With land available, arctic communities are using natural systems to treat melted wastewater.

The Big Chill

Natural wastewater treatment systems for deep freeze climates.

BY MARK LINER

WITH ITS ABUNDANT NATURAL RESOURCES AND LAND AREA, solving environmental problems using natural treatment systems seems like a logical choice for Canada. However, concerns over winter performance have often limited their adoption. In the last decade, designers have tackled the cold weather challenge head-on through a variety of pilot- and full-scale treatment systems designed for winter operation. These highly engineered "treatment wetlands" are now employed across Canada and the northern United States to provide long-term solutions for municipal and industrial facilities.

The inherent appeal of natural treatment systems is the ability to trade land for mechanical complexity. By designing a system that is mechanically simple (but may require more land area), simple and robust treatment systems can be implemented. Some natural systems rely on thermal insulation to maintain elevated temperatures for year-round operation while others are simply designed for freeze and thaw (seasonal operation). Over the past decade, consultants and suppliers have fine-tuned design practices for cold climates. The result is a list of successful treatment projects that demonstrate how the methodical practice of engineering can overcome the brutality of cold weather.

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There are certain applications that favour the use of natural systems for treatment of wastewater. These include sites where contaminant release will occur over very long timeframes (years or decades) and where land is available. These systems have been used at airports for spent deicing fluid, at mining facilities for tailings water, at refineries for groundwater remediation, at landfills for leachate, and for remote communities near the Arctic Circle. In each case, the systems are tailored to remove target contaminants by using chemical, physical or biological mechanisms. Identifying

The wetland treatment system at the remediation site in Casper, Wyoming has forged new ground for performance of natural systems in cold climates.

reaction rates that are representative of very cold temperatures is critical to the design of these systems along with proper sizing of the treatment units.

As a category, "natural treatment systems" includes a broad spectrum of alternatives that ranges from controlled discharge lagoons to recirculating gravel filters. However, in cold climates, subsurface flow wetlands (SSF) have proven particularly reliable. They are usually constructed below grade with no water surface exposed to the atmosphere, which eliminates the problem of freezing that occurs with traditional surface flow wetlands (SFWs). With SSFs, the wetland bed is composed of various sizes and types of media and flow travels either horizontally or vertically from inlet to outlet. Since there is limited water to air interface, passive oxygen transfer is low. When aerobic conditions are required, supplemental floor aeration has been found to greatly improve performance. Finally, these beds can be overlain with a blanket of peat or compost for thermal insulation. With additional snow pack on top of the mulch, the water will flow all winter long with minimal disturbance from the cold air temperatures above.

Groundwater remediation

One of the early success stories of wetland winterizing is the groundwater remediation site in Casper, Wyoming. Casper is located the mountains where winter temperatures can be as low as -35 degrees Celsius. Subsurface wetlands were constructed at the former BP refinery to provide treatment for gasoline-contaminated groundwater. The two-hectare system is capable of treating up to 11,400 cubic metres per day (m^3/d) of groundwater extracted adjacent to a nearby river. The treated water is reused for irrigation of a golf course that surrounds the underground treatment system. The system has been in continuous operation since 2004 and has provided excellent removal of petroleum hydrocarbons, iron, and other target parameters. The first of its kind, the BP Casper project was the first large-scale winterized wetland system that utilized aeration and insulating mulch.

Mining

Natural systems for mine water have historically employed cascade aerators for iron oxidation, sedimentation ponds for settling, and lime beds for pH adjustment. The ability to treat water simply by hydraulic flow through these units has always been an attractive low operation and maintenance solution for mines. Work done by Al Mattes and Jim Higgins has provided another passive process for metals removal. Wetlands are now engineered with dedicated anaerobic biochemical reactors (BCRs) specifically designed to precipitate metals as insoluble sulphides, oxides, or carbonates. These systems can be used to remove metals from mine waters at remote sites where chemical/physical means of treatment are not economically viable over the long term. Such a system has been in operation at the lead/zinc smelter in Trail, British Columbia, since 2003 for treatment of seepage from the capped industrial landfill and has proven, excellent results with respect to removing zinc and arsenic. Pilot testing at University of Guelph's Alfred College has also shown excellent removal of iron, molybdenum, and zinc for treatment of seepage from the tailings ponds of a closed gold mine.

Airport deicing fluid

Airport deicing activity results in highly variable flows and airfield runoff that must be responsibly managed to prevent contamination of the environment. One significant benefit of a wetland-based treatment system is that the relatively large size and water volume results in process stability in the face of influent fluctuations. This is important for glycol treatment systems because the use of deicing chemicals (like propylene glycol and potassium acetate) depends on the weather.

Systems at Buffalo Airport in New York, Heathrow in London, and Edmonton International Airport are used to treat glycol concentrations from 600 milligrams per litre (mg/L) to 15,000 mg/L. In each case, engineers had to create wetland environments that accommodate the growth of bacteria in

Credit: Associated Engineering

Subsurface flow wetlands, like these at Edmonton International Airport, provide treatment for glycol and other deicing fluid.

cold water in cold weather. Underground and aerated, the wetlands are designed to accommodate rapid bacterial growth during high glycol usage and then, off peak, allowed to self clean through in-situ aerobic digestion. It is a seemingly complex situation, but the wetland systems are remarkably well adapted to handling the difficult operating conditions. For example, the Buffalo Airport treatment system demonstrated 98 per cent removals throughout the very harsh 2010-2011 deicing season. The wetland treatment system at London's Heathrow Airport was upgraded in 2010 to include aeration and, this summer, the existing wetland treatment system and Edmonton International Airport will be upgraded, as well, with aeration and improved hydraulics.

Arctic communities

The communities of Baker Lake, Chesterfield Inlet, and Coral Harbour in Nunavut constructed natural treatment systems for management of domestic wastewater. In these communities, wastewater is collected and hauled to the edge of town where it is dumped. The wastewater freezes during winter and then is released during the spring melt. With land available, engineers re-graded the local topography to maximize the detention time and the travel path to receiving waters. Employing known biological removal rates, the systems were created to optimize the use of local resources and minimize operation and maintenance requirements.

Case study: Wellsville, New York

A former refinery in Wellsville, New York has constructed a wetland-based system for groundwater remediation. The former oil refinery operated from 1901 to 1958 and 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 from the site to the river. Groundwater extraction pumps deliver contaminated water to a treatment wetland. The system consists of a cascade aerator, sedimentation pond, surface flow wetland, and vertical flow wetland and provides treatment for 840 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 metres and 0.6 metres. There are four beds in parallel each 0.6 acres 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. Data from the past three years of operation indicate consistent removals for aniline (99 per cent) and nitrobenzene (94 per cent) and the system successfully meets regulatory expectations despite variations in influent and weather.

British explorer Sir Ranulph Fiennes once said, "There is no such thing as bad weather, just inappropriate clothing." The same goes with the design of wetlands in cold climates, though you might want to replace the word clothing with the word engineering. Subsurface, aerated wetlands are proving to be a suitable choice for cold climate applications. Successful use at remediation sites, mine facilities, and airports demonstrate that the systems can be adapted for Canada, the United Kingdom, and the northern United States. With appropriate winterization, the wetlands are providing long-term, low-cost solutions for wastewater treatment. WC

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