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Decreased Filter Run Volume Investigation Leads to an Unlikely Culprit

After a New York plant converted to biofiltration, staff initially thought hot summer temperatures, new procedures, and other factors were decreasing filter run volumes. But when the plant couldn't reach design-rated capacity, an evaluation revealed a deposit obstructing the filter effluent valve.

BY ERIN K. MOORE

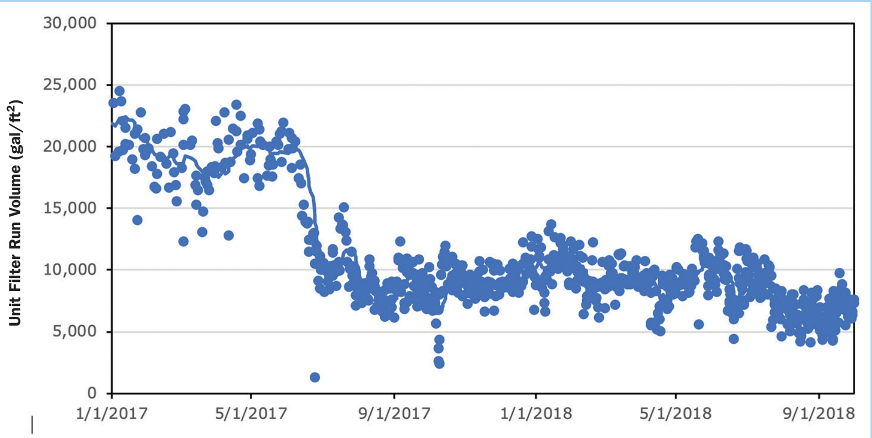
THE FILTERS AT Poughkeepsies' Water Treatment Facility (PWTF) in New York experienced lower unit filter run volumes (FRVs) since early 2017, when they became biologically active. The plant has a design capacity of 19.3 mgd, but the biofilters limited its capacity to about 12 mgd. To operate at capacity, the plant investigated its filtration processes to determine the cause of its low FRVs.

PWTF treats 10.4 mgd of Hudson River water for the town and city of Poughkeepsie. The city constructed the first water treatment facility in the United States in 1872 using slow-sand filters. With the addition of chlorine in 1909, the plant ran for 90 years before a new plant replaced it in 1962.

At that time, the PWTF treatment process included chemical addition, solids contact clarifiers, sedimentation, and conventional filtration. Ultraviolet (UV) disinfection was installed, and the filters—including underdrains and air backwash—were upgraded in 2004. Although the plant was operating well, a new water quality issue emerged caused by disinfection byproducts (DBPs), which were produced by conditions in the distribution system, not by the raw water source (the Hudson River).

Figure 1. Declining FRVs

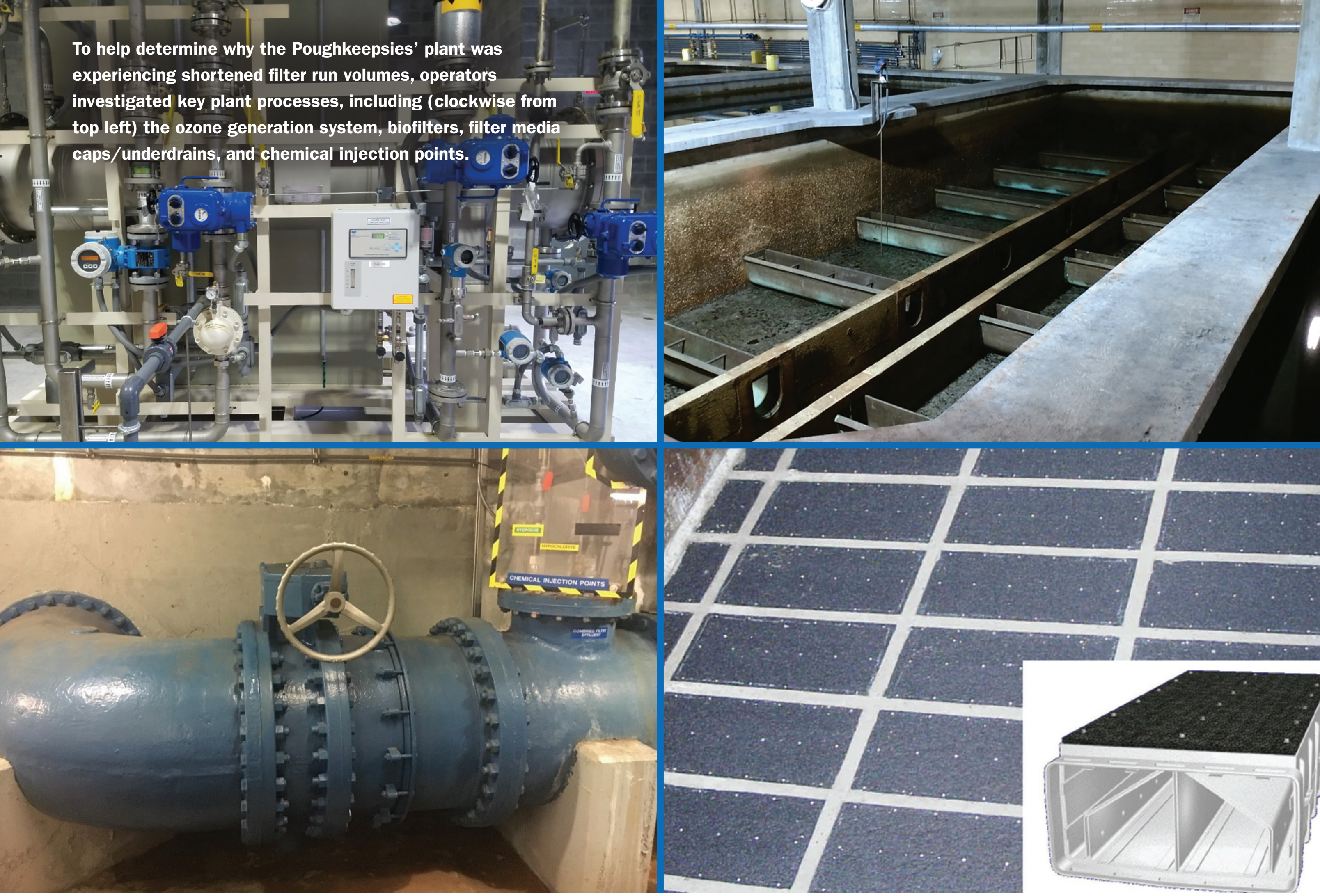
When FRVs continued to decrease, the issue became a significant concern.



DBPR COMPLIANCE

DBPs form when the chlorine residual that controls pathogens in the water distribution system has been in contact with trace natural organics, forming compounds that are hazardous to human health. The US Environmental Protection Agency (USEPA) began regulating these compounds with the Stage 1 and 2 Disinfectants and Disinfection Byproducts Rules (DBPRs); facilities where DBPs were detected were given compliance dates.

To comply with the DBP regulations, Poughkeepsies' Joint Water Project Board installed an ozone treatment system. The advantage of using ozone is its ability to break down the natural organics



To help determine why the Poughkeepsies' plant was experiencing shortened filter run volumes, operators investigated key plant processes, including (clockwise from top left) the ozone generation system, biofilters, filter media caps/underdrains, and chemical injection points.

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that can result in DBPs forming in the distribution system. However, the remaining degraded organics leaving the ozone system need enhanced filtration or they can increase biology in the distribution system. Biologically active filters that feed on organic nutrients located after the ozone system remove these organics before UV disinfection and chlorine addition.

In 2015, ozone contactors were installed prior to the filters. Also, at that time, the sand and anthracite filter media were removed and replaced with granular activated carbon (GAC) filters. The filters started to become biologically active in September 2016 when the upstream ozone process was placed online. In January 2017, operating adjustments were made to optimize organic removal.

Initially, lowered FRVs were attributed to hot summer temperatures, new operation and maintenance procedures for plant staff, and anticipated reductions known to be associated with biofiltration use. However, when FRVs in the summer of 2017 continued to decrease (Figure 1), the issue became a significant concern.

Under normal summer conditions before the conversion to biofiltration, the plant would see FRVs of at least 30,000 gal/ft^2; however, FRVs began to significantly decrease to below 10,000 gal/ft^2 during a time when the plant should be doing its best. While some FRV reduction was anticipated, this level of reduction was unexpected and made it impossible for the plant to reach its design-rated capacity of 19.3 mgd.

BIOFILTER ASSESSMENT

Based on the understanding that increased biological growth during warmer weather likely led to the shortened FRVs, plant staff evaluated the biofilters. This was a logical basis for the initial evaluation. Although biological growth has been used in the United States in wastewater treatment for years, its use in water treatment has increased because of the DBPRs. Many water treatment facilities are experiencing a learning curve when it comes to these systems.

In 2018, AWWA's international symposium on biological treatment extensively covered reduced filter run times and media clogging problems. Discussion with seven other surface water treatment plants that used ozone and biological filtration indicated that approximately 25 percent of plants experienced moderate negative effects, including shortened filter run times, after converting from conventional to biologically active filtration and ozone.

A systematic evaluation followed that investigated each biofilter component, including the following:

- Assessment of filter underdrain media caps, including evaluation of biology and capacity testing. The PWTF filters use dual parallel later underdrains with media retention caps. Backwashing protocol was also reviewed for conformance with similar facilities.
- Assessment of the biological growth on the filter media and head loss through the media, including biology and GAC media condition. GAC media condition review included abrasion number,

apparent density, ash content, iodine number, and particle size distribution.

- Evaluation of appropriate ozone dose, backwash procedures, backwash chlorination, influent chlorination, and biomass reduction using a caustic soaking procedure.

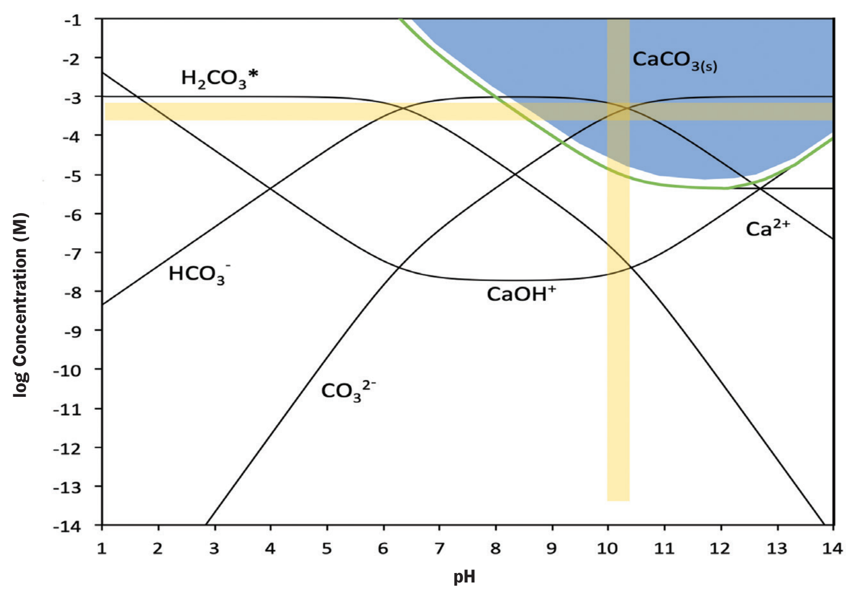
BIOFILTER OPTIMIZATION

The evaluation resulted in the following biofilter optimization recommendations that can be applied to any plant with a similar treatment process:

- Maintaining the recommended ozone-to–total organic carbon (TOC) ratio of 0.5 is important for limiting biomass growth, maintaining plant system redundancy, and conserving energy. Continued observation of ozone dosage is recommended to limit dose while achieving DBP removal potential.
- The plant should monitor the biomass concentration approximately 6 in. below the filter surface monthly for one year to understand how it varies with temperature and seasonal changes in source water quality. If biomass concentration exceeds $1{\times}10^7$ colony-forming units per gram (CFU/g), chlorine at a dose of 0.5 mg/L should be added to filter influent.
- GAC media has a limited life span. GAC testing is recommended if FRVs begin to decrease.
- Pressure gauges on the backwash line allow operators to monitor head loss during backwashing. If the pressure required to deliver the same flow rate increases over time, it might indicate fouling is occurring in the filter media and/or on the media retainer cap or sand is penetrating the cap. Excessive pressure can damage the underdrains, so monitoring pressure can help protect the underdrains.
- Differential pressure meters measuring head loss through the filters should be used to collect additional information when determining whether to terminate filter runs. For example, if head losses of 5–6 ft can't be reached at the PWTF with the filter effluent valve opened at 70 percent, plant staff should investigate other head loss sources The plant should continue to monitor cleanbed and end-of-run head loss and begin monitoring backwash pressure.
- Use a different backwash protocol during the summer and winter, as water density is temperature-dependent. Typically, filters are backwashed longer and at a lower rate during the winter. Consider seasonally modified backwash protocols.

Figure 2. Calcium Solubility Diagram

A locally elevated pH condition led to calcium precipitation and scale formation.



Note: Diagram by Jennifer Lawrence, Tighe & Bond, with reference to *Aquatic Chemistry Concepts*, Second Edition, Dr. James Pankow

The evaluation also determined backwash procedures were effective and there was no filter underdrain clogging, media clogging, or media degradation. None of the usual suspects were contributing to the plant's low FRVs.

REVEALING THE CULPRIT

While reviewing the backwash procedures, operators observed the 24-in. filter-to-waste piping could pass 3.2 mgd, but the 30-in. filter effluent piping could only pass 1 mgd. This indicated a hydraulic restriction. Although this seems like an obvious red flag, operational procedures were based on flow control valve position, not head loss through the filters. Additionally, head loss gauges measured differential before and after the filter and didn't reflect a loss occurring after the filter in the effluent piping.

During the backwash procedures, operators observed a tremendous amount of air being released through the filter-to-waste piping. It was theorized that air binding may have caused the issue, thus air release valves were installed on the filter effluent piping. Unfortunately, although the valves effectively released trapped air, they didn't affect FRVs.

There was only one component left to investigate: the final effluent valve for all the filters. Operators indicated it was opened and couldn't be closed. By draining the piping and opening the chemical injection tee, the operators were able to insert

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a camera into the piping and found a large crystalline deposit blocking the valve.

Plant staff removed the valve and replaced it with a spool piece. As shown in the photo at right, the scale blocked most of the valve, severely restricting flow and increasing the system's head loss.

A deposit sample was analyzed to determine the scale's elemental composition. The following parameters were quantified: aluminum, calcium, iron, magnesium, manganese, sodium, phosphorus, and TOC. Calcium was the most abundant of the analyzed elements, but a substantial fraction of the sample was unknown. Inorganic carbon (i.e., carbonate) might have contributed to the unknown fraction.

The valve is located immediately downstream of sodium hypochlorite (NaOCl) and sodium hydroxide (NaOH) injection points. Both chemicals are added continuously, but the NaOH dose was increased by a factor of approximately 3 (from a dose of 3–5 mg/L to 13.5–17.5 mg/L) when enhanced coagulation was practiced to remove organics before the ozone system became operational. The plant practiced enhanced coagulation with carbon dioxide addition prior to solids contact clarifiers from January to August 2017, which was the same period when the filters became biologically active. Thus, the deposit caused the low FRVs, but it was obscured by the simultaneous conversion to biofiltration.

It's likely this increased NaOH addition caused a locally elevated pH condition, which led to calcium precipitation and scale formation. The calcium concentration in the filter effluent is relatively low at 22–36 mg/L, but as shown in the calcium solubility diagram in Figure 2, it's firmly in the solid phase (indicated in blue shading) at this concentration (10^{-3} to 10^{-4} M) once pH reaches 10. It's likely a high pH occurred near the NaOH injection point because the NaOH lacked sufficient time and turbulence to mix completely.

Assuming only 1 percent of the calcium in the filter effluent contacted the high pH area and was converted into solid

PWTF staff ultimately discovered scale deposits blocked most of the filter effluent valve, severely restricting flow and increasing head loss through the system.

calcium carbonate ($CaCO_3$), a precipitation rate of 32 in.^{3}/mil gal of filter effluent could occur. For comparison, a tennis ball has a volume of 8 in.^{3} Not all precipitated $CaCO_3$ would be expected to scale the filter effluent valve, but this growth easily could have occurred over a relatively short period of time.

PROBLEM SOLVED

Well-functioning biologically active filters are critical to helping PWTF meet its hydraulic capacity and water quality targets. Biofilters help PWTF meet its treatment objectives by lowering DBP formation potentials to meet the DBPRs and lowering the assimilable organic carbon concentration, which helps limit DBP formation and microbial regrowth in the distribution system.

Although interviews with other biofiltration plants indicated biofilters can experience seasonal shortened filter run times, the biomass in the filters was determined not to cause the shortened FRVs experienced at PWTF. They were caused by the formation of a $CaCO_3$ scale on the filter effluent valve. Once the valve was removed and replaced by a spool piece, FRVs immediately increased (Figure 3). In the summer of 2019, FRVs were typically between 20,000 and 25,000 gpd/ft^2, indicating an FRV reduction consistent with expectations.

***Author's Note:** Thanks to Randy J. Alstadt, Poughkeepsies' Water Treatment Facility administrator, and James Pankow, author of the new* Aquatic Chemistry Concepts, Second Edition, *for their contributions to this article.*

Figure 3. Unit FRVs Before and After Valve Removal

Once the valve was removed and replaced by a spool piece, FRVs immediately increased.