Air Purification Systems for Large Scale Space Applied Electric Discharge Technology

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Keywords: Air Purifier, Ozone, Suppressing Viral Activity, Large Spaces

1. Introduction

The expansion of COVID-19 has increased the demand for air purifiers that can remove germs and viruses. So, authors have developed an air purifier that effectively removes viruses in large spaces such as arenas by using industrial electrostatic precipitator (ESP) technology. The new air purifier has two types; "stationary type" and "portable type". Both types produce ozone gas by electrical discharge in the device and supply it to the space when there are no people, thereby suppressing the activity of viruses existing in the space. This paper introduces the features of each product, effect of suppressing the activity of viruses by ozone, and its application in hospital facilities.[1]

2. Reasons for using ozone

As a method for removing bacteria and viruses, ozone, UV, and chemicals (alcohol, etc.) are known. The air purifier in this paper, ozone is used among them (UV and chemicals are not used), and the reason is as follows.

(1) Ozone is effective against various kinds of bacteria and viruses, and the effectiveness of ozone against the novel coronavirus (SARS-CoV-2) has already been published. [2][3][4][5][6][7]
(2) Ozone is a naturally occurring substance that does not persist, so it has little impact on organisms than chemicals.
(3) By supplying it in gaseous form, ozone can reach every corner of the room, and the activity of the virus can be suppressed over a wide area.
(4) Ozone generated by ESP for collecting fine particles can be used as it is.

3. The features of air purifier

3.1 Stationary type

The stationary type is a device which combines collection of fine particles such as virus and supply of ozone. In order to collect fine particles highly efficiently, it is quite popular to use a HEPA filter and it has also been reported to be effective for the collection of droplets containing viruses. [8][9][10] [11] However, since the pressure drop of the filter is large, there is a problem that the amount of air to be treated is small and it is not suitable for a large-scale space. On the other hand, as shown in Figure 1, the stationary type collects fine particles by the combination of ESP and a collecting filter (electret filter with lower pressure drop than HEPA filter) which has small pressure drop. By charging the fine particles electrically with ESP, the fine particles are adsorbed to the filter by electrostatic force, and the dust collection performance of the fine particles in the range of 0.3μm to 0.5μm, which is generally difficult to collect, is greatly improved. Therefore, droplets containing virus can be collected with high efficiency even if the treating air volume is so large.

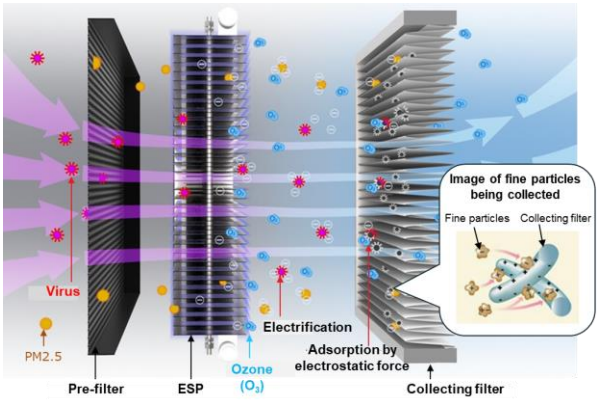

Figure 1 Fine particle collecting method in stationary type

Figure 2 shows the appearance and operation of the stationary type. During the time when people stay in the space where the air purifier is installed, ozone generated by ESP is reduced to safe concentration by an ozonolysis filter, and purified air is supplied into the space, while during the time when people do not stay in the space, such as at night, the activity of the virus existing in the space, the floor, and the wall is suppressed by supplying the ozone generated by the ESP into the space. Also, the stationary type can be incorporated into the air handling unit in the facility. As shown in Figure 3, ESP and ozonolysis filters are additionally installed, and the filter for collection is replaced with the newly recommended one. Then the same dust collecting performance as the stationary type can be obtained.

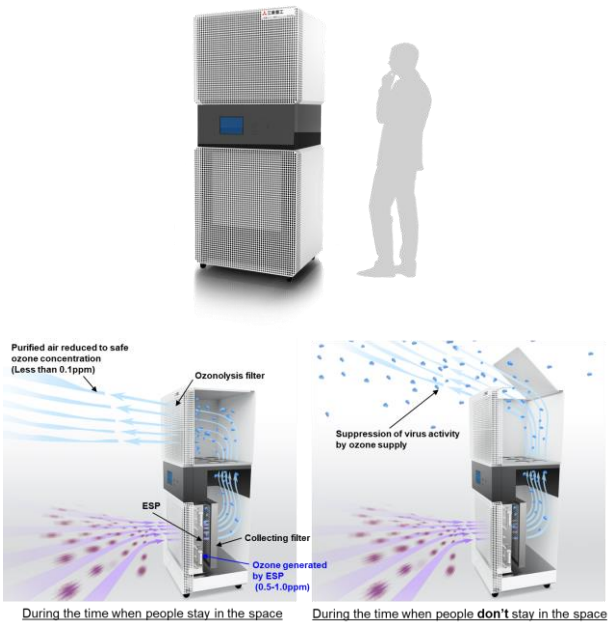

Figure 2 Appearance and operation of the stationary type

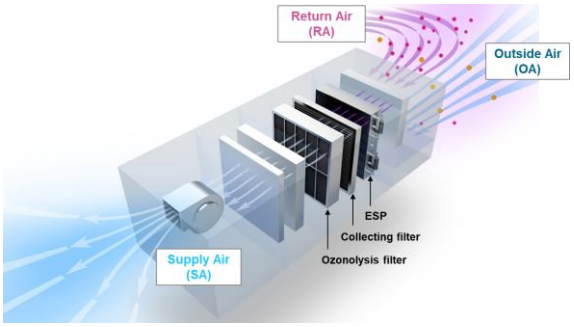

Figure 3 Application of stationary type to air handling unit

3.2 Portable type

The portable type is specialized in ozone supply and uses surface discharge which can generate ozone more efficiently than corona discharge. The portable type is shown in Figure 4. It can be easily moved by casters and is suitable for uniformly supplying ozone to a wide space such as a dome or a hall. It is supposed to be used in the necessary place during the time when there are no people.

Figure 4 Appearance of the potable type

4. Effect of suppressing the activity of attached viruses by ozone

Using ozone generated by the same discharge technologies as the stationary type and the portable type, we examined the effect of suppressing the activity of attached viruses. The results are described below.

(1) Testing institution
Public University Corporation Nara Medical University

(2) Test method
A petri dish to which the new coronavirus (SARS-CoV-2) was applied was set and exposed to the ozone gas, which was generated by the same discharge method as that of the products (stationary type and portable type), in a predetermined concentration for a certain length of time. After the lapse of the certain length of time, viruses were collected and the infectivity titer of the viruses (PFU/mL) was calculated by the plaque technique.

(3) Test results
The ozone generated by each method was exposed to the new coronavirus with the infectivity titer of the viruses of 1.10×10^5 (PFU/sample). As a result, the following virus reduction effect (reduction rate) relative to the control (base value including natural damping) was obtained.

[1]Ozone generation technology of stationary type (corona discharge method)
a. Reduction rate at an ozone concentration of 0.21 ppm to 0.23 ppm, a temperature of 27.7°C to 29.3°C and a humidity of 51.9%RH to 53.3%RH:
After 60 minutes: 84.1%, after 120 minutes: 91.8%, after 240 minutes: 99.4%

[2] Ozone generation technology of portable type (surface discharge method)
a. Reduction rate at an ozone concentration of 0.21 ppm, a temperature of 29.3°C and a humidity of 55.2%RH:
After 240 minutes: 97.4%
b. Reduction rate at an ozone concentration of 0.70 ppm to 0.77 ppm, a temperature of 28.3°C to 28.8°C and a humidity of 55.9%RH to 58.9%RH:
After 90 minutes: 99.9%

(4) Special notes
[1] These test results do not demonstrate the actual airborne virus reduction effect of the ozone generated by each of the products in a space where it is actually used.
[2] It has been reported that ozone has a certain virus reduction effect, but this does not mean or assure that ozone has preventive effects against viral infection diseases.

5. Operation examples of each product in hospitals

5.1 Operation examples of Stationary type

The case which installed the stationary type in the hospital facility is introduced. It was installed in the PCR testing center shown in Figure 5 and 6, and particulate air dust in the range of 0.3μm to 0.5μm floating in the room was measured under the condition of 50% air volume (about 25m^3/min). As a result, it was confirmed that the collection efficiency reached 80% or more at all measuring points after about 60 minutes as shown in Figure 7.

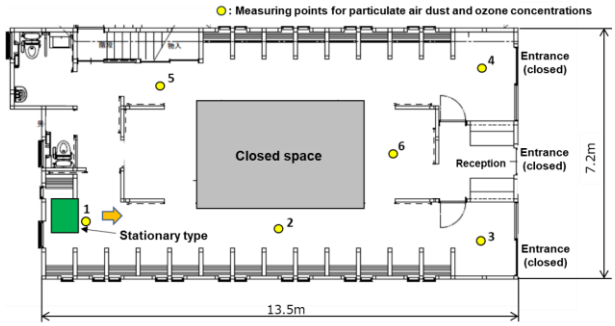

Figure 5 PCR testing center

(a) Installation state

(b) Appearance of the device

Figure 6 Operation example of Stationary type

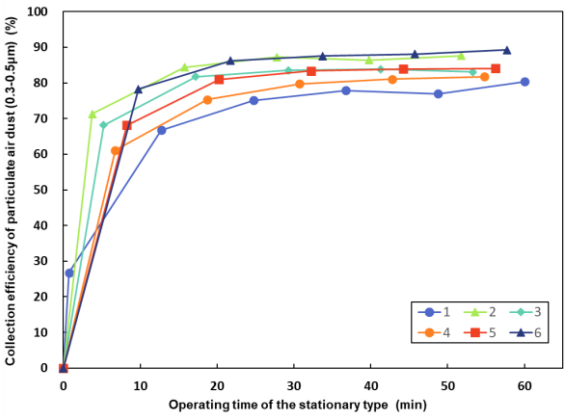

Figure 7 Collection effect of particulate air dust

In addition, as a result of supplying ozone to the room by controlling the output while the ozone concentration becomes a constant value, the ozone concentration was maintained in the range of 0.2 ppm to 0.25ppm as shown in Figure 8. It was confirmed that the ozone concentration was reduced to safe level within 10 minutes by an ozonolysis filter after the ozone supply was stopped.

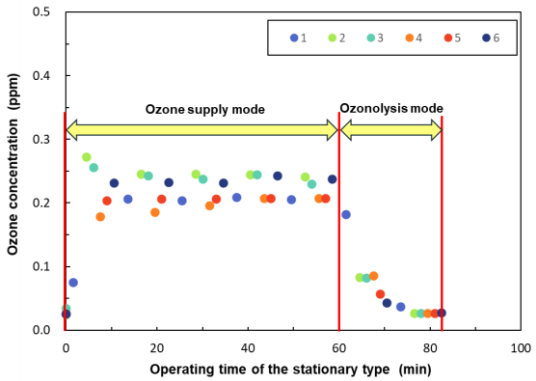

Figure 8 Results of ozone concentration measurement

In actual operation, three operation modes are automatically selected by timer setting. Figure 9 shows the daily data of the built-in ozone densitometer. During the office hour of the clinic, particles such as viruses floating in the space are collected with high efficiency, and ozone is reduced to safe concentration with an ozonolysis filter. On the other hand, a high concentration of ozone (0.5ppm) is supplied to the room by bypassing the ozonolysis filter during the period when the clinic is closed. After the CT value (Concentration x Time) required for virus inactivation is achieved, the energization is turned off and the ozone concentration is reduced to safe concentration by an ozonolysis filter. As a result of continuous operation for about 4 months, it was always confirmed to keep the set ozone concentration.

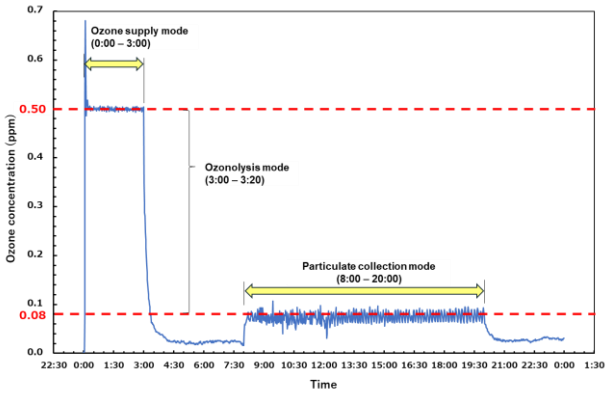

Figure 9 Ozone concentration during automatic operation

5.2 Operation examples of Portable type

As shown in Figures 10 and 11, a portable type was installed in Artificial dialysis room and operated at air volume of 50 m^3/min, during the period when the clinic is closed. Output control was performed by use of the ozone densitometer built into the device so that the ozone concentration in the space is kept at a constant value. As a result, it was confirmed that after about one hour, the ozone concentration at each measurement point in the room could be kept at 0.37 ppm to 0.5 ppm as shown in Figure 12. After that, ozone supply was stopped and the window was opened for ventilation and it was confirmed that in about 10 minutes, the ozone concentration was reduced to near a safe concentration (0.1 ppm).

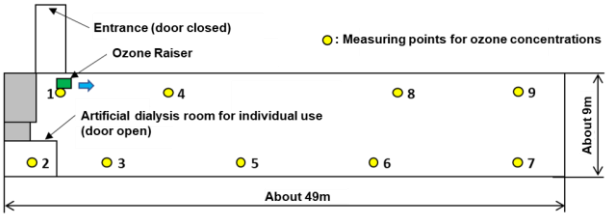

Figure 10 The artificial dialysis room

(a) Installation state

(b) Appearance of the device

Figure 11 Operation example of Portable type

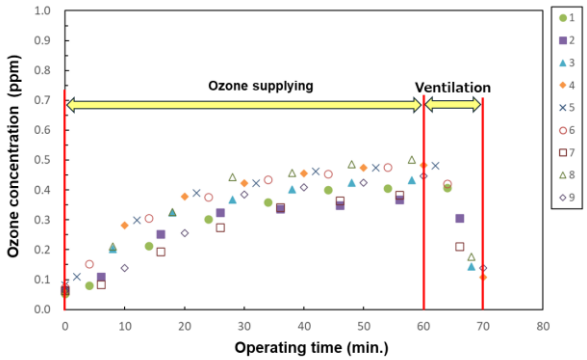

Figure 12 The effect of ozone supplying and ventilation

6. Conclusion

In the recent circumstances where the need for air purification has been increasing, our air cleaning devices can be expected to provide high-efficiency particulate collection in large spaces and suppression in the activity of viruses by ozone and serve as an aid to air purification measures. Authors will continuously offer air purification devices beneficial to environmental health and contribute to the realization of a society where people can live in safety.

Note 1: Notes on safety of ozone and measures

1. Ozone affects the human body depending on the concentration. Therefore, due care must be taken when the ozone generating products are used.
2. The product has a built-in ozone densitometer and the ozone concentration of the target space is continuously monitored. When the ozone concentration becomes high, a "high ozone concentration" warning is issued and the supply of ozone is automatically stopped.
3. Stationary type, which can be operated in an environment with people present, reduces the ozone concentration to a safe ozone concentration (0.1 ppm or less which is the working environment standard) through the ozonolysis filter and supplies purified air into the space.
4. This product can be remotely operated so that operators can avoid operating and monitoring in a space where ozone exists.

Acknowledgement

Authors would like to acknowledge to department of Microbiology and Infectious Diseases, Nara Medical University, for confirming the effect of suppressing the activity of attached viruses by ozone.

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