Alternative Wastewater Treatment: On-Site Biotreatment Wetlands at the Fernald Preserve Visitors Center - 9434

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ABSTRACT

This paper describes the design and operation of a constructed on-site biotreatment wetland at the Fernald Preserve Visitors Center. The use of constructed wetlands for treatment of domestic wastewater at the Fernald Preserve contributed to the award of Leadership in Energy and Environmental Design platinum certification from the U.S. Green Building Council.

INTRODUCTION

The Fernald Preserve is situated on a 425-hectare (1,050-acre) tract of land, approximately 29 kilometers (18 miles) northwest of Cincinnati, Ohio. The site is located near the unincorporated communities of Ross, Fernald, Shandon, and New Haven in Hamilton County. It is a former uranium-processing facility that was shut down in 1991. Since then, the site has undergone extensive remediation pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act. Remedial activities and subsequent ecological restoration have converted the site from an industrial production facility to an undeveloped park, encompassing wetlands, prairies, and forest. When the large-scale soil, remediation, and waste disposition was completed in the fall of 2006, the site was successfully transitioned to the U.S. Department of Energy (DOE) Office of Legacy Management. The Fernald Closure Project was then renamed the Fernald Preserve.

In response to stakeholder input, the site is open to the public as an undeveloped park, for walking and wildlife viewing. The Fernald Preserve Visitors Center has been established as a means of educating the public on the history, production, remediation, and ecology of the Fernald Preserve. The Visitors Center building was converted from an existing site warehouse, with the goal of achieving Leadership in Energy and Environmental Design (LEED) gold certification from the U.S. Green Building Council (USGBC). The USGBC developed the LEED rating system to provide a mechanism to design, build, and operate high-performance buildings.

LEED CERTIFICATION

DOE is committed to principles of sustainable building design, construction, and operation. Executive Order 13423, DOE Orders 450.1A and 430.2B, and the *Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding* require that energy conservation and sustainable designs are factored into building activities. LEED certification by the USGBC is a way to evaluate sustainable design principles and document that they are met. The Fernald Preserve Visitors Center was originally designed with the goal of achieving LEED gold certification. Subsequent opportunities in both the design and construction processes resulted in DOE exceeding this goal. In September 2008, the USGBC awarded the Fernald Preserve Visitors Center platinum certification, the highest possible rating, making the Visitors Center one of only 100 buildings nationwide to achieve platinum certification. A detailed explanation of the Visitors Center sustainable building design and LEED certification process is provided in J. Powell et al. [1].

As part of the LEED certification, the Visitors Center achieved Water Efficiency credits pertaining to alternative wastewater treatment. Option 2 of Water Efficiency Credit 2, Innovative Wastewater Technologies, awards 1 point toward LEED certification if 50 percent of all wastewater generated at the building is treated on site to tertiary standards. An additional point was awarded as an Innovation and Design Credit 1.2 for exemplary performance of Water Efficiency Credit 2, 100 percent wastewater treatment.

BIOTREATMENT WETLANDS

Biotreatment wetlands for wastewater treatment are becoming increasingly common in the United States and throughout the world as a cost-effective, aesthetically pleasing technology that can replace traditional treatment wastewater treatment.

Wetlands have been specifically utilized for water quality treatment in the United States since the 1970s. Hundreds of biotreatment wetland systems are currently treating municipal, industrial, and agricultural wastewater in North America [2]. Municipalities, individual homeowners, and small commercial ventures are currently utilizing biotreatment wetlands for wastewater treatment. Industries, including petroleum, pulp and paper, power, and mining, are employing biotreatment wetlands to treat process effluents. Biotreatment wetlands are also being used to treat landfill leachate from both municipal- and industrial-waste (or hazardous-waste) landfills. Biotreatment wetlands have succeeded in improving water quality in arid environments, as well as in environments that endure harsh winters [3].

Water treatment in wetlands is primarily biological and occurs in the root zone of the wetland species. Plant roots provide a substrate for microorganisms and provide oxygen to the system, resulting in an environment where the microorganisms can metabolize the pollutants. Other processes, such as plant uptake, sedimentation, precipitation, and filtration also occur in the wetland and contribute to its efficiency (R.W. Crites et al., 2006).

Biotreatment wetlands for wastewater treatment differ from natural wetlands and even wetlands constructed for stormwater management. A biotreatment wetland is an engineered system that is designed to meet site-specific effluent limits. The biotreatment wetland is hydrologically isolated from the surrounding environment, which allows wastewater to be introduced to the system without impacting groundwater or surface water. The most common method of sizing wetlands is for biological oxygen demand (BOD) removal utilizing first-order plug-flow kinetics such as the k-C* model.

There are several types of wetlands that serve as engineered systems for wastewater treatment. The most common are surface flow wetlands and subsurface flow wetlands. Surface flow wetlands, also known as open water wetlands, resemble natural marshes or wetland areas, with pools of standing water. In contrast, subsurface flow wetlands treat wastewater in gravel beds below the ground surface, and they typically do not have any freestanding water. For this reason, subsurface flow wetlands are typically better suited to colder climates than are surface flow wetlands.

Surface flow wetlands are typically less expensive to construct, but they require more land area than subsurface flow wetlands do. In addition, surface flow wetlands may become an attractive nuisance if they are in a populated area. However, surface flow wetlands may look more natural and attract more wildlife to the area.

Biotreatment wetlands offer some major advantages over traditional treatment and are becoming increasingly common as a cost-effective technology that can replace traditional wastewater treatment. Typically, they have lower capital and operation and maintenance costs than other wastewater treatment alternatives. Biotreatment wetlands are constructed from natural materials and have no energy inputs other than sunlight. Traditional treatment, such as sedimentation, activated sludge, and disinfection, relies heavily on steel, concrete, chemicals, and electricity. Chemicals, such as flocculants that generate large amounts of biosolids, are not required. Biotreatment wetlands enhance habitat and tend to be more aesthetically pleasing.

FERNALD PRESERVE VISITORS CENTER SYSTEM DESCRIPTION

The biotreatment wetland alternative complements the environmental theme of the Visitors Center. The system comprises the following components:

- Two 7,571-liter (2,000-gallon) septic tanks in series.
- A flow equalization manhole with a redundant pumping system.
- A flow distribution manhole.
- Two parallel subsurface flow wetland cells, each measuring 259 square meters (m^2) (2,790 square feet [ft^2]).
- A water-level control gate (for the subsurface flow wetland).
- A recirculation manhole with a pump.
- A surface flow wetland with an evapotranspiration/infiltration area that measures 0.62 hectare (1.53 acres).
- A water-level control gate (for the surface flow wetland).
- An emergency spillway.

Wastewater flows by gravity from the Visitors Center to two 7,571-liter (2,000-gallon) septic tanks in series, located immediately west of the Visitors Center. Primary treatment (solids settling) is achieved in the septic tanks. Once primary treatment is complete, wastewater flows by gravity through a septic tank filter to the flow equalization manhole, where a redundant pumping system conveys effluent to a manhole immediately south of the subsurface flow wetland.

Wastewater is gravity-fed from the flow equalization manhole into two parallel subsurface flow wetland cells, located west and north of the Visitors Center. The total area of the subsurface flow wetlands is 518 m^2 (5,580 ft^2), with each cell having an approximate area of 259 m^2 (2,790 ft^2). Although designated as secondary treatment, the subsurface flow wetland was designed to meet tertiary standards to ensure adequate treatment of wastewater prior to discharge. Treatment is completed within the gravel bed on the root zone of the wetland plants (Fig. 1). Wetland species planted within the subsurface flow wetland include green bulrush (*Scirpus atrovirens*), duck potato (*Sagittaria latifolia*), blue flag iris (*Iris vericolor*), river bulrush (*Scirpus fluviatilis*), and prairie cordgrass (*Spartina pectinata*, Fig. 2).

Fig. 1. The subsurface flow wetland gravel bed and mulch planting medium are being installed.

Fig. 2. Field personnel install herbaceous plugs into the subsurface flow wetland.

Following treatment in the subsurface flow wetland, water discharges by gravity to a manhole with a recirculation pump. The recirculation pump returns treated water to the equalization manhole and keeps the water from stagnating in the subsurface wetland during times of low flow. Water that does not recirculate to the flow equalization manhole and back through the subsurface wetland discharges by gravity to a 1.53-acre surface flow wetland. A sliding-gate structure, which regulates water level in the subsurface wetland, is located between the recirculation manhole and the surface flow wetland. Figure 3 demonstrates the location of the subsurface flow and surface flow wetlands.

The biotreatment wetland is designed as a zero-discharge system, in which all treated water will be lost to infiltration, evaporation, and evapotranspiration. Final disposal of the treated water is achieved in the surface flow wetland. The surface flow wetland was constructed on an existing pond that was regraded and expanded to ensure that an appropriate water depth is maintained for establishing wetland species.

Wetland species will not only increase water removal through evapotranspiration but will also increase infiltration as the root system is established. Berms approximately 6 inches high are incorporated into the footprint of the wetland to prevent short-circuiting of water. Black willows were planted along the perimeter of the surface flow wetland to increase both evapotranspiration and infiltration. The surface flow wetland was designed to retain flows (i.e., wastewater plus precipitation) from November through March, during which time there will be minimal evaporation, evapotranspiration, and infiltration. The sizing of the biotreatment wetland system was dictated by Ohio Environmental Protection Agency guidelines [4].

Fig. 3. The lined subsurface flow wetland sits adjacent to the larger surface flow wetland.

As required by the Ohio Environmental Protection Agency, an emergency discharge spillway from the surface flow wetland was included in the design. Emergency discharge will flow from the surface flow wetland over the emergency discharge spillway to the existing detention pond located west of the Visitors Center. This detention pond discharges to an existing on-site network of ponds, thus meeting the LEED criterion for on-site infiltration of treated wastewater.

SYSTEM STARTUP AND OPERATION

Startup testing of the biowetlands system began as soon as construction was complete. Adjustments to the control panels were required for the pumps in the flow equalization manhole and the recirculation manhole. While the panels were being procured, the septic tanks were opened to receive flow from the Visitors Center. The valve between the septic tanks and the flow equalization manhole was locked shut until the system was modified and tested.

After the new panels were installed, potable water was added to the flow equalization manhole to test the system. Float switches control the pumps in the flow equalization manhole. The positions of the float switches were adjusted so that the lowest float turns off the pump (or pumps), the second float starts one pump, the third float starts the second pump—so both are operating at the same time—and the fourth, and highest, float trips the high-level alarm and light. The floats were positioned based on operating experience with other lift stations at the Fernald Preserve. An alternating relay was added to the control panel for the flow equalization pumps so that use of the pump is equalized. The addition of the alternating relay is consistent with operation of other site lift stations, which are all equipped with alternating relays.

Water was pumped through the flow distribution manhole into the subsurface flow wetland. Water tended to flow to the east side of the subsurface flow wetland, but this tendency was determined not to be problematic. The plates in the water-level control structure downstream of the subsurface flow wetland were adjusted to maintain the desired depth in the subsurface flow wetland. Water then flowed into the recirculation manhole and was pumped back to the flow equalization manhole. The floats for the recirculation manhole pumps were adjusted to maintain a level in the manhole that will allow water to flow to the surface flow wetland when desired.

After testing was complete, the inlet valve was unlocked and opened, and the system was officially placed in service.

All operations personnel were trained to use the system, and an operating procedure was written. A weekly “round sheet” was developed to check key operating components, and a more in-depth monthly round sheet was developed to check vegetation and non-mechanical parts. A weekly sample is being collected and analyzed for carbonaceous biochemical oxygen demand (CBOD). The analytical detection limit for CBOD is 2 milligrams per liter (mg/L) following the approved method in use on site. Table 1 below shows the results obtained. The two detectable results may have been due to higher use during the weeks when the plants were still being established. Sampling will likely continue as long as analytical capability exists on site.

Table 1. Weekly CBOD Results at the Subsurface Flow Wetland Recirculation Manhole

Date Sampled	CBOD (mg/L)
19-Aug-08	<2.0
27-Aug-08	N/A
4-Sep-08	<2.0
9-Sep-08	4.8
16-Sep-08	<2.0
23-Sep-08	12.6
2-Oct-08	<2.0
9-Oct-08	<2.0
16-Oct-08	<2.0
23-Oct-08	<2.0
28-Oct-08	<2.0

REFERENCES

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