Utilization of Ozone Water Generators for Preventing Infection in Home Care

Koichi Umimoto, Shinichi Iguchi, Yoshimasa Shimamoto, Katsunori Tachibana, Syunji Nagata
Department of Biomedical Science
Osaka Electro-Communication University
Osaka, Japan
e-mail: umimoto@osakac.ac.jp, hpfkp523@yahoo.co.jp, yoshi_1014shima@yahoo.co.jp, tatibana@osakac.ac.jp, narasinagatashunji@yahoo.co.jp

Yuki Nakamura
Department of Medical Engineering
Morinomiya University of Medical Sciences
Osaka, Japan
e-mail: yuki_nakamura@morinomiya-u.ac.jp

***Abstract*—The prevention of opportunistic infection is important in-home care. Electrolyzation of water generates ozone water, which is strongly bactericidal. Because ozone water can be produced easily and reverts to water, it is an attractive option for hygiene management in home care. Here, we developed two devices for producing ozone water for home care and investigated the properties and bactericidal ability of the water. The first, simple device comprised a lead dioxide anode, a stainless cathode, and a diaphragm. We used the device to electrolyze 1 L of tap water and measured the ozone concentration over time. In addition, we assessed the bactericidal activity of the ozone water by performing an aerobic viable count of Escherichia coli and Staphylococcus aureus. The other device used a diamond-coated titanium plate as the anode and a stainless cathode to create ozone water from tap water flowing through an outdoor hose. The ozone concentration was measured at 0, 2, and 4 m from the hose nozzle. In the simple device, the ozone concentration was 1.1 ppm 20 minutes after starting electrolysis, but 0 ppm 70 minutes afterwards. Many colonies of E. coli and S. aureus were present in the cultures before ozone water was added, but none was detected after adding 1.1 ppm of ozone water. In the flowing water device, the ozone concentrations released at 0, 2, and 4 m were 1.6 ±0.2 ppm, 1.4±0.2 ppm and 0.6±0.3 ppm, respectively. Ozone water produced with our simple device showed strong bactericidal activity. The ozone water released within 2 m from the nozzle of the flowing water device contained more than 1.0 ppm of ozone. Thus, our devices represent an economical, environmentally friendly way to produce ozone water for use as a disinfectant in indoor and outdoor home care.**

Keywords- Home care; Ozone water; Bactericidal activity.

I. INTRODUCTION

Hygiene management for infection is required in home care, especially to prevent opportunistic infection in older adults, who have reduced resistance to infection. Generally, chemical disinfectants are used to prevent infection, however, their chemical components remain in the environment after use and contribute to global environmental pollution.

Electrolysis is a well-known technique for separating ionic substances. When water is electrolyzed with an electrolytic cell comprising two chambers separated by a diaphragm, ozone water is generated on the anode side (Figure 1). Electrolyzed ozone water is strongly bactericidal and reverts to ordinary water [1]. Economic and environmental factors make it highly suitable as a disinfectant in home care.

In this study, we developed two devices for producing ozone water for use in home care. We used the first, simple device to investigate the properties and bactericidal activity of ozone water. With the second, flowing water device, which produces ozone water for outdoor use, we studied the concentration of ozone water at different distances from the hose nozzle.

In Section 2, we present the methods of our approach. In Section 3, we give the results obtained, followed by a discussion in Section 4. Finally, we conclude our work in Section 5.

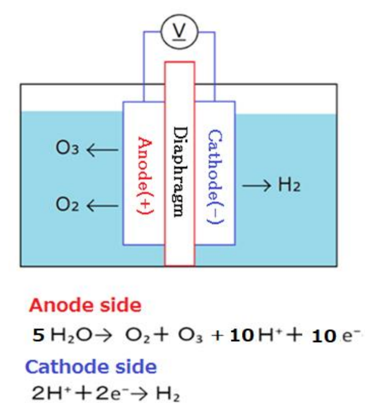

Figure 1. Principle of ozone water production.

II. METHODS

A. Development of the simple device

We developed a simple device for making ozone water. The device was a batch type, and the exterior was made of acrylic resin. The device consisted of a lead dioxide as the anode, and a stainless as the cathode, and a solid electrolyte membrane as the diaphragm. The electric power is supplied via a direct current converter (Figure 2).

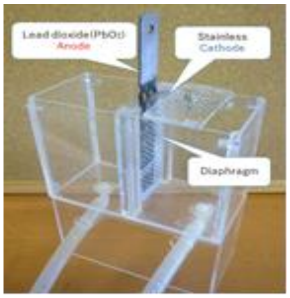

Figure 2. Prototype of batch type for producing ozone water.

B. Properties of the ozone water

We electrolyzed 1 L of tap water in the simple device by using a 20V direct current and measured the ozone concentration on the anode side. To investigate the sustainability of ozone water, we put the fresh ozone water into a beaker and measured its ozone concentration over time by 4-aminoantipirin absorption photometry.

C. Bactericidal activity

To investigate the bactericidal activity of ozone water, we prepared two strains of bacteria, *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*). *E. coli* is an intestinal, gram-negative bacterium, and *S. aureus* is a gram-positive bacterium. The bactericidal activity of the ozone water was examined by cultivating the two strains of bacteria separately at 37°C for 24 hours. Then, each culture was incubated with fresh ozone water, and the solution was added to fresh petri dishes and cultivated for 48 hours. Control samples were prepared in the same way, but no ozone water was added. The bactericidal activity was assessed by counting the number of colonies of bacteria in each petri dish.

D. Development of a flowing water device

We developed a flowing water device for making ozone water, as shown in Figure 3. A diamond-coated titanium plate was used as the anode, and a stainless as the cathode. The device consisted of an electric cell with built-in electrodes and a hose, which was directly connected to an outdoor water source. The ozone water was released by pressing the hose nozzle (Figure 4).

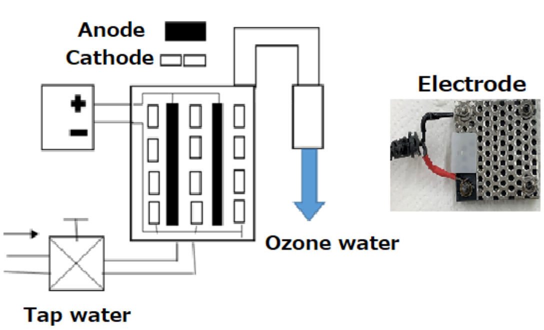

Figure 3. Principle of flowing ozone water production.

Figure 4. Prototype of the flowing water device for producing ozone water (left), and procedure for measuring the ozone concentration at various distances from the hose nozzle (right).

E. Ozone concentration in water released by the flowing water device

The leased ozone water at 0, 2, and 4 m from the hose nozzle was stored in the beaker and its ozone concentration was measured.

III. RESULTS

A. Experiments with the simple device

The ozone concentrations were 0.3 ppm at 10 minutes after the start of electrolysis and 1.1 ppm at 20 minutes, however, the concentration started to decrease immediately, and the levels were 0.3 ppm after 30 minutes and 0 ppm after 70 minutes (Figure 5).

In the control water sample, many colonies of *E. coli* (13×10^{7} cfu/mL) and *S. aureus* 35×10^{6} cfu/mL) were counted. However, no bacterial colonies were seen after cultivation with 1.1 ppm of ozone water (Figure 6).

B. Experiments with the flowing water device

The ozone concentration was 1.6±0.2 ppm in water at 0 m from the hose nozzle and 1.4±0.2 ppm in water at 2 m. Thus, the ozone concentration at both 0 and 2 m exceeded 1.0 ppm, i.e., the concentration that can be expected to have a sterilizing effect. However, at 4 m the concentration of ozone in the water was only 0.6±0.3 ppm (Table 1).

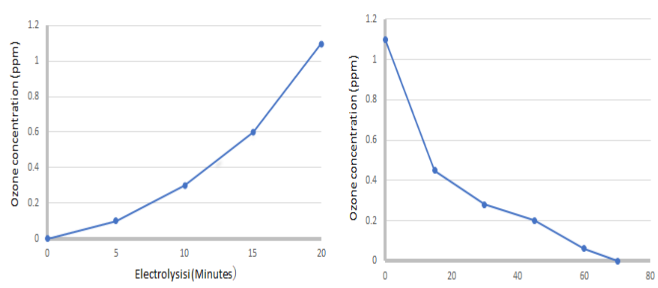

Figure 5. Changes in ozone concentration during electrolysis (left) and residual ozone concentration after ozone water generation (right).

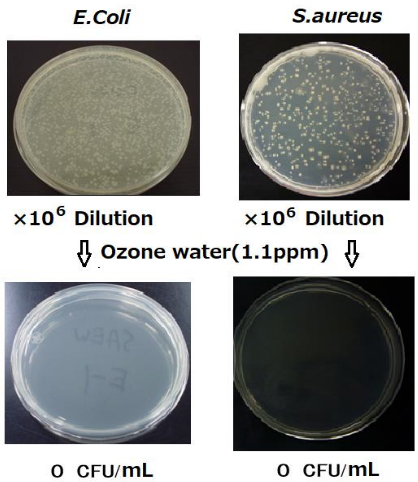

Figure 6. Bactericidal activity of ozone water.

TABLE 1. OZONE CONCENTRATION IN RELEASED WATER

Released distance of ozone water (m)	0	2	4
Ozone concentration in released water(ppm)	1.6 ± 0.2	1.4 ± 0.2	0.6 ± 0.3

IV. DISCUSSION

Generally, ozone has a strong oxidative effect and is used for sterilization and deodorization in a wide range of fields, such as medicine, engineering, and agriculture. Methods for producing ozone water include electrolysis and discharge techniques. In this study, we developed a simple device to produce ozone water by electrolysis. This device is easily installed at home and required almost no maintenance; it is also cheap to use because it requires only tap water. A concentration of 1 ppm of ozone water is required for bactericidal activity, and our device produced 1.1 ppm of ozone water within 20 minutes (Figure 4) and showed strong bactericidal activity (similar to that of chemical disinfectants) against *E. coli* and *S. aureus* (Figure 5). Our experiments showed that the ozone disappeared from the water 70 minutes after the start of electrolysis (Figure 4), meaning that there was no persistence of the chemically active substance, unlike with chemical disinfectants. This lack of persistence is an advantage of ozone water and makes it suitable for disinfection in home care.

Previously, we studied the use of acidic electrolyzed water, which is produced by water electrolysis and is strongly bactericidal [2][3][4]. However, a small amount of sodium chloride is needed to produce electrolyzed water, and electrolysis generates harmful chlorine gas [5]. In contrast, ozone water can be generated from water alone and reverts to ordinary water.

In addition to hand disinfection, the prevention of infection at home requires disinfection of utensils such as tableware, cooking utensils, and sanitary appliances such as toilets. Our study shows that ozone water can be easily produced at home and used indoors to prevent infection. Our experiment with ozone water produced by a flowing water device (Table 1) showed that the released ozone water can be used as a bactericidal agent outdoors up to about 2 m from the hose nozzle. Outdoors, ozone water can be used in a wide variety of applications, e.g, the disinfection of equipment.

Our ozone water-generating devices and ozone water experiments indicate that the production of ozone water at home may be a useful approach to infection prevention in home care. Future studies should evaluate the use of ozone water in various indoor and outdoor applications and confirm its effectiveness.

V. CONCLUSION AND FUTURE WORK

We developed two devices that can be used at home to produce ozone water for infection prevention. The simple device produces 1.1 ppm of ozone water within 20 minutes of starting electrolysis, and the ozone water shows strong bactericidal activity; the ozone disappears within 70 minutes. The flowing water device maintains a bactericidal ozone concentration up to 2 m from the hose nozzle and is suitable for outdoor use. The devices are useful for producing ozone water as a disinfectant for use in home care and are beneficial from both an economic and an environmental perspective.

In the future, we will carry out the questionnaire survey using those devices in home care and summarize the points for improvement based on usage experience.

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