Post-Lagoon Nitrification in Cold Climates

Mark O. Liner, P.E., Senior Engineer, Stantec
Merle Kroeker, P. Eng, Project Development Engineer, Nelson Environmental Inc

A pilot facility in Steinbach, Manitoba is demonstrating consistent, post-lagoon, cold weather nitrification. The aerated gravel bed is built next to the Town's aerated lagoon and has been in operation since 2007. Results from the pilot demonstrate that a cold climate lagoon can be retrofitted to consistently achieve ammonia levels less than 1 mg-N/L over the Manitoba winter. The post-lagoon nitrification bed was developed and designed by Nelson Environmental and Jacques Whitford NAWE (now Stantec) and utilizes a dual-feed mode of operation to optimize nitrification.

Introduction

Use of aerated gravel beds has proven successful in the upper Midwest for the removal of ammonia (see *Kadlec and Wallace, 2008*). These beds, which evolved from a cross between engineered wetlands and submerged attached growth bioreactors, are currently being used in a number of different applications from glycol treatment at Buffalo Niagara International Airport to remediation of petroleum contaminated groundwater at a site in Casper, Wyoming. Though simple in concept, the coupling of theoretical design, practical engineering, and day-to-day operation has greatly advanced the use of these aerated gravel beds in passive treatment systems.

Through experience with treatment of landfill leachate in Jones County, Iowa, it was clear that an aerated, subsurface gravel bed could provide exceptional treatment of high ammonia concentrations for cold climates. Using the same theoretical knowledge and experience of engineering and operating residential systems, a design for a post-lagoon nitrification bed was developed by Nelson Environmental and Jacques Whitford NAWE (now Stantec).

The subsurface beds are essentially shallow, aerated lagoons filled with large diameter aggregate. The aggregate is important because it provides a foothold for bacteria to stay resident in the bed and not wash away in the effluent. Since organic and suspended solids loads are significantly reduced by lagoons, a stable nitrifier population can be established on the aggregate with limited competition from space-hogging heterotrophic bacteria. Nitrification in attached growth systems is known to flourish when BOD concentrations are below 25 mg/L (*Grady, Daigger, and Lim, 1999*). Moreover, the beds are engineered to minimize the mass flux of organics (lb-BOD/sf/d) to levels below that which are known to cause long-term fouling in infiltration beds (*Wallace and Kadlec, 2009*). Finally, a dual-feed mode of operation is utilized to protect the nitrifying bacteria from winter-time encroachment of heterotrophic bacteria.

Table 1. Pilot Project Sampling Frequency

	Water Analysis	Locations	Frequency	# of Samples/Year
1	cBOD5	5	weekly	260
2	BOD5	5	weekly	260
3	Ammonia-N (NH4-N)	5	weekly	260
4	TKN	5	weekly	260
5	Total Nitrogen	5	weekly	260
6	Nitrates	5	weekly	260
7	Total Alkalinity	5	monthly	60
8	Total Suspended Solids	5	weekly	260
9	Total Phosphorous	3	monthly	36
10	pH	5	weekly	260
11	Turbidity	2	weekly	104
12	Total Coliform	3	bi-weekly	78
13	Fecal Coliform	3	bi-weekly	78
14	E.Coli.	3	bi-weekly	78
15	Temperature	9	hourly (using loggers)	78840

Methods and materials

The Steinbach demonstration system was constructed following the primary/secondary aerated lagoon system at the Steinbach wastewater treatment facility. The uncovered aerated lagoon, with 28 days of retention time, has effluent BOD and ammonia concentrations that are elevated during winter months.

The pilot contains two parallel treatment trains, each consisting of two (2) aerated, submerged gravel beds in series. Each train receives 5,000 gpd (19 m^3/d) of lagoon effluent with winter-time water temperatures as low as 0.2 degrees Celsius. Train #1 receives flow at the front of the train year round. Train #2 receives flow at the midpoint of the train during summer months and at the front of the train during winter. A layer of insulating mulch was placed over the gravel bed to protect against freezing of the process flow.

The dual feed system of Train #2 is designed to allow nitrifier growth in the secondary zone of the train during warmer months, when organic loadings are lower in the influent. In winter, when BOD_5 in the lagoon effluent typically rises and heterotrophic encroachment occurs, the influent is diverted to the front of the train to accommodate the seasonal fluctuation of bacterial activity.

Nine temperature loggers were installed throughout the beds and the influent streams, taking hourly measurements. Water sampling ports are located at the end of each of the four treatment beds and one sample was collected from the influent water flow for a total of five sample sites. Influent water is collected using an automatic composite sampler over a 24-hour period, while samples from the other four sites within the beds are grab samples, collected from the ports using a peristaltic pump.

Water chemistry samples are collected and delivered to an independent laboratory the same day within four hours of collection. Samples were analyzed

Steinbach SAGR Under Construction

Steinbach SAGR in Winter

for Total Alkalinity, BOD5, cBOD5, Ammonia-N, TKN, Total Nitrogen, Nitrates, Total Suspended Solids (TSS), Total Phosphorous (TP), turbidity and pH. Samples were also tested for Total and Fecal Coliforms and E.Coli.

The frequency of sampling is described in tabular form below (Table 1). This sampling program continued throughout winter with minor changes.

Results

Graph 1 displays the concentrations of cBOD5, Ammonia (NH4-N) and temperatures measured in the pilot influent and effluent streams over the 2008 and 2009 results. Results for the other parameters are not provided, but are available upon request.

Discussion

Influent temperatures dropped close to freezing around November 22, 2008 and stayed low until late March, 2009. As soon as the water temperature dropped below 1 degree Celsius, a noticeable increase in BOD concentration from the aerated lagoon can be observed that correlates with an increase in effluent ammonia in the single feed control train. It is expected that the loss of nitrification is due to encroachment of attached growth heterotrophs into the nitrification zone. The heterotrophs are known to outcompete nitrifiers for space in attached growth systems, when organic loadings are above 27 mg/L as COD (*Grady, Daigger, and Lim, 1999*). Comparison of the influent CBOD values against the effluent NH_4-N values clearly supports this.

Use of dual feed redistributes the higher organic loading and related heterotrophic growth to the front of the beds during colder temperatures, which preserves the nitrification zone at the back of the beds from encroachment by organics and heterotrophic bacteria. Maintaining a distinct nitrification zone free of CBOD allows the system to consistently achieve ammonia levels below 1 mg/L, regardless of influent water temperatures.

Conclusion

The following conclusions can be made from the results of the pilot:

- A post-lagoon aerated gravel bed can consistently nitrify during prolonged cold weather conditions.
- A dual feed mode of operation is critical in buffering the impact of heterotrophic encroachment on attached growth nitrifiers during winter months. Control of influent BOD_5 (and heterotrophic growth) is critical in ensuring consistent winter-time nitrification in the submerged, aerated gravel beds.
- Organics (measured as CBOD) are completely and consistently reduced to below 3 mg/L within the aerated gravel beds during winter months.

Acknowledgements

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References

1. Grady, Daigger, and Lim, *Biological Wastewater Treatment*, Marcel Decker, New York, 1999.
2. Kadlec and Wallace, *Treatment Wetlands*, CRC Press, Boca Raton, 2009.

Graph 1. SAGR Following Aerated Lagoon