media analysis

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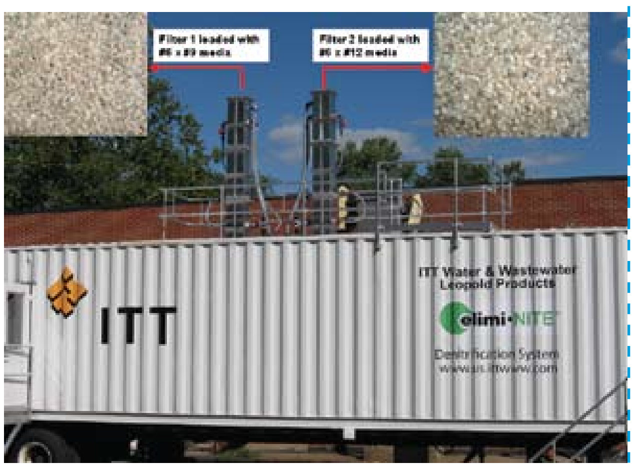
Pilot study of deep-bed denitrification filtration using different sources of siliceous media

Denitrification is a biological process in which nitrate is reduced to nitrogen gas in a step-wise manner by electron donors (usually methanol) in the absence of oxygen. It is generally recognized that denitrification is carried out with the aid of various enzymes produced during the process in the form of intracellular and extracellular polymeric substances, (e.g., nitrate reductase, nitrite reductase, nitric oxide reductase and nitrous oxide reductase).

In a down-flow deep-bed denitrification filter, wastewater enters over troughs located along the laterals or width of the filter bed, and effluent flows out from the bottom of the filter through a control valve into a clearwell. A filter must be taken out of service at regular intervals for a short backwashing cycle consisting of air scouring and backwashing with air and water. Nitrogen-release cycles are needed to remove nitrogen gas bubbles that are produced during denitrification and accumulated in the media. In designing denitrification filters, the following parameters usually are considered: loadings, empty bed retention time, temperature, sludge production, backwash frequency, media size, carbon source, etc.

Traditionally, 2- to 3-mm-size silica sands were used in deep-bed denitrification filters; however, different sources of media have different characteristics, especially in terms of size and shape. The effects of media on process performance were not understood previously. It was controversial to apply different types of media, especially in terms of sphericity, in designing deep-bed denitrification filtration systems. To provide proper design parameters in applying different types of media, a pilot study was conducted to examine the effects of two different sources of media from two leading suppliers in the U.S.



Pilot trailer, and media loaded in the filter columns.

Materials & Methods

The pilot unit was housed in a 45-ft-long container trailer mounted on a twin-axle rolling chassis. There were two filter columns installed inside the trailer. Filter No. 1 was filled with 6 ft of #6 x #9 media from Colorado and Filter No. 2 was filled with 6 ft of #6 x #12 media from New Jersey.

The voids (interstitial spaces) of the media were measured by filling a container with media and water and measuring the volume of the water that occupied the voids. The interstitial space of #6 x #9 media was 38.9%, ±1.3% (standard deviation), and that of #6 x #12 was 40.4%, ±1.2% (standard deviation). Given the standard deviations, there was not a significant difference between the two media for interstitial space.

These two media, however, looked quite different. The #6 x #9 media was round and smooth, and #6 x #12 media had angular edges. The sieve analysis for both media showed that the sizes of #6 x #12 media ranged from 1.61 mm (D8) to 3.25 mm (D92), and the sizes of #6 x #9 media ranged from 2.13 mm (D8) to 3.46 mm (D92).

The process equipment included the following:

- Dual independent filter feed systems;
- Two 1-sq-ft-by-17.5-ft-high independent filters with automatic valves;
- Common backwash system;
- Common air scour blower;
- Dual independent carbon source delivery system;
- Computer PLC control system with flow, level and analytical instrumentation data acquisition; and
- Methanol dilution and handling system.

The unit was designed to data log variables such as influent flow, influent nitrate, influent temperature, influent dissolved oxygen, influent pH, influent turbidity, effluent nitrate, effluent oxygen and effluent turbidity. From time to time, lab analysis was conducted to verify the online instrument readings.

The two filters were operated continuously in parallel at constant- and variable-level mode from May to October 2009 at the Western Butler County Authority (WBCA) in western Pennsylvania.

Results & Discussion

Three runs at a constant-level mode were selected in June and early July 2009 at a hydraulic loading of 3 gal per minute (gpm)/sq ft. Each run was defined as the operation period between two consecutive backwash events. Once the filters were backwashed, they were put in the forward-flow mode until the filter water level reached the overflow level (17 ft).

The selected three runs are summarized in Table 1. In each run, the initial head loss in the two filters was maintained at similar levels (difference of less than 1 ft). The filters were operated in a constant-level mode by modulating the effluent control valve with water levels at 15.5 ft for Runs C1 and C2 and 10.5 ft for Run C3. These three runs indicated that Filter No. 1 (#6 x #9) had longer runtimes than Filter No. 2 (#6 x #12). It is likely that the angular edges of the #6 x #12 media created an irregular fluid flow path and resulted in faster head loss buildup.

It is interesting that Filter No. 2 (#6 x #12) had better nitrate and turbidity removal (data not shown) performance than Filter No. 1 (#6 x #9). The nitrate removal difference was up to 3%. The better performance indicated that #6 x #12 media had stronger capability to conserve biomass. Figure 1 (see page 46) shows the process performance for Run C2.

The theoretical runtime calculated based on the average influent characteristics (10 mg/L NO_3^--N and 10 mg/L total suspended solids [TSS]) at WBCA

Table 1. Summary of Selected Runs for Media Comparison

	Constant Level Mode						Variable Level Mode					
	Run C1		Run C2		Run C3		Run V1		Run V2		Run V3	
	F 1	F 2	F 1	F 2	F 1	F 2	F 1	F 2	F 1	F 2	F 1	F 2
Period	June 18-22		June 22-24		July 1-5		July 21-24		July 27-31		July 31-Aug. 3	
Runtime (hours)	57	54	31.3	26.7	59.8	42.3	73	71.5	101	101	74	74
Total nitrate removed (lb)	0.59	0.56	0.41	0.34	1.00	0.67	1.27	1.30	1.60	1.67	0.78	0.86
Average loading (lb NO_3^--N removed/sq ft/day)	0.25	0.26	0.29	0.30	0.39	0.39	0.41	0.44	0.38	0.40	0.26	0.29
Average effluent nitrate (mg/L)	0.93	0.86	1.87	1.69	1.95	1.91	0.53	0.55	0.73	0.43	0.67	0.17
Average nitrate removal efficiency (%)	87.8	88.8	79.6	83.0	84.5	84.8	96.4	96.0	94.5	97.0	91.8	97.9

Note: F1, Filter 1; F2, Filter 2

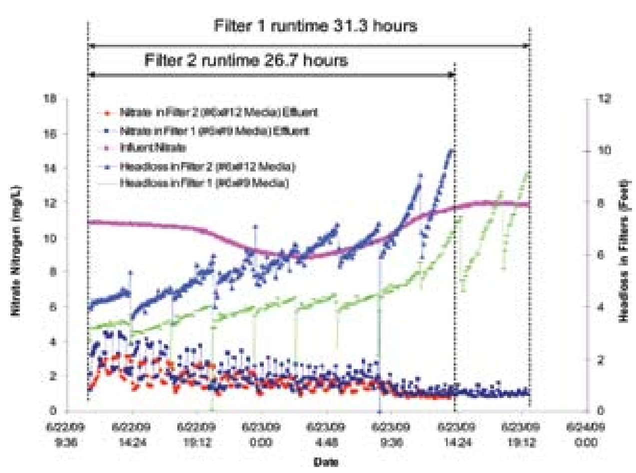
was around 72 hours, assuming the solids load of 1.2 lb/sq ft. At the constant level of 15.5 ft, it was likely that the influent suspended solids did not penetrate into the media and formed a blanket (similar to Schmutzdecke in slow sand filters) on the top of the media and generated head loss that prevented water flowing through the media.

Both filters in Run C1 had longer runtimes than in Runs C2 and C3, and the runtimes of filters No. 1 and 2 were similar. In Run C1, the influent nitrate nitrogen was lower (0.26 lb NO_3^--N removed/sq ft/day). At this loading, it appears that the influence of media on runtime was less pronounced.

Interestingly, a previous pilot study at Miami-Dade for comparison of #6 x #9 and #6 x #12 media for deep-bed filtration (suspended solids removal, only without methanol addition) indicated that the filters loaded with #6 x #12 media had longer runtimes and lower effluent TSS. This indicated that angular media provided larger capacity of storing biomass and also suggested the importance of the microbial growth on head loss buildup and solids accumulation in the bed.

In July 2009, three runs were conducted at variable-level mode, starting from 8-ft water level at the hydraulic loading of 3 gpm/sq ft. As shown in Table 1 (see page 44), the average nitrate (removed) loading of Filter No. 2 (#6 x #12) was always larger than that of Filter No. 1 (#6 x #9). This confirmed the results of constant-level mode operation in that #6 x #12 media had larger capability to conserve biology and better performance for denitrification than #6 x #9 media. These two filters had similar runtimes

Figure 1. Process Performance for Run C2



and there were no significant differences in filter runtimes. This suggests that the influent water splashed down from the top of the filters to low levels and may have driven influent suspended solids to penetrate into the media instead of forming a biomass blanket on the top of media. Filter run times in Run V2 were even longer than that calculated based on the solids load 1.2 lb/sq ft.

To meet the stringent effluent limits, it is recommended that #6 x #12 media be applied at a variable-level mode to achieve better process performance and similar runtimes of #6 x #9 media. Also, it should be applied under the situations in which nitrate loading was lower—typically no greater than 0.26 lb NO_3^--N removed/sq ft/day—at a constant-level mode to minimize oxygen pickup as influent splashing down to the filters.

Performance Results

Based on the results of this study, the following conclusions were drawn:

- Under the same operating conditions, #6 x #12 media suffered shorted runtimes as compared to #6 x #9 media under constant-level mode operation.
- The filter performance was better for #6 x #12 media in terms of nitrate and solids removal. The nitrate removal difference was up to 3%.
- The angular edges of the #6 x #12 media had stronger ability to conserve the biology inside the voids and also created irregular fluid path within the media. These characteristics and smaller particle size contributed to faster head loss buildup.
- When operated in a variable level mode, #6 x #9 media and #6 x #12 media have similar runtimes. This suggested that suspended solids were driven into the media instead of forming a biomass blanket on the top of the media. WWD

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