Measuring Turbidity in the Laser Age

Detecting early filter deterioration can be tricky. Laser nephelometers can help by providing accurate on-line measurements to help facilities meet regulatory reporting requirements and optimize filter performance and run times.

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CONVENTIONAL WATER filtration plants are usually required to monitor turbidity levels in filter effluent. Until recently, the lowest level of change that turbidimeters could measure was too high to detect early filter breakthrough, so many water treatment plants turned to particle counters. However, turbidimeter technology advancements now include laser nephelometers whose detection capabilities approach the functionality of particle counters.

Laser nephelometers can detect ultralow turbidity changes, as well as filter deterioration and breakthrough. Increasingly, these capabilities allow turbidity and particle-counting measurements to become complementary technologies. In addition, a laser nephelometer plays two roles at conventional water treatment facilities by providing accurate, on-line turbidity measurements to meet regulatory reporting requirements and serving as a sensitive, highly accurate process instrument for optimizing filter performance and run times.

FEATURES AND BENEFITS

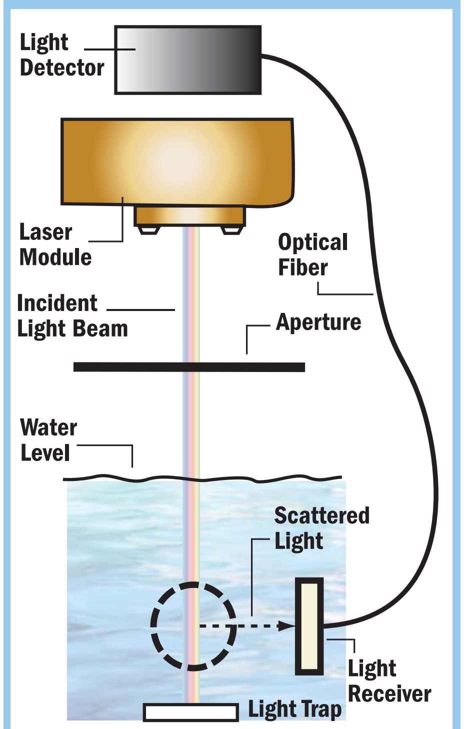
Laser nephelometers use advanced incident light to reveal a sample's scattered light reading (Figure 1). A 35-mW solid-state laser diode, rather than incandescent light, introduces a high level of sensitivity to nephelometry. Sophisticated laser optics and signal processing allow the laser nephelometer to detect turbidity changes as low as 0.0003 ntu, as well as submicron-size particles (smaller than .01 µm), which typically precede larger particles.

Laser nephelometer use is becoming common at membrane-based drinking water treatment plants in which operators usually are looking for evidence of clogged membranes and broken membrane fibers, primary issues with subtle early warning signs. Membrane plant operators monitor for evidence of slight pressure shifts and small changes in turbidity, miniscule changes that can be regularly detected with a laser nephelometer. Conventional visible light (US Environmental Protection Agency method 180.1) or long-wavelength light-emitting diode-based nephelometers (ISO7027) aren't sufficiently sensitive to detect minute changes in membrane systems.

In contrast, conventional water filtration plants monitor filter effluent for any protracted rise in turbidity. These plants have long used particle counters to detect extremely small changes in performance that standard turbidimeters

Figure 1. Laser Nephelometer Optical Configuration

Laser optics and signal processing allow a laser nephelometer to detect turbidity changes as low as 0.0003 ntu.



Advances in turbidimeter technology now provide for ultra-sensitive laser nephelometers that detect ultra-low changes in turbidity.

PHOTOGRAPH: HACH

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can't detect. However, long-term, successful application of laser nephelometers in membrane plants to detect small step changes in the filtering process indicates this instrument also can effectively monitor and optimize conventional granular media filter performance.

SUBMICRON PARTICLE EVENTS

A data-collection study was conducted at a conventional 30-mgd, 12-filter water treatment plant near Fort Collins, Colo., to determine, among other things, effective technologies for turbidity spike detection in filter effluent. Three types of instruments were used to monitor plant effluent:

- A particle counter, with size sensitivity down to 2 µm.
- A low-level regulatory-approved turbidimeter commonly used in conventional water treatment plants for regulatory filter effluent monitoring, which meets all instrument-design criteria specified by USEPA method 180.1.
- Three laser nephelometers that are about 150 times more sensitive than traditional turbidimeters and can confirm particle events that might otherwise be reported on traditional low-level turbidimeters as noise. The instruments measure turbidity in mntu units where 1 mntu = 0.001 ntu.

All instruments were used alongside regular sampling. Redundant testing with three laser nephelometers was also performed to detect minor events and isolate interferences such as bubbles or contamination.

To test its effectiveness on a conventional filter, the laser nephelometers were operated with the particle counter. Turbidity spikes were confirmed as detected by a laser nephelometer only if all three laser nephelometers detected the spikes. Particle events detected by all instruments were examined and data were collected during 66 continuous filter runs. Although the laser nephelometer and particle counter produced mostly complementary data, the laser nephelometer's sensitivity allowed it to detect submicron particle events that were otherwise undetectable (Figure 2).

Using a particle counter and a laser nephelometer also provided information about the composition of a particle event. Events detected by both instruments indicated a natural distribution of particles roughly following a $1/d^3$ relationship. In these cases, a nephelometer will detect particles slightly before a particle counter because small particles move more rapidly through the filter (Figure 3).

ASSESSING FILTRATION EXCURSIONS

The laser nephelometer automatically calculated and displayed relative standard deviation (RSD), which provided even greater sensitivity to pending filtration breakthrough or loss of membrane integrity. A separate, distinct, and dimensionless monitoring parameter, RSD quantitatively assesses turbidity fluctuation. RSD and turbidity measurement values are complementary and should be recorded and trended using the laser nephelometer's analog or digital output capabilities. Careful observation of the relationship between the two values provides an excellent diagnosis of the process excursion.

RSD is calculated as the standard deviation for a given set of measurements divided by the average for the same set of measurements. The quotient is then multiplied by 100 to express the result as a percent. For example:

$$\text{RSD} = (\text{Stdev}_n / \text{Average}_n) \times 100$$

Here n equals a defined number of measurements used to calculate the average and the standard deviation.

RSD can be used to monitor pending filtration breakthrough on conventional granular media filters because RSD will increase prior to any marked turbidity level increases. The parameter also enhances the sensitivity of detection for membrane integrity loss for microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. Combining RSD and

Figure 2. Detailing a Particle Event

During a filter run, the turbidimeters detected all particle events. The particle counter missed an event at approximately 14:24.

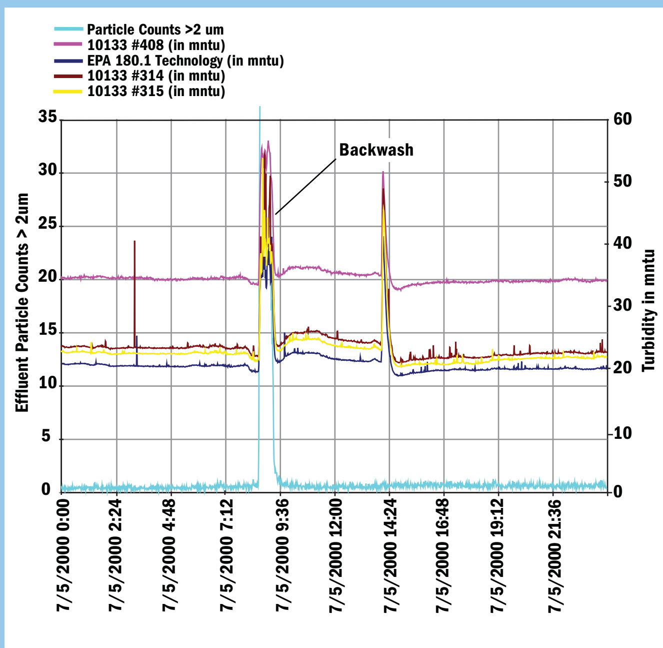
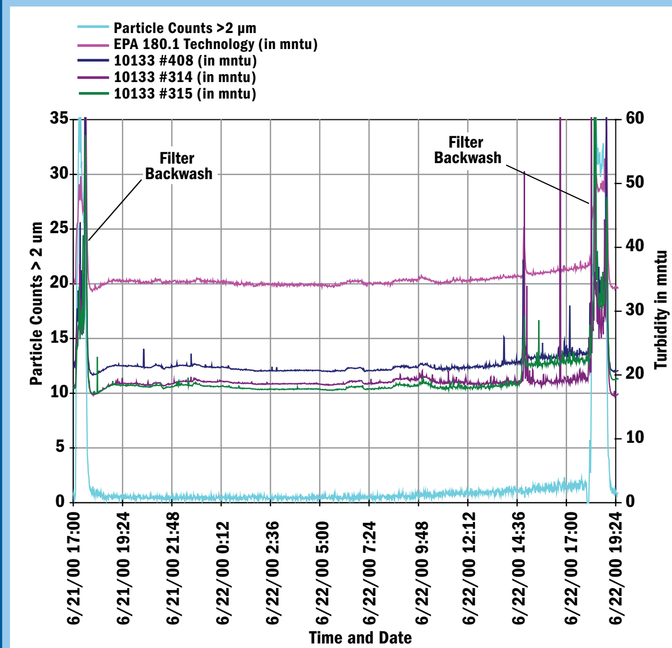


Figure 3. Measuring Sensitivity

Laser turbidimeter baselines increase in fluctuation, indicating the bleeding of low numbers of larger particles through the filter.



laser turbidity readings can provide a qualitative assessment regarding the nature of membrane integrity loss.

FIELD TEST

The laser nephelometer was also evaluated at a conventional 160-mgd water treatment plant in Southern California in summer 2007. The quality of the plant's raw water from the American River is usually high, with influent measuring below 2 ntu in the spring, with rare spikes of more than 10 ntu when the area experiences storm runoff. The plant runs 16 full-media sand and anthracite gravity filters consisting of eight filters built around 1964 and eight filters added in 2005.

The plant is not required to count particles but has been doing so to detect early breakthrough. A field test of the laser nephelometer ran in conjunction with a two-week flow test the plant underwent as part of an independent evaluation to determine component performance under high hydraulic loadings.

The plant's flow test provided a suitable testing ground for the laser nephelometer because filter breakthrough events are more likely when a plant pushes hydraulic processes. During the two-week flow test, a laser nephelometer was added to one of the filters already served by a particle counter and turbidimeter. During this test, data showed that the laser nephelometer detected the same breakthrough events as the particle counter. Readings from the conventional turbidimeter, however, remained flat. The laser nephelometer is easily calibrated and integrated well with the plant's supervisory control and data acquisition system.

VERIFICATION

Regulations are placing an increased emphasis on verifying on-line instrumentation. The laser nephelometer used in these field studies features a solid, highly stable immersion standard that allows calibration to be checked intermittently between wet calibrations.

The 20-second, self-indexing feature verifies calibration below 0.1 ntu (100 mntu) with no sample cells to recondition to bring the instrument back online. Detecting impending filter breakthrough, delineating filter ripening, maximizing effective filter run times, and collecting regulatory reporting data with the same instrument isn't new to membrane plant operators who rely on the sensitivity of laser nephelometers. These capabilities are also available to conventional water treatment plant operators as an alternative to particle counters.

Conventional water treatment plants are undergoing change as requirements gradually become more stringent. In this shifting regulatory environment, conventional water treatment plants can benefit from turbidity monitoring technology that detects ultra-low turbidity levels and submicron particles.