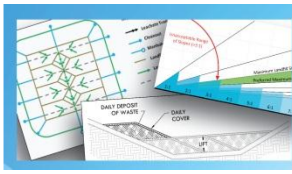

CHAPTER 2

Solid Waste Disposal Site Design and Operational Considerations

This chapter presents the best practices in SWD site design and operations to improve LFG collection. These best practices are the result of experience in striving to collect LFG efficiently, either as a safety measure or to comply with regulations. This chapter discusses the components of an SWD site necessary to collect LFG and how the lack or inadequate employment of these components will affect the generation of LFG, the methane content, and the collection efficiency of the LFG collection system. A description is provided of the basic technologies employed and the more advanced options for each of the components mentioned in the chapter. At the end of the chapter, a table summarizes the effects of the existence, or lack, of any of the SWD site components mentioned in this chapter on LFG generation and collection.

Worldwide, SWD sites are still the most common method to dispose of municipal solid waste. The types of SWD sites used vary greatly from developed to developing countries and from urban to rural settings. SWD sites can be categorized into three groups, depending on the main characteristics of the sites: open dump, controlled landfill/dump, and sanitary landfill.[1]

Landfill Operational Guidelines

The International Solid Waste Association's (ISWA) *Landfill Operational Guidelines (2nd Edition)* provides additional design and operation details about landfills that are not covered in this guide.

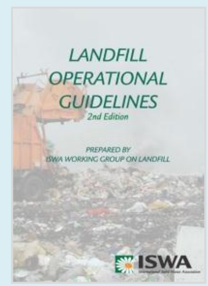

Table 2-1 compares the basic differences between the three types of SWD sites and the negative environmental and health impacts associated with each type. A direct relationship exists between the type and condition of an SWD site and the amount of LFG that could be collected from the site. For this reason, distinguishing among the different types of commonly used SWD sites is important.

Table 2-1. Comparisons of Solid Waste Disposal Sites

Factor	Open Dump	Controlled Landfill/Dump	Sanitary Landfill
Environmental Factors			
Atmosphere			
Fires	Intentional burning common	Limited, may be present	Unlikely
Release of hazardous gases	Yes, if no collection exists	Yes, if no collection exists	Yes, if no collection exists
LFG collection and control	Possible, poor collection efficiency expected	Likely, collection efficiency will depend on site conditions	Likely
Unpleasant odors	Yes	Possible, depending on site conditions and whether LFG is controlled	Minimal, if the right measures are taken to cover waste and control LFG
Ground/Soil			
Topographical Modification	Yes	Yes	Yes
Contamination (leachate)	Yes	Possible, depending on base or liner conditions	No
Gas Migration	Yes	Possible, depending on site conditions	No

[1] International Energy Agency. 2009. *Turning a Liability into an Asset: the Importance of Policy in Fostering Landfill Gas Use Worldwide*. http://www.iea.org/papers/2009/landfill.pdf.

Factor	Open Dump	Controlled Landfill/Dump	Sanitary Landfill
Water (surface and ground water)			
Channeling runoff	No	Possible, depending on site conditions	Yes
Contamination	Likely underground and surface water	Possible if low-permeability liners are not used	Minimal
Monitoring system present	No	No	Yes
Flora			
Vegetative cover alteration	Yes	Yes	Yes
Fauna			
Changes in diversity	Likely	Yes	No
Vector control	No	Potentially, depending on site conditions	No
Socioeconomic Factors			
Landscape			
Alteration of Condition	Yes	Yes, can be mitigated with visual buffer (for example, a forest buffer)	Yes, can be mitigated with visual buffer (for example, a forest buffer)
Humans			
Health hazards	Yes	Potentially, depending on site conditions	Potentially, depending on site conditions
Negative image	Yes	Yes	Yes, improved if there is post-closure utilization of land
Environmental education	No	Yes, in some cases	Yes, with careful planning
Economics			
Decline of land value	Yes	Yes	Yes
Formal employment	No	Yes	Yes
Changes in land use	Yes	Yes	Yes
Social			
Waste pickers	Yes	Yes, in some cases	No

2.1 Sanitary Landfill Design

The objective of sanitary landfill design is to provide for safe disposal of waste while protecting human health and the environment. Sanitary landfills should be designed and managed to protect soil, ground water, surface water and air. Other important objectives of sanitary landfill design are to maximize the waste disposal quantity in the available space given site conditions, geometry, consideration of slope stability and future potential uses. Additionally, a well-designed and operated sanitary landfill will provide cost savings over the life of the site as preventive measures are often less costly than mitigation efforts associated with poorly designed and operated SWD sites.

Sanitary landfill design is a science that is continuously evolving as new technologies and practices arise. As new technologies are tested and proven, they become the recommended standard for use, and in some cases, are adopted within solid waste regulations. Prescriptive standards stipulate the materials, design and construction methods to use in the development of a sanitary landfill. In contrast, performance-based standards state the goals and objectives to be achieved and allow the user flexibility in choosing materials, design and construction methods to meet the stated goals and objectives.

Effective landfill design must be a fully integrated system that is led from the regulators and those responsible for the review and project implementation of design standards. In many solid waste regulations, governments have chosen the prescriptive approach, requiring the use of certain technologies in the construction of a sanitary landfill, such as in the United States, Australia and Germany. However, in some cases and or under special circumstances, the use of other types of technologies is permitted as long as they have been demonstrated to provide equivalent protection of the environment. Some governments have taken this latter approach in their solid waste regulations, allowing just the use of performance-based SWD site standards in light of the flexibility they provide for design and construction. This flexibility is especially important in circumstances where a basic technology is more appropriate.

✔ Example: SWD Site Design Regulations

In the United States, all municipal solid waste landfills must comply with federal regulations 40 Code of Federal Regulations (CFR) Part 258 (RCRA Subtitle D) which establishes criteria for municipal solid waste landfills.[2]

✔ Example: SWD Site Design Guidance

In Brazil, no regulation exists for SWD site design, but the Brazilian Institute of Municipal Management (IBAM) published a manual on Integrated Solid Waste Management (ISWM) that contains guidance on SWD site design. Implementation of the recommendations in the manual is sometimes seen in Brazilian SWD sites.

Regulations regarding SWD site design, either by prescribing specific standards or by enumerating performance standards, are common in developed countries. However, no regulations exist for the design or operation of SWD sites in many developing countries. A general solid waste management law might mention the need for SWD sites to have a bottom liner, leachate management, final cover and LFG venting. In some countries, SWD site design and operations manuals are published by professional engineering associations or other entities, and recommendations in the manuals are commonly practiced in the country. The adoption of standards from other, more developed, countries is common in other countries that do not have SWD site design regulations or engineering association standards. The next few sections will cover the important components of a SWD site design, including bottom liner systems, leachate collection and management systems, grading and re-grading, and final capping systems.

Bottom Liner Systems

The objective of the bottom liner is to protect the soil and ground water from the pollution that originates within the waste mass. The bottom liner creates an impermeable barrier between the waste mass and underlying soils and ground water and is applied to the entire surface of the landfill to prevent both horizontal and vertical migration. Liners also serve as a barrier to LFG migration to surrounding soils. LFG seeks the path of least resistance, so as it encounters the barrier it will seek other pathways to exit the waste mass.

Bottom liner systems range from a simple single liner to composite liners. The use of a particular bottom liner system will depend on the conditions of the site, climate, SWD site size, cost, and any applicable construction regulations pertaining to the region or country where the site is located. Defining the appropriate liner system based on the physical setting of the site allows site-specific conditions to be considered and would provide efficiency in the design and installation of liners. For example, sites with high permeable *in situ* soils and high ground water levels would require a more protective liner system with low-permeable clay and a geomembrane. Sites in dryer climates with deep ground water levels

[2] Electronic Code of Federal Regulations, Title 40, Part 258 (Criteria for Municipal Solid Waste Landfills). http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title40/40cfr258_main_02.tpl.

would not require as stringent a liner system to protect the ground water, but a minimum low-permeable liner system is recommended to provide the necessary barrier for gas migration.

The bottom liner system can be composed of one or a combination of the following:

- Low-permeability clay compacted to achieve a specified minimum permeability. The general recommendation is for the clay to strive for the permeability to be less than 10^{-6} centimeter(cm)/sec[3]. This is usually achieved by using a 60-cm-thick layer of clay, compacted in 15-cm lifts.
- Different types of geosynthetic components including: geonets, geotextiles or geomembranes.

Descriptions of the different materials used in liners and information on the different types of bottom liner systems can be found in various reference materials, including *Solid Waste Landfill Engineering and Design* by McBean et al. and the Landfill Types and Liner Systems Fact Sheet produced by Ohio State University.[4] Several factors can influence the cost of the liner system. For example, the proximity of a source of clay soils and the cost for transporting them to the site can result in a large variance in the cost of a clay liner system. Additionally, the cost for shipping geomembrane from out of country or long distance also can result in large cost variances.

Documenting the bottom liner elevations with an as-built survey (to obtain horizontal and vertical dimensional data) is imperative. The bottom liner elevations are required to calculate the volume of the waste mass. In addition, accurate bottom liner elevations are critical when vertical LFG extraction wells are installed to avoid drilling through the liner systems.

Leachate Collection and Management Systems

Design Specifications and Objectives. Leachate is a wastewater formed when water percolates through or comes in contact with the waste mass. Leachate contains high concentrations of organic and inorganic constituents that can be toxic. Leachate can contain both dissolved chemicals such as chloride, sodium, iron and aluminum and suspended materials such as chemical precipitates, waste materials and bacteria colonies. In an SWD site, leachate can originate from two sources: moisture contained in the solid waste when it is disposed of, and external sources of water such as rain. At sites where rain is the principal source of leachate formation, extensive control via stormwater management is crucial for minimizing the creation of leachate in the first place. The better the stormwater management, the more control an SWD site owner has with leachate management. Effective stormwater management is especially important in tropical regions that experience large amounts of rain.

The major concerns of leachate have to do with its migration to and contamination of surface and ground water and its impediment to LFG collection when it accumulates and floods LFG collection wells. Control of leachate migration starts by properly siting, designing, constructing and operating the SWD site. A Leachate Collection and Removal System (LCRS) is designed to collect, conduct and store the leachate for its treatment on site or off site.

Excessive amounts of leachate can hinder the efficient collection of LFG because the leachate can build up and prevent movement of LFG to the well. Therefore, installation of an adequate leachate collection and removal system is instrumental to extract the leachate out of the waste mass and ensure the efficient operation of the LFG collection and control system.

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[3] California Integrated Waste Management Board. *Landfill Facility Compliance Study Task 6 Report - Review of MSW Landfill Regulations from Selected States and Countries.* 2004.

[4] McBean, E., Rover, F. and Farquhar, G. *Solid Waste Landfill Engineering and Design*. Englewood Cliffs: Prentice, 1995.

An LCRS normally consists of a drainage layer above the liner system. This drainage layer provides a means for the leachate to flow above the liner system. Typically, a network of pipes is installed within the drainage layer to transport leachate to a collection point (such as a lagoon or storage tank).[5] A typical layout of an LCRS can be seen in Figure 2-1. Note the bottom slope direction in Figure 2-1. The bottom of the SWD site needs to be gently sloped to promote leachate drainage to the cleanout lines (see Figure 2-2).

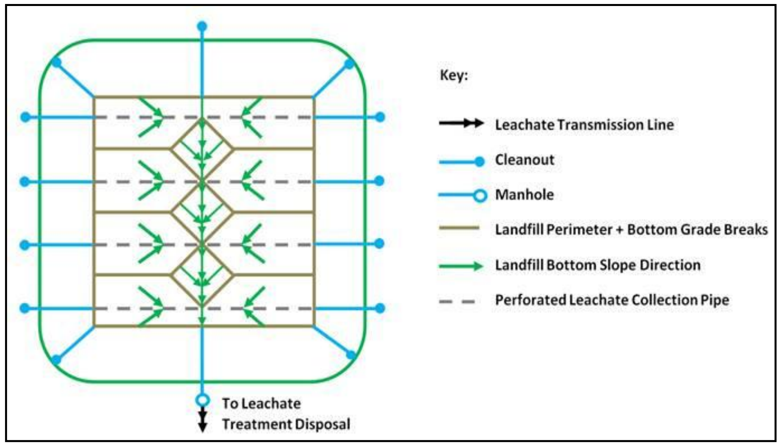

Figure 2-1. Typical Layout of Leachate Collection System (top view)

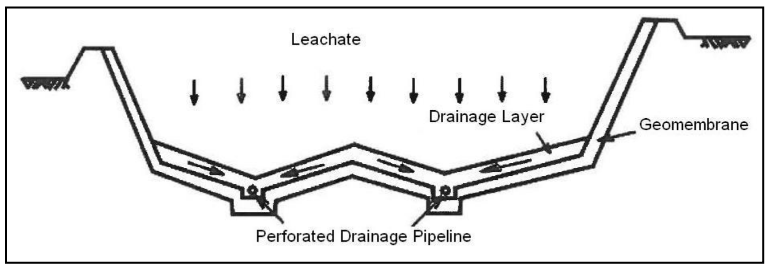

Figure 2-2. Side View of Leachate Drainage Slopes

In some developing countries, the leachate transportation conduits are sometimes combined with LFG vent wells. The leachate extraction system at many of these sites drains the leachate using gravity; however, low permeability of organic material makes gravity less effective for moving leachate. Leachate pumps can improve circulation at some sites. In the gravity systems, if the LFG vent wells are not emanating LFG because of positive pressure within the waste mass, then possible air intrusion into the waste mass can occur and result in semi-aerobic conditions. A semi-aerobic waste mass generates less LFG because activity of methanogenic bacteria is suppressed. If an active LFG extraction system is attached to vent wells that are also used for leachate management, then care should be taken to avoid air intrusion into the waste mass.

Once the leachate has been collected from the SWD site, there are several options to properly manage disposal. These options include on-site treatment (for example, aeration or reverse osmosis) and disposal to a wastewater treatment plant or discharge to surface water, transport to a wastewater treatment plant, evaporation (see Chapter 4), and recirculation (see below).

Leachate Recirculation. Some SWD sites choose to recirculate leachate as a management strategy. Leachate is re-circulated through the waste mass using surface or subsurface methods. The recirculation of leachate increases the moisture content of the waste mass, which increases the generation rate of LFG. However, leachate recirculation systems should be considered only at well-managed, stable SWD sites and must be managed diligently to avoid leachate breakouts and slope stability concerns.

World Bank's Handbook

The World Bank's Handbook for the Preparation of Landfill Gas to Energy Projects in Latin America and the Caribbean discusses the advantages and disadvantages of using leachate recirculation approaches and major considerations.

[5] Hickman, H. Jr. *Principles of Integrated Solid Waste Management*. American Academy of Environmental Engineers. 1999.

Grading and Re-grading SWD Site Slopes

SWD site slopes should be maintained to be no steeper than a 3:1 (3 horizontal to 1 vertical) grade. Steep side slopes can cause instability, leading to side slope failure, erosion and loss of the soil cover. Loss of the soil cover and the eventual side erosion can lead to breakouts of leachate and LFG, as well as air infiltration into the waste mass. The intrusion of air into the waste mass can lead to underground fires. If the SWD site has an LFG collection system, side slope air infiltration also can reach the system and dilute and lower the quality of the LFG. Figure 2-3 provides an example of slope recommendations for SWD sites.

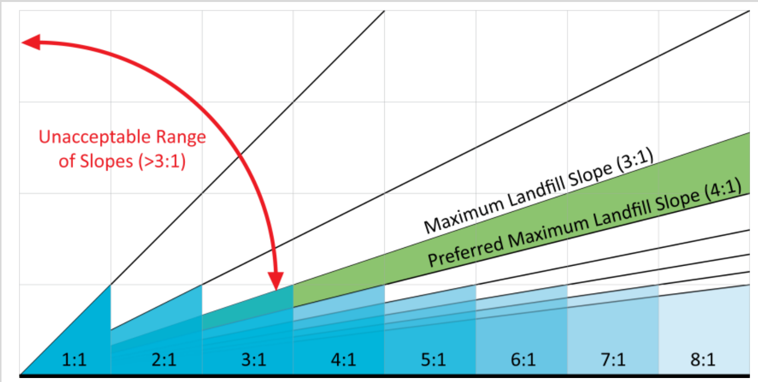

Figure 2-3. SWD Site Slope Recommendations

Side slopes should be designed to be considerably less steep, such as slopes with a grade of 5:1, in seismically active areas or in areas with poor soils.[6] A geotechnical evaluation, or slope stability analysis, will help establish the safest side slope grade. When slope angles are designed, final land use should be taken into consideration. For example, sites that may be restored to agriculture should use more shallow slope angles (10:1 to 15:1) to help with erosion control. Re-grading SWD sites with steep side slopes may be required to mitigate the problems outlined above.[7]

Final Capping Systems

The objectives of the final capping system are to: (1) minimize infiltration of precipitation into the waste mass, thus reducing leachate generation, (2) minimize air intrusion into the waste mass, (3) promote good surface water drainage, and (4) control LFG emissions. For efficient LFG collection, final covers minimize the creation of leachate and minimize fugitive emissions of LFG, allowing for improvement of LFG collection. However, in SWD sites that do not have impermeable bottom liners, a final cap will block the emissions of LFG to the atmosphere and promote its migration to the soils around and under the waste mass (methane migration). Methane migration is a safety concern and should be minimized. Installation of an active LFG collection and control system is an effective method for minimizing methane migration

Final capping systems can include different components such as a buffer layer at the waste interface, gas channels, infiltration prevention (composite liners), cover soils, erosion layer (topsoil) and vegetative cover.

For LFG collection, the most important factor of the final capping system is its permeability. Permeability affects LFG management and system performance. Low-permeability covers minimize LFG venting to the atmosphere, air intrusion, and moisture infiltration into the waste mass; they also can help improve the performance of extraction wells. The type of capping system will also need to be considered in designing an LFG collection system, as the final design of a capping system can alter LFG collection characteristics.

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[6] Ibid.

[7] Datta, M., and Vittal, P. 2010. *Stability of Cover Systems for Landfills and Old Waste Dumps*. Presented at the International Conference on Sustainability Solid Waste Management, Chennai, India, 5-7 September, 2010. http://www.swlf.ait.ac.th/IntlConf/Data/ICSSWM%20web/FullPaper/Session%20VI%20A/6_A3%20_Dr.Manoj%20Datta_.pdf.

For example, proper sealing of any penetrations into a synthetic cap should be conducted to maximize LFG collection and minimize oxygen infiltration.

Additionally, the final capping system must include stormwater controls to transport stormwater and prevent erosion of the final cover. One of the most common and essential types of stormwater controls are benches. Benches are terraces along the final side slopes of the SWD site to provide a means of breaking the downward movement of the stormwater and reduce its velocity. Benches included every 4 to 10 meters of vertical height support stormwater management and slope stability. The top of the SWD site also should be graded to promote stormwater runoff (dome shape). Finally, the recommended final side slopes of a SWD site should not be steeper than 3:1.

2.2 SWD Site Operations

Best practices for SWD site operations are discussed in this section.

Filling Operations/Fill Sequence Plan

The waste filling sequence in a SWD site has an impact on the generation and collection of LFG. The filling sequence affects the stormwater management, LFG collection and soil management systems. Implementing a fill sequence plan can promote efficient operation (especially during wet weather), aid in optimizing filling operations, planning access roads and drainage systems and establishing and implementing long-term SWD site objectives. Fill sequence plans should be based on projected waste disposal forecasts and allow for efficient installation of the LFG collection system as cells or lifts are completed.

Working Face Operations

Daily operations have an important influence on the potential collection of LFG. The area where the waste is being deposited, spread and compacted is known as the working face. It should be maintained to be narrow enough so the waste can be compacted and covered rapidly, minimizing water infiltration, blowing litter, rodents and odors. The working face also should be gently sloped through bulldozer and compactor operations to inhibit stormwater flow into the waste, thus minimizing leachate formation. Other considerations such as cover material, fire control and customer needs should be taken into account when the width of the working face is sized.

A lift is a series of adjoining working faces that are all the same height. Lift heights are normally maintained in the 2- to 5-meter range because these heights will not cause severe settlement and slope stability problems and also facilitate efficient waste compaction. Figure 2-4 provides an example of a solid waste lift. The final design elevation is reached as lifts are added, one lift upon another. SWD site depths of more than 10 meters are recommended for faster LFG generation because a deeper waste mass promotes anaerobic conditions. A deeper waste mass also allows for LFG collection via fewer wells (see Chapter 3).

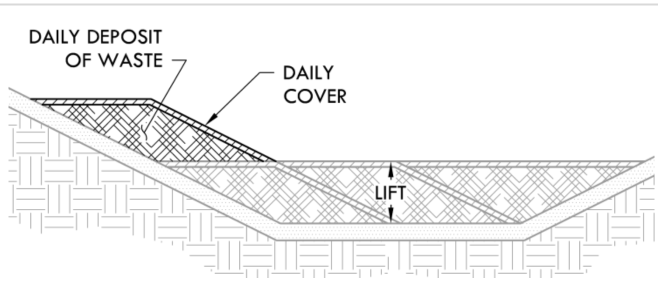

Figure 2-4. Example of a Solid Waste Lift

If LFG wells are installed at active SWD sites, care must be taken to protect the LFG collection pipes to avoid air intrusion and damage from heavy equipment. The ISWA Field Procedures Handbook for the Operation of Landfill Biogas Systems provides further details on operational considerations.

Waste Compaction

The density of the waste achieved by waste compaction has an effect on the potential LFG quantity that can be generated over time. Given that SWD sites are typically designed based on volume, increased waste density allows for more waste to be placed in a given volume. Therefore, the more waste mass disposed of in an SWD site, the more LFG that can be generated. Waste compaction also increases the anaerobic conditions necessary for LFG generation because it reduces the air pockets within the waste mass. The overall economics of an SWD site is improved through increased waste compaction in that more waste can be deposited in a fixed volume. Increased waste compaction also affords a SWD site owner other benefits such as limited permeability of the waste mass, minimized differential settlement as the waste biodegrades and reduced cover soil required relative to the amount of waste disposed of. In addition, increased waste compaction limits the spread of fires.

Daily/Intermediate Cover

Daily cover refers to the material applied to cover the working face at the end of the day. The main purposes of daily cover are to reduce stormwater infiltration, limit stormwater runoff, control odors and rodents, and help prevent fires. Daily cover is also an important management practice that aids in the production and more efficient collection of LFG. Application of daily cover seals the waste components off from the outside environment – a primary condition for facilitating the anaerobic decomposition of waste. The cover material also serves as a barrier to limit the amount of LFG that escapes to the atmosphere.

Several types of materials can be used as daily cover. In many cases, the materials will depend on what is available to the SWD site and the cost. The typical cover material is soil; however, there are other materials commonly used such as clay, sand and alternative daily covers (for example, tarps, foundry sand and contaminated soils). The use of other materials might depend on their availability and cost. The general recommendation is to spread the material as an even layer of 15 cm over the waste at the end of the working day and to remove as much as possible of the layer the next day. Removal of daily cover is important for prolonging the life of the site by limiting the amount of soil retained in the landfill volume.

The permeability of the daily cover material will affect LFG production. More permeable materials, like sand, will allow higher rates of moisture infiltration, leading to wetter waste and an increased rate of LFG production. The use of less-permeable materials, such as clay, will reduce moisture and air infiltration into the waste mass. However, if the less permeable cover is not removed the next day, it will create layered conditions inside the landfill that can allow leachate to accumulate and impede the movement of LFG toward the collection system. This condition may cause the leachate to submerge the extraction wells and may also lead to leachate seeping out of the side slope of the SWD site.

Intermediate covers are to be used in areas that will not receive waste for an extended period of time (such as 1 year), providing the same general functions as daily cover. Intermediate covers are typically less than 1 meter thick and are to be removed as much as possible once operations in the inactive area are restarted. Removing the intermediate cover will recover available airspace and reduce the number of suspended zones and ponding that could occur on top of each intermediate layer if a less-permeable cover material was used.

Leachate Management

An effective leachate management system is important for proper SWD site operations. If the leachate system does not function, leachate will build up in the waste mass, leading to slope instability and disruption of the operation of the LFG gas collection system. Proper precautions when the leachate management system is designed and the extraction system maintained, whether manual or automatic, are essential to avoid clogging the system. Blockage of the leachate system is caused by one (or more) of the following factors: sedimentation, biological growth and pipe breakage or deterioration. Another important consideration is to design the proper size for the leachate storage and treatment facility, as sizing ensures that additional and unforeseen amounts of leachate can be effectively accommodated.

Fires

Waste fires pose serious risks and some can be difficult to extinguish. While fires at well-operated SWD sites seldom happen, they frequently can be found at unmanaged or poorly managed dump sites. Prevention of fires is an extremely important task of SWD site operations, not only for the serious damage fires can cause to the infrastructure and slopes, but also to health, safety and the environment. Fires can affect the potential for LFG collection by either destroying the LFG collection system or by combusting the organic waste materials that would ultimately produce LFG.

The two types of fires at SWD sites include surface and sub-surface fires. Surface fires can be caused from loads that arrived to the site already smoldering, on fire, or contain materials that can easily ignite. Surface fires also can be started by the equipment operating on the SWD site or from smoking on the site. In open dumps, scavengers may start fires to find valuable materials to recycle such as metal. To avoid surface fires, the operator should observe all loads as they are being deposited on the working face, designate smoking areas away from SWD operations, and keep a fire extinguisher in all equipment.

Sub-surface fires can take place close to the surface or deep-seated within the waste mass. Sub-surface fires require a significant amount of resources to extinguish. Most sub-surface fires are the result of air infiltration into the waste mass; however, they are principally the result of the interaction of the three elements needed for any fire: fuel, oxygen and heat. Most waste materials in the waste mass are combustible and, along with LFG, represent the fuel supply. The heat can be created by microbial activity or spontaneous chemical reactions inside the waste mass. Oxygen can infiltrate when wastes are being deposited or can be directly drawn in through the surface.

Several methods of identifying sub-surface fires exist and range from changes in the physical aspect of the waste mass (appearance of smoke, subsidence, fissures and venting holes) to monitoring the internal temperature of the waste mass and carbon monoxide concentrations in the LFG. To avoid sub-surface fires, the recommendation is to limit all air and oxygen intrusion, monitor the site conditions regularly, and maintain all cover on closed portions of the site. If the SWD site has an LFG collection system, keeping the system balanced and monitoring well temperatures and gas composition are important. (See Chapter 3 for more information on balancing and maintaining the LFG collection and control system.)

Fire Prevention

As a general preventive measure to deal with any type of fire, the SWD site should implement a fire prevention and extinguishment program. ISWA describes a categorization of SWD site fires given levels of alert and offers recommendations on the first actions, methods of extinguishment and prevention of such fires.[8]

2.3 SWD Site Conditions and Their Effects on LFG Project Development

Many of the conditions of SWD sites in developing countries resemble poorly operated landfills or open dumps. These conditions, if not modified, will hinder the development of a successful LFG project. The minimum SWD site design and operation conditions necessary for optimal LFG collection were discussed

[8] ISWA. January 2010. *Landfill Operational Guidelines*. Second Edition.

earlier in this chapter. As many of these conditions are considered to be of the optimal design and construction of a sanitary landfill, the implementation or upgrade of SWD sites toward these conditions will have the collateral benefits that are provided by proper sanitary landfills, with the additional benefit that LFG can be feasibly collected and utilized. Table 2-2 shows a qualitative assessment of how conditions of many SWD sites in developing countries affect successful LFG project development. The conditions affect several aspects of LFG projects, including the amount of methane in the gas and the percentage of LFG that can be collected. The level of impact (no impact, increases and decreases) of each SWD site condition to each aspect is shown in Table 2-2.

Table 2-2. Conditions that Impact LFG Project Development

Component	As Found Condition	LFG Generation	Amount of Methane in LFG	Collection Efficiency
Bottom Liner	None or Inadequate	No Impact	No Impact	Decreases
	Adequate	No Impact	No Impact	Increases
Leachate Collection and Removal System	None or Inadequate	Decreases	Decreases	Decreases
	Adequate	Increases	Increases	Increases
Final Capping	None or Inadequate	Decreases	Decreases	Decreases
	Adequate	Increases	Increases	Increases
Planned Filling Operations	None or Inadequate	Decreases	Decreases	Decreases
	Adequate	Increases	Increases	Increases
Compaction	None or Inadequate	Decreases	Decreases	Decreases
	Adequate	Increases	Increases	Increases
Daily and or Intermediate Cover	None or Inadequate	Decreases	Decreases	Decreases
	Adequate	Increases	Increases	Increases
Slopes	None or Inadequate	Decreases	Decreases	Decreases
	Adequate	Increases	Increases	Increases
Fire Control	None or Inadequate	Decreases	Decreases	Decreases
	Adequate	Increases	Increases	Increases

Lastly, many of the impacts shown above can be accommodated during the LFG modeling process. These impacts and the modeling parameters that account for them will be discussed in Chapter 6, Landfill Gas Modeling.

Best Practices for SWD Site Design and Operation

Improving the conditions of an SWD site to the standard of a properly designed and operated sanitary landfill will likely improve the collection of LFG. It is important that stakeholders understand how the various components of an SWD site affect the generation of LFG, the methane content, and the collection efficiency of the LFG collection system, including how common flaws in design and overall operation can affect LFG generation. Implementing training opportunities can help to reduce these design and operational flaws. Well-designed and operated sanitary landfills will generate LFG that can be feasibly collected and used and provide cost savings over the life of the project.