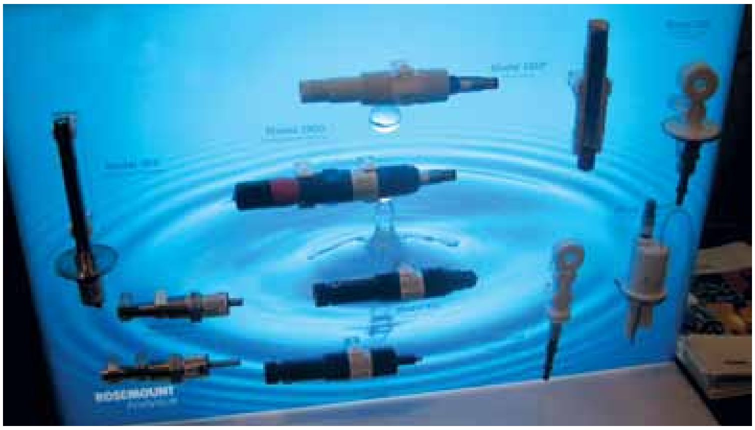
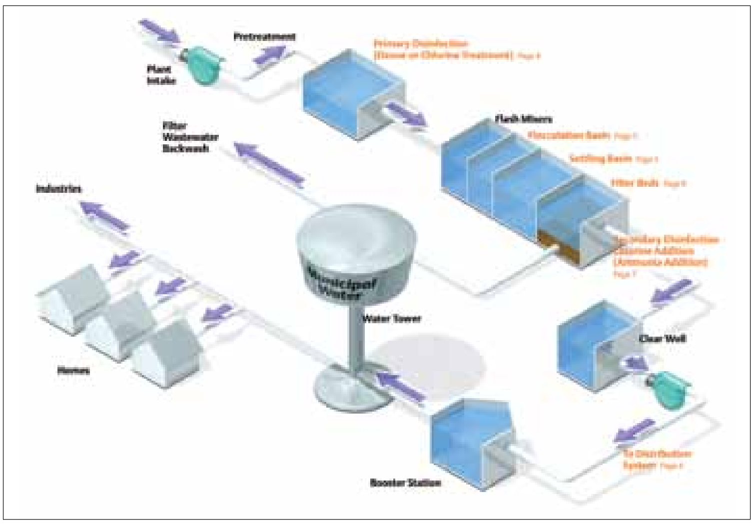
Pure by Analysis

***Ryo Hashimoto* discusses the use and importance of analytical measurements in assuring the quality and safety of drinking water.**



Water in adequate quantity and safe quality is essential for human survival. Regionally, Asia faces severe stress on water availability, primarily due to high population density, agriculture and industrial uses. The quality of drinking water is a health concern as water is a medium for disease transmission. In Southeast Asia, as in other developed regions, there can be significant water quality issues. Of these, contamination of drinking water sources by disease causing microorganisms remains the most important.

A major factor influencing the global water treatment market is the regulatory environment. More and more countries are adopting stringent policies and regulations for promoting the adoption of eco-friendly products, particularly with regard to products that involve human contact.



The key stages in drinking water treatment.

As a result, the demand for specialized water treatment products is rising to meet the requirements of a rapidly changing global environment. Demand from Asian and Latin American economies, particularly China, India, and Brazil are driving growth in the overall water treatment equipment and services market.

The demands for access to cleaner and purer water make a robust case for mobile water treatment in the rapidly growing Asia Pacific region. Mobile systems can offer a range of treatment options, including clarification, filtration, demineralization, reverse osmosis, membrane separation and/or induced air/gas flotation. Systems are skid-mounted and may be installed on-site or trailer-mounted. Trailers contain instrumentation and equipment for a fully automatic and monitored operation.

Water treatment plants also come in a wide variety of sizes, with no two plants exactly alike. But whether publicly owned, privately held, or mobile, they all share the same goal – to provide a source of safe and reliable drinking water to their communities. Liquid analysis systems play a critical role in maintaining this safety.

A combination of appropriate water treatment processes is selected by the water utilities to treat the contaminants in the raw water source used. Commonly used processes include pretreatment, coagulation, flocculation, sedimentation, filtration, and disinfection. Other treatment methods could include ion exchange, reverse osmosis, and adsorption.

Optimizing the use of liquid analytic measurements in each of these processes will save water treatment plants time and money, and help enhance water purity and safety. Using these measurements optimally helps improve both the process and the by-product.

Pretreatment stage

To better define the dynamics of the raw water source being used by a treatment plant, a number of liquid analytical measurements are made prior to entering the treatment process. Influent monitoring measurements could include pH, conductivity, temperature, turbidity, and dissolved oxygen. Some plants also 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 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.

Caustic soda is one of the basic building blocks of chemistry, and as such, it finds diversified applications. One use is in water treatment. Municipal water treatment facilities use caustic soda for pH adjustment, ion exchange regeneration, and on-site generation of sodium hypochlorite. Caustic soda, especially when used for pH control, neutralization of waste acids, and similar applications, competes with other alkalis, particularly sodium carbonate (soda ash). The common factors for selecting caustic soda are its stronger basicity and easier storage and handling.

This is one of the first steps to water treatment and is prior to the filter bed at the mixing tank. Measuring whether caustic soda is in the stream, which indicates whether the feed pumps are working, can be achieved with toroidal conductivity. Toroidal conductivity sensors are long lasting in this application and indicate by the drop in conductivity that the pump is not feeding caustic into the water stream.

Chemical	Oxidation Potential (volts)
Ozone	2.08
Hydrogen Peroxide	1.78
Hypochlorous Acid	1.48
Chlorine Gas	1.36
Hypobromous Acid	1.33
Chlorine Dioxide	0.95
Hypochlorite	0.81

Relative oxidation power of various chemicals.

Ozone sensor for monitoring ozone dosage and residuals during the primary disinfection stage.

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 well known and potentially lethal. Both surface water and groundwater sources can be contaminated by these pathogens, and inactivation is accomplished through chemical disinfection and mechanical filtration treatment.

Chlorine can be used as a chemical disinfectant of drinking water. Ozone (O_3) is also a powerful disinfectant used in water treatment. Ozone disinfects quicker than chlorine by attacking the chemical bonds of pathogens in the water, reducing the concentration of organic material, iron, manganese and sulfur, and reducing or eliminating odor and taste problems.

Chlorine, as a slow oxidizer, has limited effect on bacteria, and Cryptosporidium and Giardia are extremely resistant to it. Ozone treatment is gaining popularity as a fast and effective treatment technology in the primary disinfection stage.

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. For proper ozone disinfection to occur, suitable contact time and the proper ozone dosage are required.

Getting clarified

After pretreatment and primary disinfection, the clarification of raw water is usually a multi-step process for reducing turbidity and suspended solids, and comprises the stages of coagulation, flocculation and sedimentation.

Smaller particles combine or "coagulate" into larger fluffy particles called "floc" and settle out of the raw water source as "sediment". The coagulation process is promoted by the addition of chemical coagulant such as alum, iron salts or synthetic organic polymers. After chemical addition, the water flows through a mixing channel where it is flash mixed.

Lime in Water Treatment

Lime is used by many municipalities to improve water quality, especially for water softening and arsenic removal. In terms of annual tonnage, lime ranks first among chemicals used in the treatment of potable and industrial water supplies.

Lime has several applications:

1. pH Adjustment/Coagulation – Hydrated lime is widely used to adjust the pH of water to prepare it for further treatment. Lime is also used to combat "red water" by neutralizing the acid water, thereby reducing corrosion of pipes and mains. The corrosive waters contain excessive amounts of carbon dioxide. Lime precipitates the CO_2 to form calcium carbonate, which provides a protective coating on the inside of water mains.

2. Lime is used in conjunction with alum or iron salts for coagulating suspended solids incident to the removal of turbidity from "raw" water. It serves to maintain the proper pH for most satisfactory coagulation conditions. In some water treatment plants, alum sludge is treated with lime to facilitate sludge thickening on pressure filters.

A pH sensor is used to monitor and control the addition of chemicals for pH adjustment.

3. Effect on pathogen growth – by raising the pH of water to 10.5-11 through the addition of lime and retaining the water in contact with lime for 24-72 hours, lime controls the environment required for the growth of bacteria and certain viruses. This application of lime is utilized where "phenolic water" exists, because chlorine treatment tends to produce unpalatable water due to the phenol present. This process, called "excess alkalinity treatment", also removes most heavy metals.

The floc is mechanically stirred to attract suspended solids and microorganisms. Keeping the pH at the proper levels is important, as it improves the coagulation process, lowers the turbidity.

If the raw water source 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.

Floc settles to the bottom to form a sludge in sedimentation basins. The dirt and chemical agent become heavy enough to sink to the bottom, and the settling or sedimentation occurs naturally as larger particles settle out. Sludge is removed by mechanical scrapers and disposed of properly. Water is skimmed from the surface of the settling basins and flows into settled water channels.

Filtration process

Sedimentation removes particles 25 microns and larger, but the process is not 100 percent efficient, and thus filtration is required. The turbidity is between 1 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, as well as micro-organisms resistant to chlorine or ozone disinfection in the pretreatment stage.

Periodically, the filter must be backwashed to remove the 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. Turbidity is the clarity of the sample, and the cloudy appearance is caused by tiny particles in the water. Turbidity measurements also help monitor and improve plant efficiency. High turbidity levels are an indication that the filter is not operating properly, and backwashing is necessary.

Government rules and 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. This criteria includes the turbidity monitoring frequency, the maximum turbidity limit, and the approved turbidity measuring methods.

Secondary disinfection

Secondary disinfection prevents the re-growth of certain pathogens that may enter the treatment plant or be introduced by back-flow contamination. In compliance with the regulations requiring post residual disinfection, plants use chlorination as secondary disinfection in the final treatment step. Today, chlorine is added as chlorine gas (Cl_2), sodium hypochlorite (NaOCl), or chlorine dioxide (ClO_2) as the secondary disinfection agent.

When chlorine is added to water, free chlorine forms a mixture of hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). The relative amount of each is dependent on the pH, and the total of HOCl and OCl^- is defined as free chlorine. For disinfecting water, HOCl is not only more reactive than OCl^-, but is also a stronger disinfectant and oxidizer. HOCl is 80 to 100 times more effective than OCl.

Chlorination by-products were discovered in drinking water in 1974. They form when chlorine reacts with bromide and natural organic materials present in the water source, and have a potential health effect on humans. In an analytical instrument, chlorine diffuses through a semi-permeable membrane and develops a current proportional to the chlorine concentration inside the sensor.

Free chlorine measuring system for the secondary disinfection process.

Alternates to chlorine disinfection exist, such as chloramines. This process involves adding chlorine and ammonia compounds to the water that, when properly controlled, form chloramines.

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 the most effective water disinfectant. Plant operators using chloramination for disinfection need to accurately determine monochloramine levels in the water treatment systems.

Final treatment

Many water systems already have ammonia in their water or add ammonia during their treatment process. Excess free ammonia in water distribution systems promotes biological growth and nitrification. If the system experiences isolated areas of water quality degradation that affect the aesthetic quality of the water (i.e. taste, odor, particles in the water) or if the system has areas where it is difficult to keep acceptable chlorine levels, this might be a direct result of biological growth and nitrification.

The term “free ammonia” is used when naturally occurring ammonia is present in water and/or when chloramines are used to disinfect water. During chloramination, chlorine and ammonia are added to water to form monochloramine. The portion of ammonia that has not combined with chlorine is called free ammonia, and exists as either NH_4^+ or NH_3 depending on the pH and temperature of the water.

At typical water pH of 7.0 to 7.8 and temperature of 12 to 24 degrees Celsius, more than 96 percent of ammonia is in the ionized form of ammonium (NH_4^+). As the pH and temperature increase, the amount of NH_3 increases and the amount of NH_4^+ decreases.

The only accurate way to determine if treated water contains ammonia is to perform an ammonia analysis. If ammonia is detected, additional sampling on the distribution system for free ammonia should be explored. Ground water may have ammonia levels ranging between 0.2 to 2.0 mg/L.

Municipal drinking water plants carefully control their level of free ammonia (often also described as total nitrogen of NH_3-N) and chloramine (also called monochloramine or MCL) used to ensure that the water remains suitable for human consumption. There are panels available in single or dual measuring systems.

Wireless technologies can now enable water analysis in remote or difficult-to-access locations.

Wireless for water

One of the most significant new trends in water treatment is the use of wireless analytical technologies in remote or difficult-to-access locations. Wireless monitoring of pH and conductivity play a key role in many areas of the municipal water market. New wireless pH and conductivity transmitters can be integrated into a plant's network, making the adoption of wireless easy and painless.

New adaptor technologies allow wireless technologies to be added to Hart-enabled analyzers without the need for software upgrades, batteries or additional hardware, making the move to wireless systems cost-effective, scalable and simple. This approach reduces installation costs for water plants by up to 90 percent.

In addition, the wireless analyzers can transmit both process variables and diagnostic data back to the central system, reducing the workload of field personnel and maintenance. New systems feature onboard data logging capabilities, permitting the transfer of process data and events to a USB memory device for PC analysis, making the systems even more flexible for water plants.

In the water industry, the first clear benefit of this technology is elimination of the need for power and host communications wiring. Water plants and networks can integrate wireless pH and conductivity analyzers and sensors easily and cost effectively regardless of the wiring access challenges or remoteness of the installation.

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