The ultimate purpose of a landfill cover is to protect human health and the environment from waste materials. Typical cover designs minimise the infiltration of rainfall and melting snow into waste and protect ground water by minimising leachate production. But advances that have been made in understanding both phytocover technology and the biodegradation processes that occur within landfills warrant another look at how landfill covers are designed.

Traditionally, landfill covers have been made from natural clay, geocomposites or geosynthetic membranes. Federal regulatory closure requirements, however, are general and sometimes lead to barriers that do not suit the landfills they cover. Occasionally, the traditional solutions are unnecessarily costly, are inappropriate for certain regions of the country and do more harm than good to the environment.

Phytocovers, on the other hand, are engineered agronomic systems that harness the natural evapotranspiration process of plants to control the percolation of contaminants to groundwater. A phytocover relies on shallow and deep-rooted plants to create a root zone from which the plant can extract moisture. The phytocover subgroup of the Remediation Technology Development Forum (RTDF), part of the US Environmental Protection Agency (EPA), has established the following definition for a phytocover: 'A long-term, self-sustaining cover of plants and trees growing in and/or over materials that pose environmental risk; a phytocover reduces that risk to an acceptable level and requires minimal maintenance.'

Versatile and low-cost.
Phytocovers constitute one aspect of the larger field of phytoremediation: the use of plants to remediate contamination. The application of grasses, shrubs, trees and crops for waste treatment is not a new concept, dating back at least to the early 1970s. The research, development and use of vegetation for water uptake and remediation of contaminants increased dramatically in the 1980s and 1990s. This technology is attractive because it is a versatile, low-cost alternative that simultaneously provides remediation and site restoration. According to EPA data, phytoremediation has been studied and implemented on at least 100 sites around the world.

Phytocovers create a sponge-and-pump water-extraction system. The water-holding capacity of the soil and the waste penetrated by the root system provides the sponge that stores infiltration during the dormant season. The evapotranspiration capacity of the engineered vegetative cover provides the solar pump that reduces soil moisture, primarily during the growing season. Properly designed, this sponge-and-pump water removal system can limit the amount of water percolating below the root zone and can protect groundwater as efficiently as a traditional barrier cap. Thus, phytocover serves as a functional alternative to natural clay, geocomposite or geosynthetic membrane caps and offers several advantages over those technologies.

Various criteria should be considered in designing a phytocover system that meets the primary landfill remedial objective of protecting human health and the environment:
Hydrologic water balance calculations should be used to estimate the precipitation with the outflow of the phytocover system.

The correct types of soil, soil amendments, plants and trees must be used in the phytocover system.

The characteristics of the slopes, including configuration, stability, drainage and runoff, must be taken into consideration.

Gas emissions from the landfill must be monitored and managed.

Two key design elements in engineering a phytocover system are determining the thickness and material composition of the cover system to provide sufficient water-storage capacity during the dormant season and incorporating a supportive phytocover system to access water stored in the soil and waste for evapotranspiration to the atmosphere.

A water-mass balance analysis is the fundamental way to calculate the water-storage capacity necessary to avoid leachate generation. This analysis is a mathematical technique that tracks moisture inputs to storage and moisture outputs that influence the flow of water into the waste. The primary elements of a water-mass balance include precipitation, surface runoff, potential evapotranspiration, infiltration, soil moisture storage, actual evapotranspiration and potential water flow through the cover system.

The balancing processes within a landfill are typically evaluated using the Hydrologic Evaluation of Landfill Performance (HELP) model, developed by the Waterways Experiment Station (WES) in Mississippi, USA. The applicability of the HELP model to the design and evaluation of an engineered phytocover system has been reviewed by researchers at the RDTE, who determined that the model cannot perform the entire analysis by itself. WES engineers developed the HELP model based on the traditional use of low-permeability soils and short-rooted grasses for landfill caps. There is no opportunity for users to input the higher evapotranspiration values typical of plant species with deeper roots. Therefore, the HELP model should be used in conjunction with other water balance models to account for the higher evapotranspiration levels that are the key elements of phytocover systems.

Phytocovers provide a number of significant pollution-control, ecological and economic benefits in comparison with traditional barrier caps. A phytocover has the potential to enhance biodegradation of waste materials in the root zone. In natural ecosystems, engineers usually find high concentrations of indigenous microorganisms feeding on sugars, amino acids, carbohydrates and vitamins emitted by plant roots. These compounds sustain the microbial population that can degrade many organic compounds directly and enhance and accelerate the co-metabolic degradation of other materials that are resistant to direct degradation.

Organic acids from the roots also help immobilise metals in the root zone. By contrast, a barrier cap requires no stimulation to natural biodegradation and can alter biogeochemical conditions in the waste. If this happens, methane, carbon dioxide and ammonia can become trapped and affect pH levels and the reduction/oxidation potential, thereby inhibiting natural degradation processes.

Barrier caps are essentially impermeable and often require elaborate gas-venting systems to prevent the build-up of pressure and the lateral migration of gas. Phytocovers are porous and permeable to gases and allow passive venting. Equally important, a phytocover will allow atmospheric oxygen to diffuse into the waste and support additional aerobic biodegradation.

Both phytocovers and barrier caps are designed to be vegetated on the surface, but phytocover growths function more naturally. Barrier caps are covered with grass; deep-rooted plants are not allowed to colonise the site. Moreover, barrier protection requires that small burrowing mammals be kept away because of the breaches they could create. In contrast, the vegetation of a phytocover may provide nest sites for birds and other arboreal species and readily accept infilling by shrubs and native tree species deemed appropriate under site management criteria. Because no animal is likely to excavate below the deep root zone, it is unnecessary to prevent native species from inhabiting the phytocover. Besides their natural appeal, the trees of a phytocover serve the community as a noise and dust pollution buffer.

Although relatively intensive monitoring for diseases and pests is needed during the initial growing season, maintenance activities can eventually be curtailed because the phytocover is self-sustaining. Phytocovers also resist wind and water erosion. Unlike a barrier cap, which can suffer cracks, rifts and tears from differential settling or physical intrusion, the phytocover maintains its integrity and heals itself with new root growth when disturbed.

The expected capital cost per acre for installing a phytocover is 40 to 60 per cent less than for a traditional barrier cap. Costs associated with phytocover construction depend on the volume of material needed for the sponge portion of the cover. In many areas the volume of material necessary is less than for a barrier cap. In addition, there are fewer layers of material to place, which reduces cover construction time and installation costs. The grading requirements for the vegetation of a phytocover are flexible, in contrast to the strict barrier cap requirements.

After vegetation is established on a phytocover, the maintenance is normally limited. Barrier caps require regular, costly repairs because of breaches caused by settlement, cracking and burrowing animals. Phytocovers allow for natural biodegradation in the subsurface and natural succession at the surface of the landfill.

Not only does a phytocover entail less monetary cost, it also affords greater safety. EPA studies have shown that implementing any type of remediation poses risks to site workers, neighbours and the public. These risks are typically greater than those the public faces from exposure to site contaminants. Since phytocovers require less site work and fewer truckloads of material, constructing a phytocover would involve less risk.

Widespread acceptance of the concept that all landfills function as 'bioreactors' in a dynamic manner mandates a different approach to their long-term management. All aspects of the way in which landfills are handled, including interim and final covers, are being studied to find ways to reduce landfill life spans and overall costs and lessen the harm to the environment. The use of phytocover technology as an alternative to landfill covers is an outgrowth of this.

As is true of any technology, the application of phytocovers is not appropriate in all cases and should be evaluated on a site-by-site basis using the tools described above. But phytocovers have been implemented throughout the world as low-cost, environmentally friendly alternatives to traditional barrier caps.

While phytocover technology is being developed with the participation and oversight of the EPA, many in the regulatory community are not willing to accept this technology without extensive, long-term efforts to gather data. This acquisition of data can only be accomplished when the risks are defined and the concept is accepted.

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