Air Purification Systems for Large Scale Spaces Applied Electric Discharge Technology, “Ozopure” and “Ozone Raiser”

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In recent years, the need for the removal of bacteria and viruses—in addition to air pollutants such as particulate matter (PM2.5), yellow sand and pollen—has been increasing in order to prevent the health damage that they can cause. To deal with this issue, Mitsubishi Heavy Industries Power Environmental Solutions, Ltd. (MHI) developed and commercialized two types of new air purifier for effectively purifying large-scale spaces, to which we applied our proprietary technologies for the Electrostatic Precipitator (hereinafter referred to as ESP) that have been acquired through the development of Air Quality Control Systems (AQCS) for power generating plants. Both devices can be expected to suppress the activity of viruses through the application of ozone (Note 1) generated in the devices by using electric discharge technologies (see section 2.3). “Ozopure,” which collects particulates by electrostatic force with high efficiency and “Ozone Raiser,” which is a portable device specialized for ozone supplying and can be moved to any desired place, can be selected according to the intended use. This report introduces the features of each product and operation examples in hospitals.

1. Introduction

To cope with the recent increasing need for air purification, household air cleaners have been used in many cases so far. However, the volume of air that household air cleaners can treat is small and they are not suitable for the treatment of air in large-scale spaces. In some cases, HEPA filters with a high-performance dust removal function or quasi-HEPA filters are used, but they have a high pressure drop and must be replaced often.

One of the effective technologies to deal with the above issues is electric discharge technology using for ESP, which has actually been applied to many AQCSs for power generating plants. An ESP has a lower pressure drop compared to filters and this makes it suitable for the treatment of a large volume of air and enables the high-efficiency collection of particulates with stability for a long time. In Ozopure, an ESP and a dust collection filter with a low pressure drop are combined, so that particulates ranging in size from 0.3 μm to 0.5 μm, which have been difficult to collect, can be collected with high efficiency. In addition, the ozone generated by electrical discharge in ESP can impart a deodorization effect and a suppression in the activity of viruses can also be expected.

On the other hand, Ozone Raiser adopts surface discharge instead of the corona discharge used in an ESP and can generate ozone more efficiently.

2. Overview of air purifier

An outline of each product specifications is shown in **Table 1** and the features of each product are described below.

Table 1 Outline of each product specifications

Product name	Ozopure		Ozone Raiser	
	Standard type	Built-in type to AHU		
Power	100V	This type can be incorporated in newly-installed or existing air conditioning equipment (AHU) and individually designed according to the specifications of the air conditioning equipment	100V	200V
Size	Width 850mm Depth 700mm Hight 2,000mm		Width 700mm Depth 1,350mm Hight 1,200mm	
Ozone generation amount (per power consumption of the ozone generating part)	1.7g/h (8.5g/h/kW)		15g/h (40.5g/h/kW)	34g/h (42.5g/h/kW)
Air capacity	3,000m^3/h		3,000m^3/h	
Power consumption (Total)	1,100W		800W	1,200W
Space treated (Note)	Up to 1,800m^3		Up to 12,000m^3	
Use environment	With/without people present	With people present	Without people present	
Source air	Ambient (indoor) air			

Note:
- "Space treated (m^3)" indicates the maximum value for the size of the space where the following capacities were confirmed in the verification test.
  Ozopure: Airborne particulate dust (0.3 μm to 0.5 μm) collection capacity and ozone spraying capacity
  Ozone Raiser: Ozone spraying capacity
- "Space treated (m^3)" does not mean that each product has an effect of reducing virus particles that exist in the same volume. In addition, it does not indicate the demonstration result for the effect of reducing the new coronavirus by the ozone that each of the products generates in an actual use space.

2.1 Ozopure

(1) Standard type

With a combination of an ESP and a dust collection filter, this product allows both the collection of particulates and the supplying of ozone (**Figure 1**). The ESP electrifies particulates such as viruses—in addition to air pollutants such as particulate matter (PM2.5), yellow sand and pollen—and the collection filter on the rear stage adsorbs them by electrostatic force.

(Conceptual image)

Figure 1 Ozopure (standard type)

The performance of collecting air dust (0.3 μm to 0.5 μm) by this product was calculated from the number concentration measurement result of the particle counter and the result showed that the collection efficiency at the rear and front of the device was 95% or higher. (This is not an actual measurement value for the collection performance within a certain time in a specified space.)

In addition, it is expected that ozone generated by the ESP can suppress the activity of

viruses collected by the filter.

Furthermore, when there are people in a space such as during business hours in the daytime, ozone is reduced to a safe concentration (0.1 ppm or less which is the working environmental standard) through the ozonolysis filter and then, purified air is supplied into the space (**Figure 2**(a)). When there are no people present such as during the night, it is expected that ozone generated by the ESP is supplied into the space as-is, thereby suppressing the activity of viruses existing in the space or on the floors and walls (Figure 2(b)).

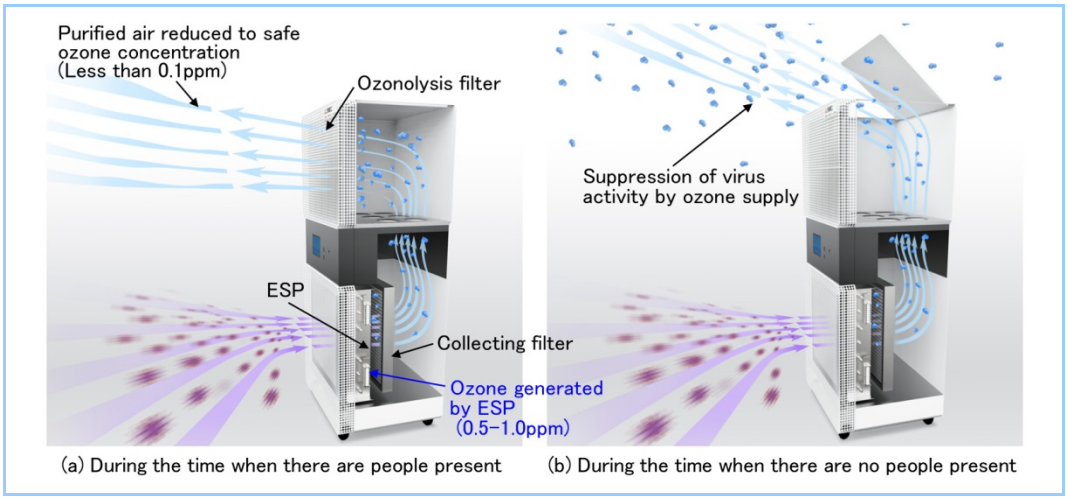
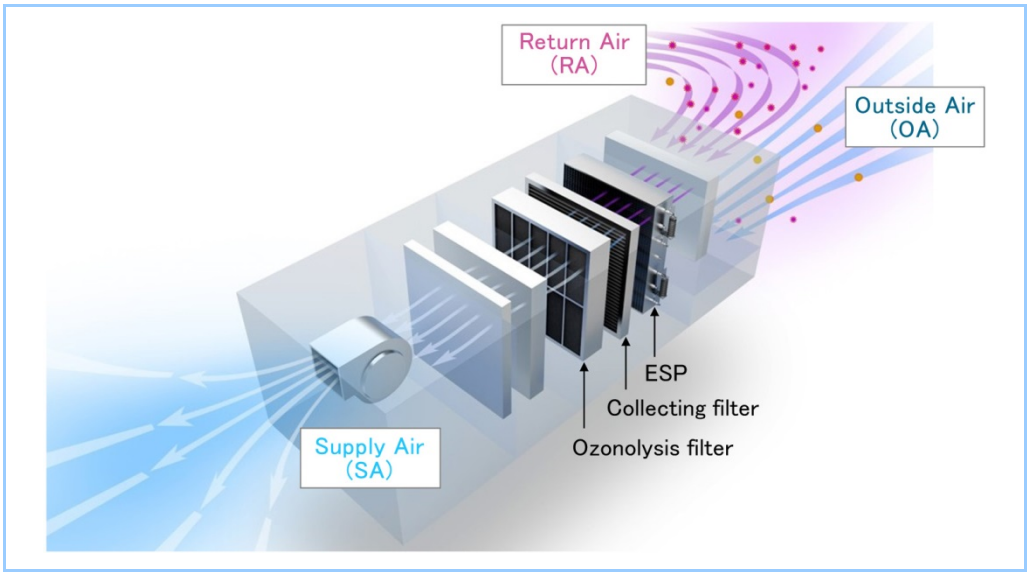


Figure 2 Operation mode of Ozopure (standard type)

(2) Built-in type to AHU

This product has a particulate collection function, which is added to newly-installed or existing air conditioning equipment (Air Handling Unit, AHU) (**Figure 3**). An ESP and an ozonolysis filter are additionally installed and the existing filter is replaced with a collection filter recommended by our company, so that the collection effect that is equivalent to that of the standard type of Ozopure can be obtained. In addition, this type can be individually designed according to the specifications of the air conditioning equipment. This product is intended to be used only in spaces where there are people present.



(Conceptual image)

Figure 3 Ozopure (Built-in type to AHU)

2.2 Ozone Raiser

This product uses surface discharge, which generates ozone with higher efficiency compared with corona discharge and is designed especially for ozone supply (**Figure 4**). Ozone Raiser does not have a particulate collection function, but it has the capacity to produce a larger amount of ozone than Ozopure. It has casters and can be easily moved. This makes it suitable for use in large

spaces such as domes and concert halls to uniformly supply ozone and purify the spaces. This product is intended to be used in any desired place during hours when there are no people present.

(Conceptual image)

Figure 4 Ozone Raiser

2.3 Effect of suppressing the activity of attached viruses by ozone

Using ozone generated by the technologies of the products described above, 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 (Ozopure and Ozone Raiser), 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 Ozopure (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 Ozone Raiser (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.

3. Operation examples of each product in hospitals

Outlines of operation examples of the products in large spaces of hospitals are described below.

3.1 Site

Medical Corporation Tokushukai Group Nozaki Tokushukai Hospital (Daito City, Osaka

Prefecture)

3.2 Operation example of Ozopure

(1) Installation space: PCR testing center (**Figures 5** and **6**)

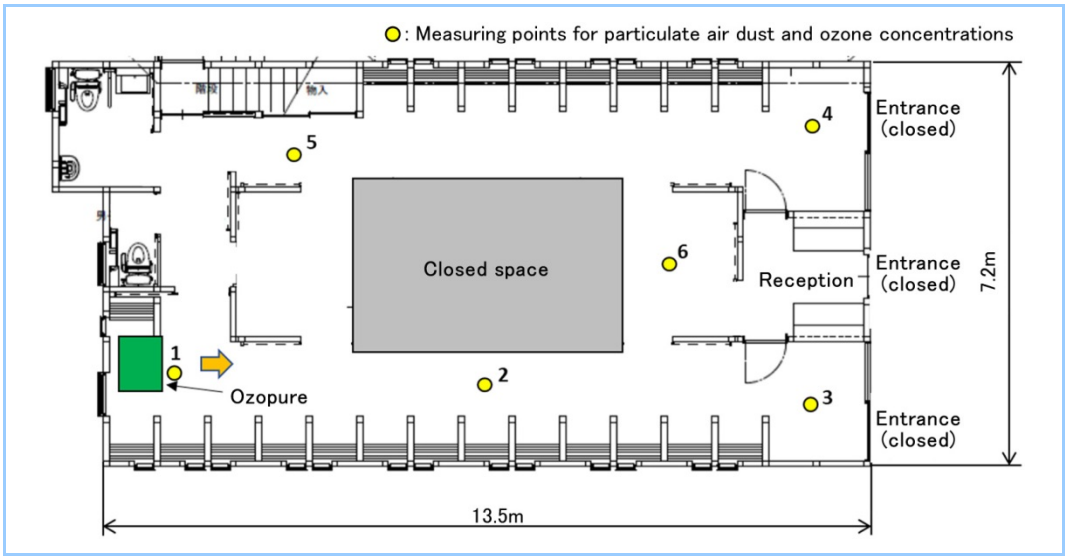


Figure 5 Floor plan of the PCR testing center

Figure 6 Operation example of Ozopure (standard type)

(2) Operation results

[1] Verification result for the airborne particulate dust collection effect

The result of operation with an air flow of 27 m^3/min is described below. Concerning the airborne particulate dust collection effect (particle size: 0.3 μm to 0.5 μm), the result calculated from the measurement result of the number concentration by the particle counter is shown in **Figure 7**. This result shows that the collection efficiency reached 80% to 90% at all the measurement points after about 60 minutes.

[2] Verification result for the effect of ozone supplying and ozonolysis

Charge control was performed by use of the ozone concentration meter 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 the ozone concentration at each measurement point in the room could be kept at 0.2 ppm to 0.25 ppm. After that, charging was stopped and the ozone in the room was decomposed by the ozonolysis filter. As a result, it was confirmed that the ozone concentration reached a safe concentration (0.1 ppm or less) within 10 minutes (**Figure 8**).

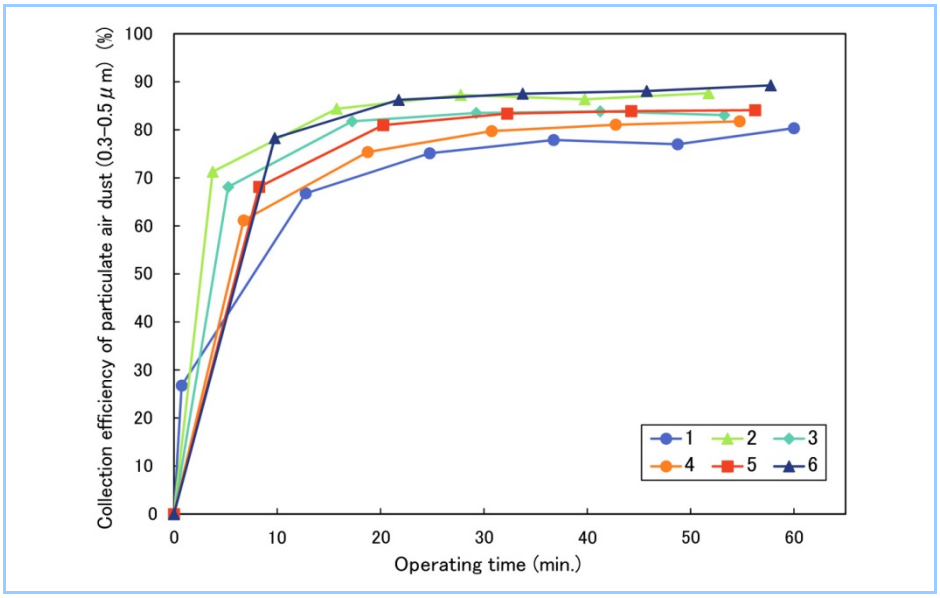


Figure 7 Collection effect of particulate air dust (particle size:0.3µm to 0.5µm)

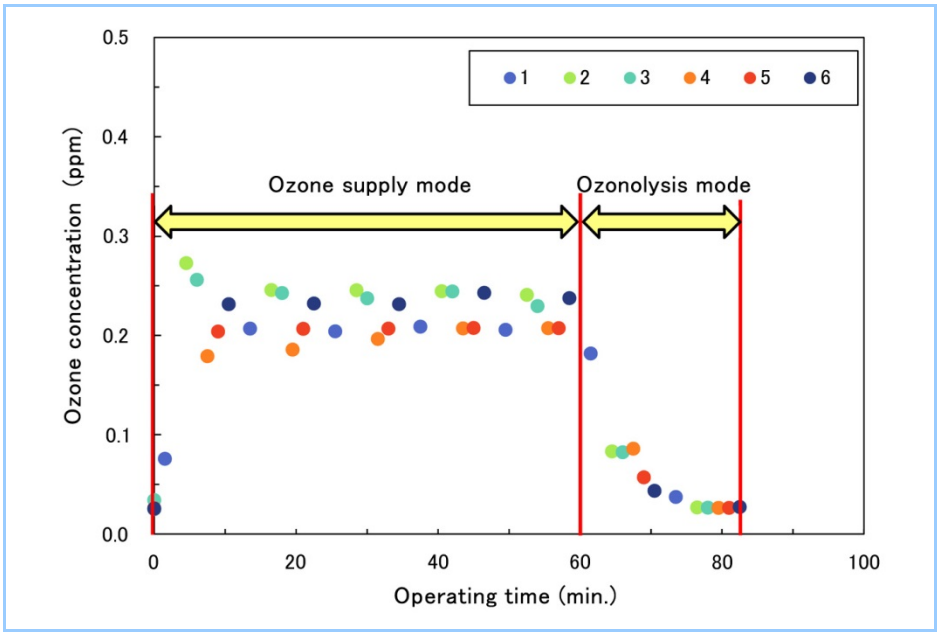


Figure 8 Verification result for the effect of ozone supplying and ozonolysis

[3] Result of long-term operation in automatic operation mode

In automatic operation mode, with a daily timer setting, the three modes described below were operated in turn to conduct long-term continuous operation for about three months. As a result, it was confirmed that the product could be stably used without issue. An example of the ozone concentration measurement data during this test is shown in **Figure 9**.

a. Particulate collection mode [during the office hour of the clinic (in an environment where there are people present)]
   Particulates such as airborne viruses in a room are collected with high efficiency. The concentration of ozone generated in the device is reduced to a safe concentration by the ozonolysis filter (0.1 ppm or less which is the working environment standard) and after that, purified air is supplied to the inside of the room.
b. Ozone supply mode [during the period when the clinic is closed (in an environment where there are no people present)]
   While the collection of particulates is continued, about 0.5 ppm ozone generated in the device bypasses the ozonolysis filter and is supplied into the room for several hours. When a predetermined CT value (concentration × time) is reached, the device automatically stops.
c. Ozonolysis mode [during the period when the clinic is closed (in an environment where

there are no people present)]

Only the fan is restarted and ozone in the room is decomposed by the ozonolysis filter and is reduced to a safe concentration (0.08 ppm or less) before the office hour. When the concentration is reduced to a safe concentration, the device automatically stops.

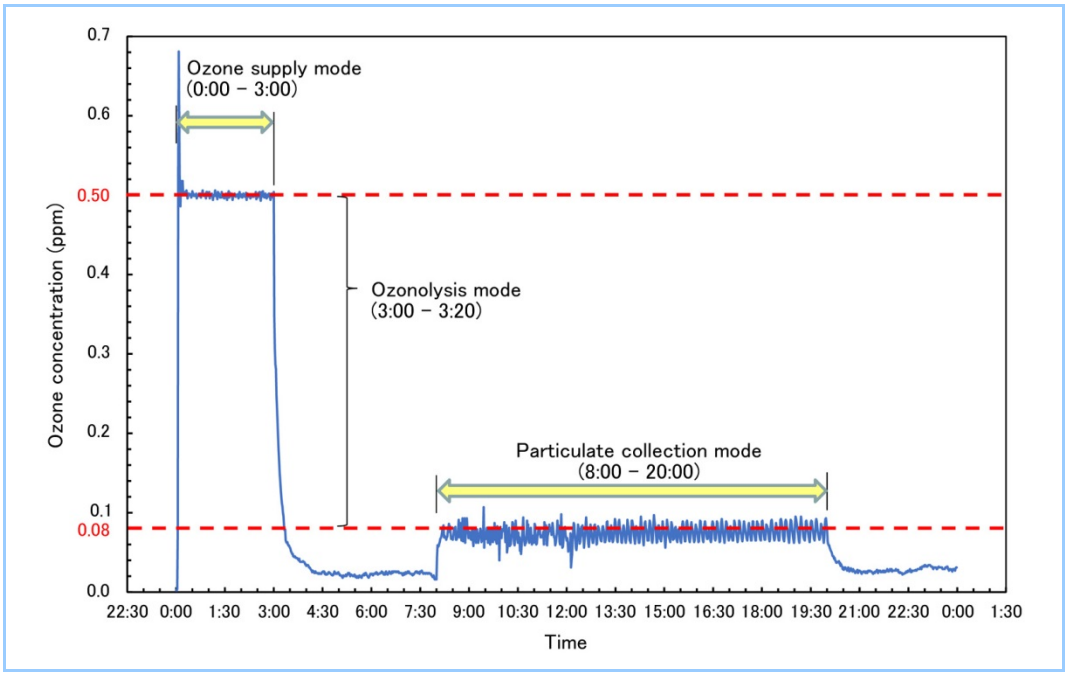


Figure 9 Example of the ozone concentration measurement data in automatic operation mode of Ozopure (Indicated values of the ozone concentration meter built into the device)

3.3 Operation example of Ozone Raiser

(1) Installation space: Artificial dialysis room [during the period when the clinic is closed (in an environment where there are no people present)] (**Figures 10** and **11**)

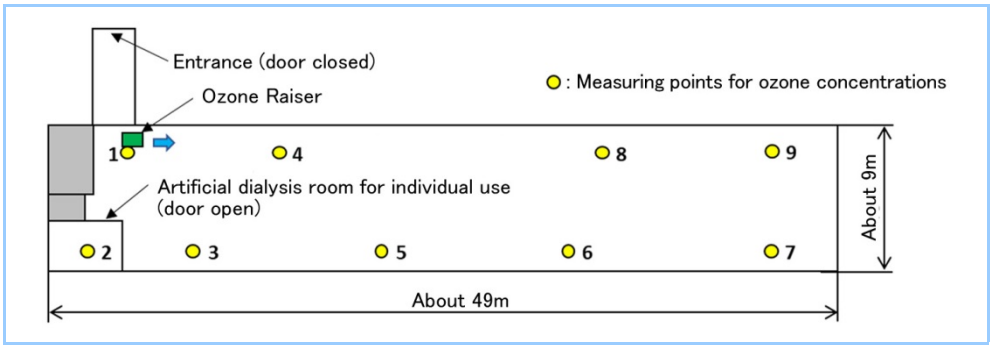


Figure 10 Floor plan of the artificial dialysis room

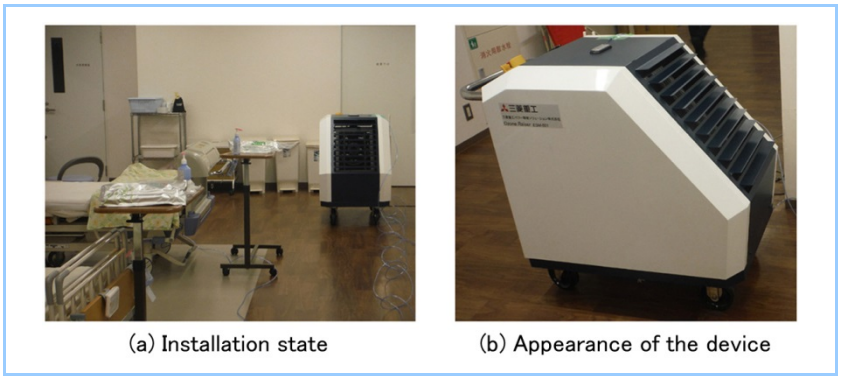


Figure 11 Operation example of Ozone Raiser

(2) Operation result

The result of operation with an air flow of 50 m^3/min is described below. Charge control

was performed by use of the ozone concentration meter 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. After that, supplying 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 12**).

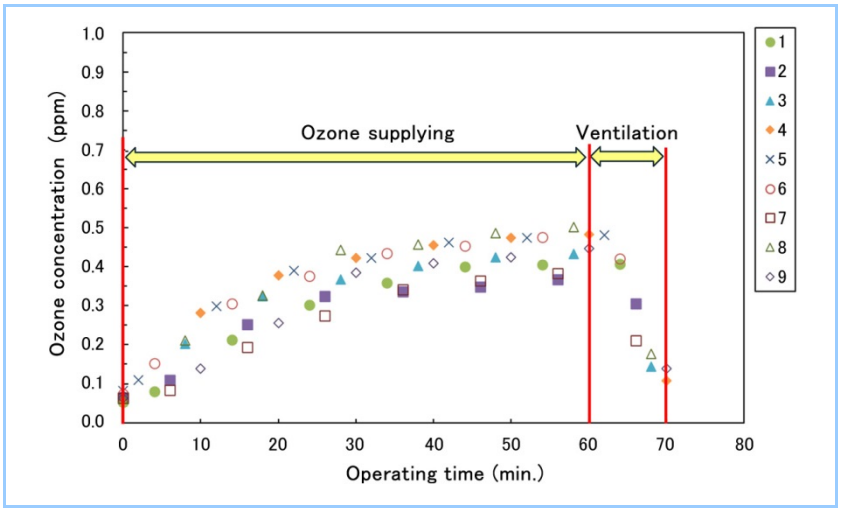


Figure 12 Verification result for the effect of ozone supplying and ventilation

4. Future development

In the recent circumstances where the need for air purification has been increasing, our air purifiers 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. We 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 concentration meter 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. Ozopure, 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 high ozone concentration exists.