At the Industry Hills Golf Courses, a chlorinated polyethylene liner was installed beneath a methane-affected green to prevent gas migration into the root zone.

What Can You Do If Your Golf Course Has Gas?

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IT IS NOT UNCOMMON for superintendents to get indigestion from the everyday rigors of the job. But for the purpose of this article, we are going to discuss a different type of gas — the gas produced by sanitary landfills. Most turf managers are highly trained to deal with above-ground turf stress caused by weather, pests, and traffic, but a small but growing number of superintendents are having to face new and different challenges: how to maintain golf courses built on landfill sites and deal with the effects of landfill gas and other problems.

Landfill Sites as Golf Courses

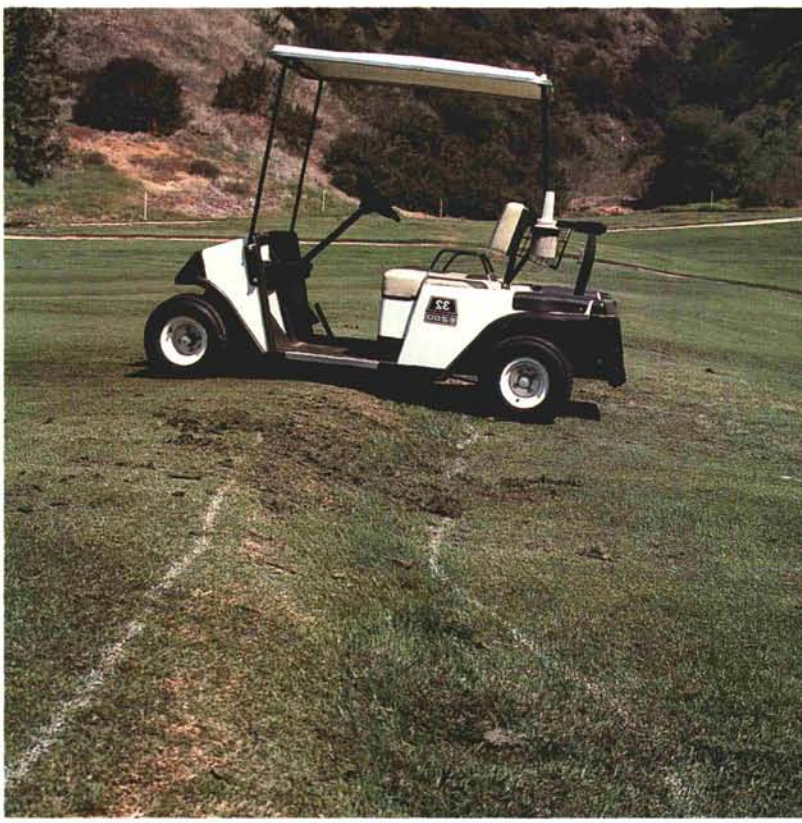
As the popularity of golf continues to grow throughout the world, there is an ever-increasing need to build more golf courses, especially public golf courses. As land resources are becoming more scarce, it is difficult to find prime land for course construction. Many cities, counties, and developers are looking at the feasibility of building golf courses on previous landfill sites. It is estimated that more than 60 golf courses in the United States have been built on landfill sites. Japan has been a leader in this area due to the popularity of golf and the limited availability of land resources in that country.

From an environmental and economic standpoint, landfills and golf courses are a good match. Golf courses are one of the few

legal land uses for landfill sites. Golf courses can recycle a previously unusable site and provide a greenbelt and recreational opportunities for the surrounding community. Furthermore, golf courses provide valuable habitat for birds and wild animals in urban settings. A landfill golf course can have a positive economic impact, too, by creating jobs and tax revenue for the community.

Landfill sites also produce large quantities of methane gas as a byproduct of solid waste decomposition. Considered a nuisance byproduct in the past, methane gas can be captured and used as a valuable energy source for heating, air conditioning, and other purposes. For example, Mountaingate Country Club in Los Angeles, California, processes 5 million cubic feet of methane gas per day. This gas is transported to nearby UCLA through a 5.5-mile pipeline and is used in the university's central steam boiler. It is estimated that energy costs at the UCLA campus have been lowered by $250,000 annually through the use of landfill gas. Another example in Southern California is the Industry Hills Conference Center and Sheraton Resort. Although only a portion of the 600-acre site is on a landfill, enough methane gas is produced to supplement the energy needs of the hotel and conference center as well as heat the two olympic-size swimming pools on the premises.

One of the benefits of a landfill site to the golf course owner or developer is the lower initial investment to purchase the land, although this saving often is offset by the higher cost of construction and the agronomic challenges associated with long-term maintenance. Developers wishing to purchase landfill sites also should be aware of future liabilities for containment of leachate (liquid waste produced by the landfill) or any remedial work necessary on the site.



(Above) Methane, a large component of landfill gas, can be captured and used as a valuable energy source. This processing plant at Mountaingate Country Club in Los Angeles processes methane for use at the nearby UCLA campus.

(Right) Soil settling occurs as the solid waste is decomposed within the landfill cavity. This is disruptive to golfers and causes severe problems with routine maintenance activities.

Agronomic Challenges

Building and maintaining a golf course on a landfill site is no easy task. If the golf course is to provide quality playing conditions on a long-term basis, several construction and maintenance considerations must be addressed.

Landfill Gas — Various gases are produced when solid waste is decomposed by anaerobic bacteria. Landfill gas is comprised of approximately 50% methane (CH_4), 50% carbon dioxide (CO_2), and trace amounts of hydrogen (H_2) and nitrogen (N_2). Gas production can fluctuate throughout the year depending on the composition of the solid waste and the amount of moisture in the landfill cavity. Soil temperature has little to do with gas production, but soil temperature does affect methane oxidation at the soil surface. These gases must be collected or vented to prevent the buildup of pressure below ground. If the gases are not adequately diverted, problems with plant growth can occur. The methane and carbon dioxide migrate to the surface and displace oxygen in the root zone. This leads to anaerobic soil conditions. Symptoms on turfgrass, trees, and shrubs include slow growth, stunting, limited root development, discoloration, defoliation, and, in severe cases, necrosis.

Ground Shifting and Settling — Landfills are capped with several feet of soil to cover and encapsulate the solid waste. As the solid waste decomposes, the soil cap tends to settle, causing cracks, shear lines, and contour changes. The uneven surface can damage equipment, disrupt mowing operations, and detract from the playability of the

Growing healthy trees and shrubs can be a challenge on a landfill site due to the effects of landfill gas and poor-quality soil often used to cover the waste.

golf course. This can be a problem in any area of the golf course, but it is most disruptive on putting greens. Engineers have developed methods to predict settling based on the composition of the solid waste, air space, and the fill method. Generally, the fill area can be expected to settle approximately 10% over time. Unfortunately, the degree and rate of settling cannot be accurately predicted in a specific area such as a green site.

Drainage — As surface contours change, drainage pathways are disrupted. Broken or crushed drain lines restrict the rapid removal of excess water, creating wet conditions or areas of standing water. This is particularly troublesome on putting greens. Due to state and local regulations, many courses are required to capture all drainage water and reuse it on their site. It is unacceptable to simply dig a dry well to collect drainage water, since this could possibly filter into the solid waste and produce harmful leachate.

Irrigation — Frequent breaks in irrigation mainlines, laterals, and wiring are other challenges associated with soil settling. This can have a devastating impact on turf quality, causing drought stress and turf loss in the affected areas.

Soil Quality — Unfortunately, the soil used to cap the landfill is not always well suited for plant growth. Generally, soil is removed from nearby areas or hillsides to cover the solid waste. Engineers prefer a heavy clay soil as a cap material. Needless to say, this type of soil poses several agronomic challenges for golf course superintendents due to poor drainage characteristics and potential compaction problems.

Fire — Methane gas can be explosive under certain conditions. This presents a potential safety risk for golfers and the golf course maintenance staff. Methane wells and recovery systems, if properly placed and installed, do a good job of capturing methane before it reaches the soil surface. Fires and explosions have been reported at some golf courses during the early stages of site development and construction.

Considerations for Construction and Renovation

The best way to minimize future problems is to employ proper construction techniques from the beginning. Sound agronomic decisions and construction methods are not always the most economical in the short term, but they can minimize disruption and costly repairs in the future.

The first item to consider is the installation of a methane recovery system. Such systems often are mandated and usually are in place before golf course construction begins. An important consideration is to make sure all areas of the golf course that will be located directly over solid waste will be serviced by the recovery system. Even if methane gas is not actively produced at the time of construction, some courses have installed vertical recovery wells in the area that can be connected to the system at a later date.

The depth of the soil cap covering the solid waste is another factor to consider. Although the architect and superintendent have little to do with recommending the actual landfill method, the depth of the soil cap can play a role in selecting suitable green sites. Personal observations and reports from golf course superintendents indicate that fewer problems are associated with sites that have a shallow, well-compacted layer of solid waste covered by a deep soil cap (approximately 35 to 40 feet). If the soil cap is inadequate in depth, problems can be anticipated when digging trenches for the irrigation system or doing other excavation work on the golf course.

To improve the chances for good plant growth, it would be ideal to cover the existing cap with 8 to 12 inches of good quality fill dirt or topsoil. Unfortunately, the cost is often prohibitive. Architect Robert Muir Graves faced this problem during the design and construction of the Santa Clara Golf and Tennis Club in Santa Clara, California. Given the different types and depths of soil cover, he believed the only way to avoid future problems was to cover the entire site with 5 to 7 feet of soil. This would add millions of dollars to the construction cost. As an alternative, it was decided to strip and stockpile the existing soil, grade the refuse to the desired contours, and then cap the golf course with the stockpiled soil. Graves was then informed that recycled wastewater would be used to irrigate the golf course. In an effort to improve the internal drainage characteristics of the soil, a good quality sand was located from a nearby dredging operation in San Francisco Bay. Due to the high price of topsoil in the area, it was more economical to plate the entire golf course with a 12-inch layer of sand. Covering the entire course with good quality sand or soil may not always be feasible, but it does improve the quality of the turfgrass and trees.

To reduce the frequency of irrigation breaks, some landfill golf courses use high-density polyethylene pipe (HDPE), especially in high-settlement areas. There are several advantages to using this product, including better flexibility, high temperature tolerance, resistance to water hammer, and flow characteristics similar to that of standard PVC pipe. There also are fewer leaks with this type of pipe since all joints are heat fused. David Bermudez, superintendent at Mountaingate Country Club, installed HDPE mainlines on two golf holes and estimated that it has

reduced repair costs by 80%. Due to the high cost of the pipe, HDPE normally is used only for mainlines.

The location and construction of putting greens is a primary concern. If at all possible, it is desirable to locate greens on solid ground. Since this is not always feasible, other construction techniques can be employed to prevent gas migration into the putting green soil profile. At the Industry Hills golf courses, one methane-affected green was rebuilt in 1989 using a 30 mil chlorinated polyethylene (CPE) liner placed beneath the green. The liner was protected above and below with geotextile fabric, and then a 6-inch soil cap was placed on top of the liner. The soil cap was shaped to the desired contours, and construction proceeded according to USGA Putting Green Construction Recommendations. An additional methane well also was installed to capture gas in the area. Kent Davidson, CGCS, Director of Golf Course Maintenance at Industry Hills, reports that the project was a complete success and no problems have been experienced since the liner was installed.

Growing healthy trees and shrubs can be difficult on a landfill site. Successful tree establishment depends mainly on the depth of the soil cap and proper tree selection. Trees planted in an area with a deep soil cap tend to have a better chance for survival. In areas with a shallow soil cap, tree mounds can be created by adding soil to the intended planting site to enhance the rooting area. Tree selection should be based on hardiness and tolerance to oxygen-poor conditions. It is reported that pines (*Pinus sp.*) and alders (*Alnus sp.*) tolerate such conditions, as do eucalyptus (*Eucalyptus sp.*), sycamore (*Platanus sp.*), and pepper trees (*Schinus sp.*). Most turfgrass species will survive on landfill sites due to the relatively shallow rooting characteristics of turfgrass plants. Currently, no turf species are considered tolerant of landfill gas.

A final consideration is compliance with laws and regulations. Legislation concerning the control and disposal of landfill gas already has been imposed by the federal government and many states. Environmental concerns about landfill gas contributing to the *greenhouse effect* have prompted much of this legislation. In California, several state and local agencies are involved in monitoring landfill sites, including the Department of Health, local Air Quality Management Districts, the California Integrated Waste Management Board, and others. In most states, the Solid Waste Division or state EPA has jurisdiction over landfill sites. Testing and routine monitoring are often required to comply with regulations and should be considered a regular part of the maintenance budget.

Maintenance Considerations

After a golf course has been built on landfill, one might say "the fun is just beginning." Problems caused by soil shifting and settling will require frequent repairs that must be planned for in the annual maintenance budget.

The budget should be expanded to account for added irrigation repairs and maintenance. Installation of HDPE pipe can help to reduce repairs on mainlines; however, lateral line repair and sprinkler head leveling will be necessary on a recurring basis. As an example, David Bermudez at Mountaingate Country Club budgets $3,000 per month for irrigation repairs at the 27-hole facility. Mountaingate also employs three full-time irrigation technicians to handle the work load.

Soil settling can be expected for several years. This can severely affect cart paths, bridges, roads, and drainage systems. Some repairs will be minor; however, recurring expenses for renovation of settlement areas and associated golf course features should be forecast in the budget.

Putting green management on landfill golf courses can be a challenge. For greens affected by methane gas, there is little that can be done except to rebuild. Mike Huck, former superintendent at Industry Hills, tried several methods to cope with the negative effects of methane gas on the 15th green of the Eisenhower Course. During the mid-1980s, Mike implemented programs that included mole plowing, deep drilling, frequent core aeration, and supplemental fertilizer applications. These programs only provided temporary relief from the anaerobic conditions until the green was rebuilt in 1989.

Soil settling and unexpected contour changes also affect greens. Sometimes, the contour changes are hardly noticeable and do not affect daily maintenance operations. Some innovative techniques have been tried to prevent settling of putting greens. For example, one course tried building greens on top of a concrete saucer in the hope that, if settling did occur, the entire green would settle evenly. Unfortunately, many of the concrete saucers broke or the greens tilted in a direction unsuitable to the direction of play. The most practical advice available is to scout nearby areas where minimal settling occurs and try to relocate the green in that area. According to Tom Shuput, Director of Project Development for SCS Field Services, areas with a deep soil cover also would be good locations for putting greens.

Due to the poor quality soil often found on the fairways, be prepared to schedule additional slicing or core aeration to relieve compaction and improve air and water penetration. Installation of a continuous cart path system and restricting carts to the paths also helps minimize compaction and maintain quality turf. Fairway topdressing can be another tool to improve conditions on fairways afflicted with impermeable, poor quality soils.

Conclusion

Many golf courses have been constructed on landfill sites. It is likely this trend will continue as available land for golf course construction diminishes. The key to success is understanding the effects of landfill gas and carefully coordinating the design and construction of the golf course with the installation and operation of a gas collection system. After a golf course has been constructed on a landfill site, there is little that can be done to prevent the damage and disruption caused by settling. In these situations, extra expenditures for repair and maintenance of the golf course should be anticipated for several years. Additional research is necessary to determine the cultural practices that can minimize the effect of landfill gas on plant materials.

Overall, golf courses built on landfill sites make a positive contribution to the environment, the economy, and the community. Despite the challenges, good quality playing conditions can be achieved — even if your golf course has gas.

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