Fixed Bed Biofilm Reactor for the Removal of Ozonation Byproducts

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Abstract
The use of ozone in drinking water is often followed by biofiltration to remove biodegradable organic matter (BOM) and reduce the risk of biofilm development in the distribution system. An alternative approach was evaluated by SNWA involving a fixed bed biofilm reactor (FBBR) with porous plastic media to promote biofilm development. A pilot study was conducted using dechlorinated full-scale filter influent water (containing iron floc particles) and sent to a 6-column pilot plant. Results showed up to 50% removal of assimilable organic carbon (AOC) and up to 40% removal of UV254 after 9 months of operation.

Introduction
The use of ozone in drinking water is often followed by biofiltration to remove biodegradable organic matter (BOM) and reduce the risk of biofilm development in the distribution system. However, several operational concerns are also associated with biofiltration including increases in head loss, particle counts, fouling of filter media support plates, and inability to feed an oxidant throughout the treatment plant. With this in mind, the Southern Nevada Water Authority (SNWA) evaluated an alternative biological treatment approach by promoting biofilm development on porous plastic media within a fixed bed biofilm reactor (FBBR).

Installation of a FBBR would be beneficial upstream of treatment plant filters to maintain their design performance criteria and provide an additional treatment barrier to sloughed FBBR biomass. The FBBR could be located in the last chamber of an ozone contactor or the ozone effluent channel, as the dissolved ozone residual is zero due to either quenching or dissipation. Further, if porous plastic media has the affinity to develop biomass without accumulating head loss, then biological treatment could be accomplished with minimal impact on operations. Therefore, SNWA conducted a pilot study to determine whether a FBBR approach would be feasible for significant AOC removal.
Materials and Methods

A pilot plant located at the SNWA was used to perform the FBBR testing. The pilot plant consisted of six columns, each with a six-inch diameter. The columns were operated under gravity feed from a head tank with flow from top to bottom. Jaeger Tri-Pack media was used due to its NSF61 certification for use during drinking water treatment. The columns were loaded and operated under the following media, hydraulic loading rate (HLR), and empty bed contact time (EBCT) conditions:

- Column #1: 1” media, 9 gpm/sf, EBCT=6 min
- Column #2: 1” media, 4.5 gpm/sf, EBCT=12 min
- Column #3: 1.5” media, 9 gpm/sf
- Column #4: 1.5” media, 4.5 gpm/sf
- Column #5: 2” media, 9 gpm/sf
- Column #6: 2” media, 4.5 gpm/sf

Full-scale filter influent water, which had been treated with ozone, free chlorine (1.8 mg/L residual), and ferric chloride, was supplied to the pilot plant. Upon entering the pilot plant, the chlorine residual was quenched with calcium thiosulfate. Each column was equipped with online instrumentation including a turbidimeter, particle counter, flow meter, and head loss transmitter. All instrumentation data was logged in the full-scale SCADA system to facilitate data acquisition.

Results

Water Quality

The pilot study operated from November 2010 through January 2012. During this time, the temperature of the influent water fluctuated between 12°C and 17.5°C (Figure 1). Throughout the testing, the pH remained between 7.6-7.8 and TOC varied between 2.4-2.6 mg/L.
Retention of Iron Floc Particles

Within 3 months, the columns began to show signs of iron floc retention (Figure 2). However, there was no significant head loss accumulation during this time.
Development of Biological Activity

When the water temperature began to increase in April 2011, the development of biomass in the columns became visible. Throughout the testing period, influent and effluent samples were collected from each column for UV254 (weekly) and AOC (monthly), as shown in Figures 3 and 4. UV254 results showed greater removal when using the smaller diameter media (1”) versus the larger diameter media (2”). Removal of UV254 reached a maximum of 40% in October of 2011 using the 1” media, as compared to a maximum of 15% with the 2” media. The removal of AOC showed a similar response as UV254; removal rates increased throughout the summer months reaching a maximum of 50% with the 1” media and 30% with the 2” media in October 2011. As the removal of AOC and UV254 increased so did turbidity (in all columns), particle count (in all columns) and head loss (in Columns #1 and #3). Due to fouling, particle counter operations were discontinued in August 2011. Overall, the columns performed the best in mid-October with biomass and iron floc accumulations visually evident (Figure 5).

Figure 3. – Decrease in UV254 absorbance during the testing period.
Figure 4. – Decrease in AOC during the testing period.

Figure 5. – Photo of column #1: November 22, 2010 (left) and October 17, 2011 (right).
Loss of Biological Activity

In November 2011, snails appeared in the columns. The snail population began to multiply rapidly throughout the month. As shown in Figure 6, egg sacs were visible within some white biomass inside the column. Five days later in the same column section, adult snails were present and the white biomass had disappeared. The snail proliferation coincided with a gradual decrease in FBBR performance. By the end of November, nearly all of the FBBR biomass had been consumed by the snails. The UV254 removal decreased to less than 10% and head loss returned to 0 ft in the best performing FBBR (Column #1). Future studies would need to incorporate a snail mitigation plan to prevent proliferation, which leads to loss of biomass and degradation of FBBR performance.

CONCLUSIONS

- The pilot study showed that 50% of the AOC could be removed through a FBBR using porous plastic media.
- The results demonstrate that the concept may be applicable to full-scale systems. However, additional pilot scale testing is warranted under greater HLRs and varying influent water quality conditions.