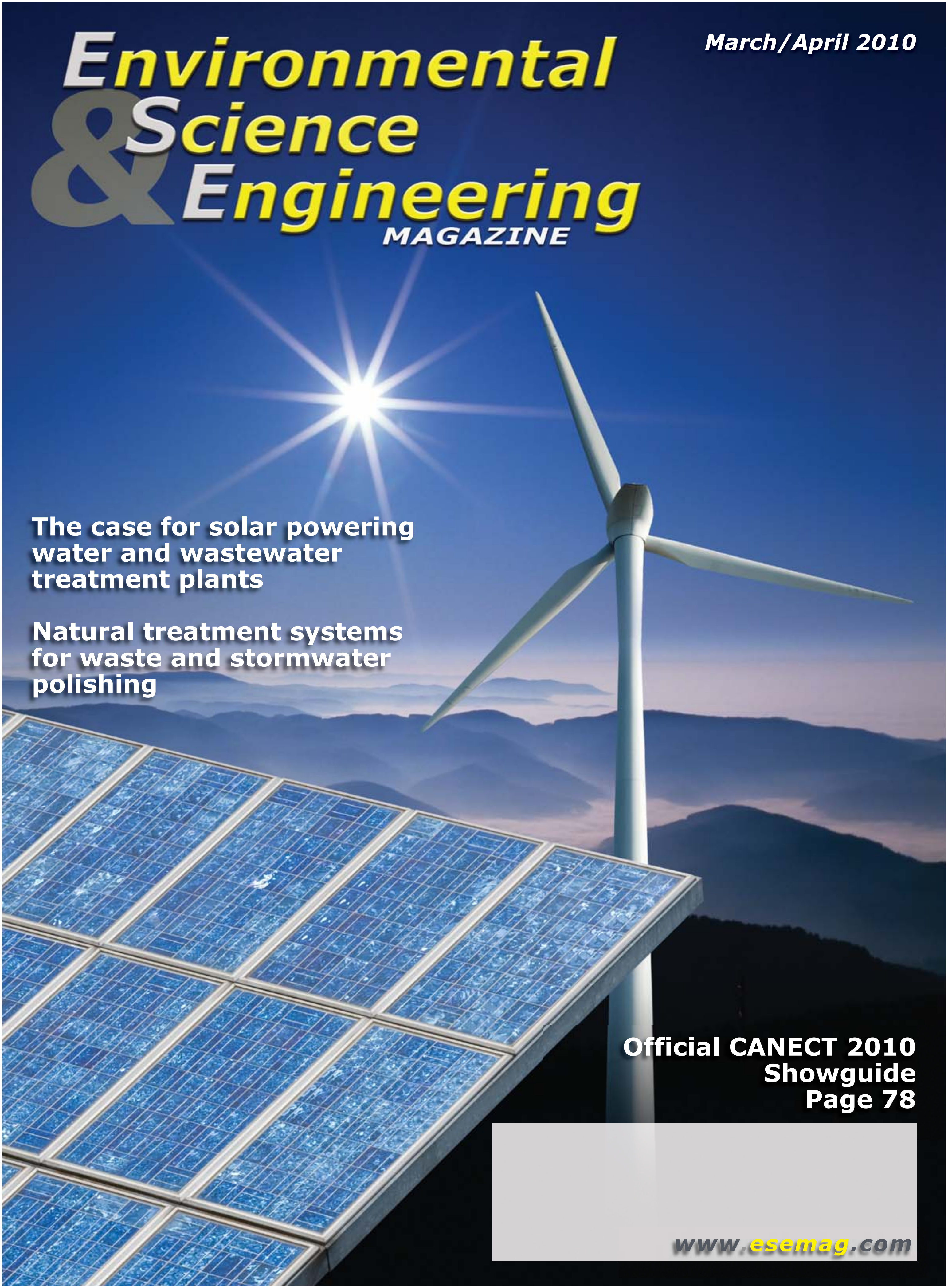
March/April 2010

Environmental & Science Engineering MAGAZINE



The case for solar powering water and wastewater treatment plants

Natural treatment systems for waste and stormwater polishing

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Engineered wetlands for municipal sewage and sludge treatment

The towns of Appleton and Glenwood are located on opposite sides of the majestic Gander River in the central region of Newfoundland. By 2002, the towns' old sewage treatment plants had become overloaded and costly to maintain and operate, so a local consulting firm, CECON Ltd., was hired to investigate the options and costs associated with a modern, more efficient treatment system.

The benefits in maintenance and operations made a combined system for both towns the preferred choice. The final review came down to two options: an aerated lagoon or the Kickuth Engineered Wetland, a wastewater treatment system that has been used for many different types of waste in over 600 projects in more than 30 countries.

In the wetland system, sludge is treated on-site, whereas the lagoon system relies on transporting sludge to a remote location for disposal. Sludge disposal costs of about $15,000 annually, or $450,000 over 30 years, are not included in the cost estimate for the lagoon system. The capital cost for the wetland includes the construction of sludge treatment cells, which is approximately $400,000. Operating and life cycle costs of the wetland also include sludge treatment.

Figure 1. Stormwater bed during commissioning.

Figure 2. Aerial view of Appleton-Glenwood system.

Although the capital costs were higher, the engineered wetland was chosen for its lower operating and life cycle costs and greater environmental benefits. The engineered wetland system was also eligible for, and received significant funding from the Green Municipal Fund.

This system would be the first full-scale Kickuth Engineered Wetland treatment system operating in Newfoundland and Labrador, and also the first of this type providing full secondary treatment in Canada. Abydoz Environmental, the North American licence-holder for the Kickuth system, was commissioned to provide the engineering design.

Design loading conditions

Design loadings were calculated based on the combined population of the two towns and provincial guidelines. The Appleton-Glenwood system services an approximate population of 1,470 and a population equivalent of 1,800.

Actual flow information showed significant infiltration into the sewage collection system and highly fluctuating hydraulic conditions, especially during spring run-off. The system was, therefore, designed for an average daily flow of 3,037 m^3 and a maximum of 1.5 times the average flow, or 4,555 m^3 /day. A separate stormwater treatment bed was designed to accommodate the large peak flows and prevent a push-through effect on the main wetland, which would result in reduced retention times and treatment.

The wetland was designed for an average organic loading of 150 kg/day BOD, with an additional 50% loading during stormwater events. Discharge limits were set by the provincial regulations for discharge into a sensitive freshwater body at 20 mg/L BOD.

Design size and configuration

Design of early wetland systems was based on empirical data and used rule-of-thumb loading methods to size the systems. This often resulted in oversized systems. More recently, wetlands have been modelled as plug flow reactors, or a series of continuously stirred tank reactors.

However, the patented Kickuth system is designed according to a specific set of calculations based on the movement of effluent through a soil matrix, with the matrix providing significant treatment. A series of first-order equations is used, with constants based on degradation curves established from analysis of different matrix designs. The data for these curves was collected from the many Kickuth systems operating worldwide, which treat various types of wastes in different climates.

In Appleton-Glenwood, the wetland size was based on the required BOD and TSS reduction, with additional sizing to account for the use of more local content in the matrix. The final design size of the main treatment wetland, excluding sludge cells, was 12,400 m^2.

The shape and configuration were selected, based on the hydraulic capabilities of the matrix and the desired configuration. A hydraulic proof was then performed using Darcy's law and varying flow conditions to determine if the shape and configuration were sufficient. The final configuration for the main treatment system was for five subsurface-flow wetland beds, consisting of one vertical-flow bed, followed by four parallel horizontal-flow beds.

Treatment system components

The sewage from both communities is pumped to the treatment facility by a combination of lift stations. On entering the treatment facility, effluent passes through a grinder and a spiral lift screen to remove non-organic materials. Flow then enters a series of settling chambers, where the majority of solids and suspended solids are removed by gravity and settle to the bottom of the chambers.

Settling chambers provide a minimum four hours retention time. Flow is then split by a weir arrangement that allows the main flow to move into the main treatment beds. Stormwater flows, which can reach 12,000 m^3/d, are diverted into a 1,216 m^2 stormwater treatment bed. This bed is designed to hold and treat storm surges and slowly release them. It has a much deeper basin than the other beds.

The main flow, after the settlement chambers, flows into the vertical flow wetland bed of 2,040 m^2. Effluent is then collected and split equally between the four horizontal flow wetland treatment beds, each 2,583 m^2. They are bilateral units with the inlet down the centre of the beds and discharges along both sides.

The main flow and stormwater flow are combined at the end of the system and flow out into the Gander River through a diffused outfall. The use of the stormwater bed means that 100% of the effluent discharged to the river is treated under all flow conditions.

Other than the screen and grinder, there are no mechanical or electrical components in the engineered wetland

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Figure 3. Sludge cells being filled at Appleton-Glenwood.

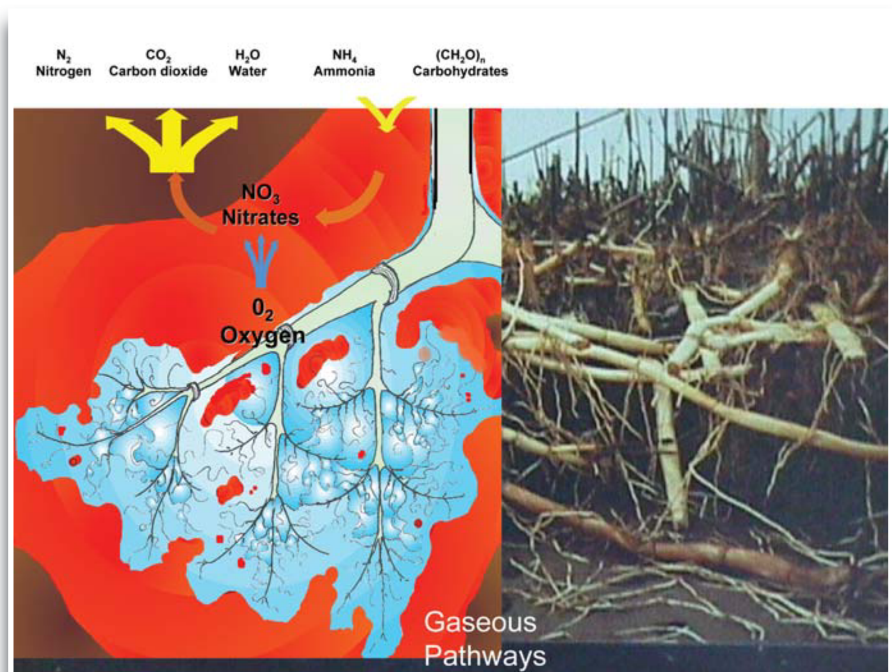

Figure 4: Gaseous pathways for oxidation and reduction around the root zone.

Wetlands for sewage and sludge treatment
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Figure 5. Plant growth as of 2009.

system, and no requirements for electricity or chemicals.

The overall layout of the system can be seen from the aerial photo in Figure 2, with the horizontal beds in the foreground, and the vertical bed and stormwater bed behind. Concrete settling chambers are to the far left, with the location of the outfall to the far right perpendicular to the system.

Sludge treatment

Solids that are removed from the settling tanks are treated by a wetland system of sludge cells. Liquid sludge from the settlement chambers is applied to the surface of the sludge cells, and flows vertically through the plants and matrix to pipes that feed the liquid back into the main wetland. Solids remain in the sludge cells to be treated.

Plants create pathways for continuous drainage, absorb water from the sludge, and provide oxygen into the root zone to stimulate biological mineralization of the sludge. The end product is a composted material that can be used for landscaping or other purposes. Up to 2.5 m of sludge can be applied to each sludge cell per year. As the plants grow up through the composted sludge, new sludge can be applied for seven to eight years before the cells need to be emptied.

Since the sludge treatment system began operating, it has provided savings of approximately $20,000 per year in transportation and disposal costs.

Secondary treatment

Wetlands purify wastewater using a variety of mechanisms. Matrix material can contain natural elements to provide for chemical interactions. The matrix also acts as a filter, trapping and binding contaminants. However, the majority of treatment occurs by biological degradation in the root zone.

Wetland beds are planted with a monoculture of nursery-produced and adapted common reed plants *(phragmites australis)*. These plants transfer oxygen to their root systems and into the surrounding rhizosphere, creating zones of varying oxygen levels within the matrix. The three main zones are an anaerobic zone containing no dissolved oxygen, an anoxic zone containing no dissolved oxygen, but having nitrite/nitrate, and an aerobic zone containing dissolved oxygen.

These zones, and the boundaries between them, create habitat for many different kinds of micro-organisms, including bacteria, amoebae, ciliates, rotifers and flagellates. In municipal applications, secondary or tertiary treatment can be achieved, depending on the size, configuration, and retention time of the beds.

Operation and treatment results

The Appleton-Glenwood system was designed in 2005. Construction was started in June 2006, and completed in November 2006. The system was turned on in December 2006, and has run continually since then, with commissioning activities being performed over the first year.

Operational requirements for the system have been as expected. The grinder and screen are checked regularly and debris from the screen is removed weekly or bi-weekly. Operational maintenance of the wetlands involves checking on the beds weekly, with a more thorough review monthly.

In the first years of a system, weeding and plant propagation need to be addressed. This is considered part of the overall commissioning and is not a long-term maintenance activity. The highest maintenance activity involves removing the settled sludge from the settling tanks, in this case every three to four months, and pumping it to the sludge cells.

In total, overall monthly requirements are approximately four to six man-days per month, or approximately 50 to 80 man-days per year. In addition to labour costs, the system only uses electricity for the grinder and the spiral screen, which amounts to approximately $2,000 per year. The overall operating costs have been lower than expected, at approximately $20,000 per year.

The system has performed above expectations from day one, even though incoming BOD levels were, on average, 40% higher than expected during the first year. Effluent is tested prior to entering the Gander River and at a downstream location. Effluent at both stations is clear, colourless and very low in organic matter, suspended solids, phosphorus, ammonia, nitrogen and pathogens. The effluent meets all standards set by the Newfoundland and Labrador government for discharge into a sensitive freshwater body.

Since the system performance during the summer months was very high, the second year's testing focussed on the spring and fall seasons.

The results were recognized in 2008, when the Town of Appleton was presented with the Newfoundland and Labrador Environmental Award.

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