Design Guidelines for AQUAMEND® Denitrification Unit (ADU) using Patent-Pending AQUAMEND® Process

This document was jointly produced by Adventus Remediation Technologies and Make-Way Environmental to provide guidance for the design, operation, and maintenance of AQUAMEND® Denitrification Units (ADU) for on-site denitrification of domestic wastewater.

Background:

Biological denitrification consists of the conversion of nitrate to nitrogen gas. The nitrate is used by microorganisms much in the same way as humans use oxygen. Once the dissolved oxygen is depleted from a municipal wastewater, the microorganisms in the AQUAMEND denitrification bioreactor will convert the nitrate to nitrogen gas, which harmlessly diffuses into the atmosphere. To perform this process, microorganisms also require a food source (i.e. carbon). ADU Liquid Carbon is metered to the system to provide this carbon source.

To implement an ADU, it must follow a tertiary treatment system, where the ammonia has been converted to nitrate, and there is very low biological oxygen demand (BOD). The ADU may provide limited removal of ammonia or other nitrogen sources, but it is only designed to remove nitrate.

The ADU Technology

The AQUAMEND Denitrification Unit utilizes the patent pending AQUAMEND® process and comprises a number of components. The AQUAMEND denitrification bioreactor houses the AQUAMEND biocarrier, which is an engineered inorganic granular media that is designed to promote significant biomass growth, and to protect that biomass in cases of system upset. The microorganisms that grow in, on the surface of, and in the pore space between the AQUAMEND media denitrify the wastewater given the appropriate ADU Liquid Carbon dosage. A second bioreactor is utilized for aerobic polishing. The aerobic polishing step removes any soluble BOD that was not consumed in the denitrification portion of the reactor. This aerobic portion ensures that sufficient ADU Liquid Carbon can be used to provide complete denitrification, without risking any excursions on BOD limits.

Another key component of the ADU is the recycle region. Water is pumped in an up-flow manner through the denitrification portion of the bioreactor. Approximately 80% of the flow is returned to the recycle region, and the other 20% is pumped into the aerobic portion of the bioreactor. Once through the aerobic portion of the bioreactor, it is typically discharged to a pump chamber. The ADU Liquid Carbon is injected into the recycle region using a Stenner Injection Pump. The Liquid Carbon is usually injected into the line returning from the denitrification basin for maximum mixing. The ADU Liquid Carbon will need to be replenished approximately every 30 to 45 days.

Operation and Maintenance

For the first 6 months of operation, the system must be closely monitored, and frequent sampling must be undertaken to ensure the system is operating properly. Once receiving fully nitrified wastewater, there will be an approximate 2-month time frame required for the proper biological community to become established in the AQUAMEND bioreactor before consistent performance can be expected. This initial sampling period should be used to optimize the frequency of changing of the ADU Liquid Carbon.

Once the system has been optimized, regular operation and maintenance will consist of replacement of the ADU Liquid Carbon, air sparging of the reactor every 6 months or as required, and regular maintenance of pumps, air compressor, and other hardware. Quarterly sampling should be performed to monitor the performance of the system.

Hydraulic Sizing of ADUs

The standard ADU consists of a denitrification reactor and an aerobic reactor. The sizing of these reactors will depend upon the average daily flow rate, and the ratio of the peak flow rate over a 1-hour period to the average daily flow rate. The size of the reactor is determined by calculating the hydraulic retention time (HRT), which is identical to the empty-bed contact time. The HRT is calculated as in Equation (1)

$$HRT = V/Q \qquad (1)$$

Where V is the volume of the portion of the region that is filled with the AQUAMEND biocarrier, and Q is flow rate. If the flow rate were 5,284 gallon per day (GPD) and the biocarrier volume was 400 gallons, then the HRT would be equal to 1.8 hours.

The hydraulic criteria used for designing the system are the following:

- the HRT based on the average daily flow rate must be at least 2 hours; and
- the HRT based on the peak flow rate must be at least 1 hour.

The net result of this condition is that when the ratio of the peak flow rate is less than 2 times the average daily flow rate, the HRT is set to 2 hours based on the average daily flow. When the ratio of peak to average daily flow is greater than 2, the HRT is set to 1 hour based on peak flow rate. Table 1 explicitly states the HRT required for a variety of ratios of peak to average daily flow rate.

Table 1. Hydraulic design criteria for HRT depending on ratio of peak to average daily flow rate.

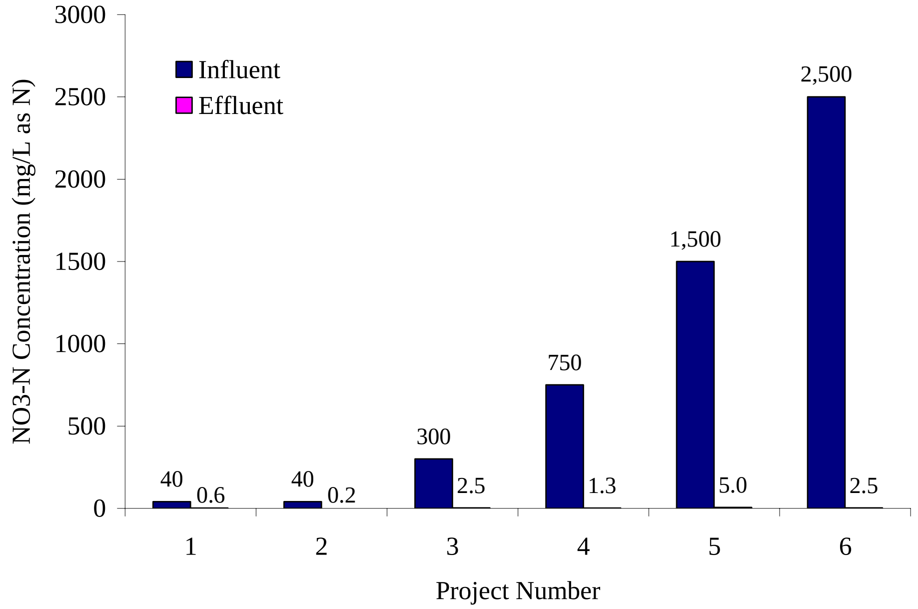
Ratio of Peak Flow Rate to Average Daily Flow Rate	HRT based on average daily flow	HRT based on peak flow
1.5 or less	2	N/A
2	2	1
2.5 or greater	N/A	1

Nitrate-Nitrogen Loading Calculation

In cases where the expected nitrate-nitrogen concentration will be very high, it may be necessary to increase the size of the unit to accommodate the higher nitrate-nitrogen loading.

Data are presented in Figure 1 that represent optimized performance of the AQUAMEND process for the removal of nitrate-nitrogen from various bench-scale and field-scale projects. The influent concentration ranged from 40 to 2,500 mg/L, and the effluent in each case was non-detect. The effluent data are plotted at half the detection limit.

From this combination of bench-scale and field-scale projects, the optimized hydraulic retention time required to provide greater than 98% denitrification of nitrate-nitrogen was plotted versus the influent nitrate-nitrogen concentration, as shown in Figure 2. This chart illustrates that as the influent nitrate-nitrogen concentration increases, the optimized hydraulic retention time required to treat the water must also increase.



Note: All effluent values were non-detect. Plotted at half detection limit.

Figure 1. **Influence of optimized AQUAMEND treatment performance on removal of nitrate-nitrogen from various wastewaters.**

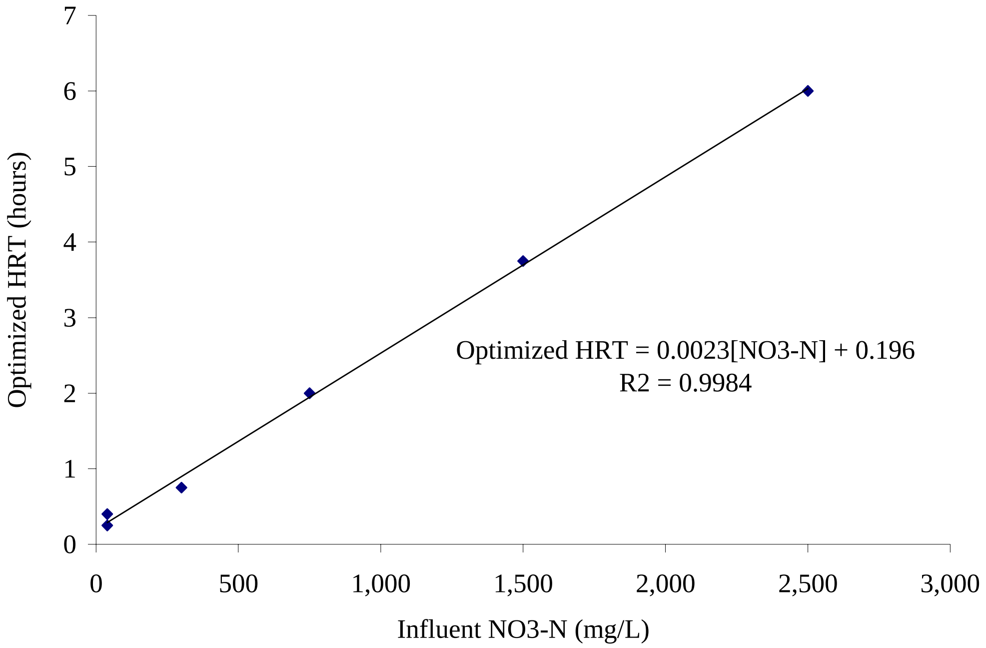


Figure 2. **Influence of influent nitrate-nitrogen concentration on optimized hydraulic retention time required to reduce nitrate-nitrogen concentration by greater than 98%.**

A straight-line curve provides an excellent fit to the data. The equation of this line is given by the following (Equation 3):

$$\text{Optimized HRT} = 0.0023 * [\text{NO3-N}] + 0.196 \quad (3)$$

where [NO3-N] is the influent nitrate concentration expressed in terms of mg/L as nitrogen, and the Optimized HRT is expressed in hours.

The condition that must be verified is the following:

The hydraulic retention time for the denitrification bed volume based on the peak flow must be at least 1.5 times greater than the Optimized HRT as determined in Figure 2 or Equation (3).

Multiplying the Optimized HRT by a factor of safety of 1.5 should allow for differences in the treatability of various wastewaters.

Summary

This process can be summarized by the following steps:

1. Determine the average and peak flow rates, and the expected influent nitrate-nitrogen concentration expressed in mg/L as N.
2. Determine if the ratio of the peak flow rate to the average daily flow rate is greater or less than 2.
3. If the ratio is less than or equal to 2, calculate the denitrification AQUAMEND bed volume using an HRT of 2 hours based on the average daily flow rate.
4. If the ratio is greater than 2, calculate the denitrification AQUAMEND bed volume using an HRT of 1 hour based on the peak flow rate.
5. Calculate the aerobic AQUAMEND bed volume by dividing the denitrification AQUAMEND bed volume by 2.
6. Calculate the Optimized HRT based on the influent nitrate-nitrogen concentration.
7. Multiply the Optimized HRT by 1.5.
8. Check to ensure that 1.5 times the Optimized HRT is less than the hydraulic HRT calculated with the peak flow rate. If so, the hydraulic HRT determines the sizing.
9. If 1.5 times the Optimized HRT is greater than the hydraulic HRT calculated with the peak flow rate, then 1.5 times the Optimized HRT must be used to determine sizing based on the peak flow rate.