Recirculating Media Filters

Brinjac Eng. Inc. was retained by Burkavage Associates Inc. to assist with the development of an alternative wastewater treatment technology with zero discharge at a commercial retreat called the Benson's Fun Station, located in Lehigh Township, Wayne County, Pa. The Fun Station project involved a commercial recreational center for families, which includes a restaurant and snack bar, paintball area, batting cages, miniature golf and go-carts center.

By Archis Ambulkar & Stephen N. Zeller

Data from a recreational facility's constructed wetlands treatment system

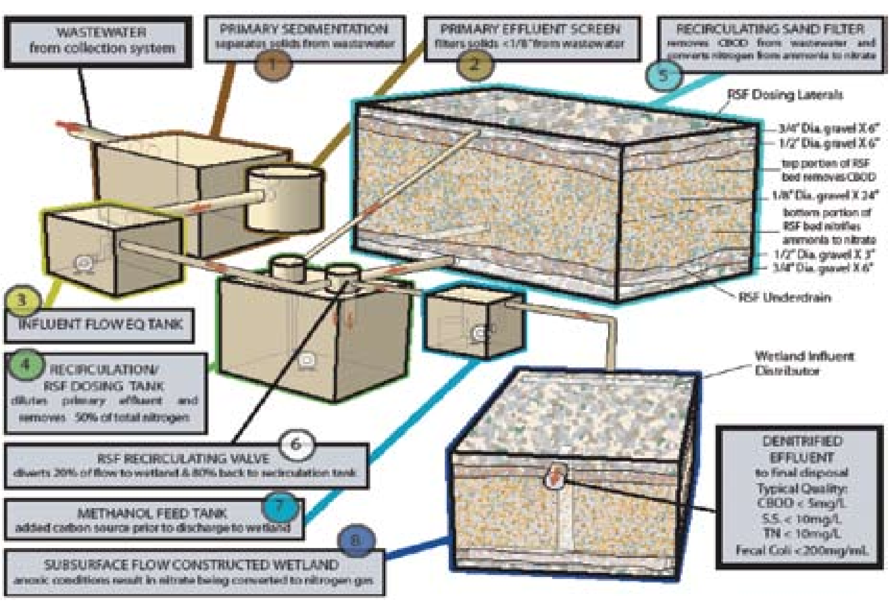
Set on a wooded summit of a mountain on the westerly side with a total development area of 35 acres, the project involved the addition of a 150-seat-capacity restaurant, 175-seat-capacity snack bar, four-toilet public restroom facility, 15-person staff and 20 office employees. It was to be a year-round facility for entertainment and dining during the day and early evening. The peak patron use was anticipated at about 500 people per day, with most activity in the restaurant facilities and bathrooms.

The development was to be serviced by private drinking water wells and a private sewage treatment facility located on the parcel. Wastewater flows, anticipated primarily from bathroom facilities and kitchens, were approximated as domestic waste in terms of the CBOD5 to total nitrogen ratio but were probably more concentrated. The wastewater flow generation from this facility was estimated to be around 7,500 gal per day (gpd) using Pennsylvania Department of Environmental Protection (DEP) Chapter 73 flow estimates. The treatment system design considered the stringent groundwater recharge and discharge regulations/limits, including denitrification, because of the glacial till soils and groundwater issues on the site.

RMF/Wetland Treatment

The proposed recirculating media filter (RMF)/constructed wetlands treatment system was designed by Whitehill Eng. Inc., who teamed up with Brinjac Eng. for the project. The process consists of primary sedimentation tanks, flow equalization tanks, recirculating packed media filter (to achieve biochemical oxygen reduction and nitrification of screened septic tank effluent) followed by denitrification in a subsurface flow constructed wetland system. This technology is licensed in the state of Pennsylvania by the DEP to discharge wastewater to soils where nitrogen removal is required or denitrification is needed. These wastewater treatment plants (WWTPs) have no aboveground components and use wetlands for polishing the effluent and for denitrification with a carbon source (methanol). The typical treatment process schematics for this selected technology is shown in Figure 1.

Figure 1. A schematic diagram of the system demonstrates the treatment process from collection to discharge in the wetland.



The RMF/wetland treatment system mainly involved two fixed-film processes in series to achieve desired wastewater purification. The first process involved a recirculating media filter, which more accurately would be termed a recirculating gravel filter due to the fact that the active part of the filter used for the project was fine gravel. This process consisted of primary tanks for solids removal, a fine screen to further remove particulate matter, recirculation tanks and the recirculating media (gravel) filter.

The settled and screened wastewater then was dosed intermittently onto a 4-ft-deep bed of various grades of gravel with an underdrain to maintain air within the void spaces in the gravel bed. The void spaces expose the wastewater to air for the oxygen required for efficient treatment. A bacterial film developed on the fine gravel media in the center of the bed would reduce the organic strength (CBOD5) of the wastewater. The bacteria deeper in the bed convert the ammonia-nitrogen in the wastewater to nitrate (nitrification process).

The wastewater typically gets recirculated through the gravel bed at an average of five to 10 times prior to discharging to the wetland treatment phase. The recirculation ratio was primarily a function of the organic strength of wastewater, and the recirculation ratio at the Benson's Fun Station RMF treatment system was considered to be between 8:1 and 12:1, typical for the strength of CBOD5 and Total Kjeldahl Nitrogen (TKN) anticipated in this wastewater. Because the RMF effluent and the primary tank effluent both get introduced to the recirculation tanks at the same point, an anoxic zone develops in the recirculation tank that partially denitrifies the wastewater prior to discharge to the wetland.

The RMF dosing frequency and duration, as well as the methanol feed rate, were controlled via a PLC that received input signals from floats mounted in the equalization tank. This arrangement consistently matched the RMF bed dosing pump operation to the rate influent wastewater was transferred to the RMF recirculation tank. This allowed the process to maintain a more constant recirculation ratio and dilution of the influent wastewater, especially beneficial to designs treating high-strength commercial or industrial wastewater or installations where the flow rate is highly variable.

The RMF effluent diverted by gravity was further treated at the wetland system. The wetland consisted of 4 to 5 ft of slightly coarser (0.5-in.-diameter) gravel, which provided the surface for bacterial growth. The gravel media in the wetland was always submerged, as opposed to the RMF, which was always drained. This "flooded" condition maintained anoxic to anaerobic conditions within the wetland, forcing the bacteria to use the oxygen in the nitrate (NO_3) ion during respiration. Stripping of oxygen from the ion resulted in nitrogen gas and denitrified the wastewater.

Final disposal of the denitrified effluent was proposed for treatment at the on-lot seepage beds. The onsite disposal beds with at-grade beds were selected because they were suitable for the soil type, undisturbed soil surface, convex landform and desire of the owner. This method of disposal promoted groundwater recharge, while the disposal bed areas included additional replacement bed areas that qualified as onsite replacement areas. Based on the perc test, the proposed 7,500-gpd WWTP was estimated to require an area of approximately 5.5 acres, primarily for the disposal beds, reserve areas and monitoring wells. The disposal beds were resigned as beds of

Figure 2. WWTP Flow Pattern During 2009-2010 Period

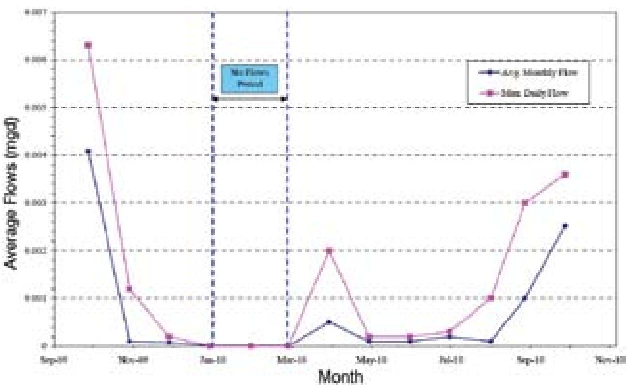


Figure 3. Effluent Total Kjeldahl Nitrogen (TKN): Nitrate and Nitrate Concentrations

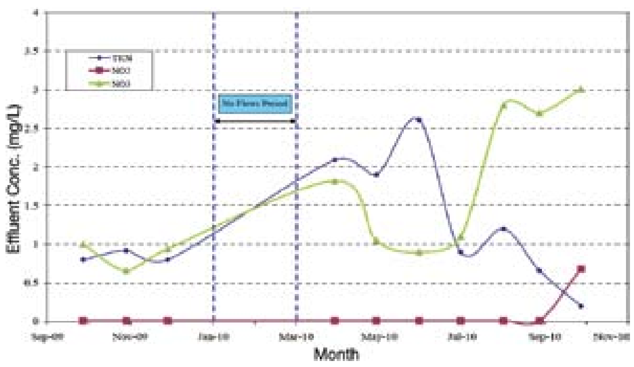
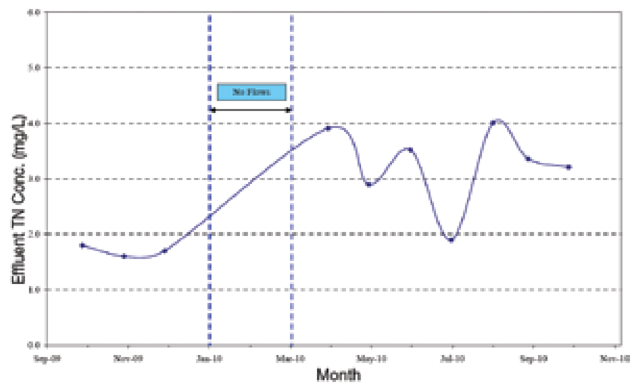


Figure 4. Effluent Total Nitrogen (TN) Concentrations



aggregate for pressure distribution on 20 in. of sand to mesh with the stumps and boulders. Monitoring wells were established in the area (two up-gradient and one down-gradient) to protect the existing groundwater from any possible contamination risks related to this project.

Post-Project Analysis

The project was completed in 2009, and the facility has been in operation since. The cost of this WWTP was estimated to be about 60% of that of conventional technology, and the operation and maintenance costs about 25% of that of conventional technology. For system performance analysis, monthly effluent data was monitored during the study period. The National Pollutant Discharge Elimination System (NPDES) permit requires the WWTP to monitor and report BOD, total suspended solids, monthly flow, nitrite, NO_3, TKN and total nitrogen (TN) concentrations. The average annual TN concentration is required to remain at less than 21.2 mg/L, whereas the pH is required to remain within 6.0 to 9.0 limits.

The treatment plant performance was analyzed based on the one-year (October 2009 to October 2010) operational data obtained from the WWTP discharge monitoring reports and was compared with the NPDES limits for compliance purposes. Figure 2 shows the treatment plant flow pattern during the one-year period.

The WWTP observed higher average daily flows during the September to October period (0.001 to 0.0041 million gal per day [mgd]), whereas the average flows remained below 0.001 mgd for rest of the year, with no flows during the January to March period. This no-flow period probably was due to no activities at the Fun Station during the winter period. The recreation facility observed increased activity in April, and this was reflected by spikes in WWTP flows during this month. Overall, the flows ranged from 0 to 0.0041 mgd (0% to 55% of design flow) during the one-year period, indicating significant variations in hydraulic loading to the treatment plant.

In addition, the ratio of maximum daily flow to the average month's daily flow ranged between 1.5 and 12, indicating the fluctuations observed in daily flows due to the seasonal nature of the Fun Station facility. This irregular flow pattern was anticipated. Considering the facility's flow projections, the WWTP flows observed were lower than anticipated, probably due to the economy and lower attendance at the facility. WWD

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