Featured Articles

Solution for Food and Beverage Plants Based on High-concentration Ozonated Water Production System

Haruo Momose
Kazuhiko Noto, PE.jp
Kazuhiro Hata
Shuichi Mori

OVERVIEW: Hitachi supplies total solutions for the construction of manufacturing plants for the food and beverage industry, which is experiencing an expansion in global markets. Hitachi has developed technology for the production of strongly oxidizing high-concentration ozonated water, a key component of these plants, and is using it for cleaning and disinfecting. Cleaning times influence plant productivity, and having confirmed its ability to shorten cleaning times in beverage plants, Hitachi is also investigating rapid disinfection techniques that can act as a substitute for chlorine-based disinfectants in fresh-cut produce plants. In these cases, Hitachi anticipates that systems that utilize the properties of ozonated water produced at a high concentration can help shorten production times, reduce utility use, and deliver safe and secure products. Use in a wider range of applications is planned.

INTRODUCTION

FOOD manufacturing is expected to experience an almost doubling of market size over the next decade due to global population growth and rising incomes. Hitachi has a track record of taking on turnkey contracts for food and beverage plants that include construction, supplying solutions that deal not only with concerns about energy efficiency and the environment, but also the concerns about food safety and security that are growing year by year. The use of new technology to rationalize the manufacturing functions of plants in this industry is particularly important, and Hitachi is now working on the development of cleaning and disinfecting techniques that use high-concentration ozonated water, seeing these as key components of such plants (see Fig. 1).

Cleaning and disinfecting are among the most important processes for ensuring quality and safety in the food manufacturing industry, and they often consume a lot of time, energy, water, and chemicals. Given this situation, Hitachi wants to help rationalize plants by adopting technology for high-concentration ozonated water.

This article describes studies focusing on the use of high-concentration ozonated water for cleaning in place (CIP)[1] on beverage production lines that need to be made more efficient to produce a variety of

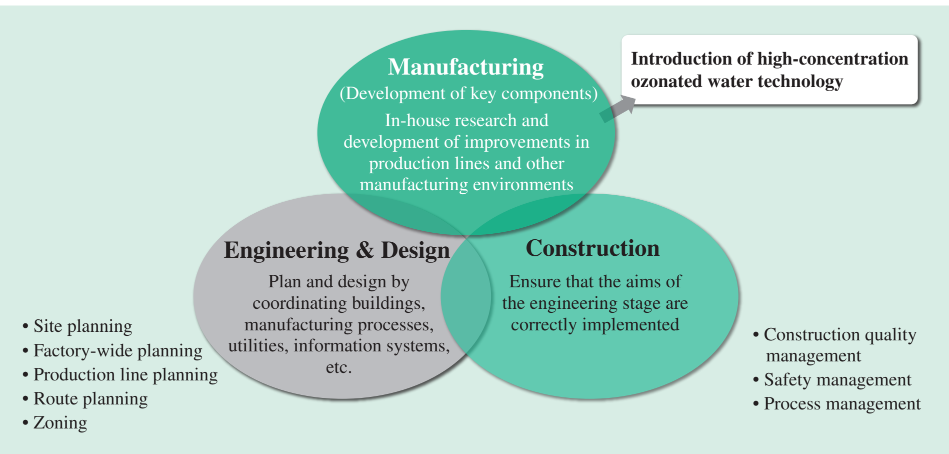

Fig. 1—Total Solution for Food Processing Plants and Introduction of High-concentration Ozonated Water Technology.
Hitachi has developed technology for the production of strongly oxidizing high-concentration ozonated water as a key component of its total solution.

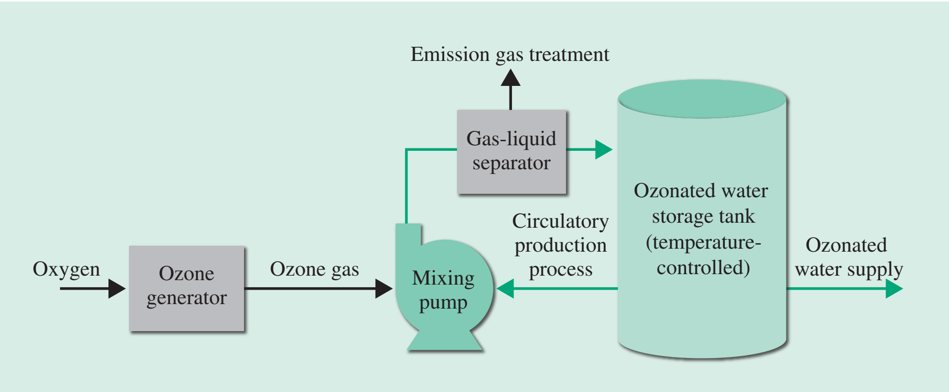

Fig. 2—Block Diagram of Ozonated Water Production System.
Higher concentration is achieved by using a circulatory production process that efficiently mixes high-concentration ozone gas with water.

different products, and for chlorine-free processes on disinfecting and cleaning lines for fresh-cut produce, a sector that is enjoying rapid growth.

PROPERTIES OF OZONATED WATER AND EQUIPMENT FOR ITS PRODUCTION AT HIGH CONCENTRATION

Properties of Ozonated Water

The properties of ozone include (1) strong oxidizing power, (2) it can be produced from air using only electricity, and (3) it does not leave a residue in food, rapidly self-decomposing into harmless oxygen. Accordingly, ozone has been used in food manufacturing for a comparatively long time, primarily for disinfecting and deodorizing. It is already recognized as an additive in Japan's food hygiene regulations and approved by the U.S. Food and Drug Administration. Although gaseous ozone, which is harmful to people, requires measures to prevent direct exposure, ozonated water (ozone dissolved in water) is comparatively safe for human use, such as its use in dental treatments, for example. Also, because the reactivity of ozonated water is higher than gaseous ozone, it is increasingly being used as a safe and reliable method for cleaning and disinfecting that does not use chemical agents or leave a residue in the product (food or beverage). However, because ozone gas is not very soluble in water and therefore tends to volatilize from ozonated water, the use of ozonated water on production lines presents challenges, because it is difficult to handle and difficult to produce and store at high concentrations.

Ozonated Water Production System

Common ways of producing ozonated water include the gas liquid mixing dissolution method, membrane dissolution method, and direct electrolytical (ozonation) method. For the solution described in this article, Hitachi has developed a high-concentration ozonated water production system based on a technique that combines circulation with gas liquid mixing dissolution using fine bubbles.

Fig. 2 shows a block diagram of Hitachi's ozonated water production system that uses this gas liquid mixing dissolution method. The main elements include the ozone generator, a mixer for mixing the ozone into the water (including a mixing pump and gas-liquid separator), a tank for storing and circulating the ozonated water, and a chiller for controlling water temperature (not shown in figure).

Parameters that control the concentration of ozonated water include the concentration of ozone gas mixed into the water, the water temperature, the gas-liquid ratio (mixing ratio for ozone gas and water), and the mixing pressure. Also important is water quality management (including pH) to reduce the decomposition of ozone while stored in the tank. While the concentration of ozonated water produced by gas and liquid mixing is fundamentally determined by Henry's Law, Hitachi also recognizes the importance of optimizing the ozonated water production system with consideration for the total efficiency of a particular application. Accordingly, Hitachi has developed a method for predicting the ozonated water concentration from the relevant control parameters and is seeking to optimize operation across the entire high-concentration ozonated water production system.

STUDIES ON THE USE OF HIGH-CONCENTRATION OZONATED WATER

Use for Piping CIP at Beverage Plant

The production line at a beverage plant consists of mixing (combining raw materials in a tank),

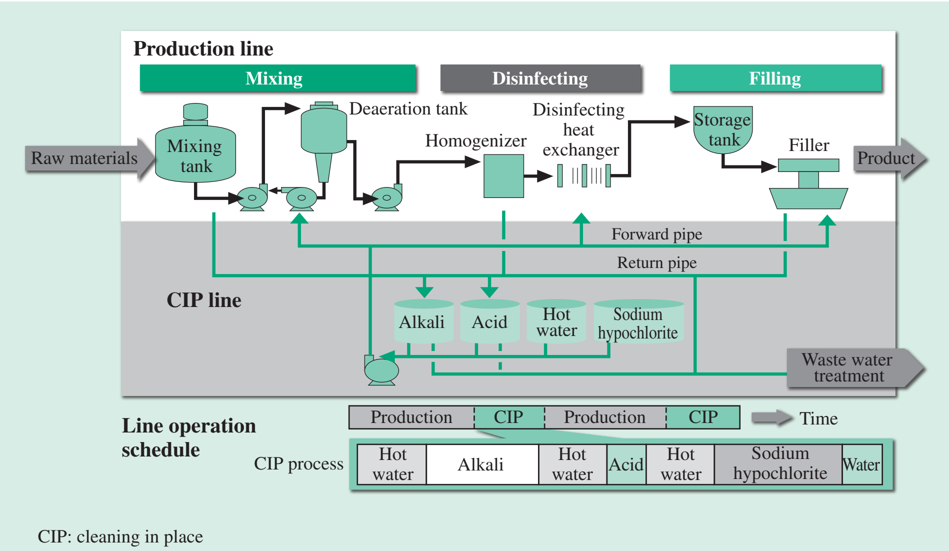

Fig. 3—Overview of a Beverage Plant.
A beverage plant consists of a production line (for mixing, disinfecting, and filling) and a CIP line for cleaning the interior of the production line. CIP is performed each time production switches to a new product.

disinfecting (heat sterilization of the product), and filling (sealing the beverage in a container) processes. Also part of the plant is an ancillary CIP line for cleaning the production line (see Fig. 3).

Since the operating schedule consists of alternating between production and CIP, and because production lines that produce a variety of different products perform CIP after each product run, increasing line utilization by shortening the time taken for CIP is an important challenge. Since the conventional practice for CIP involves the use of alkaline cleaning agents based on caustic soda, acidic cleaning agents based on nitric acid, and sodium hypochlorite to remove organic and inorganic material and sterilize the equipment, it involves problems such as the time taken for cleaning and the large quantities of highly concentrated chemical liquids and rinse water that is used.

To verify the cleaning performance of CIP using high-concentration ozonated water, Hitachi conducted testing using a model cleaning line and test samples (see Fig. 4). Transparent piping was installed along parts of the model cleaning line, and test samples were coated with model soil to be cleaned. The cleaning performance was assessed from the degree of residue left on the test samples after the cleaning fluid had been flowing through the model line for a fixed period of time. The cleaning fluids used for testing were an alkaline cleaning agent (caustic soda at a concentration of 3% and 80°C), sodium hypochlorite solution (300 ppm concentration, 23°C), and the high-concentration ozonated water (50 ppm, 30°C). The flow rate was 0.5 m/s.

Fig. 5 shows the test results. Conventional cleaning using an alkaline cleaning agent and

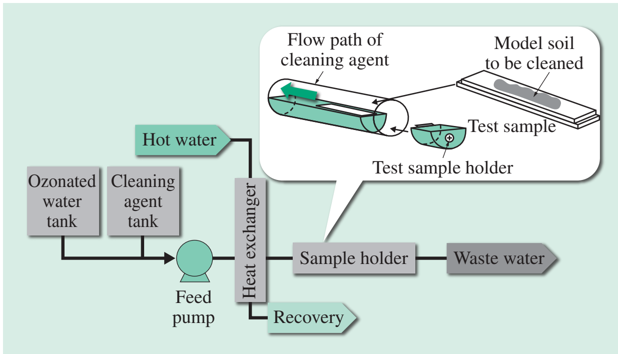

Fig. 4—Model Line for Testing CIP Cleaning Performance.
The model soil to be cleaned was baked onto stainless steel test samples and cleaning performance was assessed from the extent to which these samples were cleaned.

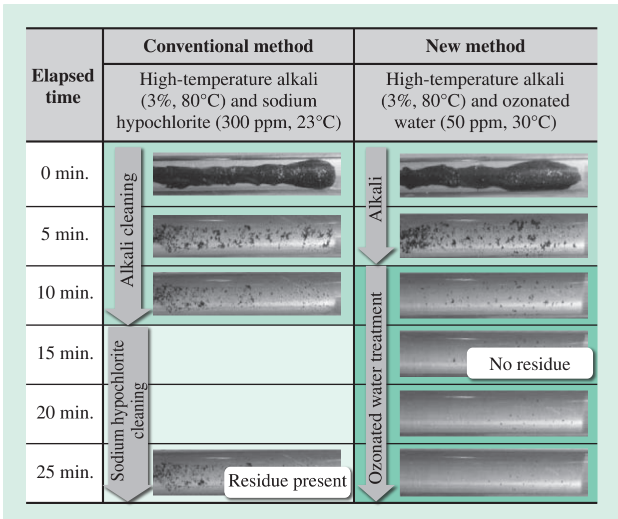

Fig. 5—Comparison of Cleaning Performance.
Cleaning efficiency was improved by replacing the conventional method with a cleaning procedure that also used ozonated water.

sodium hypochlorite solution failed to adequately clean the line, with considerable residue remaining after 25 minutes. Cleaning with high-concentration ozonated water was preceded by five minutes of alkali cleaning. It succeeded in completely removing all residue after a total time of only 15 minutes. This shows that the new technique can halve CIP time, and can increase production line capacity as well as reducing water and chemical use (see Fig. 6). However, because cleaning performance depends on the material to be cleaned, there is a need to optimize CIP conditions for each production line.

Use for Disinfecting Fresh-cut Produce

Demand for fresh-cut produce is growing along with changing lifestyles, such as the increase in the number of elderly and two-income households. Because cutting vegetables causes rapid growth in the number of bacteria attached to the vegetable surface, disinfecting is required to maintain product quality and prevent food poisoning. While sodium hypochlorite has been widely used for this purpose, the problems with this include vegetables being left with a distinctive smell of bleach, the inherent risk of leaving a residue of organic chlorine compounds, and a tendency for vegetables such as iceberg lettuce to brown* even when kept in cold storage after disinfection.

The use of ozonated water for disinfecting vegetables has been studied for the last 10 years or so, and in some cases has been implemented in practice(2). The highly oxidizing nature of ozone means that, along with disinfecting bacteria from the vegetable surface, it may also damage the vegetable. For this and other reasons, such as competition from low-cost sodium hypochlorite disinfection, it has failed to enter wider use.

Fig. 7 shows the typical processing sequence for the production of fresh-cut produce. Fresh-cut produce needs to be kept at a low temperature at the processing plant to maintain its quality. Unlike sodium hypochlorite, ozonated water can disinfect at low temperature. A cleaning system that uses less energy for cooling can be achieved by supplying high-concentration ozonated water at a low temperature based on the rate at which ozone is consumed during the cleaning process.

This article describes a study focusing on the use of a technique for cut iceberg lettuce, one of the main types of fresh-cut produce and one that is difficult to keep in good condition because it is so easily damaged. By making a number of improvements to the methods used for disinfecting, washing, packaging, and storage, Hitachi developed a cleaning technique that combines ozonated water cleaning with a heat shock (HS) treatment(3) that uses hot water.

Fig. 8 shows the procedure used to test the cleaning performance of the technique together with the test results. Commercial iceberg lettuce was cut into

* The browning of vegetables such as iceberg lettuce at the parts where they have been cut or damaged.

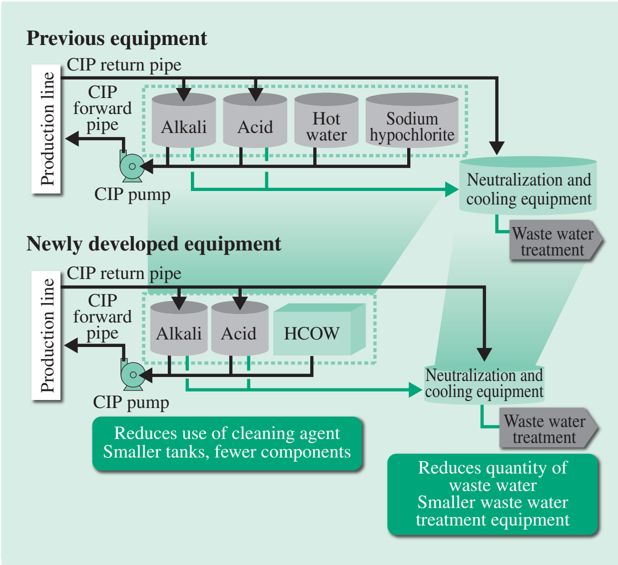

Fig. 6—Use of High-concentration Ozonated Water (HCOW) to Rationalize CIP.
Using ozonated water reduces the use of cleaning agent and rinse water and shortens the time taken for cleaning.

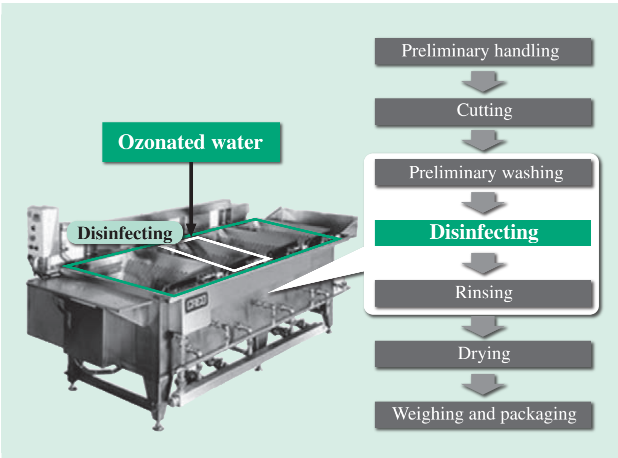

Fig. 7—Fresh-cut Produce Production Process and Cleaning and Disinfecting System.
Switching from the conventional sodium hypochlorite cleaning method to ozonated water makes cleaning and disinfecting more efficient.

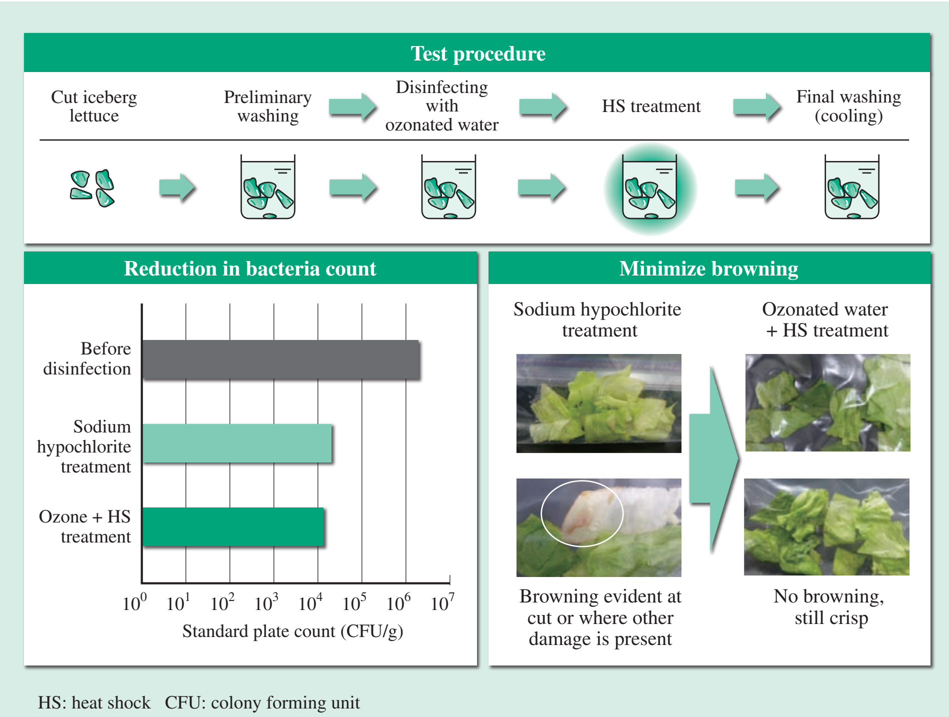

Fig. 8—Procedure and Results of Testing Cleaning and Disinfecting Performance of Ozonated Water.
Using ozonated water achieved a similar reduction in bacteria count to the conventional method using sodium hypochlorite, and also improved product quality.

3- to 5-cm squares, washed and disinfected with ozonated water, and then HS-treated with hot water. The high-concentration ozonated water was diluted to a concentration of 5 ppm. The combined ozonated water and HS treatment achieved a similar level of disinfection to sodium hypochlorite while also keeping the vegetables crisp with no browning.

Other major advantages of the new cleaning and disinfecting method are that it requires only about one minute to disinfect and is easy to rinse off (also about one minute). This means it uses less energy and water than the previous sodium hypochlorite technique, in which disinfecting takes five to 10 minutes and rinsing about 10 minutes, requiring a large amount of water. Running costs can be cut by 40% or more compared to existing sodium hypochlorite disinfecting methods. Hitachi believes the overall system can deliver new value, with sensory evaluation results indicating that using ozonated water instead of sodium hypochlorite can also keep vegetables fresh, which is what consumers want.

DEPLOYMENT OF HIGH-CONCENTRATION OZONATED WATER TECHNOLOGY AND ASSOCIATED CHALLENGES

Other than the applications discussed here, the use of ozonated water at high concentration can also help decompose chemicals that are otherwise difficult to remove and improve the elimination of microorganisms that are tolerant of heat and chemicals. One example is a system that has been developed specifically for a food processing plant to deodorize exhaust air. Because ozone can break down odor-causing substances such as lower fatty acids and sulfur or nitrogen compounds, high-concentration ozonated water is used as the spray water in a wet scrubber. The work also indicates that the system can kill heat-resistant spores in liquids (something that past techniques have found difficult) under low-temperature conditions of around 5°C. Other possibilities include building systems that can produce ozonated water centrally at high concentration and supply it as required at the point of use, and systems that can reuse used low-concentration ozonated water for wastewater treatment or for the sanitation of factories (floor, wall, surface of machines, etc.).

While this indicates the excellent potential of ozone at high concentrations for cleaning and disinfecting in the food and beverage industry, one requirement for doing so is that gaskets and similar parts be made of ozone-resistant materials.

Also, the maximum concentration of gaseous ozone allowed in the workplace in Japan and many other countries is around 0.1 ppm (exposure limit). It is necessary for systems that use ozonated water to incorporate safety measures such as ventilation at locations where there is the potential for ozone to escape into the work environment in highly concentrated gaseous or other forms. Hitachi uses simulations based on computational fluid dynamics to provide suitable countermeasures.

CONCLUSIONS

While high-concentration ozonated water is already used in semiconductor cleaning applications, this has involved high-cost systems that use high-purity oxygen gas and ultra-pure water as inputs. Now Hitachi has enabled its use in the food and beverage industry by adopting a low-cost circulation-based production technique that uses ambient air and tap water as its raw materials.

Food and beverage manufacturing requires highly reliable production processes in relation to risks such as large-scale product recalls caused by incidents such as food poisoning or product accidents. In the future, Hitachi intends to continue testing with producers of beverages and fresh-cut produce, and to make a broad contribution to the food manufacturing industry, including through plant construction, by adopting the new system as a key technology. Hitachi also plans to expand its applications beyond food manufacturing into a wide range of fields encompassing chemicals, pharmaceuticals, and biotech.

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ABOUT THE AUTHORS

Haruo Momose

Process Department, Industrial Plant Solutions Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in planning and design for food/chemical plant construction. Mr. Momose is a member of the Japan Society for Food Engineering (JSFE) and The Kinki Chemical Society, Japan.

Kazuhiko Noto, PE.jp

Technology Development Department, Industrial Plant Solutions Division, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the development of a cleaning and disinfecting process for the food and beverage industry.

Kazuhiro Hata

Air Conditioning & Plant Engineering Systems Department Matsudo Research Center, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the research and development of a cleaning and disinfecting process for the food and beverage industry.

Shuichi Mori

Air Conditioning & Plant Engineering Systems Department Matsudo Research Center, Infrastructure Systems Company, Hitachi, Ltd. He is currently engaged in the research and development of systems and instruments mainly for food/chemical/pharmaceutical plants. Mr. Mori is a member of the Parenteral Drug Association (PDA) and the JSFE.