AN INNOVATIVE APPROACH TO WASTE SITE MANAGEMENT, TREATMENT, AND REHABILITATION

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ABSTRACT

The innovative use of poplar trees at landfills and other waste sites to improve final closure cover caps and to treat and monitor leachate and stormwater runoff offers significant cost and management advantages with the potential for restoration and the commencement of ecological blending with surrounding landscapes. This paper describes the basic concepts for using poplar tree technologies and compares the poplar tree systems with the more common and ecologically sterile conventional approaches, such as the synthetic membrane cover cap and land application of leachate on grass crops. The paper also discusses where the poplar tree systems are feasible, the main elements of their implementation, and the potential cost savings that can be realized, together with the prime elements of their use as "conditioners" in longer term restoration endeavours. Current industrial and municipal applications and examples of the technology from Ontario and North America are described.

Introduction

Poplar tree systems are currently operated at landfills as final closure cover caps and to manage leachate and stormwater runoff. The Oregon Department of Environmental Quality (DEQ), the Virginia DEQ, and the Iowa Department of Natural Resources have approved these systems. The Virginia DEQ has commissioned studies to establish regulations for this promising new technology. Poplar tree systems are attracting interest among landfill operators because they are manageable, effective, environmentally friendly, and economical.

The essential components of the systems are, of course, the hybrid poplar trees themselves – one of the fastest growing trees in North America. Planted at high densities, they produce more biomass per year than any other perennial. Consequently, they consume more water and nutrients than any other kind of crop. They root deeply and tolerate poor soil and water quality conditions; therefore, they are able to flourish in adverse environments, such as might be encountered at landfill sites.

Since 1989, CH2M HILL has been a pioneer in the research, permitting, design, installation, management, and monitoring of poplar tree systems. The two types of systems described in this paper are a poplar tree landfill cover cap and a poplar tree buffer treatment system suitable for leachate or stormwater management.

Cover Caps

The poplar tree cap consists of a dense stand of poplar trees, a ground cover of grass or clover, and an associated soil system – all of which together can collect, store, and consume natural precipitation at the site. The principal concepts and design factors are illustrated in Figure 1. The critical water balance analysis that is performed as part of each design is represented by the formula: Accumulation = Input – Output ± Reactions. The standard inputs, outputs, and reactions are also shown in the figure.

At present, most landfill operators construct final closure caps out of conventional, low-permeability synthetic membranes with a thin topping layer of soil and vegetation. The cap is designed to minimize water infiltration into the refuse, prevent erosion, and protect human health and the environment. A poplar tree system can do these things cheaper with additional benefits.

Unlike synthetic membranes that deflect precipitation from the site, the poplar tree system intercepts and uses water for plant growth. Water is stored in the soil pores of the thick soil cap and removed by the tree roots. During the growing season, all precipitation evaporates or transpires from the site, dehydrating the soil. During the dormant period, soil pores in the tree root zones are recharged by storing precipitation.

The trees and grass are planted on the landfill contour for erosion control. During the first year, surface-applied compost mulch or shredded yard debris also stabilize the soil. With maturity, the trees' thick root systems hold the soil together and the canopy of leaves shields the ground from raindrop impacts and consequent erosion. When the leaves fall in the autumn, they contribute to the mulch at the site and the overall water-holding capacity of the system. A rougher ground surface develops and water flows more slowly down the slopes. With time, the cap becomes a mature forest with little wind or water erosion.

Most landfill sites are in rural or semi-rural areas. Trees planted on the landfill site help it blend more readily with the surrounding landscape. Tall trees screen daily landfill operations, such as bulldozing refuse, from adjacent landowners. They also reduce noise and odour pollution from such activities.

Because of the thick soil layer required for development of an adequate root zone, animals and insects that carry disease or pose a nuisance are physically separated from direct contact with the waste in the landfill. With the poplar tree system, water and air infiltration to the refuse is minimized but not precluded, so it is possible for the waste to continue to decompose and stabilize over the years, rather than being sealed off and preserved, as is the case with synthetic-membrane caps. Furthermore, the poplar tree cap's dense plant root system grows into a cover with the flexibility to withstand differential settling, freeze and thaw cycles, drought, and pressure from landfill gases.

Leachate and Stormwater Management Systems

The basic concepts of the poplar tree buffer are similar to that of the cap, except the system is adjusted to accommodate the treatment of leachate or stormwater runoff. Not only do poplar trees drink it up at an uncouth rate, they can also tolerate a wide range of water quality. In the various applications where they have been employed so far, poplar trees have been able to assimilate nutrients from the leachate or stormwater without impairing their vigorous reach for the sky.

A poplar tree management system usually operates in conjunction with an existing leachate collection and storage system or an existing stormwater system. The goal is to provide a cost-effective natural treatment without adversely affecting the environment. The system design must include the selection of fast-growing poplar varieties with a taste for the "local brew" – varieties that are shown by trials to grow well in the given soils and climate with the least expensive type of irrigation system and to remain healthy as they uptake the special mix of constituents the locale has to offer.

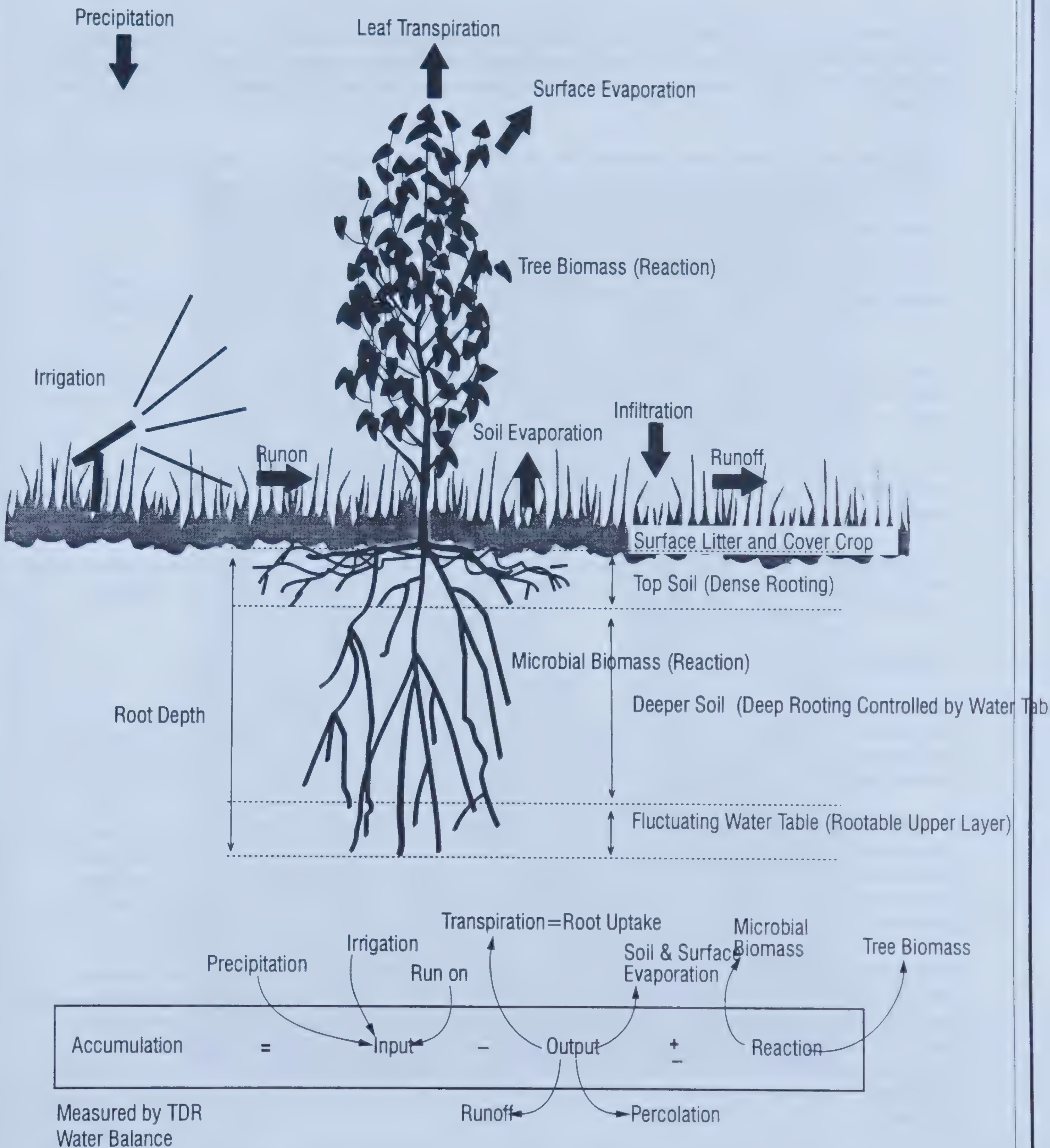

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Figure 1
Principal Water Balance Components

The system is designed for timely irrigation during the summer months to maximize evapotranspiration. An ongoing poplar tree maintenance program is established to maximize tree health. Monitoring is performed to assess and document the changes in the leachate, soil pore water, soil, crop, groundwater, and soil moisture content.

Poplar trees have a greater uptake rate and a longer uptake season than grass, as illustrated in Figure 2. Being densely planted, poplar trees require less land areas than grass.

Where Poplar Trees Will Work

The climatic zone for hybrid poplars corresponds with that of cottonwoods. A wide range of soils can be suitable with appropriate soil amendments and site management. Some leachates with toxic pollutants – herbicides, for example – may require dilution or special site management, such as blending with stormwater.

In arid climates with less than 20 inches of annual rainfall, poplar trees must be irrigated to survive. In wet climates with greater than 60 inches of annual rainfall, irrigation may not be beneficial to the trees, but, in most cases, land application permits can be obtained.

In Hawaii, southern California, and Florida, poplars do not perform well because they require a cold dormant period. Eucalyptus trees are a better choice for these areas. In extreme northern climates, willows may be more suitable.

Obviously, poplar tree systems are not a cure-all for all kinds of landfills everywhere. Each application must be analyzed for feasibility on the basis of site-specific information. The system must be properly designed, constructed, and operated.

Implementation

Implementation of a poplar tree treatment system or cap begins with a site evaluation regarding climate, soils, available cover materials, water balance, the constituents of any leachate and stormwater that will be applied, and the structural and surface characteristics of the landfill. If the project appears to be feasible and desirable, steps are taken to secure regulatory acceptance at the conceptual level and throughout the course of the project.

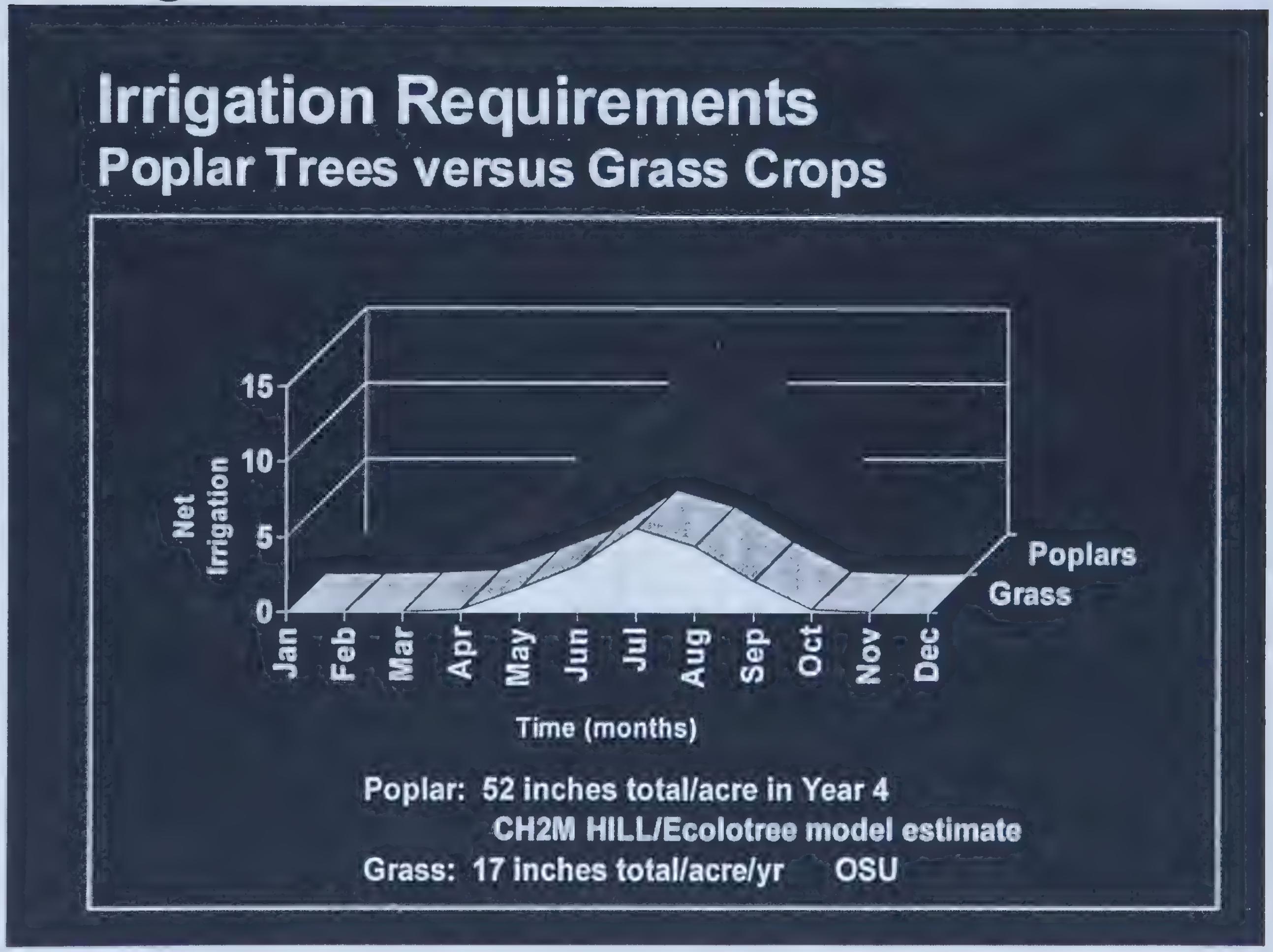
Plans are then prepared for planting of the poplar trees and ground cover plants, amending the soil, tree stress management, and tree harvesting. Any irrigation and control system needed is designed. Based on the site conditions and operational and regulatory requirements, a monitoring plan is devised and the consequent monitoring system is designed. The landfill site closure plan is modified to incorporate the poplar tree system approach.

Implementation entails preparing the site with soils and soil amendments, installing the irrigation system, purchasing and planting the trees and grass, installing the monitoring system, and training onsite staff to operate, maintain, and monitor the system. At the end of the first year, a site assessment is performed and an annual report is prepared regarding soils, tree survival and growth, water balance, irrigation system efficiency, environmental protection, and recommendations for system improvements. Depending on the situation, it may be advisable to proceed in phases – prototype, demonstration, and full-scale – to identify the optimal system for the site.

Cost Savings

In comparison with synthetic membrane cover caps, poplar tree systems offer potential cost savings of 20 to 40 percent for the following reasons:

Figure 2



Irrigation Requirements
Poplar Trees versus Grass Crops
Net Irrigation
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time (months)
Poplars
Grass
Poplar: 52 inches total/acre in Year 4
CH2M HILL/Ecolotree model estimate
Grass: 17 inches total/acre/yr OSU

- Specially skilled contractors are needed to install membrane caps. The pieces must be welded together over a large area and carefully laid to avoid rips. The soil cover must also be installed with precision to avoid disturbing the membrane. The undertaking is labour intensive. In contrast, the soil base for poplar tree caps can be installed by landfill staff using existing equipment. Specialty care is required, however, to install any irrigation system and to plant the trees.

- A tree cap can incorporate more refuse material, thereby conserving landfill air space. Material such as yard debris, sludges, and petroleum-contaminated soils that are usually landfilled can be applied to the cap of closed areas.

- Because a tree cap absorbs precipitation, rather than deflecting it like a raincoat as a synthetic membrane does, it generates less stormwater runoff. Consequently, the stormwater collection channels, detention pond, and treatment system can all be reduced in scale and their costs can be reduced by 20 to 50 percent. In addition, stormwater runoff can be collected and used to irrigate the poplar tree cap, greatly reducing or eliminating the amount of stormwater that goes offsite.

- Long-term monitoring obligations are less for poplar tree caps because differential settlement is not a concern. With synthetic membranes, differential settlement can destroy the integrity of the seal and require repairs.

- A tree cap can be compatible with the same gas collection system that would be installed for a membrane. Maintenance of the gas system is similar for both types of caps. If a gas collection system is not desired, the tree cap can be designed to breathe and vent gas naturally.

Table 1 compares the costs of conventional systems with poplar tree systems. For leachate management applications, the cost of installing the poplar tree systems is equal to or less than that for conventional crops. Poplars require a smaller land area, which can reduce operating costs. Further reductions in maintenance and site management costs are possible.

	Typical Conventional Systems		**Tree Systems**	
Landfill Application	**Construction Costs**	**Annual Operations and Maintenance Costs**	**Construction Costs**	**Annual Operations and Maintenance Costs**
Cover Cap	\$250,000/ha	\$250/ha	\$75,000/ha	\$300/ha
Leachate Treatment	\$1.30/m^3	\$2.60/m^3	\$2.60/m^3	\$1.30/m^3

Table 1
Cost Comparison of Tree Systems with Conventional Engineered Systems (U.S. \$)

Compared with pumping or trucking leachate to publicly owned treatment works (POTWs), poplar tree leachate management systems offer cost savings from 30 to 80 percent. Compared with leachate recycle injection systems, the costs are about the same. The poplar tree system, however, provides the added benefit of trees, which can be harvested or used as wildlife habitat, and it reduces leachate concentrations at the site more rapidly than leachate recycle injection systems.

Harvesting can occur every 6 to 10 years and be used to offset some of the costs of the system. Poplar, a "white wood," is one of the leading hardwoods used in the pulp and paper industry. It is also used as fuel and to make matches, toothpicks, and chipboard. If harvesting is desired, the wood products industry is typically considered in the design of the site to help ensure a consistent product and ease in harvesting.

Conclusions

In conclusion, the use of poplar trees at landfills to improve final closure cover caps and to treat and monitor leachate and stormwater runoff offers significant advantages. These systems are perfect for cover caps and landfill sites because they provide long-term landscaping and beautification, with proven economical treatment capability. Further work in the implementation, evaluation, and refinement of these systems would be beneficial.

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