Application Note 126

Defining Drinking Water Plant Backwash Profile Using the OptiQuant™ Suspended Solids and Turbidity Analyzer

Introduction

Today's drinking water plants have many challenges to meet as they produce water for a fast-growing and increasingly demanding population. They must satisfy regulatory agency requirements, address health concerns, and ultimately fill the end customer's needs by producing very high quality water in an economically feasible manner. To meet these challenges, total optimization of the drinking water plant must be achieved. A key process for optimization is filter backwash.

This application note covers issues associated with monitoring the turbidity during a filter backwash cycle including:

- Why backwash optimization is such an important step in achieving WTP optimization.
- Current methodologies used to perform backwash.
- The newest available technology (OptiQuant™ in-situ turbidimeters) and their application to on-line backwash measurements.
- A summary of the application of an OptiQuant turbidimeter at a local drinking water plant.

The Importance of Backwash Monitoring for Turbidity

Filter backwash is a challenging component of traditional drinking water treatment. Making sure the backwash is not performed excessively will help to avoid poor filter performance. Excessive backwash can eventually lead to loss of filter media and over time, to degraded filter performance. Studies have also shown that over-washing a filter can negatively affect the ripening phase. This can lead to shortened run times and can create a higher potential for filter breakthrough.

Backwashing filter beds requires a significant volume of (already treated) water. Excessive backwashing can significantly reduce the final output of a drinking water plant. As much as 3-5 percent of a treated water supply is used to backwash filters.* Such large volumes can also have a dramatic impact on the drinking water plant operating costs and profit margin. Operator judgment (visual inspection), backwash volume, or turbidity are commonly used to control backwash termination.

Termination by operator judgment assumes that the operator can accurately determine when the filter has been washed clean. This is usually signaled by the clarification (visually low turbidity) of the backwash water at the top of the filter.

Backwash termination by volume is a practice in which a specific amount of water is used to backwash a filter. In this case, the backwash run is terminated when the specified amount of water has been used. Typically, an excess of water is used to ensure the filter is washed clean.

Backwash termination by visual inspection or by volume often results in over-washing the filter.

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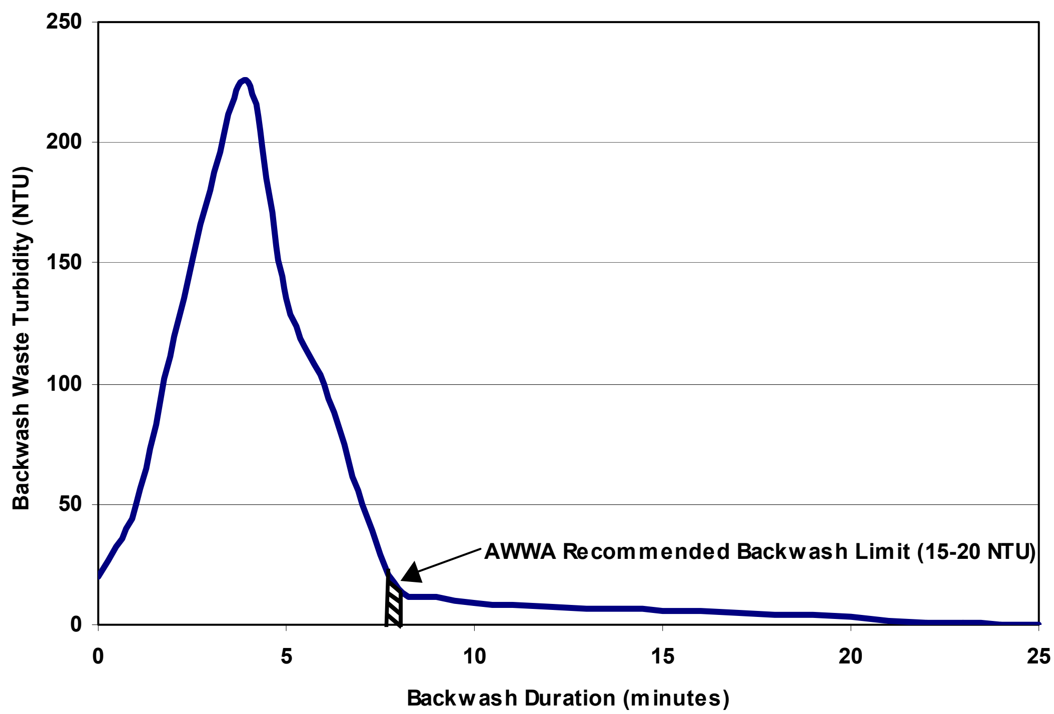
* Backwash Water Return Effects: Evaluation and Mitigation, Linda R. Moss. Proceedings from the Water Quality Technical Conference, November, 2000.

Turbidimetric analysis using reliable instrumentation is an ideal method to monitor the backwash cycle, including backwash termination. Studies have shown that the final turbidity at the termination of a backwash cycle directly correlates to subsequent filter performance and run time.

In light of these studies, the American Water Works Association (AWWA) has recommended that backwash is terminated when the turbidity is in the range of 10–15 NTU*. When the backwash cycle is terminated within this range, sufficient particulate material remains in the residual backwash water above the filter to create the proper environment for an effective ripening period in the upcoming filter run. Longer and more effective filter runs typically result.

Figure 1 displays a typical filter backwash profile with the AWWA recommended turbidity range for backwash termination identified. This figure shows that the backwash cycle is relatively short and that the turbidity changes in a backwash cycle can happen very quickly. Backwash cycle optimization requires accurate and almost immediate turbidity measurement response.

Figure 1 Backwash Turbidity Profile



* AWWA Filter Surveillance Workshop, Springfield Ill., November 16-17, 1999.

Methods for Measuring the Turbidity of Backwash

Backwash turbidity measurement is typically achieved by analyzing a grab sample or by performing on-line analysis. Each method has several issues that must be considered and addressed.

Grab Sample Analysis:
Grab sample analysis is a simple means of collecting data to determine the profile for a specific backwash. This procedure involves collecting numerous representative samples at timed intervals throughout the backwash event and testing them with a laboratory turbidimeter. The process is simple and fairly straightforward, but does require significant operator time to perform sample measurement and data analysis. In most cases, several grab sample runs are performed on each filter in an effort to define the overall average profile of the backwash run.

The following concerns are associated with grab sample analysis.

- Representative sampling is critical. Samples must be consistently collected at the same locations. The locations must be carefully chosen so the backwash turbidity is truly representative of the backwash process. Corners and along the walls of a filter bed are not good locations for collecting samples, making representative sample collection a challenge.

- Grab sample analysis is a lengthy process and must be performed often since backwash turbidity can constantly change. These changes dictate that significant effort is expended to generate an accurate and representative backwash turbidity profile. Backwash turbidity profiling by grab sample is labor and time intensive and because of these factors, is a difficult approach to utilize.

- Although several interferences are possible when performing grab sample turbidity measurements, the major interference is color. Color interference can be reduced through the use of ratio turbidimetric methods or by using an instrument with a light source that is not affected by the media or matrix within the sample. Many laboratory turbidimeters have features to eliminate this interference, but design limitations have restricted the application of ratio methods in process instruments.

On-line Analysis for Backwash Turbidity:
On-line (process stream) analysis of the backwash water as the filter is cleaned is a consistent means of determining the turbidity of the water as it passes upward through the filter. Two types of on-line analysis are available, traditional (slip stream collection) turbidity analysis, and in-situ analysis.

Traditionally, a small representative portion of the sample stream is diverted to a chamber in the turbidimeter. The light source and photodetector are suspended in the sample chamber and the turbidity result is obtained as the sample flows through this chamber. The size of the chamber dictates the sample response rate and therefore, dictates how soon a change in turbidity is seen. Typically, these instruments exhibit slow response relative to backwash changes and are not generally applied.

In-situ analysis involves placing the turbidity monitor at a location in the filter bed directly (1–2 feet) above the filter media. Placing the monitor at this location allows the filter media to expand during backwash and turbidity measurements to be taken exactly where turbidity changes can be seen at the earliest possible time. Measurements are taken at frequent intervals to capture the rapid turbidity changes that occur during the backwash cycle. This approach allows every stage of every backwash to be profiled and relieves the operator of sample collection and preparation duties. On-line in-situ analysis coupled with rapid response is the ideal method of predicting turbidity changes during the backwash cycle.

Two unique concerns must be considered to employ successful application of a process turbidimeter in backwash monitoring and profiling:

- Several interferences, specifically ambient light, color, surface reflections, and bubbles must be accounted for.
- Instrument response time is a critical factor. Because the backwash turbidity is a rapidly changing parameter, the instrument must have a quick and accurate response to correctly derive the backwash profile for a filter.

Ultimately, if interferences and instrument response time can be overcome, process control of backwash based on turbidity can be achieved.

Modern Probe Turbidimeter Technology – a Backwash Optimization Answer

Hach Company recently began the application of a new in-situ turbidimeter. Designed to help the drinking water plant personnel optimize the backwash cycle, it will ultimately contribute to total plant optimization. The new instrument, the OptiQuant Suspended Solids and Turbidity Analyzer (SST), has several key features to address the issues that have limited the application of conventional on-line turbidimeters to monitoring backwash. These features are discussed below.

- Probe Design – The probe design of the OptiQuant SST is perfect for in-situ measurement. Using an appropriate mounting apparatus, the probe can be suspended directly above the filter media. This allows for representative sampling and reduces the interference from surface reflection, filter media, and bubbles.
- Light Source – The light source used in the OptiQuant SST probe is a narrow band of collimated light, with an approximate wavelength of 860 nm. This light source is modulated, eliminating ambient light interference. The 860-nm wavelength dramatically reduces color interference because it is a wavelength that is not typically absorbed by the constituents found in backwash water. This design provides high linearity and very accurate turbidity measurements over a wide turbidity range of 0.3 to 1000 NTU.
- Real-time Measurement – The instrument is capable of near-instantaneous response to the turbidity fluctuations that occur during the backwash cycle. Unlike batch turbidimeters, in-situ measurement eliminates the lag time created when a sample is diverted from the process stream into an instrument. The probe design allows the sample to be measured as it passes across the face of the probe and measurements can be made as often as once per second. The instrument has a user-selectable range and allows for measurement averaging.
- Data Collection – The OptiQuant Interface module can log data at the rate of one point per second. The data can be plotted on the screen for immediate analysis or transmitted via 4-20 mA or digital means to a peripheral data collection system. Backwash profiles are easily generated for each backwash event. Each filter can be optimized because the backwash cycle is monitored with unbiased instrument analysis.
- Regulatory Compliance – The OptiQuant SST is manufactured to meet the European instrument design requirements of ISO 7027. This turbidity monitoring method governs most European drinking water plant.

The OptiQuant SST Analyzer eliminates all the typical interference problems in backwash measurement and allows real-time monitoring during a backwash event. Accurate backwash profiling allows the operator to determine exactly when the backwash cycle should be terminated for optimum filter run performance.

Application of the OptiQuant SST Analyzer for Backwash Profiling at a Colorado Water Treatment Plant

The Water Treatment Plant

This water treatment plant is a 38 MGD facility with 12 filter beds. The filter beds are constructed using a conventional dual-media filter design. The raw water is drawn from a stable reservoir source with an initial turbidity of between 10 and 20 NTU. The raw water undergoes the typical treatment of coagulation, followed by sedimentation and filtration. Each of the processes at this plant are highly optimized. A high quality final effluent is produced with a turbidity that rarely exceeds 0.030 NTU. Typical filter run length averages 24 hours. This plant, a member of the Partnership for Safe Drinking Water, consistently exceeds their membership requirements.

The personnel at this plant are continuously searching for ways to improve their processes and posed the following questions with respect to optimizing backwash:

1. **Question:** Can accurate profiles be consistently achieved?

   Answer: To do this, the interferences discussed above (ambient light, color, and bubbles) must be substantially reduced.

2. **Question:** The backwash cycle involves several flow changes and also involves a surface wash of the media. With respect to the current backwash cycle, which phases impact the turbidity the most and are there any stages that have little or no impact on the turbidity?

   Answer: Studying the phases of the backwash cycle can identify those phases that have little or no impact on filter cleaning and the focus can be shifted to those phases that contribute to the most efficient and thorough cleaning of the filter.

3. **Question:** Do the water treatment plant operators currently backwash the filters to a consistent level of cleanliness?

   Answer: Unknown at this time.

4. **Question:** Do the water treatment plant operators currently over-wash the filters?

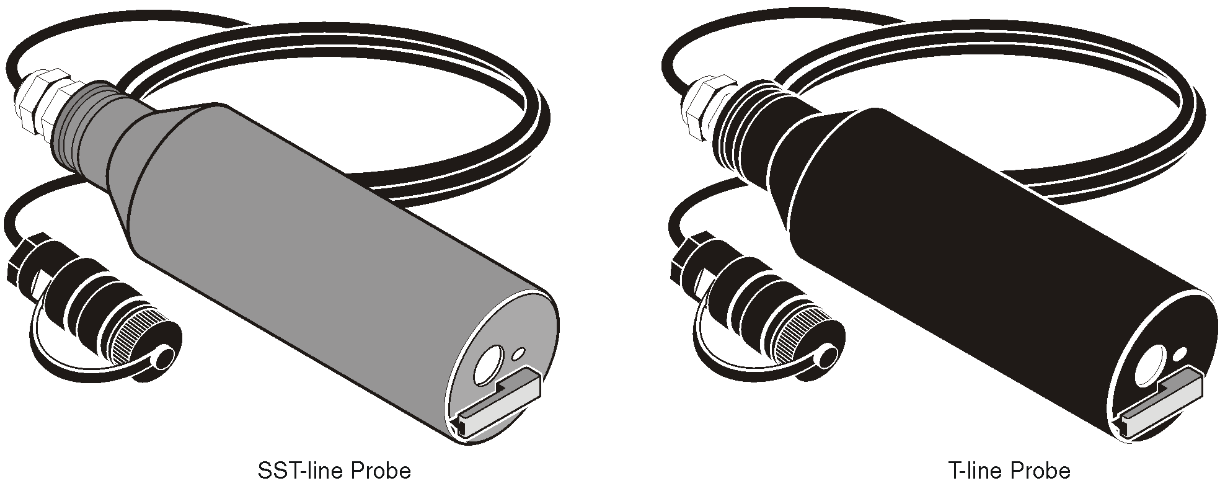
   Answer: The turbidity at backwash termination is normally between 0.5 and 2 NTU and the AWWA-recommended backwash termination turbidity is 10–15 NTU. Using the AWWA criteria, the filters are currently being over washed.

The Installation

At this plant the OptiQuant SST Analyzer was mounted using the standard mounting hardware for open channel mounting. The probe was submerged approximately 4 feet below the surface of the water, which reduced bubble interferences. The probe was held in a horizontal position directly into the water approximately 18 inches above the filter media to allow bed expansion to occur without interfering with turbidity measurements. The probe faced away from any wall or object in the filter that could result in a reflective interference. Once a representative sampling location was obtained, filter influent and backwash profile turbidity measurements were taken.

Note: *Two instrument models within the OptiQuant SST Analyzer line are available for the measurement of backwash turbidity, see Figure 2. The SST-line probe monitors either turbidity or total suspended solids and the T-line probe monitors only turbidity.*

Figure 2 OptiQuant SST-Line and T-Line Probes



Data Collection

Backwash turbidity typically changes very rapidly. Data was logged every five seconds to create an accurate profile that provided a correlation between turbidity and backwash cycle stages. Time versus turbidity data was then plotted to relate the specific steps that were made during a backwash to a turbidity measurement. Doing so allowed the evaluation of the impact of each step to the overall effectiveness of the backwash.

Figure 3 shows a backwash profile from the local water treatment plant with each stage in the backwash denoted by a letter. Table 1 describes each stage. The turbidity measurements were recorded every 5 seconds and signal averaging was set to 30 seconds (to reduce noise levels that occur because of turbulence above the filter).

Figure 3 Backwash Profile at a Local Water Treatment Plant

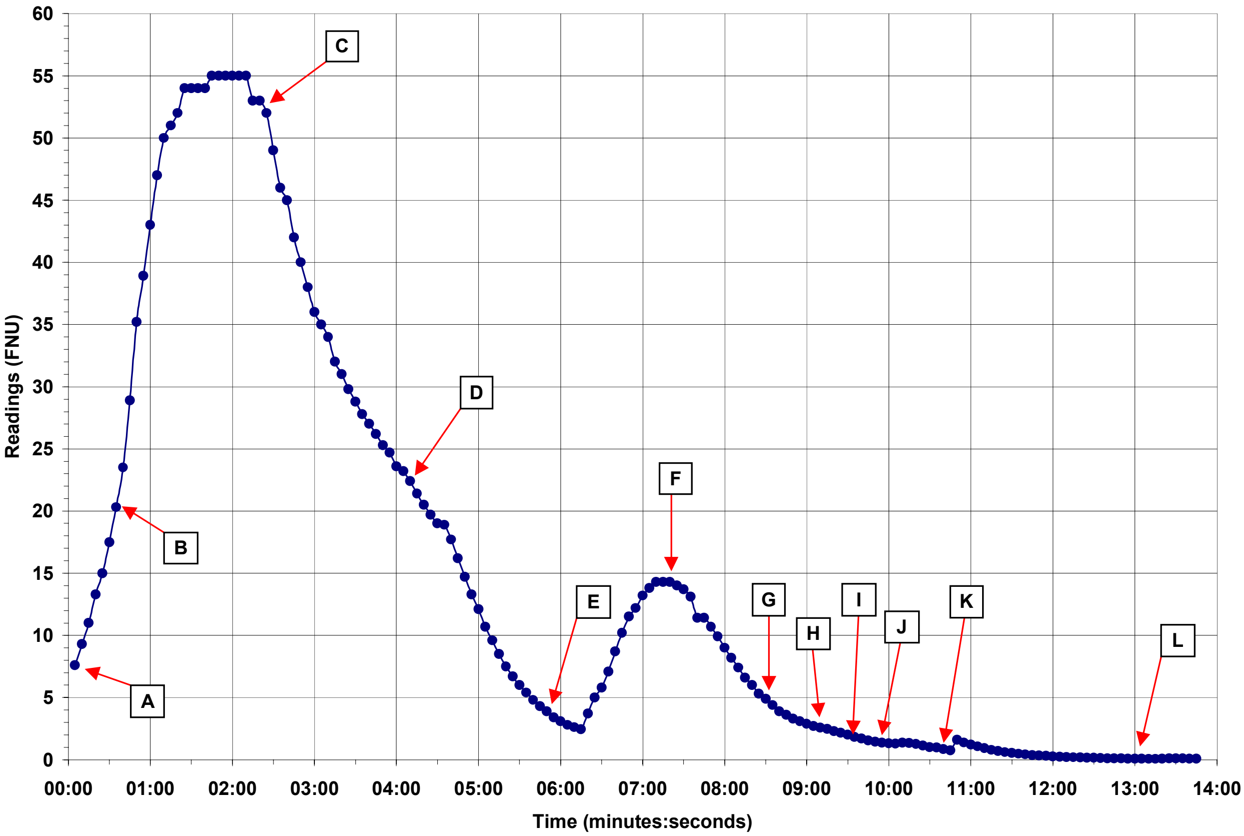


Table 1 Detailed Description of the Backwash Strategy

Point	Description	Reading (FNU) at initial point	Time (minutes:seconds)	Delta Time (minutes:seconds)
A	Surface Wash On	7.60	00:05	03:55
B	Flow Rate = 4,000 gpm	23.5	00:40	01:30
C	Flow Rate = 6,000 gpm	55.0	02:10	03:45
D	Surface Wash Off	23.6	04:00	01:55
E	Surface Wash On; Flow Rate = 3,900 gpm	3.10	05:55	Surface Wash On = 1:15; Flow Rate = 3,900 gpm for 1:15
F	Surface Wash Off; Flow Rate = 6,000 gpm	14.3	07:10	Surface Wash Off for the rest of the backwash = 6:35; Flow Rate = 6,000 gpm for 1:30
G	Flow Rate = 5,300 gpm	3.90	08:40	00:30
H	Flow Rate = 4,600 gpm	2.57	09:10	00:25
I	Flow Rate = 3,900 gpm	1.70	09:35	00:20
J	Flow Rate = 3,200 gpm	1.35	09:55	00:45
K	Flow Rate = 2,600 gpm	0.85	10:40	02:20
L	Flow Rate = 2,000 gpm	0.081	13:00	02:55

Results and Discussion

The profile displayed in Figure 3 shows a smooth curve with two distinct peaks. The backwash cycle proceeds as follows:

1. This backwash cycle begins with a surface wash, gradually increasing the flow up to 6000 gallons per minute (gpm).
2. When the flow reaches 6000 gpm, the turbidity of the backwash level has peaked at 55 NTU.
3. The turbidity begins to drop and within six minutes is below 5 NTU.
4. A second (and final) surface wash procedure is initiated. The backwash turbidity ramps up to a second peak value of 15 NTU, at which time the surface wash is terminated.
5. The backwash flow rate is slowly reduced from 6000 to 2000 gpm.

At nine minutes into the procedure, the backwash turbidity is between 1 and 2 NTU, which is the same turbidity as the settled water immediately prior to its application to this filter. As the backwash cycle progresses, the filter becomes exceedingly clean with the final backwash turbidity measuring at 0.081 NTU at the end of the backwash cycle. From start to finish, the backwash cycle lasted just under 14 minutes.

Based on this profile, several observations can be made. The turbidity at termination of the backwash was 0.081 NTU; substantially below the AWWA-recommended backwash termination turbidity of 10-15 NTU. This indicates that the filter was over-washed. The overall effect on subsequent filter runs was not documented but, if adhering to AWWA recommendations, the backwash could have been terminated at the peak of the final surface wash when the turbidity was approximately 15 NTU.

Over a period of time it was found that BW termination turbidity was between 0.5 and 2 NTU. The operators do terminate backwash to a relatively narrow range, but because the level of turbidity is so low, overwashing the filters may be occurring. If longer runs are desired, backwash termination at a slightly higher level of turbidity should be considered. As was noted earlier, the filter was washed beyond the turbidity of the settled water coming into the filter. If the wash would have been terminated when the turbidity was equal to that of the settled water (9 minutes into the wash), a substantial quantity of backwash water could have been saved. Especially during times of high throughput, using less water for backwash could contribute substantially to efficient plant operation.

When determining the profile of a backwash cycle, it is important to understand that the turbidity readings will contain a significant level of noise if the measurement settings are not optimized. The noise is primarily due to the very turbulent state of the backwash water as it passes from the filter surface to waste. A large percentage of the particles that pass in front of the sensing zone of the turbidimeter are large and most process instruments see large particles as noise. To compensate for this noise, instrument measurement averaging (signal averaging) must be employed. Signal averaging allows several consecutive measurements to be taken, averaged together, and displayed. As each new measurement is taken it replaces the oldest measurement in the average calculation and a new average value is produced.

When using signal averaging for process monitoring, the level of averaging that is necessary must be carefully considered. A longer averaging period results in a slower displayed response to the changing sample. Conversely, a shorter averaging period creates a faster displayed response to sample changes. The trade-off between actual response time and the level of definition of the backwash profile must be considered when determining the signal averaging rate. Ideally, the shortest signal averaging that will yield meaningful information should be used. The data shown in Figure 3 indicates that a signal average time of 30 seconds shows no significant difference in the occurrence of real-time events when compared to a 1-second signal average time.

Using the OptiQuant SST Analyzer can provide a substantial amount of accurate and timely information for backwash profiling. It is crucial that the instrument be installed in the correct location and that the instrument settings allow for noise reduction while still providing useful data. Once the backwash profile is constructed, the water treatment plant personnel can determine changes that need to be made to the backwash cycle so more efficient and economical backwash regimes result.

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