Deficiencies in US EPA Subtitle D Landfills in Protecting Groundwater Quality for as Long as MSW is a Threat: Recommended Alternative Approaches

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Abstract

There is growing recognition that the US EPA's minimum Subtitle D landfills with a single composite liner, minimum Subtitle D cover and the typical groundwater monitoring well array at the point of compliance for groundwater monitoring that is being allowed today by regulatory agencies, at best only postpones for a short period of time compared to the infinite period of time that the municipal solid wastes (MSW) in a Subtitle D "dry tomb" type landfill will be a threat. The eventual failure of the single composite liner to collect leachate generated within the landfill due to deterioration of the plastic sheeting layer of the liner, as well as the ineffectiveness of the minimum Subtitle D landfill cover in preventing moisture from entering the landfill that can generate leachate for as long as the wastes in the landfill will be a threat (effectively forever) will lead to a situation where moisture will enter the landfilled wastes that will generate leachate that will ultimately lead to groundwater pollution impairing their use for domestic and other purposes through the presence of hazardous and deleterious chemicals.

The highly unreliable nature of the typical Subtitle D groundwater monitoring system being permitted today which involves monitoring wells spaced at hundreds of feet apart coupled with each monitoring well's zone of capture of about one foot on each side for sampling groundwaters at the point of compliance, means that the inevitable groundwater pollution that will occur at virtually every minimum Subtitle D landfill will be first detected at off-site groundwater production wells. Basically, as promulgated and as is being implemented, minimum Subtitle D MSW landfilling is a fundamentally flawed approach for protecting groundwaters from impaired use for as long as the wastes in the landfill will be a threat. Subtitle D landfilling as is being practiced is a facade with respect to protecting groundwaters from pollution by landfill leachate. There is an urgent need to change Subtitle D regulations to eliminate some of the fundamental deficiencies in the regulations and especially to recognize the inability of state and local regulatory agencies to implement the intent of Subtitle D regulations so that groundwaters beyond the point of compliance for groundwater monitoring will be protected from pollution by leachate for as long as the wastes in a MSW landfill will be a threat. This report reviews many of the problems associated with minimum Subtitle D landfills as they are being developed today in protecting groundwaters from pollution by MSW leachate. It also presents an overview discussion of changes that need to be made in Subtitle D regulations and especially in their implementation at the state and local level in order to achieve true groundwater quality protection from waste derived constituents for as long as the waste in the landfill will be a threat.

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Eventual Failure of Composite Liner

There is growing recognition (Lee and Jones-Lee 1996) that the minimum design Subtitle D MSW landfills, at best, only postpone when groundwater pollution by leachate occurs for those landfills sited at locations where there are groundwaters hydraulically connected to the base of the landfill. This was the conclusion of the US EPA in their proposed Subtitle D regulations released in August 1988. However, the US EPA, in 1991 as part of adopting the Solid Waste Disposal Final Rule stated in the preamble to this Rule, *"The composite liner is designed to be protective at all locations, including poor locations."* This statement was in significant contrast to the statements made by the US EPA (1988a) in the proposed Subtitle D regulations where the Agency's assessment as presented in the US EPA Solid Waste Disposal Criteria was,

"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."

Further, the US EPA Criteria for Municipal Solid Waste Landfills (1988b) stated,

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

When the Final Subtitle D regulations were released in October 1991, the authors contacted the US EPA to determine if the Agency had new information which would justify the US EPA changing its position with respect to the inevitable failure of a minimum Subtitle D single composite liner in preventing leachate from migrating through the liner into the underlying groundwater system. D. Clay, Assistant Administrator for the US EPA Office of Solid Waste and

Emergency Response, responded that the Agency still finds that a single composite liner would not prevent groundwater pollution by landfill leachate for as long as the wastes in the landfill will be a threat.

While in the late 1980s, those familiar with landfill liner properties relative to the potential threat that municipal solid waste components represent through leachate formation and pollution of groundwaters that could impair the use of groundwaters were just beginning to realize the significant long-term deficiencies associated with a single composite liner of the type specified in minimum Subtitle D landfills, today it is clear that the US EPA's 1988 assessment of the eventual failure of a single composite liner system to prevent leachate from passage through it was then and is currently a correct assessment of the situation. There is no doubt now that eventually all minimum design Subtitle D landfills will, during the post-closure period, fail to keep moisture out of the landfill that will generate leachate. The liner system will ultimately fail to collect the leachate that is generated in the landfill during the post-closure period, eventually leading to the transport of sufficient leachate through the liner into the vadose zone underlying the liner and then into the groundwater system, polluting the groundwater with a variety of hazardous and deleterious chemicals.

The key to achieving groundwater quality protection under US EPA Subtitle D regulations is the development of a reliable groundwater quality monitoring program that will detect incipient groundwater pollution by landfill leachate before widespread pollution of the groundwater resources of the landfill area occurs. While in principle, the Subtitle D groundwater monitoring programs of Detection and Assessment monitoring has the potential to restrict groundwater pollution to no more than 150 meters from the down groundwater gradient edge of the waste management unit, in practice as implemented, the typical Subtitle D groundwater monitoring program has a low probability of detecting the inevitable failure of the composite liner system before widespread offsite groundwater pollution occurs.

Subtitle D requires that,

"A ground-water monitoring system must be installed that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield ground-water samples from the uppermost aquifer" and

"Represent the quality of ground water passing the relevant point of compliance specified by Director of Approved State under Section 248.40(d) or at the waste management unit boundary in unapproved States."

The point of compliance for groundwater monitoring must be located on the landfill owner's property and can be no more than 150 meters from the edge of the waste deposition area. Those responsible for approving Subtitle D landfills typically **assume** that a few monitoring wells spaced a few hundred feet apart at the point of compliance will comply with Subtitle D groundwater monitoring requirements of having a high probability of detecting incipient groundwater pollution by US EPA Subtitle D, Appendix 1 constituents in MSW landfill leachate. While this approach for establishing the location of groundwater monitoring wells was satisfactory for classical sanitary unlined landfills which allowed leachate to enter the

groundwater system underlying the landfill over the entire bottom of the landfill, it is a highly inappropriate, technically invalid approach for establishing the location of groundwater monitoring wells for a US EPA Subtitle D single composite-lined landfill. This issue, above all others, needs immediate attention by the US EPA and state regulatory agencies in order to address the facade that exists on the protective nature of today's Subtitle D landfills.

Inability to Reliably Monitor Subtitle D Liner Failure

Cherry (1990) pointed out that the initial leakage through a plastic sheeting-lined landfill, such as a minimum design Subtitle D landfill with a single composite liner, will generate finger plumes of leachate that will be no more than a few meters wide at the point of compliance for groundwater monitoring (Lee and Jones-Lee 1994a). The width of such plumes is determined by the characteristics of the aquifer materials. A plume width of a few meters at the maximum distance of the point of compliance applies to landfills sited above homogeneous sand aquifer systems. However, for fractured rock systems, the plumes of leachate will be even narrower in which the leachate will pass through fractures, past the point of compliance for groundwater monitoring in narrow bands of polluted groundwaters.

The typical Subtitle D groundwater monitoring system adopted today involves groundwater monitoring wells spaced hundreds to a thousand or so feet apart. Each monitoring well has a zone of capture for sampling groundwater of about one foot from the well in many aquifer systems. This means that the leachate-polluted groundwaters that will be generated in minimum Subtitle D lined and closed landfills will ultimately cause significant groundwater pollution beyond the point of compliance where this pollution will likely be first detected by off-site production wells used by adjacent/nearby property owners.

Basically, regulatory agencies are assuming that the groundwater monitoring approach used for unlined landfills is reliable for plastic sheeting lined landfills. Obviously, based on the work of Cherry and others, such an assumption is fundamentally flawed. Parsons and Davis (1992) pointed out that in order for a groundwater monitoring system to be protective of offsite groundwater quality, the zones of capture of the monitoring wells must intersect the finger-like leachate plumes that are generated by plastic sheeting lined landfills. For most aquifer systems, this will require a monitoring well spacing at the point of compliance of no more than about ten feet. Monitoring wells spaced hundreds of feet apart, as typically allowed by regulatory agencies, therefore, have a low probability of detecting MSW leachate polluted groundwaters before offsite groundwater pollution occurs. It may, therefore, be concluded that one of the most significant deficiencies in Subtitle D regulation implementation and, for that matter, within the regulations is that the plastic sheeting layer of a single composite liner makes the monitoring of groundwater pollution by landfill leachate highly unreliable. The typical Subtitle D groundwater monitoring systems are now becoming recognized as largely cosmetic and essentially a waste of funds because of their inability to detect incipient leachate polluted groundwaters at the point of compliance as required by Subtitle D.

There is considerable unreliable information fostered on the public and regulatory agencies by landfill applicants, consultants, and others on the pollutional characteristics of Subtitle D MSW leachate. While some who have not reliably evaluated the pollution potential of today's MSW

leachate characterize it as almost drinkable, the fact is that Subtitle D landfill leachate has a wide variety of hazardous and deleterious chemicals at high concentrations. It is well known that small amounts of today's MSW leachate can pollute large amounts of groundwater with hazardous and otherwise deleterious chemicals that render a groundwater that is contaminated by MSW leachate unsafe and unusable for domestic and many other purposes.

Further, while landfill applicants claim that through garbage load checking it will be possible to prevent hazardous wastes and, in some cases, hazardous materials (chemicals) from being deposited in Subtitle D landfills, the facts are that garbage load checking does not prevent hazardous chemicals, including hazardous waste, from being disposed of in Subtitle D landfills. At best, garbage load checking can prevent large amounts of regulated hazardous waste from being deposited in a Subtitle D landfills and, therefore, reduce the amount of hazardous waste and, to some extent, the hazardous chemicals that are deposited in Subtitle D landfills. Garbage load checking does not cause today's MSW leachate to be innocuous as it is sometimes characterized. Further, even if it was possible to control all hazardous chemicals from entering the municipal waste stream and, therefore, being deposited in an MSW Subtitle D landfill, the so-called non-hazardous chemicals, such as inorganic salts, many of the organics, etc., would cause a groundwater polluted by such leachate to have to be abandoned as a domestic water supply source because of the large amounts of conventional pollutants.

Eight states have appropriately concluded that a minimum Subtitle D design landfill will not be protective of groundwater resources for as long as the wastes in the landfill will be a threat. The wastes in a municipal solid waste "dry tomb" type landfill, i.e. minimum Subtitle D type landfill, will be a threat to groundwater quality and resources effectively forever. The "dry tomb" design attempts to achieve a tomb where the wastes in the landfill, once the landfill cover is in place, are isolated, to some extent, from moisture until such time as the cover low permeability layer is inadequately maintained.

Inability of Subtitle D Landfill Covers to Prevent Leachate Generation

While it is often superficially said that a minimum Subtitle D landfill cover can be maintained to minimize the amount of moisture entering the landfill, in fact, it is not possible to detect the failure of the cover with conventional minimum Subtitle D design since the low permeability layers are buried under at least one and likely several feet of a drainage layer and topsoil layer. While with a Subtitle D cover installation, it is possible to greatly reduce leachate generation, in time, with deterioration of the low permeability characteristics of the cover, sufficient moisture will enter the landfill to again generate leachate.

The well-known deficiencies in minimum Subtitle D landfills have caused several states to adopt at least a double composite-lined landfill for MSW management. Other countries (in western Europe) and parts of countries, such as Ontario, Canada, will not allow a minimum Subtitle D landfill to be constructed because of its inevitable failure to prevent groundwater pollution by landfill leachate.

Need for Site-Specific Evaluation Approach

Ontario, Canada's Ministry of Energy and Environment requires that the landfill applicant predict, on a site-specific basis, the contaminating lifespan of the wastes within a proposed municipal solid waste landfill and the expected service life of all components of the landfill containment system, such as the leachate collection and removal system. If it is found, any essential component of the leachate collection and removal system that cannot be repaired, such as the plastic sheeting in a landfill liner system that has an expected service life less than the expected contaminating lifespan for the wastes in the landfill, then the landfill cannot be licensed (permitted). However, in the US and for other countries which are copying the US EPA minimum Subtitle D regulations, minimum design Subtitle D landfills are being constructed at geologically unsuitable sites with respect to natural protection of the groundwater resources hydraulically connected to the base of the landfill. At such sites, it is only a matter of time until groundwater pollution occurs destroying the groundwaters polluted by MSW leachate for use as domestic water supplies and many other purposes.

Use of Double Composite Lined MSW Landfills

The double composite-lined landfilling approach adopted in New York, New Jersey, Pennsylvania, Michigan, Oregon, Florida, Arizona, Arkansas, Kentucky, and possibly other states for MSW management provides an opportunity to determine when the minimum Subtitle D upper composite liner fails through the collection of leachate in the leak detection system between the two composite liners. It is possible to determine when such liner failure occurs, i.e. when there is sufficient leachate passing through the upper composite liner to cause groundwater pollution if the lower composite liner were not in place. Whenever the upper composite liner in a double composite-lined landfill leaks leachate at a sufficient rate to cause groundwater pollution if the lower composite liner were not present, it is essential that action be taken by the landfill owner/operator to stop leachate generation through maintenance of the cover or remove the municipal solid wastes from the landfill through landfill mining. Failure to take this action will eventually lead to groundwater pollution even in double composite-lined landfills.

Since the typical Subtitle D landfill covers will not keep the wastes dry after the cover is installed at waste management units for as long as the wastes will be a threat, i.e., in perpetuity, it will likely be necessary to exhume (mine) the wastes in a Subtitle D landfill in order to prevent groundwater pollution by landfill leachate. Recently, an alternative approach to successful "dry tomb" landfilling has been developed through the use of leak detectible covers for landfill closure. Several firms have developed leak detection systems for flexible membrane liner-FML (plastic sheeting) that use either electronic or vacuum based leak detection systems. Through the use of these systems, it is possible to determine when the plastic sheeting layer in the landfill cover has developed holes that will allow moisture to enter the wastes through the cover. At that time, repairs on the cover can be conducted and, thereby, prevent significant moisture from entering the landfill that leads to leachate production and groundwater pollution.

The key to taking action when leachate has been found in the leak detection system between a double composite lined landfill or when the landfill cover leak detection system has detected a hole which will allow moisture to enter the landfill is the availability of adequate funding in the

effectively infinite future after closure of a landfill to address all contingencies that can arise when the upper composite liner is found to be leaking and the landfill owner is either unable or unwilling to stop moisture from entering the landfill through the cover which generates leachate that is passing through the upper composite liner. While, as discussed by Lee and Jones-Lee (1994b) there was some doubt as to whether adequate contingency funding would be available to address the inevitable failure of minimum Subtitle D landfill liner and cover systems, unfortunately, the post-closure funding requirements for addressing possible contingencies have recently been significantly weakened by the US EPA's action relaxing post-closure care funding requirements. L. Hickman (1997), former Director of the Solid Waste Management Association of North America, has recently commented on the inappropriateness of weakening the post-closure care funding requirements for municipal solid waste Subtitle D landfills.

Inadequate Post-Closure Maintenance, Monitoring and Contingency Funding

As discussed by Hickman (1997), the US EPA's recent weakening of the post-closure funding for contingencies has made the likelihood of landfill owners/operators providing the necessary funds to take action to ensure that when either the upper composite liner has failed for a double composite-lined landfill or off-site groundwater production wells or monitoring wells at the point of compliance detect leachate-polluted groundwaters for minimum design Subtitle D landfills even more questionable. The post closure care funding situation that will likely develop at that time is similar to that faced today with respect to the pollution of groundwaters by the classical sanitary landfills where groundwater pollution is being allowed to occur by tens of thousands of landfills that exist across the US because the local governmental agencies are not making the funds available to address this problem even though the regulatory requirements mandate that this be done. The post-closure funding situation in the future will not likely be any better than it is today with respect to protecting groundwater resources from pollution by landfill leachate from today's minimum Subtitle D landfills or even double composite-lined landfills.

To address this situation, Hickman promotes the use of a dedicated trust fund established from tipping fees of sufficient magnitude to ensure that adequate funding will be made available in perpetuity, i.e. for as long as the wastes represent a threat, to address the contingencies that will have to be addressed at essentially every Subtitle D landfill. Lee and Jones-Lee (1993a) estimate that at most landfills the additional cost beyond the cost of a minimum Subtitle D landfilling is about $0.10 per person per day more than is paid for management of solid waste in a minimum Subtitle D landfill that will ultimately fail to protect groundwater resources for those landfills sited at geologically unsuitable sites where natural protection of groundwater is not provided. These costs are well within the disposable income of almost all US Americans. They are a small cost that should be paid for protection of future generations groundwater resources from pollution by Subtitle D landfill leachate.

"Natural" Protection of Groundwater Resources

Another area of confusion/misinformation that is frequently encountered in connection with the permitting of Subtitle D landfills, especially in areas with a low groundwater table, is the so-called natural protection afforded by distance between the base of the landfill and the groundwater table as well as by clay layers that underlie the landfill. Landfill applicants and their

consultants frequently will assert that the geological strata underlying a landfill will be protective of groundwater resources from pollution by landfill leachate "even if" (more properly, when) the Subtitle D landfill liner system fails. A critical review of this situation at most landfill locations, however, shows that the so-called protective nature of the natural strata is similar in character to the minimum Subtitle D composite liner in that it only slows down for a period of time relative to the period that the wastes will be a threat, when groundwater pollution will occur. Since adjacent and nearby property owners/users will want in perpetuity and should have groundwaters that are not polluted by MSW leachate, slowing down when groundwater pollution occurs is not protection of groundwater quality for as long as the wastes represent a threat.

Whether the water table underlying a landfill is five feet below the bottom of the waste, i.e., the minimum prescribed distance in Subtitle D regulations, 50 feet, 100 feet, or several hundred feet is not the issue of concern with respect to providing true protection of groundwater resources by landfill leachate for as long as the wastes represent a threat. The issue that must be addressed in permitting a landfill in accord with Subtitle D requirements is whether the natural strata underlying a landfill will, in fact, prevent groundwater pollution for as long as the wastes in the landfill will be a threat. While landfill applicants and some regulatory agencies attempt to mislead the public and regulatory boards into believing that Subtitle D only requires protection of groundwater quality for 30 years, in fact, a proper interpretation of Subtitle D is that the siting, design, closure, and post-closure care for an MSW landfill must be protective of groundwater quality for as long as the wastes in the landfill will be a threat.

Subtitle D regulations require that lateral expansion of existing landfills meet the same landfill design and other requirements as new landfills. In such situations it is often possible to evaluate the natural attenuation of the geological strata by examining whether the existing waste management units have polluted groundwaters. Obviously, if the existing unlined parts of the landfill have polluted groundwaters, then the expansion of the landfill will also lead to groundwater pollution when the single composite liner fails to prevent leachate from passing through the liner.

Another issue that is often presented as natural protection of groundwater resources from pollution by landfill leachate is the so-called attenuation of leachate associated constituents as they pass through the clay layer of a composite liner and the clay/silt layers of the natural strata underlying the landfill. Frequently, landfill applicants, their consultants, and regulatory agency staff will state that the clays have the ability to attenuate (sorb) leachate derived constituents and, thereby, prevent their transport from the base of the landfill when the liner systems fail to the groundwater table underlying the landfill or within the saturated groundwater system associated with the landfill. While clays and, to a lesser extent, silts have some sorption capacity for certain types of leachate associated constituents, they are not effective in controlling the migration of a number of leachate derived constituents such as inorganic salts, some heavy metals, and low molecular weight organics that are present in MSW leachate.

Since many of these constituents are also highly persistent, i.e., are not transformed chemically or biochemically, attenuation by physical and/or chemical interactions with the aquifer media is not real protection of groundwater resources by constituents in MSW leachate. The only attenuation that can and should be considered is dilution within the saturated part of the aquifer.

It is possible, through dilution, to reduce the concentrations of known potential pollutants in MSW leachate to those that represent limited threats to the use of groundwaters polluted by leachate. However, dilution for known pollutants has been frequently found to require several miles of transport from the landfill before the concentrations of known pollutants can be considered below critical levels. Further, and most importantly, the non-conventional, unregulated potential pollutants in MSW leachate could contain constituents which represent even greater threats to groundwater quality than any of the known pollutants that are now regulated under Subtitle D. Typically, only a hundred or so chemical constituents are regulated today in landfill groundwater quality investigations. There are over 75,000 chemicals in use in the US today. About 1,000 new chemicals are developed each year within the US. Many of these chemicals and their transformation products are present in the municipal solid waste stream and in MSW leachate. Every few years new chemicals are found in MSW leachate that were not known to be there previously. It is never appropriate to assume that because a groundwater contaminated by MSW leachate meets drinking water standards (maximum contaminant levels - MCL's) that the water is safe to consume because of the unregulated chemicals present in MSW leachate. It is prudent public health policy to assume that any groundwater that contains MSW leachate derived constituents is unsafe for domestic and many other purposes.

Inappropriate Definition of "Protective"

Frequently, landfill development involves situations where the landfill applicant and, in some cases, the regulatory agencies propose minimum Subtitle D landfill designs at sites where there are high quality groundwaters hydraulically connected to the base of the landfill. On several occasions, the landfill applicant, their consultants and some of the regulatory agencies staff assert that since the US EPA in its adoption of Subtitle D regulations stated, *"The composite liner is designed to be protective at all locations, including poor locations,"* that there is no need to develop a more protective landfilling approach than that provided by a minimum Subtitle D single composite lined landfill. Obviously, it is inappropriate to assume that groundwater resources hydraulically connected to a minimum Subtitle D landfill will be protected from pollution by landfill leachate for as long as the wastes in the landfill will be a threat. Those who advocate the construction of a minimum Subtitle D landfill at a geologically unsuitable site fail to realize or point out that the US EPA's definition of "protective," that was used when the Subtitle D regulations were adopted in 1991, do not include the protection of groundwaters hydraulically connected to the base of the landfill through the vadose zone from impaired use by all constituents present in municipal landfill leachate for as long as the wastes in the landfill will be a threat.

The US EPA's definition of "protective" assumed that there would be a limited number of people within the sphere of influence of the landfill over several hundred years who could be exposed to an increased cancer risk due to considering a restricted number of potential carcinogens that are known to occur in the MSW leachate. Basically, the Agency's definition of "protective" is based on the concept that only a limited number of people will be exposed over several hundred years to a limited number of carcinogens in MSW leachate for a considerable distance from the landfill. This definition does not address the fact that over the next several hundred years that the US EPA had considered in adopting Subtitle D regulations definition of protective, the number of people, agricultural and industrial interests potentially impacted by the landfill will almost

certainly be far greater than that assumed by the Agency. Subtitle D does not restrict the number of people who could construct water supply wells on their property near their property line with a Subtitle D landfill where waste deposition has occurred near the landfill property line. Therefore, the Agency's definition of "protective" is unrealistic and not protective with respect to what will typically occur on adjacent properties over the next several hundred years with respect to using groundwaters that could be polluted by MSW landfill leachate.

Minimum Subtitle D landfill applicants and regulatory agencies also ignore there are a large number of unregulated, potentially hazardous and deleterious chemicals in MSW leachate that could be more hazardous and deleterious than the chemicals considered in the definition of protective with respect to carcinogen impacts. Further, the US EPA, in its definition of the conditions which serve as a basis for "protective," fail to include a variety of conventional and non-conventional (unregulated constituents) in MSW leachate that when present in groundwater cause the owner of a well that intersects a leachate plume to have to abandon the well for use for domestic and many other purposes. In 1988, the US EPA acknowledged as part of promulgating proposed Subtitle D regulations that once a well is contaminated by MSW leachate, the well will have to be abandoned since it is not possible to clean up the contaminated groundwater and aquifer so that it could be considered "safe" for human and animal consumption and for use for many other purposes.

Obviously, this so-called "protection" afforded by a minimum Subtitle D landfill does not, in fact, provide real long-term protection of groundwater resources hydraulically connected to landfills sited at geologically unsuitable sites, i.e. those without natural protection afforded by the geological strata which prevent the transport of all constituents in MSW leachate that can impair the use of the groundwater from any perspective that is of concern to the public, ranging from tastes and odors to increased hardness, TDS, a wide variety of conventional pollutants, as well as the focus of the US EPA's attention in promulgating Subtitle D, principally a few Priority Pollutant carcinogens. The Agency, in promulgating Subtitle D, did discuss the restricted nature of its definition of "protective." However, many regulatory agencies and the public failed to review the fine print in Subtitle D regulations and, thereby, learn that "protective" does not mean protection of groundwaters from all impaired use by landfill leachate-derived constituents for as long as the wastes in the landfill will be a threat. This is the meaning of protection that the Agency should have used in promulgating Subtitle D regulations. It is the meaning of protection that the potentially impacted public, whose groundwater is potentially contaminated by landfill leachate from an existing or proposed Subtitle D landfill, should expect to achieve.

Suggested Changes in Implementation of Subtitle D Regulations

Subtitle D regulations represented a political compromise in which the Agency was being sued by environmental groups to adopt Subtitle D regulations in accord with congressionally mandated RCRA requirements. At the same time, the Agency staff understood that a minimum Subtitle D landfill would not be protective of groundwater use for as long as the wastes in the landfill represent a threat. While the US EPA (1988a,b), informed the public about the inevitable failure of a Subtitle D minimum single composite landfill liner system to prevent leachate from passing through it and that a groundwater well would have to be abandoned if MSW leachate

polluted the well, the US EPA in 1991 made the statement that a composite liner in a Subtitle D landfill will be "protective" at all locations.

The US EPA Office of Solid Waste and Emergency Response should now address this issue and correct the problems in the implementation of Subtitle D regulations arising from the confusion as to what is meant by "protective." The current US EPA administration should,

- reliably inform the public on what is meant by "protective at all locations" associated with the use of a minimum Subtitle D landfill composite liner, and
- provide guidance on how to protect groundwater resources from impaired use by MSW leachate-derived constituents for as long as the wastes represent a threat in a minimum Subtitle D "dry tomb" type landfill.

Regulatory agencies should not continue to assume that a minimum Subtitle D landfill liner and groundwater monitoring system of the type typically used today will be "protective." They should conduct a site-specific investigation of the situation governing the real protection afforded by the proposed landfill or landfill expansion design, operation, closure, and post-closure care and the natural geological strata underlying the landfill in providing groundwater quality protection from all impaired use by waste-derived constituents for as long as the wastes represent a threat. This mechanical approach to landfill permitting should immediately be terminated where the landfill applicant and the regulatory agencies fail to conduct a site-specific evaluation of the contaminating lifespan of the landfill and the expected service life of the landfill containment system components to prevent pollution of groundwaters from landfill leachate for as long as the wastes represent a threat.

Suggested Approach for Landfilling MSW That Would Protect Groundwater Resources

Lee and Jones-Lee (1995) developed a report "Recommended Design, Operation, Closure and Post-Closure Approaches for Municipal Solid Waste and Hazardous Waste Landfills," devoted to how municipal solid waste management can be conducted in "dry tomb" type landfills and be protective of groundwater quality for as long as the wastes will be a threat. This report provides guidance on the issues that should be addressed by the US EPA and other regulatory agencies in first informing the public about the deficiencies in minimum Subtitle D landfills and provide information on how to address these deficiencies by requiring a site-specific evaluation of the potential for municipal solid wastes being disposed of in a certain landfill design at a particular location to cause groundwater pollution for as long as the wastes remain a threat. The adoption of this approach would take the landfilling of municipal solid wastes from a basically technically invalid approach that is being used today that is a facade with respect to providing true groundwater quality protection, to one that begins to address through technically valid, scientifically and engineering-wise sound basis, the management of municipal solid wastes without inevitable groundwater pollution. While initially changing the current minimum Subtitle D landfilling approach may be somewhat politically unpopular because of the increased initial costs, ultimately, when the facts are properly presented and discussed, the US EPA and/or state regulatory agency administrations that are willing to take this step will gain considerable support for having the gumption to address a significant, long-term environmental problem associated with managing municipal solid waste.

Subtitle D requires the closure of all existing inactive landfills with a low-permeability cover to "reduce" the entrance of moisture into the landfill that generates leachate that leads to further groundwater pollution. Typically, the approach used for closure of classical, unlined sanitary landfills is to place fill material over the top of the waste or existing cover materials, to achieve the desired base for the placement of a few-foot thick compacted "clay" layer. That layer is then covered by a drainage layer and topsoil layer. This landfill closure approach is considered to be "expensive" (a million or so dollars per acre) for local governments since the landfill is no longer generating income through collection of tipping fees. Even so, such a closure is largely cosmetic; it cannot be relied upon to prevent further significant groundwater pollution by the landfill. The basic problem with that approach is that the low-permeability clay layer will quickly develop extensive desiccation cracks that will allow large amounts of moisture to enter the waste and generate leachate that will lead to further groundwater pollution by the Subtitle D-closed landfill. Those desiccation cracks will not be visible by inspection of the surface topsoil layer. Under the current Subtitle D requirements, all closures of classical sanitary landfills and today's Subtitle D landfills should require the installation of a leak-detectable cover and the development of a dedicated trust fund of sufficient magnitude to operate and maintain the integrity of the leak-detectable cover in perpetuity.

An alternative approach for closing classical sanitary landfills and other unlined landfills is to abandon trying to keep the wastes dry and start to treat/manage the wastes and polluted groundwaters arising from the leachate generated in the landfill. This approach is used in some other countries or parts of countries such as in Ontario, Canada; Australia; Great Britain, etc. Basically, this approach acknowledges that without a leak detectable cover that is operated and maintained forever, it will not be possible to prevent further groundwater pollution at the landfill since Subtitle D landfill covers are an expensive facade with respect to preventing moisture from entering the landfill that will generate leachate for as long as the waste in the landfill will be a threat that will pollute groundwater. This approach sets aside a part of the aquifer as part of the landfilled waste treatment system for leachate management. This part of the aquifer has likely already been polluted by the leachate, and therefore can never be used again for domestic or other purposes.

Since it is relatively easy to monitor leachate polluted groundwaters from unlined landfills, it is possible at most sites to develop pump and treat operations similar to those being used at Superfund or hazardous chemical sites that are under remediation that would capture leachate polluted groundwaters and remove them from the aquifer. A pump and treat operation will be needed at virtually every classical sanitary landfill in order to control the spread of the leachate polluted groundwaters that are associated with these types of landfills. Therefore, the development of a pump and treat operation as part of the proposed landfilled waste treatment system will not represent an additional cost beyond the funds that will have to be spent to control groundwater pollution by classical sanitary landfills.

While today, the Subtitle D approach for managing groundwater pollution at classical sanitary landfills is to try to minimize further groundwater pollution by placing a low permeability cap on the landfill at a cost of a million or more dollars per acre, it would be far more cost effective and technically valid to abandon the low permeability cap approach and admit that this approach is fundamentally flawed as being practiced today. Rather than trying to keep the waste dry, the

landfilled waste treatment system would deliberately enhance moisture input to the classical sanitary landfill to enhance fermentation and leaching of the wastes. The additional leachate produced during this waste treatment period would be collected by the pump and treat system where, during the early phases of the treatment program, part of it could be recycled back into the landfill in a leachate recycle program. The remainder of the leachate that cannot or should not be recycled would be managed by approaches that are typically being used today for Subtitle D landfills such as construction of a leachate treatment and disposal system or transport to a POTW for treatment and dilution with domestic wastewaters.

Once the landfill gas production has ceased in the classical sanitary landfill undergoing landfill waste treatment by enhanced moisture addition, then a program of addition of "clean" water to the landfill should be practiced in order to remove any non-fermentable waste residues such as the salts, heavy metals, and persistent organics that are present in the wastes after leachate recycle. The pump and treat polluted groundwater collection and management system would be continued through the clean water leaching phase of the landfilled waste treatment program in order to collect the constituents leached from the wastes during this program.

Eventually, this treatment of the wastes in the classical sanitary landfill would produce under controlled conditions a landfilled waste residue that represents limited threat to pollute groundwaters. Basically, this approach is no different from what will occur naturally in the classical sanitary landfills that will be closed under Subtitle D requirements, except that rather than having an uncontrolled release of constituents from the landfill in the leachate generated within the landfill because of the inability of the Subtitle D landfill covers to prevent further moisture from entering the landfill that generates leachate, the million or so dollars per acre for ineffective landfill cover that does nothing more than slow down for a period of time further groundwater pollution by the landfill, these funds would be used to develop and operate a landfilled waste treatment system involving the establishment of a pump and treat operation to collect any leachate polluted groundwaters that have been developed by the landfill in the past as well as those that would develop during the landfilled waste treatment program. This approach is far more technically valid, protective of groundwater resources, and cost-effective than the Subtitle D approach for closing classical sanitary landfills. The adoption of this approach, however, would require Subtitle D to be changed to allow a regulatory agency approved landfilled waste treatment program to be developed and implemented.

Fundamentally Flawed Nature of "Dry Tomb" Landfilling

One of the fundamental problems with the US EPA's approach for landfilling of municipal solid wastes was the adoption of the "dry tomb" approach in which there is an attempt to isolate the wastes from moisture for as long as the wastes represent a threat for either landfill gas generation or leachate production. While Congress in developing RCRA mistakenly included a minimum 30 year post-closure care period based on a lack of understanding of landfill processes with respect to leachate generation and landfill gas production, the actual needed post-closure care period for "dry tomb" type landfills will effectively be infinite since the waste in such landfills will be a threat effectively forever. Even classical sanitary landfills, where moisture is allowed to enter the landfill in wet climates, have been found to generate leachate that is a threat to groundwater quality for thousands of years. The 30 year **minimum** post-closure care period, often cited as the

period that a landfill applicant will have to provide post-closure care for a landfill, is actually an infinitesimally small part of the time that highly effective post-closure care will be needed in a Subtitle D "dry tomb" type landfill. Those who understand the processes that take place within MSW landfills know that municipal solid waste will, in fact, remain a threat in a "dry tomb" landfill effectively forever. Inorganic salts, heavy metals and many of the organics will not decompose or otherwise disappear from the landfill. They will be a threat to generate leachate which can impair the use of groundwaters for domestic and many other purposes effectively forever.

The fundamentally flawed nature of "dry tomb" landfills has caused several individuals to advocate leachate recycle as part of developing bioreactor (wet-cell) landfilling to "treat" the wastes within the landfill. The fermentation/leaching approach in which municipal landfill leachate is recycled into a properly designed landfill followed by leaching of the wastes with water to remove the constituents that are leachable and not convertible to landfill gas can produce MSW treated residues that would represent limited threats to groundwater quality. Through the use of a double composite liner system and appropriate leachate recycle followed by clean water leaching of the wastes, it would be possible to develop, within the expected effective lifetime of the liner system, waste residues that will provide limited long-term threats to groundwater quality. The fermentation leaching approach requires that the MSW placed in the landfill be shredded to eliminate the adverse impacts of garbage bags from interacting with the additional moisture added to the landfill. One of the most significant problems with the US EPA current landfilling policy is its elimination of research support for the bioreactor approach for MSW management.

Fermentation/Leaching Bioreactor Approach

Rather than terminate research support for the wet cell landfilling approach, the US EPA should aggressively pursue the fermentation/leaching of wastes in a properly designed and operated bioreactor for waste treatment and eventually abandon the "dry tomb" landfilling approach because of its inevitable failure to protect groundwaters from impaired use from waste-derived constituents. While the initial cost of this approach is somewhat more than the current "dry tomb" minimum Subtitle D landfilling approach, the longer term cost considering the inevitable groundwater pollution that will occur and the associated lost resources and the future development of "Superfund" sites to clean up the groundwater pollution that will occur by today's minimum Subtitle D MSW landfills, the fermentation/leaching approach will, in fact, be cheaper. The current approach of estimating the landfilling costs for minimum Subtitle D landfills that ignores the many millions to tens of millions of dollars that will have to be spent at virtually every minimum Subtitle D landfill in Superfund-like groundwater clean-up is flawed economics that significantly underestimates the real cost of MSW management compared to alternative waste management approaches, including the three R's. It is in the best interest of society to pay the true cost of MSW management today in order to protect future generations' groundwater resources and their health and welfare.

Role of the MSW Three Rs in Protecting Groundwater Quality

Tierney, in an article entitled "Recycling Is Garbage" that appeared in the June 1996 *New York Times Magazine*, claimed that there was no point in spending the extra money needed to recycle, reuse, and reduce-divert municipal solid waste components that are landfilled since today's Subtitle D landfills are "safe." His distorted discussion of this issue has brought to the attention of many, including a number of national environmental groups that were not previously aware of the deficiencies in Subtitle D regulations, that today's minimum Subtitle D landfills, at best, only postpone groundwater pollution by landfill leachate for a short period of time relative to the time that the wastes will be a threat. It has now become more widely recognized that the recycling, reuse, reduction and diversion of municipal solid waste components is important from the perspective of reducing the number of Subtitle D landfills that need to be constructed, in order to prevent groundwater pollution that will inevitably occur at most of these landfills. It is likely, because of the Tierney article, that the US EPA and other regulatory agencies could gain support from environmental groups for changing Subtitle D implementation so that non-recyclable MSW residues are managed in landfills that will provide true protection of groundwater resources for as long as the wastes are a threat.

Addressing Justifiable NIMBY Issues

The US EPA, as part of promulgating Subtitle D regulations, stated under "Other Benefits,"

"First, EPA believes that the promulgation of federal municipal solid waste landfill criteria will increase public confidence that landfills are designed to protect human health and the environment. EPA believes that this increased confidence will reduce opposition to landfills and make the siting of new landfills less difficult."

That statement was, at best, naive with respect to addressing justifiable NIMBY issues of concern to those within the sphere of influence of an existing or a proposed landfill or landfill expansion. Subtitle D focused on groundwater quality protection issues with some attention to landfill gas control and the impact of birds on aircraft. Even for those issues, the Agency focused on short-term protection; it did not address long-term issues that must be considered to address the public's concerns. Furthermore, it did not address many of the issues that cause justifiable opposition to an existing or proposed landfill, such as odors, dust, litter, noise, adverse impacts of birds attracted to the landfill, truck traffic, altered viewshed, lost property value, etc. As discussed by Lee and Jones-Lee (1993b), "Environmental Impacts of Alternative Approaches for Municipal Solid Waste Management: An Overview," and Lee and Jones-Lee (1994c) "Addressing Justifiable NIMBY: A Prescription for MSW Management," (both of which are available at the authors' web site) the key to addressing many of these adverse impacts of typical Subtitle D landfills is rigorous enforcement of the regulations addressing these issues, coupled with an adequate buffer of landfill owner owned land around the landfill in which uncontrollable fugitive emissions of odors, dust, litter, etc. can be dissipated on the landfill owner's property.

Rarely, however, are Subtitle D landfills "good neighbors," because regulatory agencies rarely rigorously enforce landfilling regulations, and almost without exception, landfills are allowed to be developed with inadequate land buffers. Subtitle D needs to be changed so that citizens can

file suit against the landfill owner/operator and the regulatory agencies if odors, dust, litter, birds, etc. trespass onto public roads or adjacent properties. At most sites, at least a one-mile buffer of landfill-owner owned land should be established during the active life of the landfill in order to dissipate the non-controllable fugitive emissions. In some areas, several miles of such bufferland may be needed to dissipate the adverse impacts from the landfill on the health, welfare and interests of those who own or use properties near the landfill. In addition, since even well-run landfills are adverse to people for considerable distances from the landfill in terms of decreased property value, increased truck traffic, altered viewshed, etc., the landfill owner (those who deposit wastes in the landfill) should financially compensate those who are within the sphere of influence of a landfill for the uncontrolled adverse impacts. This compensation should be part of the cost of landfilling. Adoption of this approach would, in fact, achieve *reduced opposition to landfills and make the siting of new landfills less difficult* and could change "NIMBY" to "GIVE-ME" in the siting of new landfills.

Need for Immediate Action

It is important that the Clinton administration and various state administrations immediately take the necessary steps to address the significant deficiencies in minimum Subtitle D "dry tomb" landfilling of municipal solid wastes. If these administrations do not begin to immediately address this issue so that revisions of Subtitle D regulations are promulgated during these terms, there will be little likelihood of achieving the necessary regulatory reform in the foreseeable future.

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