Industrial Treatment Wetland Systems: A Track Record of Performance

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**Introduction**

Engineering treatment wetlands for complex industrial waste streams involves designing systems that can treat extreme ranges of flows and concentrations in varying climatic and operating conditions. For example, the inclusion of aeration in treatment wetlands, an approach pioneered by the team at Naturally Wallace Consulting (NWC), has greatly advanced the ability of these natural systems to reliably degrade organic chemicals and ammonia. This is critical for the design of performance-based wetland systems for the management of produced water from oil wells, treatment of spent deicing fluids at airports, groundwater remediation, and tailings water from gold mines. By using understood hydraulic and thermodynamic principles grounded in chemical engineering, NWC designers are creating wetland “reactors” that are stable and competitively sized, and that have a superior track record of performance over time.

**Treatment Wetland Performance Examples**

**Petroleum Remediation:**

*NWC leads the engineering community by having designed effective petroleum remediation treatment wetland system for more than 15 years. These include the award-winning remediation systems at a former BP refinery in Casper, Wyoming, the design of a post-closure remediation system to treat Diesel and Gasoline Range Organics (DRO and GROs) at a refinery in El Dorado, Kansas, a treatment wetland system to handle elevated levels of iron, manganese, aniline and nitrobenzene at a former refinery site in New York State, along with a pump-and-treat wetland system at Wurtsmith Air Force base in Oscoda, Michigan to treat groundwater contaminated with TCE and other chlorinated hydrocarbons.*
Performance Results: Former Refinery Groundwater Remediation System, Wellsville, New York

A three-hour drive from Toronto, a former refinery next to the Genesee River in Wellsville, New York, has a NWC-designed, constructed wetland-based system for groundwater remediation. As part of the long-term closure plan for the refinery, which operated from 1901 to 1958, a barrier wall was constructed to prevent migration of contaminated groundwater from the site to the river. Groundwater extraction pumps deliver contaminated water to a treatment wetland system that 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 while 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 0.3m and 0.6m. There are four beds in parallel, each 0.6 acres, designed to expedite the biodegradation of petroleum hydrocarbons in the water (Figure 1). 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 indicates consistent removals for aniline (99%) (Figure 2) nitrobenzene (94%) (Figure 3) and iron (Figure 4). The system successfully meets regulatory expectations despite variations in influent and weather.

Figure 2 – Aniline Removal at the Wellsville, New York Treatment Wetland
Figure 3 – Nitrobenzene Removal at the Wellsville, New York Treatment Wetland

Figure 4 – Iron Removal at the Wellsville, New York Treatment Wetland
Performance Results: Buffalo Niagara International Airport, Buffalo, New York

In the United States, airports have collectively expressed concern over the “undue financial burden” that will be placed on them to comply with the new EPA airport deicing regulation. However, some airports, like the Buffalo Niagara International Airport (BNIA), are finding that onsite treatment of aircraft deicing fluid (ADF) actually saves money. “In the last year, the treatment system saved the airport $500,000 in operations cost,” noted Kim Minkel, executive director of the Niagara Frontier Transportation Authority (NFTA) during the opening remarks of the Snow Symposium held in Buffalo on April 18th.

With more than 2.5 meters of snowfall per year, BNIA ranks as one of the “big sprayers” in terms of annual ADF use. Located 30 minutes from Niagara Falls and one and a half hours from Toronto, Canada, the busy airport receives contaminated stormwater and snowmelt for six months of the year. To provide treatment for the land limited airport, an innovative underground treatment system was installed just outside of the “Object Free Area” next to the runway (Figure 5).
The treatment system has been in operation for two years now, and represents one of the major applications of aerobic treatment systems for glycol-based deicing fluids. The full-scale system is designed to remove 4,500 kg/d of biochemical oxygen demand (BOD5). Unique to the system is its ability to handle a wide fluctuation of influent concentrations while still maintaining a high level of treatment (>90%). Performance results from the 2010-2011 deicing season are provided below (Figures 6 and 7).
Langenreichenbach, Germany Research Facility

*NWC has been collaborating with the Helmholtz Center for Environmental Research to investigate direct, side-by-side comparisons of standard horizontal- and vertical-flow subsurface treatment wetlands and compare these against their “intensified” counterparts (wetlands using aeration or fill-and-drain pumping). The Langenreichenbach (LRB) research site developed by the Helmholtz Association allows comparative investigation of eight different wetland configurations (Figure 8, Table 1), three of which include NWC design elements.*
Figure 8 – Aerial View of the treatment wetland research facility in Langenreichenbach, Germany

Table 1 – Treatment wetland technologies being evaluated at Langenreichenbach, Germany

<table>
<thead>
<tr>
<th>System Type</th>
<th>Saturation Status</th>
<th>Depth of Main Media</th>
<th>Size of Main Media</th>
<th>Area (m²)</th>
<th>Hydraulic Loading Rate (L/m²·d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF (25 cm depth)</td>
<td>Saturated</td>
<td>25 cm</td>
<td>8 – 16 mm gravel</td>
<td>5.6</td>
<td>17</td>
</tr>
<tr>
<td>HF (50 cm depth)</td>
<td>Saturated</td>
<td>50 cm</td>
<td>8 – 16 mm gravel</td>
<td>5.6</td>
<td>34</td>
</tr>
<tr>
<td>VF Sand (bi-hourly dosing)</td>
<td>Unsaturated</td>
<td>85 cm</td>
<td>1 – 3 mm sand</td>
<td>6.2</td>
<td>97</td>
</tr>
<tr>
<td>VF Sand (hourly dosing)</td>
<td>Unsaturated</td>
<td>85 cm</td>
<td>1 – 3 mm sand</td>
<td>6.2</td>
<td>97</td>
</tr>
<tr>
<td>VF Gravel (hourly dosing)</td>
<td>Unsaturated</td>
<td>85 cm</td>
<td>4 – 8 mm gravel</td>
<td>6.2</td>
<td>97</td>
</tr>
<tr>
<td>VF with Forced Bed Aeration™</td>
<td>Saturated</td>
<td>85 cm</td>
<td>8 – 16 mm gravel</td>
<td>6.2</td>
<td>97</td>
</tr>
<tr>
<td>HF with Forced Bed Aeration™</td>
<td>Saturated</td>
<td>100 cm</td>
<td>8 – 16 mm gravel</td>
<td>5.6</td>
<td>128</td>
</tr>
<tr>
<td>Fill-and-Drain (FAD)</td>
<td>Alternating</td>
<td>85 cm</td>
<td>8 – 16 mm gravel</td>
<td>12.4</td>
<td>172</td>
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</table>
NWC’s contributions at LRB include the design of the aerated vertical flow, aerated horizontal flow, and fill-and-drain (tidal flow) wetland cells. With more than one year of performance data collected to date, the LRB research team is redefining the relative benefits of wetland intensification. Research results to date indicate that aerated wetlands can have dramatically smaller footprint area, and still achieve superior treatment performance (Figure 9).

![Figure 9](image)

**Figure 9 – Total Nitrogen mass removal rates for five treatment wetland designs at Langenreichenbach.**

The LRB team is currently investigating wind-powered aeration technology for decentralized wastewater management in developing countries such as Mongolia.

**The Look Ahead**

At the present stage of treatment wetland development and with the documentation of successful performance of these systems, it is apparent that the range of industrial applications will continue to expand worldwide. Changing regulatory climates and available datasets proving the efficacy of treatment wetland systems will support their use. As the range of industrial applications increases, so will the requirement to improve existing methods and to create new solutions for the increasingly complex mixtures of pollutants under constrained process and site availability conditions. NWC will continue to be a leader in this process using the track record of data accumulated from successful designs and installation as a catalyst for the further evolution of complex wastewater treatment solutions.