Modern Landfills:

A Far Cry from the Past

National Waste & Recycling Association℠

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INTRODUCTION

Regardless of where we live, work, or play, we generate trash. According to the United States Environmental Protection Agency (EPA), American's generated 254.7 million tons of municipal solid waste (MSW) in 2005 and more than half (138.3 million tons) was disposed of in landfills.[1]

A modern municipal solid waste landfill with a gas collection and energy recovery system.

To ensure that our garbage does not harm the public health or the environment, today's modern, state-of-the-art landfills are technically sophisticated and highly regulated. These landfills are commonly referred to as "municipal solid waste landfills" to distinguish them from the open dumps of the past.[2] Unlike old dumps, modern landfills include engineered protective liners, leachate collection systems, groundwater monitoring, gas collection equipment, and environmental reporting requirements.

This paper explains the history behind the development of modern landfills and provides details on how today's landfills are designed, operated, and regulated to protect human health and the environment.

THEN AND NOW

Since the dawn of mankind, humans have generated waste. However, waste disposal was not a problem when we had a nomadic existence; we simply moved away and left our waste behind. Around 10,000 BC, humans started to abandon their nomadic existence and live in communities. With the advent of non-transient communities came trash that was dropped on the ground or floor where people lived.

Alternative waste disposal methods were not developed until waste began jeopardizing city defenses. In 500 BC, Athens, Greece, established the first municipal waste dump in the western world by requiring scavengers to dispose of waste at least one mile from the city's walls so invaders could not easily scale the walls using the waste placed there. However, dumping waste within cities remained the primary disposal option in Europe and the United States until the late 1800s when a connection was made between disease and filthy environmental conditions.

Toward the end of the 19th Century, many cities realized that throwing waste into the streets was causing health and political problems. In response, cities created garbage collection and disposal systems using horse-drawn carts to collect garbage and dispose of it in open dumps, incinerators, or at sea. Even in the 1920s, garbage, incinerator ash, and dirt were commonly used to reclaim wetlands near cities.

In the late 1860s, garbage was placed in leaking barrels on the street edge and picked through by scavengers and otherwise left for animals.

In 1935, the precursor to the modern landfill was started in California where waste was thrown into a hole in the ground that was periodically covered with dirt. The American Society of Civil Engineers in 1959 published the first guidelines for a "sanitary landfill" that suggested compacting waste and covering it with a layer of soil each day to reduce odors and control rodents.

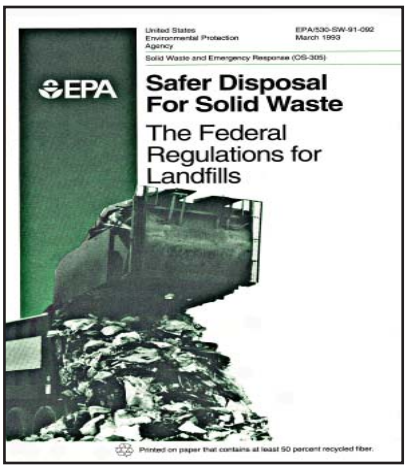
Early efforts at waste collection in cities consisted of horse-drawn wagons.

The first federal legislation addressing solid waste management was the Solid Waste Disposal Act of 1965 (SWDA) that created a national office of solid waste. By the mid-1970s, all states had some type of solid waste management regulations. However, the contents of these regulations varied widely. During this time, many states' laws banned the open burning of waste at dumps and began replacing them with sanitary landfills. In addition, some states required disposal facilities to obtain permits and meet minimal design and operational standards.

In 1976, the U.S. House of Representatives passed the Resource Conservation and Recovery Act (RCRA) that dramatically expanded the federal government's role in managing waste disposal. RCRA divided wastes into hazardous and non-hazardous categories, and directed the EPA to develop design and operational standards for sanitary landfills and close or upgrade existing open dumps that did not meet the sanitary landfill standards.

In 1979, EPA developed criteria for sanitary landfills that included: siting restrictions in floodplains; endangered species protection; surface water protection; groundwater protection; disease and vector (rodents, birds, insects) control; opening burning prohibitions; explosive gas (methane) control; fire prevention through the use of cover materials; and prevention of bird hazards to aircraft.[3]

RCRA was amended in 1984 to require EPA to assess and, if appropriate, revise the sanitary landfill requirements.[4] In 1991, EPA established new federal standards for municipal solid waste (MSW) landfills that updated locational and operational standards and added design standards, groundwater monitoring requirements, corrective action requirements for known environmental releases, closure and post-closure care requirements, and financial assurance requirements to demonstrate the ability to pay for long-term care of the landfill.[5]



EPA issued guidelines for the newly promulgated landfill regulations.

SAFER LOCATIONS AND OPERATIONS

In the past, little regard was given to where landfills were located and how they were operated. Today's modern landfills are built in locations that protect human health and the environment as well as the structural integrity of the landfill. For example, modern landfills are restricted from being constructed in:

- Floodplains unless engineering measures are in place to prevent a flood from washing MSW out of the landfill into local streams or rivers;
- Wetlands unless the landfill will not cause significant degradation of the wetland and the loss of wetlands is avoided; and
- Fault areas, seismic impact zones, and unstable areas unless the landfill is designed to maintain structural integrity during a geologic event.

In addition, modern landfills have instituted a number of protective operational procedures. Landfills now have plans that ensure hazardous waste is not accepted and disposed of at the facility, wastes are not openly burned, unauthorized access is controlled, and bulk and non-containerized liquids are not accepted. Finally, owners of modern landfills keep records and routinely report to state regulatory agencies on groundwater, surface water, and air monitoring activities.

BETTER DESIGNS

In about 30 years, landfills changed from little more than holes in the ground to highly engineered, state-of-the-art containment systems requiring large capital expenditures. Typically, older landfills were designed by excavating a hole or trench, filling the excavation with trash, and covering the trash with soil. In most instances, the waste was placed directly on the underlying soils without a barrier or containment layer (liner) that prevented leachate (water percolating through the waste and picking up contaminants) from moving out of the landfill and contaminating groundwater.[6]

Old landfills used open burning to reduce space, but this also created air pollution.

Dumped garbage was openly burned to save space for future waste disposal, creating air pollution and health hazards. When the waste reached a predetermined height, a final cover of soil was placed on top and sometimes vegetation was planted. In many instances, the vegetation failed to grow or died because of methane gas (a natural by-product of waste degradation) escaping through the final cover. Also, the landfill gas could move off-site into buildings and homes potentially creating explosion risks.

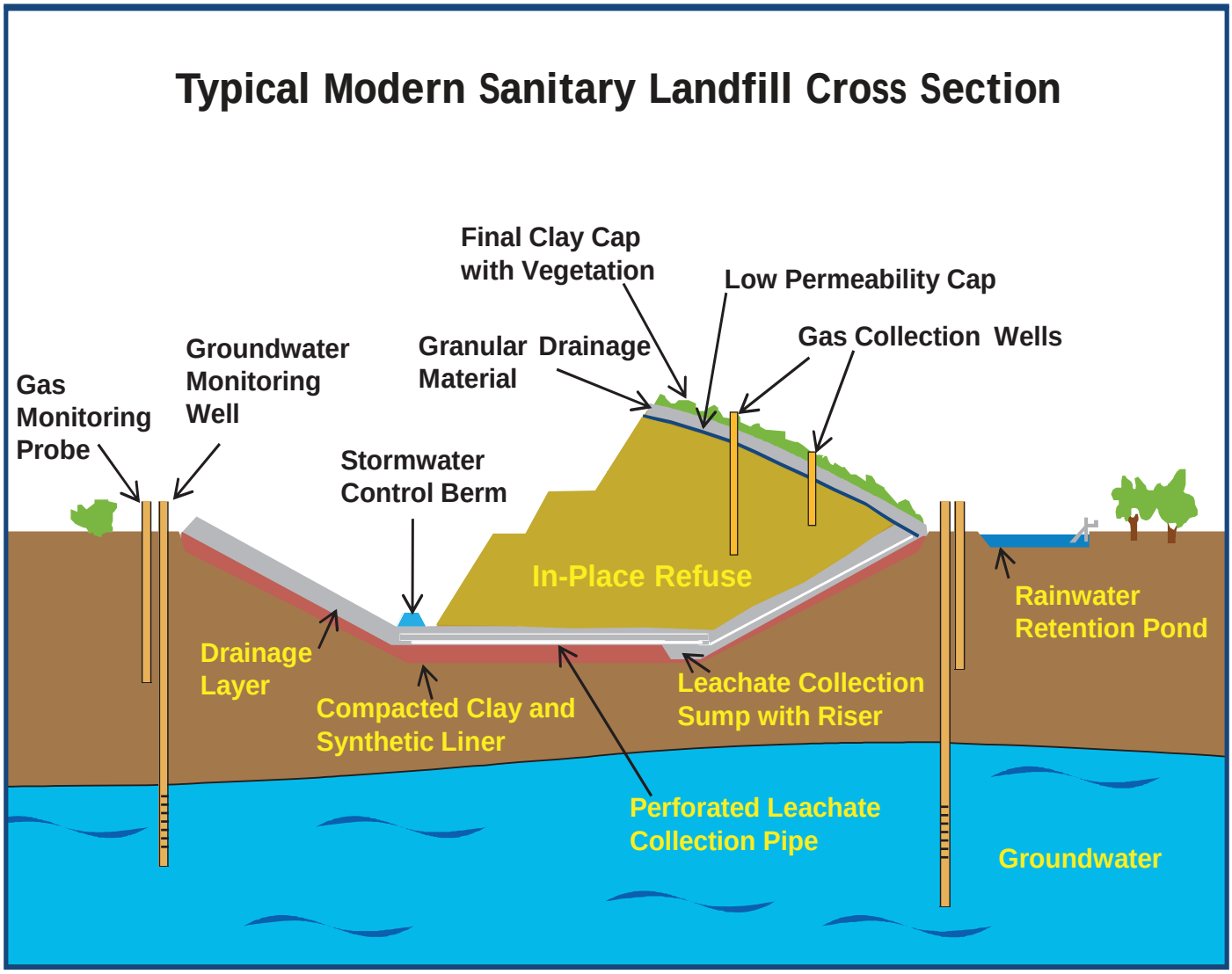
In contrast, modern landfills are specifically designed to protect human health and the environment by controlling water and air emissions. The diagram shown on page 5 provides a typical cross-section of a modern landfill.

Liquid containment within a modern landfill results from a combination of the liner and the leachate collection system performing complementary functions to prevent groundwater contamination. Liners prevent leachate and gas migration out of the landfill while directing liquids to the leachate collection system.

Liner systems are typically constructed with layers of low-permeability, natural materials (compacted clay) and/or synthetic materials (high-density polyethylene). The leachate collection system removes the liquid contained in the liner. A typical leachate collection system may consist of (from bottom to top) a perforated leachate collection pipe placed in a drainage layer (gravel), a filter blanket, and a leachate collection layer.

Waste is placed directly above the leachate collection system in layers. Delivered waste is placed on the working face that is maintained as small as possible to control odors and vectors. Heavy, steel-wheeled compactors move the waste into the working face to reduce the waste's volume.

Synthetic materials can be used as landfill liners to prevent contamination of groundwater resources.



At the end of each day, the waste is covered with six inches of soil or an alternative daily cover (foam, tarps, incinerator ash, compost) to control vectors, odors, fires, and blowing litter.

Once the landfill has reached its permitted height, the landfill is closed and engineered to prevent water infiltration by installing a low permeability cap similar to the liner system. The final cap can be comprised of a compacted clay and/or synthetic material. A granular drainage layer is placed on top of the low-permeability barrier layer to divert water off the top of the landfill. A protective cover is placed on top of the filter blanket and topsoil is placed as the final layer to support vegetation.

In short, the engineered systems in a modern landfill ensure protection of human health and the environment by containing leachate that can contaminate groundwater, preventing the infiltration of precipitation that generates leachate after closure of the landfill, and collecting landfill gas that can be used as an energy source or destroyed.

Compactors are used on the working face of landfills to move garbage and reduce the waste's volume.

GREATER ENVIRONMENTAL PROTECTION

Historically, open dumps were associated with a number of environmental problems; however, the goal of today's modern landfill design and operation is to control and eliminate any environmental impacts.

Landfill Gas

Gas collection wells at modern landfills protect public health by preventing methane from migrating off site.

When MSW is disposed of in a landfill, naturally occurring microorganisms (bacteria) degrade the waste. The amount of water in and the temperature of the MSW control the rate of degradation. This process turns the organic portion of the waste into methane (a primary constituent of natural gas) and carbon dioxide in about equal proportions. The degradation process also generates very small quantities of organic compounds.

Additionally, some organic compounds may be released directly into the gas from products contained in the waste, such as household cleaning materials. The non-methane organic compounds (NMOC) in the gas amount to less than one percent of the total gas created by waste degradation. Gas generated can threaten human health and the environment if it migrates off site or is not collected and destroyed.

Under federal Clean Air Act standards, larger modern landfills with estimated uncontrolled emissions of 55 tons per year of NMOC or more are required to install a gas collection and destruction system. Large landfills are defined as having a design capacity of equal to or greater than 2.76 million tons and 3.27 million cubic yards. Many smaller landfills voluntarily install gas collection and destruction systems for various reasons, including earning emission reduction credits by reducing their greenhouse gas (GHG) emissions or being a "good neighbor." The gas collection system directs gas to a central location where it can be processed and treated depending on its ultimate use. From this point, gas can be destroyed in a flare (similar to a gas stove) or used as an energy source to produce electricity, replace natural gas, or as a fuel to power vehicles.

Improved Quality and Destruction

According to recent EPA studies, modern landfills generate significantly lower concentrations of NMOCs than older sites. Of 48 NMOCs regulated by federal Clean Air Act rules, 58 percent of them are one to three orders of magnitude lower (an order of magnitude is a ten-fold decrease) in concentration in modern landfills than in older landfills. In fact, 5 of 28 NMOC compounds were not detected at modern landfills, but were present in high concentrations in older landfills. Since comparable data are from test programs conducted in the late 1980s, older landfills are likely to have higher concentrations of NMOCs than modern landfills.

Gas collection systems at modern landfills can be used to generate electricity to supply energy to local communities.

In addition to the environmental benefits of lower concentrations of NMOCs in gas from modern landfills compared to older ones, the potential risks to human health and the environment of gases from modern landfills is significantly less than older landfills because the devices used to combust the gas have destruction efficiencies of more than 99 percent for methane and greater than 98 percent for all other NMOCs.[7]

Green Energy

Devices used to combust gas at modern landfills have more than a 99 percent destruction efficiency for methane and a 98 percent rate for other gases.

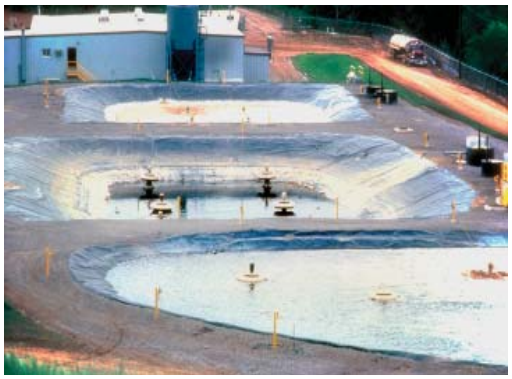
As noted earlier, collected landfill gas can be used to generate electricity or heat for powering industrial facilities, providing lighting and temperature control to homes and businesses, or as fuel for use in vehicles. EPA's latest data show that there are more than 455 operational gas-to-energy projects in 42 states. These projects collect some 7245 million standard cubic feet pending (mmscfd) of landfill gas and generate 1,383 megawatts (MW) of electricity per year. The annual environmental benefits from current landfill gas-to-energy projects are equivalent to:

- Planting over 20.5 million acres of forest per year;
- Preventing the use of over 177 million barrels of oil;
- Removing the carbon dioxide emission equivalents of over 14.5 million cars; or
- Offsetting the use of 370,000 railcars of coal.[8]

Because methane is a potent GHG (approximately 21 times more global warming potential than carbon dioxide), an additional benefit of modern landfill gas collection and destruction equipment is the reduction of methane released to the atmosphere where it contributes to global warming. Actual GHG net emissions from landfill operations in 2006 were 126.2 teragrams of carbon dioxide equivalents ($TgCO_2E$)[9] compared to 149.6 in 1990.[10, 11] Modern landfill practices used in 2006 prevented the release of 23.9 $TgCO_2E$ compared with what would have been emitted if 1990 practices were still being used. Further, EPA has recognized that modern landfills are a sink for carbon, sequestering some 10.5 $TgCO_2E$.

Leachate

As referenced earlier, few older landfills had liners and leachate collection systems to prevent leachate movement out of the landfill. Modern landfills are equipped with liners and leachate collection systems that prevent the leachate from leaving the facility and contaminating groundwater. Based on recent EPA studies, a liner and leachate collection system constructed to current standards typically has a liquid removal efficiency of 99 to 100 percent and frequently exceeds 99.99 percent.[12]



Leachate treatment facilities are capable of removing 100 percent of trace organics and over 85 percent of heavy metals.

EPA research shows that most trace chemicals are detected at lower concentrations in leachate from modern landfills than from older ones. In most instances, contaminant concentrations in leachate from modern landfills are one to two orders of magnitude less

Testing of water samples in groundwater monitoring wells at modern landfills ensures that leachate collection systems are working correctly to protect public health and the environment.

compared to older landfills. Moreover, EPA research anticipates that the quality of leachate will continue to show improvement over time as the existing public database for modern landfills increases.

Releases of trace constituents contained in the leachate from modern landfills are practically eliminated because leachate is collected, removed, and treated. Leachate collected at landfills is either treated on-site or transported off-site for treatment. Federal requirements mandate that treatment must meet drinking water quality standards, which are set to prevent harm to public health, or more stringent state standards to protect sensitive environments (high quality streams, trout streams).[13]

Research has shown that leachate treatment facilities at modern landfills are capable of removing 100 percent of the trace organics and over 85 percent of the heavy metals.

To ensure the liner and leachate collection system are operating properly, groundwater monitoring wells are installed around the landfill and tested regularly for indications of releases from the landfill. Groundwater quality reports are provided to the appropriate state regulatory authorities on a routine basis. If contaminants indicative of a release from the landfill are found in monitoring wells at levels above health-based standards, the landfill must correct any problems that resulted from the release and restore groundwater to its original quality.

RECLAMATION AND REUSE

Older dumps were commonly only closed with a thin layer of dirt and revegetated sparsely, if at all. With open space shrinking and environmental awareness expanding, many communities wanted to reclaim and make productive use of older landfill sites. Today, landfills are designed from the start to ensure protection of the environment and public health, and the safe and productive use of the site after closure.

Post-closure uses of landfill sites can be grouped into three broad categories: (1) Open space, agricultural, and passive recreation; (2) Active recreation, parking, or industrial/commercial activities; and (3) Intensive uses such as residences, industry, and commercial development.

Category 1 uses are the least recognizable and most numerous because they may appear to be nothing more than an open field. Examples are:

- Cal Sutton's Farm, Arizona - agricultural land;
- Westview Sanitary Landfill, Georgia - cemetery;
- Palomar Airport, California - clear zone around runways; and
- Griffith Park, California - hiking trails.

The clear zone around the runways at the Palomar Airport in California are built on a Category 1 closed landfill.

Category 2 uses for closed landfills include children's playgrounds such as this soccer field.

Category 2 uses are more intensive and are typically characterized by not having major structures, but may have utilities, light structures, or paving. Examples are:

- Settler's Hill Landfill, Illinois - golf courses and a minor league baseball field;
- Union City, Tennessee - fairgrounds;
- Germantown Sanitary Landfill, Wisconsin - ski slope; and
- Mayor Thomas W. Danehy Park, Massachusetts - softball fields, soccer fields, children's play areas, horseshoe pits, and trails.

Category 3 uses are the most intensive and are typically characterized by major structures. Examples are:

- Mile High Stadium, Colorado - football stadium;
- Brickyard Shopping Center, Illinois - shopping mall;
- Yorktown Landfill, Texas - federal post office; and
- Columbia Point, Massachusetts - John F. Kennedy Presidential Library, University of Massachusetts State Archives Building.

Mile High Stadium near Denver, Colorado is an example of a Category 3 post-closure use of a landfill.

FUTURE OF LANDFILLS

The waste industry continues to investigate innovative operations and designs that further protect human health and the environment. One promising innovation is the bioreactor landfill. A bioreactor landfill operation and design adds liquids and/or air to the waste, which accelerates the waste biodegradation process and waste stabilization.

Based on research, the environmental benefits of a bioreactor landfill include:

- Shorter time periods (7-10 years) over which air and water emissions are generated compared to 30 or more years in a conventional landfill;
- Shorter post-closure care periods (10-15 years) compared to 30 or more years for a conventional landfill;
- Increased efficiency of the gas collection system; and
- Quicker return of the property to a productive end-use.

Researchers at this bioreactor landfill are testing the liquids distribution system using permeable blankets built into the lifts.

Another promising innovation is the use of biocovers (composted yard waste used as a final cover) to further reduce air emissions at landfills. The benefits of biocovers are that air emissions of methane and other organic compounds are oxidized and destroyed in the biologically active compost. Research has shown that biocovers are effective for controlling air emissions when used:

- On areas where more waste will be added at a later date and a landfill gas system is not fully operational; or
- To control air emissions when the gas system is shutdown for maintenance and repair.

Researchers at this bioreactor landfill are testing the use of biocovers as an alternative cap system.

CONCLUSION

As in the past, landfills will continue to play an important role in our nation's MSW management system. However, gone are the past problems associated with older landfills such as groundwater and air contamination, acceptance of hazardous waste, and inappropriate locations in sensitive areas. Modern landfills, in contrast, are highly engineered containment systems that are designed and operated to minimize the impacts of municipal solid waste disposal on human health and the environment.

The private solid waste management industry and its trade association, the National Solid Wastes Management Association, have been in the forefront of promoting and operating safe and efficient MSW landfills. The industry continues to explore innovative designs and operations that will further protect human health and the environment.

NOTES AND SOURCES

[1]EPA. 2006. Municipal Solid Waste in the United States 2005 Facts and Figures. EPA 30-2-06-011.

[2]According to EPA, MSW landfills accept wastes primarily derived from houses, apartments, hotels, motels, campgrounds, and picnic areas as well as commercial solid wastes (e.g., restaurants, offices, grocery stores, and retail malls), and industrial solid waste.

[3]Title 40 of the Code of Federal Regulations part 257 (40 CFR part 257).

[4]Hazardous and Solid Waste Amendments of 1984 (HSWA).

[5]Title 40 of the Code of Federal Regulations part 258 (40 CFR part 258).

[6]EPA defines leachate as liquid that has passed through or emerged from solid waste and contains soluble, suspended, or miscible materials removed from such waste.

[7]EPA. 1999. Municipal Solid Waste Landfills, Volume 1: Summary of the Requirements for the New Source Performance Standards and Emission Guidelines for Municipal Solid Waste Landfills. EPA-453R/96-004.

[8]www.epa.gov/lmop.

[9]1 teragram is equal to 1.1 million U.S. tons.

[10]Carbon dioxide equivalents are a measure used to compare the emissions of different greenhouse gases based upon their global warming potential.

[11]EPA. 2008. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006. EPA-436-R-08-005.

[12]EPA. 2002. Technical Resource Document: Assessment and Recommendations for Improving the Performance of Waste Containment Systems.

[13]Title 40 of the Code of Federal Regulations parts 136 and 445 (40 CFR parts 136, 445).

This paper was developed by the National Solid Wastes Management Association (NSWMA) staff (revised August 2008). For further information on landfills and NSWMA's Landfill Institute, contact Edward Repa, Ph.D., Director, Environmental Programs, at 800-424-2869 or erepa@envasns.org.

NSWMA is the non-profit trade association representing for-profit companies providing solid and medical waste collection, recycling, and disposal services throughout North America.

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For more information on NWRA's Municipal Solid Waste Landfill Facts, contact Anne Germain Director, Waste & Recycling, at 202-364-3724 or agermain@wasterecycling.org..