Comments on the O'Brien ARF SWANA Article,
"**The Solid Waste Managers' Guide to the Bioreactor Landfill–A 2009 Update**,"
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J. O'Brien (2010), Director of Applied Research for Solid Waste Association of North America (SWANA) Applied Research Foundation (ARF) published an article in the May 2010 issue of *MSW Management* that presented highlights of the ARF FY2009 Disposal Group's report entitled, "The Solid Waste Managers' Guide to the Bioreactor Landfill–A 2009 Update" developed to update its 2002 guide. The O'Brien article reportedly summarized the SWANA ARF FY 2009 Disposal Group's perspective on current information concerning the use of bioreactors (leachate recycle) in landfilling of municipal solid wastes (MSW), and the development of bioreactor technology over the past 8 years. It also identifies specific "benefits" of that approach for MSW management. Unfortunately the article leaves a number of misimpressions.

Landfill Stabilization

O'Brien listed, as one of the "Benefits" of bioreactor landfills, the following:
"*Stabilization of Landfilled Waste — One of the primary goals of bioreactor landfills is to accelerate the biodegradation and, consequently, the stabilization of the landfilled waste. Data from recent research support conclusions reached by previous research that operation of an MSW landfill as a bioreactor results in accelerated solids decomposition. However, the degree of waste stabilization in a bioreactor landfill has yet to be quantitatively established.*"

It is misleading, at best, to tout landfill "stabilization" as a "benefit" of bioreactor landfills and merely mention in passing the fact that the "degree of waste stabilization" that actually can be achieved with this approach has not been quantified. There can be wide disparity between what can be accomplished in "research" and what can be economically and practically accomplished in real practice. In order for a credible claim of "benefit" to be made, there must be demonstrable, quantitative, and consistent documentation that the "benefit" can, in fact, be economically and practically achieved in practice. Rather than a claim of this "benefit" that is, at best, speculative at this time, the point that should have been made is the lack of quantitative information regarding the increased stabilization that can actually be accomplished through bioreactor landfilling, as well as the changes in MSW management that would need to accompany bioreactor landfilling in order to achieve this benefit.

In the 1980s the US adopted the "dry tomb" landfilling approach in which the MSW is to be landfilled in a plastic sheeting and compacted soil liners system. The great paradox of the "dry-tomb" landfill for MSW "management" is that such a landfill is designed only to postpone leachate migration and pollution. Leachate generation and migration are held at bay only for as long as, and as well as, the wastes are kept dry through rigorous and vigilant monitoring and perpetual maintenance of the containment systems, even those that exist under the buried wastes. The longer the dry-tomb keeps the wastes dry, the longer the threat is postponed, and responsibility for dealing with leachate migration and pollution passed along. The wastes in a dry-tomb-type MSW landfill will be a threat to generate leachate and landfill gas for extraordinarily long periods of time – hundreds to thousands of years or more – as long as the wastes are kept dry. The potential advantage of incorporating leachate recycle in a properly designed and managed MSW landfill is the reduction in the amount of leachate that has to be managed in an offsite facility, and the diminishing of long-term public health and environmental quality threat and liability problems inevitable with dry tomb landfills. A comprehensive review of technical flaws in "dry tomb" landfilling as allowed under compliance with minimum US EPA Subtitle D landfilling regulations is available at:

> Lee, G. F., and Jones-Lee, A., "Flawed Technology of Subtitle D Landfilling of Municipal Solid Waste," Report of G. Fred Lee & Associates, El Macero, CA, December (2004). Updated May (2010).
> http://www.gfredlee.com/Landfills/SubtitleDFlawedTechnPap.pdf

The O'Brien (2010) article is remiss in not addressing some of the major, well-known problems with, and limitations in, the ability of bioreactor landfills to achieve waste stabilization to a sufficient degree that the remaining waste material no longer poses a threat to groundwater quality through release of leachate and landfill gas. We have been involved in the review of the potential benefits and problems with landfill leachate recycle (now called bioreactor landfill operations) since the early 1980s when we conducted a review of the use of such processes at US military base landfills, for the US Army Construction Engineering Research Laboratory. Our report and summary publication on that work, referenced below, discussed potential problems and limitations with the use of leachate in conventional MSW landfills.

> Lee, G. F., Jones, R. A. and Ray, C., "Review of the Efficacy of Sanitary Landfill Leachate Recycle as a Means of Leachate Treatment and Landfill Stabilization," Report to the US Army Construction Engineering Research Laboratory, Champaign, IL, October (1985).
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> Lee, G. F., Jones, R. A., and Ray, C., "Sanitary Landfill Leachate Recycle," *Biocycle* **27**, 36-38 (1986).

As discussed in those writings, leachate recycle increases the hydraulic loading of the landfill, which may lead to increased groundwater pollution by leachate. Also, leachate recycle as normally practiced in the 1980s as well as today, produces a residual waste that still has the potential to generate leachate that can cause groundwater pollution. A major review of those issues as they relate to practicing leachate recycle in US EPA Subtitle D single-composite-lined landfills was published in the proceedings of an international landfill symposium nearly two decades ago.

> Lee, G. F. & Jones-Lee, A. "Landfills and groundwater pollution issues: 'Dry tomb' vs F/L wet-cell landfills." *Proceedings of Sardinia '93 IV International Landfill Symposium*, Sardinia, Italy, pp. 1787-1796 (1993).
> http://www.gfredlee.com/Groundwater/lf-conta.htm

In that paper, we discussed problems with dry-tomb-type landfills in affording reliable protection of public health and environmental quality and how leachate recycling could be practiced to enhance landfill waste stabilization through fermentation and leaching of the landfilled wastes.

We introduced the concept of "fermentation and leaching" (F/L) of properly prepared MSW in a properly designed wet-cell landfill to achieve a truly stabilized waste residue. In order to achieve true waste stabilization – so that the waste residual would no longer be a threat to cause groundwater pollution – it is necessary to significantly change how MSW is handled and how landfills are designed, operated, and closed relative to conventional Subtitle D landfilling practice. During the early to mid-1990s we published a number of papers on these issues in MSW journals; those papers are available on our website [www.gfredlee.com] in the "Landfills–Groundwater" section, "Fermentation/Leaching 'Wet Cell' Landfills" sub-section [http://www.gfredlee.com/plandfil2.htm#wetcell]. Among those papers is one in which we discussed changes that would need to be made in minimum design, operation, and closure of MSW dry-tomb landfills to potentially make them amenable to inclusion of conventional leachate recycling for waste stabilization:

> Jones-Lee, A. and Lee, G. F., "Appropriate Use of MSW Leachate Recycling in Municipal Solid Waste Landfilling," Proc. Air & Waste Management Assoc. 93rd annual national meeting Salt Lake City UT paper 00-455 CD ROM Pittsburgh, PA, June (2000). http://www.gfredlee.com/Landfills/leachatepapsli.pdf

As discussed in our writings, leachate recycle/bioreactor landfilling should not be practiced in single-composite-lined landfills for a variety of reasons including

- the increased hydraulic loading on a liner system that, under the best of conditions and low head, will not prevent the migration of leachate through it. The increased hydraulic loading of the landfill liner system under leachate recycle operations will lead to earlier and greater rates of groundwater pollution.
- the lack of a liner leak detection system that would detect the first failure of the single composite liner to collect all leachate generated in the landfill, before groundwater pollution occurs.
- the unreliability of allowed groundwater monitoring systems. The allowed monitoring systems employ vertical monitoring wells spaced hundreds of feet apart at the groundwater monitoring point of compliance for the detection of incipient pollution. Such systems have a very low probability of detecting incipient groundwater pollution owing to the manner in which leachate will emanate from a lined landfill.

Leachate recycle should not be practiced without first addressing the design of the liner systems to function properly with the anticipated head, providing reliable groundwater monitoring that will, in fact, be capable of detecting incipient groundwater pollution from the landfill, and addressing long-term funding issues in the event that the system fails to perform as intended. Then, it should not take place without a double-composite-lining of the landfill and a suitable leak-detection layer between the liners. When leachate is first detected in the leak detection layer underlying the upper composite liner, the leachate recycle must be stopped and the landfill cover installed and maintained to prevent moisture from entering the landfill for as long as the wastes in the landfill will be a threat to generate leachate when contacted with water. If an assessment is made that stabilization (fermentation and leaching) is "complete," the landfill and area groundwater would still need to be monitored and maintained in perpetuity. This mode of operation will require that the Subtitle D 30-year postclosure care and funding period be abandoned in favor of perpetual care (forever) funding for monitoring, and maintenance of the landfill.

Another major change in MSW landfill operations that will need to be made is the shredding of wastes prior to fermentation/leaching (processing in the bioreactor) so that the wastes disposed of in plastic bags are fully exposed to the recycled leachate and subsequent rinse water added to the landfill; the crushing of bagged waste as currently prescribed is inadequate to ensure proper fermentation and leaching. Without proper shredding, wastes disposed of in plastic bags can remain hidden from the fermentation/leaching process until the plastic bag decomposes, which could be hundreds of years in the future, well-after the landfill has been declared "stabilized." As the plastic bags decompose, moisture that interacts with the newly exposed wastes will generate leachate and landfill gas. Under the current Subtitle D landfilling practice that requires no assured perpetual-care postclosure funding, the eventual decomposition of the plastic-bagged garbage can readily occur when there is no operation of the leachate collection system and monitoring of this system and the groundwaters that have been polluted by leachate generated by the landfill. Similarly, the eventual decomposition of plastic-bagged wastes would be expected to generate landfill gas, likely well-after the cessation of monitoring for landfill gas migration and operation of the landfill gas collection system. In order to prevent long-term problems associated with the resumption leachate and landfill gas generation at some undeterminable point in the future, MSW must be shredded prior to placement in a bioreactor landfill.

Another advantage of shredding of MSW before landfilling is that it can greatly reduce/eliminate the need for daily cover to try to control odor releases from the landfill and thereby improve the hydraulics of adding moisture to the landfill in the leachate/bioreactor operation.

Yet another key element that needs to be incorporated into a "bioreactor" landfill if it is to render a non-polluting residue is the thorough rinsing of the treated ("bioreacted") wastes with clean water. Effective conventional leachate recycle fermentation serves to decompose fermentable organic matter, but does not render hazardous and otherwise deleterious components of municipal solid waste innocuous; it leaves a large residue of persistent organic and inorganic chemicals in the waste residue. Some of this material, if left in the landfill, will inevitably leak from the landfill. Therefore, after landfill gas generation has essentially stopped with the completion of fermentation, which can require five to ten years of leachate recycle with properly shredded wastes, clean water needs to be passed through the residues until the leachate no longer contains excessive amounts of hazardous and otherwise deleterious materials. Fermentation/leaching (bioreactor) also requires reliable management, treatment, and disposal of all of the leachate and rinse waters generated and used in this process.

Properly conducted, managed, and monitored fermentation/leaching that incorporates the aspects discussed above has the potential to rendered stabilized MSW residue that has limited potential to cause future groundwater pollution and landfill gas release. Achieving such a residue can compensate for significant errors made by congress in its adoption of the dry-tomb landfilling approach for MSW management.

Landfill Gas Generation

In his list of "Benefits" of bioreactor operations for MSW, O'Brien stated,
"*Higher Rate of Landfill Gas Generation—A consequence of accelerated waste biodegradation is an increase in the rate of LFG generation. Research published on the Waste Management*

bioreactor project at the Outerloop Landfill in Louisville, KY, has indicated that the rate of LFG generation in the as-built bioreactor cells was greater than that of the control cells and, as a result, provided a greater potential rate of energy production."

While his statement is factual as far as it goes, it is misleading in that it fails to address the long-term issues of landfill gas generation in conventional MSW dry-tomb landfills and bioreactor landfills discussed above. In our "Flawed Technology" review referenced above, and in Lee and Jones-Lee (1999), we have discussed errors commonly made in the estimation of landfill gas generation rates and duration by landfill applicants' engineers and approved by regulatory agencies; gas generation rates characteristic of classical sanitary landfills, which are typically used in landfill applications, are not appropriate for dry-tomb landfills. During the active life of an MSW landfill, when the wastes are open to the atmosphere or are covered only with a permeable soil layer, landfill gas generation rates can be typical of those at classical unlined sanitary landfills. However, once a cell is closed with a low-permeability cover the landfill gas generation rates can be greatly retarded; the rate of gas generation is controlled by the amount of water that enters the wastes through the cover. As discussed above, the longer the waste can be kept dry, the longer the gas generation is postponed; as the integrity of a dry-tomb landfill eventually and inevitably declines and allows greater amounts of moisture into the buried wastes, landfill gas production will resume. As discussed by Lee and Jones-Lee (1999, 2010) the US EPA-sponsored Landfill Gas Emissions Model (LandGEM) used to estimate landfill gas generation rates is not reliable for estimating landfill gas generation rates for closed dry-tomb landfills..

Post-Closure Cost Reduction

O'Brien indicated that another benefit of bioreactor landfills was:

"*Potentially Reduced Post-Closure Care Costs—Bioreactor landfills have the potential to save on post-closure care costs. To date, regulatory authorities have not reduced the long-term monitoring frequency and duration for bioreactors."*

That claim is highly misleading for conventional leachate-recycle bioreactor landfills. As discussed above, proponents of conventional leachate-recycle landfills neglect to discuss well-known types of long-term care realities and problems and associated long-term costs faced by owners of such landfills. There is no justification for regulatory agencies to allow a reduction in the duration of post-closure care, or a reduction in required post-closure funding for so-called bioreactor landfills.

O'Brien's Conclusions

O'Brien presented several conclusions from the ARF review of bioreactor technology. One conclusion was:

- "*The Bioreactor Landfill Is Still in the Demonstration Stage of Development—As documented in the updated guide, significant progress has been made regarding the development and demonstration of the bioreactor landfill alternative. However, to date, most of the bioreactor landfills have been implemented at the pilot-scale or control cell levels. As a result, long-term full scale bioreactor landfill applications are yet to be fully evaluated and long-term monitoring data are still lacking."*

Proponents of bioreactor landfills and those who approve those approaches for managing MSW need to reliably address significant technical issues with bioreactor landfilling of MSW, including those issues discussed above. Until that is done, bioreactor landfills will not be adequately evaluated for their ability to effectively stabilize MSW; nor will they be capable of addressing long-term problems of dry-tomb landfilling or alleviate the long-term liability of landfill owners.

Another conclusion O'Brien stated,

- "*Standard Subtitle D Containment Systems Work Well for Bioreactors—Although some adjustments—such as the use of coarser drainage materials—may be required, Subtitle D containment systems appear to work well with respect to environmental protection.*

Contrary to that conclusion, Subtitle D containment systems (dry-tomb landfills) cannot be relied upon to provide technically sound, long-term protection of public health or environmental quality. The basis by which the assessment was made that they "appear to work well with respect to environmental protection" was not addressed. Not only is their long-term integrity not demonstrable in practice, but also there are significant technical deficiencies in the dry-tomb landfilling concept and requirements that would preclude the expectation that they can, in fact, ensure long-term environmental quality protection. As discussed in the "Flawed Technology" review cited above, the unreliable monitoring of single composite landfill liner failure by vertical monitoring wells spaced hundreds of feet apart at the point of compliance prevents the reliable assessment of the adequacy of a single-composite liner system. For many Subtitle D landfills, the detection of landfill liner failure will not occur until pollution of offsite groundwater production wells is detected. Once that occurs, these types of landfills will become "superfund" sites requiring very high expenditures for remediation of polluted groundwaters.

Another conclusion states,

- "*Retrofit Bioreactors Can Work Effectively—This important conclusion reached by EPA Research has significant implications for traditional landfills."*

What is claimed to be the "effectiveness" of bioreactors landfills as being practiced by retrofitting minimum-design Subtitle D landfills is based on a very limited assessment of accelerated landfill gas production for part of the deposited, unbagged MSW and landfill air space recovery. Such an assessment does not adequately consider the true, long-term problems of leachate-recycle (bioreactor) landfills discussed in these comments.

The final conclusion stated,

- "*The RD&D Permit Program Needs Improvement—The RD&D program does not appear to be effective in achieving its objective of encouraging the implementation of bioreactor landfills for demonstration purposes. More leadership and funding are needed from the EPA to encourage the demonstration and development of this technology*."

We, too, have found significant deficiencies in the US EPA RD&D for leachate-recycle landfill demonstration projects. We live in Yolo County, California and were asked to review a proposed US EPA RD&D demonstration project of leachate recycle at the Yolo County landfill; our comments are available at:

> Lee, G. F., "Comments on EPA Project XL: Final Project Agreement for the Yolo County Accelerated Anaerobic & Aerobic Composting (Bioreactor) Project, Dated June 22, 2000," Comments submitted to US EPA Region 9 by G. Fred Lee & Associates, El Macero, CA, July 1 (2000), with additional comments dated September (2000).
> http://www.gfredlee.com/Landfills/ProjectXL.pdf

Our primary comment was that that then-proposed bioreactor project would only effectively "demonstrate" what was already well-known, namely that adding water to an MSW landfill will accelerate landfill gas generation rates. None of the very important issues of the type discussed in the literature and herein were to be addressed in that proposed project. As far as we have been able to find, those in charge of the US EPA bioreactor program has thus far failed to even acknowledge, much less begin to address, the types of issues discussed in this review.

References

O'Brien, J., "The Solid Waste Manager's Guide to the Bioreactor Landfill - A 2009 Update. MSW Management pp 14-May (2010). http://www.mswmanagement.com/issues/index.aspx

Lee, G F and Jones-Lee, A., "Unreliability of Predicting Landfill Gas Production Rates and Duration for Closed Subtitle D MSW Landfills," report of G. Fred Lee & Associates, El Macero, CA September (1999). http://www.gfredlee.com/Landfills/lf_gas_paper.pdf

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Reference these comments as,
Lee, G. F., and Jones-Lee, A., "Comments on the O'Brien ARF SWANA Article, 'The Solid Waste Managers' Guide to the Bioreactor Landfill–A 2009 Update,' MSW Management 20(3):14,16 May (2010),'" Report of G. Fred Lee & Associates El Macero, CA, Submitted to MSW Management, June (2010).
http://www.gfredlee.com/Landfills/SWANABioreactorCom.pdf