

Development of a Potentially Protective Landfill: Issues Governing the True Cost of Landfilling

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Typically today new or expanded municipal solid waste (MSW) landfills are sited, designed, operated, closed and receive post-closure care equivalent to the minimum that is required under current US EPA Subtitle D regulations. However, a critical review of the characteristics of municipal solid wastes and the properties of the landfill containment systems (covers and liners) as well as the groundwater monitoring systems that are being used, shows that minimum Subtitle D landfills are not suitable landfills where there are useable groundwaters hydraulically connected to the base of the landfill. While most landfill sites are not adequately investigated to define how rapidly the pollution of the underlying aquifer will occur by landfill leachate once the leachate penetrates the landfill liner system, typically they are adequately investigated to demonstrate that the natural geology of the area provides inadequate protection of the groundwater resources from pollution by landfill leachate. Usually, it is only a matter of time once the liner systems for the landfill fail until offsite groundwater pollution occurs.

While under current federal and state regulations, which are recognized as being significantly out-of-date and under-protective, a minimum Subtitle D landfill can be permitted at almost any location under current interpretation of regulatory requirements, the permitting of such landfills will be significantly detrimental to the interests of those within the sphere of influence of the landfill during the landfill's active life (receipt of wastes) due to releases of waste-derived constituents from the landfill in the form of odors, dust, litter, landfill gas, etc. Further, most new landfills being permitted under Subtitle D regulations will ultimately pollute substantial amounts of high quality groundwaters, rendering them unusable for domestic and many other uses during the landfill's post-closure period. Today's landfills will likely become a significant financial burden to cities/counties by the cities/counties having to address the landfill as a "Superfund" site. Current regulations are inadequate to ensure that the necessary funds needed to address long-term problems of the inevitable groundwater pollution that will occur at landfills are available. Therefore, ultimately, while the city/county could gain a small amount of income associated with the development of the landfill under a host fee arrangement, in the long-term, the cost to city/county residents will be far greater than the income generated during the active life of the landfill.

In many parts of the US, local county boards of supervisors or other elected officials must approve the siting of a landfill in their area. This normally results in the issuance of a permit establishing conditions for the development and operation of a landfill. In many areas, this permit takes the form of a use permit. While use permits must comply with minimum requirements such as US EPA Subtitle D and any state regulations, often they can be more "protective" of public health, the environment, groundwater resources and the interests of those within the sphere of influence of the landfill. While typically boards of supervisors focus their

attention on immediate problems, in the case of permitting landfills, the "boards" should recognize that today's federal and state regulations are inadequate to protect the current as well as future county's residents' interests from the impacts of the landfill. There are a number of political jurisdictions in the US, such as cities, counties, states, etc., that have recognized the problems of the current, out-of-date regulations governing the landfilling of wastes and have adopted more stringent regulations in order to protect the interests of those within their jurisdiction. County boards of supervisors and other political entities should adopt use permit conditions that address those situations where current regulations do not adequately control the adverse impact of a proposed landfill.

As part of the authors' work over the past 30 years on the impacts of landfills on public health, groundwater resources, the environment and the interests of those within the sphere of influence of the landfill, Drs. Lee and Jones-Lee have developed several papers and reports that discuss these problems and, most importantly, approaches that can be used to address problems on a site-specific basis. This report presents an overview discussion of the approach that a county board of supervisors should require as part of developing a use permit for a landfill that could potentially address many of the well-known significant problems that will occur if a landfill is permitted. A listing of the most pertinent papers and reports providing additional information on these issues is provided in Table 1.

Table 1
Selected References on the Impact of Landfills and
Recommended Approaches for Landfilling of MSW

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

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

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Lee, G.F. and Jones, R.A., "Municipal Solid Waste Management in Lined, 'Dry Tomb' Landfills: A Technologically Flawed Approach for Protection of Groundwater Quality," Report of G. Fred Lee & Associates, El Macero, CA, 68pp, March (1992).

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- Lee, G.F. and Jones-Lee, A., "Municipal Landfill Post-Closure Care Funding: The 30-Year Post-Closure Care Myth," Report of G. Fred Lee & Associates, El Macero, CA, 19pp, (1992).
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- Lee, G.F. and Jones-Lee, A., "Environmental Impacts of Alternative Approaches for Municipal Solid Waste Management: An Overview," Report by G. Fred Lee & Associates, El Macero, CA, 52pp, August (1993).
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- Lee, G.F. and Jones-Lee, A., "Detection of the Failure of Landfill Liner Systems," Report of G. Fred Lee & Associates, El Macero, CA, April (1996).
- Lee, G.F. and Jones-Lee, A., "Landfill Leachate Management," *MSW Management*, 6:18-23 (1996).
- Lee, G.F. and Jones-Lee, A., "Landfilling of Solid & Hazardous Waste: Facing Long-Term Liability," IN: Proc. 1994 Federal Environmental Restoration III & Waste Minimization II Conference, Hazardous Materials Control Resources Institute, Rockville, MD, pp. 1610-1618, April (1994).
- Lee, G.F. and Jones-Lee, A., "Overview of Landfill Post Closure Issues," Presented at American Society of Civil Engineers Convention session devoted to "Landfill Closures - Environmental Protection and Land Recovery," San Diego, CA, October (1995).
- Lee, G.F. and Jones-Lee, A., "Practical Environmental Ethics: Is There an Obligation to Tell the Whole Truth?," Published in condensed form "Environmental Ethics: The Whole Truth" *Civil Engineering, Forum*, 65:6 (1995).
- Lee, G.F. and Jones-Lee, A., "The Cost of Groundwater Quality Protection in Landfilling," Report of G. Fred Lee & Associates, El Macero, CA, 8pp, July (1993).
- Lee, G.F. and Jones-Lee, A., "Development of a Stormwater Runoff Water Quality Evaluation and Management Program for Hazardous Chemical Sites," To be presented at ASTM Third Symposium on Superfund Risk Assessment, San Diego, CA, January (1998).

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

Potential Impacts of MSW Landfills

Table 2 presents a summary of the potential impacts of landfills. The impacts of landfill releases are usually divided into two major periods: the active life--while the landfill is receiving wastes, and the post-closure period--the period of time that the wastes that have been landfilled will be a threat to public health and the environment. A summary of the potential impacts of the landfill during both of these periods is discussed below.

Table 2
Potential Impacts of Subtitle D Landfills

- Groundwater and Surface Water Quality Impairment - Public Health, Economics, Aesthetics
 - Migration of Methane and VOCs - Public Health, Explosions, Toxicity to Plants and Animals
 - Illegal Roadside Dumping and Litter near Landfill - Aesthetics, Public Health, Economics
 - Truck Traffic - Highway Safety
 - Noise - Nuisance, Public Health
 - Odors - Nuisance, Public Health
 - Dust - Nuisance, Public Health
 - Wind-Blown Litter - Aesthetics, Public Health
 - Vectors, Insects, Rodents, Birds - Nuisance, Public Health
 - Condemnation of Adjacent Properties for Many Future Uses
 - Impaired View
 - Decreased Property Values
-

Active Life

Many of the potential impacts of landfills listed in Table 2 occurred during the active life of the landfill. They are typically associated with inadequate management of the landfill operation by the owner/operator to control the releases of waste-derived materials to the environment and waste management activities. Of particular concern is illegal roadside dumping and litter near the landfill, truck traffic, noise, odors, dust, wind-blown litter, vectors (insects and rodents) and birds. Landfill owners do not adequately or reliably address the well-known problems that occur with each of these types of releases or consequences of developing and operating a landfill. With few exceptions, there are significant adverse impacts on adjacent and nearby property owners due to many, if not all, of these types of problems. The basic problem is that landfill owners do not provide adequate bufferlands between the areas of landfilling and adjacent property lands to dissipate the odors, dust and windblown litter and the potential impacts of birds that will develop

at this landfill. Few landfills do not cause trespass of landfill-derived odors, dust and litter onto adjacent properties.

Inadequate Bufferlands. Subtitle D regulations, as well as various state regulations, do not adequately address and/or are not adequately implemented to provide for the protection of adjacent property owners' health, welfare and interests associated with odors, dust and litter releases from MSW landfills. Subtitle D regulations fail to address the primary reason for justifiable NIMBY (not in my backyard), such as landfill odor, dust, litter, etc. From a review of problems of this type at many different landfills, it can be concluded that at many landfill settings at least one mile of landfill operator-owned lands between the edge of where landfilling occurs and adjacent properties is needed to dissipate the landfill-derived odors, dust, litter, etc. that will be released from a typically operated Subtitle D landfill. Even one mile of bufferlands may not be adequate to dissipate releases from the landfill for certain topographic settings and those associated with an inadequately managed landfill.

It is recommended that a board of supervisors or other entity responsible for approval of land use for landfill and protection of public health, groundwater resources and the environment adopt a use permit condition for a proposed landfill that requires that the landfill owner acquire, at fair market value, at least a one mile bufferland around the proposed landfilling area. If the adjacent and nearby property owners will not sell their property at fair market value, then the applicant may have to pay considerably more to acquire the necessary bufferlands. If adjacent property owners will not sell at any price, then landfill applicants would not be able to develop the landfill because of inadequate bufferlands.

The recommended approach is justified since, as part of developing a landfill, the developer should have planned for the acquisition of adequate bufferlands to protect the health, welfare and interests of those within the sphere of influence of the landfill. This common sense approach is ignored by many landfill applicants when selecting a site for a proposed landfill. Landfill applicants must either acquire the necessary bufferland property or not be able to develop the landfill. The cost of acquisition of the bufferlands should be part of the cost of developing the landfill which is reflected in tipping fees associated with the landfill's operations.

While some may naively equate odorous, dusty or littered conditions on adjacent properties associated with the landfill's operation as an aesthetic problem, as discussed in the papers and reports listed in Table 1, it is now well known that highly malodorous conditions, such as those associated with municipal solid waste landfills, are significantly detrimental to an individual's health. Similarly, off-site dust associated with the landfilling operation can readily be a source of PM₁₀ particles which are known health hazards. Further, roadside litter as well as litter derived from inadequate control during landfilling operations can readily contain food waste which can increase the rodent population in an area and thereby increase the potential for hantavirus transmission to humans. Hantavirus is becoming a widely recognized disease that is highly fatal to humans who come in contact with rodent populations that are carrying the virus.

The use permit should also stipulate that if landfill-derived odors, dust, litter, bird impacts, etc. occur at the adjacent property owner property line, that landfill owners must develop operating approaches, including curtailment of operations at certain times, which lead to offsite trespass of

releases from the landfill such as odor, dust, litter, etc. If more than two such releases occur during a year, the use permit would be revoked ,and landfill owners would have to cease operation and close the landfill because of its inability and/or unwillingness to operate the landfill in such a manner as to prevent offsite releases that are detrimental to those within the sphere of influence of the landfill.

The authors have participated in proposed landfill impact assessment hearings as part of the review of environmental impact statements/reports where landfill applicants claim, as part of gaining permission to construct a landfill, that they will control odors, dust, litter, etc. so that there is no adverse impact to adjacent properties. A review of the operating landfill's records after the landfill becomes operational, however, frequently shows that the neighbors of the landfill have experienced significant adverse impacts. While in many areas the regulations prohibit trespass of constituents released from landfills to adjacent properties, the local enforcement agencies frequently do not fully enforce the regulations. Even if the agency staff files a report on violations, these violations are often ignored by their management or those responsible for protecting public health, the environment and the interests of those within the sphere of influence of a landfill.

This situation has lead to a justifiable NIMBY . The authors have yet to find an individual who wants a landfill next to their property, including a new, modern Subtitle D landfill. This is the result of past and, for that matter, present landfills being poor neighbors. The only way to correct this situation is to put the landfill owner/operator on notice that if they cause more than two violations in a year, they will have to close the landfill. Adoption of such an approach would go a long way in addressing the justifiable NIMBY that exists today due to dust, odors, litter, birds, rodents, etc.

Roadside Dumping. One of the common problems with municipal solid waste landfills is roadside dumping near the landfill. There are substantial numbers of the public who take the attitude that if they dump their garbage near the landfill, someone will pick it up and dispose of it in the landfill. In addition to an aesthetic problem, this can also be a health problem due to attracting rodents and their associated diseases. The county board of supervisors should require that the landfill applicant police all roads near the landfill daily and pick up all fugitive waste loss from trucks as well as any roadside dumping. Failing to pick up the waste for more than two days in a row would represent a violation of the use permit that would terminate the operation of the landfill.

Impact on Property Values. One of the significant impacts of construction of a municipal solid waste landfill in a region is a decrease in property value for nearby properties. Based on the studies of Hirshfeld *et al.* (1992), decreased property values can extend several miles from a landfill. This situation is due to a combination of actual adverse impacts and perceived adverse impacts. Even perceived impacts are real to the property owners in terms of lost value on their property. The result is that constructing a landfill in a region adversely impacts the financial interests of those who own properties within several miles of the landfill.

The county board of supervisors should, as part of issuing a use permit for a proposed landfill, require that the landfill applicant financially compensate those who own properties within the

sphere of influence of the landfill whose property values could be adversely impacted by the presence of the landfill. The amount of compensation should be set at no less than the fair market value in the absence of a landfill, and justifiably above it to compensate those who will have to spend time and resources addressing the impacts of the landfill on their interests.

Truck Traffic Impacts. The use permit should require that the landfill owner/operator control the garbage truck traffic to the landfill so that it does not interfere with normal traffic of the area. Further, the landfill owner/operator should be required to upgrade and maintain the roads to the landfill to be able to handle the increased truck and other traffic associated with the landfill operations.

Surface Water Impacts. Direct surface water impacts associated with stormwater runoff from the landfill area can be a source of pollutants for nearby surface and groundwaters. An area of particular concern at some landfill sites are the rivers, streams, lakes, ponds, canals or other waterbodies that are near the landfill. In addition to the potential for direct surface runoff from the landfill to a waterbody or water course, there is a potential for airborne transport of waste-derived constituents in dust and windblown litter to the waters. While there are US EPA stormwater runoff monitoring requirements for landfills, it has been found that regulatory agencies are not necessarily requiring verified, adequate monitoring of surface water runoff from landfills. There is a documented case where exposed hazardous wastes, associated with a landfill, have and continue to be washed by each rainfall runoff event carrying hazardous constituents to the nearby watercourses. While this was brought to the attention of the regulatory agencies several years ago, the agencies and the landfill owner, which is a public agency, have still failed to act on this matter.

The use permit should require that a more comprehensive surface water monitoring program be carried out during the active life and post-closure care period than is normally conducted at municipal landfills. This monitoring should include comprehensive monitoring of the potential for airborne transport of waste-derived constituents from the landfill to the nearby surface waters of the region.

Post-Closure Care

Typically the two greatest concerns for adverse impacts during the post-closure care period of a landfill are the releases of leachate that pollute groundwaters and the releases of landfill gas that are a threat to the environment and public safety through hazardous and explosive components of the gas. While both of these problems can occur during the active life of a landfill, especially landfills with long active lives and several landfilling cells some of which close earlier than others, they are principally problems associated with the post-closure care period.

Adequacy of 30-Year Post-Closure Care Period. One of the most significant deficiencies of the US EPA Subtitle D landfilling regulations is the myth the Agency perpetuated that the wastes in a Subtitle D landfill could only be a threat to generate landfill gas and leachate for 30 years after closing the landfill. The nature of "dry-tomb" type landfilling set forth in Subtitle D is to try to create a tomb made out of plastic sheeting and compacted soil that will keep the wastes dry forever, i.e. as long as the wastes are a threat. In a Subtitle D landfill, the wastes will be a threat effectively forever. However, Subtitle D regulations allow landfill owners to only plan for 30

years of post-closure care assured funding. The regulations do not limit to post-closure monitoring and maintenance the 30 years of post-closure care funding, but specifically state that the post-closure care period may be extended if needed.

There is no question that there will be need to extend the post-closure care funding at most Subtitle D landfills to an infinite period of time. Many of the waste components of a "dry tomb" type landfill will be a threat to generate leachate that contains constituents which can be hazardous or detrimental to groundwater quality, effectively forever. As it stands, now, the county or other local jurisdiction that is responsible for the landfill, either directly through its development or through permitting its development, will have to try to find a mechanism to fund the large amounts of funds that will be needed beginning in year 31 after closure of the landfill. At that time, the landfill would have been closed for 30 years, with the result that there is no income associated with its operations that can be used as a source of revenue for continued post-closure care funding. The situation will likely develop then which is similar to the situation that exists today where inadequate protection of public health, groundwater resources and the environment occurs at previously closed/inactive landfills. This situation should be recognized by the board of supervisors and planned for as part of developing the use permit conditions.

Adequacy of Typical Landfill Cover. As discussed in the papers and reports listed in Table 1, it is widely recognized that the amount of funds that the landfill owner must assure will be available for 30 years of post-closure care represents a small part of the total funding that will be needed to provide adequate post-closure care. A critical review of post-closure care funding issues shows that the currently required funding is not adequate to even address the first 30 years after closure of a landfill cell for such issues as proper maintenance and repair of the landfill cover. The landfill cover will, during this period, develop points of deterioration which will lead to significantly increased moisture entering the landfill than that predicted by the landfill applicant's consultants who typically use the US EPA HELP model. This model is known to be reasonably reliable for a new landfill cover. It, however, has limited ability to predict the rate of moisture entering the landfill as the landfill cover deteriorates. The key layers of the cover that are of concern, i.e. the low permeability layer that prevents moisture from entering the landfill, frequently consisting of plastic sheeting and compacted clay, are buried below a topsoil layer and a drainage layer, and, therefore, points of deterioration are not evident from the surface of the landfill.

This problem is recognized by some of those in the landfilling field where several companies have developed leak detectible covers for landfills. The use permit developed by the county boards of supervisors should require that the landfill applicant construct and maintain, in perpetuity, a leak detectible cover for the landfill that will, in fact, keep the wastes dry for as long as they are a threat to produce leachate and/or generate landfill gas. For planning purposes, this period of time should be assumed to be infinite.

The additional cost for the construction, operation and maintenance of the leak detectible cover should be built into the landfill tipping fees. Funds for *ad infinitum* operation and maintenance of the cover should be developed during the operating life of the landfill and maintained in a dedicated trust.

Landfill Gas Control. While Subtitle D requires that landfill gas emissions be controlled through the development of a gas collection system, there is no assurance that such a system will be maintained for as long as the wastes in the landfill can produce gas. In the classical sanitary landfills where a soil layer cover was installed which was not designed to keep the wastes dry but allowed infiltration of moisture, typically landfill gas production took place over 30 to 40 years in wet climates, i.e. 30 or more inches of precipitation in the area per year. In arid climates, the period of gas production is longer due to a long period each year where there is little moisture entering the landfill.

For "dry-tomb"-type landfills, landfill gas production will occur associated with the moisture that enters the landfill cells during their active life, i.e. while the cell is open to the atmosphere. With the closure of the cell and the associated installation of the cover, there will be a period of time where the amount of moisture entering the landfill that can lead to gas production through biochemical processes in which bacteria convert some of the organic wastes to landfill gas is severely limited by a lack of moisture. However, over time, with the deterioration of the low permeability layer of the cover, landfill gas production will begin to occur again. This could readily be after the 30-year mandated post-closure care period. There is no assurance that there will be funds at that time to maintain and operate the gas collection system.

Landfill gas has been found to contain a variety of hazardous chemicals including carcinogens such as vinyl chloride. Vinyl chloride is a known, highly potent human carcinogen. Landfill gas management will have to be practiced to control not only explosions associated with the methane component of landfill gas, but also for human health and wildlife who could be exposed to landfill gas escaping from the landfill surface and nearby areas.

The county board of supervisors should require that the landfill applicant establish a dedicated trust fund derived from disposal fees of sufficient magnitude to ensure that the landfill gas collection, monitoring and management system will be operated and maintained for as long as the wastes in the landfill have a potential to generate landfill gas. For planning purposes, this period of time should be considered to be infinite.

While there may be some who assert there should be no concern about failure to maintain the landfill gas collection and management system since there are no residences or current land use within the sphere of influence of landfill gas that could escape from the proposed landfill, such an approach assumes that adjacent property owners do not have the right to use their properties as they could have, including constructing dwellings and other structures near their property line if the proposed landfill was not constructed. Landfill gas generation in a proposed landfill has a potential to take place for hundreds of years. The combination of the "dry-tomb" approach for landfilling coupled with the fact that much of the solid waste in the landfill will be placed in plastic bags by waste generators (homeowners) which are not shredded or adequately broken up at the time of landfilling means that moisture, which is essential for landfill gas development, will only slowly reach many parts of the wastes. This will greatly increase the time over which landfill gas production will occur. During this hundreds of years period, adjacent property owners could want to construct dwellings or other structures near their property lines where inadequate landfill gas control could lead to public health safety through explosion and public health hazards through the hazardous components of landfill gas.

One of the areas of growing concern is the public health and other impacts of landfill gas, including the use and flaring of the gas for its disposal. Often landfill owners, especially for small landfills, will flare/burn landfill gas. While landfill applicants and their consultants claim that this flaring destroys all hazardous constituents, such claims are inaccurate. In fact, the temperature conditions and the nature of the gases being burned have been found to develop dioxins within the landfill gas flares. These dioxins are emitted to the atmosphere of the area and represent threats to humans and wildlife.

Recently, the US EPA has announced that it is considering regulating landfill gas management in order to provide for greater public health protection. At this time, the regulations of landfill gas emissions, and especially the hazardous components, are deficient compared to the regulations being required for other sources of these same components to the atmosphere. Various landfill owners and landfill owner associations have protested such regulatory requirements based on increased costs. This is more of the efforts by the landfill owners to perpetuate the cheaper-than-real-cost landfilling of municipal solid waste at the expense of the health and welfare of those within the sphere of influence of the landfill. It is unclear whether the US EPA will have the political power to mandate that landfill owners across the country properly monitor and manage their landfill gas. Until such time that this is done, local regulatory agencies such as county boards of supervisors should protect the interests of the people in the region of the proposed landfill through adopting use permit requirements that mandate that landfill gas management systems incorporate state-of-the-art information on the monitoring and management based on the hazardous components of the landfill gas. The current regulatory approaches which allow landfill owners to dispose of the gas without adequate monitoring should no longer be permitted. If, for political or other reasons, the federal and state agencies will not require this level of protection, then county boards of supervisors should incorporate these requirements into the use permit.

A county board of supervisors should require that the landfill owner adequately monitor the landfill gas flares and other combustion processes for dioxins and other hazardous components. If excessive concentrations are found based on regulatory requirements for other sources of these same constituents, then landfill owners should be required to control releases so that the concentrations of hazardous components released to the environment, including from the gas flares, do not represent a threat to public health and the environment, including wildlife.

Groundwater Pollution. The minimum Subtitle D single composite liner that is typically proposed for new landfills or landfill expansions will, at best, only postpone when groundwater pollution occurs. The US EPA, as part of promulgating Subtitle D regulations in 1988, stated in the Agency's Solid Waste Disposal Criteria (August 30, 1988),
"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."

The US EPA Criteria for Municipal Solid Waste Landfills (July 1988) state,
"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."

While in the late 1980s the landfilling field was just beginning to understand the deficiencies in a single composite liner system for landfills in protecting groundwaters from landfill leachate for as long as the wastes represent a threat, today these deficiencies are well understood. Some states, have taken a position of ignoring what has been well-known for many years about the inadequacy of a single composite liner in preventing groundwater pollution by landfill leachate for as long as the wastes in the landfill will be a threat. There are eight US states or parts of states that have recognized this problem and have adopted double composite-lined systems for lining municipal solid waste landfills. There are a number of state solid waste regulatory agency staffs who have indicated to the authors that they understand the deficiencies in a single composite-lined landfill of protecting groundwaters from impaired use for as long as the wastes represent a threat, but are prohibited from adopting regulations requiring a more appropriate liner system by the state legislature which has passed regulations that prohibit the state agencies from adopting more protective landfilling and other requirements than the minimum set forth by the US EPA.

A county board of supervisors should, as part of establishing a use permit for a proposed landfill, require that landfill applicants construct a double composite liner system for the landfill. Further, it should prohibit the use of geosynthetic clay liners as a substitute for two feet of compacted clay in the composite liner. While the geosynthetic clay is being allowed by regulatory agencies, it is now being recognized as an unreliable approach for construction of a composite liner because of the rapid transport of constituents through the liner by diffusion and the potential for liner failure due to minor structural stresses on the geosynthetic clay layer.

It should be delineated in the use permit that the purpose of the second composite liner that underlies a leak detection system that is located between the upper and lower composite liners is to serve as the base for this leak detection system. The primary containment liner for the proposed landfill would still be the minimum Subtitle D liner. If landfill applicants wish to add additional components to the uppermost liner, such as a geosynthetic clay system, this should be encouraged. It should not, however, replace any of the minimum requirements. Several years ago the state of Michigan recognized the unreliability of traditional groundwater monitoring being used for Subtitle D landfills and adopted the double composite liner system for its municipal landfills as part of improving the monitoring of liner leakage from such landfills. This is the approach that should be used at a proposed landfill.

Justification for adopting a double composite liner where the lower composite liner is part of the leak detection system for the upper liner stems from the fact that the minimum Subtitle D groundwater monitoring system being permitted today of vertical monitoring wells placed hundreds to a thousand or more feet apart at the point of compliance for groundwater monitoring is recognized to be an unreliable approach for detecting landfill liner leakage before widespread groundwater pollution by landfill leachate occurs. As discussed in the Table 1 papers and reports, the initial leakage through a single composite landfill liner system will be through points of deterioration, rips, tears, etc., that will be of a few inches to a few feet long. As discussed by Cherry (1990), such points of leakage will generate finger-like plumes which can have dimensions of ten feet or so in width at the point of groundwater monitoring compliance. With each of the monitoring wells used in the typical groundwater monitoring approach having zones of capture (sampling) of about one foot, it is evident that monitoring wells hundreds of feet apart

have a low probability of detecting leachate- polluted groundwaters before widespread offsite groundwater pollution by landfill leachate occurs.

Funding of Additional Protection. The board of supervisors should require that landfill applicants develop a dedicated trust fund of sufficient magnitude from disposal fees to provide for all plausible worst-case scenario failures that could occur at the proposed landfill, including the need for waste exhumation and proper waste residue management. For planning purposes, the period of the trust fund should be assumed to be infinite. If several hundred to a thousand or more years from now it is found that the funds are no longer needed, then any excess funds available in the dedicated trust could be returned to the county.

These dedicated trust funds should be used in part to monitor for leachate leakage through the uppermost composite liner. When such leakage is found, where the landfill owner cannot stop further leakage, then the dedicated trust fund would be used to exhume (mine) the wastes. However, it should be possible to stop further leakage of leachate through the liner through proper operation and maintenance of a leak detectable cover, i.e. restoration of the "dry tomb" character of the landfill so there is no leachate generation within it. The trust fund would also be used for cover maintenance. If the leak detectable cover is constructed and maintained, there should never be any leachate detected in the leak detection system between the two composite liners. Under these conditions, a true "dry tomb" would be maintained and there would be no need to exhume the wastes. The waste exhumation part of the use permit is a necessary requirement as additional protection in the event that the landfill owner/operator and the regulatory agencies do not adequately operate and maintain the leak detectable cover.

Post-Closure Use of Bufferlands. It would be possible to start to use the one-mile bufferlands established during the active life of the landfill to dissipate inadequately controlled releases of odors, dust, etc. for other purposes after the landfill is closed. Caution should be exercised, however, about the development of residences and other structures close to the landfill area because of the landfill gas migration problem. Further, it would not be possible to construct large agricultural wells within this buffer area which could change the hydraulic gradient, thereby accelerate the transport of leachate-polluted groundwaters should the above-described landfill containment and monitoring systems fail to function as expected.

Implementation

The implementation of the use permit conditions at the county level is typically carried out by the local health department. Normally today city or county health departments have limited ability to address issues of the type that must be addressed if the development of a Subtitle D landfill in their area is to be protective of the county's interests. Since a county cannot rely on state agencies to protect their interests from the long-term impacts of municipal landfills, it may necessary to require that the landfill applicant provide the necessary funds to a county agency, such as the health department, to ensure that the use permit conditions are properly carried out for as long as the wastes in the landfill are a threat. This will require that the local health agency be provided with a substantial amount of funding that will enable it to acquire staff with the necessary expertise and experience to ensure that the landfill is developed, operated, maintained and closed in accord with use permit conditions. Much of this work could be done under contract with private consulting firms who would not have a conflict of interest arising from working for

landfill applicants. Part of the funds set aside in the dedicated trust should be allocated for this purpose.

Independent Third-Party Monitoring

One of the justifiable concerns of those within the potential sphere of influence of a landfill is the adequacy of the monitoring of operations and releases that will take place. Landfill release monitoring, like other aspects of landfill management, is known to generally be inadequate for protection of public health and the environment. While landfill applicants will often assert they will comply with monitoring requirements as part of gaining a permit for a facility, there are numerous examples where inadequate monitoring to even meet the current requirements is carried out, much less the monitoring needed to properly detect, with a high degree of assurance, incipient landfill releases of hazardous or deleterious constituents before widespread problems occur. The public has justifiably grown to distrust the regulatory agencies' ability to reliably monitor and implement regulatory requirements. Examples of day after day offsite odors, litter, dust, groundwater pollution, etc. arising from a landfill which are allowed by regulatory agencies leads to the justified NIMBY.

In order to protect the interests of those within the sphere of influence of a landfill, the board of supervisors in issuing a use permit should require that third-party independent monitoring be supported by the landfill applicant. For a proposed landfill, the county board of supervisors should require that the landfill applicant develop a dedicated trust fund from disposal fees that would generate sufficient income in perpetuity to ensure that there are adequate funds for those potentially impacted by the landfill to have a highly qualified team of experts conduct independent monitoring of the landfill operations for as long as the wastes in the landfill represent a threat. This would require several hundred thousand dollars per year income from the trust. This independent monitoring, while paid for by the landfill applicant, would be conducted by individuals who would report directly to a committee representing the potentially impacted public and local regulatory agencies. This monitoring would not eliminate the need for the landfill owner and the regulatory agencies to conduct the current, at least minimum, monitoring requirements set forth in Subtitle D and any other applicable regulations.

The use permit should establish a mechanism where if repeated violations of operating conditions are found by the monitoring, then the landfill operations can be terminated and the landfill closed.

Dedicated Trust

Current Subtitle D regulations allow a variety of financial instruments to be used to provide for landfill post-closure care monitoring and maintenance. It is well-recognized in the field, as discussed in the papers and reports listed in Table 1, that many of these financial instruments are of limited reliability to ensure that funds will be available when needed even during the mandated 30- year post-closure care period. Further, as discussed herein, there is no assurance that funds will be available in year 31 after closure of the landfill cells. Garbage companies and public landfill owners are generating massive liabilities associated with the inevitable failure of its landfills. Many of these landfills will become future "Superfund" sites. As discussed in the papers and reports listed in Table 1, there have been analyses on the ability of private garbage companies to be able to stay in business over the long term when the liabilities that are now

developing begin to occur which conclude that the long-term financial viability of the company is highly questionable.

For private landfills, is there any reason to believe that in year 31 after the landfill is closed that the landfill owner at that time will come forth with the large amount of money that will be needed to monitor and maintain the site in perpetuity, especially under conditions where there is no income being generated from the site for the past 30 years? There can be no doubt that this liability will be dumped on the county or other local political jurisdiction. The county, however, may be in no better position to address this issue than the landfill owner. There is increasing evidence that county solid waste management entities are failing to make payments into the closure fund for a county landfill. Further, it appears that some county landfills may close prematurely because the cost of operation is higher than what other landfills are charging for disposal of wastes. This means that a county may be faced with a situation of not having funds to close its landfill in accord with regulations.

L. Hickman (1992,1997), former executive director for the Solid Waste Association of North America, has written several editorials on the importance of developing a dedicated trust generated from disposal fees to ensure that post-closure care funding will, in fact, be available when needed to address the inevitable problems that will occur at today's Subtitle D landfills. A discussion of Hickman's work on this topic is presented in the papers and reports listed in Table 1. Hickman (1997) recently commented on the US EPA's lessening the financial assurance requirements for public landfills. The Agency, rather than strengthening these requirements, is bowing to political pressure to lessen the requirements of assured funding for post-closure care. This is not based on a finding that less funds will be needed for post-closure care for the minimum 30 years, but one of the Agency continuing to promote initial less-than-real-cost garbage disposal at the expense of future generations' health, groundwater resources and interests.

A county board of supervisors should, as part of issuing a use permit for a landfill, require that a landfill applicant develop a dedicated trust fund of sufficient magnitude to address the necessary active life operating costs and all plausible worst-case scenario failures that could occur at a landfill for as long as the wastes in the landfill will be a threat. For planning purposes, this period of time should be considered infinite. Basically, this means that the tipping fees for a proposed landfill should be increased to a sufficient amount to not only cover the proper siting and development of the landfill as well as the reliable operations of the landfill during its active life, but also to cover all plausible problems that could occur after closure of the landfill for as long as the wastes in the landfill will be a threat. The magnitude of this funding should be sufficient to exhume (mine) the wastes from the landfill and properly manage them at any time in the future should this be necessary.

It is appropriate to adopt this approach since this is a part of the true cost of landfilling at most landfill sites. Since most sites are a geologically unsuitable site for a minimum Subtitle D landfill, there will eventually be large-scale groundwater pollution associated with a proposed landfill. Adoption of the approaches suggested herein in issuing the use permit for the landfill will ensure that the funds to address these problems will, in fact, be available when needed. While this will increase the initial cost of solid waste disposal in the proposed landfill, it will

ultimately save the county residents large amounts of money by not having to pay for "Superfund" site-like cleanup without having the financial resources available.

Those who follow the municipal solid waste landfilling situation in the US today know that the field is in chaos. The abolition of flow control which enables waste generators/haulers to take their waste to any landfill has created a situation in which there is significant economic competition for solid waste streams among landfill owners. This, coupled with rail haul and long truck haul of municipal solid waste in which the wastes picked up from the residents and commercial establishments are taken to a transfer station where they are reloaded into larger trucks or rail cars, is leading to long distance transport of wastes at costs which are less than the cost of operating a small to mid-size regional landfill.

In California and in many parts of the country, there is already excess waste disposal capacity. A large new landfill (Mesquite) has been permitted in the southern California desert where the owners cannot get a waste contract from communities, even though their tipping fees will be in line with those typically available today. There are two other large landfills under review that would be developed in the southern California desert which will, if approved, like the Mesquite landfill, lead to even greater competition among landfills for the solid waste stream. The result of this competition is an exacerbation of the already prevalent cheaper-than-real-cost garbage disposal where the true costs are passed on to those within the sphere of influence of the landfill during the active life and to future generations within the area of the landfill and the local political jurisdiction, in general, in terms of groundwater pollution-caused lost groundwater resources, Superfund-like clean-up costs and a generally degraded environment.

It is estimated that the real cost of municipal solid waste management in a properly developed landfill is between \$60 to \$90 per ton. In addition, there are the collection and transportation costs to the landfill that would have to be paid by the waste generators. Any landfill owner that proposes to only charge \$20 to \$40 or so per ton for disposal of wastes in their landfill is practicing cheaper-than-real-cost garbage disposal. The differential between the currently paid disposal fees and the true cost that is being paid now in part by those within the sphere of influence of the landfill through the adverse impacts of the types described herein as well as to future generations, is in many locations substantial. As long as federal and state regulatory agencies allow landfilling to take place at cheaper-than-real-cost, the local regulatory agencies such as the boards of supervisors, municipalities, etc., will have the responsibility of protecting the near-term as well as long-term interests of their constituency in the development of a landfill in their region.

While there will be those who assert that doubling or tripling the disposal costs of landfilling of municipal solid wastes in a manner that protects the health, welfare and interests of those within the sphere of influence of a landfill and the groundwater resources in the vicinity of the landfill, as well as eliminating the long-term liability that future generations will have to pay as the result of today's society practicing cheaper-than-real-cost garbage disposal is unaffordable, in fact, when translated to a cost on a per person per day basis, it amounts to about 10 to 20 cents more per person per day than what is being paid now. There are few individuals who could not afford to pay the additional cost for managing their municipal solid wastes and thereby eliminate the justifiable NIMBY created by how landfills are sited, operated and closed. This additional cost

will also eliminate the Superfund-like costs that will ultimately have to be paid and the cost of lost groundwaters resources.

Another cost that is arising out of the cheaper-than-real-cost garbage disposal being practiced today under Subtitle D landfilling is the call for reduced practice of the 3R's (waste reduction, recycling and reuse). It is difficult to get political jurisdictions to adopt and continue aggressive 3R implementation under conditions where these diverted wastes can be disposed of at costs that are a fraction of the cost of the implementation of 3R's. Reducing 3R activities because of cheaper-than-real-cost solid waste landfilling is an extremely short-sighted approach in that it is essential as part of conservation of natural resources for this society to develop highly effective, extensive 3R programs in order to protect the interests of future generations.

Overall, it is concluded that landfill applicants cannot develop a minimum Subtitle D landfill at most proposed sites that will protect the interests of those within the sphere of influence of the landfill and the county residents in general. These landfills cannot become economically viable and provide this level of protection. The permitting of a minimum Subtitle D landfill will almost certainly lead to the perpetuation of the inadequate public health and environmental protection that is occurring at existing landfills. It will also lead to further long-term financial drain on the county or other local political jurisdiction.

Since it appears unlikely that flow control of the solid waste streams will be reinstated in the near future, boards of supervisors, as part of permitting a landfill in their region, need to carefully evaluate the potential for either a public or private landfill to be developed in their area where a few years after development the public will find that they can dispose of their wastes cheaper at another location. This could readily lead to a landfill becoming economically unstable and being abandoned. In light of the chaotic situation that exists today in the landfilling field, a county board of supervisors should proceed cautiously in developing a landfill which is sited at a geologically unsuitable site with inadequate bufferlands, inadequate design and inadequate post-closure care funding for as long as the wastes represent a threat. This situation could readily become another situation similar to the one that most counties already face with their existing landfills where there are inadequate funds available to close an existing landfill(s) in accord with regulatory requirements, much less to close existing landfills so they will not continue to be significant threats to public health, groundwater resources and the environment.

Summary of Use Permit Conditions

A county board of supervisors or other local political jurisdiction responsible for the permitting of a landfill in their area should incorporate into the use permit the following requirements for a proposed landfill.

- A one-mile buffer owned by the landfill applicant between the edge of the waste management units and the adjacent property line for dissipation of inadequately controlled releases of odors, dust, litter, etc. from the landfill.
- Requirement that more than two violations per year of offsite dust, odors, litter, etc. will constitute a violation of the use permit which will result in revocation of the permit and the termination of the operation of the landfill.
- Require daily pickup of roadside litter associated with fugitive waste releases from garbage trucks and roadside dumping.

- Require that the additional truck traffic associated with landfill operations does not interfere with normal traffic of the region and that the landfill owner upgrade the roads where necessary and maintain the roads associated with the additional traffic caused by the landfill.
- Financially compensate all of those who experience a loss of property value due to the siting of the landfill in their region.
- Require a double composite liner in which the lower composite liner is part of a leak detection system for the upper composite liner. When leachate is found in this leak detection system, the landfill owner must stop leachate generation or exhume the wastes.
- Require that a leak detectable cover be installed and maintained in perpetuity for the landfill.
- Require more comprehensive stormwater runoff monitoring than typically performed at landfills to ensure that surface waters of the area are not polluted by landfill-derived wastes, including by airborne transport.
- Require that a dedicated trust fund of sufficient magnitude to operate and maintain a landfill gas collection system for as long as the wastes in the landfill have potential to generate landfill gas. For planning purposes, this period of time should be considered infinite.
- Require that adequate monitoring of landfill gas emissions for hazardous and deleterious constituents be carried out to ensure that these emissions do not represent a threat to public health and the environment, including to wildlife. This monitoring should include monitoring for dioxins associated with landfill gas flaring and gas use which involves combustion. If excessive concentrations of hazardous constituents are found in landfill gas emissions, then control programs would have to be initiated to reduce the risk to public health and the environment to acceptable levels.
- The landfill owner should provide funding of a local agency to fully and reliably implement the use permit conditions.
- Third-party independent monitoring of landfill operations and potential impacts paid for by the landfill owner but responsible to the potentially impacted parties who own or use properties near the landfill should be conducted. If the monitoring finds repeated violations of operating or containment requirements, then the landfilling operations can be terminated and the landfill closed.
- A dedicated trust fund developed from disposal fees of sufficient magnitude to control adverse impacts associated with active life operations of the landfill and plausible worst-case scenario failures that could occur for as long as the wastes in the landfill represent a threat. The planning period for this dedicated trust should be infinite.

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