverside Extension, Riverside, CA, May (1993b).
- Lee, G. F., and Jones-Lee, A., "Landfill Post-Closure Care: Can Owners Guarantee the Money Will Be There?," Solid Waste and Power, 7(4):35-39 (1993c).
- Lee, G. F., and Jones-Lee, A., "Groundwater Quality Monitoring at Lined Landfills: Adequacy of Subtitle D Approaches," report G. Fred Lee & Associates, El Macero, CA and short course notes, Landfills and Groundwater Quality short course, University of California, Riverside Extension, Riverside, CA, June (1993d).
- Lee, G. F., and Jones-Lee, A., "Landfills and Groundwater Pollution Issues: 'Dry Tomb' vs F/L Wet-Cell Landfills," Proceedings of Sardinia '93 IV International Landfill Symposium, Sardinia, Italy, October (1993e).
- Lee, G. F., and Jones-Lee, A., "Revisions of State MSW Landfill Regulations: Issues in Protecting Groundwater Quality," Environmental Management Review, Government Institutes, Rockville, MD, August (1993f).
- US EPA, "Solid Waste Disposal Facility Criteria; Proposed Rule," Federal Register 53(168):33314-33422, 40 CFR Parts 257 and 258, US EPA, Washington, D.C., August 30 (1988a).

US EPA, "Criteria for Municipal Solid Waste Landfills," US EPA Washington, D.C., July (1988b).

US EPA, "Solid Waste Disposal Facility Criteria; Final Rule," 40 CFR Parts 257 and 258, Federal Register 56(196):50978-51119, October 9 (1991).