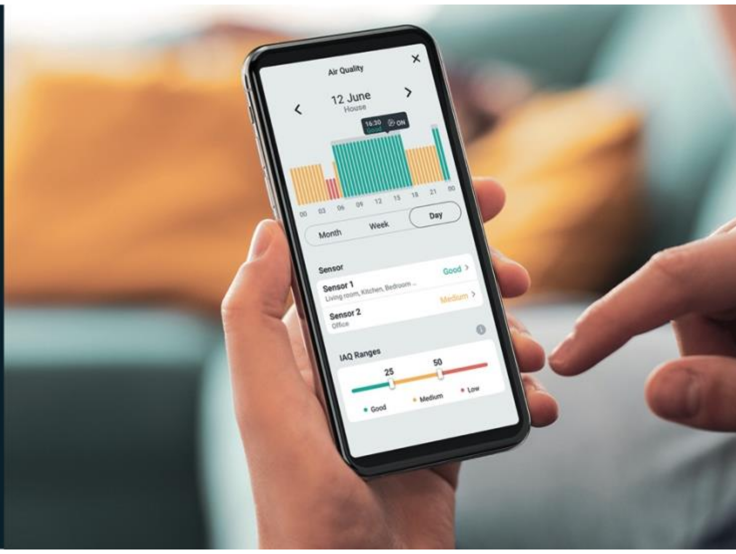
Smart climate control

Airzone **IAQ technology** performance report



Introduction

Airzone is firmly committed to guaranteeing people's well-being and protecting the environment. For this reason, all the control solutions designed by the company aim to achieve high levels of both comfort and energy efficiency.

There is an undeniably increasing trend for people to spend long hours indoors. In urban areas, 90% of people's time is spent in enclosed spaces [1]. This trend in living habits implies significant changes both in terms of energy consumption in buildings, and in the demands made for comfort and indoor air quality within them.

For this reason, Airzone has developed a solution that combines hygrothermal control and purification of the air supplied to occupied spaces.

The initial premises for the development of this solution were as follows:

- The purification treatment can be carried out in the presence of people.
- The control and purification system is integrated into the air distribution network, taking advantage of the characteristics of existing fans.

Thanks to Airzone technology it is possible to remotely control the main operation parameters (on/off, operation mode, fan speed and set-point temperature) of the AC units, and also to reduce the time that fine particulates are suspended in the air.

The air quality purification solution developed by Airzone's engineering department has a compact design. It can therefore be installed in Airzone diffusion elements (motorized and non-motorized) and in the supply of AC units zoned with Easyzone.

Various studies carried out in Airzone's laboratories have demonstrated empirically that the use of this device results in a 47% reduction in the maximum concentration of particulate matter of 2.5 µm or $PM_{2.5}$ from a point source, and a reduction of up to 55% in the time these particles spend in suspension in the air.

The device developed by Airzone has also been tested in external laboratories and its positive effect on combating allergies caused by dust mites, pet hair, tobacco smoke and pollen has been verified. Similarly, its effectiveness on the elimination of VOCs (Volatile Organic Compounds), bacteria and viruses has been verified.

This evidence shows that the solution designed by Airzone improves indoor air quality and increases energy savings by reducing the amount of outside air needed to dilute pollutants.

This report provides performance data on the purification solution developed by Airzone.

Indoor Air Quality and $PM_{2.5}$ Particulates

Indoor air quality is closely linked to the absence of particulate matter, among other aspects.

Particulate matter is a heterogeneous and complex mixture of liquid and/or solid particles, organic and inorganic substances, which are suspended in the air.

Particulate matter is an aspect of air pollution and represents a risk to human health. So much so that particulate matter is considered an air pollutant, together with SO_2 (sulfur dioxide), NO_x (nitrogen oxide), CO (carbon monoxide), Pb (lead), C_6H_6 (benzene) and O_3 (ozone), under Directive 2008/50/EC [2].

The composition of particulate matter is very varied and its main components include: sulfates, nitrates, ammonia, sodium chloride, coal, mineral dust, metal ash, pollen, dust mites, tobacco smoke, etc.

Particulate matter is categorized according to its size:

- Coarse particles: 10 µm > aerodynamic equivalent diameter > 2.5 µm.
- Fine particles: aerodynamic equivalent diameter < 2.5 µm.

Prolonged chronic exposure to particulate matter increases the risk of cardiovascular diseases [3], respiratory diseases (asthma [4], lung disorders [5] and allergies [6]), and lung cancer [7].

Due to their size, $PM_{2.5}$ particulates pose a greater health risk than PM_{10} particulates for three reasons.

1) They can travel deep into the lungs, penetrating into the respiratory tract and settling in the lung's alveoli, even reaching the bloodstream. As a result, they can cause damage to any organ of the human body.
2) In general, they are composed of more toxic elements (such as heavy metals and organic compounds) than those that make up larger particles.
3) They are lighter and remain suspended in the air for longer periods. This not only prolongs their negative effects, but also facilitates their transport in the air.

For these reasons, the WHO sets the exposure threshold for $PM_{2.5}$ particulates at 10 µg/m^3 (annual average) and 25 µg/m^3 (24-hour average), while for PM_{10} particles the exposure threshold is 20 µg/m^3 (annual average) and 50 µg/m^3 (24-hour average) [8].

Ionization Technology

Airzone has implemented negative ionization technology as a technique to remove particulates from the air.

Air ionization is a process that occurs when electrons are removed from or added to atoms, resulting in an imbalance in charge. The electrical configurations of the air ions thus formed include H^+, H_3O^+, O^+, N^+, OH^-, H_2O^- and O_2^-.

Such ionized molecules act as condensation nuclei for small particulates which, as they clump together, grow and increase in mass. Thus, they precipitate more easily and are captured by coarser filters.

Air ionization can reduce particle residence time, thereby reducing inhaled particles by up to 46% [9], [10] and [11]. This technique can achieve particle removal rates that are 20% higher than those achieved by high efficiency filtration [12] and [13].

There is also scientific evidence of the benefits of ionization in preventing the effect of allergies due to dust mites, pet hair, tobacco smoke or pollen [14], [15], [16] and [17].

Ionized air molecules are also able to act on volatile organic compounds [18] and [19], kill bacteria (*Serratia marcescens* [20] and [21], *E. coli* [22] and [23], *Candida albicans* [24] and [23], *Staphylococcus aureus* [25] and *P. fluorescens* [26]) and inhibit viruses (NDV [27] and Influenza [28]). Ionized molecules damage the outer membrane of viruses and expose their RNA to oxidation.

Ion dispersion is achieved by electrostatic repulsion. Ion migration will depend on the alignment of the magnetic field generated between the emission point and the surrounding objects. The concentration of ions surrounding the ion generators is not homogeneous and decreases significantly with distance. Therefore, installing ionizers together with fans will increase the ion dispersion area.

The process of air ionization can be achieved artificially by different mechanisms. In recent years, air ionization techniques have progressed exponentially, evolving from ionization lamps to the needlepoint technology used by Airzone. This has made it possible to drastically reduce the size of the units and minimize maintenance and replacement costs.

The current global situation has popularized the implementation of different air purification technologies. However, not all of these technologies are suitable for coupling with the AC units conventionally used in the residential and tertiary sector. To better understand the reasons why Airzone has opted for ionization technology, Table 1 below shows a comparison of the characteristics of the main technologies on the market at present.

	Negative ionization	Ozone	Ultraviolet	Photocatalytic oxidation	High-efficiency filtration
Treatment during occupation	**YES**	**YES** Concentration < 100 μg/m^3 [8]	**YES** Dose < 2.8 mJ/cm^2 [31]	**YES**	**YES**
Biocide	**NO** Not officially recognized	**NO** Not officially recognized [29] Concentration > 2 mg/m^3 Oxidant that reacts with proteins and lipids, but incompatible with occupancy	**YES** λ = 253.7 nm Dose = 50 mJ/cm^2 (ε = 99%) Alters DNA and impedes reproduction	**YES** Volatile organic compound oxidizer and DNA alterer	**NO**
Assembly and safety restriction	Very low levels of ozone generation	H > 2.20 m, limiting control and light signal [30]	Avoid direct exposure	Avoid direct exposure	Removal of protection filters
Compatible with AC units	**YES**	**NO** Highly reactive and corrosive to metals	**YES** Avoiding direct exposure on polymers due to photo-oxidative degradation [32]	**YES** Avoiding direct exposure on polymers due to photo-oxidative degradation [32]	**NO** High loss of load
Cost	Low	Medium	Medium	High	Low
Maintenance	Replacement of ionizer (8 years)	Replacement of ozonizer (4 years)	Replacement of lamp (2 years)	Replacement of lamp (2 years)	Filter cleaning (4 months)

Table 1. Comparison of air purification technologies on the market.

Laboratory Testing

The technology developed by Airzone has been subjected to various performance tests. The tests carried out and the results obtained in these tests are described below.

Removal of $PM_{2.5}$ particulates

The Airzone laboratory is equipped with a room that emulates the real conditions prevailing in a home or office.

This testing room has a volume of 70 m^3, with a tiled floor and plaster ceiling and walls. The dimensions of the room are: 7.15 m long, 3.80 m wide and 2.55 m high.

The 3.5 kW thermal unit was tested in this testing room.

The air distribution network consists of the following elements:

- Easyzone supply plenum.
- 10 meters of insulated circular flexible ducting with 3 elbows.

- Grille plenum.
- 300 × 150 mm diffusion grille.

The concentration of $PM_{2.5}$ particulates was artificially generated through the burning of 4 incense sticks.

In the first test the purification system was deactivated. In the second test the purification system was activated. In both cases the evolution over time of the $PM_{2.5}$ particulate concentration was monitored by a network of sensors (Honeywell HMP and Panasonic SN-GCJA5) placed both in the room and in the supply and return air distribution network.

The AC unit was tested with the low speed setting selected at all times. Thus, the airflow rate supplied to the room was 360 m^3/h (i.e. 5 renewals/hour) with a supply air velocity of approximately 2.5 m/s at the grille.

The evolution over time of the concentration measured in the return plenum is shown in Figure 1. The four incense sticks were burned over an interval of approximately one hour. During this period of time, the concentration of particulates rose. The maximum peak with the purification system deactivated (orange line) was 512 $\mu g/m^3$, while with the purification system activated (green line), it only reached a value of 273 $\mu g/m^3$. This represents a 47% reduction in the maximum point-source concentration during the test.

Once the incense sticks were consumed, the particulate concentration started to decrease. However, when the purification system was deactivated (orange line), a total time of 11 hours and 45 minutes was required to remove all particulates. In contrast, with the purification system active (green line), only 5 hours and 20 minutes were needed. This means that the time that $PM_{2.5}$ particulates spent in suspension in the air was reduced by 55% when using the Airzone device.

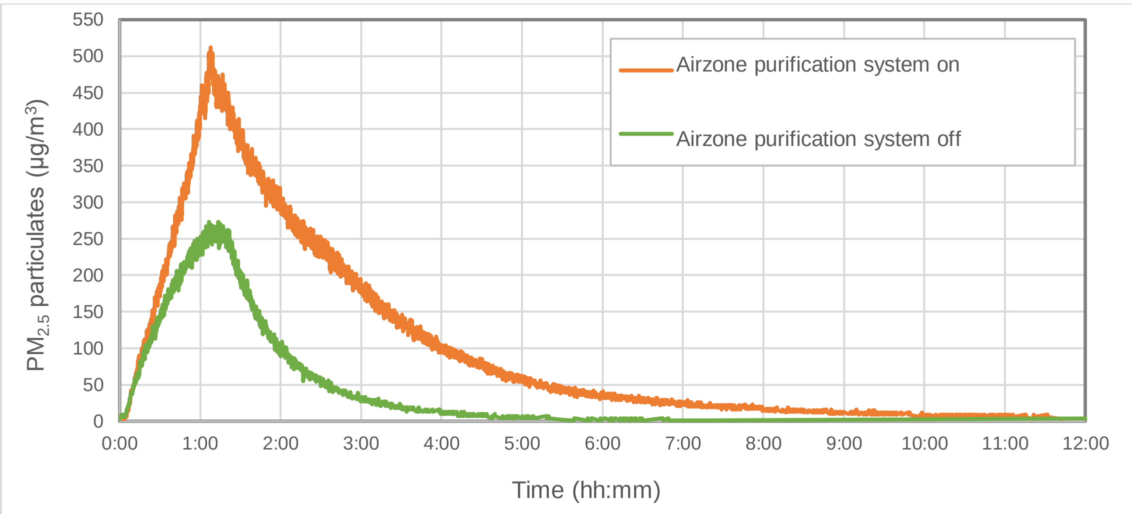


Figure 1. Evolution of the concentration of $PM_{2.5}$ particulates over time.

The beneficial effect of the Airzone solution in terms of indoor air quality due to the absence of suspended particulates can therefore be demonstrated.

Deodorizing effect on VOCs

The Japanese laboratory Boken Quality Evaluation Institute has demonstrated the powerful deodorizing effect of the Airzone purification solution on sources of volatile organic compounds, in particular CH_2O (formaldehyde) and H_2S (hydrogen sulfide).

Figure 2 shows the evolution of the concentration of CH_2O over time. This demonstrates a 60% reduction in the volatile organic compound formaldehyde with an exposure time of 2 hours.

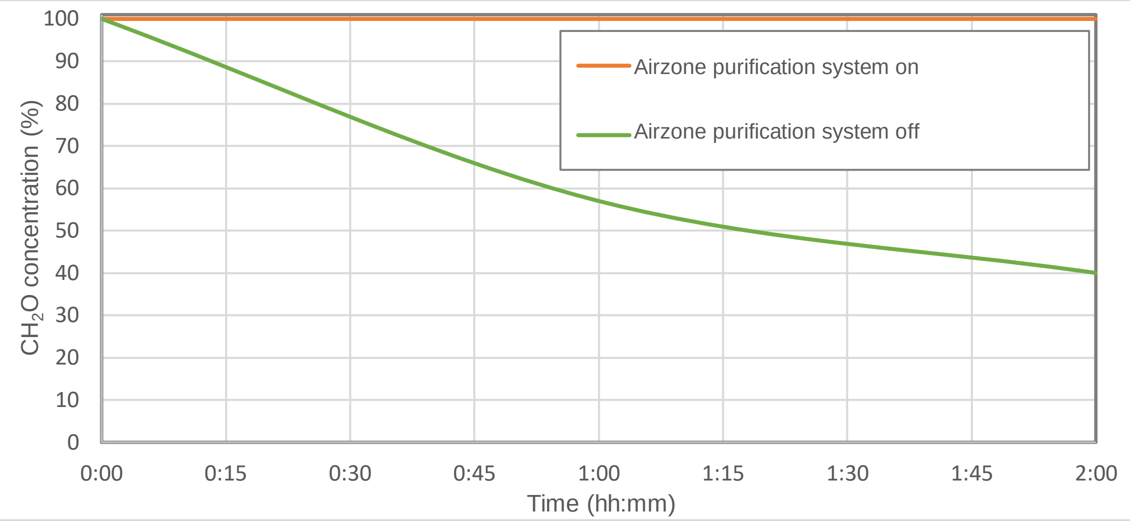


Figure 2. Evolution of the concentration of CH_2O (formaldehyde) over time.
Source: Murata Manufacturing Co., Ltd - Boken Quality Evaluation Institute.

Figure 3 shows the evolution of the concentration of H_2S over time. This demonstrates a 100% reduction in the volatile organic compound hydrogen sulfide with an exposure time of 2 hours.

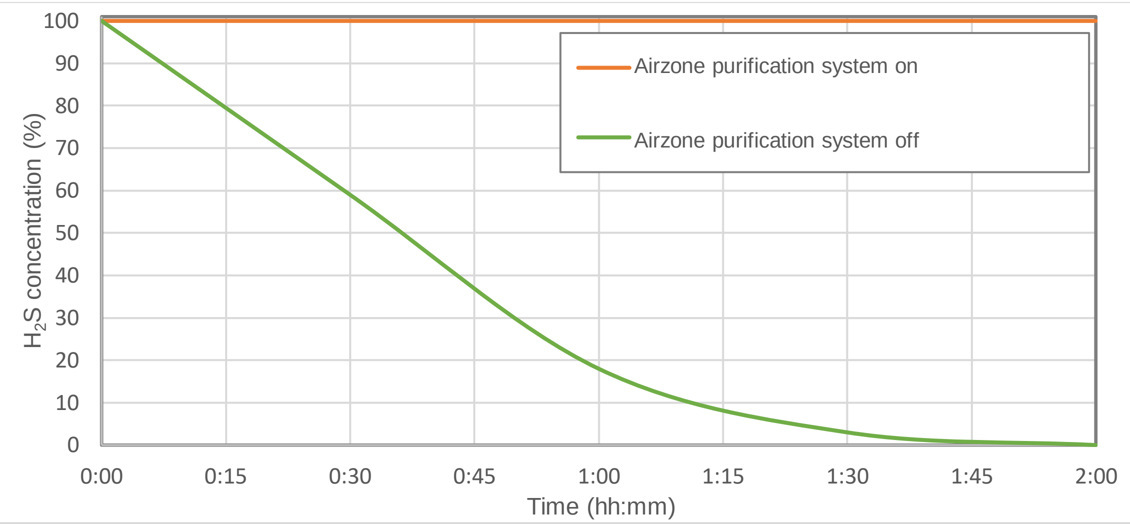


Figure 3. Evolution of the concentration of H_2S (hydrogen sulfide) over time.
Source: Murata Manufacturing Co., Ltd - Boken Quality Evaluation Institute.

These tests show that Airzone's purification technology reduces volatile organic compounds and mitigates against unpleasant odors in the environment.

Antibacterial effect

The Japanese laboratory Boken Quality Evaluation Institute has demonstrated the high antibacterial potential of the Airzone purification solution, in particular against *Bacillus coli* and *Staphylococcus aureus*.

Figure 4 shows the evolution of colony forming units of *Bacillus coli* over time. It demonstrates how in one day the colony thrives to reach 130 cfu with the Airzone purification system deactivated (orange line). In contrast, the colony is completely eliminated within one day when the Airzone purification system is activated (green line).

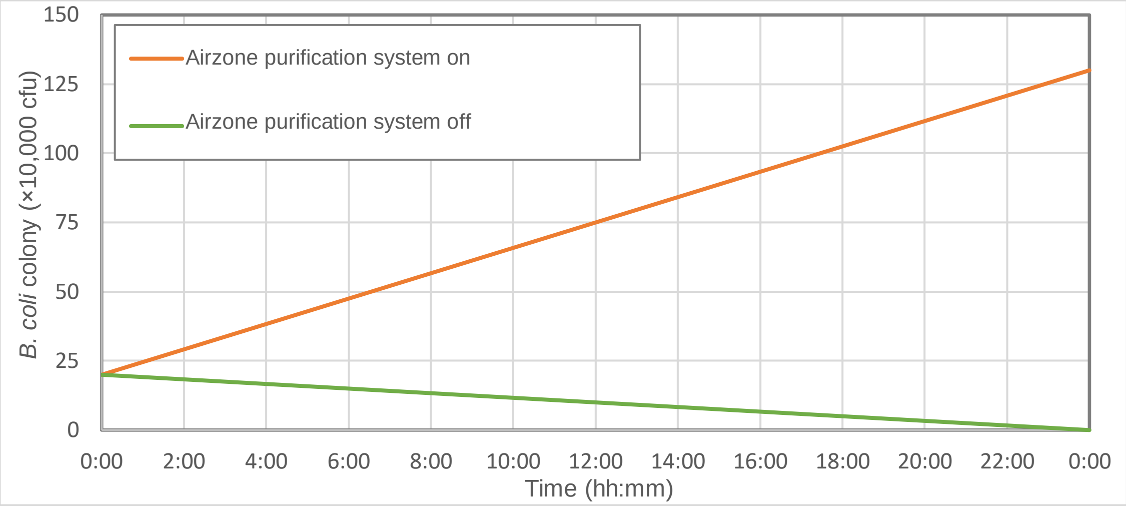


Figure 4. Evolution of colony forming units of *Bacillus coli* over time.
Source: Murata Manufacturing Co., Ltd - Boken Quality Evaluation Institute.

Figure 5 shows the evolution of colony forming units of *Staphylococcus aureus* over time. It demonstrates how in one day the colony thrives to reach 160 cfu with the Airzone purification system deactivated (orange line). In contrast, the colony is completely eliminated within one day when the Airzone purification system is activated (green line).

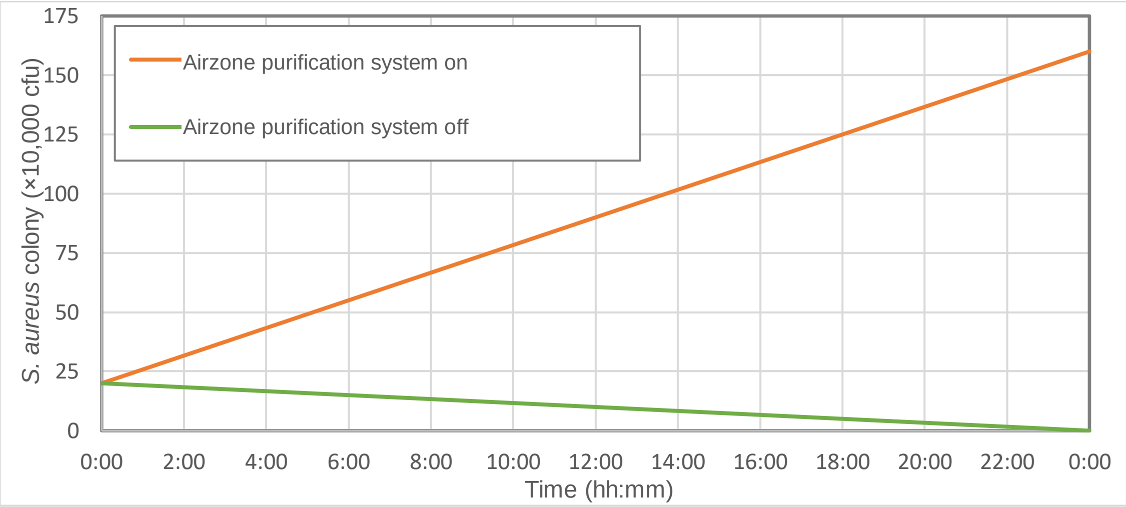


Figure 5. Evolution of colony forming units of *Staphylococcus aureus* over time.
Source: Murata Manufacturing Co., Ltd - Boken Quality Evaluation Institute.

These tests show that Airzone's purification technology eliminates different types of bacteria.

Antiviral effect

The BSA (Biomedical Sciences Association) at the Texas School of Veterinary Medicine and Biomedical Sciences has demonstrated the inhibitory effect of the Airzone purification solution on the H3N2 Influenza virus by reducing its infectivity rate.

The infectivity rate is defined as the number of viral particles capable of invading a host cell.

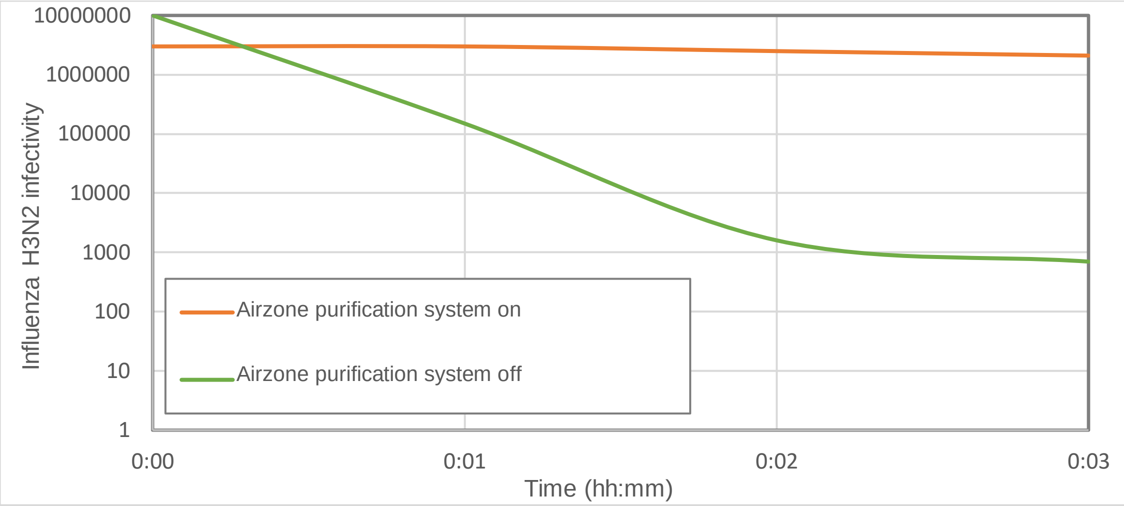


Figure 6. Evolution of the infectivity rate of the Influenza H3N2 virus over time.
Source: Murata Manufacturing Co., Ltd - Biomedical Sciences Association (Texas A&M University).

Figure 6 shows the evolution of the infectivity rate of the Influenza H3N2 virus over time. It demonstrates how the infectivity rate hardly decreases when the Airzone purification system is deactivated (orange line). However, there is a logarithmic drop in the first two minutes when the Airzone purification system is activated (green line). After three minutes of exposure, infectivity is reduced from 10^7 to 700.

Therefore, direct exposure to Airzone purification technology is shown to have an inhibitory effect on viruses.

Sizing (UL 2998)

Airzone has paid particular attention to the sizing of the purification system in order to comply with the UL 2998 standard - Air cleaner validation for zero ozone emissions.

This product safety and quality standard for the United States and Canada stipulates that no domestic unit should produce a concentration greater than 0.05 ppm in the volume described in section 37.2 of said standard.

The testing room is between 950 and 1100 cubic feet (27 and 31 m^3) in size. In addition, it must comply with certain specific proportions. The width of the testing room must be at least 8 feet (2.4 m) and the maximum height must be 10 feet (3 m).

During the test, the testing room must be kept under stable conditions. The temperature must be 77 ± 4°F (25 ± 2°C) and the relative humidity must be 50 ± 5 per cent.

The product under test must be located in the center of the test room at a distance from the floor of 30 inches (762 mm).

The ozone emission must be monitored for 24 hours to determine the concentration.

Under test conditions, the ozone density was 2.14 kg/m^3 and its molar mass was 48 g/mol. The air density was 1,184 kg/m^3.

With this information and bearing in mind the amount of ozone generated as a by-product of ionization (15 mg/h per ionizer) as certified by Murata in its report JEHVAA-0141B, the minimum discharge volume given in Table 2 must be respected.

	Thermal power of the unit		
	< 5 kW	**7.1 kW**	**10-14 kW**
Minimum discharge volume	27 m^3 (3 × 3 × 3 m)	54 m^3 (4.25 × 4.25 × 3 m)	81 m^3 (5.2 × 5.2 × 3 m)

Table 2. Volume (and size ratio) of the minimum air discharge space.

These volumes are designed with safety in mind, since the purification system will not be active 24/7.

Conclusions

The performance information for the purification solution developed by Airzone allows us to state that it is a safe and compact device, capable of improving indoor air quality in the following aspects:

- Reduction of fine airborne particulates in the air, with performances superior to high-efficiency filtration.
- Benefits to respiratory problems and allergies caused by dust mites, pet hair, tobacco smoke and pollen.
- Elimination of odors due to the reduction of VOCs in the air.
- Inhibition of bacteria and viruses.

All this, without compromising the functional performance of the indoor unit fans.

The Airzone purification solution not only improves indoor air quality, but also reduces electricity consumption by reducing the rate of outside air supplied to the air-conditioned spaces. It also allows remote control of the AC units.

All these features make the Airzone purification device a very attractive solution for sustainable building certifications such as BREEAM or LEED, where a higher score can be achieved by including the Airzone solution.

Bibliography

[1] Klepeis, N. et al. Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*. Vol. 11 (2001), pp 231–252.

[2] Directive 2008/50/EC of the *European Parliament and of the Council* of 21 May 2008 on ambient air quality and cleaner air for Europe.

[3] Liang, F. et al. Long-Term Exposure to Fine Particulate Matter and Cardiovascular Disease in China. *Journal of the American College of Cardiology*. Vol. 75-7 (2020), pp 707–717.

[4] Hakan, L. et al. Particulate Matter (PM2.5, PM10-2.5 and PM10) and Children's Hospital admission for Asthma and Respiratory Diseases: A Bidirectional Case-Crossover Study. *Journal of Toxicology and Environmental Health*. Vol. 71–8 (2008).

[5] Hou, D. et al. Associations of long-term exposure to ambient fine particulate matter and nitrogen dioxide with lung function: A cross-sectional study in China. *Environmental International*. Vol. 144 (2020).

[6] Wang, M. et al. The association between PM2.5 exposure and daily outpatient visits for allergic rhinitis: evidence from a seriously air-polluted environment. *International Journal of Biometeorology*. Vol. 64 (2020), pp 139–144.

[7] Raaschou-Nielsen, O. et al. Particulate matter air pollution components and risk for lung cancer. *Environmental International*. Vol. 87 (2016), pp 66–73.

[8] World Health Organization. Occupational and Environmental Health Team. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update 2005 Summary of risk assessment.

[9] Tanaka A. and Zhang, Y. Dust settling efficiency and electrostatic effect of a negative ionization system. *Journal of Agricultural Safety and Health*. Vol. 2-1 (1996), pp 39–47.

[10] Mayya, Y. S., Sapra, B. K., Khan, A. and Sunny, F. Aerosol removal by unipolar ionization in indoor environments. *Journal of Aerosol Science*. Vol. 35-8 (2004), pp 923–941.

[11] Sawant, V.S. Removal of particulate matter by using negative electric discharge. *International Journal of Engineering and Innovative Technology*. Vol. 2 (2013), pp 48–51.

[12] Pushpawela, B., Jayaratne, R., Nguy, A and Morawska, L. Efficiency of ionizers in removing airbone particles in indoor environments. *Journal of Electronics*. Vol. 90 (2017), pp 79–84.

[13] Lee, B. U., Yermakov, M. and Grinshpun, S. A. Removal of fine and ultrafine particles indoor air environment by the unipolar ion emission. *Atmospheric Environment*. Vol 38 (2004), pp 4815–4823.

[14] Cutis, N. J., Woodfolk, J. A., Vaughan, J. W. and Platts-Mills, T. A. E. Quantitative measurement of airbone allergens from dust mites, dogs, and cats using an ion-charging device. *Clinical & Experimental Allergy*. Vol. 33 (2003), pp 986–991.

[15] Goodman, N. and Hughes, J. F. The effect of corona discharge on dust mite and cat allergens. *Journal of Electrostatics*. Vol. 60 (2004), pp 69–91.

[16] Sawant, V. S., Meena, G. S. and Jadhav, D. B. Effect of negative air ions on fog and smoke. *Aerosol and Air Quality Research*. Vol 12 (2012), pp 1007–1015.

[17] Kawamoto, S., Oshita, M., Fukuoka, N., Shigeta, S., Aki, T., Hayashi, T., Nishikawa, K. and Ono, K. Decrease in the Allergenicity of Japanese Cedar Pollen Allergen by Treatment with Positive and Negative Cluster Ions. *International archives of allergy and immunology*. Vol. 141-4 (2006), pp 313–321.

[18] Wu, C. C. and Lee, G. W. M. Oxidation of Volatile Organic Compounds by Negative Air Ions. *Atmospheric Environment*. Vol. 38 (2004), pp 6287–6295.

[19] Kim, K., Szulejko, J. E., Kumar, P., Kwon, E.E. and Adelodun, A. A. Air ionization as a control technology for off-gas emissions of volatile. *Environmental Pollution*. Vol. 225 (2017), pp 729–243.

[20] Phillips, G., Harris, G. J. and Jones, M. W. Effects of air ions on bacterial aerosols. *International Journal of Biometeorology*. Vol. 8 (1964), pp 27–37.

[21] Zhou[a], P., Yang[c], Y., Huang, G. and Lai[b], C. K. Numerical and experimental study on airborne disinfection by negative ions in air duct flow. *Building and Environmental*. Vol. 127 (2018), pp 204–210.

[22] Tyagi, A. K., Nirala, B. K., Malik, A. and Singh, K. The effect of negative air ion exposure on Escherichia coli and Pseudomonas fluorescens. *Journal of Environmental Science and Health. Toxic/Hazardous Substances and Environmental Engineering*. Vol. 43 (2008), pp 694–699.

[23] Noyce, J. O. and Hughes, J. F. Bactericidal effects of negative and positive ions generated in nitrogen on Escherichia coli. *Journal of Electrostatics*. Vol. 54 (2002), pp 179–187.

[24] Shargawi, J. M., Theaker, E. D., Drucker, D. B., MacFarlane, T. and Duxbury A. J. Sensitivity of *Candida albicans* to negative air ion streams. *Journal Applied Microbiology*. Vol. 87 (1999), pp 889–897.

[25] Dobrynin, D., Friedman, G., Fridman, A. and Starikovskiy, A. Inactivation of bacteria using DC corona discharge: Role of ions and humidity. *New Journal of Physics*. Vol. 13 (2011).

[26] Timoshkin, I. V., Maclean, M., Wilson, M. P., Given, M. J., MacGregor, S. J., Wang, T. and Anderson, J. G. Bactericidal effect of corona discharges in atmospheric air. *IEEE Transactions on Plasma Science*. Vol. 40-10 (2012), pp 2322–2333.

[27] Bailey, W. Mitchell, P. and Daniel, J. K. Effect of Negative Air Ionization on Airborne Transmission of Newcastle Disease Virus. *Avian Diseases*. Vol. 38 (1994), pp 725–732.

[28] Hagbom, M., Nordgren, J., Nybom, R., Hedlund, K., Wigzell, H. and Svensson, L. Ionizing air effects influenza virus infectivity and prevents airborne-transmission. *Scientific Reports*. Vol. 5 (2015).

[29] Productos virucidas autorizados en España. Secretaría de Estado de Sanidad. Subdirección General de Sanidad Ambiental y Salud Laboral (2020).

[30] UNE 400201:1994. Generadores de ozono. Tratamiento de aire. Seguridad química.

[31] Directive 2006/25/EC. Minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation).

[32] Ghatge, N. and Vernekar, S. Evaluation of ultraviolet light absorbers in poly vinyl chloride (PVC). Macromolecular Materials and Engineering. Vol. 20-1 (1971), pp 175–180.