Comments on "'**Assessment of the Performance of Engineered Waste Containment Barriers'**

Developed by Committee to Assess the Performance of Engineered Barriers
National Research Council of the National Academies
Washington, DC (2007)"

Comments submitted by
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September 2009

The ability of municipal solid waste (MSW) landfills' engineered waste containment systems to prevent pollution of groundwater by chemicals that leach from such waste, for as long as the wastes can generate leachate, is of great concern to those who use, or otherwise desire to protect the quality of groundwater near landfills. Significant technical and conceptual deficiencies and limitations of engineered systems that continue to be allowed for MSW landfills under US EPA Subtitle D regulations have been discussed in the literature over the past several decades. A thorough review of these technical issues by the National Research Council (NRC) of the National Academies was seen as an important step toward highlighting these deficiencies and improving the protection provided for groundwater from landfill leachate. Unfortunately, the "Assessment of the Performance of Engineered Waste Containment Barriers" report developed from the NRC review did not provide a critical evaluation of the information available on the foreseeable or actual performance of minimum-design Subtitle D landfills – today's so-called "modern" landfills – in preventing pollution of groundwater by landfill leachate for as long as the wastes in those landfills are a threat to generate leachate.

Background

The senior author (Dr. G. Fred Lee) has been involved in various aspects of impacts of landfilled waste on water quality and the efficacy and long-term reliability of engineered landfill systems to prevent groundwater pollution, since the mid-1970s. At that time, he was asked by the US EPA Groundwater Research Branch to investigate the ability of landfill liner systems, such as compacted clay, to prevent landfill leachate from leaving a landfill through the liner containment system and entering the underlying groundwaters and thereby impairing their use for domestic and other purposes. Since the early 1980s, Dr. Lee has been involved in advising state regulatory agencies, local governmental agencies, and public and private groups on potential environmental quality problems that can arise from the municipal and industrial solid waste landfilling practices.

In the early 1980s, at the urging of environmental groups, the US Congress mandated that a "dry tomb" approach be followed for "managing" wastes in landfills. The foundation of that approach is to keep landfilled wastes dry and isolated from water. When moisture comes in contact with wastes, leachate is formed; that leachate contains waste-derived constituents and can carry those constituents to groundwater. In principle, as long as the wastes are kept dry in a "dry tomb" they will not generate leachate that can pollute groundwater. Thus, the key to developing a true dry tomb landfill is the placement and maintenance of landfill liner and cover systems that can and

will, in fact, keep the wastes dry, forever, because once moisture enters the landfill through areas of deterioration or breach, years, decades, or hundreds of years after closure, leachate will be generated. It is only a matter of time before this occurs and the problems become collecting, removing, and treating all of the leachate before it contaminates groundwater, for as long as it takes to leach all of the wastes in the landfill.

When the US EPA proposed RCRA (Resource Conservation and Recovery Act) Subtitle D landfilling regulations prescribing "dry tomb" landfilling in the late 1980s, it was recognized that even the best of the landfill liner systems being advanced would eventually fail to prevent groundwater pollution by MSW leachate. Indeed, as part of adopting the RCRA Subtitle D regulations, the US EPA stated in the draft regulations (US EPA, 1988a),

> *"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 (1988b) Criteria for Municipal Solid Waste Landfills 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."*

Since the early 1990s when the US EPA adopted Subtitle D landfill regulations Drs. Lee and Jones-Lee have reviewed and continued to evaluate the ability of minimum-design US EPA-allowed Subtitle D (MSW) landfills and Subtitle C (hazardous waste) landfills to protect groundwater quality. They developed a series of reviews of current information on the ability of compacted-clay and plastic-sheeting liners of the type being prescribed in those regulations and used in landfills, to prevent groundwater pollution by landfill leachate for as long as the wastes in the landfill will be a threat, and compiled much of that information. Their papers and reports on these issues are available from their website, www.gfredlee.com, in the Landfills-Groundwater section at http://www.gfredlee.com/plandfil2.htm.

In the early 1990s, out of concern about the fundamentally flawed technology and approach embraced by Subtitle D regulations that preclude reliance upon the regulations to prevent groundwater pollution by MSW landfill leachate that penetrates the liners, or protect groundwater resources, public health, and environmental quality from landfilled wastes, Lee and Jones-Lee wrote a comprehensive review of the literature and their findings on these issues entitled, "Flawed Technology of Subtitle D Landfilling of Municipal Solid Waste." They have subsequently periodically updated that review to incorporate additional issues and new findings. The most current version of their "Flawed Technology" review is:

> Lee, G. F., and Jones-Lee, A., "Flawed Technology of Subtitle D Landfilling of Municipal Solid Waste," Report of G. Fred Lee & Associates, El Macero, CA, December (2004). Updated September (2009).
> http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf

In their "Flawed Technology" review, Lee and Jones-Lee (2009) discussed the political situation in the early 1990s that caused the US EPA to adopt those MSW landfilling regulations despite the recognition that they would not ensure protection of public health, groundwater resources, or the

environment for as long as the MSW would be a threat. They characterized the landfilling of solid wastes in a minimum-design Subtitle D landfill as a "flawed technology" for protecting groundwater for as long as the wastes in the "dry tomb" are a threat, because the plastic-sheeting and compacted clay liners will inevitably experience deterioration and eventually fail to prevent passage of leachate through them. As discussed in the literature cited in the Lee and Jones-Lee (2009) review, the inability of plastic-sheeting and compacted clay liners to protect groundwaters from pollution by landfill leachate for as long as the wastes will be a threat is well-understood in the literature. Furthermore, the groundwater monitoring approaches prescribed and allowed do not provide a technically sound, reliable back-up plan to detect the inevitable failure of the cover and liner systems to keep the wastes dry.

Specific Comments on NRC Review

With support from the US EPA, US Department of Energy (DOE), National Science Foundation, and the US Nuclear Regulatory Commission, the National Resource Council (NRC) of the National Academies of Science and Engineering established a Committee to Assess the Performance of Engineered Barriers to "assess *the effectiveness of surface and subsurface engineered barriers over the long term*." The Committee published its findings in 2007 (NRC, 2007). The technical foundation and reliability of that Assessment are of significant importance as it is cited as support for claims that today's "modern" landfills are protective of public health, groundwater quality, and the environment. For example, the Solid Waste Association of North America (SWANA) published an opinion piece by O'Brien (2009) entitled, "SWANA" in its journal, MSW Management, that quoted the NRC Assessment:

> "*In summary, as concluded by one major recent study: 'Based on as much as 20 years of observations, the committee concluded that most engineered waste-containment barrier systems that have been designed, constructed, operated, and maintained in accordance with current statutory regulations and requirements have thus far provided environmental protection at or above specified levels.' (National Research Council. 2007. Assessment of the Performance of Engineered Waste Containment Barriers. Washington, DC: National Academies Press. p.1.)"*

However, as discussed below, the NRC committee "Assessment" was not based on a critical evaluation of the information available on the actual and realistically expected performance of minimum design Subtitle D landfills in preventing groundwater pollution by landfill leachate. The NRC committee finding quoted by O'Brien is misleading at best.

The key to reliably evaluating the performance of a Subtitle D landfill is the ability to detect failure of the landfill liner system using the existing monitoring systems. As discussed by Lee and Jones-Lee (2009) from the earliest versions of their review, the currently allowed containment-failure-detection approach does not have a sound or realistic technical foundation and is unreliable for this purpose. It necessitates the pollution of groundwater with leachate and then relies on the detection of the first instance of that pollution by groundwater monitoring wells located at the point of compliance for groundwater monitoring. The point of compliance must be on the landfill-owner property no more than 150 meters from the down-gradient edge of the landfill. With the monitoring systems prescribed and allowed, it is unlikely that incipient groundwater pollution will be detected at the point of compliance monitoring wells. Groundwater monitoring wells at the point of compliance are commonly placed hundreds of feet apart; each well is capable of assessing

the character of the groundwater within about one foot of the well which is the zone of capture of each well (presuming the typical evacuation of three borehole volumes of water). Since, as discussed by Lee and Jones-Lee (2009) (see also further discussion below), incipient leakage from lined landfills can be expected to move down-groundwater gradient in finger-like plumes rather than as a broad front, the typical point-of-compliance monitoring leaves a hundred to several hundred feet between each well through which finger plumes of leachate-polluted groundwater can pass undetected. Such monitoring can, therefore, not be relied upon for the assessment of whether or not a landfill containment system is performing as intended and preventing groundwater pollution. These problems in making a reliable assessment of the performance of engineered waste containment barriers should have been discussed in the NRC Assessment Chapter 3 "Monitoring of Barrier Performance," but was not.

As noted by Lee and Jones-Lee (2009), Bumb et al. (1988) and Glass et al. (1988) discussed that the initial leaking of leachate from lined landfills will occur from point sources in the liners, rather than uniformly from the landfill bottom as it may be expected to occur from unlined landfills. The initial leaks will occur from holes, rips, tears, and points of deterioration in the plastic sheeting liner. Cherry (1990) reported that the lateral spread of a plume of leachate-contaminated groundwater is limited. Therefore, incipient leakage from a lined landfill can be expected to move down-groundwater gradient as narrow fingers of pollution. In a study of the lateral dispersion of leachate plumes from lined landfills, Smyth (1991) of the Waterloo Centre for Groundwater Research, University of Waterloo, reported that a 0.6-m (2-ft)-wide point-source tracer spread laterally to a width of only about 2 m (6 ft) after traveling 65 m (213 ft) in a sand aquifer system. Thus, both in expectation and field experience, it is clear that leakage from point sources such as holes in liners can move downgradient as narrow "fingers" of leachate rather than in the traditionally assumed fan-shaped plumes. This means that conventional wells used for monitoring of groundwater pollution caused by lined landfills must be placed close enough together at the point of compliance to detect narrow fingers of leachate, if the monitoring program is to comply with Subtitle D requirements for the detection of incipient groundwater pollution from waste management units at the point of compliance when it first reaches this point.

On May 14, 2008 the CA Department of Toxic Substances Control (DTSC) and the US EPA Region 9 held a Remediation Technology Symposium (the agenda for which is available at http://www.dtsc.ca.gov/HazardousWaste/upload/Remediation_Technology_Symposium_Agenda.pdf). At that symposium Einarson (2008) made a presentation entitled, "Site Characterization and Monitoring in the New Millennium," devoted to problems with conventional groundwater monitoring approaches used at hazardous chemical sites. He discussed the fact that, as Cherry (1990) had discussed nearly two decades ago, groundwater pollution plumes emanating from plastic-sheeting-lined landfills tend to have limited lateral spread. Because of this characteristic, groundwater monitoring wells spaced hundreds of feet apart at the point of compliance for groundwater monitoring have a low probability of detecting groundwater polluted by landfill leachate when it first reaches the point of compliance for groundwater monitoring.

Even if the groundwater monitoring approach were reliable, the NRC (2007) conclusion quoted above is misleading in its presumption that its basis in a nearly 20-year period of observation supports its credibility. Subtitle D landfill liners have been in use only since the early 1990s, for fewer than 20 years. As discussed by Lee and Jones-Lee (2009), simple calculations show that it

would take about 25 years for leachate that passes through a hole in the plastic sheeting liner under 1 ft of leachate head, to penetrate a 2-ft compacted clay liner. Thus, it could be expected that leachate that escaped through a hole in the plastic sheeting liner 20 years ago would not yet have breached the compacted clay layer, and may not reach the point of compliance for a number of years to come. Contrary to the implication that a 20-year history engenders faith in the protection provided by the engineered containment systems, proper examination of the nature of the systems and the behavior of landfilled materials should make it clear that it is, in fact, too early to detect the failure of a landfill liner system that may have occurred during the past two decades. This defect in analysis, combined with the aforementioned unreliability of the typical groundwater monitoring system for detecting failure of the landfill liner system for minimum design Subtitle D landfills, means that most likely, landfill liner failure will not be recognized until offsite water supply wells have been contaminated.

The NRC "Assessment" did not address these technical issues that are of paramount importance in controlling, and assessing, the protection afforded by engineered barriers in MSW landfills. Without reliable consideration of these factors, the NRC committee conclusion, "*that most engineered waste-containment barrier systems that have been designed, constructed, operated, and maintained in accordance with current statutory regulations and requirements have thus far provided environmental protection at or above specified levels."* is not justified. The fact is that the actual performance of Subtitle D landfill liner systems in isolating MSW and its leachate and protecting groundwater quality during the 20 or so years in which they have been used is not known at this time because the monitoring systems allowed are unreliable for detecting initial failure of the liner systems. It is unfortunate that critical consideration of the substantial technical literature that addresses these issues was not reflected in the NRC committee "Assessment."

The NRC (2007) committee report placed considerable reliance on reported results of the New York State Department of Conservation (NYDEC) which states,
"*Based on groundwater monitoring data from onsite monitoring wells, NYDEC did not find a single instance of an adverse impact to groundwater that could be attributed to leakage through a containment system at any one of these facilities."* In its Assessment, the NRC committee should have critically considered that finding of the NYDEC in light of the potential reliability of the typical monitoring well array for detecting the initial failure of the landfill liner to prevent leakage of leachate through the liner to the underlying groundwater system. That it did not do so, and, indeed, incorporated that finding into its own Assessment, is a serious technical deficiency of the Assessment.

The NRC committee correctly concluded that there could readily be long-term problems in the ability of engineered barriers to prevent groundwater pollution by landfill leachate. The SWANA/Obrien June 2009 review presented a similar conclusion. Therefore, there is general agreement that the Subtitle D landfilling is a "Flawed Technology" for the protection of groundwater from pollution by landfill leachate for as long as the wastes in such landfills are a threat to generate leachate that can pollute groundwaters.

Lee and Jones-Lee (2009) have discussed how "dry tomb"-type landfill can be developed to afford greater protection of groundwaters from pollution associated with the eventual failure of the plastic sheeting and compacted clay lined landfills. Basically, it involves using a double-composite liner

that incorporates a leak-detection system between the two composite liners. When leachate is detected in that layer, action would need to be taken to prevent water from entering the landfill through the cover. Further, it would require the availability of adequate postclosure funding and responsibility to maintain the cover, operate the leachate collection system and leak detection system, and the ability to effect repairs in all systems, for as long as the wastes in the landfill can generate leachate when contacted by water. Several states including Pennsylvania and California have developed postclosure funding requirements that should support this level of postclosure funding.

Literature Cited

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

Qualification to Provide Comments

Summary Resume – G. Fred Lee, PhD, PE, BCEE (American Academy of Environmental Engineers Board Certified Environmental Engineer)

Dr. G. Fred Lee is President of G. Fred Lee and Associates, of which Drs. G. Fred Lee and Anne Jones-Lee are the principals. They specialize in addressing advanced technical aspects of water supply water quality, water and wastewater treatment, water pollution control, and solid and hazardous waste impact evaluation and management. Dr. Lee earned a B.A. degree from San Jose State College, a Master of Science in Public Health degree from the University of North Carolina focusing on water quality in 1957, and a PhD degree from Harvard University in Environmental Engineering in 1960. For the ensuing 30 years, Dr. Lee held graduate faculty positions at several US universities; he taught graduate-level environmental engineering and environmental science courses, he conducted over $5-million in research, and published more than 475 papers and reports on that work. He was also active as a part-time consultant during his university teaching and research career. In 1989, Dr. Lee retired from university teaching and research. During the past 20 years, he has maintained a full-time consulting practice and developed another 600 papers and reports on his work and findings. One of the areas in which he specializes is the development of technically valid water quality investigations and cost-effective pollutant control programs to protect the designated beneficial uses of waterbodies without significant unnecessary expenditures for constituent control. Drs. G. Fred Lee and Anne Jones-Lee have established a website, www.gfredlee.com, on which they list and make available their recent papers and reports. Additional information on Dr. G. Fred Lee's professional activities is available upon request.

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EDUCATION

Ph.D.	Environmental Engineering & Environmental Science, Harvard University, Cambridge, MA, 1960
M.S.P.H.	Environmental Science-Environmental Chemistry, School of Public Health, University of North Carolina, Chapel Hill, NC, 1957
B.A.	Environmental Health Science, San Jose State University, San Jose, CA, 1955

ACADEMIC AND PROFESSIONAL EXPERIENCE
Current Position: Consultant; President, G. Fred Lee & Associates 1989 – present

Previous Positions:

- Distinguished Professor, Civil and Env. Engr, New Jersey Inst Technol, Newark, NJ 1984-89
- Senior Consulting Engineer, EBASCO-Envirosphere, Lyndhurst, NJ, (part-time) 1988-89
- Coordinator, Estuarine and Marine Water Quality Management Program, NJ Marine Sciences Consortium Sea Grant Program 1986-1988

- Director, Site Assessment and Remedial Action Division, Center for Research in Hazardous & Toxic Substances, NJIT et al., Newark, NJ 1984-1987
- Professor, Environmental Engineering, Colorado State University 1978-1982
- Professor, Environmental Engineering & Sciences; Director, Center for Environmental Studies, University of Texas at Dallas 1973-1978
- Professor of Water Chemistry, Department of Civil & Environmental Engineering, University of Wisconsin-Madison 1961-1973

Registered Professional Engineer, State of Texas, Registration No. 39906

American Academy of Environmental Engineers Board Certified Environmental Engineer Certificate No. 0701. Dr. Lee serves as the AAEE Chief Examiner for Board Certification for Northern California

PUBLICATIONS & AREAS OF ACTIVITY: Published over 1100 professional papers, chapters in books, professional reports, and similar materials. The topics covered include:

- sources, significance, fate and the development of control programs for chemicals in aquatic and terrestrial systems;
- analytical methods for chemical contaminants in fresh and marine waters;
- landfills and groundwater quality protection issues;
- impact of landfills on public health and environment;
- environmental impact & management of wastewater discharges including municipal, mining, electric generating station, domestic & industrial wastes, paper & steel mill, refinery;
- stormwater runoff water quality evaluation;
- stormwater BMP development for urban areas, highways and agricultural areas;
- eutrophication-excessive fertilization – causes and control;
- impact of land disposal municipal & industrial wastes on groundwater & surface water quality;
- environmental impact of dredging and dredged material disposal;
- water quality modeling;
- hazard assessment for new and existing chemicals;
- water quality and sediment criteria and standards;
- water supply water quality;
- assessment of actual impact of chemical contaminants on water quality.

LECTURES:

- Presented over 860 lectures at professional society meetings, universities, and to professional and public groups.

GRANTS AND AWARDS:

- Principal investigator for over $8 million of contract and grant research in the water quality and solid and hazardous waste management fields.

KEY PROFESSIONAL SOCIETY ACTIVITIES:

- Member: American Chemical Society, American Fisheries Society, American Society of Civil Engineers, American Water Works Association, Society of Environmental Toxicology and Chemistry, Water Environment Federation
- Reviewer, Natl. Academy of Sciences & Engineering Panel on Water Quality Criteria, 1971
- Member, Water Pollution Control Federation Sediment Water Quality Task Force, 1992-94; Water Quality Criteria Task Force, 1993
- Reviewer, American Fisheries Society-US EPA Water Quality Criteria, 1977
- Chairman, Water Pollution Control Federation Standard Methods Subcommittee, "Interpretation and Application of Bioassays," 1979-1988
- Chief Examiner, American Academy of Environmental Engineers, North Central California, 1991 – 2009
- Led development of California Groundwater Resources Association, 1992-1993
- Member, California EPA Comparative Risk Project Human Health Committee, 1993-1994
- Member, WEF Urban Stormwater Quality Task Force, 1994-1997
- US EPA TAG Advisor for the UCD/DOE LEHR Superfund site, 1995 – present
- US EPA TAG Advisor for the Lava Cap Mine Superfund site, 2001-2004
- PI for $2 million/yr CALFED research project on the San Joaquin River DO TMDL Program
- Member, Editorial Board, Journal Stormwater, 2001 – present
- Member, Editorial Board, Journal Remediation, 1999 – present
- Member, CVRWQCB Ag Waiver Technical Issues Committee, 2004 – present
- Served various times, as member editorial board of several journals including Environ. Science & Technol., Journ. Society for Environmental Toxicology & Chemistry, Journ. Ground Water, Journ. Stormwater

HONORS AND AWARDS:

- Elected member of the following: Sigma Xi; Delta Omega, Honorary Public Health Scholastic Society; Phi Lambda Upsilon, Honorary Chemistry Scholastic Society; Diplomate, American Academy of Environmental Engineers
- Tied for first place for best paper presented at the Fifth Annual ASTM Aquatic Toxicology meeting in Philadelphia, PA, October, 1980
- Charles B. Dudley Award - American Society for Testing and Materials award for contribution to Hazardous Solid Waste Testing, "Application of Site-Specific Hazard Assessment Testing to Solid Wastes," published 1984
- Journal AWWA paper selected by the Resources Division of the AWWA as the best paper published in the Journal during the year, 1984
- Received Certificate of Appreciation from the Corps of Engineers for work on the Dredged Material Research Program, 1978
- Tribute of Appreciation - Groundwater Resources Association of California, September 2000.
- Certificate of Appreciation – American Academy of Environmental Engineers for service as State Representative – Northern California

Additional information on Dr, Lee's qualification, experience and publications is available on his website, www.gfredlee.com at http://www.gfredlee.com/gflinfo.htm