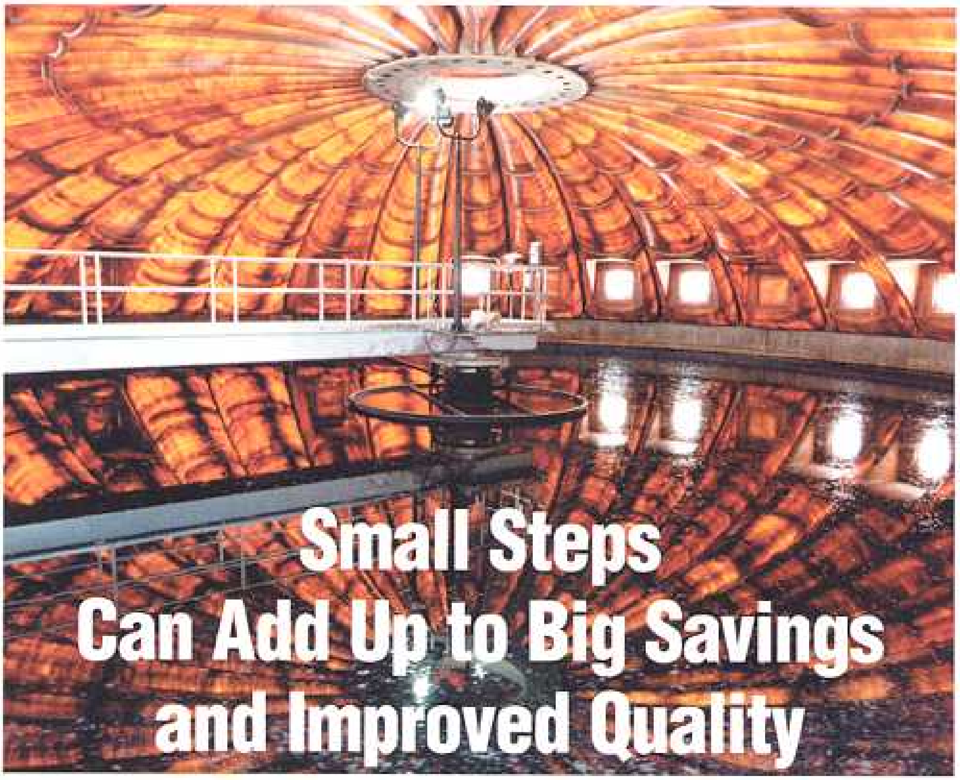


Small Steps Can Add Up to Big Savings and Improved Quality

By John Volbeda

Introduction

While more than 70 percent of the planet is covered in water, less than one percent is usable fresh water and since water demand increases with population growth, the reuse of water and proper treatment methods are a critical necessity. As water travels through the ground or sits in lakes and rivers, it comes into contact with organic materials that dissolve in water. These organics in water become a food source for microorganisms. Even the most minute nutrient sources will support growth and that spells disaster since these microorganisms (like *Giardia lamblia* or *Cryptosporidium*) can be harmful or even lethal to humans.

Some smaller treatment plants using groundwater systems can meet local and national requirements without any treatment, but many other systems need additional treatment and disinfection. Governmental agencies such as the U.S. Environmental Protection Agency (EPA) protect the public health by specifying water treatment components and appropriate disinfection levels. To meet these requirements, a variety of water treatment methods are used to remove contaminants from drinking water and are arranged in a sequence or a treatment train.

A combination of appropriate water treatment processes is selected by the water utilities to treat the contaminants in the raw water sources used. Commonly used processes include pretreatment, primary disinfection, coagulation, flocculation, sedimentation, filtration and secondary disinfection. Throughout these processes, there are several analytical 'best practices' that help plants reduce costs, improve water quality, meet environmental and governmental regulations and help ensure the safety and security of the water supply.

Pretreatment

To better define the dynamics of the raw water source being used by a water treatment plant, a number of liquid analytical measurements are made prior to entering the treatment process. Influent monitoring measurements may include pH, conductivity, temperature, turbidity (the clarity of the sample), dissolved oxygen and total organic compounds (TOC). It is a good idea to keep a permanent record of each of these measurements for future reference or for detecting seasonal changes in the source water.

Before water is clarified, it passes through coarse filters to remove sticks, leaves, fish and other large objects, preventing them from entering the water treatment plant. Pretreatment also includes primary disinfection using either chlorine or ozone to treat algae growth and for oxidation of chemicals and microorganisms.

Primary disinfection

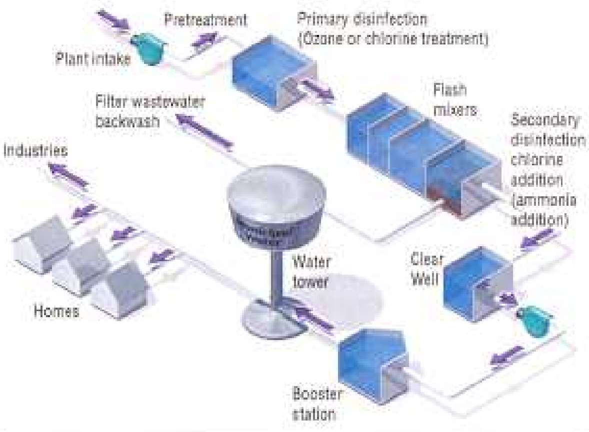
Since water is a universal solvent, it comes in contact with several different pathogens (bacteria, viruses and parasitic protozoa), some of which are potentially lethal. Both surface water and ground water sources can be contaminated by these pathogens and inactivation is accomplished through chemical disinfection and mechanical filtration treatment.

Chlorine was first used in the U.S. in 1908 as a chemical disinfectant of drinking water and some plants continue to use chlorine as a primary disinfectant today. However, many plants are now choosing to use ozone as it is the most powerful of the oxidants currently used in the water treatment industry and has been used extensively for water treatment in Europe for over a century. Unlike chlorine, ozone does not form potentially hazardous by-products. Ozone destroys organic compounds while improving the odor and taste of the water.

Ozone is a very powerful oxidant and it disinfects in less time than is required with chlorine. Ozone attacks the chemical bonds of pathogens in the water, reducing the concentration of organic material, iron, manganese and sulfur. That results in a reduction or elimination of odor and taste problems. Chlorine is a slow oxidizer and only has a limited effect on bacteria. In particular, *Cryptosporidium* and *Giardia* are extremely resistant to chlorine disinfection. The most effective use of ozone is to install several ozone monitors for continuous measurement in key points in the contact basin.

Ozone consists of three oxygen atoms and degrades back to oxygen forming a free oxygen radical that survives less than 30 minutes. The rate of degradation depends on the water chemistry, pH and temperature. Since ozone is unstable, it is generated on site at plants. Ozonated air is bubbled up through the water in contact chambers. By the time the water reaches the end of the contact chambers, primary disinfection is complete and the ozone has converted back to oxygen. Ozone treatment is gaining in popularity as a fast and effective treatment technology in the primary disinfection stage.

Figure 1. Drinking water treatment overview



Coagulation, flocculation and sedimentation

After pretreatment and primary disinfection, the clarification of raw water is usually a multiple-step process for reducing turbidity and suspended solids. Smaller particles combine or coagulate into larger fluffy particles called floc and sediment. The coagulation process is promoted by the addition of chemical coagulants such as alum, iron salts or synthetic organic polymers. After chemical addition, the water flows through a mixing channel where the water and chemicals are flash mixed.

The floc is mechanically stirred to attract suspended solids and microorganisms. The pH measurement plays an important role in the coagulation process. Keeping the pH at the proper levels improves the coagulation process and lowers the turbidity. In addition, as pH is lowered, the TOC removal is improved. With continuous on-line monitoring of pH, plants can best determine and control the addition of chemicals required for pH adjustment to ensure the efficiency of the coagulation process and to avoid wasted chemicals and costs.

If the raw water has an unusually high hardness, chemicals such as lime and soda ash are added to reduce the levels of calcium and magnesium. Lime softening can produce water from 60 to 120 ppm hardness, but will result in a higher pH. Therefore, the treated water is buffered to reduce the pH to make it acceptable for further processing.

Filtration

The sedimentation process removes particles 25 microns and larger, but the

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process is not 100 percent effective and filtration is required. The turbidity is usually between one and 10 NTU as it enters the filtration stage.

Water flows through sand filters and percolates down through a combination of sand, gravel, anthracite coal and a mixture of support gravel and fine sand. Larger particles become trapped first and smaller particles such as clay, iron, manganese, microorganisms, organic matter, precipitates from other treatment processes and silt are also removed, resulting in crystal clear water.

The filtration stage also removes residual matter resulting from the oxidation of organic chemicals and microorganisms in the primary disinfection stage. Finally, microorganisms resistant to chlorine or ozone disinfection in the pretreatment stage are effectively removed during filtration.

Periodically, the filter must be backwashed to remove the fine suspended matter and accumulated sediment that collects in the filter media. As an indication of filter performance and the need to backwash filters, the effluent from the filter beds is continuously monitored with a turbidimeter. Cloudiness in the appearance of the water is caused by tiny particles in the water. Continuous, on-line turbidity measurement is used to provide the filter effluent reports for governmental regulatory reporting purposes and also helps monitor and improve plant efficiency, since high turbidity levels indicate that the filter is not operating properly and backwashing is necessary.

Government regulations apply to public water systems and water treatment plants are required to achieve a minimal reduction of harmful microorganisms and viruses. Filtration systems are presumed to achieve the minimal percent reduction of harmful *Cryptosporidium*, *Giardia* and viruses by meeting certain turbidity limits in combination with adequate disinfection. The adequacy of the filtration process and the removal of these microorganisms are determined by measuring the turbidity of the combined filter effluent water to meet governmental criteria, including the turbidity monitoring frequency, the maximum turbidity limit and the approved turbidity measurement methods.

Two approved methods have been accepted for making turbidity measurements for compliance monitoring purposes, the EPA Method 180.1 and the ISO Method 7027. The EPA method is used in the U.S. and in some other countries.

Table 1. Comparison of USEPA 180.1 and ISO 7027

Item	EPA 180.1	ISO 7027
Light source	Tungsten lamp	LED or tungsten lamp
Wavelengths	400-600 nm	860 ± 30 nm
Characteristics	Long warm-up time	Low stray light
	More sensitive to smaller particles	Less sensitive to smaller particles
	Color interferences	Low color interferences

The ISO method is used outside of the U.S., in Canada, Europe, Latin America and Asia.

Secondary disinfection

In compliance with the regulations requiring post-residual disinfection, plants use chlorination as secondary disinfection in the final treatment step. Ozone does not provide the germicidal and long-lasting disinfection residual to inhibit or prevent re-growth of pathogens in the water distribution system that chlorine does. However, chlorination byproducts were discovered in drinking water in 1974 and fears that these byproducts could be potential human carcinogens has led the EPA to establish maximum levels for these disinfection by-products. Today, many plants are using chloramines as a safer alternative to chlorine disinfection. This process adds

Photo 1. Electrochemical water quality monitoring system ensures water safety and quality throughout the distribution system

Photo 2. Reagent-free chlorine analysis system

Photo 3. Analytical systems directly measure monochloramine without chemical reagents to condition the sample

Photo 4. Clarity package: turbidity analysis system

chlorine and ammonia compounds to the water for chloramination.

Compared to chlorine, chloramines produce fewer disinfection by-products and exist as monochloramine, dichloramine or trichloramine. Monochloramine is the most desirable of the three forms since it contributes little or no taste or odor and is considered to be the most effective at disinfecting water. Plant operators using chloramination for disinfection need to accurately determine monochloramine levels in the water treatment systems. If a plant is instead using chlorination disinfection processes, it's important to take pH and temperature into account to accurately measure free chlorine concentrations. The pH value can be entered manually into an analyzer, but it is much more accurate and reliable to use an online pH sensor for automatic and continuous monitoring and pH correction.

Whether a plant is using chlorine or monochloramine, the effective use of the proper analysis systems can help lower overall expenses and reduce equipment maintenance time. One key area where drinking water treatment plants can reduce costs is by selecting reagent-free systems for free chlorine and monochloramine measurement. Typical chlorine and monochloramine analyzers use chemicals (or reagents) to convert chlorine into a form an instrument can measure.

However, there are drawbacks to reagent-based systems. The primary disadvantage is reagent consumption. Most bottles of reagent or sample buffering agent last approximately a month, so plants must constantly plan for these chemical costs. In addition, replacing bottles of reagents and ordering, storing and tracking stock all require staff resources and labor. Some plants also monitor residual chlorine levels at several points along the distribution system and this remote monitoring requires even more time and money.

In terms of equipment costs, a reagent-based system also calls for a sample conditioning system: a pump to inject reagents, tubing to carry reagents and sample and a mixing device. The tubing in such a system needs periodic replacing and mixing chambers need cleaning, so a reagent-based system requires maintenance beyond simply replacing chemicals. Finally, a plant operator who is busy replacing reagents and tubing is not getting other jobs done, so it is potentially a drain on skilled personnel. By using today's reagent-free systems for monitoring chlorine and monochloramine, plants lower the costs of buying, storing and disposing of reagents, while saving valuable personnel time by reducing maintenance requirements.

Distribution monitoring

The prevention of contamination in the distribution system, thereby reducing the risk of waterborne disease, requires regular monitoring for disinfec-

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tant levels, microbial levels and corrosion products. Although water may be safe upon leaving the treatment plant, it is important to monitor for contamination by growth of microorganisms, pressure problems, water main breaks or security breaches. Monitoring can also indicate formation of biofilms, malfunctioning piping valves or other threats to the system.

Because pathogens can enter the distribution system through cracks and joints in pipes, water systems are required to provide continuous disinfection of the drinking water entering the distribution system and maintain a detectable residual level within the distribution system. Regular monitoring includes microbial monitoring to meet public health standards, chlorine residuals in the distribution system and tracking pH levels to confirm that the proper corrosion control chemicals are being applied at the treatment plant. A minimum of 0.2 mg/L of chlorine residual is advisable at the last tap on the distribution system and prompt investigation is required to correct a low- or no-residual reading. A continuous on-line chlorine measurement is especially important in ensuring adequate disinfection levels throughout the distribution system. The monitoring data can be transmitted back to the plant and automatically stored for future reference, historical trends and detection of seasonal fluctuations.

Water quality within the distribution system can be monitored on a continuous basis and since there can be numerous points of vulnerability in various locations throughout a municipal water system, many large water utilities have installed water quality monitoring systems throughout their district to ensure water safety and quality.

By continuously monitoring several critical water quality measurements online at strategic points in the distribution system, plant operators can develop a baseline for measurements that indicate normal water conditions, so they can better understand and predict what measurement data is appropriate. Using that baseline as a guide, plant operators can then identify critical changes in the water composition that could indicate when a contamination event has occurred. If a change in the water composition is detected, the plant operator can then take steps to analyze it further to determine whether or not the change poses a risk or indicates a problem in the water system. In order to develop an accurate baseline, it is generally recommended that plants conduct and track continuous on-line measurements for at least a year, so that operators can understand the normal variances and identify unusual changes.

This kind of continuous, on-line, systematized monitoring makes up a critical early warning system that can often detect chemical or microbial risks, indicating to the plant the need for further water quality analysis at a particular point in the water system. An early warning system monitors a variety of critical water quality measurements continuously to provide real-time water quality data on such parameters as chlorine, monochloramine, pH, ORP, conductivity, dissolved oxygen and turbidity. By monitoring these measurements throughout the distribution system, plants can help ensure water quality and security for the communities they serve.

Tying it together with digital automation

By using instrumentation as part of a complete architecture, plants can use open and interoperable devices and systems to build process solutions. Digital automation architecture should include intelligent field devices, scalable platforms, standards and integrated modular software, all working together to create, capture, use and distribute information and process control data. By implementing a digital automation architecture, plants can reduce capital and engineering costs, reduce operations and maintenance costs, increase process availability, reduce process variability and streamline regulatory reporting.

Conclusion

With ever stricter EPA regulations, tightened operations budgets and new homeland security concerns the demands on drinking water plants today are constantly changing. However, a series of small steps in analytical instrumentation selection, use and maintenance can help to reduce costs, eliminate headaches and increase safeguards and efficiencies.

About the author

With over 20 years of industrial process and control experience, John Volbeda serves as industry manager for the water and wastewater industries for the Liquid Division of Emerson Process Management, Rosemount Analytical. Rosemount Analytical can be reached at www.raihome.com, 800-854-8257 or at 2400 Barranca Parkway, Irvine, Calif., 92606.

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