Geosynthetic Liner Systems for Municipal Solid Waste Landfills: An Inadequate Technology for Protection of Groundwater Quality

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Waste Management & Research published a paper by Fluet *et al*. entitled, "A Review of Geosynthetic Liner System Technology" in its March 1992 issue. The geosynthetic liner system technology that they addressed was an engineered containment system for use in lined "dry tomb" landfills in which are placed untreated municipal solid waste (MSW). The "dry tomb" landfilling approach relies on a cover system to in theory keep the wastes dry and a liner system (liner and leachate collection and removal system) to collect and remove leachate. The performance of a "dry tomb" landfill depends on the functioning of the cover and of the liner system for as long as the wastes represent a threat.

The Fluet *et al*. review suggests to the reader that flexible membrane liner systems of the type being constructed today in municipal solid waste landfills will protect groundwater quality from pollution by landfill leachate. Critical examination of the Fluet *et al*. (1992) review article, however, reveals that they omitted from their discussion some of the most important topics that need to be considered in an evaluation of the efficacy of landfill liner systems in providing truly long-term protection of groundwater quality. Those neglected topics contribute to the assessment of: **whether the liner system will prevent groundwater pollution for as long as the wastes represent a threat to groundwater quality.**

The incorporation of liners or liner systems of any kind into landfill designs was borne from the knowledge that landfills will generate leachate that will pollute the groundwater with which it comes in contact. Therefore, a review of the ability of geosynthetic liner systems to prevent the pollution of groundwater for as long as the wastes represent a threat is the major essential aspect of a review of that technology. In their abstract Fluet *et al*. made appropriate observations about the common discrepancy between meeting design guidelines of regulations and the achievement of protection of groundwater quality. The paper itself, however, focused on the design components of a geosynthetic liner "system" without adequate consideration of the realities of the use of such systems in landfill applications and the manner in which such systems will eventually fail to protect groundwater quality. The review should be recognized as missing that critical component.

Presented below is a discussion of key issues that should be considered in evaluating the efficacy of a proposed landfill liner system.

Regulatory Requirements

Fluet *et al*. (1992) noted in the abstract regarding regulatory requirements,

"Regarding regulatory considerations, the paper discusses how liner systems must be selected and designed in conformance with regulatory performance standards in order to ensure long-term protection of the environment, and notes that many American state regulations for municipal waste landfills include minimum design guidelines that may be inadequate to meet the state's performance standards."

The US EPA October 9, 1991 Subtitle D regulations governing municipal solid waste landfills stated with regard to performance standards,
"The rule's standard requires that an approved State's program be capable of protecting ground water that is currently used or reasonably expected to be used for drinking water at the relevant point of compliance [i.e., 150 m from waste management unit boundary on land owned by the owner of the unit]."

Those regulations also stated,
"The design must ensure that the concentration values listed in Table 1 of this section will not be exceeded in the uppermost aquifer at the relevant point of compliance..."

The US EPA also specified that the landfill liner and cover shall consist of a composite liner, the uppermost component of which must be a 30-mil (7.6-mm) (minimum) flexible membrane liner (FML) and the lower component of which must be at least a 2-ft (0.6-m) layer of soil compacted to achieve a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec. If the FML is high density polyethylene, it must be at least 60-mil (15.2-mm) thick. The FML component must also be installed in direct and uniform contact with the compacted soil component.

The state of California Chapter 15 regulations governing municipal solid waste landfills require that the landfill containment system be sufficient to **protect groundwater quality for as long as the wastes represent a threat.** Lee and Jones-Lee (1991) have reviewed the potential threat that municipal solid wastes and their leachates represent to the use groundwaters for domestic water supply. The following conclusions were evident.

MSW's and their leachates contain a wide variety of chemical constituents in high concentrations that can readily render a groundwater and associated aquifer unsuitable for domestic water supply purposes.

A small amount of MSW leachate can pollute very large amounts of groundwater rendering them unusable for domestic water supply purposes.

Because of the large amounts of unidentified, unscrutinized, unregulated non-conventional pollutants in MSW leachate, any contamination of a groundwater by MSW leachate should cause the groundwater to be considered unsuitable for domestic water supply use.
Inorganic salts, heavy metals, non-degradable organics and non-degradable organic residues associated with leachate from lined "dry tomb" MSW landfills will represent a threat to groundwater quality indefinitely, i.e., forever.

Therefore, MSW will be a threat to groundwater quality for as long as it remains buried, and hence engineered groundwater protection systems must function properly forever in order to

achieve long-term protection of groundwater quality.

While the US EPA municipal landfill regulations address only a few so-called "hazardous chemicals" in groundwater, the state of California requires protection of groundwater quality from all chemicals that can impair its uses. Total dissolved solids (TDS), hardness, alkalinity, chloride, sulfate, etc. present in MSW leachate can readily pollute groundwaters, impairing their use. While the US EPA regulations do not prohibit impairment from those types of pollutants, the state of California regulations do prohibit such impairment.

The authors agree with Fluet *et al*.'s (1992) observation that a geosynthetic or any other type of liner system that is used for municipal solid waste landfills needs to achieve the performance standards set forth by the regulations. In California that means that the geosynthetic liner system has to provide for the unequivocal protection of groundwater quality for as long as the wastes represent a threat, i.e., forever. Fluet *et al*. (1992) also noted that the minimum design standards in many states are not adequate to achieve the performance standards. California is one such state because of the manner in which the "minimum design standards" requirement is being interpreted. The Chapter 15 regulations explicitly state that the liner (or liner system) must be capable of preventing degradation of the waters of the state, have a permeability equal to or less than $1x10^{-6}$ cm/sec, and be of sufficient thickness to prevent vertical migration of fluid (including waste in leachate) to the waters of the state causing degradation.

While the Chapter 15 regulations state that the minimum design standards are whatever is necessary to achieve the performance standard of groundwater quality protection, regulatory agencies have allowed landfill applicants and their consultants to interpret those regulations to mean that a liner design of a 1-ft (0.3-m) layer of soil compacted to achieve a permeability of $1x10^{-6}$ cm/sec is the design standard for municipal landfills. It is such lack of enforcement of the Chapter 15 requirements in the state of California by the regulatory agencies that is allowing the construction of inadequate liner systems. It may therefore be concluded that even where the regulations make it clear that the performance standards shall be achieved, the implementation of the regulations at the regional or local level may well not provide that degree of protection.

Because of the current and growing importance of groundwater for domestic supply, and because once polluted with municipal landfill leachate, groundwaters and associated aquifers cannot be restored to provide a reliable water supply, it is the authors' view that the performance standards must require protection from impairment of groundwater for as long as the wastes represent a threat. Since the wastes will be a threat forever, the geosynthetic (or other) liner system used in a landfill must be able to perform perfectly forever as a barrier to leachate migration through it. Any landfill liner system that does not achieve that level of protection is allowing today's society to enjoy garbage disposal for cheaper-than-real cost at the expense of the public health, groundwater resources and economic and other welfare of future generations.

An important observation about such well-intentioned performance standards for municipal landfills is that no material or engineered component can be ensured to last forever, i.e., for as long as the wastes represent a threat to groundwater quality. This is especially critical for components that are buried beneath hundreds of feet or meters of garbage and/or otherwise not amenable to routine and thorough inspection, repair, and replacement. The authors have seen this

dilemma "addressed" in a number of different ways, each inadequate to ensure protection of groundwater resources. Technical issues of claims such as that the wastes and hazards will "degrade," that groundwater monitoring programs will provide advance warning of pollution, that liner systems provide redundancies for protection, that only cap maintenance is of significance to groundwater quality protection, and that only "small amounts" of leachate will leak through modern liner systems, have been addressed elsewhere (Lee and Jones-Lee, 1991, 1992a, 1992b).

Geosynthetic Liner System Leakage

There is a myth developing that because a "liner system" contains a number of components, none of the individual components has to be fail-safe to provide protection. In discussing the theme of their paper, the difference between "liners" and "liner systems," Fluet *et al*. (1992) noted,

"In fact, since liners depend solely on their material properties to inhibit flow of fluids through them, it is impossible to construct large scale liners that do not leak. However, this does not mean that landfills must leak, because landfills constructed with liner systems consisting of one or more liner(s) and leachate collection layer(s) can be constructed with de minimis or no leakage. Liner systems are able to succeed where simple liners fail, because, whereas liners depend solely on material properties, liner systems utilize both engineering design and material properties to prevent leakage."

There is a variety of mechanisms by which failure of not only liners but also leachate collection and removal systems will inevitably occur (Lee and Jones-Lee, 1992a). The integrity of most such systems is governed by the integrity of a synthetic liner, itself imperfect and subject to penetration and deterioration. Clogging of the leachate collection and removal system is another mechanism becoming recognized as problematic in maintaining their performance.

In their discussion of the role of the leachate collection systems in liner system design to "prevent" groundwater pollution, Fluet *et al.* tried to develop an analogy between the design of a landfill liner system and that of a ship's hull. They did not discuss, however, at least one very significant difference between a ship's hull design and a landfill liner design, namely that a ship's hull is accessible for and subjected to inspection, maintenance, and repair. Further, even a well-maintained ship does not have to be kept sea-worthy forever. A landfill liner is buried under often hundreds of feet (or meters) of solid wastes and cannot be inspected and cannot be repaired without waste exhumation. The landfill liner must function perfectly forever if it is going to prevent groundwater pollution for as long as the wastes represent a threat.

Fluet *et al*.'s (1992) paper was reportedly originally submitted to Waste Management & Research in February 1990. Subsequent to that time, a considerable amount of new information has been published on landfill liner leakage. That information was recently reviewed and summarized by Lee and Jones-Lee (1992a). As they pointed out, for example, Bonaparte and Gross (1990) reported,

"Based on the data in this study, an action leakage rate of 50 lphd [liters per hectare per day] *is too restrictive and presents a performance standard that, if promulgated by US EPA, frequently*

will not be met by facilities that were constructed to present standards with rigorous third-party CQA [Construction Quality Assurance] *programs. An action leakage rate of 200 lphd appears to be reasonable for landfills that have been constructed using rigorous third-party CQA programs."*

Further, the US EPA (1989) stated,

"EPA realizes that even with a good construction quality assurance plan, flexible membrane liners (FMLs) will allow some liquid transmission either through water vapor permeation of an intact FML, or through small pinholes or tears in a slightly flawed FML. Leakage rates resulting from these mechanisms can range from less than 1 to 300 gallons per acre per day (gal/acre/day)[9 to 2800 lphd]."

In January 1992 the US EPA released its regulations regarding *de minimis* - or "accepted" - leakage rates for hazardous waste landfills. There seems to be general agreement that a *de minimis* leakage rate of less than 20 gals/acre/day [200 lphd] would be very difficult to achieve when the liner system is new (US EPA, 1992). US EPA (1992) did not recommend a fixed *de minimum* leakage rate.

Lee and Jones-Lee (1992a) pointed out that *de minimis* leakage rates should be based on protection of groundwater quality, not on what can be routinely achieved with a particular existing technology of FML's and compacted soil liner systems. They also discussed the fact that the existing liner system materials were selected not because they have a demonstrated ability to provide groundwater quality protection for as long as wastes represent a threat. Landfills are built with the least expensive materials and systems that will allow them to be approved by the regulators. A *de minimis* leakage rate should represent a rate of leakage that will not, under any reasonable circumstance, result in groundwater pollution that can impair the uses of the groundwater for domestic or other purposes. The establishment of *de minimis* leakage rates based on the performance of geosynthetic liner systems that can be routinely achieved is technically invalid and highly inappropriate. If that, or any other, liner system cannot perform to prevent groundwater pollution, that liner system cannot be considered to meet the performance standard of protection of groundwater quality for as long as the wastes represent a threat.

It is concluded that leakage of municipal landfill leachate at a rate of 20 gal/acre/day [200 lphd] can pollute millions of gallons of groundwater daily, rendering it and the associated areas of the aquifer unsuitable for domestic water supply. Therefore, shortly after a geosynthetic liner system is put into service, it may fail to protect groundwater quality from pollution by municipal landfill leachate.

Long-Term Performance of Geosynthetic Liner Systems

Fluet *et al*. (1992) did not properly address the expectations for long-term performance of FML's and compacted soil as effective liners, or of the long-term performance of "liner systems." They simply stated in this regard:

"Geosynthetic liner systems have performed very well and should continue to provide society with a cost effective and safe means of containing waste. The foreseeable dangers lie not with the geosynthetic liner systems but with untrained designers, careless contractors, imprudent operators and unknowledgable regulators. Any of these can result in inappropriate geosynthetic liner systems and the resulting problems reflect poorly on all of us. Let us all commit to designing, installing, operating, and approving the types of geosynthetic liner systems which will reflect well on all concerned and, most importantly, will protect the environment well into the future."

First, the issue is not protection of the environment simply *"well into the future."* The regulatory, and indeed the groundwater quality protection, requirements are not met by the liner system's working for awhile and deteriorating sufficiently to allow widespread pollution. US (federal) requirements do not explicitly specify a performance duration but they imply that the performance duration has no time limit on it. The state of California regulations are explicit in requiring protection for as long as the wastes represent a threat. Therefore, claiming protection "well into the future" as Fluet *et al.* have done is not only inadequate, but also highly misleading. By that choice of language, Fluet *et al*. tacitly acknowledge that they cannot claim that geosynthetic liner systems will meet performance requirements to protect groundwater quality for as long as the wastes in the landfill represent a threat.

The ensuing notation of the vulnerability of groundwater quality protection components of landfill systems to *"untrained designers, careless contractors, imprudent operators and unknowledgable regulators"* expresses a fundamental, and fatal, flaw of the "dry tomb" lined landfilling approach. While systems may be able to be conceived that should in theory protect groundwater quality *ad infinitum*, they will **always** be subject to human error, carelessness, and societal neglect. If there is vulnerability to these types of human error in the development and operation of a new landfill, they can only be assumed to multiply once the landfill is closed and the landfill company is relieved of responsibility for it or society "forgets" that the area is a landfill. However, even if the design, construction and operation of landfills with geosynthetic liner systems were to be done without error or imperfection, the liner system will, based on the Second Law of Thermodynamics, eventually fail to prevent leakage of leachate to pollute groundwater. Thus, the issues of inadequate design, construction, operation, etc. associated with geosynthetic liner systems, only speak to **when** groundwater pollution will occur, not to **whether** it will occur. The less attention to perfection in design, construction, and operation, the earlier it may be expected to fail. Since groundwater needs to be protected from landfill leachate for as long as the waste represents a threat, pollution that does not occur for 50 years is as much of concern as pollution that occurs after 5 years.

Key Findings on Issue of Long-Term Protection

Based on their review of the recent literature, characteristics of municipal solid wastes and their leachates, and the characteristics and research on the long-term performance of FML's and compacted soil layers, and other liner system components, Lee and Jones-Lee (1992a) drew the following conclusions about the expected performance of geosynthetic liner systems.

Geomembrane liner systems, including those with composite liners and covers, will typically leak leachate shortly after being placed in service at a rate sufficient to pollute groundwater, impairing its use, and the use of that part of the aquifer, for domestic water supply purposes.

The leachate retention capabilities of geomembrane liner systems will deteriorate over time, leading to an increase in the rate of leachate migration through the liner and pollution of groundwater with conventional, non-conventional, and hazardous pollutants.

Geomembrane liner systems cannot be expected to perform perfectly - i.e., prevent groundwater pollution - for as long as the waste represents a threat to groundwater quality.

Geosynthetic liner systems are often designed, constructed, and operated at the lowest cost possible. Once a landfill is put into service, there is no opportunity to inspect, repair, or replace system components as they deteriorate or fail. Therefore, the system components must function perfectly for as long as the wastes represent a threat, i.e., forever.

The geomembrane liner systems of the type being used today, including those with double-composite liner systems, is a flawed technology that will not provide for groundwater quality protection from pollution by municipal landfill leachate.

Conclusion

Fluet *et al*. should have discussed the ability of geosynthetic liner systems of the type they describe to unequivocally prevent groundwater pollution for as long as the wastes represent a threat. Since those systems cannot be relied upon to provide that level and duration of protection, must be considered to be a flawed technological approach. A review of the literature (Lee and Jones-Lee, 1992a) shows that contrary to statements made by Fluet *et al*. (1992), geomembrane liner systems have not performed well, nor would they be expected to provide the necessary protection of groundwater quality for as long as the wastes represent a threat.

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