Missouri Waste Control Coalition
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Proceedings of the Session:

Bioreactor Landfills

Moderator: Mark Russell, City of Columbia

Speakers

John Bowders, University of Missouri-Columbia
Mark Hudgins, Environmental Control Systems, Inc.
Chet McLaughlin, US EPA Region 7
Jim Hull, Missouri Dept of Natural Resources
Followed by Questions and Answers From the Participants

Abstract

Session IV-D held on Tuesday, July 18, 200 at the Missouri Waste Control Coalition conference in Columbia Missouri was entitled Bioreactor Landfills. Four speakers presented background on the development, design, operation and regulatory issues associated with this emerging technology. A written summary of the four presentations along with a summary of the questions and responses during the session are included in this proceeding. The reader is encouraged to contact any of the speakers regarding further information on this technology. Contact information is provided on page two.

Contact Information

John Bowders **"MSW Landfills – Bioreactors"** pp 3
Professor of Civil Engineering
Civil & Environmental Engineering,
University of Missouri-Columbia,
E2509 EBE,
Columbia, MO 65211-2200,
Ph 573.882.8351, Fx 573.882.4784,
bowders@missouri.edu

Mark Hudgins **"Innovative Methane Mitigation Using an Aerobc Landfill System"** pp 7
Vice President Landfill Technologies Div.,
Environmental Control Systems, Inc.,
1120 Edgefield Highway,
Aiken South Carolina, 29801,
Ph 803.643.1755, Fx 803.643.1756,
markh@aerobiclandfill.com

Chet McLaughlin **"EPA View of Bioreactor Landfills – Shaping the Debate"** pp 14-17
Pollution Prevention Expert,
US EPA Region 7, ARTD,
901 North 5th Street
Kansas City, KS 66101,
Ph, 913.551.7666, Fx 913.551.7512,
mclaughlin.chilton@epa.gov

Jim Hull **"Thoughts on the Future of Bioreactor Landfills in Missouri"** pp 17-18
Program Director,
Solid Waste Management Program,
Missouri Dept of Natural Resources,
PO Box 176,
Jefferson City, MO 65102,
Ph 573.751.5401,
nrhullj@mail.dnr.state.mo.us

Mark Russell **"Questions and Comments from the Session"** p. 18
Superintendent,
Columbia Landfill,
City of Columbia, Public Works Dept.
5700 Peabody Road,
PO Box N,
Columbia MO 65205,
Ph 573.886.0722, Fx 573.886.0268,
MSR@ci.columbia.mo.us

Municipal Solid Waste Landfills – Bioreactor Landfills

John Bowders, Civil & Environmental Engineering, University of Missouri-Columbia
Mark Russell, Dept of Public Works, City of Columbia

Abstract

Land disposal of solid waste has changed dramatically over the last 30 years. Open garbage dumps have given way to environmentally secure Subtitle D sanitary landfills. Operating under the Subtitle D philosophy, these facilities have essentially stopped any groundwater pollution from newly constructed landfills. New facilities have also ensured that the waste will be preserved for an indefinite period due primarily to the lack of moisture that is required for biological degradation of the organic fraction of the waste mass.

Absence of waste degradation means larger volumes of waste to be contained. Increased volumes mean larger or more landfills are necessary. One option for reducing the volume is to actively biodegrade the waste. A *landfill bioreactor* offers the possibility of degrading the organic fraction of waste within the landfill. Operating a landfill in a bioreactor mode promotes rapid stabilization of the waste, improved leachate and gas management, and reduces the long-term risks posed by the landfilled wastes.

Operating a bioreactor landfill requires additional moisture be added to the landfill – a change in the basic philosophy of Subtitle D regulations. There are challenges – technical as well as regulatory, facing widespread acceptance of this mode of landfill operation.

Introduction

- Conventional (MSW) Landfill Design – Dry Tomb

Objective: Control the liquids associated with the landfill, i.e., limit infiltration and collect any leachate.

- Bioreactor Landfill Design – Wet Cell

Objective: Degrade and stabilize the organic waste constituents as rapidly as possible.

Benefits of Bioreactor Landfills

- Rapid organic waste stabilization. Reduced risk of long term pollution.
- Maximization of landfill air-space.
- Maximization of landfill gas production and energy recovery.
- Improved leachate treatment and storage.

- Reduction in post closure and care.
- Increased environmental stewardship.
- Economics.

Challenges for Bioreactor Landfills

- Regulatory hesitancy to change: Dominant approach is dry tomb, this works, why change?
- Public perception that bioreactor may increase odors and air emissions.
- Landfilling is moving toward just disposing of the “non-recoverable”, non-degradables.
- Significant capital investment for bioreactor (probably more than dry tomb).
- Operational challenges: leachate recirculation system maintenance, uniform wetting of waste mass, settlement of the system, clogging of LCS, …
- Little data (to date) to show that current containment systems are adequate.
- Regulatory agencies are unlikely to simply reduce the 30 year Post Closure and Care Period.
- Impacts on designs:

    - Leachate collection systems,
    - Bottom liners,
    - Side slope liners
    - Covers,
    - Gas collection system,
    - Slope stability (the waste mass and liner system)
    - Bottom stability (overall or global stability),
    - Leachate/liquid distribution system,
    - Operations,
    - Post closure and care period, (PCCP)
    - Active life time performance monitoring,
    - Contingency plans, …

Where Do We Go From Here?

- Need a comprehensive, up to date, compilation, analysis and results of all the bioreactor facilities and research performed or operating currently.
- Need full-scale field tests and well-instrumented and monitored facilities to provide the field performance data that will show the merits and shortcomings of the bioreactor.
- Designs for bioreactors need to be “from the ground up” not retrofits of existing “dry tomb” facilities.
- Designs for the facilities should be performed based on function, i.e., what is the function of the particular unit of the facility, e.g., leachate collection system, and design it for the purpose intended.

Conclusions

Performance monitoring of Subtitle D (composite lined, dry tomb) landfills to date has shown the liners to be exceptionally effective at containing landfill leachate from escaping into the subsurface (Othman et al. 1997). In other words, the current landfill designs are working well and meeting their intended design goals. Why change?

Given the design goals remain the same, there is little reason to change the design, regulations, or our approach to solid waste disposal; however, the design goals *are* changing! Partially by better engineering for long-term solutions, partially by public pressure and partially by economics, the goals of our solid waste disposal philosophy are evolving and will continue to evolve. As our goals change, we must engineer solutions to meet the changes.

Thirty years ago, the research data, performance data and know-how for Subtitle D lining systems did not exist. It took 20 years to get there, but the solution met the goals set for controlling the escape of leachate into the subsurface. Now the bar is being raised – conserve landfill space and provide longer term, even permanent solutions, for our solid wastes. Bioreactors, in regard to the organic constituents, may provide the next generation of solid waste disposal. Requirements for research, development and field performance monitoring of prototype systems should not preclude the concept but rather, similar to Subtitle D development, should be employed judiciously and critically to arrive at the best practicable solution.

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The following paper was *Presented at the 2nd International Methane Mitigation Conference, Novosibirsk, Russia - June 21, 2000*

Innovative Methane Mitigation Using An Aerobic Landfill System

Mark Hudgins, Environmental Control Systems, Inc., Aiken, South Carolina (USA)
Leon Green, Environmental Control Systems, Inc., Aiken, South Carolina (USA)

Abstract

Municipal solid waste (MSW) landfills worldwide are experiencing the consequences of conventional landfilling techniques, whereby the landfill leachate and gases that are generated from these units have been determined, in many cases, to be risks to human health and the environment. The two primary gases that are commonly found in landfill gas (LFG), methane and carbon dioxide, are considered "green house" gases which may contribute to global warming.

Two unique landfill projects were conducted in Georgia (USA), whereby it was demonstrated that the aerobic degradation of MSW within a landfill can not only significantly increase the rate of waste decomposition and settlement as well as reduce the level of contaminants in the leachate, but it was observed that this approach also decreased the production of methane by over 90% and significantly reduced levels of offensive odors that are typical of conventional landfills. In addition, the aerobic process reduced the toxicity of the leachate (a major source of groundwater contamination), reduced net offsite leachate volumes and pathogens due to controlled heat generation, and eliminated the foul odors associated with anaerobic decay of waste.

This approach could be a natural, low-cost option in reducing methane emissions at MSW landfills worldwide, especially where WTE or other options are not economically attractive. Furthermore, combining these benefits with the possibility of landfill reuse (via landfill mining) will make landfills less harmful and will increase the potential for a sustainable landfill strategies to significantly extend the life of the landfill.

1 Introduction

Many of the nation's landfills are becoming significant risks to the environment. In a typical landfill, much of the waste that is buried (generally containing 60% or more in organic content) degrades via fermentation processes under anaerobic conditions. Landfill leachate, generally acidic in nature, is produced dissolving soluble components, hydrolyzed materials, and degradation products from the refuse. These anaerobic conditions within a landfill result in the production of methane and carbon dioxide (the larger percentage), as well as non-methane organic compound (NMOCs) emissions to the extent that MSW landfills are the largest anthropogenic (man-made) source of methane in the U.S., according to the EPA[1]. In addition, certain NMOCs present in the landfill gas can contribute to leachate toxicity and groundwater contamination (where are landfills leaking). Lastly, the toxic leachate produced by the landfill can impact groundwater resources and pose serious health risks.

Due to the to impact water resources and the atmosphere, many landfills collect and manage landfill leachate and gas (LFG) via leachate and gas collection systems. In addition, the risks posed by the collection and management (controlled flare or other end use) can be significant, with respect to worker safety.

2 LFG Control Technology To Date

Two strategies that many landfills consider in controlling LFG are 1) reduction of wastes placed into the landfill (waste diversion and/or recycling) to reduce LFG emissions, and 2) direct use of gas as a reusable energy source, e.g. waste-to-energy (WTE). Other strategies that are being evaluated and/or demonstrated include highly advanced uses of LFG, such as the production of acid fuels cells.

However, there are several issues that have limited the effectiveness of these strategies, despite their feasibility. For example, waste diversion, composting, and recycling programs are underway in many states. However, many landfills are having difficulty meeting target waste reduction goals (in the U.S., 35% is proposed) which would reduce the amount of organic waste that enters their landfills and, consequently, LFG emissions. If this continues, it is uncertain whether landfilling of these wastes (currently at 52% of U.S. waste generated) and LFG emissions would drop, especially if the total volume of waste generation increases each year, as estimated.[2]

With respect to WTE, this methane management approach can offset landfill costs through the sale or use of LFG at large landfills. However, WTE may not offer attractive economic advantages for many other US landfills. The EPA’s Methane Outreach Program (1997) estimates that of the approximately 3,700 landfills in the nation, only 750 are considered candidate WTE landfills.[3] This leaves approximately 3,000 non-candidate landfills, many of which may face methane gas compliance with few low-cost LFG management options. This assessment is based on factors such as the size of U.S. landfills, their location and proximity to a potential LFG user, and potential market conditions.

In an attempt to increase the yield of LFG to make WTE possibly more economically attractive, some landfills are looking at leachate recirculation under anaerobic conditions to increase the production of methane. However, according to the EPA, there are several issues of potential concern with respect to WTE and enhanced-LFG programs.[4] These include the potential for increased fugitive emissions, increased regulatory compliance, increased capital costs, and uncertain energy market conditions. In addition, WTE and enhanced-WTE projects still operate under anaerobic conditions, doing little to reduce environmental risks.

Lastly, new LFG-use technologies, such as use of LFG in the production of acid fuels cells, LFG to vehicle fuel use, and LFG use to evaporate landfill leachate, have shown promise[5]. However, according to the EPA, there can be barriers associated with their deployment, including: increased capital costs, perception of high risk, regulatory permitting, lack of information on the technology, siting issues, and establishing local governments' priorities on solid waste management.

3 Aerobic Landfills As A Potential Solution

One of the assumptions in managing a landfill is that waste degradation is slow and that methane gas will always be produced, in many cases, over 50% by volume of the total LFG gases. However, active aerobic biodegradation processes, such as composting, have demonstrated that not only can the biodegradable portion of MSW be stabilized in a significantly shorter time frame (as compared to anaerobic conditions) but, due to the increased availability of oxygen, methane production is reduced. Laboratory experiments, such as those conducted at the University of South Florida, have demonstrated that creating an aerobic environment in MSW can have positive results for the landfill. In these studies, it was shown that by recirculating the leachate back into the waste and, at the same time, injecting air into the waste, the facultative and respiring bacteria converted the biodegradable mass of the waste and other organic compounds to mostly carbon dioxide and water, instead of methane, with a degraded humus remaining[6].

This work led to the idea that the landfill waste can be used as a treatment bed on a larger scale, whereby air, moisture, and nutrients are combined together, promoting the aerobic treatment of the waste as well as the leachate in the manner described above. In these cases, the landfill cell serves as a large closed vessel and managed to control leachate, LFG, and factors associated with aerobic waste composting (e.g. waste moisture content, temperature). As observed in most wastewater treatment facilities, aerobic treatment processes can also reduce concentrations of certain organic compounds typically found in their influents. Compounds such as toluene, MEK, vinyl chloride, as well as many odor-causing compounds (e.g. ammonia) can be treated in aerobic lagoons, rotating beds, and fixed media systems. If deployed on a larger scale, the need for subsequent landfill leachate treatment could also be reduced, depending on applicable regulations. As an additional benefit, there would be an increase in the rate of waste stabilization as well as an increase in the rate of waste subsidence. This creation of landfill “air space” can maximize the useful life of a landfill.

Therefore, the aerobic landfill could provide a natural, cost-effective approach to reducing “greenhouse gases," while at the same time, help make landfilling wastes more acceptable to the public. At many landfills, one of the short-term cost savings associated with this benefit would be the costs that would, otherwise, be directed to methane gas treatment and management options.

4 Results From Two Aerobic Landfill Systems

Beginning in January of 1997, two independent aerobic landfill demonstrations were conducted at separate Subtitle D landfills in Georgia (USA) based on these ideas. The first system, referred to as Aerobic System Number 1, was installed within the 16-acre Subtitle D portion of the Columbia County Baker Place Road Landfill (CCBPRL), located near Augusta. The second system, Aerobic Landfill Number 2, was conducted at a private landfill in Atlanta.

Both landfills utilized leachate recirculation approaches, whereby the landfill leachate that is collected in the landfill's existing leachate collection system was injected through an intermediate cap into the MSW. At the same time, either an air compressor or blower injected air into these same waste areas via vertical wells.

4.1 System Design

Both landfills were constructed under EPA Subtitle D regulations, whereby each Cell was constructed with a composite plastic liner and leachate collection system. The waste in each study Cell was overlain by a 12-inch intermediate clay cover. Leachate that was generated in each Cell or not utilized during the aerobic process after re-injection, drained back into the respective leachate collection system. For each aerobic landfill system, the air injection mechanism comprised of electric blowers or an air compressor and piping, all connected to vertical air injection wells that were installed directly into the waste. Leachate, collected in holding tanks at each site, was pumped into each aerobic system through a leachate recirculation system installed on top of the intermediate cap. This part of the system, consisting of either 2-inch diameter PVC vertical wells or drip irrigation hoses, injected leachate through the intermediate clay cap and into the waste mass. The leachate then percolated downward through the waste mass and mixed with the air that was forced into the waste. Leachate that was not utilized during aerobic decomposition migrated downward to the leachate collection system was pumped back to the tank, to be recirculated again. *(Note: Future systems can be constructed of similar materials and may not need a bottom liner/leachate collection system)*

The CCBPRL is located approximately 12 miles west of Augusta and just off Interstate 20. The Subtitle D portion of the CCBPRL was opened on October 3, 1995 and is located immediately east of a 60-acre closed, unlined landfill. It is designed to handle approximately 965,113 cubic yards of waste. Presently, the CCBPRL receives approximately 260 tons of waste daily. The incoming waste is typically placed in cells that are approximately 10 to 12 feet deep and compacted to approximately 1300 pounds per cubic yard (lb/CYD).

The CCBPRL also includes separate leachate collection systems within its two 8-acre waste cells (North and South). Landfill leachate is collected in each cell separately and is pumped from individual pump houses to the leachate holding tank, an aboveground 250,000-gallon storage tank, located just north of the Subtitle D area. These collection systems consist of a network of six-inch diameter perforated collection piping which drain by gravity to two separate pump houses, Pump House Numbers 1 and 2. Upon reaching the tank's holding capacity, leachate collected in the tank is sent to a local wastewater treatment facility. Prior to operation of the aerobic system, the Subtitle D portion generated approximately 120,000 gallons of leachate per month. The leachate collection piping is embedded within a one-foot gravel layer which is covered by a geotextile fabric and a one-foot protective sand layer. System Number 1, was installed within the 8-acre northern portion of this landfill and operated for approximately 21 months. Over the course of the project, the northwest 4 acres received air and leachate while the remaining 4 acres received leachate only. Monitoring was conducted in both portions. Average waste depth was 10 feet. Through a minor modification of the landfill's operating permit, the aerobic landfill was approved by the Georgia Environmental Protection Division (EPD)[7]. The system was then installed in approximately two weeks.

Site 2 Landfill is located just south of the City of Atlanta and just off Interstate I-285. Presently, the landfill receives approximately 3,000 tons of waste daily. The incoming waste is typically placed in cells that are approximately 10 to 12 feet deep and compacted to approximately 1,300 pounds per cubic yard (lb/cyd). System Number 2, installed in the new Cell 3A of the Landfill, was operated for nine months. This 2.5-acre cell contained approximately 75,000 cubic yards of waste and an average depth of 30 feet. Critical operation data was monitored using a comprehensive system of real-time instruments and portable gas equipment. Upon completion of the project, approximately 5,000 cubic yards of the degraded waste were excavated to evaluate the effectiveness of the process. In addition, the waste was characterized to determine potential future uses of the recovered waste.

4.2 Overall Results

At both sites, the aerobic landfill systems demonstrated either: 1) a significant increase in the biodegradation rate of the MSW over anaerobic processes, 2) a reduction in the volume of leachate as well as organic concentrations in leachate, and/or 3) significantly reduced methane generation. In addition, waste settlement was observed as each system degraded the organic portions of the waste mass. These benefits were obtained while maintaining an optimum moisture content of the waste mass and waste mass temperatures. Table 1 below provides a summary of the results:

Parameter	**CCBPRL Results (8)**	**Site 2 Landfill Results (9)**
Biodegradation Rate	Increased > 50%	Increased >50%
Leachate BOD_5	Reduced by >70%	Inconclusive
Leachate VOCs, Metals	Reduced by 70% - 99%	No VOC data, Metals remained stable
Leachate Volume	Reduced by 86%	Significant volume of moisture evaporated, estimate to be 50%
MSW Settlement (ft/ft)	Average: 4.5%	Greatest: 10%
Methane Generation	Reduced by 50 – 90%	Reduced by 50 – 90%

4.3 Landfill Gas Measurements

During the initial operation of the system, the air delivery rate at Site 1 was approximately 1,000 scfm. After 5 months, the air flowrate was increased to 2,000 scfm[10]. During the initial operation of System 2, the air delivery rate was approximately 200 scfm. After 4 months, the air flowrate was increased to 700 scfm.[11] With this additional air, methane at both sites was reduced to less than 10% (v/v). Typical landfill gas and waste mass temperature data for Site 1 are presented in Figure 1.

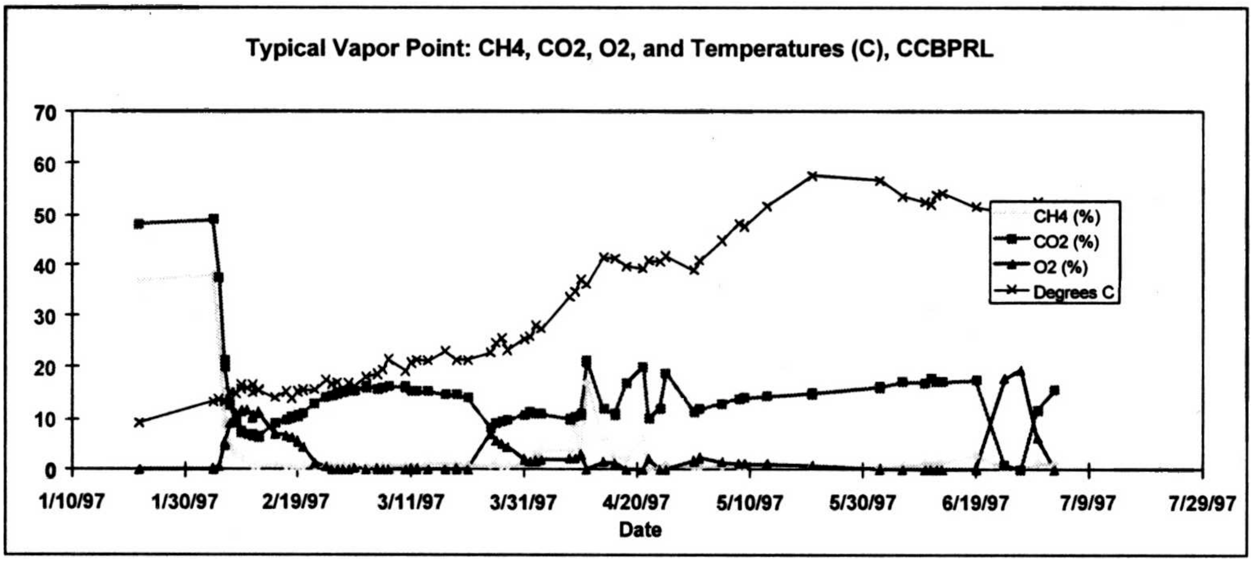

Figure 1: Typical Vapor Point/Thermocouple Measurements, System Number 1

4.3.1 Methane, Carbon Dioxide, and Oxygen

During the project, blowers were occasionally cycled on and off, or shut down for maintenance. As with many biological systems, System 1 demonstrated its ability to recover quickly during periods of system cycling, depletion of nutrients (O_2, etc.) and moisture, and/or during a temporary shutdown. Repeated blower cycling and the addition of more blowers increased variance in gas concentrations, but allowed the above relationship to re-establish itself each time.

At System 2, the landfill gas results were similar. Shortly after start up (about 4 weeks), average methane concentrations decreased from 46% (v/v) to less than 10%. During the same time, carbon dioxide concentrations decreased from 54% (v/v) to less than 10%, as well and oxygen levels increased to approximately 10%. [12] The "rebound" of gas concentrations as a result of the cycling of air was also observed at this Site.

Within both aerobic landfill systems, O_2 initially increased in many of the monitoring points at system startup. In conjuncture with this, CO_2 fell initially and then rose in close correlation with O_2 consumption. When observed with the methane levels, these gas readings indicated a transformation from anaerobic to at least partial aerobic metabolism: CO_2 rises as O_2 is consumed and CH_4 production falls off.

At System 1, gas samples collected from several of the vapor points indicated that the waste in the aerobic areas were reverting back to anaerobic metabolism after two months as oxygen, initially supplied in this area [13]. The addition of vertical injection wells and blowers near these points provided additional air (oxygen) to reverse anaerobic trends and re-establish aerobic activity. Temperature data supports this interpretation with a significant increase (40% over 20 days) since the introduction of vertical injection wells.

Based on direct measurements from thermocouples inserted in the waste at Site 2, waste mass temperatures remained relatively stable between 40 $_{o}$C and 60 $_{o}$C after aerobic conditions had been reached. Waste mass moisture was above 50% (w/w) in the most active areas, as determined by gypsum blocks installed into the waste or by laboratory analyses of waste samples. Again, as O_2 was utilized and CO_2 increased, the temperature of the waste increased, indicating the metabolic conversion of organic materials into CO_2 and water. The greater the temperature, the more carbon that was utilized.

Vapor and temperature data at both Sites clearly support that aerobic waste degradation had been established and proceeded, in many areas, at a rapid rate. It is highly unlikely that temperatures reported in these waste cells could have occurred in the presence of oxygen without it being aerobic. The stoichiometric relationship between aerobic carbon utilization and heat release supports this observation; a significant amount of carbon was converted to cellular products via aerobic metabolism. In addition to the reduction of methane, waste samples that were excavated from the "aerobic" areas at both sites appeared as dark to brown degraded matter with a musty, composting odor. When compared to the samples collected from the control ("anaerobic") area which had the relatively same age waste, the difference was obvious. The organic waste samples collected in the control area were virtually undegraded, with foul odors noted.

4.3.2 Volatile Organic Compounds (VOCs) and Odors

During the demonstration at Site 1, a portable photoionization (PID) detector was used to analyze LFG samples from many of the sampling points; PID measurements did not reach above 1 parts per million (ppm). In addition, LFG samples were collected and analyzed for VOCs in a certified laboratory. Samples were collected in Tedlar bags and shipped overnight to the laboratory.

Based on this data, it is concluded that the aerobic mechanism that contributed to the reduction in leachate VOCs, as well as CH_4 and CO_2 may have also had a positive impact on vapor-phase VOC reduction. This is supported by the fact that the strong odors detected in the control areas, which can contain vapor-phase VOCs, were minimal in the "aerobic" areas. From a public acceptance perspective, this benefit can be important to solid waste planners during the siting of new landfills or to address odor complaints at existing ones.

5 Benefits of the Aerobic Landfill

As a result of these and other aerobic projects, there have been discussions among many in the solid waste industry as well as state and federal regulatory agencies on the possible benefits this approach could have on future solid waste management worldwide.

- With respect to LFG, there could be benefits ranging from relief under certain CAA requirements to improved risk reduction as well as meeting certain “greenhouse gas” reduction goals. Due to its potential significant impact on landfills, the EPA's Office of Research and Development (ORD) has recognized this approach as an emerging ‘Tier II” LFG control technology and that it *“is expected to become a prime candidate technology for landfills in the U.S. and elsewhere that can not generate LFG in sufficient quality or quantity to economically recover the associated energy.”*[14] In addition, EPA's Landfill Methane

- Existing WTE sites that drop below LFG production thresholds at some point in the future may still be required to continue LFG collection and management. In these cases, the LFG collection system can easily be reconfigured into an aerobic landfill system (blowers, piping, controls) to degrade the remaining organic matter, thus eliminating the need to supply fuel to burn low volumes of LFG.

- The concentrations of organic compounds typically found in aging leachate streams, such as toluene, methylene chloride, and methyl-ethyl ketone (MEK), as well as BOD (a measurement of leachate strength), can be more rapidly reduced (as compared to under anaerobic conditions) along with pathogen destruction. In addition, the net volume of landfill leachate can be reduced due to evaporative effects caused by elevated waste mass temperature. It is believed that virtually all of the leachate that the landfill produces can be utilized. Thus, with only one system, a landfill can be operated much more safely and pose less of an environmental threat.

- The concept of Open Market Emission Credit Trading could economically benefit landfills in certain countries and could be a cost-effective means to offset costs as well as maintain regulatory compliance.

- In the U.S., MSW landfills are presently being considered by the EPA as "area sources" where a Maximum Achievable Control Technology (MACT) may be required. [15] If landfills are required to install MACT systems, an aerobic landfill may be the least-cost alternative.

- In previous laboratory and bench-scale studies, MSW settlement by aerobic degradation has been observed to be 30% and greater [16]. This could lead to extensive landfill life extension with minimal LFG management.

- From a life-cycle perspective, this approach also offers the possibility of a long term, sustainable approach to solid waste management. Once the waste is degraded, a landfill site could be redeveloped for commercial activities. On the other hand, the landfill could be mined and reused as a new landfill, potentially increasing revenues through recycling or sale of recovered materials, avoiding new landfill sitings, and/or reducing overall methane production., i.e. a “sustainable" landfill can be developed.

When compared to the benefits, this approach can provide, in many cases, the most cost-effective option. In the U.S., the combined costs of piping, blowers, controls, licensing, and operation, have shown to be much less that than the overall cost benefit provided. Through the continued deployment of this technology and working with the resources available in each host country, overall costs are expected to decrease. At the same time, the aerobic landfill will foster a new perspective on landfilling waste, as well as reduce the cost burdens of landfill operations and/or site remediation.

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EPA View of Bioreactor Landfills - Shaping the Debate

Chet McLaughlin, US EPA Region 7

Thank you for the opportunity to speak briefly on the status of EPA’s landfill program and where we are going.

Beginning almost with the publication of the Municipal Solid Waste Landfill Criteria was the debate over how to safely operate landfills to accelerate decomposition of the organic fraction and stabilize the waste therein. The debate has been carried to all the waste management forums including the MWCC in at least four of eight years since the publication of the MSWLC in 1991. With the Regulatory Flexibility Act required 610 Review of the MSWLC late in 1999, the first formal opportunity to speak out on the issue came available. And you responded. Approximately 185 comments from 42 commenters including MDNR, Burns and McDonnell, and other firms that do business in Missouri were received.

On Bioreactor: Almost half of the commenters requested special regulations allowing leachate recirculation and promote the use of bioreactor technology. Suggestions for detailed regulation changes for liners, covers, groundwater monitoring and closure were submitted that would encourage bioreactor landfills. One county expressed concern about allowing for leachate recirculation and liquids addition die to liner failure potential.

The summary of comments available in March indicated strong support for reexamination of the MSWLC and lead to the publication of the April 6, 2000 Request for Information and Data in the Federal Register. Specifically EPA linked the need to examine alternative liner performance, leachate recirculation and bioreactor landfills. We posed a number of questions concerning these issues and asked for responses on leachate recirculation by August 7 and bioreactor by October 6, 2000.

Because the Federal Register is detailed in the request, I will not paraphrase it but will quote it below specifically on bioreactor.

"VIII. Concerns With Respect to Bioreactor

Recent communications from MSWLC stakeholders indicate that there is a growing interest in bioreactor landfills. Bioreactor landfills represent a potential new approach to solid waste management. A bioreactor landfill can be generally defined as a sanitary landfill operated to transform and stabilize the readily and moderately decomposable organic constituents of the waste stream by purposeful control to enhance microbiological processes. While categorizations of bioreactor landfills vary, operational parameters often employ leachate recirculation, alternative cover designs, liquids addition to optimize moisture content in the waste, and state-of-the-art landfill gas collection systems. Bioreactor landfills have been operated under both anaerobic and aerobic conditions. Thus, the term Bioreactor landfill is a management concept for MSWLCs encompassing a variety of MSW landfill practices.

Information Needs With Respect to Bioreactor

At this time, EPA lacks adequate data and information on the design, operation, and performance of Bioreactor landfills to evaluate this technology. We are unsure about the appropriateness of revising the MSWLC Criteria, as some stakeholders have suggested to the Agency, to allow for design and operation of bioreactor landfills (e.g., allowing the addition of additional liquids to municipal landfills to optimize waste degradation). Therefore, we are today seeking data and other information on the design, operation, and performance of bioreactor landfills. We are specifically requesting comment and data in the following areas.
The nature and scope of current bioreactor landfill projects both within the U.S. and abroad.
The impact (advantages and disadvantages) of leachate recirculation and liquids addition (with or without the addition of air) on leachate quality, waste settlement, waste slope and stability, and landfill gas yield.

Modifications that have been made to daily cover to optimize biodegradation.
Changes to final cover that have been made to optimize biodegradation or to incorporate materials which convert landfill gas to carbon dioxide and water. See, for example ``Approaching Sustainable Land filling," Alexander Zach, et al.; and ``Biological Pretreatment of MSW as a Measure to Save Landfill Volume and Deter Birds," Florian Koelsch and Richard T. Reynolds, Proceedings of Fifteenth International Conference on Solid Waste Technology and

Management, December 12-15, 1999, Philadelphia, PA. Proceedings published by Widener University School of Engineering and the University of Pennsylvania.

Additional monitoring requirements necessary to ensure that a Bioreactor (with or without air addition) is functioning properly over the life of the landfill.
Approaches that have been taken to close bioreactor landfills and to care for the landfill during the post-closure care period to ensure protection of human health and the environment.
The potential public health, environmental, and economic impacts of adding liquid wastes, such as sewage sludge, grey water or animal feedlot liquid wastes to the MSWLC.
For bioreactor which have been operating in the aerobic mode, what methods have been used to provide for aeration and how to control temperature in the waste mass.
The appropriateness of liner designs different from the specific design described in 40 CFR 258.40(a)(2) when liquids are added to a MSWLC to enhance biodegradation.
Project economics for the design, construction, and operation of Bioreactor landfills (with or without air addition).

The Clean Air Act Section 111(d) and greenhouse gas emissions impact of operating a municipal solid waste landfill as a Bioreactor landfill, i.e., will the addition of air or liquids affect the ability of a landfill to comply with air regulations?
The comparative cost effectiveness and environmental benefits of the bioreactor landfill relative to managing segregated organic wastes through composting and placing non-compostable waste in a standard municipal landfill (i.e., one not operated as a Bioreactor).
Are there management and safety issues associated with landfill gas generation and control at Bioreactor landfills that need to be addressed in regulations or guidance?
Are there relevant patent issues associated with anaerobic, aerobic, or other bioreactor landfills of which EPA should be aware?"

In a subsequent meeting with SWANA officials Dwight Hlustick was asked to provide some follow up questions as a result of the continuing discussions and he added the following clarifications to the debate concerning leachate recirculation specifically.

From Dwight Hlustick's notes from the meeting with SWANA participants on bioreactors:

EPA INFORMATION NEEDS FOR LEACHATE RECIRCULATION OVER ALTERNATIVE LINERS

April 6, 2000 FR Notice

1. Information on recirculated leachate.

2. Information on why specific alternative liners are equal to or superior to composite liners.

3. Should a leachate leak detection system be required for alternative liners?

4. What is an acceptable leakage rate between liners?

5. What do we do about existing liners (which are at least as good as composite liners) with respect to leachate recirculation.

6.What criteria are important in defining a superior liner system?

Almost as a terminology debate, a second issue has arisen concerning “BIOREACTOR TERMINOLOGY” which may make it hard to gain acceptance for the concept.

Most attendees believed that the term “Bioreactor “ has a negative reaction from the general public. The term “reactor” it self has a negative reaction since many associate it with things like a nuclear reactor. The only place it doesn’t seem to have a negative reaction is Yolo County, CA since it is believed that the outside stakeholders understand what a Bioreactor landfill really is. There is a preference by many to use an alternative description. Alternatives discussed included:

- Biostablization
- Bioprocessor
- Bioenhancement
- Accelerated (Biological) Stabilization - My favorite
- Biocells

A logical place to begin such a change in terminology would be in the Project XL FPAs and FR Notices. This has to be done fairly quickly, however, let me know what you think.

Finally EPA has approved the Project XL project in Yolo County, California and is considering others which will provide data in the long term. However if we are going to make changes to the MSWLC in the short term we have to obtain useful information in the short term and make it part of the public record to support the changes you feel are necessary. Please support Dwight with information if you have it and help us make these regulation responsive to your needs.

Chet McLaughlin - July 11, 2000

Thoughts on the future of Bioreactor Landfills in Missouri

Jim Hull, Director, Solid Waste Management Program, Missouri Dept of Natural Resources.

At the MWCC session in Columbia I said that I believed that Bioreactors were the next generation of landfills: however, I cautioned listeners that it has taken a quite a long time to gain political and public acceptance (comfort) with Subtitle D landfills and we need to be careful not to loose this acceptance in taking this next step. I also said that I didn't see Missouri landfills jumping on the bandwagon in pursuing bioreactor landfill designs as long as EPA indicates that they have to be permitted as an EXCEL project. Possibly inroads could be made in demonstration or pilot projects involving a small phase of a landfill. It will be awhile before EPA changes their regulations to provide for bioreactor landfills and then after that Missouri might have to have regulatory changes also. I am afraid that no one yet knows just exactly how to design and operate the perfect bioreactor landfill. I think it will be a little while before the bugs are worked out and even then designs may have to be tailored on a case by case basis. All in all, it is my opinion that Subtitle D liners, caps and accompanying internal collection systems will not last forever so there is a basic need to move in a direction that will help the landfill to reach equilibrium in a much shorter time frame before those systems break down.

As a parting thought, possibly the terminology being used might not be best suited. Perhaps we should be talking in terms of "*sustainable landfills*" not bioreactor landfills. Some of the newest ideas coming down the pike encompass using the same landfill site for a long, long time. Using combinations of bioreactors and landfill mining may someday be common place and decrease the need to site new landfills - thus the *sustainable landfill* is created...

-- Jim Hull, Director July 26, 2000
Solid Waste Management Program
Missouri Department of Natural Resources

Questions and Comments from MWCC 2000 on Bioreactors July 18, 2000

Q. What will happen to the inorganics?
A. The waste will degrade and stabilize becoming inert. Inorganics may need to be recovered.

Q. Will inorganics be oxidized?
A. The metals may become more mobile and it may stabilize more metals. A study showed the pH was approx. neutral and lead (Pb) dropped out. Metals may concentrate and simplify recovery of these metals.

Q. Is there an optimum density for waste in a bioreactor?
A. MSW 900lbs/yd^3 generally. 400-500lbs/yd^3 sometimes. Less compaction worked best in aerobic conditions in terms of recirculation of leachate and air.

Q. What is coming out of the moisture and gases vented out of landfill?
A. Mixture of O_2 and Methane, but it is not an explosive mixture

Q. Any concerns with fires?
A. Don't have fire, heat, and source together in an aerobic landfill. Tests show that gases being vented are at an explosive mixture level.

Q. Are there any odors at the aerobic site?
A. Comparing aerobic with anaerobic landfills, the aerobic landfill produces an earthy compost smell. The anaerobic landfill produced offensive odors.