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Refined engineering for reliable remediation

ADVANCED WETLAND DESIGNS OFFER DECADES OF DURABLE, LOW-COST WASTEWATER TREATMENT AT HYDROCARBON AND CHEMICAL-CONTAMINATED SITES.

By Scott Wallace, P.E.

Inclusion of aeration in subsurface wetlands has greatly advanced the ability of the systems to degrade contaminants such as hydrocarbons and ammonia aerobically.

Improvements in the engineering of wetlands for wastewater treatment during the last decade have helped increase the reliability of these natural systems. Engineers have borrowed the biology, chemistry, and hydraulics principles of the wastewater industry and are employing them successfully to create remediation systems that perform like conventional sewage plants but look like, well, just "plants."

Project
Hydrocarbon and chemical wastewater treatment
Product application
Engineered wetlands provide long-term and low-cost remediation options for contaminated sites.

Inclusion of aeration in subsurface wetlands has greatly advanced the ability of the systems to degrade contaminants such as hydrocarbons and ammonia aerobically. This is critical for the design of wetland systems in applications such as produced water treatment or for nitrifying ammonia found in tailings ponds for gold mines. And by using hydraulic and thermodynamic principles, designers are creating wetland "reactors" that are stable and efficient.

As the design approach has advanced, the engineering of the systems also has been refined — from biological empiricism to chemical reactor design. This trend is particularly apparent for pump-and-treat remediation systems where engineered wetlands are proving successful and durable.

Wetland systems are larger than mechanical systems; however, there is a trade-off between the mechanical complexity and land utilization. Lagoons and wetlands don't need as much attention or maintenance as their mechanical counterparts; they are big, simple, and low maintenance. With minimal moving parts, natural systems can be operated for decades without the need for overhaul or equipment replacement. The bottom line asset here is low lifecycle cost. The more that we exploit bacteria and other natural mechanisms, the less mechanical effort we need to use to get the job done (and ultimately, the lower the cost).

In addition, for site managers faced with the liability of contamination plumes affecting their neighbors' groundwater, the liability is long term — decades not days. When pump-and-treat systems are used, the "treat" part must do the job for the long term as well. Treatment wetland systems have been selected for a number of high-profile remediation projects. They work and have low, or in some cases no, operation costs aside from routine yard maintenance.

Through a unique combination of natural processes, wetland systems are being used to remediate petroleum hydrocarbons found in groundwater. 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. Engineering a system that provides a consistent environment to allow such microbial communities to flourish during the extended life of the system is the challenge.

Remediation wetlands in action

Wellsville, N.Y. — Such a system is in operation at a former refinery in Wellsville, N.Y. The former site of an oil refinery from 1901 to 1958 is located next to the Genesee River. The long-term closure plan for the site includes a barrier wall to prevent migration of contaminated groundwater to the river. Groundwater extraction pumps deliver water to a treatment wetland constructed onsite. The system consists of a cascade aerator, sedimentation pond, surface flow wetland, and vertical flow wetland and provides treatment for 650 cubic meters per day (m^3/d) of groundwater. The influent has elevated levels of iron, manganese, and petroleum hydrocarbons (including aniline and nitrobenzene).

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 meters and 0.6 meters. There are four cells in parallel (each 0.6 acres) designed to expedite the biodegradation of petroleum hydrocarbons in the water. Flow then is introduced into a vertical flow wetland comprised of limestone aggregate. The limestone beds are used to buffer the pH depression related to the upstream iron precipitation.

Casper, Wyo. — British Petroleum (BP) in Casper, Wyo., also constructed a petroleum hydrocarbon remediation system. The site includes an office park, river-front trails, and a whitewater kayak course. The Casper system provides treatment of as much as 11,400 m^3/d of gasoline-contaminated groundwater. It is anticipated to operate effectively for more than 100 years.

This award-winning wetland project is one of the largest petroleum remediation wetlands in North America, and one of the first wetland treatment systems designed specifically for cold-weather hydrocarbon removal. The design of the wetland was integrated into the golf course and many of the water features have dual uses for treatment and golf course play.

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.

Refinery site, Midwest region — Groundwater extracted from a former refinery site contains diesel range organics and gasoline range organics along with other conventional parameters. A treatment system based on constructed wetlands was selected to provide treatment of the groundwater because it could be constructed within the existing pond infrastructure onsite and designed to have low, long-term power requirements.

The system includes a cascade aerator, mineral settling basin, and a three-stage wetland system: 1) a reducing stage, 2) an oxidizing stage, and 3) a polishing stage. The reducing stage is designed to facilitate the reductive dehalogenation of chlorinated organics such as tricholoroethane and vinyl chloride, while the oxidizing stage is designed for aerobic degradation of benzene, gasoline range organics, and diesel range organics. Stage 1 (reducing wetland) employs a vertical, downflow configuration and stage 2 (oxidizing wetland) uses a conventional free surface wetland interspersed with aerobic zones. The polishing stage wetland is designed similar to the stage 2 oxidizing wetland but without aeration.

Wurtsmith Air Force Base, Oscoda, Mich. — A wetland treatment system is planned for construction at Wurtsmith Air Force Base. The pump-and-treat system is designed for a flow of 0.63 million gallons per day and treatment of trichloroethylene and other chlorinated hydrocarbons. The need for hydrocarbon remediation here results from a landfill onsite that was used during World War II and the Cold War. The system employs a cascade aerator for oxidation of metals. From the cascade aerator, the flow travels through a sedimentation pond where precipitates are allowed to settle. Following the sedimentation pond, flow continues through a free water surface wetland and a subsurface wetland before final disposal by soil infiltration.

There are no motors or other mechanical components following the pumps that deliver the groundwater to the cascade aerators; operation and maintenance is limited to routine visual monitoring and grounds keeping. The subsurface wetland will be constructed with aeration lines in place as a contingency measure, but the manifold for the lines is not expected to be connected to a blower unless needed. Ongoing operations costs will be limited primarily to the cost of operating the groundwater extraction pumps.

Looking good at 30

Treatment wetlands designed on proven science and common engineering practices are proving financially viable over the long haul. The good news is that the systems in the ground now will be around for many years to come and are expected to be working long past 30 years of age.

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