LANDFILLING OF SOLID & HAZARDOUS WASTE: FACING LONG-TERM LIABILITY[1]

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PREFACE

Although this paper was published in 1994, the information presented remains relevant today, more than two decades later. The authors' more recent and periodically updated professional literature-review-based discussion of many of the key technical issues and concerned associated with providing true, long-term protection of public health and environmental quality from landfilled wastes (Lee and Jones-Lee, 2015) is available on their website, www.gfredlee.com at http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf. Also available on their website is their invited overview paper concerning landfill post-closure and post-post-closure care funding issues (Jones-Lee and Lee, 2014) [http://www.gfredlee.com/Landfills/Funding_Issues_WasteAdvantage.pdf]. GFL and AJL 11/20/2015

ABSTRACT

In the past, the "cheapest" method available was used for the management of solid "non-hazardous" and "hazardous" waste. Now with "cradle-to-grave" liability, many companies are more critically evaluating the near-term and long-term liabilities and costs associated with various options for solid and liquid waste management. Recycle and reuse of wastes with residue management that eliminates long-term liability are the most desirable. However, most waste management programs involve some landfilling of wastes and/or treated residues. While claims are made about the environmental protection afforded by "modern" landfills of the type prescribed by the US EPA in Subtitles C and D for "hazardous" and "non-hazardous" wastes, the technical deficiencies in that "dry tomb" landfilling approach for the protection of groundwater quality for as long as the buried wastes represent a threat, are coming to be well-recognized in the technical community. The disposal of "hazardous" and "non-hazardous" wastes in such landfills carries a significant, perpetual liability for clean-up of contaminated groundwaters and eventual "Superfund"-like activities for waste removal and proper management. Recycling and reuse can reduce long-term liability but waste residues associated with recycling, reuse, and treatment can, if not properly managed, create other areas of long-term liability.

The inability of US EPA-prescribed Subtitle C and D landfills to prevent groundwater pollution by landfill leachate for as long as the wastes are a threat should be of significant concern to all waste generators. Solid and hazardous waste generators should critically evaluate the potential near-term and long-term liabilities associated with any particular approach for waste management, resource recovery (including fuel blending, solvent recovery, and reuse), and management of waste residues. This paper reviews why landfills of the type being

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developed today do not eliminate long-term liability associated with wastes and issues of long-term liability associated with alternative methods of waste management.

INADEQUACIES OF CURRENT LANDFILL DESIGN, OPERATION, CLOSURE AND POST-CLOSURE MAINTENANCE

In the early 1980's the US EPA adopted the "dry tomb" landfilling approach for what it classifies as "hazardous" waste (Subtitle C). It officially adopted the "dry tomb" landfilling approach for municipal solid waste (MSW) management (Subtitle D) in October 1991. While the Agency has not yet promulgated Subtitle D regulations for "non-hazardous" industrial wastes, many states are using Subtitle D regulations for landfilling of those types of waste, as well.

The "dry tomb" landfilling approach allows the placement of untreated MSW and untreated or partially treated waste classified as "hazardous" in lined landfills that are eventually covered with low-permeability covers at the time of closure. The premise is that if buried wastes can be kept dry, they will not generate leachate; if no leachate is generated, groundwaters will not be polluted.

No treatment is required for MSW or "non-hazardous" industrial waste buried in a Subtitle D landfill. At this time, the US EPA allows some types of hazardous wastes to be buried without treatment, in a Subtitle C landfill. For other types of hazardous wastes, it requires technology-based degree of treatment; the degree of treatment required, however, is not judged based on the elimination of threat to groundwater quality. For other types of hazardous wastes, sufficient treatment has to be provided for the wastes to pass the TCLP test.

The TCLP test, a leaching test used for classifying wastes as "hazardous," is technically inappropriate. A waste can "pass" the TCLP test if the concentrations of selected contaminants are less than 100 times the respective drinking water standards. The factor of 100 has no technical basis and was established by the US EPA to minimize the number of wastes that would have to be managed as hazardous waste under RCRA. It is well-recognized that a waste determined to be "non-hazardous" by the US EPA's definitions, can cause highly significant groundwater pollution and render groundwaters hazardous to public health and the environment or otherwise unsuitable for domestic water supply purposes. Jones-Lee and Lee (1) discussed significant deficiencies in the US EPA and many states' approaches for waste classification and determination of the degree of treatment required for certain of the wastes classified as "hazardous" before placement of the treated residues in a Subtitle C landfill.

Lee and Jones (2) and Lee and Jones-Lee (3) provided an in-depth discussion of technical inadequacies of the "dry tomb" landfilling approach being used today and its underlying presumptions, that preclude its providing for reliable protection of the beneficial uses of groundwater and associated aquifers for as long as the wastes represent a threat. While the focus of those reviews was MSW, they are equally applicable to industrial "non-hazardous" waste, untreated hazardous waste, and commercial/industrial "treated" hazardous waste residues. Key findings discussed in those reviews as well as by Lee and Jones (4) and Lee and Jones-Lee (5) are summarized below.

The key to keeping moisture out of a landfill is the landfill cover. A landfill cover of the type allowed today for Subtitle C and D landfills cannot be expected to prevent entrance of moisture into the landfill to create sufficient leachate to pollute groundwaters, for as long as the wastes are a threat. "Dry tomb" landfills rely on the containment features of a leachate collection and removal system (LCRS) and a liner or liners and to keep leachate that is generated from leaking into area groundwaters. Subtitle C and D landfilling regulations both prescribe a composite liner composed of plastic sheeting (flexible membrane liner - FML) and compacted soil/"clay" as a primary barrier

between the waste and the groundwater regime associated with the landfill. Subtitle D landfills are only required by the US EPA to use a single-composite liner. Some states, however, recognize significant deficiencies with that approach and require double-composite liners. The US EPA requires double-composite liners for Subtitle C (hazardous waste) landfills.

Whether there is a single- or double-composite liner, the liner systems allowed will not prevent passage of all leachate generated in the landfill. The functioning of the LCRS above the liner relies significantly on the integrity of the FML beneath it. FML's are not be impenetrable even at the initiation of landfill operation, and deteriorate over time. Further, LCRS's are prone to clogging that impedes the flow of leachate and can cause ponding and the build-up of head on the liner to further reduce the efficacy of the LCRS to collect leachate before it enters the groundwater system. The LCRS will allow the passage of some leachate through the liner system shortly after the landfill is put into operation, the amount increasing with the age and degree of deterioration of the system. The double-composite liner systems used for leachate containment provide an additional barrier to leachate transport, but they too, are not impermeable at the time of landfill operation and will deteriorate over time; they serves only to provide additional delay to the leakage of leachate.

While Subtitle C and D landfilling approaches will likely protect groundwater quality for the mandated 30 years after closure, neither protects groundwater quality from pollution by landfill leachate for as long as the wastes and treated waste residues are in the landfill. An important consideration in the matter of long-term landfill functioning and integrity is that the key containment components of a "dry tomb" landfill system are buried under typically hundreds of feet of garbage. They are not accessible to inspection, proper maintenance, and repair.

MSW, untreated non-hazardous and hazardous wastes, and treated hazardous waste residues in a "dry tomb" landfill contain hazardous and otherwise deleterious components that will be a threat to groundwater quality forever. Even with highly effective control of input of household and commercial hazardous chemicals, MSW will still contain substantial components that will, upon contact with moisture, produce a leachate that will contain large amounts of conventional pollutants, non-conventional pollutants, and identified highly hazardous chemicals that can readily cause groundwaters to be unusable for domestic and many other purposes.

As long as MSW and degradable organic hazardous wastes in the landfill are kept dry, fermentation ("stabilization") will be postponed. As sufficient moisture enters the landfill to allow fermentation, substantial amounts of leachate would be expected to be produced. Fermentation, however, does not "degrade" or render innocuous all hazardous and otherwise deleterious components of wastes that can adversely affect groundwater quality. Small amounts leachate from those materials can pollute very large amounts of groundwater. Without appropriate waste treatment, MSW waste-stream composition cannot be sufficiently modified by recycling, collection of hazardous substance, etc. to render waste residues that will not pollute groundwaters rendering them unusable for domestic purposes.

The US EPA and state regulatory agencies allow Subtitle C and D landfills to be sited in areas hydraulically connected to groundwaters; the inevitable failure of containment systems will result in groundwater pollution. Some claim that groundwater monitoring systems provide the last, fail-safe line of defense against groundwater pollution by landfill leachate. However, groundwater monitoring systems of the type prescribed by the US EPA and states for monitoring of lined, "dry tomb" landfills do not detect liner leakage, but rather require that groundwater first be polluted. That notwithstanding, they have a low probability of detecting groundwater pollution before widespread pollution has occurred.

Subtitle C and D regulations include a groundwater monitoring system with vertical monitoring wells at the down-groundwater-gradient point of compliance for groundwater protection; the wells are spaced hundreds to a thousand or more feet apart. The detection of a statistically significant increase in concentration of few selected parameters in the groundwater across the landfill signals containment failure. Downgradient monitoring wells, with zones of capture of a foot or so, have little likelihood of detecting the narrow finger-plumes of incipient pollution of groundwater characteristic of lined landfills. By the time the monitoring system detects groundwater pollution by landfill leachate, widespread groundwater pollution would have already occurred. Once a groundwater is contaminated with landfill leachate, neither the groundwater nor the associated aquifer area can be "cleaned up" so as to provide a reliable source of water for domestic and certain other purposes.

Despite the perpetual threat of components of wastes buried in Subtitle C and D landfills, Subtitles C and D mandate only 30 years of post-closure care monitoring and maintenance of the landfill containment structure and groundwaters. Many states, however, have explicit performance standards for landfills that specify that there be no impairment of beneficial uses of groundwaters by landfill leachate. Some states, e.g., California, explicitly require that that protection be maintained for as long as the wastes represent a threat to groundwater; others place no limit on the period over which groundwater quality protection must be provided. While landfill applicants try to assert that such protection requirements apply only for the 30-year minimum post-closure care period, that period is unrelated to, and an infinitesimal portion of, the time during which buried municipal and industrial solid wastes and "treated" hazardous waste residues represent a threat to groundwater quality.

In its proposed MSW regulations the US EPA (6) stated,

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

In addition, the US EPA (7) stated with reference to lined municipal solid waste landfills,

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

The US EPA has acknowledged that once groundwater is polluted by MSW landfill leachate, water supply wells drawing from that source must be abandoned (8). In practice, the "dry tomb" approach for municipal and industrial "non-hazardous" and "hazardous" waste landfills is a flawed technology that at best only postpones groundwater pollution; it will not prevent it. Many of the components of the "dry tomb" landfilling approach will not, and would not be expected to, function reliably without significant failure for the infinite period over which MSW, many of the so-called "non-hazardous" industrial solid wastes, and treated "hazardous" waste residues represent a threat to groundwater quality. There is a pressing need to develop an alternative approach to the "dry tomb" storage of MSW, industrial "non-hazardous" waste, and treated "hazardous" waste residues if perpetual groundwater quality protection is to be achieved.

ALTERNATIVE APPROACHES

The issue of concern is the cost-effective management of MSW, "non-hazardous" industrial wastes, and treated "hazardous" waste residues in such a manner that they do not adversely affect public health, environmental quality, or water resources for as long as the wastes represent a threat. Those considerations lead to the following categories of alternatives:

- condemn groundwater aquifer systems that are

in any way hydraulically connected to substrata beneath a "dry tomb" landfill and acknowledge that the "beneficial use" of those groundwaters is to accept landfill leachate to allow cheaper disposal of MSW and "non-hazardous" and hazardous industrial wastes;

- locate storage facilities for untreated or partially treated wastes, such as "dry tomb" landfills, only in areas where there are no groundwaters hydraulically connected to strata beneath the landfill that could, with or without treatment, be used for water supply; or

- treat the wastes sufficiently to remove all components that could adversely affect beneficial uses of the groundwater, prior to permanent storage of the residues.

While some advocate "managed" leachate-pollution of groundwater as the most cost-effective method of solid waste management, the inability to reliably predict the extent and degree of pollution of groundwater makes this approach tenuous at best. The sanctioned condemnation of groundwater to prevent its use for domestic water supply would require changes in federal and state regulations. Lee and Jones-Lee (9) discussed the role of proper siting of landfills for the protection of groundwater quality; areas in which groundwaters are hydraulically connected to the strata beneath a landfill can generally not be considered to provide the perpetual protection that is warranted. While there may be sites in which groundwater is not hydraulically connected to the substrata and that would thus not be threatened by "dry tomb" landfill siting, it should not be anticipated that such sites are readily available or easy to document. The remaining option, the proper treatment of wastes, offers the potential to truly protect groundwater quality.

Aerobic composting and incineration have been, and will continue to be, used for treatment of at least part of the MSW stream in some areas. It is becoming recognized, however, that substantial parts of the MSW stream and many industrial wastes cannot be composted, and that compost containing hazardous chemicals is difficult to re-use. The public's opposition to MSW incinerators, and associated concerns about air emissions from incinerators and ash management have greatly curtailed the use of incineration for management of MSW in the US.

Lee and Jones-Lee (10) discussed a fermentation/leaching (F/L) "wet-cell" approach for management of MSW in landfills. Rather than trying to keep the wastes dry in perpetuity and ultimately failing to do so, the F/L wet-cell approach deliberately adds leachate during the fermentation period when landfill gas is produced. It is expected that the fermentation period would be completed within five years for MSW and many industrial organic wastes. After fermentation, the waste would be leached with "clean" water to remove those components of the waste that pose long-term threats to groundwater quality. The leachate produced during that leaching period would be collected and treated. It is estimated that the leaching period would be completed in 10 to 15 years. The total treatment period of 15 to 20 years is well-within the period during which the components of a properly constructed double-composite-lined landfill including the FML would be expected to function effectively to collect essentially all of the leachate generated within the landfill.

Since the US EPA's approach for monitoring landfill liner failure requires that groundwater first be polluted, and since it has a low probability of detecting incipient groundwater pollution, Lee and Jones-Lee (5, 11, 12) recommended that all landfills hydraulically connected to groundwater that may be used at any time in the future for domestic water supply purposes, be constructed with double-composite liners. The lower composite liner would not serve as a containment liner, but rather as the foundation of a leak detection system for the upper composite liner. Between the two composite liners would be a leak detection system of the type typically used in Subtitle C landfills and some states' Subtitle D landfills. When leachate is detected in the leak detection

system in sufficient amounts to lead to groundwater pollution were it not for the lower composite liner, the use of the landfill for storage of wastes would be terminated and the waste residues removed from the landfill and properly treated; any non-recyclable, adequately-treated residues would then be buried in a landfill. This approach recognizes and addresses the technical flaws in the US EPA's Subtitle C and D groundwater monitoring approaches for "dry tomb" landfills.

WASTE REDUCTION AND RECYCLE

One of the best ways to limit the long-term liability for public and private interests associated with landfilling of MSW and industrial non-hazardous and hazardous waste is to reduce the waste stream to the maximum extent practicable through waste minimization and reuse/recycle. It is important, however, to understand that not all waste diversion from a landfill is necessarily more protective of public health and the environment. While diverting the waste stream from a landfill to some other location for management may reduce the liability associated with the landfilling, the other methods of management may create their own significant problems and liabilities. Lee and Jones-Lee (9, 13) discussed the importance of properly evaluating the potential near-term and long-term impacts of alternative approaches for solid waste residue management so that the alternatives do not also create significant problems for those in the vicinity of the waste management area/facility and cause long-term liability that will ultimately have to be addressed by the waste generators.

Incineration

If properly conducted, incineration is an effective way to reduce the magnitude of the hazardous waste stream that must be managed in a landfill. Incineration has proven to be costly compared with other methods of waste combustion, and requires very close regulatory supervision to ensure proper incineration and perpetual management of the incinerator bottom ash and solids derived from air pollution controls. Those solids are typically classified as hazardous and are landfilled. If that landfilling is done in a Subtitle C landfill, the industries that send waste to the incinerator could ultimately become responsible parties for long-term problems at those landfills.

The use of high-BTU industrial wastes as supplemental fuels for industrial furnaces, such as cement kilns, can be highly effective and results in limited long-term threat to public health and the environment and hence limited long-term liabilities. The high temperature, long residence time, and presence of cement, make a cement kiln highly effective for combustion of organics and immobilization of combustion residues and non-combustible components of the waste. Dellinger et al. (14) reviewed potential problems associated with hazardous waste management in cement kilns. They concluded that while there are potential problems associated with improper handling of the waste and their addition to a cement kiln, those problems can be readily managed.

There are significant limitations on the waste stream that can be managed in cement kilns. Wastes with high concentrations of heavy metals that will either be released to the atmosphere or represent a hazard in the cement and fly ash produced, must be controlled. Cement kiln operators are placing increasingly strict requirements on the contaminants that can be accepted in blended supplemental fuel in order to better control the impact of contaminants on the characteristics of the cement and the dust recovered from the kiln exhaust air cleaning operation.

Solvent Recycling

Recycling of waste organic solvents has been practiced for many years for cost-savings. With the development of RCRA, many firms that had disposed of spent solvents are now recovering them. The typical recovery approach is the distillation of the solvent from the contaminants. A market exists for many recycled solvents.

The high-BTU solvents that cannot be sold can be blended as a waste fuel. Still bottoms and other residues associated with solvent recovery can also often be blended as a supplemental waste fuel for cement kilns. If incinerated in a hazardous waste incinerator many of these contaminants would cause the ash to be classified as a hazardous waste. However, in cement kiln incineration, the contaminants are converted to chemical forms that represent limited threats to public health and the environment.

CURRENT WASTE MANAGEMENT PRACTICES RELATIVE TO LONG-TERM LIABILITY

The current approach to addressing the long-term liabilities of solid waste management by landfilling range from ignoring the issues, to managing wastes to eliminate long-term labilities, “cradle to grave.” In the latter case, the "grave" is complete destruction of the organic residues and the proper fixation of the non-destructible residues such as the inorganics so that they will not be a threat to groundwater quality. Fixing the waste residues to just achieve TCLP maximum limits, however, cannot be presumed to eliminate the threat to groundwater quality. Instead, a site-specific hazard assessment should be conducted of the "fixed" residues to evaluate whether the degree of fixation is adequate for the specific location at which waste residues would be deposited. Lee and Jones (15, 16) provided guidance on the factors that should be considered in conducting site-specific leaching tests and hazard assessments for particular types of wastes for particular disposition.

The public and their representatives commonly object to even nominal increases in the cost of MSW management, although the authors believe that this would not be a significant issue if the public were properly informed of the long-term costs and consequences of current landfilling approaches and how wise use of funds could substantially reduce their risks. While the US EPA (8) estimated that the cost of implementing minimum Subtitle D requirements was about 0.3¢/person/day greater than the cost for a classical sanitary landfill, others are finding that the real cost increase is on the order of 3¢/person/day (17). Lee and Jones-Lee (17) estimated that the cost of landfilling of MSW in a manner that will not pose a long-term threat to groundwater resources in the vicinity of the landfill is about 10¢/person/day. The costs of failing to provide such protection will be much larger and will be accompanied by a permanent loss of groundwater resources. One of the most significant aspect of the costs is that they will have be paid by future generations as "superfund" clean-up costs, loss of groundwater resources, etc.

The cost of proper management of industrial hazardous and non-hazardous wastes is highly specific to the waste and industry. The costs are, to some extent, passed on to the public in the prices of products unless competition makes that disadvantageous. Typically, however, the increase in the price of a product to achieve limitation on long-term liability for waste management is small.

Some industries will not use waste disposal approaches that have long-term liabilities. For example, some firms have established strict policies against using hazardous waste TSD firms that cannot assure them that their waste will not be co-mingled with other wastes that are managed by approaches that will ultimately result in groundwater pollution by landfill leachate, such Subtitle C or D landfills. One firm has established a policy that requires that its waste residues be placed in up-groundwater-gradient landfill cells so that it will not be named as a responsible party when the landfill is found to be polluting groundwater. The theory is that leachate-pollution of groundwater would be detected first from other firms' wastes placed downgradient, so that action could be taken on its own wastes before they contribute to the pollution. Such an approach may not work because of the unreliability of US EPA's and many states' groundwater monitoring programs at Subtitle C and D landfills. By the time that

groundwater pollution is detected, the upstream waste disposal cell will likely have contributed to significant groundwater pollution with the result that the firm would have superfund liability.

Industries should understand that all landfills are not created equally with respect to their potential to cause leachate-pollution of groundwater and the associated long-term liability. The US EPA and many states allow the siting of Subtitle C and D landfills independent of the value of the groundwater that would ultimately be polluted by leachate from a dry tomb landfill. Public and private waste generators should track all of their wastes from cradle to grave. If a landfill is part of the management of the wastes, an independent assessment should be made of the potential for that landfill to cause groundwater pollution at any time in the future. If the landfill's location (siting), design, operation, and proposed closure and post-closure care are not protective of the groundwater resources, anther landfill should be found that will provide the degree of protection that the industry wishes to achieve.

The autumn 1993 issue of WMX Technologies, Inc. *Views* contained an article on the importance of using Subtitle D landfills rather than "sanitary" landfills to reduce the long-term liability for disposal of industrial solid wastes was discussed. However, that discussion did not provide adequate information on liabilities associated with Subtitle D landfills. Landfills that conform to minimum Subtitle D requirements as now being implemented will, at most locations, only postpone the manifestation of the liabilities. Industry and the public must look to other ways of managing solid waste to eliminate long-term liability for wastes.

CONCLUSIONS

The placement untreated solid waste or partially treated hazardous waste residues in Subtitle C or D landfills exposes the waste generator to considerable liabilities for the inevitable pollution of groundwaters. Landfill cover systems cannot be expected to prevent entrance of moisture into the landfill in perpetuity. The LCRS will not prevent leachate from leaving the landfill, especially as the FML at its base deteriorates; the system is not accessible for inspection and repair. The groundwater monitoring approach advanced by the US EPA and many states will not detect liner leakage or groundwater pollution before widespread pollution occurs. These deficiencies are characteristic not only of single-composite-lined landfills, but also double-composite-lined landfills; the latter only offers somewhat greater delay of pollution. The best approach for adapting the "dry tomb" landfill for greater groundwater quality protection is to use two composite liners and develop the lower composite liner system to function as the base of a full-landfill-area pan lysimeter liner leak detection system rather than as an additional containment layer. Waste removal and proper treatment would be required once the lysimeter system detected leachate leakage.

In order to reduce or potentially eliminate the long-term liabilities associated with current landfilling practices, it will be necessary to remove those components of the wastes that can ultimately lead to public health and environmental problems, prior to or shortly after their placement in the landfill. Of primary concern are components that lead to formation of landfill gas or leachate which when added to groundwaters can cause them to become unusable for domestic water supply purposes.

Public and private interests need to critically evaluate all components of the cradle-to-grave management of its wastes to determine if the assess their long-term liabilities. The US EPA's and states' regulatory approaches governing the "grave" aspect ("dry tomb" landfills) is technically flawed and will result in future generations' having to conduct Superfund-like programs at what are today's approved Subtitle C and D landfills to clean up the contaminated groundwaters, handle the buried wastes, and replace lost groundwater resources. There is an immediate need to understand the realities of "dry tomb" landfilling and terminate the use of

that approach in areas hydraulically connected to groundwaters that are being, or could at any time in the future be, used for domestic water supply. Alternative approaches are available that will not pass on part of the costs of the management of today's MSW's, industrial non-hazardous wastes, and hazardous waste residues to future generations.

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