LANDFILLS AND GROUNDWATER POLLUTION ISSUES: "DRY TOMB" VS WET-CELL LANDFILLS

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SUMMARY: The common approach to management of MSW today is burial in lined, "dry tomb" landfills. While incorporating systems to postpone leachate generation and leakage to pollute groundwater, "dry tomb" landfills do not provide protection of groundwater quality for as long as the wastes represent a threat. An alternative approach is discussed that uses available technology to treat MSW to remove leachable, polluting contaminants, prior to final disposition of residues.

INTRODUCTION

The US EPA (1991) officially adopted the "dry tomb" landfilling approach for municipal solid waste (MSW) management in the US. That approach is the placement of untreated MSW in lined landfills that are eventually covered. The concept is based on the premise that if buried wastes can be kept dry, they will not generate leachate; if no leachate is generated, groundwaters will not be polluted. The typical features of a "dry tomb" landfill and intended functioning include:

- Liner. The liner is typically a composite liner composed of a compacted clay underlayer with an overlying flexible membrane liner (FML) which is thin plastic sheeting. The liner is relied upon to prevent escape of leachate from the landfill to surrounding geological strata and to serve as the foundation for the leachate collection and removal system.
- Leachate collection and removal system (LCRS). The LCRS is a drainage system located above the liner that is relied upon to collect and transport all leachate to a point from which it can be removed by pumping or gravity flow. Leachate is generated by the contact of the wastes with moisture that enters the landfill from precipitation, and, for landfills with wastes below the watertable, from the groundwater.
- Cover. A low-permeability covering is placed over the landfill once it has been filled. The cover is relied upon to keep atmospheric and run-on moisture out of the landfill.
- Groundwater monitoring wells. A groundwater monitoring program is relied upon to signal the failure of the landfill system to control leachate.
- Other systems may be incorporated in a "dry tomb" landfill design to enhance the ability of the system to repel moisture or to manage leachate.

Lee and Jones (1992a) provided an in-depth discussion of technical inadequacies of the "dry tomb" landfilling approach as it is being used today and its underlying presumptions, that preclude its providing for reliable protection of the beneficial uses of groundwater

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

Proceedings Sardinia 93, Fourth International Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 11-15 October 1993

associated aquifers for as long as the wastes represent a threat. While the focus of that review was MSW, the discussion is equally applicable to industrial "non-hazardous" waste and commercial/industrial "treated" hazardous waste residues. Key findings discussed in that review as well as by Lee and Jones (1991, 1992b,c) are summarized below.

A landfill cover cannot be expected to prevent entrance of moisture into the landfill to create sufficient leachate to pollute groundwaters. Landfill liner systems will not prevent passage of all leachate generated in the landfill. It is only a matter of a short time before gases and liquids that pass through the FML through holes or by permeation will penetrate the compacted clay layer below. The functioning of an LCRS is significantly influenced by the integrity of the liner beneath it, which will not be impenetrable, even at the initiation of landfill operation, and will deteriorate over time. 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 liner. Thus, the LCRS will allow the passage of some leachate through the liner system, the amount increasing with the age of the system. Key components of a "dry tomb" landfill system are not accessible to inspection, proper maintenance, and repair.

As long as the wastes in the landfill are kept dry, fermentation ("stabilization") processes will be postponed. As sufficient moisture has entered the landfill to permit fermentation, substantial amounts of leachate would be expected to be produced. Fermentation does not "degrade" all hazardous and otherwise deleterious components of the waste that can adversely affect groundwater quality. Groundwater monitoring systems of the type being used today for monitoring associated with lined, "dry tomb" landfills have limited ability to detect groundwater pollution before widespread pollution has occurred. Once a groundwater is contaminated with MSW leachate, neither the groundwater nor the associated aquifer area can be "cleaned up" so as to provide a reliable source for domestic and certain other purposes.

MSW in a "dry tomb" landfill will be a threat to groundwater quality forever. Small amounts of MSW landfill leachate can pollute very large amounts of groundwater. 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 non-usable for domestic and many other purposes. The MSW waste-stream composition cannot be sufficiently modified by recycling, collection of hazardous substance, etc. without actual waste component treatment, to render waste residues that will not pollute groundwaters rendering them unusable for domestic purposes.

In its MSW regulations specifying a single-composite liner as the minimum requirement for an MSW landfill, the US EPA (1991) stated, "The composite liner system is designed to be protective in all locations, including poor locations." That statement has been used by landfill proponents to claim that the US EPA has found that a single-composite-lined landfill will protect groundwater quality for as long as the wastes represent a threat to it. As discussed by Lee and Jones-Lee (1992d), review of the assumptions and constraints considered by the US EPA in making that statement shows that it does not reflect a position that a single-composite liner of the type prescribed by the US EPA will protect groundwater quality for as long as the wastes in the landfill represent a threat.

Many states have explicit performance standards for landfills that there be no impairment of beneficial uses of groundwaters by landfill leachate. Some states explicitly require that that protection be achieved for as long as the wastes represent a threat to groundwater; others simply 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 over which buried municipal solid wastes represent a threat to groundwater quality.

In making the statement cited above, the US EPA assumed that there will be failure of the composite liner systems to prevent leachate from polluting groundwater. In its proposed MSW regulations the US EPA (1988a) stated,

"First, even the best liner and leachate collection system will ultimately fail due to natural

deterioration, and recent improvements in MSWLF (municipal solid waste landfill) containment technologies suggest that releases may be delayed by many decades at some landfills."

In addition, the US EPA (1988b) 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."

Even the US EPA recognizes that its statement that a composite liner will be "protective at all locations" does not mean that there would not be leachate-pollution of groundwater. The US EPA's MSW regulations do not require protection of groundwater quality against all types and causes of impairment, only against a selected group of chemicals that are classified under regulation as "hazardous." The US EPA has acknowledged that once groundwater is polluted by MSW leachate, water supply wells drawing from that source must be abandoned (US EPA, 1991).

Therefore, the US EPA's definition of "protective" is not adequate to comply with the fundamental need to prevent impairment of beneficial uses of groundwater for as long as the wastes represent a threat to it. In practice the "dry tomb" landfilling approach now adopted for municipal and "hazardous" waste landfills is a flawed technology that at best only postpones groundwater pollution; it will not prevent groundwater pollution. Many of the components of the "dry tomb" landfilling approach will not and would not be expected to perform their functions reliably without significant failure over the infinite period over which the MSW's, many of the so-called "non-hazardous" industrial solid waste residues, 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, as well as treated "hazardous waste" residues in such a manner that they do not adversely affect public health, environmental quality, and water resources. Key problems presented by such wastes that must be addressed in their management are that: left untreated or insufficiently treated, the wastes remain a threat forever; systems designed today to isolate untreated or partially treated wastes from groundwater cannot provide perpetual protection of groundwater quality; society has grown accustomed to paying little to have its garbage and other wastes "disappear;" and embellishment of the flawed "dry tomb" waste management approach with additional components increases the cost of waste management, may provide some further postponement of groundwater pollution, but will not in the end provide protection of groundwater quality 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 garbage and other 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 any component that could adversely affect beneficial uses of the groundwater, prior to permanent storage of the residues.

As discussed by Lee and Jones-Lee (1992d) sanctioned condemnation of groundwater to preclude its use for domestic water supply would require changes in federal and state regulations. Lee and Jones-Lee (1992d) also 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 ad infinitum 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, which offers the potential to truly protect groundwater quality, is the treatment of wastes prior to disposal of residues.

Aerobic composting and incineration are approaches that 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 cannot be composted and that compost containing hazardous chemicals from the waste stream 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.

Fermentation/Leaching (F/L) Wet-Cell Approach

In the context of MSW management, "fermentation" is the anaerobic, biochemical conversion of certain types of organic matter into CH_4 and CO_2. That process, also known in the solid waste arena as "stabilization," requires moisture; the CH_4 and CO_2 produced, along with chemicals that volatilize, make up "landfill gas." Fermentation does not act on most of what are considered to be hazardous and deleterious components of municipal solid waste, such as heavy metals, non-fermentable organics, salts, and many of the conventional pollutants. It has been known for many years (see review by Lee et al., 1985; Lee and Jones, 1990) that the recycle of leachate through a classical, wet "sanitary" landfill can greatly accelerate the stabilization of the wastes with respect to methane-formation. The leachate produced through leachate-recycle, however, has a tremendous potential to pollute groundwater, even after the "stabilization" is considered complete (i.e., when gas formation ceases). Therefore, the so-called "stabilized waste" still must be considered a highly significant threat to groundwater quality.

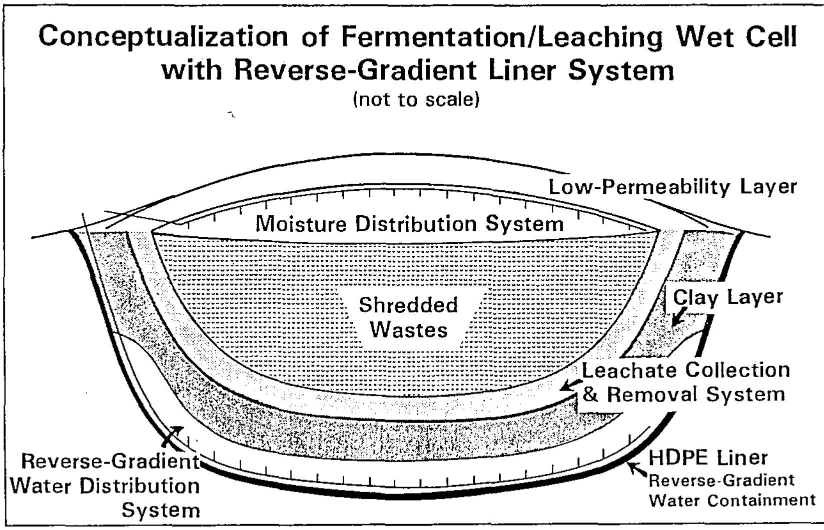
The key to proper MSW management for the protection of groundwater quality is the treatment of the wastes to remove those components that could adversely affect groundwater quality. The threat to groundwater quality comes from essentially anything that can be leached from the wastes or their fermentation residues. The F/L Wet-Cell approach proposed involves the addition of moisture to shredded MSW to ferment the fermentable organics in the waste, and the subsequent leaching of the soluble, potentially polluting components of the stabilized wastes with clean water. There has been limited study of the leaching characteristics of "stabilized" solid waste, especially over the long-term. However, a study conducted by EMCON (1975, 1976) and the Department of Public Works of Sonoma County, California provided data that showed that the addition of clean water to a landfill over a four-year period significantly reduced the pollutional character of leachate generated. It is clear from that study, as well as from consideration of elementary chemical principles, that by the addition of clean water to a fermented waste, the leachable contaminants should eventually be removed.

The primary siting considerations for an F/L Wet Cell remain prevention of groundwater pollution and prevention of adverse impact on owners/users of adjacent and nearby properties. As discussed by Lee and Jones-Lee (1992d), it is best to site such facilities in areas not hydraulically connected with sensitive or significant groundwater resources.

A key to proper F/L Wet-Cell design and operation is the deposition of waste in the landfill in such a manner that allows the added moisture to come in contact with all of the waste components. This will require that the waste be shredded prior to placement in the treatment cell. Waste shredding could also eliminate the need for daily cover; Ham (1975) found that if MSW is shredded, the residues do not need to be covered with soil each day. Waste-shredding has been practiced at the Highway G Landfill near the city of Eagle Mountain, Vilas County, Wisconsin for the past several years at a cost of about \$10/ton. That landfill is reported to cause localized odors at some times, of a nature and magnitude similar to those caused by landfills that receive daily cover. The shredding of the wastes would increase the capacity of the landfill by about 20% owing to greater waste compaction and the elimination of daily cover.

Figure 1 provides a conceptual drawing of the components of an F/L Wet Cell described herein.

Figure 1



During the fermentation and leaching process there is a potential for groundwater pollution to occur. There is, therefore, need to design and operate the system to prevent leachate from leaving the cell to pollute groundwaters in the vicinity of the landfill. It might be possible to use a double-composite liner system of the type specified for hazardous waste landfills and being used in some US states, for the fermentation and leaching cell. However, the ability to construct such systems so that they will not allow sufficient leachate to pass through the liner system over the 15 to 20 years after landfill closure that fermentation and leaching will likely have to occur, is questionable. It is therefore recommended that a reverse-gradient liner system be constructed and operated beneath the cell. Such a system would provide a positive head of clean water from beneath the cell to maintain movement of that water up through the clay layer into the leachate collection and removal system to prevent the downward leakage of liquids from the system. An 80-acre reverse groundwater gradient landfill, the Gallatin National Landfill, has been constructed near Fairview, IL (Angell, 1992; Burke and Haubert, 1992).

The conceptual system would consist of the following components (Figure 1):

- Leachate collection and removal system. An LCRS of the type typically used today, with appropriate collection pipes in small gravel, would be placed beneath the wastes. No geonets would be used because of their potential lack of stability and their susceptibility to biological clogging. The LCRS would have a permeability of no less than 10-1 cm/s and would have sufficient capacity to transport all of the clean water added from below, as well as the recycled leachate and clean water added from the top of the waste as part of the fermentation and leaching process. The design of the LCRS should incorporate features to enable the flushing of the system to remove biological clogging of the gravel system and transport-pipe openings.
- Clay layer. Beneath the LCRS would be a clay layer at least 3 ft thick. It is suggested that the clay have a permeability of about 1x10-6 cm/sec. This is a significant deviation from the current requirements of US EPA regulations and those of a number of states that specify a maximum permeability of the compacted soil-clay layer in landfill liners of 1x10-7 cm/sec. The clay layer prescribed for the reverse-gradient liner system, however, does not serve the same function as that prescribed by those regulations. The greater permeability is recommended to promote the upward movement of the clean water through the clay layer to counteract the diffusional transport of leachate-derived components down through the clay. If the permeability of the clay

layer were to be 1x10-7 cm/s, over extended periods of time the diffusional transport downward could be sufficient to allow leachate-derived components to break through the clay layer and thereby contaminate the underlying reverse-gradient water distribution system.

- Beneath the clay layer would be a sand or small-gravel bed about 2 ft thick in which the piping for the reverse-gradient water distribution system would be located. Into that system clean water would be introduced to ensure that a positive head of about one foot would exist at the top of the clay layer. The geology of some sites may allow the water head from beneath the cell to be provided by the area groundwater.
- Beneath the reverse-gradient water distribution header system would be placed an HDPE FML, at least 80-mil but preferably 100-mil thick, or other suitable liner material.
- Upper header system. On top of the shredded wastes would be placed another header system, consisting of perforated pipes, for the introduction of recycling leachate and clean water for the fermentation and leaching processes. That system could also collect the landfill gas that will be generated during the fermentation phase of the operation. If the dual purpose cannot be served, a separate gas collection would be needed.
- Cover. Above the upper header system would be placed a low-permeability cover whose primary function would be in the collection and recovery of landfill gas. It would not be designed and would not have to function as a moisture barrier as it would in a "dry tomb" landfill. The cover could be composed of compacted clay and/or a flexible membrane liner.

Based on the work in Sonoma County, CA (EMCON, 1975, 1976) as well as on the findings of other investigators (e.g., Pohland and Harper, 1987), it is anticipated that the leachate-recycle phase of the fermentation operation would be completed within 4 to 5 years. The duration of the leaching process would depend on the thickness of the waste, the ability to penetrate the waste with adequate moisture for leaching, the areal hydraulic loading of clean water, and the characteristics of the waste. In wet climates there may be need to remove some of the leachate during the fermentation phase to maintain an appropriate water balance. In dry climates or during drought periods in wet climates, there may be need to add water beyond the leachate-recycle to maintain adequate moisture in the landfill to optimize biological fermentation.

The leachate that is removed from the cell would have to be treated as a complex industrial wastewater. It may be possible to blend the leachate in small amounts into a publicly owned treatment works (POTW) waste stream. However, because of the increasingly stringent limitations on contaminants in POTW discharges, it may be necessary to pre-treat the leachate to produce a wastewater that would be compatible with the POTW operations and not cause violations of discharge limits. As discussed by Lee et al. (1985), such treatment could involve a combination of aerobic and anaerobic treatment with powdered activated carbon and chemical precipitation.

It may be necessary to use activated carbon beds as a polishing step for treatment of leachate generated during some phases of the fermentation and leaching process. Further, for some systems, especially in arid areas, the TDS concentration in the leachate could be sufficient so as to require a reverse osmosis treatment step.

The US EPA (Lawrence, 1992) indicated that the wet cell approach is compatible with federal MSW regulations and that it is being investigated by the US EPA as an alternative to the "dry tomb" approach. It is important to note, however, that a "wet cell" approach that does not incorporate exhaustive leaching of the stabilized wastes will not result in a residue that would no longer be a threat to groundwater quality. Deliberate and exhaustive leaching of the stabilized waste residues is essential to eliminate the components that lead to groundwater pollution.

Once the characteristics of the leachate collected above the clay layer remain such that the leachate no longer represents a threat to groundwater quality, the deliberate addition of moisture to leach the waste can be stopped and the head on the reverse-gradient liner system can be lowered so that water would no longer pass upward through the clay layer. The reverse-gradient water distribution system under the clay layer should be maintained in an operational condition, however, for a projected 20 years or more after the wastes are believed to have been sufficiently leached. During that time, the water in the water distribution system should be periodically sampled to determine if leachate-derived components have contaminated the water. Such contamination would indicate that pockets of waste had not been properly leached during the fermentation and leaching period. If problems of this type are encountered it may be necessary to re-activate the deliberate addition of moisture and the reverse-gradient flow to reach the areas of the waste that had not been properly leached during the previous operation of the system.

The low-permeability cover, constructed on top of the landfill, would only need to be maintained during the first approximately 5 years of unit operation, i.e., during the gas production phase. After that time there would be no need to maintain the low-permeability nature of the cover; the addition of moisture from precipitation would not represent a potential threat to groundwater quality either because moisture was being added to the landfill for fermentation or leaching, or because the wastes in the unit would have been sufficiently leached so that additional moisture would not produce leachate that would represent a significant threat to groundwater quality.

The lands above a "dry tomb" landfill are extremely difficult, if not impossible, to ever reuse because of the potential for cover disturbance that exacerbates leachate production. However, the addition of moisture would be no problem for a closed F/L Wet Cell since the buried waste residues would have been stabilized and the leachable components removed. Thus, the buffer area around an F/L Wet Cell landfill as well as the land above the landfill can be reused for other purposes, and the highly expensive perpetual care that would be needed for a "dry tomb" landfill cover is eliminated.

Because of the possibility that the reverse-gradient liner system and/or the HDPE liner could fail to prevent leachate-contaminated water from leaving the system, it would be necessary to monitor the groundwaters downgradient from the landfill as long as the site remains active. Because the F/L Wet-Cell system would be underlain by an HDPE liner, the leakage would initially be through point sources in the liner (holes and imperfections). Such leakage would produce fairly narrow plumes or "fingers" of leachate-contaminated groundwater such as would be produced from "dry tomb" landfills. As discussed by Lee and Jones (1992c), the vertical monitoring well system that is typically used today with "dry tomb" landfills does not provide a high probability of detecting groundwater pollution before widespread pollution has occurred. Such a monitoring approach would not be any more effective for the F/L Wet Cell than it is for the "dry tomb" landfills. Therefore, it is recommended that a series of horizontal wells be constructed across the downgradient face of the F/L Wet Cell just below the watertable. Samples would be collected periodically along the length of the wells to determine if leachate-derived contaminants were polluting the surface layers of the watertable (see Lee and Jones, 1992c).

While there would be some additional known early-term costs associated with the F/L Wet-Cell approach that would not be incurred with the "dry tomb" landfill, over the long term the F/L Wet-Cell approach would save money in post-closure care costs as well as in the preservation of groundwater resources. Furthermore, the costs and time of expenditures would be predictable and fairly well-known with the F/L Wet Cell. By contrast, many inevitable expenditures for a "dry tomb" landfill such as associated with cover replacement, leachate treatment, gas collection and handing, and remediation of groundwater pollution, would occur at unpredictable times decades to a century or more into the future.

The basic landfill components employed in an F/L Wet Cell, while arranged differently and in some cases serving different functions, would be basically the same as those used in a "dry tomb" landfill. Therefore the costs of those aspects of the F/L Wet Cell would be about the same as those of a "dry tomb" landfill. With the F/L Wet Cell there would be initial costs associated with the header systems-plumbing and gravel layers under the clay layer and on top of the waste, as well as a cost of about $10/ton of waste for shredding. The cost of shredding, however, would be offset by the gain of about 20% of the air-space volume resulting from the elimination of daily cover and additional compaction. An F/L Wet Cell would save the cost incurred at some "dry tomb" landfills for the purchase of daily cover material.

A major source of difference in early-term cost of the F/L Wet Cell compared with that of the "dry tomb" approach is in leachate treatment. Both an F/L Wet Cell and a "dry tomb" landfill would generate leachate during their active lives, prior to closure, owing to the entrance of precipitation into the landfill. That leachate generated in a "dry tomb" landfill would presumably be collected in a new and functioning LCRS, and would have to be treated. A similar amount of leachate would be expected to be generated from entrance of precipitation onto an open F/L Wet Cell. Once closed, however, the two types of waste management units would exhibit significantly different patterns of leachate generation that would influence the near-term and long-term costs. Leachate generation during the initial post-closure period of a "dry tomb" landfill should be very low, but unpredictable and variable over time and among landfills in similar climatic regimes because of its dependence on the ability to maintain the low-permeability cover and the efficacy of the water vapor removal in the gas extraction from the landfill. By contrast, large amounts of leachate would be generated during the initial post-closure period of an F/L Wet Cell; the volume of leachate should be fairly predictable owing to its dependence on the amount of moisture added.

During the first 5 yrs of the fermentation period, much of the leachate would not need to be treated but rather would be recycled through the landfill. During the leaching phase of the F/L Wet-Cell operation, i.e., beginning about 5 yrs into the process, the leachate generated would have to be removed (i.e., would not be recycled) and treated as a complex liquid industrial waste. Again, however, the volume and approximate timing of leachate treatment could be better predicted and prepared-for with an F/L Wet Cell.

With an F/L Wet Cell there would be a finite, definable period over which post-closure care activities would have to be executed. Cessation of those activities at the appropriate time would not threaten groundwater quality since the components of the wastes that could adversely affect beneficial uses of groundwater would have been removed. However, "dry tomb" landfills require perpetual (everlasting) care and monitoring. Inevitably groundwater pollution will occur that will require whatever "remediation" can be offered, but will render the polluted groundwater and associated area of the aquifer unsuitable for domestic and certain other uses. Important also is the fact that the source of that pollution would remain unless the wastes were to be exhumed; such costs are not anticipated by today's landfill applicants and thus would become a burden to future generations. The costs for treatment of leachate generated by a "dry tomb" landfill, as well as for perpetual maintenance, groundwater remediation, and arresting of the pollution source will be substantially greater than that being encountered today or being anticipated by landfill applicants even during the first 30 years following closure. The long-term costs associated with "dry tomb" landfills will be substantially greater than those associated with the F/L Wet-Cell treatment.

In order to provide assurance that the fermentation and leaching process is carried out to its full extent, it is necessary to establish a trust fund dedicated to this purpose and established from waste disposal fees collected from those who deposit waste in the F/L Wet Cell. Those funds would be available to carry through the complete F/L Wet Cell process that would produce stabilized and leached waste residues that represent no significant threat to groundwater pollution. If after about 20 years of monitoring of the system once it appears to have been stabilized and leached, and no problems have developed, it may be appropriate to consider release of the funds obligated for that landfill for use for other purposes. It should be noted that if all costs of the F/L Wet-Cell approach are considered in the establishment of the disposal fees, the amount charged may be expected to be greater than that typically charged today for disposal in a "dry tomb" landfill.

However, as the long-term costs and consequences of the "dry tomb" landfilling approach become better known and appreciated, disposal fees for that type of operation will inevitably significantly increase beyond what would be required for an F/L Wet Cell.

Advantages of Fermentation/Leaching Wet Cell Approach

The F/L Wet-Cell approach offers significant advantages over the "dry tomb" landfill.

- The F/L Wet-Cell approach can produce waste residues that will not be a long-term threat to groundwater quality.
- There should be little problem in achieving effective performance of the compacted clay layer

and flexible membrane liner in an F/L Wet-Cell liner for the active life and duration of treatment. This is in contrast to the perpetual and flawless functioning required of such systems for "dry tomb" landfills owing to the location of the liners beneath hundreds of feet of garbage and the perpetual threat of the untreated wastes. Unlike the "dry tomb" landfills, the functioning of the F/L Wet Cell is completed within the capabilities and expected useful life of system components that have been properly manufactured, constructed, and operated.

- Gas recovery can be more readily accomplished with an F/L Wet Cell due to the defined, short-term, high-intensity nature of gas production. With a "dry tomb" landfill, the onset, rate, and duration of significant gas production after closure would be unpredictable since it would depend on when sufficient moisture breached the barrier systems to cause the generation of gas and on the rate of leakage of moisture into the landfill.
- The groundwater resources of the region would be protected by the F/L Wet-Cell approach, but will be damaged as the result of waste "management" with the "dry tomb" approach.
- The costs for cover maintenance and the duration of cover maintenance would be significantly less for the F/L Wet Cell than for the "dry tomb" landfill. Overall, considering all costs, there would be cost-savings with the F/L Wet Cell.
- The technology to implement the F/L Wet-Cell approach is available today. It is certainly possible to design header systems of the type described herein that can introduce moisture into the landfill and to introduce clean water under the clay layer of the cell.
- Many of the justifiable concerns expressed by those disparagingly referred to as "NIMBY's" will be addressed by the F/L Wet Cell approach to MSW management.

SUMMARY & CONCLUSION

The F/L Wet-Cell approach for MSW management is a reasonable and advantageous alternative to current approaches for MSW management, largely the "dry tomb" landfill. With the F/L Wet-Cell approach, wastes are treated to stabilize fermentable organics and leach soluble components that could otherwise pollute groundwater. Treatment is effected by adding moisture (leachate-recycle followed by clean water) to shredded MSW to enhance anaerobic biochemical fermentation of fermentable organic components of the waste and to leach soluble components from the waste. The residues will not threaten groundwater quality since the leachable components will have been removed. The F/L Wet-Cell approach offers the potential for a low-cost waste treatment system which, when combined with a reverse-gradient liner, can protect groundwater quality. Even considering the limited additional initial cost compared with the cost associated with "dry tomb" landfilling, the long-term costs of the F/L Wet-Cell approach will be far less than those of the "dry tomb" landfill. The F/L Wet-Cell technology is available for implementation today.

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