Common engineering practices are being integrated into natural systems to support their use in non-municipal application, like treatment of airport deicing fluid at Buffalo Niagara International Airport in New York. Photo by Naturally Wallace Consulting

Advanced wastewater treatment technology included within natural treatment systems is expanding the range of applications from domestic sewage to airport deicing, landfill leachate, mining waste, and remediation of petroleum hydrocarbons and other pollutants, according to Senior Engineer **Mark O. Liner** of Naturally Wallace Consulting.

Natural systems treat industrial wastewater

Domestic sewage accounts for most wastewater treatment and rarely changes on a daily basis except for the occasional rain event or infrequent industrial discharge. People and the solutions for managing their wastewater are predictable; however industrial wastewater treatment can involve an extreme range of flows, concentrations, and operating conditions.

For example, the treatment of deicing fluid at airports requires the capacity to cope with extreme volume. Some 200 liters of propylene glycol could be required to deice a medium-sized airplane, which equates to approximately 200 kgs of biochemical oxygen demand (BOD). A large airport can discharge more BOD during an ice storm than a municipal sewage plant discharges in one year. In landfill leachate cases, the characteristics of wastewater alter as the landfill ages such that the treatment system bought for day five to remove organics is no longer the right system on day 5000 to remove metals.

Natural treatment systems such as lagoons and wetlands are well suited for industrial strength situations because they can handle relatively large volumes and have slower reaction rates that exhibit inertia against disturbances. These natural systems are routinely used for conventional treatment of organics, solids, and nutrients, but have been found to provide treatment for exotic elements and compounds including selenium, fluoride, TCE, MTBE, tetrahydrofuran, aniline, and nitrobenzene, and other substances. This treatment capacity is now being employed at airports, landfills, mines, and remediation sites by pairing the advanced treatment with the simple and robust methods of civil engineering.

Engineering of lagoons and wetlands for wastewater treatment has improved over the past decade, which has helped increase the predictability of performance. One reason is the use of insulation. Insulated covers are now accepted as critical to maintaining lagoon temperatures. A small insulation layer goes a long way toward keeping wastewater warm and reaction rates high. It also protects systems from dramatic changes in weather. Subsurface wetlands are also being insulated and this approach is proving that six inches of peat mulch on top of the bed provides significant conservation of heat and stabilization of the wetland even in the coldest climates. Field observations, supported by a basic understanding of thermodynamics, led to the conclusion that a steady temperature is less likely to be affected by weather changes.

Engineering tools commonly employed in the design of sewage plants such as aeration, reactor configuration, and online monitoring are also being used for natural treatment systems. The inclusion of such advanced wastewater treatment technology has extended the use of natural treatment systems over a larger spectrum of applications.

Airport deicing

An innovative approach using aerated wetlands is being employed at Buffalo Niagara International Airport in the US state of New York to treat spent glycol found in stormwater during the deicing season. The system is built for 4,545 kgs of oxygen demand per day and

Engineered wetlands provide treatment for chlorinated hydrocarbons at a British Petroleum remediation site in Casper, Wyoming. Photo by Naturally Wallace Consulting

is approximately the size of four football fields. Aeration of these beds is critical to supply oxygen to bacteria attached to the gravel and can be controlled to accommodate the level of glycol being treated.

Of primary interest at the airport is the ability of the system to accommodate large fluctuations in flow and wastewater strength. The fundamental design constraint is pollutant loading not volumetric flow, which means the system can handle large dilute and lower concentrated flows.

The treatment system consists of four discrete wetland cells excavated from an existing open area near the airport's main runway. At ground level, only a field of grasses will be observable growing from a "dry" mulch surface. An important factor of the design is the relatively large size of the gravel used and the porosity of the bed, which allows for accumulation of bacterial biofilm (slime) that grows during the deicing season and degrades in the summer.

The system is engineered to maintain an active biomass within the wetland throughout the winter. It is built below ground with an insulating mulch layer on top to maximize the benefits of consistent water temperature. During the warmer summer months, the accumulated biomass will degrade and be consumed by larger "bugs" that graze on the slime-covered gravel.

Similar systems have been constructed at airports in Canada and the United Kingdom and designers and engineers there are looking to expand on the experience gained from the Buffalo Niagara International Airport project for these systems.

Petroleum hydrocarbon remediation

Through a combination of processes, natural treatment systems are being used to treat groundwater contaminated by petroleum hydrocarbons resulting from drilling and processing operations. Scientists occasionally use a pump-and-treat approach to minimize the progression of carcinogenic plumes into water supplies. Treatment of a wide range of compounds including benzene, toluene, ethylbenzene, and xylene (BTEX) occurs through volatilization and aerobic biodegradation. Microbial communities in wetlands are known to break down many of these and other volatile organic compounds. The challenge is to engineer a system that provides a consistent environment to allow such microbial communities to flourish.

A former refinery in Wellsville, New York, is the site of a system that treats groundwater with elevated levels of iron, manganese, and petroleum hydrocarbons. The system provides treatment for 1,060 m^3/d of groundwater using a cascade aerator, sedimentation pond, surface flow wetland, and vertical flow wetland.

The cascade aerator provides passive aeration of the influent flow, permitting the iron and manganese to be oxidized. The oxidized metals generate precipitates that are allowed to fall out in the downstream sedimentation pond. After the sedimentation pond, the flow enters a surface flow wetland, which is lined and operates at water depths between 0.3 m and 0.6 m. Four 0.25-hectare beds in parallel are designed to expedite the biodegradation of petroleum hydrocarbons in the water. Flow is then introduced into a vertical flow wetland comprised of limestone aggregate. The limestone beds are used to adjust for the pH depression related to the upstream iron precipitation.

British Petroleum (BP) constructed a petroleum hydrocarbon remediation system in Casper, Wyoming, USA that treats up to 11,400 m^3/d of gasoline-contaminated groundwater. The site includes an office park, river front trails, and a whitewater kayak course. The system blends into the middle of a premier golf course and is anticipated to operate effectively for more than 100 years.

This project design includes a cascade aeration system for iron oxidation and air stripping, a soil-matrix biofilter for gas-phase benzene removal, surface flow wetland cells for removal of ferric hydroxide precipitates, stormwater retention wetlands, and radial subsurface flow insulated wetland cells for BTEX removal. Support of the design required conducting a pilot to determine site-specific rate constants.

In both cases, natural systems were engineered to exploit various chemical, physical, and biological mechanisms to reduce the concentrations of carcinogens in the groundwater. Proven to be effective for a wide range of influent concentrations, the system provides a long-term stable means for controlling the migration of contaminated groundwater.

Landfill leachate

Given the variable nature of landfill leachate, a treatment system must be able to receive and properly treat an expansive range of parameters over a wide variety of concentrations. A complete leachate system design must include a number of unit processes that each target removal of a certain group of parameters. Wetland treatment systems used in concert with other processes perform well in this application. Aerobic and anaerobic zones can be engineered in the wetland to expedite the degradation of xenobiotic compounds. Subsurface wetlands with properly sized gravel media provide a stable surface for attached growth bacteria, which allows the bacteria to be resident in the wetland and acclimate to the variable load.

For the Anoka County Landfill in Minnesota, a bioremediation system was designed to treat 1,000 cubic meters per day of leachate-contaminated groundwater, and included eight 0.5-hectare horizontal subsurface flow wetland treatment cells. The wetlands are insulated using energy balance design methods to provide year-round treatment. Forced bed aeration is also employed within the wetland cells to create alternating aerobic/anaerobic zones for degradation of complex organic compounds including tetrahydrofuran.

Detailed pilot work on an engineered wetland has also been conducted at the Jones County Landfill in Anamosa, Iowa, USA. The pilot was designed to remediate up to two cubic meters per day of landfill leachate and is operated as a research facility by the University of Iowa Department of Civil and Environmental Engineering. Results from the pilot have focused on the ability of the wetland to treat for ammonia during cold weather and have dramatically illustrated the benefits of wetland aeration.

Conclusion

A natural system was designed for each of the above applications using advanced engineering concepts and procedures to provide management of highly diverse influent concentrations and loadings without complicated and costly-to-operate mechanical plants. The application of current science with a seasoned understanding of wastewater engineering practice has improved the use of natural systems. That they are now commonly used outside of domestic wastewater applications is a huge asset to wastewater treatment in the types of large-scale industrial applications. This is especially good news for facilities that need industrial-level wastewater treatment, but don't have the resources to keep full-time operators on staff. With the addition of aeration and other engineering modifications, these natural treatment systems are easily competing with conventional approaches because they provide the same level of treatment with less effort and more stability.

Author's Note

Mark O. Liner, P.E is a senior engineer with Naturally Wallace Consulting. In his 20-year career, he has worked as a regulator at the US Environmental Protection Agency headquarters in Washington, DC, a process and equipment supplier for wastewater treatment systems, a design-build project manager for a US$ 20-million sewage plant in Venezuela, and as a consultant engineer for municipal and industrial clients. He has developed designs for more than 500 new and retrofit lagoon treatment systems around the world. He specializes in the design of onsite treatment systems for industrial facilities with an emphasis on airport deicing, mines, landfill leachate, and remediation.