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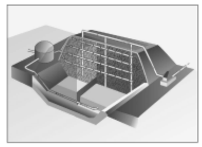
Welcome – Thanks for joining us.
ITRC's Internet-based Training Program

Characterization, Design, Construction, and Monitoring of Bioreactor Landfills



ITRC Technical and Regulatory Guideline for Characterization, Design, Construction, and Monitoring of Bioreactor Landfills

This training is co-sponsored by the US EPA Office of Superfund Remediation and Technology Innovation

Bioreactors are landfills where controlled addition of non-hazardous liquid wastes, sludges, or water accelerates the decomposition of waste and landfill gas generation. According to the Environmental Protection Agency, there are approximately 2,500 permitted municipal solid waste landfills (MSWLFs) currently in operation in the United States. Approximately 10% of these facilities will involve retrofitting bioreactors and commence leachate recirculation on existing landfill infrastructures. Current trends indicate that 10-15 new landfills are being constructed each year, with two to four facilities being constructed as bioreactors.

The bioreactor process enhances gas generation that can provide a revenue stream and decrease the contaminant load in the leachate. Both of these activities reduce the potential risks associated with the landfill while increasing its long-term stability. When evaluating the bioreactor landfill concept, three additional advantages can be identified:

•Decomposition and biological stabilization of the waste in a bioreactor landfill can occur in a much shorter time frame than occurs in a traditional "dry tomb" landfill

•Bioreactors reduced leachate handling costs

•Accelerated waste stabilization reduces the amount of post-closure care that may be necessary for the facility

This training, based on the ITRC *Technical and Regulatory Guideline for Characterization, Design, Construction, and Monitoring of Bioreactor Landfills* (ALT-3, 2006), teaches the principles used to make critical decisions faced by regulatory agencies, consultants, and industry during permitting, operating, and monitoring a bioreactor landfill. This training also provides a general understanding of the biological degradation of solid wastes under aerobic and anaerobic waste conditions and the degradation products associated with each process.

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org

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ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization
- Network
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    - All 50 states and DC
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    DOE DOD EPA
  - ITRC Industry Affiliates Program
  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
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- Products
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    - Technical and regulatory guidance documents
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The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

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ITRC Course Topics Planned for 2008 – More information at www.itrcweb.org

Popular courses from 2007

- Characterization, Design, Construction, and Monitoring of Bioreactor Landfills
- Direct Push Well Technology for Long-term Monitoring
- Evaluate, Optimize, or End Post-Closure Care at MSW Landfills
- Perchlorate: Overview of Issues, Status and Remedial Options
- Performance-based Environmental Management
- Planning & Promoting Ecological Re-use of Remediated Sites
- Protocol for Use of Five Passive Samplers
- Real-Time Measurement of Radionuclides in Soil
- Remediation Process Optimization Advanced Training
- Risk Assessment and Risk Management
- Vapor Intrusion Pathway: A Practical Guideline

New in 2008

- Bioremediation of DNAPLs
- Decontamination and Decommissioning of Radiologically-Contaminated Facilities
- Enhanced Attenuation: Chlorinated Solvents
- LNAPL
- Phytotechnology
- Quality Consideration for Munitions Response
- Remediation Technologies for Perchlorate Contamination
- Sensors
- Survey of Munitions Response Technologies
- More in development…

More details and schedules are available from www.itrcweb.org under "Internet-based Training."

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Characterization, Design, Construction and Monitoring of Bioreactor Landfills

Logistical Reminders

- Phone line audience
  - ✓ Keep phone on mute
  - ✓ *6 to mute, *7 to un-mute to ask question during designated periods
  - ✓ Do NOT put call on hold
- Simulcast audience
  - ✓ Use ? at the top of each slide to submit questions
- Course time = 2¼ hours

Presentation Overview

- Regulatory flexibilities for demonstration and full permitting
- Advantages and disadvantages
- Bioreactor mechanisms of degradation
- Design considerations for demonstration and full application
- Questions and answers
- Construction considerations
- Operational considerations
- Monitoring considerations
- Links to additional resources
- Your feedback
- Questions and answers

No associated notes.

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Meet the ITRC Instructors

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Mark Searfoss has been with the New Jersey Department of Environmental Protection, Division of Solid and Hazardous Waste, for nineteen years. He is currently a case manager overseeing the remediation of landfills throughout New Jersey. He was previously a permit writer and project manager for regional solid waste landfills and has been involved in all aspects of landfill design, construction, operations and closure activities. In that capacity, Mr. Searfoss also evaluated environmental health impact statements and engineering designs for state-of-the-art sanitary landfills and bioreactors. This required extensive permit application coordination with other state and federal agencies involving air and water pollution control and RCRA regulations. He has also provided project management for brownfield redevelopment projects involving abandoned landfills. Mr. Searfoss previously wrote technical manuals for the Division relating to specific permit activities for sanitary landfills and has also participated on the Department's Regulations Development Committee. He was responsible for updating New Jersey's landfill regulations (NJAC 7:26-2A) for two consecutive rule readoptions. Mr. Searfoss holds a bachelor's and master's of science degrees in engineering and is a licensed professional engineer.

Michael Kukuk, P.G., is a Principal and one of three original founders of Aquaterra Environmental Solutions, Inc., headquartered in Overland Park, Kansas. With a background in geology and civil engineering he has worked in the environmental engineering and solid waste field since 1983. Since 1988, Mike has managed several diverse groups of environmental professionals providing solid waste and environmental remediation services to public and private clients. Since 2000, Mike's technical focus has been on the development of alternative landfill covers in both wet and dry climates, phyto-remediation and phyto-technology applications, as well as leachate recirculation technologies at municipal solid waste landfills. He is currently Principal-In-Charge for the modeling, design, and construction of five evapotranspiration alternative landfill covers in the state of Kansas. Mr. Kukuk serves as a director for the Kansas SWANA Sunflower Chapter.

Thabet Tolaymat has worked for the U.S. EPA Office of Research and Development in Cincinnati, Ohio since 2003. Currently, he leads EPA's national research program in the area of solid waste research. His main research areas are solid waste management, bioreactor landfills, waste containment performance, construction and demolition waste landfills, fate and transport of environmental pollutants. Thabet was a member of the ITRC Alternative Landfill Technology team. He earned a doctorate in environmental engineering from University of Florida in Gainesville, Florida in 2003.

Graham Simmerman is Regional Waste Compliance and Permitting Manager for the Virginia Department of Environmental Quality (DEQ) Valley Regional Office in Harrisonburg, Virginia. He has been with the Virginia DEQ since 2003. He leads a team in a diverse program that includes the permitting of solid waste facilities and inspection of solid and hazardous waste facilities. He has twenty years of experience in engineering geology, civil engineering, hydrogeology, and environmental science. Graham was in environmental consulting practice for fifteen years and has worked in diverse projects on more than eighty landfill, hazardous waste, and superfund sites in ten eastern states. His career has moved progressively from the siting, monitoring, and remediating waste facilities toward the design and installation of complex landfill systems including liners, closure covers, and environmental controls, and into daily landfill operations. He has been involved in the design and permitting of several leachate recirculation and landfill gas extraction. Graham formerly served as a board member and established the technical committee in SWANA's North Carolina Chapter and served on SWANA's Landfill Division Steering Committee where he was involved in early efforts to bring bioreactor landfills to the forefront of solid waste management technology. Since 2004, Graham has been an active member of the ITRC Alternative Landfill Technologies team. He earned a bachelor's degree in geology from Radford University in Radford, Virginia in 1983 and earned a master's degree in geology from North Carolina State University in Raleigh, North Carolina in 1986. He is a licensed professional geologist in Virginia and North Carolina.

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Why Are We Here?

With my background as a regulator, we are often told not to consider the "M" word when making our regulatory decisions, however, the Alternative Landfill Technologies team believes that if properly designed, constructed and operated, bioreactor landfills have potential for making additional…well you know…Money. However, Money is not the only reason to pursue a bioreactor landfill, and in today's presentation, we hope to educate you on many aspects of these facilities.

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What You Will Learn…

What is a bioreactor landfill?

What is leachate recirculation?

What are the critical regulatory understandings/interpretations for bioreactor landfills?

What are some of the advantages and disadvantages of bioreactor landfills?

What are the bioreactor processes?

Well now that I've got you all thinking about making money, I'm going put my regulator hat on and try to give a bit of background and a better understanding of the bioreactor landfill process. I am going to address

What is a bioreactor landfill?

How are bioreactor landfills different from leachate recirculation projects.

What are some of the critical regulatory understandings/interpretations for bioreactor applications

•For example does Subtitle D allow leachate addition above approved liner systems

•Is there flexibility allowed by research demonstration and development regulations for leachate recirculation projects

What are some of the advantages and disadvantages of bioreactor technologies

What are the bioreactor processes

•The degradation mechanisms operating in bioreactors

•The phases of waste decomposition

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Additional Information

- Design considerations
- Bioreactor construction issues
- Operational parameters
- Monitoring considerations

Mark Searfoss will get into some and the nuts and bolts associated with designing bioreactor landfill, and some of the constructions issues which must be understood to build a long term successful bioreactor landfill.

Michael S. Kukuk will then discuss some of the operational issues which must be understood in order to have a successful bioreactor project.

Graham Simmerman will then discuss some of the monitoring considerations for the waste itself, the leachate and the gas produced by these projects.

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Key Findings

- Bioreactors can be fully permitted
- Wet cell operations are a viable alternative to dry tomb storage of waste
- Recirculation of leachate and liquid addition is allowable for increasing moisture content of the waste
- Bioreactor landfills accelerate waste stabilization

One of the goals of the ITRC organization is to gain consensus among the regulators, regulated entities, both public and private, consulting companies, as well as community stakeholders on various key issues associated with a new or immerging technology. I would urge everyone to keep these key findings in the back of their minds during the remainder of the presentation.

In the case of bioreactors, we would like everyone to come away with an understanding that bioreactors can be fully permitted facilities. That approved liquids can be added to Subtitle D landfills, and that the Research Demonstration and Development regulations allow regulatory flexibility for liquids addition and recirculation on approved liner systems.

That wet cell operations can be a viable alternative to traditional dry tomb methods of waste storage.

That recirculation of leachate is allowable for increasing the moisture content of waste.

That bioreactor landfills can accelerate waste stabilization.

And that bioreactor landfills are operated fundamentally different from Subtitle D landfills and that post closure care requirements and timeframes may differ for these types of landfills.

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Why a Bioreactor Project?

Control Cell

Bioreactor Cell

Why would anyone want to do a bioreactor project? Well I think looking at these two pictures the answer becomes quite obvious. Shown on this slide are two test cells constructed at the Yolo County Landfill in Davis, California. Both of these test cells were approximately on quarter acre in size and had waste placed around 40 feet thick. The Control Cell on the left had waste placed and handled in typical Subtitle D fashion, minimizing the amount of water infiltrating into the waste. The Bioreactor Cell on the right, which can clearly to be seen to have been substantially degraded as evident by the sagging cover, has been operated as a anaerobic bioreactor. Approximately 1.14 million gallons of water was added to the Bioreactor Cell. Settlement on the control cell was approximately 11 inches, settlement on the bioreactor cell was 46 inches in a two-year timeframe.

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Background - Subtitle D

- Provides a secure and dry repository for waste
- Prevents the migration of leachate into the earth and groundwater using
  - Low permeability caps
  - Engineered liners
  - Leachate collection systems
- Liquids addition to the landfill can be permitted
  - But only by way of leachate recirculation as allowed in 40 CFR 258.28 (a) (2)

Now that I've got your attention, lets discuss how we have evolved to where we are today. The municipal solid waste landfill regulations commonly known as Subtitle D set forth a basic design premise to keep waste as dry as possible to prevent to the extent possible the breakdown of wastes. As a result, low permeability caps, engineered liners and leachate collection systems were used to prevent the migration of leachate and gases into the environment. Subtitle D in effect provides a secure repository for wastes – A dry tomb that retards the microbial activity necessary to breakdown organic matter and expedite the stabilization of wastes material. In most instances, the addition of liquids into the waste has been discouraged over the years. Liquids addition into the landfill was only possible by way of leachate and gas condensate recirculation as allowed in 40 CFR 258.28 (a) (2) of the Subtitle D regulations.

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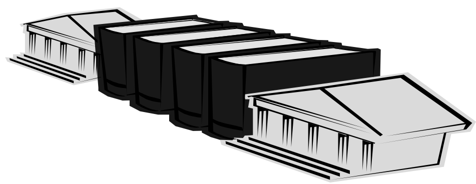
Subtitle D

In the preamble to Subtitle D, EPA recognized that

"…landfills are, in effect, biological systems that require moisture for decomposition to occur, and that this moisture promotes decomposition of the wastes and stabilization of the landfill. Therefore, adding liquids may promote stabilization of the unit…"



The dry tomb approach to waste management is an effective method for providing a safe repository for wastes. Traditional Subtitle D landfills have proven themselves effective since Subtitle D became effective. However, as far back as the preamble to Subtitle D, EPA recognized that ….read slide….

We are here today to explore alternative methods of managing wastes within the boundaries allowed by current regulations.

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Typical Subtitle D Landfill

Here is a picture of a typical Subtitle D landfill both in operation mode and in construction mode. This particular landfill is located near the coast of South Carolina. As you can see lots of soil is being used in the operating portion of the landfill. In the area under construction, we can see the impermeable liner system being constructed. All of this in an effort to minimize the amount of moisture that is allowed into the landfill.

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What Makes a Bioreactor Work?

A Lot of Hard Work and…..

WATER

So what makes a bioreactor work? Well as in the case of all landfills, it takes a lot of hard work. But, in the case of a bioreactor landfill the magic component is water, lots of water. Remember my bioreactor test cell side a bit earlier, 1.14 million gallons of water in a test cell ¼ acre in size. Obviously, water is the one Key component to making any type of bioreactor work.

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Regulatory Tools

- EPA has promulgated the Research Demonstration and Development (RD&D) Regulation (2004) FR 69 No. 55, pp. 13242-13256
- RD&D Regulations allow authorized States to issue research permits for 3 years (renewable 4 times) to landfills that want to demonstrate bioreactors

Subtitle D regulations by themselves effectively limit the kinds of liquids that may be added to bioreactor units. However, liquids addition is in most instances a key component to the bioreactor concept. Most large landfills do not generate sufficient volumes of leachate necessary to optimize the degradation process. As a result, EPA developed and promulgated the Research Demonstration and Development regulation commonly referred to as the RD&D rule. The RD&D rule can be used as a mechanism to allow the permitting of a bioreactor landfill and the injection of the necessary liquids to make it work properly. The federal version of the RD&D rule allows research permits to be issued for 3 years and to be renewed for up to 4 times so that landfill can demonstrate the effectiveness of new technologies such as the bioreactor systems. Without this mechanism to allow additional sources of liquids to be added to the landfill, bioreactors could likely never be optimized to their full potential. As a side note, bear in mind that states may have a different version of the RD&D rule from the federal version, so remember to check with the regulatory body early in the permitting process.

FR 69 No 55, pp 13242-13256 http://www.epa.gov/epaoswer/non-hw/muncpl/mswlficr/rdd-pre.pdf

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Bioreactor Definitions

- EPA's Office of Research and Development's (ORD) definition of a bioreactor is:

  "Bioreactors are landfills where controlled addition of non-hazardous liquid wastes or water accelerate the decomposition of waste and landfill gas generation."

Further

- ORD states a bioreactor is:

  "A landfill designed and operated in a controlled manner with the express purpose of accelerating the degradation of MSW inside a landfill containment system."

What is a bioreactor? The concept of a bioreactor landfill is not a particularly new concept. As you can see from the quotes taken from several organizations who have attempted to develop a definition for bioreactors, the basic concept of accelerated waste decomposition is a common thread. Bioreactors have been defined as….

EPA's Office of Research and Development defines a bioreactor as landfills where controlled addition…

Other organizations such as Solid Waste Association of North America (SWANA) and The University of Central Florida have published definitions for bioreactors and that information can be found in greater detail within our Tech/Reg guidance document.

"ITRC Technical and Regulatory Guideline for Characterization, Design, Construction, and Monitoring of Bioreactor Landfills" is available at www.itrcweb.org under "Guidance Documents" and "Alternative Landfill Technology."

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Picture of Bioreactor Landfill

Traditional solid waste management practices embody a practice of minimizing the amount of water allowed to enter the waste during the operational and post closure care life of a landfill. In essence creating a dry tomb of waste. As discussed in previous slides, the bioreactor concept is based on a paradigm shift in which liquids are introduced into the waste. Shown on this slide is several leachate injection lines at a landfill. Although the concept of the bioreactor landfill is a relatively new and emerging technology, the recirculation of leachate into the waste is not a new concept. It is an often used technique for managing leachate with the obvious benefit of reducing leachate handling costs. What is new concerning bioreactors is that these projects are now being performed as a full scale operation. This allows for optimization of conditions and an increased level of performance. By creating an environment within the landfill where microbes can thrive, we can accelerate the rate at which waste is decomposed. By controlling the addition of liquids, and in some cases air, we can greatly accelerate the rate at which waste is decomposed. Although anaerobic organisms are the traditional players in the degradation of organic wastes, degradation of wastes using aerobic processes or a combination of aerobic and anaerobic processes are somewhat new to the bioreactor concept.

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Leachate Recirculation

- Allows the addition of leachate collected from the bottom of waste pile back into the facility
- Does not optimize degradation of waste, but does enhance degradation rates over traditional type landfills
- Has many of the same operational issues as fully operating bioreactors
- Has gained acceptance within the industry and with regulators

Often the terms “leachate recirculation” and “bioreactor” are used interchangeably. The process of leachate recirculation can almost be thought of as the light version of a bioreactor. By placing leachate generated by the facility back into the facility, we are able to realize many of the same benefits as a full blown bioreactor, however, we have many of the difficulties of a bioreactor as well. Leachate recirculation’s goal is not to optimize the moisture content of the waste, however as a result of the addition of leachate, waste degradation is enhanced. Leachate recirculation has many of the operational issues that full bioreactor facilities have, and this fact must be taken into account when proposing a leachate recirculation facility. On the positive side, leachate recirculation has been used in the waste industry for some time, and as a result has gained a measure of acceptability among the regulated community.

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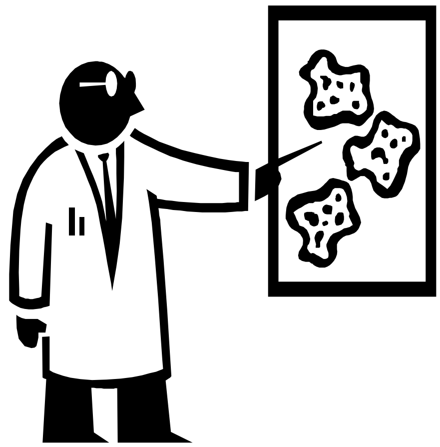
Bioreactor Types

- Anaerobic
- Aerobic
- Hybrid



Given our definitions of what a bioreactor is in the previous slides, there are three main types of bioreactor landfill designs. These are anaerobic, aerobic, and hybrid facilities. Anaerobic landfills are more traditional in nature and use methane producing bacteria in an environment lacking oxygen to accomplish the breakdown of organic materials. Aerobic bioreactors use an oxygen rich environment to enhance the growth of aerobic microbes to breakdown organic materials. Finally, hybrid landfills use a combination or anaerobic and aerobic processes to breakdown organic materials.

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Anaerobic

- Utilizes microbes who thrive in oxygen depleted environments to degrade organic materials
- Rapid degradation possible
- High liquid demand
- Final products
  - Methane
  - Carbon dioxide

Anaerobic bioreactors use methane producing microbes, who thrive in oxygen depleted environments to degrade organic materials. When moisture content is optimized and oxygen is no longer present in the waste pile, rapid degradation of waste is possible using this method. There is a high liquid demand for this process to occur, as is the case with all of the bioreactor types. Methane and carbon dioxide are the two major end-products of the anaerobic process. Once the landfill reaches a certain level of maturity, methane production will be intense and should be planned for in the design phase.

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Aerobic

- Utilizes microbes who thrive in oxygen rich environments to degrade organic materials
- Fastest degradation but requires high volumes of water addition
- Highest temperatures
- Final products
  - Water
  - Carbon dioxide

Aerobic bioreactors are simply what their name implies, they are facilities that utilize microbes who thrive in an oxygen rich environment to degrade organic materials. Typically the addition of the necessary oxygen is handled through the injection of pressurized air into the waste pile. Aerobic bioreactors have the highest rates of degradation, but they also require a high volume of liquids to be added to the waste. As a result of the rapid rate of decomposition using this method of running a bioreactor, a significant amount of heat is generated during the process. Carbon dioxide and water are the final products of the aerobic process. Aerobic landfills do not produce methane as an end-product of the degradation process.

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Hybrid

- Utilizes a process of alternating aerobic and anaerobic conditions to break down organic materials
  - Aerobic > Anaerobic > Aerobic > Anaerobic
- Accelerated waste degradation
- Methane production near the completion of stabilization

Hybrid bioreactors are the final type of bioreactors currently being considered. The hybrid process uses alternating aerobic and anaerobic conditions within the waste pile to more completely break down waste materials than either of these processes by themselves are capable of. These facilities are highly complex in their design, construction, and operation and require a significant day-to-day understanding of what is going on inside of the landfill. The payoff, of course, is an accelerated waste decomposition as well as a more complete degradation of wastes. Typically these facilities end in an anaerobic state, and methane production is generated near the completion of stabilization.

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Advantages

- Decomposition and biological stabilization occurs at an accelerated rate
  - 20-40% gain in landfill space due to settlement of waste mass
- Reduced leachate handling costs
- Increased landfill gas (LFG) generation
- Optimization of existing sites
- Possibility of reducing post-closure care time frames, monitoring requirements and costs

So now that we know what bioreactors are, what are some of the advantages to operating a bioreactor type landfill? By providing the biological microorganisms with all of the tools necessary to flourish, we can greatly accelerate the decomposition process and allow biological stabilization to occur quicker. The result can be a 20 to 40 percent increase in landfill space due to settlement and stabilization of the waste pile. This space can be reclaimed and additional waste placed in this reclaimed capacity. The economic benefits to this are obvious, as well as intangible benefits such as fewer landfills needed to provide necessary capacity. As leachate is reintroduced into the waste pile, there is the benefit of reduced leachate handling costs for the facility and saved capacity on wastewater treatment facilities. If the bioreactor process is anaerobic, then increased landfill gas generation occurs in the form of methane. This increased methane generation can be captured and used for energy recovery projects or the methane can be sold as a commodity generating additional cash flow for the facility. Another benefit for bioreactor landfills is the possibility of reducing post-closure care for the facility. For example as the landfill gas generation curve is accelerated, it is possible that the amount of time gas is monitored may be reduced as gas production at the facility declines. These are just some of the advantages that a bioreactor has over a traditional landfill. Other advantages are discussed in our guidance document.

"ITRC Technical and Regulatory Guideline for Characterization, Design, Construction, and Monitoring of Bioreactor Landfills" is available at www.itrcweb.org under "Guidance Documents" and "Alternative Landfill Technology."

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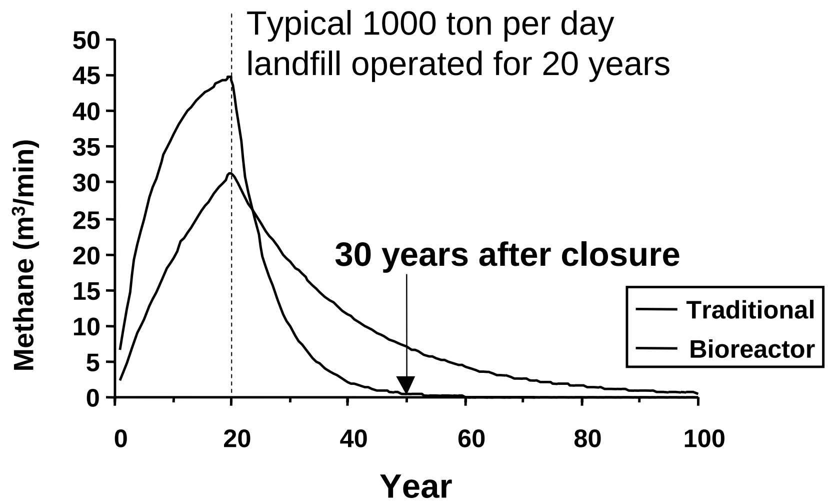
Landfill Gas Comparison



Since landfill gas is such an issue with bioreactors, lets take a look at how landfill gas production can be evaluated between a typical Subtitle D landfill and a bioreactor landfill. In this graph, we see a hypothetical landfill which accepted 1000 tons per day of waste and operated for a 20 year time period. The graph in red shows what a landfill gas production curve would look like if the facility were operated as a typical Subtitle D landfill. The graph in pink shows what the expected gas production curves would look like if the facility was operated as a bioreactor. We can see that gas production ramps up very quickly with the bioreactor and peaks at a higher level than a Subtitle D landfill. In a bioreactor landfill, gas production is more intense in the short term but tends to tail off quicker as organic materials are consumed. Also, if we look at the 50 year mark, which would be 20 years of operation and 30 years of post closure, we can see that gas production has slowed to almost zero with the bioreactor facility, while the typical Subtitle D facility is still producing a significant quantity of gas.

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Disadvantages

- Need to manage increased volumes of landfill gas
  - Methane handling and migration issues
  - Odor issues
- Increased operation and maintenance requirements
  - Complex construction and operation
  - Higher level of oversight
  - Additional monitoring requirements
  - Higher capital costs
  - Non-uniform settlement and stability issues
- Increased stress on leachate management system
- Additional need for moisture (liquid addition) for operational purposes
  - Regulatory resistance
- Higher risk of fire (aerobic design)
  - Higher temperatures may also damage liner systems

Well as you can imagine with something as complex as a bioreactor landfill, there are some potential disadvantages to be aware of as well. As we saw in our previous slide, there is a need to manage increased volumes of landfill gas early in the landfilling process. The bioreactor process in effect supercharges the ability of methane producing microbes to produce gas. Your gas handling and collection systems must be up to the task of handling the gas volume. If your system is not up to the task, migration of gas will become a compliance problem and odors may also become a problem. These facilities are complex, therefore there is increased operations and maintenance requirements. Construction of the facilities is more complex as well. These systems typically require a higher level of oversight to optimize operations. There may be additional monitoring requirements both in numbers of parameters and frequency, particularly in the area of leachate. There will likely be higher capital costs in the short term, at least until some of the benefits associated with these facilities can be realized. Non-uniform settlement may be an issue along with stability issues, particularly along the side slopes.

Because we are adding additional volumes of liquids to the waste, there is increased stress on the leachate collection system. The leachate management system must function properly for bioreactors to reach their full potential. Also, additional liquids will be needed for bioreactor landfills to function as designed. The disadvantage to this point is that there may be regulatory resistance from the permitting entity. Finally, with aerobically designed bioreactors, there is an increased risk of fire within the landfill associated with injecting oxygen into the waste pile. Also, because aerobic bioreactors typically operate at higher temperatures there may be some additional stress placed on the liner system and collection systems due to the elevated temperatures.

As you can see, there are disadvantages of bioreactors however, they can all be overcome by proper design and operations.

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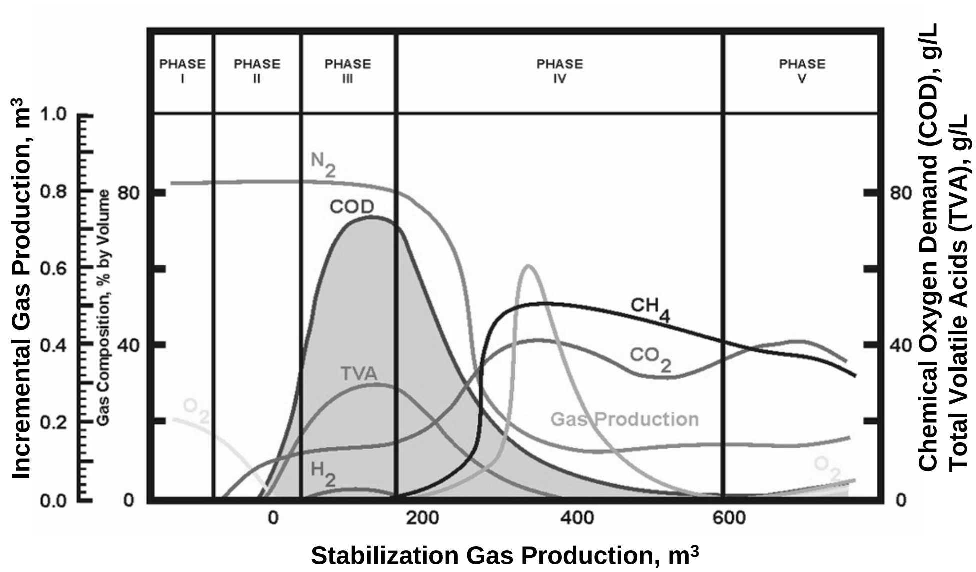
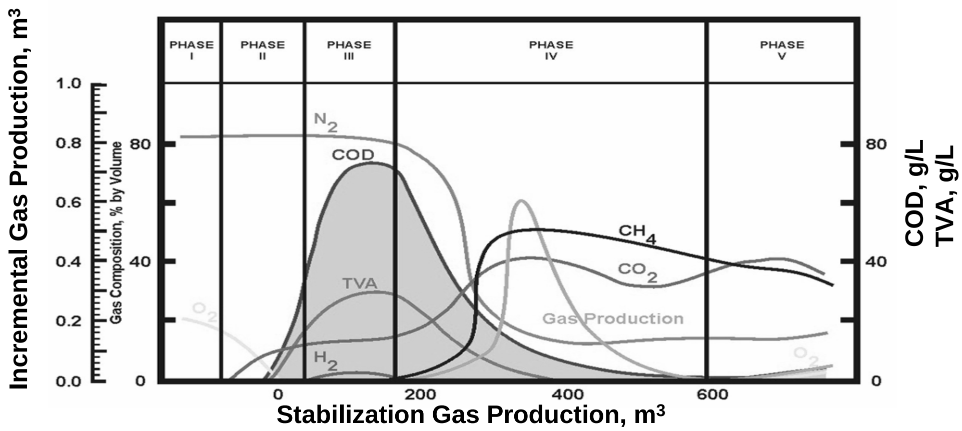
Phases of Anaerobic Waste Degradation (Modified After Pohland and Harper, 1986)



I would now like to quickly run thru a series of slides which show the five major phases of decomposition in an anaerobic landfill. These phases occur in both traditional Subtitle D landfill and anaerobic bioreactor landfills, the difference being the amount of time between phases and the time to completion of degradation. More importantly than the actual numbers on these slides is the relationship of the changes that occur, with the chemistry of the landfill during the various phases. I would like for you to get a basic understanding of the complexity and phase changes that a landfill undergoes during its life. The parameters shown on this graph include Oxygen, Nitrate, Carbon Dioxide, Methane, Total Volatile Acids (TVA) and Chemical Oxygen Demand (COD), and show how they change with time.

28 **Phase I of Biological Degradation – Aerobic Degradation** (Modified After Pohland and Harper, 1986)

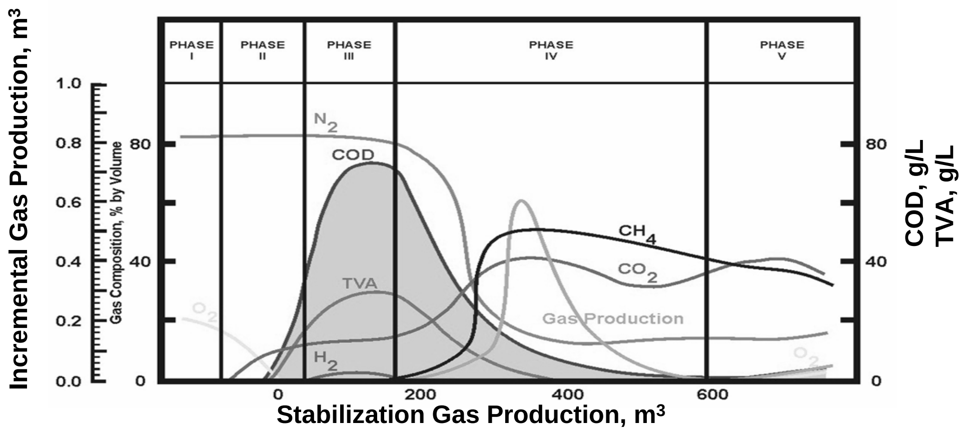


- Also know as the Lag Phase
- Beginning of the decomposition process
- Aerobic microbes consume moisture within the waste and available oxygen
- Typically short in duration

Phase I is know as the Aerobic Phase, and is also sometimes referred to as the Lag Phase. This is the beginning of the decomposition process. During this time aerobic microbes within the waste begin to consume water that is already in the waste at the time of deposition, along with available oxygen. This phase is typically short as available oxygen is exhausted quickly, and is the limiting factor.

29

Phase II of Biological Degradation – Anaerobic Degradation (Modified After Pohland and Harper, 1986)

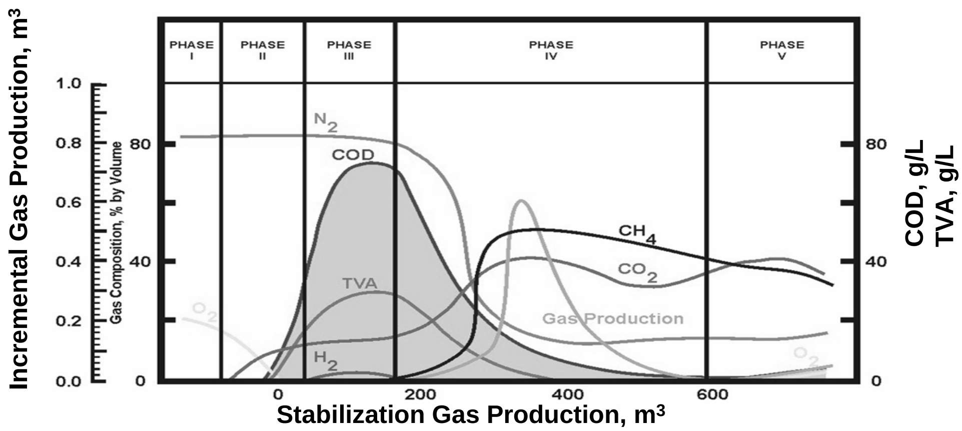


- Also know as the Transition Phase
- Predominate bacteria switch from aerobic to anaerobic
- Oxygen is depleted
- Total volatile acids (TVA's) begin to appear

Phase II of the process is known as the Transition Phase, as the predominant bacteria degrading organic matter is switching from aerobic to anaerobic. Oxygen levels within the waste pile will bottom out during this phase. Total Volatile Acids (TVA) begins to appear.

30

Phase III of Biological Degradation – Acid Phase (Modified After Pohland and Harper, 1986)



- pH of leachate starts to drop as waste is converted to TVA's
- Degradation of organic matter is rapid
- Chemical oxygen demand (COD) is high

Phase III is also known as the Acid Phase. The pH of the leachate will start to drop as organic materials in the waste are converted to volatile acids. Degradation of organic matter is rapid during this phase and the resultant lowered pH mobilizes metals and possibly volatile organic compounds within the leachate. As there is no free oxygen in the waste, chemical oxygen demand peaks during this phase.

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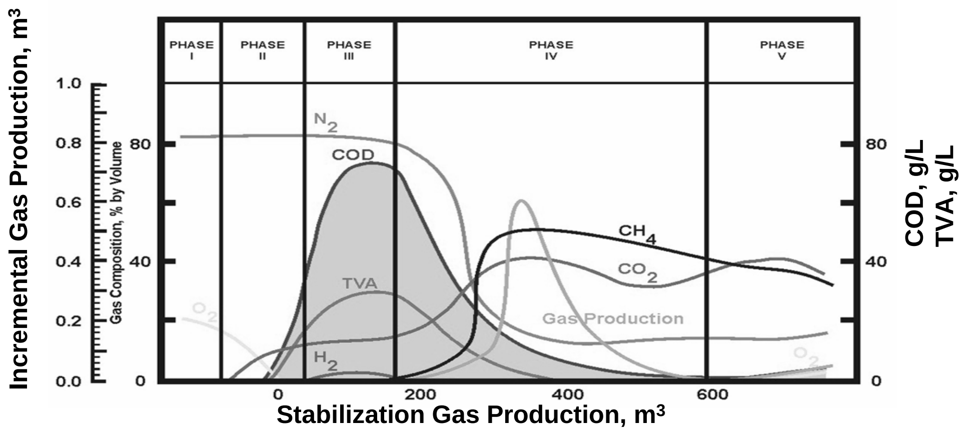
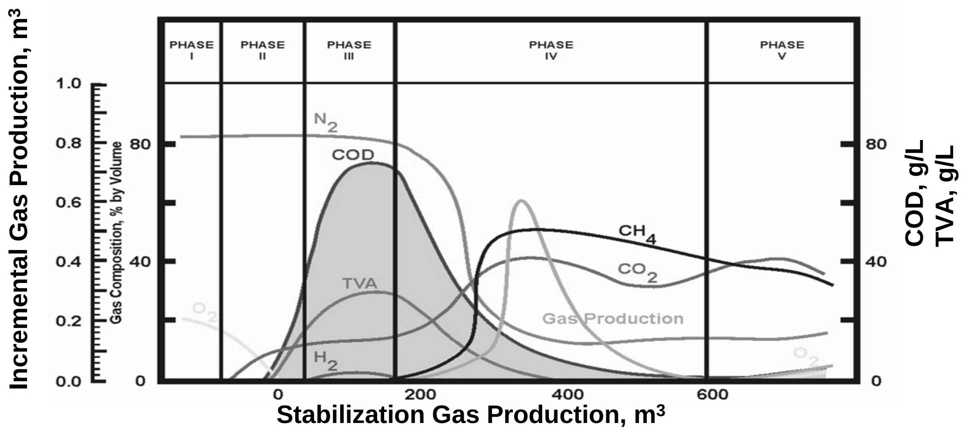
Phase IV of Biological Degradation – Methanogenic Phase (Modified After Pohland and Harper, 1986)



- Acids produced in earlier phases are converted to methane and carbon dioxide
- pH returns to more neutral levels
- Landfill gas production peaks in this phase
- Typically begins within one year of waste placement

Phase IV is known as the Methanogenic Phase. The acid compounds produced in earlier phases are converted to methane and carbon dioxide as microbes consume the acids. pH will return to a more neutral condition, and the mobility of constituents from the waste starts to decline. In this phase landfill gas production peaks. Generally, this phase begins within one year of first waste placement.

32 **Phase V of Biological Degradation – Maturation Phase** **(Modified After Pohland and Harper, 1986)**



- Marked by a significant drop in gas production
- Availability of organic matter and nutrients become limiting
- Concentrations of constituents within leachate stabilize
- Continued slow degradation of more recalcitrant organic matter

Phase V is known as the Maturation Phase and is the final phase in the process. The beginning of this phase is marked by a significant drop in landfill gas production. The availability of biodegradable matter and nutrients becomes the limiting factor. At this phase the concentrations of constituents in leachate stabilizes and continued relatively slow degradation of more recalcitrant organic matter continues to occur. Of note is the fact that several of these phases of degradation may be going on all over the landfill depending on the availability of organic matter, water, oxygen, nutrients and time.

It is the goal of the bioreactor landfill process to provide microbes with all of the materials needed to expedite the 5 phases of biological degradation. Water is the one factor that can limit the speed at which these processes take place. Hence the reason for liquids addition to these types of landfills at such high levels.

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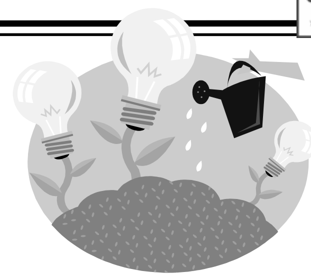
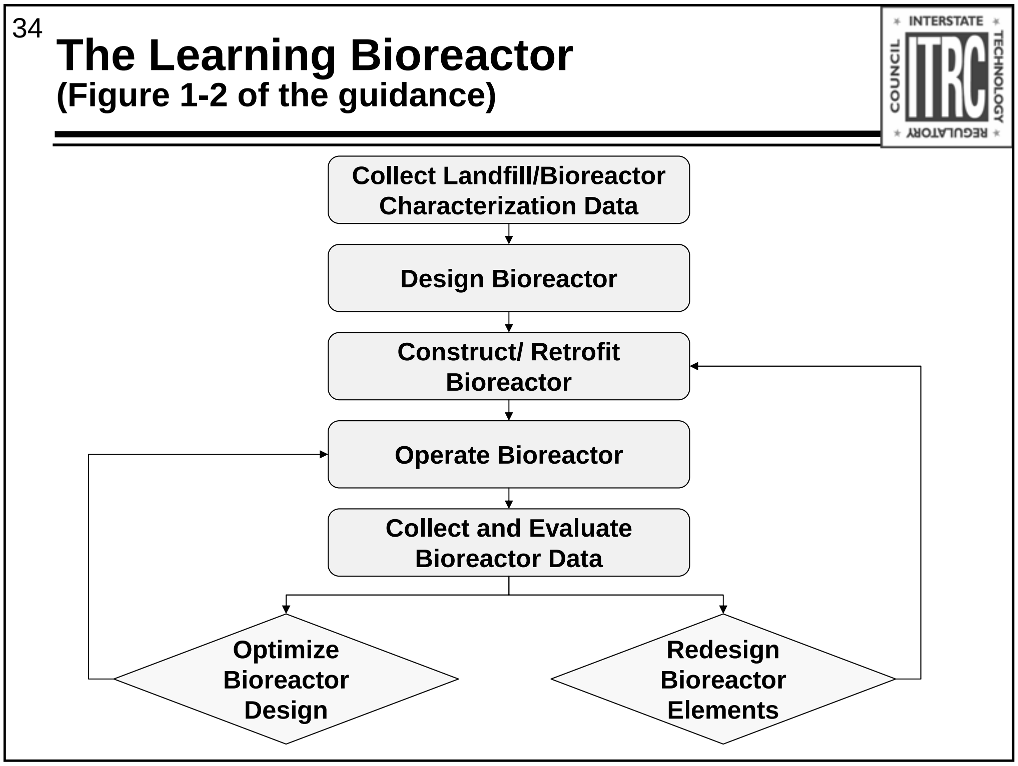
Landfill Optimization



- Increase moisture content
  - Leachate recirculation
  - Water addition
- Accelerate reaching the methanogenic phase (IV)
- Increase the rate of LFG production
- Shorten the period of LFG production
- Stabilize the landfill

So how do we go about operating the landfill to ensure that the various bioreactor functions are indeed optimized? We know Water is one of the critical controlling factors in allowing this process to occur, so we must increase the moisture content of the waste. This can be done by leachate recirculation, or other methods of water and liquids addition. It is generally our goal to accelerate the landfill reaching Phase IV or the Methanogenic Phase. We want to increase the rate of landfill gas production. The quantity of this natural byproduct of the breakdown process gives us a good indication of how efficiently our bioreactor is working. A side benefit of this is that we will be shortening our period of landfill gas production. Finally after the bioreactor process has run its course so to speak, the landfill should become more stable. Further ahead in this talk presenters will be outlining specific methods to optimize these goals for our landfill.



On this slide we see the basic thought process and decision tree for operating a bioreactor landfill. Before we can begin a project such as this, we must collect landfill and bioreactor characterization data. Once this is evaluated, we can properly move to designing our bioreactor with reasonable confidence that the process will be successful. The next step is to actually construct the bioreactor. Construction may be an ongoing process that occurs during the entire life of the facility. After construction comes obviously operation of the bioreactor. During operation we must constantly collect and evaluate date on the performance of our facility. Based on our performance we are constantly trying to optimize the performance of the facility for maximum benefit. If the landfill is not operating at optimum, then a redesign of some element of the facility may be in order. This would require looping back up to the construction phase and operating and collecting data to evaluate performance again. This entire decision making process is something that should occur on a very routine basis throughout the life of the bioreactor facility.

At this point I would like to hand the presentation over to Mark Searfoss to discuss design and operation of bioreactor facilities.

Figure 1-2 of “ITRC Technical and Regulatory Guideline for Characterization, Design, Construction, and Monitoring of Bioreactor Landfills” is available at www.itrcweb.org under “Guidance Documents” and “Alternative Landfill Technology.”

35

Design Components of a Bioreactor

- Design requires a multi-disciplinary approach
- In general, a comprehensive landfill design, bioreactor or otherwise, will focus on
  - Liner systems
  - Leachate collection, storage, and conveyance systems
  - Landfill gas and recovery systems
  - Surface water controls
  - Access roads
  - Groundwater monitoring wells
  - Appurtenant structures

Design components for landfills include bottom liner systems; leachate collection, storage and conveyance systems; and landfill gas collection systems. Specific design considerations for bioreactors are largely dependent on the bioreactor setting, available infrastructure, applicable regulatory requirements, stakeholder concerns, and other issues. Therefore, there is no such thing as a “one size fits all” design for landfills, much less bioreactors.

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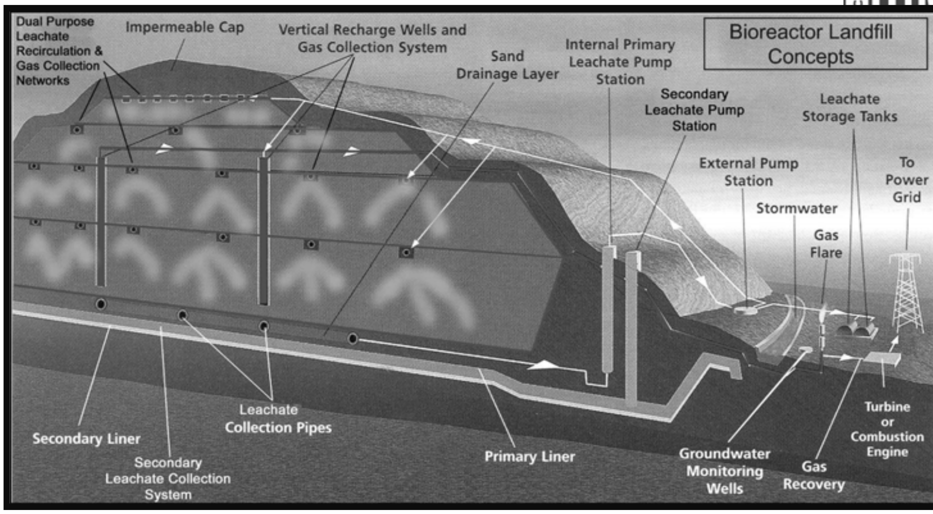
What is a Bioreactor?



EPA's ORD proposed the following definition: "A landfill designed and operated in a controlled manner with the express purpose of accelerating the degradation of MSW inside a landfill containment system."
(Graphic from Waste Management, Inc.)

Note that this graphic shows an impermeable cap on the bioreactor. The placement of an impermeable cap is usually postponed, or possibly altogether eliminated, following successful bioreactor operations. Also, the graphic shows a dual network of gas and leachate recirculation piping systems. We do not encourage the use of dual purpose piping systems; it is preferred that these systems be dedicated single-use systems.

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Design Considerations

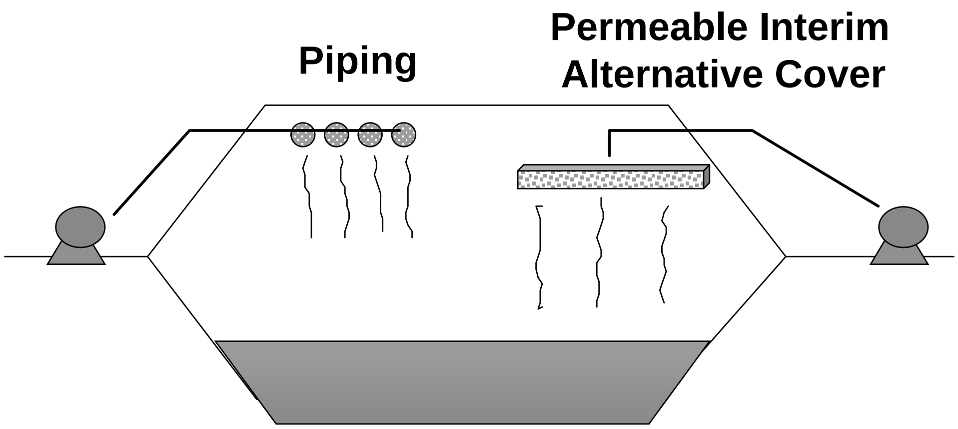
Specific design parameters may vary depending on bioreactor type and degree of recirculation

- No recirculation (dry)
- Limited or sporadic recirculation
- Moderate, controlled recirculation
  - Moisture content is below field capacity
- Heavy, continuous recirculation
  - Moisture content is at or near field capacity

No associated notes.

38

Leachate Recirculation



Waste Management Technology Center, Inc.

During the operating life of the landfill, the use of permeable cover materials is encouraged in order to promote leachate infiltration throughout the waste mass. The degree of recirculation that one wants to achieve throughout the bioreactor will depend on how extensive the leachate recirculation network is.

39

Design Topics

- Geotechnical issues
- Landfill hydraulics
- Head on liner
- Landfill gas extraction systems
- Design optimization objectives

No associated notes.

40

Geotechnical Issues

- The addition of significant amounts of liquids increases the total weight of waste mass
- Increase in weight does not contribute to shear strength
- Some geometries used in dry landfills may not work for bioreactors
- Must also evaluate changes to unit weight, friction angle and cohesion values resulting from decomposition process

Given a specific site, some geometries used for dry landfills may not work for wet (i.e. leachate recirculation) landfills because of differences in unit weights, friction angles, and cohesion values resulting from the leachate recirculation/decomposition process (e.g. bottom grades, side slopes of cell excavation, interim and final grades).

The addition of leachate and liquids adds weight to the waste mass but does not contribute to shear strength. For example, unit weights in dry landfills typically range from 55-65 pcf at the surface and 85-100 pcf at depth. In-situ measurements for certain landfills within saturated waste zones indicate that unit weights range from 100 pcf at the surface and up to 135 pcf at depth. Also, pore pressures from water displacement and gas flow will increase, which must be factored into the slope stability analysis.

pcf = pounds per cubic foot

Landfill Hydraulics

- Total volume of leachate and other liquids that will be available for introduction into the waste mass may be determined using a water budget approach
- Water budget analysis can be used to determine pumping rates and supplementary liquid volumes needed to attain desired moisture content

No associated notes.

42

Landfill Hydraulics (continued)

- Site-specific parameters used for Water Budget
  - Incoming waste moisture
  - Hydraulic capacity of waste
  - Method of moisture distribution
  - Runoff
  - Evapotranspiration
  - Infiltration
  - Waste field capacity
  - Volume of waste

No associated notes.

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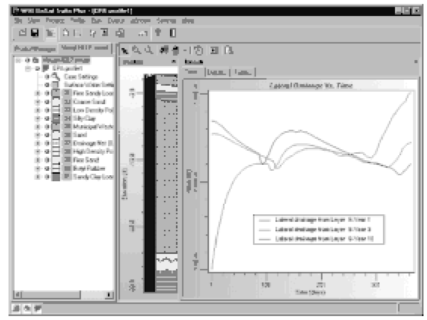
Hydrologic Evaluation of Landfill Performance (HELP)



- Computer program
  - Estimates water balances
  - Different design scenarios
- Model can estimate
  - Quantity of leachate
    - Within the waste layers
    - Removed by the collection system
    - Leaking through the liner system
  - Leachate head on the liner

The Hydrologic Evaluation of Landfill Performance (HELP) computer program is widely employed to estimate water balances under different design scenarios. The HELP model was developed at the U.S. Army Corps of Engineers Waterways Experiment Station under a cooperative agreement with the USEPA that computes estimates of water balances for municipal landfills, RCRA and CERCLA facilities and confined disposal facilities (CDFs). The model (version 3.0) is available for desktop computers.

The model can estimate:

quantity of leachate within the waste layers

quantity of leachate removed by the collection system

quantity of leachate leaking through the liner system, and

leachate head on the liner

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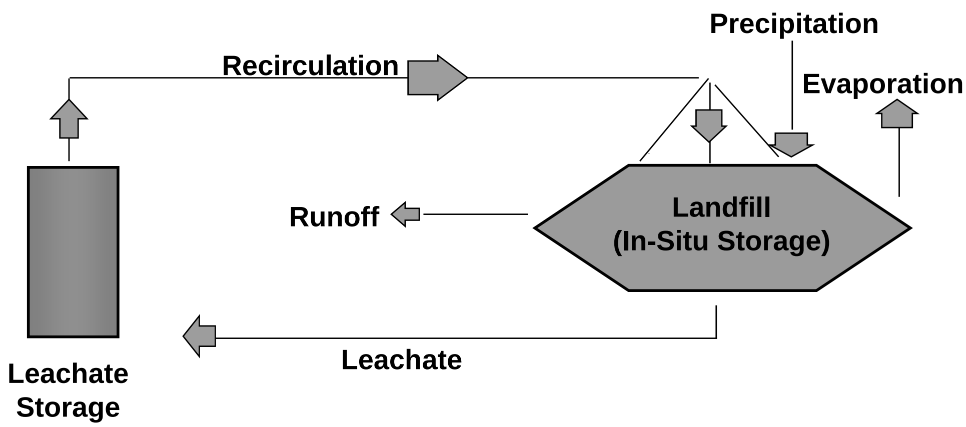
Storage = Infiltration + Recirculation - Leachate Generation



Waste Management Technology Center, Inc.

In-situ storage of liquids is an important aspect of bioreactor design. In-situ storage of liquids in a landfill is possible since the moisture content of the waste received at the gate is below the maximum absorptive capacity of the waste. In general terms, in situ storage is defined as the infiltration received plus the amount of recirculation minus the leachate generation. The HELP model can estimate all of these factors.

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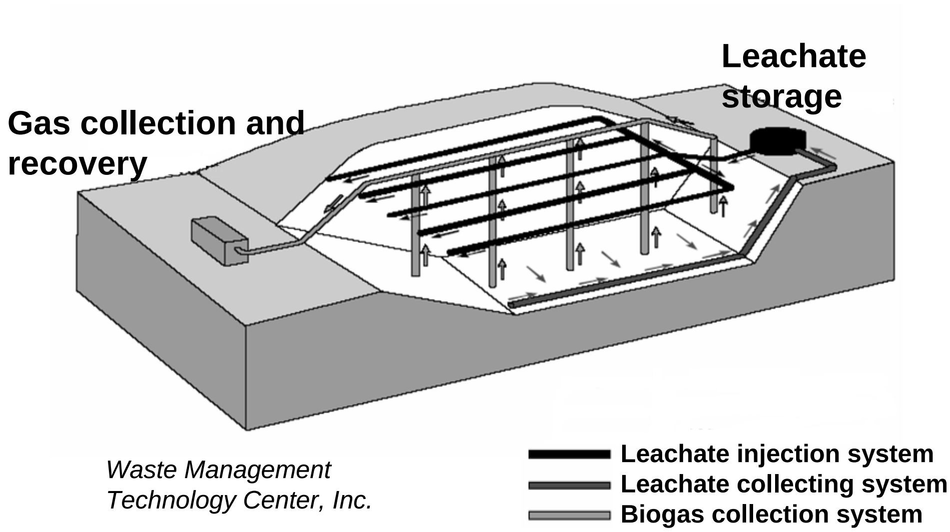
HELP Model – Leachate Recirculation



Waste Management Technology Center, Inc.

Based upon a water balance analysis for a given bioreactor, leachate injection and collection systems can be designed to accommodate the projected leachate generation/recirculation rates.

46

Head on Liner

- Head on liner must be controlled
  - Hydrostatic forces on liner must not be exceeded as a result of increased leachate flow
- 30 cm (=12 inches) of head
- Incorporate network of head sensing devices
  - Such as pressure transducers

Using the HELP model, a sensitivity analysis can be performed to control the design head on the liner. For example, using a geonet and/or decreasing the distance between collection pipes and increasing the slope will reduce the head on liner.

47

Landfill Gas Systems

- Accelerating the biodegradation process increases the production of landfill gas (methane gas for anaerobic and non-methane gas for aerobic bioreactors)
  - Gas venting system must be sized to peak gas generation rates during the active bioreactor operation phase
  - Gas emission models (i.e. USEPA LandGem) are used to estimate quality and quantity of landfill gas using site-specific parameters
  - Recommend installation of gas system as bioreactor is being constructed

Software products are used to design pipe network distribution systems, such as landfill gas collection systems.

LandGEM (Version 3.02) is a popular landfill gas emissions model used by landfill designers.

To determine head losses in a gas collection piping system, computer models such as KYGAS (University of Kentucky) can be used.

48

Factors Affecting Design Optimization

- Emplaced waste materials
  - Volume
  - Composition
  - Waste density
  - Moisture content
- Precipitation
- Landfill geometry
  - Including interim height and final elevations
- Hydraulic capacity of the waste mass and leachate recirculation system
- Recirculation methods
- Placement and type of daily and intermediate cover materials

As a rule of thumb, it will take approximately 1.75 inches of leachate and liquids per foot of landfill thickness to raise the initial moisture content of waste at 25 percent to 45-50 percent at an in-place density of 1200 pounds per cubic yard. Chapter 5 of the technical guidance document contains extensive information, including spreadsheets, regarding moisture requirements.

49

Design Optimization – Infrastructure Issues

- Type of liner system
- Hydraulic capacity
  - Leachate recirculation
  - Collection and removal systems
- Consider multi-liquid delivery systems
  - Vertical and horizontal wells to improve recirculation efficiency
- Techniques to measure hydrostatic head on liner system and use of appropriate sensors

No associated notes.

50

Design Optimization – Infrastructure Issues (continued)

- Long term performance of the leachate collection system with regard to potential for clogging
- Optimize landfill gas control
- Ability to monitor effectiveness and uniformity of liquid distribution
- Keep injection wells away from slopes
- Geotechnical considerations involving static and pseudostatic forces of waste mass
  - Data for site-specific waste types and material properties for accurate slope stability analyses

Based on experience, liquid injection lines and wells should be placed at least 50 feet from the edge of the slopes in order to minimize leachate seeps from the sideslopes, especially at high recirculation rates (more than 0.3 gpd/sf).

51

Design Optimization – Operational Issues

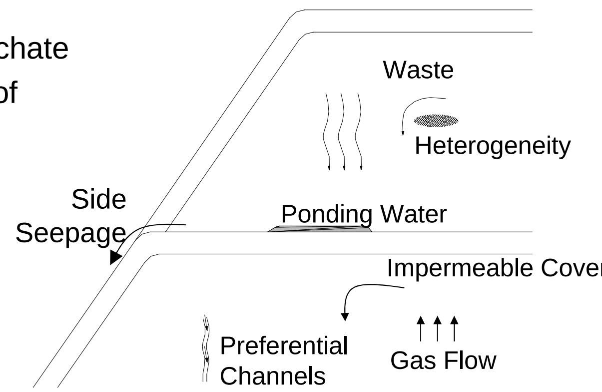
- Define the ideal compaction goal
- Promote use of alternate daily and intermediate cover materials
- pH adjustment of leachate
- Benefits of waste preprocessing
- Nutrients may be used to enhance the biodegradation process
- Change in moisture requirements as stabilization of waste mass proceeds

Some of these issues are discussed in greater detail during the operations portion of this presentation and in the ITRC technical guidance document.

52

Problems Due to Improper Design

- Leachate ponding
- Side seepage of leachate
- Jeopardize stability of landfill
- Interfere with gas collection
- Excessive head on liner system



Processes Affecting Leachate Movement through a Landfill

Improper design methods could lead to:

Leachate ponding due to the use of impermeable cover. This can result in side slope seepage of leachate.

The heterogeneity of waste materials can lead to preferential channels, resulting in an uneven distribution of recirculated liquids.

The stability of the bioreactor can be compromised.

Inefficient gas collection could occur due to hydraulic blocking of the system. Gas flow can also be impeded by impermeable cover materials.

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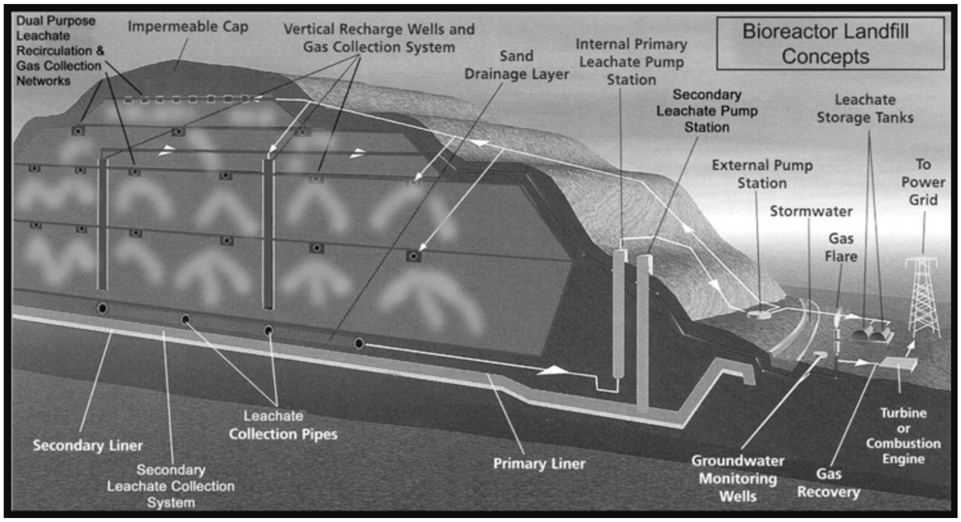
Questions and Answers



Graphic from Waste Management, Inc.

No associated notes.

54

Construction

- Construction procedures for new and retrofit bioreactors must be as rigorous as those used for any conventional landfill (i.e. new cell and cap construction)
- Installation of instrumentation used for monitoring during bioreactor operations is increased

No associated notes.

55

Construction Phases/Element

- Site preparation and grading
- Erosion and sediment control
- Trenching, backfilling, and compaction
- Liquid distribution / injection / monitoring / storage system

No associated notes.

56

Construction Quality Control

- Construction quality assurance (CQA) and construction quality control (CQC) plan
  - Laboratory and field test methods are specified
  - Ensure construction materials and installation procedures satisfy design criteria and manufacturer's specifications

A comprehensive construction quality assurance (CQA) and construction quality control (CQC) plan should address the observations and tests that will be used before, during, and following bioreactor construction to ensure that the construction materials and installation satisfy the design criteria and manufacturer's material specifications.

57

Recordkeeping

- Construction documentation should include
  - Daily inspection reports
  - Testing summary reports
  - Record drawings
  - Field documentation and certification sign-off sheets
- All laboratory reports and field testing results should be reviewed, signed, and dated by the QC inspector

No associated notes.

Operation

- Waste filling and compaction
- Anaerobic bioreactor operations
  - Goals
  - Application rates
  - Leachate recirculation and liquid addition
  - Operational issues
- Aerobic bioreactor operations

Photo Courtesy of
Waste Management, Inc

No associated notes.

59

Operational Issues – Waste Filling

- Thin spreading of waste where possible
- Wet the waste at the working face
- Can fill cell to final elevation plus (i.e. top of cover elevation) and allow settlement
- Fill cells in circular pattern to allow for inward gradient

No associated notes.

60

Operational Issues – Compaction and Daily Cover

- Over-compaction prior to wetting
  - Inhibits moisture distribution
  - Can cause leachate outbreaks
- Working face process
  - Trash loose initially
  - Wet waste
  - Apply compactive effort
- Use permeable daily cover; or,
- Remove impermeable daily cover when starting a new lift

No associated notes.

61

Anaerobic Bioreactor Operations

No associated notes.

62

Benefits of an Anaerobic Bioreactor

- Airspace recovery
  - 20-40% settlement
- Accept off-site liquid waste (for profit?)
- Accelerated gas production
  - renewable energy source
- Possible reduction of post-closure care period
- Reduced long-term environmental liability
  - Stabilize waste for future generations

No associated notes.

63

Leachate Recirculation and Liquid Addition – Anaerobic Bioreactor

- Allow uniform re-introduction of leachate into fill
- Operational goals
  - Simpler is better
  - Compatible with normal landfill operations
  - Staff Training
  - Cost effective

No associated notes.

64

Anaerobic Bioreactor Cautions

- Leachate alone seldom provides enough moisture to treat all of the cells
- Well designed leachate and gas collection systems are a must
- Adding liquids in the winter that are cold (<~50F) will decrease the degradation rate

No associated notes.

65

Moisture Application Rates

- Typical incoming MSW moisture rates are 10% to 25%
- Increase moisture content to 40% to 45%

- Example:

  To reach design moisture content, need to apply liquid
  - Need 25 to 75 gallons of liquid per ton (Typical Range)
  - 1,000 tons/day x 50 gal/ton = 50,000 gal/day needed

No associated notes.

66

Moisture Introduction

- Potential moisture sources
  - Leachate
  - Condensate
  - Storm water
  - Biosolids
  - Industrial waste water

No associated notes.

67

Application Rates

Cell Density (lbs/cubic yard)	Gallons per day /acre (based on cell foot print in acres)
2000	500
1800	1000
1600	2000
1400	2400 - 2600
1200	2600 - 3000

Looser waste can take on more moisture

No associated notes.

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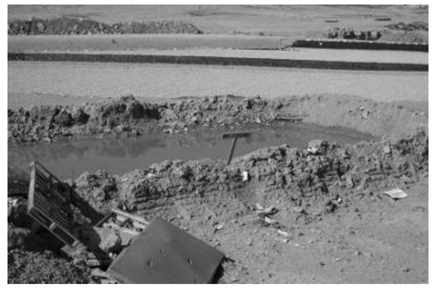
Leachate Recirculation and Liquid Addition – Anaerobic Bioreactor

How To Apply:

- Surface infiltration ponds
- Surface spraying/spray Irrigation
- Working face
- Horizontal trenches
  - As the landfill is built
- Vertical injection wells
  - Retrofit landfills



No associated notes.

Surface Infiltration

Spray Irrigation

Horizontal Trench

Make sure that any construction-related work on a bioreactor/landfill has a health and safety plan (HASP) in place. Prepare for the unexpected.

71

Operational Issues – Anaerobic Bioreactor

- Gas management system
  - Increased production of landfill gas
  - In-place prior to commencement of recirculation (odor control)
- Final cover
  - Open without final cap as long as possible (airspace gain)
  - May affect gas control (less) and leachate generation rates (more)
- Biological permeable cap
  - 1 meter ± zone of compost
  - Methane oxidation layer

No associated notes.

72

Operational Issues – Anaerobic Bioreactor (continued)

- Settlement
  - Enhanced settling may have a negative impact on leachate and gas collection pipes/wells/trenches
- Odor
  - Potentially exacerbated by increased waste exposure and moisture content
  - Higher rate of landfill gas (LFG) generation
  - Potential additional odor from biosolids and liquid waste streams

No associated notes.

73

Operational Considerations

- Sources of liquids
- Leachate head level maintenance
- Leachate outbreaks
- Slope stability – run a stability analysis!
- Gas generation
- Winter operations

No associated notes.

Aerobic Bioreactor Operations

No associated notes.

75

Aerobic Bioreactors

- Minimizes landfill gas emissions
- Installation, operation, and maintenance on some sites has been cost prohibitive
- Area of influence of air addition is limiting in retrofits because of low permeability
- Numerous pilots have ended with mediocre results
- New technology pilot tests are on-going

No associated notes.

76

Aerobic Bioreactors – As Built or New Cells

- Temperature monitoring and control is critical
- Working face should be watered prior to aeration
- Horizontal piping or vertical wells
- Aeration time is dependent upon waste characteristics
  - Food content
  - Moisture content
  - Density, saturation, and permeability

Aeration should be capable of delivering 0.01 to 0.06 (scfm/bcy).

A higher aeration rate (up to 0.06 scfm/bcy) is acceptable but evaporative loss of water could make temperature management more difficult and adversely impact the biodegradation rates

scfm = standard cubic foot (feet) per minute

bcy = bank cubic yard

77

Monitoring Approach

- Identifies key parameters to monitor
  - Enhance operational control
  - Assess environmental impacts
- Provides a template to enable evaluation of the technology nationally
- Uses parameters and techniques currently available to owner/operators, emphasis on
  - Waste stabilization
  - Leachate management


Photo Courtesy of
Waste Management, Inc

No associated notes.

78

Monitoring Parameters

- Physical parameters
  - Geotechnical considerations
  - Head on liner
  - Mass balance
  - Moisture balance
- Analytical monitoring parameters
  - Leachate
  - Solids
  - Gas
- Industrial liquid addition criteria

Liquid amendments that are between pH of 4 to 9 and must be non-hazardous by characteristic and definition

Liquids amendments that are 95-99% aqueous

Liquid amendments currently accepted by bioreactor demonstration sites are

biosolids (2 to 9 % fresh or treated sewage sludge from POTWs (Publicly Owned Treatment Works) (from raw sludge, digestors or lagoon clean-outs)),

liquid rejects from food and beverage manufacturers,

paint rejects or paint spray booth materials (acrylic water based paints),

tank clean-outs and oily waters (95% aqueous),

antifreeze waters, dye and ink test waters, dry well water,

leachates from other sites,

liquid sludges from non-hazardous waste treatment plants (commercial and industrial), and

remedial liquids from companies that specialize in remediation and transport

High concentration of soluble and degradable organic liquids.

Liquids not acceptable include:

Surfactant based fluids, oily or petroleum based fuels, pickling wastes, aluminum dross, and high sulfur content wastes.

Liquids that can be degraded quickly to simple sugars, such as tomato food rejects, should be used in combination with other aqueous amendments to avoid rapid fermentation to volatile acids.

Liquids with total phenols > 2000 ppm

Liquids that are sulfide or cyanide reactive, ignitable, or corrosive

Liquids that may be classified as hazardous waste or substances

79

Geotechnical Considerations

- Slope stability studies that examine final and interim slopes
- Avoid toe excavation
- Avoid filling waste at steep slopes >3:1
- On-site roads and soil may cause instability

Graphic from ITRC's Alternative Landfill Covers Internet-based training. See www.itrcweb.org for more information.

No associated notes.

80

Head on Liner

- Head on primary liner needs to be designed not to exceed 30 cm
- Leachate collection system needs to be designed to handle the increase in leachate flow

Photo Courtesy of Waste Management, Inc

No associated notes.

Mass Balance

- Mass of municipal solid waste (MSW)
- Mass of construction debris and demolition
- Mass of soil (other than daily cover)
- Mass and type of daily cover
- Landfill volume
  - Conducting volume surveys on regular basis GPS (Global Positioning System)
  - Compaction
  - Settlement

No associated notes.

82

Moisture Balance

- Volume of leachate added
- Rainfall
- Volume of outside liquids added
- Volume of leachate generated
- Mass of sludge added
- Wet basis moisture content of sludge

No associated notes.

83

Leachate Monitoring

- Temperature
- pH
- Conductance
- Total dissolved solids (TDS)
- Alkalinity
- Chloride
- Biological oxygen demand (BOD)
- Chemical oxygen demand (COD)
- Total organic carbon (TOC)
- Ammonia

Photos Courtesy of Waste Management, Inc

No associated notes.

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Leachate Monitoring (Secondary)

- VOCs (40 CFR 258 Appendix I)
- SVOCs
- Volatile fatty acids
- Metals
  - As, Ba, Cd, Ca, Cu, Cr, Fe, Pb, Mg, Hg, K, Na, Se, Ag, Zn

No associated notes.

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Solids Monitoring Parameters

- Average temperature
- Average pH
- Average volatile solids content
- Average wet based moisture content

No associated notes.

86

Gas Monitoring Parameters

- Total gas flow
- Gas composition
  - Carbon dioxide (CO_2)
  - Methane (CH_4)
  - Oxygen (O_2)
  - Carbon monoxide (CO)
- Follow National Emissions Standards for Hazardous Air Pollutants (NESHAP) requirements
  - Well head gas
  - Fugitive emissions

No associated notes.

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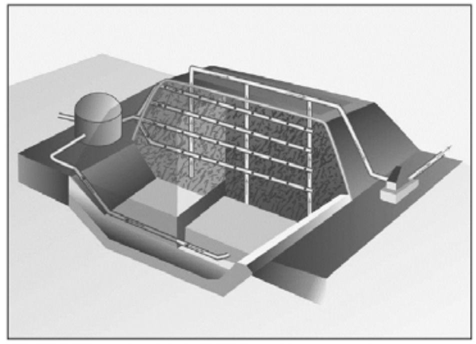
Conclusion

- Monitoring approach provides practical methods to assess landfill bioreactor operations and environmental impacts
- As more field data is accrued, monitoring strategy will be refined to reflect advances

No associated notes.

Summary

- Bioreactor technology is a viable means of waste disposal and stabilization
- Bioreactor landfills have advantages over dry tomb landfills
- Current regulatory framework allows implementation of bioreactor designs



Bioreactor technologies are a viable way to handle solid waste disposal. Although bioreactor landfill technology is somewhat new, many of the construction and operational issues associated with these types of facilities are not all that different from traditional Subtitle D style landfills. In fact bioreactor landfills have many advantages over traditional style landfills such as accelerated waste stabilization, increased settlement and therefore reclaimed airspace, reduced leachate handling costs and other factors previously discussed in this presentation.

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Thank You for Participating

- Links to additional resources
  - http://www.clu-in.org/conf/itrc/bioreactors/resource.cfm
- 2nd question and answer session

Links to additional resources:
http://www.clu-in.org/conf/itrc/bioreactors/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/bioreactors

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC’s technical team and other activities

✓Be an official state member by appointing a POC (State Point of Contact) to the State Engagement Team

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects