Review of Potential Impacts of Landfills & Associated Postclosure Cost Issues

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US EPA RCRA Subtitle D establishes the regulatory framework and minimum prescriptive standards for the landfilling of municipal solid waste (MSW) and what are classified as "non-hazardous" solid wastes with the intent of protecting public health and environmental quality from adverse impacts of the wastes. The approach to landfilling outlined in Subtitle D can be described as creating a "dry-tomb" for the wastes – with engineered containment systems including a liner and leachate removal system, a cover to keep moisture out, and a groundwater monitoring program to detect liner failure before offsite groundwater pollution occurs. The objective for the design is to keep the buried wastes dry after landfill closure to prevent future formation of landfill gas and leachate so as to protect groundwater from pollution with landfill-derived chemicals.

Many permitted landfills in the US and some other countries are designed to just meet minimum US EPA Subtitle D prescriptive regulatory requirements for liners and covers. It has, however, been recognized in the technical literature and by US EPA staff for decades that the provisions of Subtitle D are inadequate at all locations to protect groundwater resources and public health from pollution by landfills for as long as the wastes will be a threat. Among other deficiencies, inadequate attention is given to the inevitable deterioration of the engineered systems, the inability to thoroughly and reliably inspect and repair system components, fundamental flaws in the monitoring systems allowed, the truly hazardous and otherwise deleterious nature of landfill gas and leachate, and the fact that as long as the wastes are kept dry, gas and leachate will not be generated. Subtitle D "dry-tomb" landfilling does not render buried wastes innocuous; at best, it only postpones groundwater pollution. Thus, meeting the minimal requirements of Subtitle D cannot be relied upon to prevent pollution for as long as the wastes represent a threat.

Compounding deficiencies in the allowed design of "dry-tomb" landfills is the fact that current US EPA Subtitle D regulatory provisions only require that a landfill owner/developer provide assured postclosure funding for 30 years. The states/counties and other political jurisdictions in which landfills are located are, or should be, justifiably concerned that private landfill companies that develop landfills will not provide reliable protection of the area water resources for as long as the wastes in the landfill will be a threat to generate leachate that can pollute groundwater–which can be expected to be hundreds of years or more. Under some regulations, if a private landfill company fails to provide adequate postclosure monitoring, maintenance and groundwater remediation when the landfill liner system fails, the responsibility for postclosure care becomes the responsibility of the people of the state, county, or local community. Even if the landfill owner meets its obligations for 30-year postclosure care, the hazards of a dry-tomb landfill continue long after that period. While a local political jurisdiction, such as a county/ municipality, receives permit fees and fees for hosting the landfill during the active life of the landfill, the amount of funds received can readily be far-less than amounts that will be required the after the postclosure period funds needed to properly monitor and maintain the landfill and remediate polluted groundwater. That responsibility can pose a significant long-term financial burden to the state/county and or local political jurisdiction.

Local/regional/state jurisdictions that will bear the impacts of landfill failures and to which responsibility for *ad infinitum* landfill care will eventually fall often do not have full understanding of the truly long-term nature of the hazards posed by Subtitle D-permitted “dry-tomb” landfills. This report highlights technical issues associated with the ability of the minimum design and near minimum Subtitle D landfill to provide protection of public health and environmental quality for as long as the wastes in the landfills will be a threat to generate leachate that can pollute groundwater, and release landfill gas. It also provides an overview discussion of issues that need to be evaluated to assess the potential post-postclosure care costs for monitoring and maintaining such landfills after the postclosure period, and long-term threats to public health/welfare and environmental quality posed by these landfills that could require remedial corrective and reparative action by the jurisdiction at some time in the future. In this discussion the term “post-postclosure” is used to identify the period of time beyond the required “postclosure” period during which a landfill owner is responsible for implementing and funding maintenance, monitoring, and other activities that are needed to control releases of hazardous and deleterious chemicals from the landfill to the environment.

These comments are based on Dr. Lee’s expertise and 50 years of experience reviewing the impacts of about 85 existing and proposed landfills in various areas of the US and Canada. Additional information on the authors’ qualifications and experience on the matters addressed in these comments is provided on their website, www.gfredlee.com, in the “About G. Fred Lee & Associates” section at http://www.gfredlee.com/gflinfo.html.

Overall Issues of Protection Provided by “Dry-Tomb”-Type Subtitle D Landfills

Following the approach set forth by the US EPA, many state landfill regulatory agencies allows the development of “dry-tomb”-type solid waste landfills that, while giving the appearance of being protective, actually pose predictable threats to the health, welfare, and interests of those who own/use property in the sphere of influence of the landfills, as well as to groundwater resources and other aspects of environmental quality in the sphere of influence of the landfills. The sphere of influence can extend for several miles from a landfill. The superficiality of the protection provisions enables the disposal of wastes for costs to waste generators including the public far at less than those which would be required to provide for true long-term protection of public health and environmental quality for as long as the wastes in the landfill represent a threat. While the current approach leads to cheaper-than-real-cost initial solid waste management for the waste generators, in the long term it will be very costly to future generations who will have to pay the balance in monetary resources, public health and environmental compromise, lost resources, and “Superfund-like” cleanup of polluted groundwater.

Today’s “dry-tomb”-type landfills typically incorporate plastic sheeting and clay liners, and low-permeability covers at closure in an effort to keep the buried wastes dry. The principle of the design approach is that if the wastes are kept dry, bacterial decomposition of organic matter and solubilization/leaching of waste components will not occur, and thus leachate and landfill gas should not be generated. However, as moisture enters the wastes, these processes will occur, and gas and leachate will be generated. Well-designed, installed, and maintained engineered containment features of “dry-tomb”-type landfills – the cover, liners, and leachate collection and removal systems – can be anticipated to initially provide for isolation of the wastes. However, such systems are not generally amenable to rigorous and effective inspection and repair; they are buried beneath surficial coverings or beneath the wastes, themselves. Even with rigorous visual and other achievable inspection, as those systems age and deteriorate, moisture can be expected to enter the wastes; leachate containment and management systems can be expected to fail; and leachate can be expected to pass out of the landfill into the surrounding strata initially at many locations as finger-like plumes.

Groundwater monitoring systems that are typically incorporated into post-closure care requirements are inadequate to detect incipient leakage from the landfill before pollution of area groundwater. Furthermore, chemical parameters analyzed in such monitoring programs include only a few of the myriad hazardous and otherwise deleterious chemicals that are reasonably expected to be present in solid wastes, in addition to those that are not yet known or not yet recognized or regulated. Groundwater contaminated with waste components could be judged “not contaminated” by virtue of the results of the typical monitoring program yet be unhealthful or unusable for domestic, agricultural, or other purposes.

It may be expected that in the short-term, permitted landfill “containment” systems that are well-designed and placed may forestall leachate and gas generation for tens of years and give the appearance of protecting public health and environmental quality, over time they will deteriorate and diminish in their effectiveness. As moisture enters the wastes, leachate will be generated and will eventually begin to escape the containment systems. Leachate can be expected to be generated as long as there are leachable components buried in the landfill, for hundreds to thousands of years – effectively forever. A technical discussion of these and related issues, with references to the professional literature, is provided in our “Flawed Technology” review:

> 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 July (2011). http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf

We periodically update our “Flawed Technology” review with new and emerging information and commentary; the page and section references that are given in this report refer to the July 2011 update of the review, which is the version that presently appears on our website. When our review is updated in the future, the page references that appear in this paper may no longer be accurate, but they should be close to the proper pages in the updated reviews.

Some state landfill regulatory agencies require that private developers of certain types of landfills (ash, C&D and industrial) provide post-closure monitoring and maintenance for only 20 years. As noted above, a well-designed, constructed, and maintained landfill may well be able to prevent leakage of leachate and gas collection for 20 or more years, and evidence of leakage that does occur may be obscured for decades owing to inadequacies in allowed groundwater monitoring programs. Even if leachate and gas generation were to be prevented during the post-closure period, two decades is a very small part of the period during which landfilled wastes are a threat to cause environmental pollution through the release of waste-derived constituents in leachate and landfill gas. Limiting the responsibility of a private landfill developer for post-closure monitoring, maintenance, and remediation to 20-30 years virtually ensures that the real problems caused by landfilling of wastes and the associated costs, in addition to perpetual routine maintenance and monitoring, will be passed on to parties who did not share in the profits of the landfilling operation. Likewise, if the fees charged to those who deposit wastes in a landfill are not sufficient to provide reliable and adequate funding for perpetual care of the landfill and remediation of public health/welfare and environmental quality impacts of the landfill ad infinitum, the waste generators are benefitting from less expensive waste disposal and are also passing the balance of the costs on to the state/county and local political jurisdiction.

For some types of landfills, state/county could require that the host county assume very large financial obligations for perpetual post-post-closure landfill care (monitoring, maintenance and groundwater remediation) should the private landfill developer fail to provide this care without their being a reliable enforced mechanism for collecting adequate funds from the landfill owner and waste generators during the active life of the landfill to cover the post-post-closure funding needs; after closure, there is no income stream from the landfill. That approach could in effect relieve the private landfill developer/owner from long-term financial responsibility for protection of public health and the environment and places the real financial responsibility for the landfill and its consequences onto the state/host county/community.

The growing understanding of the inability of today's "dry-tomb"-type landfills to provide reliable, *ad infinitum* protection of public health/welfare and environmental quality from adverse impacts from landfilled wastes, and the transfer of the long-term financial consequences of landfills to the public lead to justified NIMBY ("not in my backyard") attitudes by nearby property owners/users; virtually everyone becomes a NIMBY when faced with the prospect of having a landfill sited nearby. A discussions of issues associated with justified NIMBY begin on page 65 of our "Flawed Technology" review; a summary of key concerns with today's "dry-tomb"-type landfills, including those that contribute to justified NIMBY attitudes, is presented below.

Summary of Key Dry-Tomb Landfill Technology Flaws

Landfill Location (Siting)

Current federal and state landfilling regulations do not restrict the siting of landfills based on the degree of "natural protection" provided by the underlying geological strata or on the presence or utility of waters down-groundwater gradient from the landfill. Landfills located in hydrogeological areas that are sandy and will thus allow fairly rapid transport of liquid downgradient from the landfill (a foot or so per day). Such areas and many other less permeable strata provide essentially no natural protection of groundwater quality from leachate that penetrates through the landfill liner. Thus, when the liner in a dry tomb type landfill fails to collect all leachate that is generated in the landfill, off-site groundwaters will be polluted by chemicals derived from the wastes in the landfill. (See "Flawed Technology" review page 64 for further discussion of this issue.)

Landfill Design

Subtitle D type landfills are designed as "dry-tomb"-type landfills. The "dry-tomb"-type landfilling approach was first adopted in the early 1980s by the federal congress at the suggestion of environmental groups. Because bacterial decomposition of organic matter with production of gas, and the leaching of waste components both require moisture, "dry tomb" landfills were conceived as a way to keep wastes "dry;" the belief was that if the wastes were kept dry, no leachate or landfill gas would be generated. However, it was recognized in the technical community at the time the regulations requiring "dry-tomb"-type landfills were promulgated by the US EPA in the early

1980s, and is now widely recognized, that in practice the approach has serious flaws; it only serves to postpone release of waste-derived constituents to the environment. A "dry-tomb"-type landfill relies on a cover to keep moisture out of the landfill, and a liner system to contain leachate that is generated and allow it to be removed so it does not migrate to groundwater. Also incorporated is a groundwater monitoring system intended to ensure that leachate has not migrated to offsite groundwater downgradient from the landfill.

Liners. The liners in minimum design landfills allowed in Subtitle D landfills are single-composite liners comprised of a layer of plastic sheeting (high density polyethylene – HDPE) and either a clay layer or a geosynthetic clay liner (GCL). With high quality construction and adequate waste placement to protect the liners, these landfills can be expected to initially provide for collection of leachate generated in the landfill to protect groundwater quality. However, there are numerous factors that preclude this protection's extending for the duration of time that the wastes in the landfills will be a threat. For example, over time the plastic sheeting layer in the liner will deteriorate and fail to prevent leachate from entering the groundwater underlying the landfill. Intrinsic in the clay liner is a finite rate of transport of leachate through it; the rate depends on a number of factors. (See "Flawed Technology" review pages 9 and 10 for further discussion of this issue.) The initial leakage of the landfill liner will be through holes, rips, and points of deterioration that can lead to finger-like plumes that can pass by the monitoring wells undetected. Of particular concern is liner failure near the down-groundwater-gradient edge of the liner where the lateral spread of the plume would be the least. (See "Flawed Technology" review page 27 for further discussion of this issue.)

Landfill Cover. Once a "dry-tomb"-type landfill is closed and no longer accepts wastes, the key to keeping the wastes dry is the integrity of the landfill cover. The typical Subtitle D landfills have standard US EPA Subtitle D landfill covers consisting of a soil base that covers the wastes, overlain by a thin plastic sheeting layer of low density polyethylene, overlain by a soil layer and a top soil layer. In principle, water that penetrates the top soil layer of the cover will be conveyed to the edge of the landfill on the plastic sheeting layer and therefore not enter the wastes. As discussed in the "Flawed Technology" review, if this type of landfill cover is constructed properly it should have the ability to prevent water that falls on the landfill surface as rain or snow melt from entering the wastes when the cover is new. However, over time the plastic sheeting layer will deteriorate in its ability to prevent water from penetrating the cover; as that water contacts the landfilled wastes, leachate and landfill gas will be generated. A variety of factors can cause compromises in the ability of the plastic sheeting layer in the cover to prevent entrance of water into the wastes. Differential settling of the waste will put additional stress on the plastic sheeting layer, which would tend to increase the rate of deterioration. Ultimately, the plastic sheeting layer will succumb to free radical attack. Such attack can be much more pronounced and significant in the cover layer than in the bottom liner because of the proximity of the surface plastic sheeting layer to the atmosphere where oxygen, the source of the free radicals, is present.

Landfill permits carry requirements for visual cover inspection and repair of defects. However, breaches of the low permeability layer of the cover can occur in many ways that are not readily visible. Further, deterioration of the integrity of the plastic sheeting layer is not visible from the surface of the landfill since it is buried under the top soil and other soil/drainage layers above the plastic sheeting. The presence of leachate in the leachate collection system after the landfill has been closed is evidence that the landfill cover has not been properly installed. The appearance of leachate in the leachate collection system after a period of there being none, is evidence that the integrity of the plastic sheeting layer of the cover has deteriorated and needs to be repaired.

Even if it is found that the cover is allowing moisture to enter the landfill, identification of the areas of breach in the plastic sheeting layer of the cover, and the repair of those areas will not be easily accomplished because the plastic sheeting layer is not visible from the surface of the landfill. Further, since many landfills have a single sump for collection of all leachate generated in the landfill, it will not be possible to even isolate a part of the landfill cover that has deteriorated to the point at which it is allowing sufficient water to enter into the landfill waste to generate leachate. Considerable exploratory work will have to be done by the landfill owner during the post-closure, and by the state/county during the post-post-closure period to find all areas of the cover that have deteriorated to the point of allowing sufficient water to enter waste and generate leachate. This could make the cost of repairing the cover considerably greater than the cost of replacing the plastic sheeting layer that has deteriorated.

Landfill developers such as Waste Management, Inc. have made assertions that a landfill owner's obligation to provide post-closure care should terminate once the cover is installed and leachate generation that occurred before covering has ceased. Such an assertion ignores the fact that over time the integrity of the plastic sheeting layer will deteriorate and allow water that reaches the plastic sheeting layer to enter the wastes. While the rate of deterioration of the integrity of the plastic sheeting layer in a landfill cover depends on a variety of factors, as with the landfill liner the plastic sheeting layer will ultimately fail to prevent water from penetrating through the plastic sheeting layer. (See "Flawed Technology" review page 20 for further discussion of this issue.)

Landfill permit applications mention that the HELP model was used to estimate the rate of leachate generation in the closed landfill. While that model can provide useful information when applied to a landfill with a new, well-designed and well-constructed cover, its reliability diminishes for assessing leachate generation over time. It does not reliably account for the deterioration of the integrity of the plastic sheeting layer and the much greater amounts of water that will be allowed to enter the wastes and generate leachate as well as landfill gas. While this deficiency is readily recognized by examining the components of the HELP model, it is routinely ignored by landfill consultants and the regulatory agency staff that review landfill permit applications. State landfill regulatory agencies' staff allowed the landfill owners to develop post-closure funding estimates without adequate provision for funds for repair of the plastic sheeting layer in the cover.

Leachate Collection System. Leachate collection systems included in Subtitle D landfills rely on an intact liner along which leachate would flow to a sump. Leachate collects at the sump to a point at which it gets pumped from the landfill. Over time, however, areas in the leachate collection system will become increasingly plugged with accumulations of chemical precipitates and physical blockages within the collection system, which will impede or halt the flow of leachate to the sump. These blockages will create areas of pooling of leachate on the upgradient side of the blockage, which will increase the head (depth of leachate) on the liner, which, in turn, can diminish the expected efficacy of the liner. Leachate leakage through areas of deterioration or holes in the liner will be enhanced by the increased head. Because the leachate collection system is located beneath the buried wastes, it is not subject to thorough routine inspection and repair. As the leachate collection system deteriorates, increased leakage of leachate from the landfill can be anticipated and will have to be addressed as increased pollution of groundwater.

Lysimeter Liner Leak Detection. Some landfills include a "lysimeter" liner leak detection system. This system consists of a small HDPE/clay liner under the leachate sump where the leachate collects before being pumped to the surface, and is intended to enable early detection of a failure of the landfill liner at that location. Locating the lysimeter under the sump is somewhat justified because, with an intact liner, the sump area is the site of the greatest depth (head) of leachate, and the rate of leachate passage through a hole in the liner is proportional to the depth of leachate above the hole. However, it will not identify and warn of leachate build-up and leakage at sites of blockage in other areas of the liner system. The very limited number of specific areas known to be vulnerable to liner failure at which lysimeters may be incorporated can be expected to comprise a small portion of the areas at which, over time, the landfill liner will deteriorate and allow leachate to pass through it into underlying clay liner system. A far more reliable approach for detecting the deterioration and failure of the composite liner would be to incorporate a second composite liner with a leak detection system between the two liners throughout the bottom of the landfill. Such a double-composite liner system is already being used in several states, including Michigan. (See "Flawed Technology" review page 33 for further discussion of this issue.)

Landfill Gas Management

MSW landfills and some other types of landfills contain organic wastes that through bacterial action produce landfill gas. This gas is primarily methane and carbon dioxide. Methane is a gas that can explode and cause fires. MSW landfill gas contains highly obnoxious odorous chemicals that at times without adequate control can be detected by smell at several miles from the landfill. MSW landfill gas also contains VOCs that are a threat to human and animal health through causing cancer. MSW landfills should be constructed with landfill gas collection systems that are effective in collecting and treating the landfill gas to destroy the methane and VOCs. A landfill gas collection piping system should be constructed in the area of the leachate collection system to collect all landfill gas that is present in this area to prevent it from migrating through the landfill liner. This migration can occur through intact liners without holes by diffusion. A landfill gas management system needs to be operated and maintained for as long as the wastes in the landfill can generate landfill gas when contacted by water. MSW has a very large potential to pollute groundwater with a variety of hazardous and otherwise deleterious chemicals. Our "Flawed Technology" review contains an extensive discussion of the pollution of groundwater by MSW landfill gas and information on managing landfill gas to protect public health and the environment beginning on page 39.

End of Postclosure Care

Neither the states nor the US EPA provides guidance on how to determine when postclosure care can be ended without compromise of public health/welfare or environmental quality. While a 30-year postclosure care period is typically incorporated into landfill permits, landfills will continue to pose a threat to public health/welfare and environmental quality until such time that the wastes in the landfill can no longer generate leachate that could cause groundwater pollution and/or release landfill gas. As suggested in our "Flawed Technology" review a reasonable approach to determining an appropriate endpoint for postclosure care could be to collect representative samples of the wastes from throughout the landfill and properly expose them to water; if the wastes do not produce gas or leachate that could impair the use of groundwater or surface water for domestic or other purposes, including animal water supply, a compelling argument could be made for cessation of postclosure care. However, protocols for collecting an adequate number of truly representative samples of the landfilled wastes for this purpose and for reliable evaluation of gas/leachate production potential do not exist; existing protocols used for assessing leaching potential of wastes are known to be unreliable. Furthermore, commonly used "indicators" of the "quality" of groundwater, e.g., comparison with MCL levels for a limited list of "pollutants" is not reliable for assessing the impairment of groundwater quality. States and/or the US EPA need to develop a protocol to make reliable, objective evaluations of when postclosure care can be terminated without compromising long-term protection of public health/welfare and environmental quality.

The postclosure period during which the wastes continue to present a threat to public health/welfare and environmental quality can be very long (decades to hundreds of years or more) depending on how well the wastes are kept dry. Because dry-tomb landfilling does not render the buried wastes innocuous, the longer the wastes are kept dry, the longer the postclosure care period needs to be.

On page 57 of the "Flawed Technology" review, the potential for construction and demolition (C&D) wastes to generate leachate that can pollute groundwater with chemicals that are hazardous and/or otherwise detrimental to the use of the groundwater is discussed. As with MSW, burying C&D wastes in a dry-tomb landfill does not render them innocuous; the longer they are kept dry, the longer groundwater pollution may be postponed. Unless demonstrated otherwise by site-specific studies the C&D landfills of interest should be considered to represent very long-term threats to pollute groundwater.

Overall, in time, all minimum design landfills of the type allowed by US EPA Subtitle D regulations, that are located in areas where the underlying geology/hydrology does not provide natural protection, will pollute groundwater under the landfill. It is not known when that pollution of groundwater will occur; it could occur within a few years of waste deposition at the landfill or may be delayed for many years, decades, to hundreds of years or more depending on the quality of liner construction and other site-specific factors. From the perspective of post-post-closure care funding, it should recognized that evidence of groundwater pollution may well be delayed past the period during which the landfill owner has financial responsibility, and if possible prepare to fund the post-post-closure care and groundwater remediation.

Groundwater Monitoring

The groundwater monitoring programs that states typically permit for landfills involve vertical monitoring wells spaced hundreds of feet apart near the edge of the landfill liner, with each well capable of sampling water within only about one foot of the well. Since initial leakage of the landfill liner will be through the holes, rips, and points of deterioration that can lead to finger-like leachate plumes, the monitoring regimen will leave hundreds of feet between each down-groundwater-gradient well through which leachate-polluted groundwater can pass without being detected by the monitoring wells. While as discussed in the "Flawed Technology" review this fundamental deficiency in conventional groundwater monitoring programs at landfills has been well-known for decades, the states and US EPA are still allowing such monitoring programs that have little likelihood of detecting groundwater pollution when it first occurs as required in Subtitle D regulations. Of particular concern is liner failure near the down-groundwater-gradient edge of the liner from which there would be the least lateral spread of the leachate plume. (See "Flawed Technology" review page 27 for further discussion of this issue.) The reliability of the groundwater monitoring program that is developed as part of the permitting of a landfill is a key issue in determining the magnitude of the cost of groundwater remediation..

Inadequate Buffer Land

Adequate landfill-owner-owned buffer land between waste deposition areas and adjacent properties is essential in order to provide a reasonable opportunity for dissipation of gaseous emissions/odors and attenuation/dilution of polluted groundwater before either trespasses onto adjacent and nearby properties. The greater the amount of such buffer land the greater the attenuation/dilution of waste-derived pollutants that can occur in groundwater beneath landfill-owner-owned property before the polluted groundwater trespasses to adjacent properties. In a sandy aquifer system pollutants released from an MSW landfill may be attenuated/diluted to levels below those of water quality and environmental quality consequence within a mile or two of the landfill. However, many landfills are developed with only few tens of feet between waste deposition areas and adjacent properties. This provides very limited opportunity for dilution/attenuation of polluted groundwater under the landfill before it trespasses onto adjacent properties. The very limited buffer lands at Subtitle D landfills means that the state, county, and/or local political jurisdictions face having to address significant off-site groundwater pollution on nearby properties.

The minimal buffer lands at landfills also provide minimal opportunity for dissipation of landfill gas before it trespasses onto adjacent properties. MSW landfill odors have been found to travel a mile or more from the landfill. As discussed in the "Flawed Technology" review, hazardous chemicals in MSW landfill gas pose a significant public health threat. It has also been well-established that MSW landfill odors cause illness in some individuals. Gas released from landfills sited without adequate buffer lands can be expected to trespass onto adjacent and nearby properties and threaten public health and welfare because of hazardous chemicals in the gas and the odors of the gas. (See "Flawed Technology" review page 66 for further discussion of this issue.) The amount of buffer land between waste deposition areas and adjacent properties, especially those down-groundwater-gradient, affects the cost of remediation of leachate-polluted groundwater.

Plastic-Bagged Wastes

MSW landfills accept MSW that is bagged in plastic. Plastic bags that are only crushed by compaction equipment during disposal tend to hide associated wastes from moisture that is present early in the landfilling process. This shielding of pockets of waste throughout the landfill from moisture can be expected to delay the fermentation of organics and leaching of those waste residues and associated formation of gas and leachate from them beyond the time that landfill gas and leachate generated could be managed by the new or well-maintained liner and gas management system. This delay can also contribute to the misleading appearance of cessation of gas and leachate production in the landfill when, in fact, gas and leachate production can be expected to resume as the plastic bags eventually deteriorates sufficiently over decades or centuries, well after the state/county has assumed responsibility for funding maintenance and remediation. (See "Flawed Technology" review page 39 for further discussion of this issue.)

Key Issues Not Adequately Addressed in Subtitle D

Stormwater Runoff Water Quality Impacts

It has been our experience that stormwater runoff from landfill areas is often inadequately monitored for occurrence, and especially impacts on water quality. Attention to the occurrence of stormwater runoff is especially important at landfills at which leachate has been used for dust control. (See “Flawed Technology” review page 43 for further discussion of this issue.)

Surface Water Impacts

Groundwaters beneath some landfills enter surface waters indirectly via spring discharges, or by direct discharge. Leachates from MSW and other types of landfills contain chemicals that can adversely affect aquatic life; in fact, aquatic life can be much more sensitive to adverse impact from some chemical than are humans who drink the water. Even if landfill-derived pollutants transported via groundwater to a large river of other waterbody, and the pollutants in the polluted groundwater are sufficiently diluted by the waterbody to prevent them from causing water quality problems in the waterbody overall, they could adversely impact nearshore aquatic life in areas where the leachate-polluted groundwater enters the waterbody. Concentrations of landfill-derived pollutants and conservative components should be monitored along the flow path of leachate-pollution plume to determine if they are diluted/attenuated to inconsequential levels prior to the groundwater’s reaching a surface waterbody.

Full Range of Domestic Water Supply Pollutants

The very limited extent of buffer land between waste deposition areas and adjacent property lines for most MSW landfills makes it highly unlikely that there will be significant dilution/attenuation of landfill-derived pollutants in the groundwaters beneath the landfills of interest to the state/county or other local jurisdiction. This means that off-site groundwater pollution can be expected. The current groundwater monitoring required by states for the landfills focus on chemicals with regulatory limits for primarily chemicals of human health concern in drinking water. In addition to those chemicals there is a wide variety of other hazardous and otherwise deleterious and obnoxious chemicals in MSW, C&D wastes, and ash, and leachates from those landfilled wastes that can pollute groundwater to impair its use for domestic and other purposes. There can be expected to be chemicals that are currently unknown, unrecognized, unmeasured, or unregulated but that can be reasonably expected to adversely affect human health and welfare. In addition, other chemicals of concern include those that cause taste and odors, salts, and others, which while not necessarily considered to be “hazardous,” can render groundwater unusable for domestic and some other purposes. Even if the groundwater monitoring program were adequate for characterizing leachate migration, it would be inappropriate for a regulatory agency to determine that a landfill leachate is not polluting groundwater on the basis of the finding that none of the measured constituents MCLs are exceeded in samples of groundwater. Groundwater monitoring for the landfills of interest to the state/county should be expanded to include all parameters that can impair the use of groundwater for domestic and other purposes.

Isolating the Landfill from Flood Waters

If dikes are used to try to prevent flood waters from entering the area of the landfill, postclosure care should include thorough, independent, yearly inspection of the dikes to check on the adequacy of maintenance by the landfill owner to repair cracks, and other defects caused by burrowing animals, plant roots, etc.

Deed Restrictions and Future Land Use

Each closed MSW landfill should have a deed restriction on future land use and activities to prevent uses/activities that would disrupt or interfere with the functioning or integrity of the landfill cover and monitoring system. Typically landfill developers claim that once the landfill is closed the landfill cover area can be put into a beneficial use such as a golf course, park, farm land, wildlife area etc. For example Waste Management, Inc. has made claims on national TV ads that its closed landfills make ideal wildlife habitat, and sites for golf courses and public recreation areas including dirt bike trails. Such claims appear in its "Think Green" campaign at http://www.thinkgreen.com/ in its discussion of "Beneficial Land Reuse," as well as in a number of television advertisements. It cites locations at which such reuse has been made of landfill cover areas. The unmistakable implication is that the public should not be concerned about the potential long term threats to public health, groundwater and surface water quality, or to wildlife, at a closed landfill. However, as discussed by Lee and Jones-Lee paper entitled, "Closed Landfill Cover Space Reuse: Park, Golf Course, or a Tomb?" many of the touted reuse activities atop closed landfills are ill-advised at best, and such implications are highly misleading. One reason for this is that many of the land "enhancements" and activities being promoted stand to damage the integrity of the landfill cover upon which the integrity of the landfill containment system depends. As discussed elsewhere herein, in order to prevent formation of landfill gas and leachate that will eventually escape the landfill containment, the wastes must be kept dry. Placing water features such as ponds, wetlands, idyllic streams, or water hazards on a golf course, or deep-rooted vegetation such as trees and shrubs, atop or in close association with landfill covers promotes entrance of moisture into the cover.

A plan for effective *ad infinitum* implementation of the deed restrictions needs to be in place to ensure that future agencies responsible for implementation of the deed restriction adequately implement its requirements. At no time in the future should uses be permitted on the area of the landfill cover that include addition of irrigation water to the surface of the landfill. Severe land use restrictions should be enforced for as long as the wastes in the landfill when contacted by water can generate leachate/landfill gas.

Post-Closure and Post-Post-Closure Care Funding

The landfill permit applications and some operations reports provide a "standard" listing of post-closure care (monitoring and maintenance) activities and associated projected costs over the post-closure care period. The annual post-closure funding over the 30 years appears to be established based on prior years' estimates, multipliers, and adjustments for estimated rates of inflation.

A rudimentary estimate of amount of money that the state/county will need to spend for post-post-closure care in year-31 and beyond after landfill closure can be made based on the estimates of year-30 post-closure funding provisions. To the estimate based on the minimal monitoring and maintenance of the landfill covered by the year-30-based estimate must be added costs of addressing readily anticipated problems such as the repair of the landfill cover as the landfill starts, or continues, to generate leachate. Typically the landfill owners are not required to provide assured funding for repair of the cover should that be required during the 30-year post-closure period; the cover will unquestionably need repair/replacement during the post-post-closure period. Landfill cover repair will be required periodically over the time that the wastes in the landfill will be a threat.

Another major issue that can be anticipated, but is not typically included in post-closure care cost estimates, is remediation of polluted groundwater. Funding for remediation of polluted groundwater and dealing with consequences of polluted aquifers can be expected to be needed during post-post-closure. Again, over the very long period of time during which the wastes in the landfills will be a threat to generate leachate that have been required to post contingency funding in the form of a Surety Bond, Performance Bond, or other source of funding for unexpected expenditures. There is need to understand how regulatory agencies establish the contingency funding levels for the landfills. It is often not clear how these funds can be used, if at all, by county or other agency or whether they are reserved for use by the state in the event the landfill owner fails to meet its obligations during the operating and monitored 30 year post-closure period. Such contingency funding should be required for the period of time that the wastes in a landfill can generate leachate when contacted by water which will be well beyond the 30 year period of funded postclosure care.

County Host Fee. Landfill owners provide the county/local jurisdiction with permit and host fees of a specified amount per ton of waste deposited. These fees are only paid during the active life of the landfill, while wastes are being deposited. The landfill owners pay for post-closure care from funds they have generated during the active life of the landfill. The state/county/local political jurisdiction may need to fund post-post-closure care from the host fees it accumulated during the active life of the landfill, and other unspecified sources as necessary. This approach will greatly increase the amount of host fees that need to be paid to the local community/county to cover post postclosure funding needs.

Post-Postclosure Funding. An issue that will need to be addressed is whether or not the state/county administration has an understanding of long-term funding issues. From a public health/environmental quality perspective, the period during which post-post-closure care will be required for the landfills in may be indefinite; the issues that will inevitably need to be addressed during the post-post-closure period at the closed landfills are enormous. The state/county/local community should collect sufficient host fees during the landfill active life of the landfill to establish a trust fund of sufficient magnitude to generate adequate annual interest during the post-closure and post-post-closure period to enable the state/county to pay for post-post-closure care and contingencies that will likely occur. This will place the financial responsibility for waste management more on those who generate and deposit the wastes in the landfill and potentially less on those who happen to reside in the county and area of the landfill for decades or centuries into the future.

A number of years ago, the *Barons* financial newsletter carried an article about the long-term liability associated with post-closure care of landfills developed by private companies under US EPA Subtitle D regulations. While those regulations obligate private landfill companies to provide assured funding for 30 years after closure of the landfill, they also contain a provision by which the US EPA Regional Administrator may determine that post-closure care must continue for as long as the waste in the landfill are a threat. For example, the California landfilling regulations, in theory, obligate the landfill owner to provide post-closure care for as long as the waste in the landfill are a threat to pollute groundwater, i.e., impair its use for domestic or other purposes. California has recently adopted regulations that require landfill owners to provide post closure care funding for 100 years which can be extended.

Characteristics of the Pollution Potential of Solid Wastes Landfills

MSW Landfills

MSW has a very large potential to pollute groundwater with a variety of hazardous and otherwise deleterious chemicals. Our "Flawed Technology" review contains an extensive discussion of the pollution of groundwater by MSW.

Electric Generation Ash Landfills

Some landfills receive that electric generating station combustion wastes (ash) that arise from burning coal. Considerable attention was paid to potential environmental pollution by coal ash residues following the failure of a large TVA coal ash pond several years ago near Kingston, TN. "Earth Justice" published a report entitled, "Coal Ash Pollution Contaminates Groundwater, Increases Cancer Risks," on September 4, 2007 that is available at: [http://earthjustice.org/news/press/2007/coal-ash-pollution-contaminates-groundwater-increases-cancer-risks]. It summarizes the results of a report issued by the US EPA entitled, "Human and Ecological Risk Assessment of Coal Combustion Wastes," Draft report prepared by RTI for U.S. Environmental Protection Agency, Office of Solid Waste, Research Triangle Park, NC August 2007 [http://earthjustice.org/sites/default/files/library/reports/epa-coal-combustion-waste-risk-assessment.pdf]

That incident was also addressed in a report to Congress:

> Luther, L., "Managing Coal Combustion Waste (CCW): Issues with Disposal and Use," Congressional Research Service report for Congress, January 12 (2010). [http://www.fas.org/sgp/crs/misc/R40544.pdf]

that provides a summary of potential impacts of coal combustion wastes. That report states, "*…the primary concern regarding the management of CCW usually relates to the potential for hazardous constituents to leach into surface or groundwater, and hence contaminate drinking water, surface water, or living organisms. The presence of hazardous constituents in the waste does not, by itself, mean that they will contaminate the surrounding air, ground, groundwater, or surface water. There are many complex physical and biogeochemical factors that influence the degree to which heavy metals can dissolve and migrate offsite—such as the mass of toxins in the waste and the degree to which water is able to flow through it. The Environmental Protection Agency (EPA) has determined that arsenic and lead and other carcinogens have leached into groundwater and exceeded safe limits when CCW is disposed of in unlined disposal units*."

That report also states that the concerns about CCW management generally center around a number of issues including:

- *The waste likely contains certain hazardous constituents that EPA has determined pose a risk to human health and the environment. Those constituents include heavy metals such as arsenic, beryllium, boron, cadmium, chromium, lead, and mercury, and certain toxic organic materials such as dioxins and polycyclic aromatic hydrocarbon (PAH) compounds.*

- *Under certain conditions, hazardous constituents in CCW migrate and can contaminate groundwater or surface water, and hence living organisms. For example, EPA determined that the potential risk of human exposure to arsenic and other metals in CCW (via the groundwater-to-drinking-water pathway) increased significantly when CCW was disposed of in unlined landfills. That risk criterion was slightly higher for unlined surface impoundments."*

US EPA minimum-design, single-composite liner and conventional groundwater monitoring wells spaced hundreds of feet apart, in time the leachate generated in that landfill can be expected to pollute groundwater with hazardous and otherwise deleterious chemicals.

Refuse-Derived Fuel (RDF) Ash Landfills
Some landfills receive refuse-derived fuel (RDF) ash from the combustion of MSW. Characteristics of such wastes were described by Hasselriis and Aleshin:

> F. Hasselriis, and E. Aleshin "How Residues from Waste to Energy Plants Can Be Used Safely," Presented at the ASTSWMO Conference, Los Angeles, CA, September (1986). [http://www.seas.columbia.edu/earth/wtert/sofos/hasselriis/Abstracts%20-%20Hasselriis%20Presentations.pdf]

They stated in the abstract of that paper:
"*As the use of combustion as a means of reduction of municipal solid waste increases, methods for safe disposal of increasing amounts the flyash and bottom ash residues must be provided. Incinerator ash has been used beneficially for landfill cover, construction fill, highway construction, and as aggregate for concrete. However, while these residues contain mainly benign materials similar to natural earth, they also contain heavy metals which, depending upon the disposal method, might be leached out and result in contamination of the groundwater. Whether or not these metals could be leached out under the conditions of disposal depends on the chemical form of the metals. Ash residues appear to have sufficient alkalinity, or buffering ability, to resist acid rain when stored in ashfills, while the metals are slowly leached out producing leachates with low metals concentrations."*

C&D Waste Landfills
Our "Flawed Technology" review (beginning on page 57) discusses the potential for C&D wastes to cause groundwater pollution. There it is stated,

> "*Potentially significant concentrations, compared to drinking water maximum contaminant levels (MCLs), were found of 1,2- dichloroethane, methylene chloride, cadmium, iron, lead, manganese and total dissolved solids (TDS)" have been found in C & D waste leachate*." They report that "*Constituents causing groundwaters to exceed the drinking water MCL were iron, manganese, TDS and lead."*
>
> "*An issue of increasing concern about waste wood is the potential for treated wood to leach arsenic, copper and chromium. Townsend and his associates at the University of Florida have conducted a number of studies on the leaching of these chemicals from treated wood."*

It has also been recently found that some C&D wastes contain PCBs from caulking that was once used in buildings and other structures. Studies have shown that the demolition debris from old buildings can contain PCBs that can be released to the environment.

While the composition of C&D waste leachate can be somewhat variable depending on the type and source of C&D wastes deposited in the landfill, in general that type of waste can contain a variety of potential pollutants that are a threat to pollute groundwater with a hazardous and otherwise deleterious chemicals.

Industrial “Non Hazardous” Wastes
Some landfills receive “non-hazardous “industrial wastes.” The potential for these wastes to cause groundwater pollution is unknown at this time and requires site specific studies.

Leachate Recycle and Fermentation/Leaching Approaches
Our “Flawed Technology” review includes a summary of the use of leachate recycle and leaching to enhance the fermentation and leaching of MSW to shorten the period during which the buried wastes are a threat. As discussed in the paper cited below, MSW that has been shredded and exposed to leachate can be converted to a residue that no longer will produce landfill gas. This should be able to be accomplished in about 5 to 10 years provided that the leachate is evenly distributed and is adequate to ferment the wastes. At the end of landfill gas generation, clean water (e.g., local groundwater) should be added to the landfilled wastes to leach the readily leachable components of the remaining residues in the wastes. Leaching should be repeated until the leachate is of such a character that it would not represent a threat to groundwater. The leaching water should not be recycled through the waste but rather properly treated before discharge to the environment. (See “Flawed Technology” review page 78 for further discussion of this issue.)

> Lee, G. F. and Jones-Lee, A., "Landfills and Groundwater Pollution Issues: `Dry Tomb' vs F/L Wet-Cell Landfills," Proc. Sardinia '93 IV International Landfill Symposium, Sardinia, Italy, pp. 1787-1796, October (1993).
> http://www.gfredlee.com/Landfills/Fermentation-Leaching-Sardinia.pdf

It is important to understand that the fermentation/leaching approach discussed above differs significantly from today’s “leachate recycle.” For example, the fermentation/leaching approach stipulates that the wastes be shredded to reduce the “hiding” of MSW in plastic bags (which are only crushed in conventional landfilling) so that wastes are more fully and reliably exposed and subjected to fermentation and leaching. The fermentation/leaching approach also subjects the fermented wastes to sequential leaching with clean water, such as a local groundwater; that step is a key to removing residual potential pollutants that could otherwise leach from the fermented wastes and escape the landfill to pollute groundwater. The practice of fermentation/leaching of wastes should be restricted to properly designed and constructed double-composite-lined landfills that incorporate leachate detection systems between the two composite liners. That arrangement better enables the detection of compromises in the integrity of the upper composite liner to the point at which it no longer collects all the leachate generated in the landfill, at a time when the bottom liner still protects groundwater quality. Early detection of compromise of the upper liner provides the opportunity for termination of leachate recycle and early repair of the cover for better groundwater protection. Conducting leachate recycle in a single-composite-lined landfill, as is allowed today, can lead to increased groundwater pollution because of the increased amount of liquid in the landfill that has the potential to penetrate the liner and move to the groundwater without being detected by the groundwater monitoring wells that are typically used in today’s subtitle D landfills. Increased depth of leachate (head) on the liner will also increase the rate of leachate migration through the liner (See “Flawed Technology” review page 28 for further discussion of this issue.)

For ash and C&D landfills that do not include fermentable waste components and thus do not generate landfill gas, leaching of the wastes with clean water should be practiced to remove the leachable components that are a threat to pollute groundwaters. Of particular concern is the high salt content of ash landfill leachate. C&D waste landfills that receive tree stumps and other vegetative debris will produce not only landfill gas but also hydrogen sulfide gas through interaction with calcium sulfate in wallboard. At this time it is unclear how long wastes in ash landfills as well as some other types of landfills, such as industrial solid “non-hazardous” waste landfills, would leach chemicals that have the potential to pollute groundwater, impairing its use for domestic and other purposes. This will need to be evaluated on a site specific basis to understand the long-term threat posed by the ash residuals and potential benefits to be derived from leaching of ash with this process.

Need for Independent Third-Party Monitoring/Surveillance

For a variety of reasons including inadequate funding, regulatory agencies do not provide sufficiently diligent postclosure and post-postclosure monitoring, inspection, and/or supervision to ensure, with a high degree of certainty, that public health/welfare and environmental quality are protected from adverse impacts from landfills. As a supplement to the regulatory agency inspection, the landfill owner should provide funds to those in the sphere of influence of the landfill to hire an independent consultant to conduct an independent oversight review and to report findings to the nearby property owners/users and the regulatory agencies.

One of the components of the ongoing postclosure oversight should be a review of the literature of recent findings of new, previously unrecognized, and unregulated potential pollutants to determine if the water quality and air quality monitoring programs need to be expanded to include additional chemicals that are not included in the current monitoring program. For example, as discussed in our “Flawed Technology” review, there are numerous examples of what had been previously unrecognized pollutants in MSW – such as PPCPs, flame retardants, pesticides/herbicides used around the home/commercial establishments and industry – being found in MSW leachate. Such chemicals, not included in the typical groundwater monitoring program for MSW landfills, would need to be added to the monitoring regimen. There is need to have an ongoing review of the adequacy of the groundwater monitoring program parameters, as well as analytical detection limits relative to concentrations of concern, to keep it up-to-date with the current knowledge about chemicals that are a threat to cause water pollution.

As part of postclosure care landfill owners should fund independent, periodic (at least semiannual) monitoring of all offsite groundwater wells, including those used in agriculture and for animals) located within several miles of the landfill to determine if landfill leachate components have reached the well water. This distance may need to be extended in fractured rock aquifer and cavernous limestone systems to consider that leachate polluted groundwater can travel very long distances in fractures. The results of the monitoring should be reported to the property owner/user and the regulatory agency. If MSW leachate has entered the well an alternate water supply source should be provided, even if the pollutant concentrations are below MCLs, since there could be unrecognized or unmonitored hazardous chemicals in the well water.

Overview of MSW Landfill Development Issues as Related to Costs of Post-Postclosure Care Costs to Public Agencies

The need for funding provisions for care and remediation of MSW and other types of landfills during the post-postclosure period, i.e., after the statutory minimum postclosure funding period expires, has been sorely neglected. Postclosure funding periods are typically established at a given number of years – e.g., 30 yrs – following formal closure of the landfill in an effort to hold the landfill owner responsible for aftereffects of the landfilling operation. However, such a postclosure duration designation has essentially no relationship to the period during which the wastes in the landfill will pose a threat to public health/welfare or environmental quality.

As discussed herein there are numerous MSW landfill siting, design, operation, closure, and postclosure issues that state/county and other jurisdictions and public agencies need to evaluate and address to more reliably define the financial requirements and structure that will be needed to ensure that the owners of new, privately developed MSW landfills are held responsible for the totality of landfill monitoring and maintenance, and groundwater remediation for as long as the wastes in the landfill will be a threat to public health/welfare and environmental quality. The present practice of cessation of assured postclosure care after a given number of years, irrespective of the continued threat posed by the landfill ensures that the truly long-term post-postclosure care costs will be borne not by the waste generators or the landfill owner, but by the public in the vicinity of the landfill, in money and adverse impacts.

The fundamental problem is that the US EPA Subtitle D MSW landfilling regulations are inadequate, unreliable, and misleading for the development of MSW landfills that have the ability to protect public health/welfare, groundwater and surface water resources, and air quality within the sphere of influence of the landfill (typically a several-mile radius about the landfill) for as long as the wastes pose a threat. Public landfill developers also face the same long-term impact concerns, and postclosure and post- postclosure funding needs as private landfill developers. The public entities that develop landfills (e.g., cities and counties) however, cannot walk away from the responsibility for funding landfill monitoring, maintenance, and groundwater remediation as easily as private landfill developers.

Many of the deficiencies in federal and state landfilling regulations have been well-understood in the technical and regulatory communities since the late 1980s. Political considerations and administrative expedience have caused the US EPA and states to ignore, dismiss, or evade addressing these issues largely because it would cause the public that generates the garbage to pay significantly more for disposal/"management" of their wastes. Further, the overriding waste management strategy is to remove wastes from the densely populated urban areas and dispose of it in "remote" or "sparsely populated" areas – where there are fewer people to adversely impact – for as little money as possible. Thus, by and large, the bulk of the people who generate most of the waste are not faced with the public health/welfare and environmental quality consequences of the "disposal" of their waste. Those impacts are disproportionately inflicted upon the "fewer people" in rural environments in the vicinity of the landfills. This reality continues to lead to justified NIMBY ("not in my backyard") attitudes and actions by those in the vicinities of proposed MSW landfills. If MSW landfills were located in urban areas where the wastes are primarily generated, the waste-generating public would become much more cognizant of and less complacent about the deficiencies in today's US EPA and state landfilling regulations in the near-term while the landfill is receiving wastes as well as in the long-term.

As long as urban dwellers who generate the garbage can have their solid wastes "disappear" from their homes, businesses, and industry at relatively low cost (a few tens of cents per person per day), and not have to experience any of the adverse short-term or long-term impacts of MSW landfills, there will be little motivation to increase the costs of garbage disposal sufficiently to enable proper management of MSW in landfills that are fully protective of public health/welfare, and water/environmental resources in the sphere of influence of the landfill. Because of the grossly inadequate provisions for post-postclosure funding for MSW landfill care for as long as the wastes in the landfill will be a threat to generate leachate and landfill gas when contacted by water, the public in both urban and rural areas will have to pay for post-postclosure care and Superfund-like groundwater remediation costs, which are likely to be several tens of millions of dollars. The current landfilling approach will not only be a major financial burden to all the people in the area of the landfill/county/state and disproportionately those of rural areas, but also result in adverse health impacts and loss of water resources in the area of the landfill.

An approach for addressing this situation could be for local agencies such as municipal, county and state agencies that face long-term post-postclosure funding liabilities to require improvements in landfill regulations over the minimum required by the US EPA Subtitle D regulations to provide for technically valid and reliable landfill development and funding. Several states or parts of states have understood this situation and have adopted improved landfilling regulations, such as requiring a double-composite liner system with a leak detection system between the liners to better enable the early detection of the inevitable failures of the upper composite liner to collect the leachate generated in the landfill. As discussed herein and in our "Flawed Technology" review, the detection of leachate in such a leak detection layer would signal the need to locate and repair the areas of degradation or failure in the cover to stop the entrance of water into the landfill that generates leachate. The currently allowed landfilling approach for MSW and so-called "non-hazardous" waste does not provide the funding to make implement such an approach. Instead, as noted above and discussed in our "Flawed Technology" review, under the current approach there will inevitably be widespread groundwater pollution by landfills before deterioration and failure of landfill containment systems are recognized and addressed, consequences that may well be delayed until after the required postclosure care period has concluded. This leaves the public agencies in the area of the landfill with the responsibility for addressing the landfill and environmental consequences and the public with the public health/welfare and environmental quality impacts, as well as the financial burden of increased taxes to pay for the remediation.

In our writings (see "Flawed Technology" review), we suggest that those who generate solid waste be required to pay for the full costs of proper, reliable, and protective management of that waste as part of their garbage disposal fees. Sufficient funds need to be collected and placed in a dedicated trust fund that could be used only for post-postclosure plausible worst case care needs for as long as the wastes posed a threat. It is estimated that that approach could double to triple the cost of garbage disposal for those who generate the wastes, but it would more likely result in people's paying the true costs for the disposal of the wastes they generate.

Questions or comments on these issues should be directed to Dr. G. Fred Lee gfredlee33@gmail.com.

Announcement of American Society of Civil Engineers (ASCE) Election of Dr. G. Fred Lee as ASCE Fellow

In December 2009 Dr. G. Fred Lee was elected as an ASCE Fellow. This election recognizes Dr. Lee five decade career as a national/international leader university graduate level educator and environmental consultant. The ASCE announcement of this election is presented below.

G. FRED LEE, Ph.D., P.E., BCEE, F.ASCE, earned his Master of Science in Public Health from the University of North Carolina in 1957 and his PhD degree in environmental engineering from Harvard University in 1960. For 30 years he served on the graduate civil and environmental engineering/science faculty of several major US universities where he taught, conducted research, mentored the Masters and PhD work of 90 students, published extensively in professional journals, and actively undertook public service for the regulatory, professional, and lay communities.

In 1989 Dr. Lee retired from his academic career to focus on private consulting and public service; he is president of G. Fred Lee & Associates. Areas of emphasis include domestic water supply water quality focusing on how land use in a water supply watershed impacts water supply water quality; investigation and management of surface and groundwater quality, stormwater runoff, contaminated sediments, land surface activities that impact groundwater quality, and use of reclaimed wastewater; and investigation and management of impacts of solid and hazardous chemicals including MSW and hazardous waste landfills, Superfund, and other hazardous chemical sites.

Dr. Lee has served on the editorial boards for several professional publications, and currently serves on the editorial board for the Journals *Stormwater* and *Remediation*. Dr. Lee has long served on the American Academy of Environmental Engineers' (AAEE) examination board for AAEE professional engineer certification; until 2009 he served as Chief Examiner for Northern California in Water Supply and Wastewater and in the Hazardous Waste areas for 20 years.

Dr. Lee has published more than 1100 professional papers and reports many of which are posted on his website [www.gfredlee.com]. In addition, out of the need for greater influence of science and engineering in water quality regulation and management, he created and authors an email-based Stormwater Runoff Water Quality Newsletter which he has distributed about monthly for the past 12 years, at no-cost, to about 8,000 subscribers.