Revision of Solid Waste Landfill Criteria – Leachate Recirculation

G. Fred Lee & Associates
27298 E. El Macero Dr.
El Macero, California 95618-1005
Tel. (530) 753-9630 · Fax (530) 753-9956
gfredlee33@gmail.com http://www.gfredlee.com

January 30, 2000

via email
hanlon.deborah@epa.gov,
hlustick.dwight@epa.gov

Deborah Hanlon
Dwight Hlustick
Office of Solid Waste and Emergency Response (5306G)
US EPA (EPA HQ)
401 M St, SW
Washington, DC 20460

Dear Ms Hanlon and Mr. Hlustick:

Dr Anne Jones-Lee and I wish to provide comments pertinent to the Agency's current review of MSW leachate recirculation. We have been active in review of the benefits and problems of MSW landfill leachate since the mid 1980s. We have published extensively on these issues. Our papers are available from our web site, www.gfredlee.com. Recently we have completed a review paper on this topic for the AWMA national conference that will be held in Salt Lake City in June 2000. This paper is appended to this comments in Adobe pdf format. It presents a summary of our findings on the appropriate use of MSW leachate recirculation. As discussed we support appropriate leachate recirculation . However, as being practiced at many locations it will lead to greater groundwater pollution.

Please contact me if you have questions or comments on our findings on MSW leachate recycle.

G. Fred Lee, PhD, PE, DEE

Appropriate Use of MSW Leachate Recycling in Municipal Solid Waste Landfilling[1]

Anne Jones-Lee, PhD and G. Fred Lee, PhD, PE, DEE
G. Fred Lee & Associates
El Macero, CA 95618-1005
gfredlee33@gmail.com
www.gfredlee.com

ABSTRACT

There is considerable interest today in the so-called "biocell" approach toward municipal solid waste (MSW) landfilling in which leachate is introduced back into the landfill. This approach reduces the cost of leachate management and is said to reduce/eliminate the potential for long term landfill gas production and groundwater pollution. However, a critical review of the typical approach being used today in biocell landfilling in Subtitle D landfills shows that the biocell approach will fall far short of appropriate landfilling of MSW that will prevent long-term gas production problems and groundwater pollution. Today's minimum Subtitle D landfills can cause groundwater pollution at the time of landfill construction due to the inherent rates of leakage of leachate associated constituents through the liner system. Further, over time the flexible membrane liners' (FMLs') ability to collect leachate will decrease as the FML deteriorates. The groundwater monitoring systems allowed by regulatory agencies at minimum Subtitle D landfills have a low probability of detecting leachate polluted groundwaters before significant offsite groundwater pollution occurs. Leachate recirculation in a minimum Subtitle D landfill increases the hydraulic loading of the landfill which can lead to increased groundwater pollution.

One of the principal problems with reintroduction of leachate into today's MSW landfills as a means of decreasing the time for landfill "stabilization" is that a large part of today's MSW is disposed of in plastic bags that are not shredded at the time of burial. These plastic bags "hide" the waste from the moisture which would allow increased landfill gas formation rates and leachate generation during the time that the landfill liner system can possibly be an effective barrier to groundwater pollution. While the addition of moisture to shredded municipal waste can greatly reduce the time of landfill gas production, unshredded solid waste will produce landfill gas and leachate over very long periods of time related to the rate of decomposition of the plastic bags.

This paper discusses the problems with current approaches for leachate recycle (biocell landfilling) and recommends how such landfilling should be practiced to achieve increased rates of landfill stabilization while protecting nearby groundwater resources from leachate pollution. Biocell landfilling should be practiced using shredded MSW in a double composite lined landfill in which the lower composite liner is a leak detection system for the upper composite liner. After landfill gas production has essentially stopped, then clean water should be added to the landfill to wash/leach the solid waste residues to remove potential pollutants. This washing should be done

---

[1] Air & Waste Management Association 93 annual meeting, Salt Lake City, UT, June (2000)

without leachate recycle. Adoption of this “fermentation leaching” wet cell approach will lead to a rapid stabilization of the fermentable waste components in the landfill and remove those constituents from the landfill that can lead to groundwater pollution. While initially more expensive than biocell landfilling, in the long term the cost will be cheaper than the cost of municipal solid waste management in minimum Subtitle D landfills since the long term “Superfund” cost associated with this approach will be eliminated.

KEY WORDS municipal solid waste, leachate recycle, groundwater pollution, landfill gas formation

INTRODUCTION

The US Environmental Protection Agency's (US EPA, 1991) Resource Conservation and Recovery Act (RCRA) Subtitle D requirements for municipal solid waste (MSW) landfilling basically prescribe the placement of MSW in a "dry tomb" landfill. In concept, it is intended that such systems keep the buried wastes dry; as long as the wastes are kept dry, they will not ferment and produce landfill gas, or generate leachate. However, the buried wastes remain a threat to groundwater quality for as long as they are in the "dry tomb."

Lee and Jones-Lee (1993a,b; 1998a,b) discussed the problems with the "dry tomb" landfilling approach that preclude its ensuring protection of groundwater quality for as long as the wastes represent a threat. They noted among other problems that liners of the type currently used leak from the time a landfill is placed in service and deteriorate over time; the leachate collection and removal systems depend on the integrity of the liner system and are subject to biological fouling; groundwater monitoring programs typically used are inadequate to detect incipient liner leakage or incipient groundwater pollution by landfill leachate; inadequate attention is given to sufficiently funding the post-closure care of landfill covers that will be required in perpetuity. At best, "dry tomb" landfills postpone groundwater pollution and pass the costs for corrective action, proper waste handling, and lost groundwater resources on to future generations (see Lee and Jones-Lee, 1993c).

There is growing consensus that the "dry tomb" storage of MSW should be abandoned in favor of *in situ* treatment of MSW so as to remove at the outset, components that could otherwise eventually leak from the landfill to pollute groundwater. The "fermentation/leaching wet cell" (F/L wet cell) shows considerable promise for achieving such treatment in a cost-effective manner. In that system, moisture is introduced into the buried wastes to enhance the stabilization of fermentable organics (those that undergo anaerobic bacteriological transformation to methane and carbon dioxide), and to leach the leachable chemicals from the wastes that could otherwise escape the landfill to adversely affect the beneficial uses of groundwater. A potential source of moisture for the fermentation is leachate generated in the landfill. While recycling leachate through the wastes can aid in waste "stabilization," there is considerable misinformation being advanced today about the role of leachate recycle in the "treatment" of MSW to reduce the potential for the leachate to pollute groundwater.

Presented below is a discussion of potential benefits of leachate recycle with particular reference to its potential use in protecting groundwater from pollution by landfill leachate.

APPROPRIATE USE OF MSW LEACHATE RECYCLING IN MUNICIPAL SOLID WASTE LANDFILLING

Leachate Recycle in MSW Management

Lee, *et al*. (1985; 1986), Pohland and Harper (1987), Otieno (1994) and Reinhart and Townsend (1998) discuss that leachate recycle has been used for many years as a means of "disposing" of MSW landfill leachate and to enhance "stabilization" of fermentable organics in MSW. The rate of methane generation is controlled by the amount of moisture present in the waste. In the classical sanitary landfill where no attempt is made to restrict entrance of moisture, landfill gas formation typically takes place for 30 to 50 years. As additional moisture is added to the waste, the rate of methane formation increases. It has been well-documented in the literature that by adding moisture through leachate recycle the period during which methane is generated under ideal conditions in a sanitary landfill can be reduced to 5 to 10 years.

Christensen and Kjeldsen (1989) reported on a study of the impact of the moisture content of MSW on gas production rate. They reported that gas production essentially ceased when the percent moisture in the waste is less than about 20%. The rate of gas production increased with moisture content up to the maximum moisture content evaluated, about 60%. It is possible, although not investigated by them, that higher rates of gas production could have occurred with higher moisture content.

In cooperation with the Sonoma County (CA) Department of Public Works, EMCON (1975; 1976) conducted one of the most comprehensive and definitive studies of the impact of leachate recycle on the chemical characteristics of MSW landfill leachate. A set of landfill test cells (measuring 18x18x2.4m (60x60x8ft)-deep) was developed; each cell was filled with about 477 mtons (525 tons), about 909 m3 (1000 yd3), of MSW. Each cell received leachate that had been produced within the cell, or clean water, or no supplemental moisture, or one of various other treatments. The chemical characteristics of the leachate were determined periodically over a 4-year period. It was found that during the test period, the test cell that received recycled leachate produced methane at the greatest rate; by the end of the test, the rate of methane formation had been significantly reduced.

The test cell that received only clean water, with no recirculated leachate, also produced methane at a rapid rate, but the rate was initially somewhat slower than that of the cell that received recycled leachate. Methane formation from stabilization of the fermentable organics in the waste in that test cell was also almost completed during the 4-year period. By contrast, the test cell that received no moisture other than atmospheric precipitation that penetrated the clay cover (which was not designed to be a "low-permeability" cover of the type being developed today for "dry tomb" landfills), produced very little methane by the end of the 4-year test period.

As might be expected, the groundwater pollution potential of the leachate produced in each of the three test cells at the end of the 4-year test period was different. The leachate from the test cell that had received only precipitation that naturally penetrated the cover had characteristics similar to those of classical MSW sanitary landfill leachate; it contained a wide variety of chemical contaminants in concentrations that would represent a significant threat to beneficial uses of groundwater. At the end of the 4-year test period, the leachate from the test cell that had received recycled leachate also still contained a wide variety of chemicals in concentrations that would represent a significant potential to pollute groundwater. The leachate from the test cell that had received clean water during the test period had somewhat less potential to pollute groundwater than that from the cell that had received recycled leachate. It was evident that the clean-water washing (leaching) of the wastes effected the lowering of concentrations of constituents that represented a significant potential for groundwater pollution. That was not accomplished in the test cell that received recycled leachate.

The Sonoma County studies further demonstrated that recycling of leachate in an MSW landfill does significantly enhance the rate of landfill gas production and stabilization of the fermentable components of the MSW. The stabilized MSW residues developed after leachate recycle, however, were still a significant threat to groundwater quality. These authors (Lee and Jones-Lee) conclude from the Sonoma County studies, as well as the information in the literature, that leachate recycle as it has been practiced will not produce MSW residues that are no longer a significant threat to groundwater quality.

While it is evident from the literature that leachate recycle can significantly hasten the rate of stabilization of fermentable components of MSW, there are significant amounts of material in normal MSW that are not converted to methane and carbon dioxide under anaerobic conditions (i.e., are not fermentable). It is also clear that some of the fermentation residues, as well as nonfermentable materials in typical MSW contain readily leachable components; because of those components, leachate developed has a significant potential to pollute groundwater hydraulically connected to the landfill area. Therefore, leachate recycle *per se* does not address the primary concern about the landfilling of municipal solid wastes, namely groundwater pollution by leachatederived constituents. This was demonstrated in the Sonoma County study discussed above.

Some landfill owners/operators practice leachate recycle as a means of reducing the costs of leachate treatment. By recycling the leachate back into the landfill, the amount of leachate that must be treated by other means can be lessened. This is especially effective when the leachate is sprayed over the surface of the landfill and given significant opportunity to undergo evaporation and evapotranspiration. However, that approach does not remove many of the contaminants in MSW landfill leachate; re-introduction of the leachate into the landfill replaces the chemical contaminants in the landfill or at its surface where they remain subject to leaching and transport to the surface waters and groundwaters of the region.

Another significant factor that must be considered today in assessing the utility and effectiveness of MSW leachate recycle is the fact that much of the garbage received by MSW landfills is in plastic bags. Such bags significantly obstruct the contact between the recycled leachate and the fermentable components of the solid waste. This would detract from the appearance of accelerated fermentation noted with leachate recycle. The results of the laboratory studies by various investigators, as well as the Sonoma County studies, would be expected to be significantly different if significant amounts of the waste were contained in plastic bags that inhibited contact between the recycled leachate and the waste.

Unreliable Discussion of the Potential Problems with MSW Leachate Recycle

Over the years there are many papers, reports and a book that discuss/promote MSW leachate recycle. With few exceptions the authors of these papers, etc., fail to discuss the potential problems with leachate recycle. These problems have been discussed in the solid waste management literature (see Lee, *et al*.1985, 1986; Lee and Jones 1990; Lee and Jones-Lee, 1993b, 1994a,b, 1995a, 1996) over the past 15 years. States have reviewed these issues and concluded that these problems are sufficient to prevent leachate recycle. Yet these issues are not discussed by many of those who wish to promote MSW leachate recycle. A notable exception is Magnuson (1996). The landfill owners, regulatory agencies and the public are entitled to a balanced discussion of the advantages and disadvantages/potential problems of MSW leachate in minimum Subtitle D landfills sited where the increased groundwater pollution can occur than is occurring today (see Lee and Jones-Lee1995b).

Fermentation/Leaching Wet-Cell Approach

Lee and Jones (1990) and Lee and Jones-Lee (1993b) described an *in situ* fermentation/leaching wetcell treatment approach by which it should be possible to treat MSW to produce a residue that represents little long-term threat to groundwater quality. The concept is to stabilize the fermentable components of MSW employing leachate recycle, and then to actively leach the residues to remove and treat those components that would otherwise eventually leak from the landfill and pollute groundwater. Wastes would be shredded prior to placement to reduce impediments to contact of the liquid with the waste components. A double-composite-lined landfill with appropriate liner leak detection systems would be used; a reverse groundwater gradient liner system (hydraulic trap) may be employed where indicated to provide additional protection against groundwater pollution.

It is expected that leachate would be recycled through the landfill for a period of 3 to 5 years; that should provide sufficient time for the fermentation of those components that are subject to anaerobic fermentation to methane and carbon dioxide. At the end of the leachate recycle period, clean water would be added to leach the waste; leaching should be practiced until the leachate produced no longer represents a significant threat to groundwater quality. Depending on the design of the landfill cells and the hydraulic loading, it is estimated that a leaching period of 15 to 20 years should be sufficient to produce MSW residues that are no longer a significant threat to groundwater quality. If during the course of the leaching period, leachate were to pass through the upper-composite liner, it would be necessary to stop the leaching process, exhume the wastes, and treat them to produce non-polluting residues.

The fermentation/leaching wet-cell approach for *in situ* treatment will initially be more expensive than the conventional "dry tomb" landfilling owing to the additional costs of treating the leachate produced in the clean-water washing of the garbage. The magnitude of the increased cost is highly site specific and depends on the methods used for leachate management. However, in the long term, the F/L wet-cell approach would be less expensive since it has the potential to eliminate the need for, and very high cost of, providing landfill cover maintenance *ad infinitum*, and since it would significantly reduce the potential for having to spend funds to try to clean up leachate-contaminated groundwaters near the landfill, and replace lost groundwater resources.

It is important to distinguish the "fermentation/leaching wet-cell" approach discussed by Lee and Jones-Lee (1993b) and briefly described above, from what some refer to as a "wet cell" landfill that only incorporates leachate recycle. As noted above, thorough leaching of the wastes with clean water is essential to reducing the pollution potential of MSW landfill leachate.

Permitting of Leachate Recycle

In the review conducted by Lee, *et al*. (1985), it was found that a number of states, such as New Jersey, prohibited leachate recycle because of the increased potential for groundwater pollution associated with the increased hydraulic loading on the landfill. As discussed by Lee, *et al*. (1985), the more rapid onset of groundwater pollution is a real, potentially significant problem that needs to be properly addressed if leachate recycle is to be practiced. It is clear that leachate recycle should not be practiced in an unlined landfill or a landfill that does not have a highly reliable liner leak detection system.

Lee and Jones-Lee (1994c, 1998a,b) discussed problems inherent in trying to use conventional groundwater monitoring systems, with vertical monitoring wells spaced hundreds to a thousand or so feet apart, for the detection of incipient liner leakage or incipient groundwater pollution from a lined MSW landfill. Based on the manner in which lined landfills leak from point sources in the liners, and the manner in which leachate moves in groundwater systems in "finger" plumes, such conventional monitoring systems have a low probability of detecting incipient groundwater pollution by landfill leachate at the point of compliance before widespread groundwater pollution has occurred.

Because of the inherent unreliability of single-composite liner systems that depend on the monitoring of groundwater to detect liner-leakage of landfill leachate, the authors strongly recommend against the practice of leachate recycle in a single-composite-lined landfill of the type prescribed as the US EPA Subtitle D minimum prescriptive standards.

Leachate recycle should only be allowed at those landfills sited where groundwater pollution by leachate is considered to be of no consequence, or that incorporate a double-composite liner system in which the lower-composite liner is part of a leak detection system designed to determine when the upper-composite liner fails to prevent leachate transport through it. Further, as described by Lee and Jones-Lee (1993a, 1998a), sufficient funds must be available in a dedicated trust fund derived from waste disposal fees to exhume the wastes and treat them to produce non-polluting residues that may be safely buried in a landfill, when the upper-composite liner fails to prevent leachate transport through it.

As a stop-gap approach, a landfill owner/operator may try to prevent further passage of leachate through the upper-composite liner once it is detected in the liner leak detection system, by immediately ceasing leachate recycle and trying to prevent entrance of moisture into the landfill through the cover. While costing more than the amount of money typically provided for landfill cover maintenance during the post-closure care period, it may be possible to isolate MSW from moisture that can generate leachate for those landfills sited above the watertable by using appropriate leak detection systems in the cover and aggressive maintenance *ad infinitum* as discussed by Lee and Jones-Lee (1998a). It is clear that any leachate recycle project must plan for the inevitable failure of the liner system to manage leachate and have the funds available in a dedicated trust fund to address the failure when it occurs.

It is in the best interest of protecting groundwater resources for future generations to allow properly conducted leachate recycle as part of fermentation/leaching treatment of wastes. As part of revisions of solid waste management regulations, provisions should be included for leachate recycle in doublecomposite- lined landfills in which the lower composite liner is part of a liner leakage monitoring system, and where adequate funds have been set aside in a dedicated trust fund to properly address all plausible worst case scenarios for liner failure, *ad infinitum*, including waste exhumation and treatment. Leachate recycle should not be allowed in single-composite-lined landfills. Further, leachate recycle should be recognized as only providing stop-gap relief from leachate treatment costs; it will not eliminate or even significantly reduce the potential for groundwater pollution by solid waste components. Regulations prohibiting the *in situ* treatment of MSW should be amended to allow fermentation/leaching wet-cell treatment in properly designed and constructed doublecomposite- lined landfills of the type recommended in this discussion.

At this time the US EPA is reviewing the need to revise Subtitle D regulations so that it is easier for landfill owners to recycle MSW leachate. If these regulations do not address the numerous problems associated with MSW leachate recycle, then these regulations should not be adopted. Simply discharging MSW leachate into a minimum Subtitle D landfill could increase groundwater pollution.

CONCLUSION

As it has been practiced, leachate recycle does not produce MSW residues that are not significant threats to groundwater pollution. Leachate recycle should not be practiced in a single-composite-lined landfill that relies on groundwater monitoring to detect the failure of the composite liner to prevent significant transport of leachate through it. Leachate recycle can and should be practiced in appropriately designed and constructed double-composite-lined landfills in which the lowecomposite liner serves as a leak detection system for the upper-composite liner. Leachate recycle must be followed by clean-water leaching (washing) of the fermented solid waste residues in order to remove those components of MSW that represent threats to groundwater quality by their presence in leachate.

REFERENCES

Christensen, T. & Kjeldsen, P. Basic biochemical processes in landfills. In *Sanitary Landfilling: Process, Technology and Environmental Impact*. San Diego, CA, USA: Academic Press, pp. 29-49 (1989).

EMCON. Sonoma county solid waste stabilization study and Twelve-Month extension Sonoma county solid waste stabilization study. Report SW-65d.1. Washington, D.C., USA: US Environmental Protection Agency Office of Solid Waste (1975; 1976).

Lee, G. F. & Jones, R. A. Managed fermentation and leaching: An Alternative to MSW Landfills. *Biocycle* **31**, 78-80, 83 (1990) .

Lee, G. F. & Jones-Lee, A. Revisions of state MSW landfill regulations: Issues in protecting groundwater quality. *Journal Environmental Management Review* **29**, 32-54 (1993a).

Lee, G. F. & 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, pp. 1787-1796 (1993b).

Lee, G. F. & Jones-Lee, A. Geosynthetic liner systems for municipal solid waste landfills: An inadequate technology for protection of groundwater quality? *Waste Management & Research*, **11(4)**, 354-360 (1993c).

Lee, G.F. and Jones-Lee, A., "Leachate Recycle Process Offers Pros and Cons," World Wastes 37(8): 16,19, August (1994a).

Lee, G.F. and Jones-Lee, A., "Advantages and Limitations of Leachate Recycle in MSW Landfills," World Waste 73(8): 16,19 August (1994b).

Lee, G.F. and Jones-Lee, A., "A Groundwater Protection Strategy for Lined Landfills," Environmental Science & Technology, 28(13):584-5 (1994c).

Lee, G.F. and Jones-Lee, A., "Wet Cell Versus Dry Tomb: Pay a Little Now or More Later," MSW Management 5(1):70,72 (1995a).

Lee, G.F. and Jones-Lee, A., "Practical Environmental Ethics: Is There an Obligation to Tell the Whole Truth?," Published in condensed form "Environmental Ethics: The Whole Truth" Civil Engineering, Forum, 65:6 (1995b).

Lee, G.F. and Jones-Lee, A., "Landfill Leachate Management," MSW Management, 6:18-23 (1996).

Lee, G.F. and Jones-Lee, A., "Assessing the Potential of Minimum Subtitle D Lined Landfills to Pollute: Alternative Landfilling Approaches," Proc. of Air and Waste Management Association 91st Annual Meeting, San Diego, CA, available on CD ROM as paper 98-WA71.04(A46), 40pp, June (1998a).

Lee, G.F. and Jones-Lee, A., "Deficiencies in Subtitle D Landfill Liner Failure and Groundwater Pollution Monitoring," Presented at the NWQMC National Conference *Monitoring: Critical Foundations to Protect Our Waters*, US Environmental Protection Agency, Washington, D.C., July (1998b).

Lee, G. F., Jones, R. A. & Ray, C., "Review of the efficacy of sanitary landfill leachate recycle as a means of leachate treatment and landfill stabilization," Report to the US Army Construction Engineering Research Laboratory, Champaign, IL, USA (1985).

Lee, G. F., Jones, R. A. & Ray, C., "Sanitary landfill leachate recycle," *Biocycle* **27**, 36-38 (1986).

Magnuson, A., “Disposal,” MSW Management 6(7):30-42, Dec. (1996).

Otieno, F. A. O. “Stabilization of solid waste through leachate recycling.” *Waste Management & Research* **12**, 93-100 (1994).

Pohland, F. G. & Harper, S. R. “Critical review and summary of leachate and gas production from landfills.” EPA/600/S2-86-073, Cincinnati, OH, USA: US Environmental Protection Agency (1987).

Reinhart, D.R. and Townsend, T.G., Landfill Bioreactor Design & Operation, Lewis Publishers, (1998).

US EPA, “Solid Waste Disposal Facility Criteria; Final Rule” US Environmental Protection Agency Federal Register 40 CFR Parts 257 and 258, pp 50978-51119 October 9 (1991).

Qualifications to Undertake This Review

My (Dr. G. Fred Lee) work on municipal landfill impact matters began in the mid-1950s while I was an undergraduate student in environmental health sciences at San Jose State College in San Jose, California. My course and field work involved review of municipal solid waste landfill impacts on public health and the environment.

I obtained a Master of Science in Public Health degree from the University of North Carolina, Chapel Hill in 1957. The focus of my masters degree work was on water quality evaluation and management with respect to public health and environmental protection from chemical constituents and pathogenic organisms.

I obtained a PhD degree specializing in environmental engineering from Harvard University in 1960. As part of this degree work I obtained further formal education in the fate, effects and significance and the development of control programs for chemical constituents in surface and groundwater systems. An area of specialization during my PhD work was aquatic chemistry.

For a 30-year period, I held university graduate-level teaching and research positions in departments of civil and environmental engineering at several major United States universities, including the University of Wisconsin-Madison, University of Texas at Dallas and Colorado State University. During this period I taught graduate-level environmental engineering courses in water and wastewater analysis, water and wastewater treatment plant design, surface and groundwater quality evaluation and management, and solid and hazardous waste management. I have published over 850 professional papers and reports on my research results and professional experience. My research included, beginning in the 1970s, the first work done on the impacts of organics on clay liners for landfills and waste lagoons.

In the 1980s, I conducted a comprehensive review of the properties of HDPE liners of the type being used today for lining municipal solid waste and hazardous waste landfills with respect to their compatibility with landfill leachate and their expected performance in containing waste-derived constituents for as long as the waste will be a threat.

My work on the impacts of municipal solid waste landfills began in the 1960s where, while directing the Water Chemistry Program in the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison, I became involved in the review of the impacts of municipal solid waste landfills on groundwater quality. In the 1970s, while I was Director of the Center for Environmental Studies at the University of Texas at Dallas, I was involved in the review of a number of municipal solid waste landfill situations, focusing on the impacts of releases from the landfill on public health and the environment.

In the 1980s while I held the positions of Director of the Site Assessment and Remediation Division of a multi-university consortium hazardous waste research center and a Distinguished Professorship of Civil and Environmental Engineering at the New Jersey Institute of Technology, I was involved in numerous situations concerning the impact of landfilling of municipal solid waste on public health and the environment. I have served as an advisor to the states of California, Michigan, New Jersey and Texas on solid waste regulations and management.

In the early 1980s while holding a professorship in Civil and Environmental Engineering at Colorado State University, I served as an advisor to the town of Brush, Colorado on the potential impacts of a proposed hazardous waste landfill on the groundwater resources of interest to the community. Based on this work, I published a paper in the Journal of the American Water Works Association discussing the ultimate failure of the liner systems proposed for that landfill in preventing groundwater pollution by landfill leachate. In 1984 this paper was judged by the Water Resources Division of the American Water Works Association as the best paper published in the journal for that year.

In 1989, I retired after 30 years of graduate-level university teaching and research and expanded the part-time consulting that I had been doing with governmental agencies, industry and community and environmental groups into a full-time activity. A principal area of my work since then has been assisting water utilities, municipalities, industry, community and environmental groups, agricultural interests and others in evaluating the potential public health and environmental impacts of proposed or existing hazardous, as well as municipal solid waste landfills. I have been involved in the review of approximately 50 different landfills in various parts of the United States and in other countries.

Dr Anne Jones-Lee obtained a bachelors degree in biology form Southern Methodist University and a PhD degree in Environmental Sciences from the University of Texas at Dallas in 1978. For 11 years she taught and conducted university graduate level environmental engineering and environmental sciences courses and conducted research on various aspects of water quality management. She and Dr. G. Fred Lee have worked together as a team since the mid 1970s.

Dr. Anne Jones-Lee and Dr. G. Fred Lee have published extensively on the issues that should be considered in developing new or expanded municipal solid waste and hazardous waste landfills in order to protect the health, groundwater resources, environment and interests of those within the sphere of influence of the landfill. Our over 40 professional papers and reports on landfilling issues provide guidance not only on the problems of today's minimum US EPA Subtitle D landfills, but also how landfilling of non-recyclable wastes can and should take place to protect public health, groundwater resources, the environment, and the interests of those within the sphere of influence of a landfill. I make many of my publications available as downloadable files from my web site (www.gfredlee.com).

In the early 1990s, I was appointed to a California Environmental Protection Agency's Comparative Risk Project Human Health Subcommittee that reviewed the public health hazards of chemicals in California's air and water. In connection with this activity, Dr. Jones-Lee and I developed a report, "Impact of Municipal and Industrial Non-Hazardous Waste Landfills on Public Health and the Environment: An Overview" (Lee and Jones-Lee, 1994a), that served as a basis for the human health advisory panel to assess public health impacts of municipal landfills.

In addition to teaching and serving as a consultant in environmental engineering for over 39 years, I am a registered professional engineer in the state of Texas and a Diplomate in the American Academy of Environmental Engineers (AAEE). The latter recognizes my leadership roles in the environmental engineering field. I have served as the chief examiner for the AAEE in north-central California and New Jersey, where I have been responsible for administering examinations for professional engineers with extensive experience and expertise in various aspects of environmental engineering, including solid and hazardous waste management.

My work on landfill impacts has included developing and presenting several two-day shortcourses devoted to landfills and groundwater quality protection issues. These courses have been presented through the American Society of Civil Engineers, the American Water Resources Association, the National Ground Water Association in several United States cities, including New York, Atlanta, Seattle and Chicago, and the University of California Extension Programs at several of the UC campuses, as well as through other groups. I have been and continue to be an American Chemical Society tour speaker, where I am invited to lecture on landfills and groundwater quality protection issues, as well as domestic water supply water quality issues throughout the US.

SUMMARY BIOGRAPHICAL INFORMATION

NAME: G. Fred Lee
ADDRESS: 27298 E. El Macero Dr.
El Macero, CA 95618-1005
DATE & PLACE OF BIRTH: July 27, 1933, Delano, California, USA
PHONE (home/office): 530-753-9630
E-MAIL: gfredlee33@gmail.com WEBSITE: http://www.gfredlee.com

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 1955

ACADEMIC AND PROFESSIONAL EXPERIENCE

Current Position: Consultant, President, G. Fred Lee and Associates
Previous Positions:

- Distinguished Professor, Civil and Environmental Engineering, New Jersey Institute of Technology, 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, Industry, Cooperative Center for Research in Hazardous and Toxic Substances, New Jersey Institute of Technology et al., Newark, NJ, 1984-1987
- Professor, Department of Civil and Environmental Engineering, Texas Tech University, 1982-1984
- Professor, Environmental Engineering, Colorado State University, 1978-1982
- Professor, Environmental Engineering & Sciences; Director, Center of 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

PUBLICATIONS AND AREAS OF ACTIVITY

Published over 850 professional papers, chapters in books, professional reports, and similar materials. The topics covered include:

- Studies on 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 and management of various types of wastewater discharges including municipal, mining, electric generating stations, domestic and industrial wastes, paper and steel mill, refinery wastewaters, etc.

Stormwater runoff water quality evaluation and BMP development for urban areas and highways

Eutrophication causes and control, groundwater quality impact of land disposal of municipal and industrial wastes, 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 environmental impact of chemical contaminants on water quality.

LECTURES Presented over 750 lectures at professional society meetings, universities, and to professional and public groups.

GRANTS AND AWARDS

Principal investigator for over six million dollars of contract and grant research in the water quality and solid and hazardous waste management field.

GRADUATE WORK CONDUCTED UNDER SUPERVISION OF G. FRED LEE

Over 90 M.S. theses and Ph.D. dissertations have been completed under the supervision of Dr. Lee.

ADVISORY ACTIVITIES

Consultant to numerous international, national and regional governmental agencies, community and environmental groups and industries.

Surface and Groundwater Quality Evaluation and Management
and
Municipal Solid & Industrial Hazardous Waste Landfills
http://www.gfredlee.com

Dr. G. Fred Lee and Dr. Anne Jones-Lee have prepared professional papers and reports on the various areas in which they are active in research and consulting including domestic water supply water quality, water and wastewater treatment, water pollution control, and the evaluation and management of the impacts of solid and hazardous wastes. Publications are available in the following areas:

- Landfills and Groundwater Quality Protection
- Water Quality Evaluation and Management for Wastewater Discharges, Stormwater Runoff, Ambient Waters and Pesticide Water Quality Management Issues
- State Stormwater Quality Task Force Activities
- Impact of Hazardous Chemicals -- Superfund, LEHR Superfund Site Reports
- Contaminated Sediment -- Aquafund, BPTCP
- Domestic Water Supply Water Quality
- Excessive Fertilization/Eutrophication
- Reuse of Reclaimed Wastewaters
- Watershed Based Water Quality Management Programs:
    - Sacramento River Watershed Program,
    - Delta -- CALFED Program, and
    - Upper Newport Bay Watershed Program
    - San Joaquin River Watershed DO and OP Pesticide TMDL Programs
    - Stormwater Runoff Water Quality Science/Engineering Newsletter

For Further Information Contact:
Dr. G. Fred Lee, PE, DEE
G. Fred Lee & Associates
27298 East El Macero Drive
El Macero, California 95618-1005
ph: (530) 753-9630, fx: (530) 753-9956, E-mail: gfredlee33@gmail.com

Municipal Solid Waste Landfills and
Groundwater Quality Protection Issues Publications

Drs. G. Fred Lee and Anne Jones-Lee have prepared several papers and reports on various aspects of municipal solid waste (MSW) management and hazardous waste management by landfilling, groundwater quality protection issues, as well as other issues of concern to those within a sphere of influence of a landfill. These materials provide an overview of the key problems associated with landfilling of MSW and hazardous waste utilizing lined "dry tomb" landfills and suggest alternative approaches for MSW management that will not lead to groundwater pollution by landfill leachate and protect the health and interests of those within the sphere of influence of a landfill. Copies of many of these papers and reports are available as downloadable files from Drs. G. Fred Lee's and Anne Jones-Lee's web page (www.gfredlee.com). Copies of these papers and reports listed below as well as a complete list of their publications on this and related topics are available upon request.

Overall Problems with "Dry Tomb" Landfills

Lee, G.F. and Jones-Lee, A, "`Dry Tomb' Landfills," MSW Management, 6:82-89 (1996).

Lee, G.F. and Jones-Lee, A., "Municipal and Industrial Non-Hazardous Waste Landfills Impact on Public Health and the Environment: An Overview," Report to State of California Environmental Protection Agency Comparative Risk Project, Berkeley, CA (1994).

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., “Deficiencies in US EPA Subtitle D Landfills in Protecting Groundwater Quality for as Long as MSW is a Threat: Recommended Alternative Approaches,” Report of G. Fred Lee & Associates, El Macero, CA (1997).

Lee, G.F. and Jones-Lee, A., "Subtitle D Municipal Landfills vs. Classical Sanitary Landfills: Are Subtitle D Landfills a Real Improvement?" Report of G. Fred Lee & Associates, El Macero, CA, 5pp, May (1996).

Lee, G.F. and Jones-Lee, A., “ Developing Landfills that Protect People: The True Costs,” MSW Management 7(6):18-23, Nov/Dec (1997).

Liner Failure Issues

Lee, G.F. and Jones-Lee, A., “Assessing the Potential of Minimum Subtitle D Lined Landfills to Pollute: Alternative Landfilling Approaches,” Proc. of Air and Waste Management Association 91st Annual Meeting, San Diego, CA, available on CD ROM as paper 98-WA71.04(A46), 40pp, June (1998). Also available at www.gfredlee.com.

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," Report of G. Fred Lee & Associates, El Macero, CA, 68pp (1992).

Lee, G.F. and Jones, R. A., "Geosynthetic Liner Systems for Municipal Solid Waste Landfills: An Inadequate Technology for Protection of Groundwater Quality?" Waste Management & Research, 11:354-360 (1993).

Lee, G.F., "Comments on Tisinger and Giroud `The Durability of HDPE Geomembranes'," Letter to the Editor, Geotechnical Fabrics Report, Minneapolis, MN Submitted by G. Fred Lee & Associates, El Macero, CA, 4pp (1994).

Lee, G.F. and Jones-Lee, A., "Disadvantages of Synthetic Liners for Landfills," Letter to the Editor, National Environmental Journal, Submitted by G. Fred Lee & Associates, El Macero, CA, 2pp (1994).

Groundwater Pollution by Leachate

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, pp. 1093-1103 (1993).

Lee, G.F. and Jones-Lee, A., "Landfill Leachate Management: Overview of Issues," MSW Management 6:18-23 (1996).

Groundwater Monitoring

Lee, G.F. and Jones-Lee, A., “Deficiencies in Subtitle D Landfill Liner Failure and Groundwater Pollution Monitoring,” Presented at the NWQMC National Conference *Monitoring: Critical Foundations to Protect Our Waters*, US Environmental Protection Agency, Washington, D.C., July (1998).

Lee, G.F. and Jones-Lee, A., “Unreliability of Groundwater Monitoring at Lined Landfills,” HydroVisions 6(3):3, 10-12 (1997).

Lee, G.F. and Jones-Lee, A., "A Groundwater Protection Strategy for Lined Landfills," Environmental Science & Technology, 28:584-5 (1994).

Lee, G.F. and Jones-Lee, A., "Groundwater Quality Monitoring at Lined Landfills: Adequacy of Subtitle D Approaches," Report of G. Fred Lee & Associates, El Macero, CA, 28pp (1993).

Lee, G.F. and Jones-Lee, A., "Detection of the Failure of Landfill Liner Systems," Report of G. Fred Lee & Associates, El Macero, CA, 13pp (1996).

Post-Closure Care

Lee, G.F. and Jones-Lee, A., "Landfill Post-Closure Care: Can Owners Guarantee the Money Will Be There?" Solid Waste & Power, 7:35-38 (1993).

Lee, G.F. and Jones-Lee, A., "Municipal Landfill Post-Closure Care Funding: The '30-Year Post-Closure Care' Myth," Report of G. Fred Lee & Associates, El Macero, CA, 19pp (1992).

Lee, G.F. and Jones-Lee, A., "Overview of Landfill Post Closure Issues," Presented at American Society of Civil Engineers Convention session devoted to "Landfill Closures - Environmental Protection and Land Recovery," San Diego, CA (1995).

Lee, G.F. and Jones-Lee, A., "Landfilling of Solid & Hazardous Waste: Facing Long-Term Liability," Proceedings of the 1994 Federal Environmental Restoration III & Waste Minimization II Conference, Hazardous Materials Control Resources Institute, Rockville, MD, pp. 1610-1618 (1994).

Lee, G.F. and Jones-Lee, A., "Closed Landfill Cover Space Reuse: Park, Golf Course or a Tomb?" Report G. Fred Lee & Associates (1994).

Permitting of Landfills

Lee, G.F. and Jones, R. A., "Review of Proposed Landfills: Questions that Should Be Answered," Report of G. Fred Lee & Associates, El Macero, CA, 22pp (1991).

Lee, G.F. and Jones-Lee, A., “Questions that Regulatory Agencies Staff, Boards and Landfill Applicants and their Consultants Should Answer About a Proposed Subtitle D Landfill or Landfill Expansion,” Report of G. Fred Lee & Associates, El Macero, CA, April (1997).

Lee, G.F. and Jones-Lee, A., "Evaluation of the Potential for a Proposed or Existing Landfill to Pollute Groundwater," Report of G. Fred Lee & Associates, El Macero, CA, 18pp, July (1996).

Lee, G.F. and Jones-Lee, A., “Development of a Potentially Protective Landfill: Issues Governing the True Cost of Landfilling,” Report of G. Fred Lee & Associates, El Macero, CA, July (1997).

Lee, G.F. and Jones-Lee, A., “Potential Impacts of the Proposed Minimum Subtitle D Landfills on Agricultural and Greater Area Municipal Resident Interests,” Report of G. Fred Lee & Associates, El Macero, CA, August (1997).

Lee, G.F. and Jones-Lee, A., "Recommended Design, Operation, Closure and Post-Closure Approaches for Municipal Solid Waste and Hazardous Waste Landfills," Report of G. Fred Lee & Associates, El Macero, CA, 14pp (1995).

Lee, G.F. and Jones-Lee, A., "Permitting of New Hazardous Waste Landfills and Landfill Expansions: A Summary of Public Health, Groundwater Resource and Environmental Issues," Report of G. Fred Lee & Associates, El Macero, CA, 82pp, October (1996).

Lee, G.F. and Jones-Lee, A., "Subtitle D Municipal Landfills vs Classical Sanitary Landfills: Are Subtitle D Landfills a Real Improvement?" Report of G. Fred Lee & Associates, El Macero, CA, 5pp (1996).

Lee, G.F., “Comments on State Board Revisions to Chapter 15 Governing Landfilling of Municipal Solid Wastes,” Letter to J. Caffrey, State Water Resources Control Board, Sacramento, CA, October 12 (1997).

Lee, G.F. and Jones, R.A., "Comments on US EPA `Solid Waste Disposal Criteria' Final Rule - October 9, 1991," Report of G. Fred Lee & Associates, El Macero, CA, 14pp (1991).

Lee, G.F. and Jones-Lee, A., "Evaluation of the Potential for a Proposed or Existing Landfill to Pollute Groundwater," Report of G. Fred Lee & Associates, El Macero, CA, 18pp, July (1996).

Lee, G.F. and Jones-Lee, A., "The Cost of Groundwater Quality Protection in Landfilling," Report of G. Fred Lee & Associates, El Macero, CA, 8pp (1993).

Lee, G.F., and Jones-Lee, A., "Practical Environmental Ethics: Is There an Obligation to Tell the Whole Truth?," Published in condensed form as "Environmental Ethics: The Whole Truth" Civil Engineering 65:6 American Society of Civil Engineers (1995).

Lee, G.F. and Jones-Lee, A., "Revisions of State MSW Landfill Regulations: Issues in Protecting Groundwater Quality," Environmental Management Review, 29:32-54, Government Institutes Inc., Rockville, MD, August (1993).

Lee, G.F, "Petition to the State Water Resources Control Board to Review California Regional Water Quality Control Board Waste Discharge Requirements for University of California, Davis Class III Landfill, Yolo County, Order 96-228, Adopted on August 9, 1996," G. Fred Lee & Associates, El Macero, CA 22pp, September 9 (1996).

Fermentation/Leaching "Wet Cell" Landfills

Lee, G.F. and Jones, R. A., "Managed Fermentation and Leaching: An Alternative to MSW Landfills," Biocycle, 31:78-80,83 (1990).

Lee, G.F. and Jones-Lee, A., "Leachate Recycle Process Offers Pros and Cons," World Wastes 37(8): 16,19 (1994).

Lee, G.F. and Jones-Lee, A., "Advantages and Limitations of Leachate Recycle in MSW Landfills," Report G. Fred Lee & Associates (1994).

Lee, G.F. and Jones-Lee, R. A., "Wet Cell Versus Dry Tomb: Pay a Little Now or More Later," MSW Management 5:70,72 (1995).

Lee, G.F. and Sheehan, W., "MSW Recycling Protects Groundwaters: Reply to `Recycling is Garbage'," Letter to the editor New York Times, Hydrovision 5(3):6 (1996).

Lee, G.F., and Jones-Lee, A., "MSW Landfill Leachate Recycle and Groundwater Quality Protection," Report of G. Fred Lee & Associates, El Macero, CA, November (1995).

Lee, G.F. and Jones-Lee, A., "Landfills and Groundwater Pollution Issues: `Dry Tomb' vs F/L Wet- Cell Landfills," Proc. of Sardinia '93 IV International Landfill Symposium, Sardinia, Italy, pp. 1787- 1796 (1993).

Landfill Mining

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, 9pp, July (1990).

Lee, G.F. and Jones, R. A., "Managing Solid Wastes with Landfill Mining," Water Environment and Technology, Water Pollution Control Federation 3:32-34 (1991).

Landfills and the 3R's

Lee, G.F. and Sheehan, W., "Landfills Offer False Sense of Security," Biocycle 37(9):8 (1996).

Lee, G.F. and Jones-Lee, A., "Three R's Managed Garbage Protects Groundwater Quality," Report of G. Fred Lee & Associates, El Macero, CA, July (1996).

Lee, G.F. and Sheehan, W., "MSW Recycling Protects Groundwaters: Reply to `Recycling is Garbage'," Letter to the editor New York Times, Hydrovision 5(3):6 (1996).

Lee, G.F. and Jones-Lee, A., "Three R's Managed Garbage Protects Groundwater Quality," Presented at California Resource Recovery Association annual meeting, Monterey, CA, May (1997).

NIMBY Issues

Lee, G.F. and Jones-Lee, A., "Environmental Impacts of Alternative Approaches of Municipal Solid Waste Management: An Overview," Report of G. Fred Lee & Associates, El Macero, CA, 52pp (1993).

Lee, G.F. and Jones-Lee, A., "Addressing Justifiable NIMBY: A Prescription for Siting MSW Landfills," Environmental Management Review, 31:115-138, Government Institutes Inc., Rockville, MD (1994).

Lee, G.F., Jones-Lee, A., and Martin, F., "Landfill NIMBY and Systems Engineering: A Paradigm for Urban Planning," IN: "Systems Engineering: "Proc. Fourth Annual International Symposium of the National Council on Systems Engineering, 1:991-998 (1994).

Review of Specific Landfills

Lee, G.F., "Technical Deficiencies in the CVRWQCB Order No. 96-227 Discharge of the UCD "West" Landfill Leachate-Polluted Groundwater to Putah Creek Presented to CVRWQCB September 20, 1996 Hearing," Report of G. Fred Lee & Associates, El Macero, CA, 19pp (1996).

Lee, G.F., “Comments on Addendum Subsequent EIR Groundwater Pollution Issues - Landfill Liner Integrity Presentation to Colusa County Board of Supervisors, March 17, 1997,” Report of G. Fred Lee & Associates, El Macero, CA, April (1997).

Lee, G.F., "Overview Assessment of the Potential Public Health, Environmental and Groundwater Resource and Other Impacts of the Proposed Adams Mine Site Landfill," Report to the AMSLF Public Liaison Committee and Metropolitan Toronto, Toronto, Canada, December (1995).

Lee, G.F. and Gallaugher, B., "Comments on the SENES/Notre Review of the Overview Comments Submitted by G. Fred Lee on the Potential Problems of Developing the Adams Mine Site as a Municipal Solid Waste Landfill for Metropolitan Toronto," Report of G. Fred Lee & Associates, El Macero, CA, July (1996).

Lee, G.F., “Comments on ‘Calabasas Landfill Special Use Permit Environmental Assessment’ Prepared by the US Department of Interior, National Park Service, Santa Monica Mountains

National Recreation Area Dated February 1997," Report of G. Fred Lee & Associates, El Macero, CA, August 3 (1997).

Lee, G.F., "Evaluation of the Water Quality Impacts of the Proposed BFI Rosser Landfill," Report
to the City of Winnipeg, Manitoba, G. Fred Lee & Associates, El Macero, CA, November (1995).

Lee, G.F., "Comments on Final EIR/EIS for the Proposed Rail Cycle • Bolo Station Landfill," Submitted to San Bernardino County Planning Commission, 72pp, August (1994).

Lee, G.F. and Jones-Lee, A., "Comments on the `Draft Environmental Impact Report UC Davis Landfill Expansion and Permit Revision,' dated August 1994," Submitted to University of California, Davis, 42pp, August (1994).

Lee, G.F., "Comments on the Azusa Landfill Revised ROWD," Submitted to California Regional Water Quality Control Board, Los Angeles Region, 26pp, December (1994).

Lee, G.F., "Review of Regulatory Compliance of the Western Regional Sanitary Landfill, Placer County, California," Report of G. Fred Lee & Associates, El Macero, CA, 145pp, February (1995).

Lee, G.F., "Review of January 1990 Draft Environmental Impact Report Environmental Impact Statement for the Proposed North County Class III Landfill," Report of G. Fred Lee & Associates, El Macero, CA, March (1990).

Lee, G.F., "Comments on Final Environmental Impact Statement/Environmental Impact Report Eagle Mountain Landfill and Recycling Center Project, Volume 1, Final EIS/EIR," Report of G. Fred Lee & Associates, El Macero, CA, June (1997).

Gallaugher, B., and Lee, G.F., "Review of Potential Public Health, Groundwater Resource, Financial and other Impacts of the Proposed Crane Mountain Landfill," Report of G. Fred Lee & Associates, El Macero, CA, February (1997).

Hazardous Waste Landfills

Lee, G.F. and Jones-Lee, A., "Stormwater Runoff Water Quality Evaluation and Management Program for Hazardous Chemical Sites: Development Issues," *Superfund Risk Assessment in Soil Contamination Studies: Third Volume, ASTM STP 1338,* American Society for Testing and Materials, pp. 84-98, (1998).

Lee, G.F. and Jones-Lee, A., "Evaluation of the Adequacy of Hazardous Chemical Site Remediation by Landfilling," to be published in Remediation of Hazardous Waste Contaminated Soils, 2nd Edition, Marcel Dekker, Inc. (1999).

Lee, G.F. and Jones-Lee, A., "Evaluation of Surface Water Quality Impacts of Hazardous Chemicals," *Remediation*, 9:87-118, 1999) (1999).

Lee, G. F., “Review of the Adequacy of the BFI/CECOS Aber Road Hazardous Waste Landfill Facility Closure and Post-closure Plans to Protect Public Health and the Environment ,” Report to Clermont County Board of Commissioners by G. Fred Lee & Associates, El Macero, CA, January (1999).

Lee, G.F. and Jones-Lee, A., "Superfund Site Remediation by On-Site RCRA Landfills: Inadequacies in Providing Groundwater Quality Protection," Proc. Superfund/Hazwaste Management West Conference, Las Vegas, NV, pp. 311-329 (1996).

Lee, G.F., "Management of Hazardous Wastes: Issues in Mexico," Presentation Greenpeace Mexico Conference, "Foro Ciudadano Sobre Desechos Toxicos," San Luis Potosi, SLP, Mexico (1995).

Lee, G.F. and Jones-Lee, A., "Permitting of New Hazardous Waste Landfills and Landfill Expansions: A Summary of Public Health, Groundwater Resource and Environmental Issues," Report of G. Fred Lee & Associates, El Macero, CA (1996).

Lee, G.F. and Jones-Lee, A., “Hazardous Chemical Site Remediation Through Capping: Problems with Long-Term Protection,” Remediation 7(4):51-57 (1997).

Lee, G.F., “Redevelopment of Brownfield Properties: Future Property Owners/Users Proceed With Your Eyes Open,” Environmental Progress 16(4):W3-W4 (1997).

~~~~~~~

Reference as: Lee, G. F., and Jones-Lee, A, "Revision of Solid Waste Landfill Criteria - Leachate Recirculation," comments submitted to US EPA Washington, DC, January (2000).
~~~~~~~