Case Study: How Particle Counting Can Improve Water Quality – 01/01/2000

What do particle count data reveal about water quality? How can utilities use particle count data to optimize plant processes for particle/pathogen removal?

With increasing requirements to remove pathogens, such as *Giardia* and *Cryptosporidium*, the need to optimize processes to remove particles has become obvious. Particle counters reveal minute changes in water quality that can identify opportunities to modify operations or design for particle removal.

Role of Water Research Foundation Research

The Foundation has produced several reports that have been used by the drinking water community to assess, install, and maintain particle counters in order to optimize treatment processes for particle and pathogen removal:

- Hargesheimer, E.E. et al. 1992. Evaluation of Particle Counting as a Measure of Treatment Plant Performance. Denver, Colo.: AwwaRF and AWWA (Order #90595).
- Hargesheimer, E.E. and C.M. Lewis. 1995. A Practical Guide to On-Line Particle Counting. Denver, Colo.: AwwaRF and AWWA (Order #90674)
- McTigue, N.E., et al. 1998. National Assessment of Particle Removal by Filtration. Denver, Colo.: AwwaRF and AWWA (Order #90757)
- Patania, N.L., et al. 1995. Optimization of Filtration for Cyst Removal. Denver, Colo.: AwwaRF and AWWA (Order #90699).

Research has shown that particle counting provides an important tool for assessing source water quality, finished water quality, unit process performance, and total treatment efficiency. Plant influent and filter effluent are the most important sampling locations for assessing plant performance. Particle counters are best suited to monitoring water with turbidity less than 7 to 10 ntu. Sampling locations with high particle concentrations tend to require frequent maintenance and cleaning.

Particle counts in excess of the instrument concentration limit will introduce coincidence errors into the results. Because both particle number and size can be used in optimizing drinking water treatment, the most useful information available from many sequential particle count analyses includes the cumulative total number of particles, the differential number of particles, and percentile statistics.

For example, research shows that chemical pretreatment is the single most important factor influencing *Cryptosporidium* and *Giardia* removal. Without chemical pretreatment, filters do not act as an effective barrier against cyst and oocyst-sized particles. Different coagulation conditions (alum-cationic polymer versus ferric chloride, ferric chloride with and without cationic polymer) can produce equally effective removal of *Cryptosporidium* and *Giardia* providing each condition produces effective particle removal.

Increasing concentrations of particles are generally associated with increasing concentrations of *Cryptosporidium* and *Giardia*. However, it is difficult to determine conclusively if particles can be surrogates for pathogens since protozoa detection methods are subject to error. Although the use of particle counting as a surrogate measure of *Giardia* cyst removal for regulatory compliance may be controversial, its fundamental value for drinking water treatment plant performance monitoring remains unchallenged.

Utility Application of the Research

A number of utilities and consultants have applied Foundation research in developing and implementing on-line particle counting to optimize treatment processes.

Pioneering water application. In 1979, Southern Nevada Water System became the first drinking water utility in the country to install on-line particle counters for plant control and to optimize coagulation. Source water from Lake Mead supplies 0.5-ntu water to the utility's 600-mgd plant for metropolitan Las Vegas. With such low-turbidity influent, particle counters were needed to reveal minor changes in water quality previously unobserved with turbidimeters .

Each of the utility's 26 filters has a particle counter at the effluent, and the utility has made changes in filter operations based on particle counting data. Filter backwash frequency is determined by parti- cles, turbidity, run hours, and head loss, but particle count dominates. Through practice, Southern Nevada determined that 20 particles/mL, larger than 2 µm in size represent the best compromise between the usual 10 particles during the filter run and the particle breakthrough that occurs shortly after filter effluent reaches 20 particles/mL. Southern Nevada minimizes particle spikes after backwash by adding a 20-min filter-to-waste period and feeding polymer to backwash water.

The utility takes advantage of its pilot plant equipped with a particle counter to optimize coagulant dosage. Given the plant's low-turbidity influent, pilot plant results are more reliable than jar testing. Turbidity could not reveal the minor changes that particle counters show. Minor changes can provide major savings on coagulant in a 600-mgd plant. The surprise was how quickly the particle counters paid for themselves. Making minor changes in coagulant gave the utility a payoff in around two years.

Piloting for new construction. Massachusetts Water Resources Authority has used particle counters in two rounds of piloting and demonstrations for a new filtration plant. The utility found that turbidity was not a sensitive enough indicator of water quality changes and began using particle counters. Particle counting has revealed that source water varies in ways not previously understood.

For example, MWRA has two sequentially linked reservoirs in which the quality of water is similar when turbidity is the comparison, but quite different when particle count and organic carbon content are the parameters. MWRA has found that both reservoirs have turbidity levels close to 0.3 ntu, but the particle count for one source is 50 to 100 percent higher than the other source. This variation serves as an indicator of how well water from the two sources have mixed at various points in the reservoir and indicates how to transfer water to optimize water quality.

MWRA is using the results of pilot tests to build a new treatment plant, optimizing processes to take into account variations in source water quality. The design of the plant, among many variables, includes particle counters on each filter with the objective of minimizing spikes in particle counts.

Using a batch sampler with on-line monitoring. In order to ensure the production of high-quality water, Milwaukee, Wis., has made major process and operations changes. The utility has added particle counters to source water influent and to each filter's effluent and developed filter water particle guidelines of fewer than 2/mL. Staff began using a batch sampler in the plant for quality assurance, but data acquired from the batch sampler showed more particles than those from the on-line samplers.

Although numbers from the batch sampler particle counter are higher than numbers from the on-line unit, experience has taught staff what to expect in terms of normal differences in readings. Milwaukee's staff use a batch sampler frequently to check on-line particle counters and to troubleshoot processes throughout the treatment train.

Particle counting has had a profound impact. It has become one of the most important criteria in ensuring water quality. For example, changes in filter operations have reduced filter spikes after backwash to between 50 and 100 particles/mL larger than 2 µm and shortened their duration to less than 30 min. until a return to base numbers. Each shift compares batch to on-line values for source water, settled water, filter effluent, and plant effluent. Particle counters have improved water quality by revealing operations and maintenance problems, providing advance warning of events throughout the water treatment process, and by validating efforts to fine tune operations.

Validating instrument calibration. Alameda County Water District, Calif., operates two plants, a 1975 plant with two filters and a 21-mgd plant built in 1993 with six granular activated carbon biological filters. Source water is from the Sacramento-San Joaquin delta, by way of the South Bay Aqueduct. The utility installed on-line particle counters at each filter's effluent to evaluate filtration performance. The greatest difficulty with particle counters involved integrating them into the SCADA system. Now manufacturers provide software and equipment that delivers a 4-20 milliamp signal so that particle counters are more easily installed in water treatment systems.

A second difficulty associated with particle counters involved calibration. Alameda County sends particle counters to the manufacturer once a year to calibrate lasers. The manufacturer provides classes on instrument calibration. However, the expense of equipment to align the laser makes sending instruments out more cost effective for Alameda. The utility validates calibration of on-line particle counters three times a year by using a batch sampler as a reference. Alameda County also uses a newly developed standard solution of polystyrene latex spheres. If on-line instrument readings vary more than five to ten percent from the standard solution, the instrument is sent to the manufacturer. By validating calibration, the utility may find they are able to return instruments to the manufacturer for calibration less frequently.

Initially, particle counters were used to compare differences in filtration performance between the older and newer plants and to investigate filter media performance with GAC in one filter and dual media/ anthracite in the other five filters. Results showed that GAC provided more stable performance and longer filter runs. Particle counters have made the biggest difference in day-to-day control of filtration and result in better operational decisions. Quality control procedures provide confidence in comparing system processes to make operational changes. For example, storage for backwash water in the six-filter plant is minimal. Two filters may be at 0.09 ntu and have the same length of filter run time. The operator can select the higher particle count filter for backwashing, because particle breakthrough generally occurs several hours before turbidity breakthrough. In this way, filters are backwashed more accurately to prevent cyst-sized particles from breaking through the filter.

Conclusions

As utilities implement particle counting in system operations, they are discovering its usefulness for fine-tuning systems and finding unanticipated opportunities to optimize water quality. Research results have provided practical assistance to utilities implementing particle counters including technologies and methods to overcome technical obstacles; practical on-line sampling, data handling, and quality assurance protocols specifically for water treatment process control; and the application of these innovations to full-scale drinking water treatment monitoring.