OPEN ACCESS
Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

The Design of Ozone Placement and Determining Dosage as a *Sterilizer* in Meeting Rooms during a Pandemic Using the *PtD* Method

Slamet Hariyanto[1*], Isdaryanto Iskandar[1]

[1]Faculty of Engineering, Atma Jaya Catholic University of Indonesia, Jl. Jen, Sudirman No.51, Jakarta

DOI: 10.36348/sjet.2021.v06i11.004 | **Received:** 09.10.2021 | **Accepted:** 13.11.2021 | **Published:** 21.11.2021

***Corresponding author:** Slamet Hariyanto

Abstract

The beginning of year 2020, the COVID-19 pandemic has hit all parts of the world, including Indonesia. This pandemic is caused by the SARS-CoV-2 virus and its various mutants and variants. This virus is known to attack the human respiratory system. The virus is transmitted through direct contact or through the air, which makes it *Airborne*. Even though there are variety of disinfectants that can prevent transmission between humans, not many can maintain the sterility of the room continuously. Disinfectants on its own have a level of danger to humans when exposed at a certain doses and for a certain time. Ozone (O_3) is known as the most potent disinfectant. This paper is intended to determine the appropriate placement and dose of Ozone when used in a meeting room at an office, which is widely known as the centre of the Covid-19 spreading in Jakarta, using the Prevention through Design (*PtD*) method. In designing the right Ozone placement, the existing air system will also be studied. The calculation of the levels of O_3 is based on mathematical calculations. The result from this study shows that the positioning and dosing control of O_3 can effectively disable/kill the virus, while still considered safe for humans, so that productivity will be maintained.

Keywords: Ozone, Effective, Safe, Pandemic, COVID-19, *PtD*.

I. PRELIMINARY

Currently, the way safety is addressed through design is not only taking into account of their *safety factors*, safety checklists, following certain standards, or by merely attaching warning labels to hazards. Safety through design (*PtD*) is an approach to achieving safety that prioritizes technical *control* (*engineering control*) rather than an intervention of the employees or people's behaviour[1].

Safety through design (*PtD*) anticipates and eliminates hazards in tools, equipment, processes, materials, structures, and work organization, which is the most effective way to prevent work accidents, illness, and fatal injuries[2].

Early of 2020, it was the first time where Indonesia was attacked by an outbreak called COVID-19. Fast forward to more than a year, Indonesia's situation got worse, many clusters of crowds occurred in offices, markets, and restaurants. At that time, the government had issued a regulation to update the air system by increasing the outside air entering office buildings, but these results in a loss of comfort for workers. In addition to that, the government had also required the holding of sterilization in every room in the office, but this is not enough considering that sterilization is only effective for once, precisely, only a few moments after the sterilization process is complete. There are many effective disinfectants that could help overcoming this pandemic, but these disinfectants turn out to be dangerous for humans who are exposed to them, one of which is quats, ozone, and others. The purpose of this paper is to design a closed room (especially the meeting room, which was attended by several people at a time) with an air circulation that utilized sterilizers for the air, but still considered safe for humans, by using Ozone (O_3) in the form of gas. Through this method, a clean room that is safe from the virus can be achieved so that workers can continue to work safely which leads to productivity increases.

II. Theoretical basis

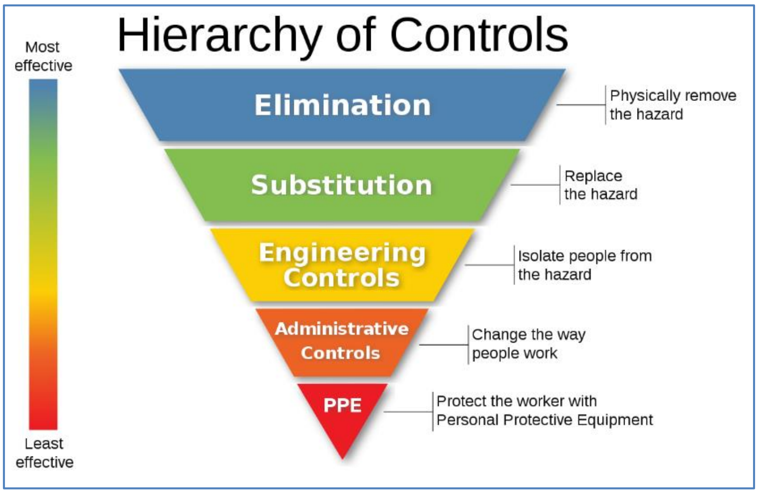

Fig-1: Control Hierarchy of PtD

Safety through design (*PtD*) prioritizes technical control, namely analysing and identifying what causes the hazard and how to reduce the hazard with design changes, before the hazard causes problems [1]. The Hierarchy of Control and Hazard Elimination can be seen in the diagram below.

PtD plays at the level of *Elimination* and *Substitution*, in which a design must have eliminate the hazards that exist or toned it down into something that is considered to be 'less dangerous'.

III. METHOD

This study uses the inherent safety design, which belongs to the nature of something (in this case the ozone in gaseous form) or owned by a person, where its true nature cannot be described. The safety design itself is approached with two methods, namely *Moderate* and *Simplify*. *Moderate* means the design will reduce the strength of Ozone's side effects while *Simplify* means designing with the intention to eliminating current problems rather than implementing another tool for preventions purposes. This study uses a comparison method with other research methods that have been carried out, continued by a series of mathematical calculations, and then comparing the results with corresponding datas taken from the international standards. Other than that, swabs and exposure tests are also carried out to determine the effectiveness of Ozone.

This COVID-19 pandemic is caused by a virus called SARS-CoV-2, in which if it attacks the human body, there will be no cure can be made. The virus can only strictly be fought by a one's immune system. Someone that may appear healthy and physically strong doesn't necessarily mean that they have enough endurance to fight the SARS-CoV-2 virus which has mutated into many variants that attacks the respiratory system. The only way to prevent it is to make sure the active virus does not enter the human body. The spread of this virus takes place in 2 ways, namely through airborne (*Aerosol particle*) which has a size below 5 m, or through direct and indirect contact with droplets measuring between 5 m – 10 m. The main challenge today is finding effective solutions to prevent the spread of this virus.

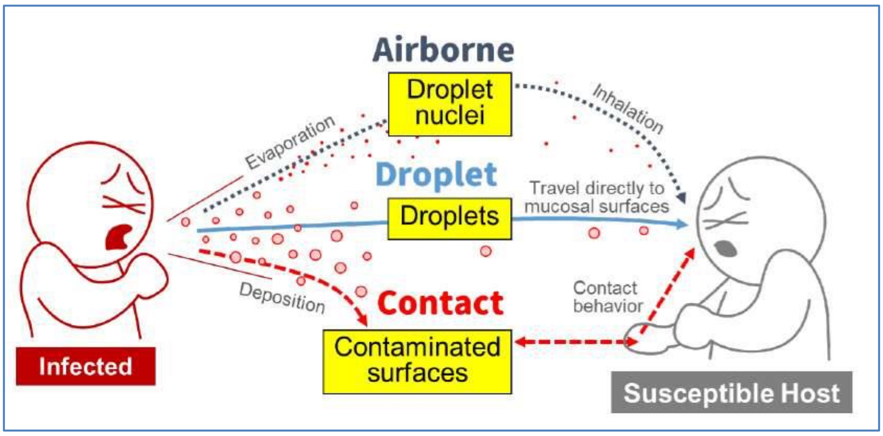

Fig-2: [3] Mode of Transmission

Particles of the virus that causes COVID-19 to have an average size of 0.125 microns (0.125 μm).

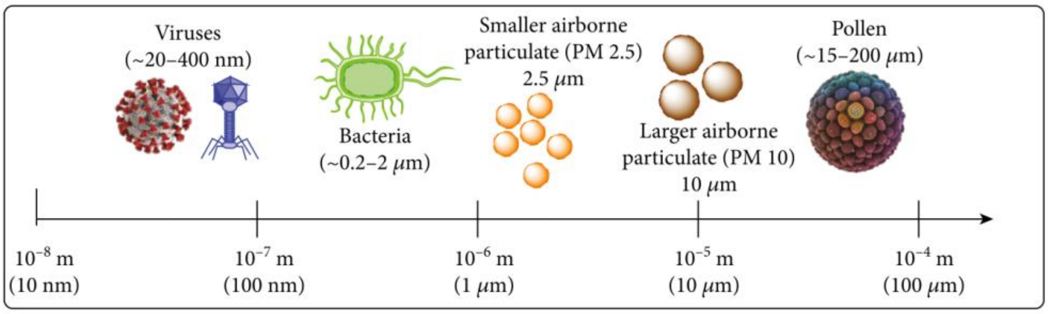

Fig-3: Particle Size

And this virus can survive in still air for more than 41 hours and in turbulent air will disappear more quickly as stated by Baron and Willeke [4].

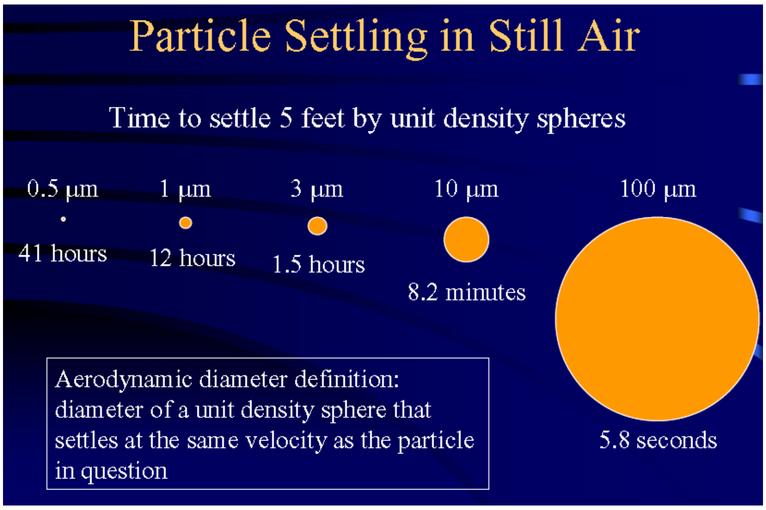

Fig-4: Particles in still air

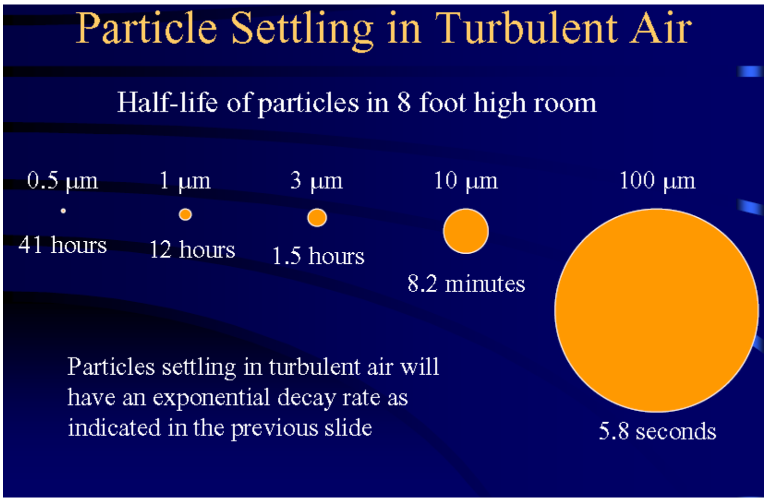

Fig-5: Particles in turbulent air

Baron and Willeke said that large particles can be lost on itself through their decaying period (*half-life*). Small particles on the other hand, will be lost with a new circulation of the air, by removing the air inside the room and replacing it with the air from outside.

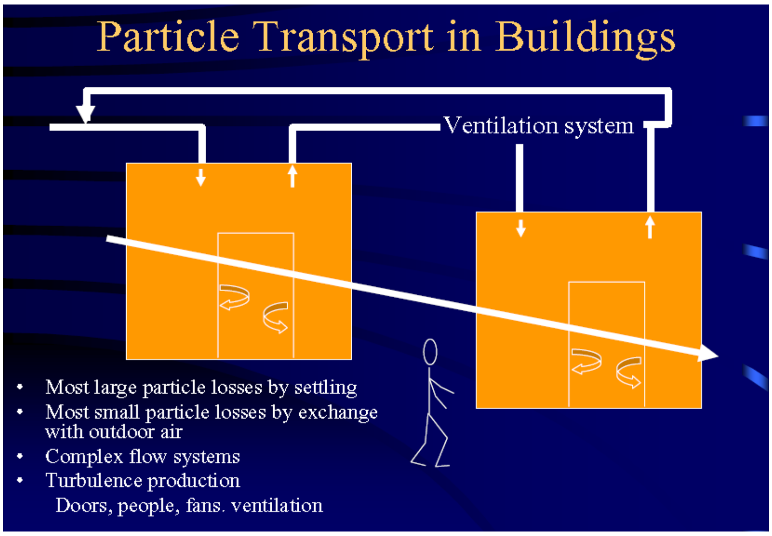

Fig-6: Schematic of particle displacement

Therefore, because the SARS-CoV-2 virus is small in size, it is important for the design to circulate the air by bringing in the outside air and removing the air inside.

However, due to the presence of a fan, it will cause turbulence that results into a complex flow of the small particle, hence there is still a possibility that this virus will be exposed to humans when this virus travels to the *exhaust* or *returns* from the air system.

To destroy this virus, several types of chemicals are obtained as *anti-microbial* or disinfectants. From the table below, the most powerful chemical type without the need for a reaction from other chemicals is Ozone (O_3) with a value of 2.1 electron-Volts.

Table 1-1. Oxidant strengths

Chemical species	Standard oxidation potential (volts)	Relative strength (chlorine = 1)
Hydroxyl radical ($OH^{\bullet}$)*	2.8	2.0
Sulfate radical ($SO_4^{\bullet}$)	2.5	1.8
Ozone	2.1	1.5
Sodium persulfate	2.0	1.5
Hydrogen peroxide	1.8	1.3
Permanganate (Na/K)	1.7	1.2
Chlorine	1.4	1.0
Oxygen	1.2	0.9
Superoxide ion ($O^{\bullet}$)*	-2.4	-1.8

*These radicals can be formed when ozone and H_2O_2 decompose.
Source: Siegrist et al. 2001

There are several ways of disinfection, as shown in Figure 7 below

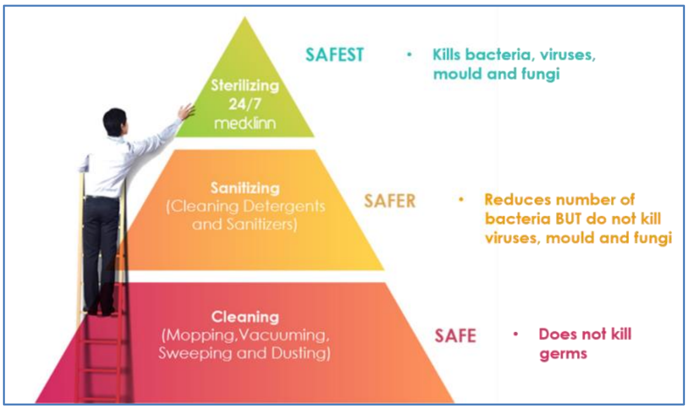

Fig-7: Disinfection levels

It is said that the safest way is to sterilize the room (air and surface) continuously. This study uses a tool that generates O_3 as a means to sterilize.

O_3 although effective to eradicate the virus but is harmful for human exposure on a specific dosage and time, as stated by some of the following international standards.

International Guidelines
for ozone exposure levels:

OSHA: Permisable Exposure limit: 8 hour TWA **0.1 ppm** ANSI/
ASIM: 8 hours TWA **0.1 ppm**/ STEL: **0.3 ppm** ACGIH: 8 hours
NIOSH: TWA **0.1 ppm**/ STEL: **0.3 ppm**
ACGIH: Exposure Limit Ceiling Value: **0.1 ppm** (light)/ **0.08 ppm** (moderate)/ **0.05 ppm** (heavy)
NAAQS: 8 hours **0.07 ppm**
EPA: 8 hours **0.07 ppm**

Source:
1. Ozone in workplace Atmostpheres, OSHA
2. Emergency and Continuous Exposure Limits for Selected Airborne Contaminants: Volume 1,NCBI
3. NAAQS table, EPA
4. Eigh-hour Average Ozone Concentrations, Ground-level Ozone, New England, US EPA

Fig-8: Ozone Exposure Limits of some international standards

For the first time in the world, Prof. Takayuki Murata of *Fujita Health University*, Japan, discovered that a new type of coronavirus can be deactivated with low concentrations of Ozone (0.05 or 0.1 ppm) which is considered a level that is safe for human health [5].

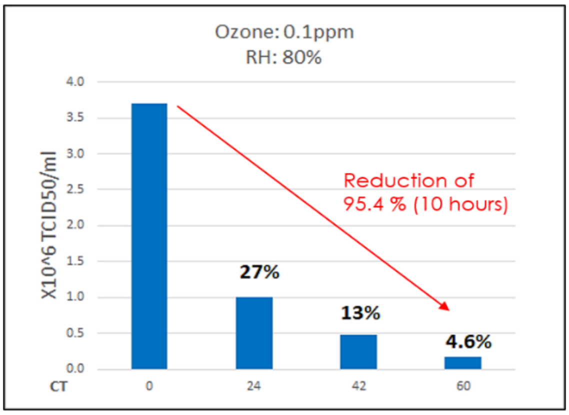

Fig-9: Dose 0.1 ppm

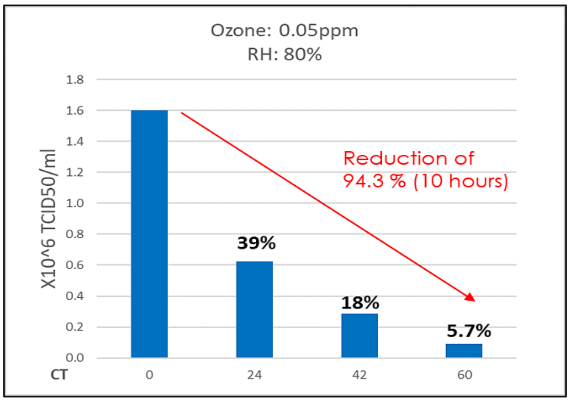

Fig-10: Dosage 0.05 ppm

Research from Tel Aviv University, Israel, has demonstrated injected water with O_3 at low doses that are rubbed on the surface, has successfully sanitize these surfaces against exposure to Coronavirus in a very short time [6].

Other research has also been carried out by the *Center for Disease Control* (*CDC*) which states that Ozone is very effective for inactivating various viruses, especially *enveloped viruses* such as SARS-CoV-2. Within seconds, Ozone can dissolve the lipid/protein membrane of the virus [7].

The main focus of this paper is the design of a meeting room in an office in Jakarta. What led to the focus of meeting room is because it is estimated that 15 - 20 people hold meetings, meaning that several people are together in a closed room by doing physical activities, such as speaking, debating, presenting, and writing, where all of these activities are likely to produce droplets or aerosol particles. On top of that, the presences of windows that allow the entry of outside air are rare in this type of room. With that said, the safety for the people in the room heavily depends on the air conditioning system.

This room has an area of 66 m^2 with a ceiling height of 2.8 m

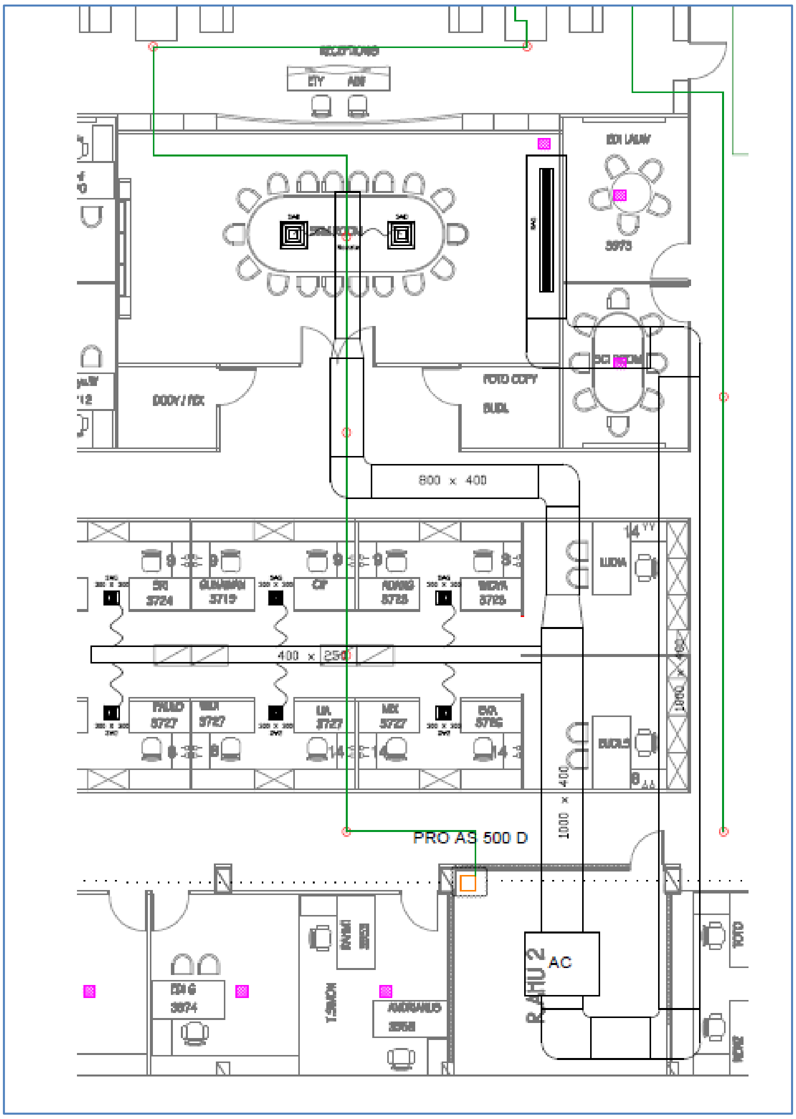

Fig-9: Layout of Central AC and Ozone generator

It uses Central AC as the installed air conditioning system that has been equipped with an exhaust fan. On the entire floor installed tools with the following specifications:

Product Specification	
Ozone Output (max)	1 g/hr
Adjustable Ozone Output	Yes
Casing	Galvanized steel epoxy powder coated
Power Plug Type	2 pin / 3 pin Plug
Input Voltage	220 - 240 VAC / 50Hz
Input Current (max)	0.5 A
Power Consumption	115 W
Coverage Area*	5000 ft² / 465 m²
Installation	Distributed System

Fig-10: Product specifications

The form of the device is centralized where O_3 will be channelled through the FEP hose and removed through the *Nozzles* scattered across the floor, with a total of 10 *nozzles*. In the meeting room, 1 *nozzle is* placed near the diffuser so that it can help spread Ozone evenly throughout the room

Fig-11: Product and nozzle photos

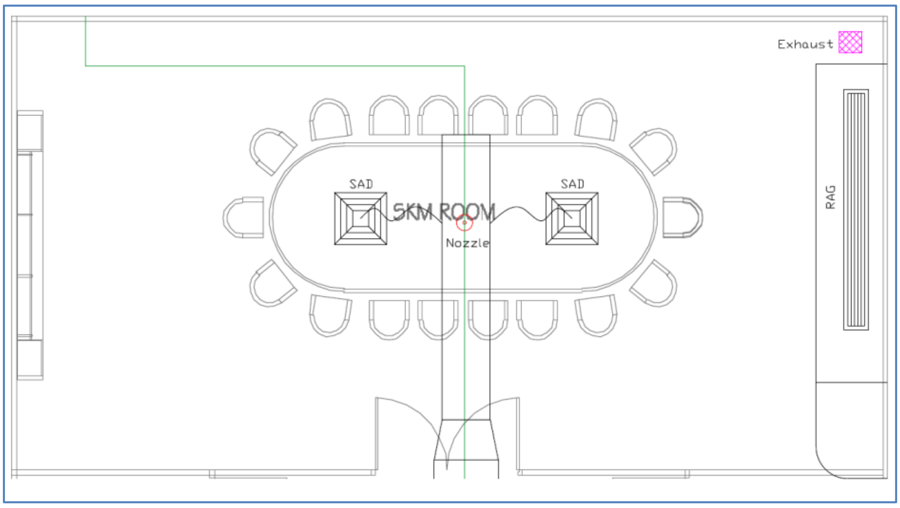

Fig-12: Meeting room plans, air conditioning, and nozzle placement

IV. RESULTS AND ANALYSIS

In this design, we have to measure how much Ozone is in the meeting room. The meeting room as shown in Figure 12, it appears there are two diffusers (SAD) where one returns the air recirculation/*return* grille (RAG), and one exhausts the fan (*exhaust fan*). The new air is flown in through the mixing with the recirculated air, and is directed to enter the meeting room through 2 diffusers. Fresh air from outside that enters is 680 m^2 / h, this number is obtained based on the ASHRAE standard[8] which states that a minimum of 17 ft^3 /min/person is required, in this case it eill be 20 ft^3 /min, hence with the design of the meeting room that is attended by a maximum of 20 people at a time, it takes 20 cfm (ft^3 /m) x 20 people = 400 cfm ≈ 680 cmh (m^3/hour) clean air that enters the meeting room which means in 1 hour there is clean air with the incoming oxygen content of 680 m^3, while the volume of the room is 66 m^2 x 2.8 m = 184.8 m^3. Therefore, in 1 hour the air in the room will change as much as 3.68 times. The air that is discharged out, is made to be equal to the clean air entering the room, with the amount of 680 m^3; with the reason to maintain the pressure of the meeting room to remain in the position of neutral or zero, meaning that no air going out or in that is not controlled from the slits between doors or other unnoticed gaps.

The calculation of the Ozone concentration uses calculations on the outside air itself because the circulated air is mixed with carbon dioxide (CO_2) which is produced from exhalation (*breathing out*).

The concentration of Ozone released by the device as shown in Figures 10 and 11 is 1 gram per hour, with 1 system installed with 10 *nozzles*, 1 *nozzle* will emit 1 g/hour: 10 *nozzles* = 0.1 g/hour 100 mg/hour.

According to ACGIH the calculation of "*Threshold Limit Values"* for chemical substances and physical substances (such as: UV radiation, lights, vibrations, and sound, or more widely known as *physical agent,)* and the Biological Exposure Index the formula is as follows.

$$TLV\ in\ ppm\ =\ \frac{24.45\ x\ (TLV\ in\ \frac{mg}{m3})}{(gram\ molecular\ weight\ of\ substance)} \quad \text{…….. Equation 1}$$

Ozone has a molecular weight of 47,997 g/mol

TLV in mg/m^3 is obtained by calculating the concentration of ozone per hour in the air which entered at 680 m^3/h, namely

TLV in mg/m^3 = 100 mg/hour / 680 m ^{3}/hour = 0.147 mg/m^3

From here we go into equation 1 and it will become:

$$TLV\ in\ ppm\ =\ \frac{24.45\ x\ (0.147\frac{mg}{m^3})}{47.997\frac{g}{mol}}$$

$$TLV\ in\ ppm\ =\ \frac{3.594\frac{mg}{m^3}}{47.997\frac{g}{mol}}$$

$$TLV\ in\ ppm\ =\ 0.075\ ppm$$

After 1 month of installation, exposure tests (air samples) and surface swabs were carried out at three points:

TRIAL OZONE MEDKLIN [redacted]

Tanggal pengambilan sampel : 1 Maret 2021 (pertama), 30 Maret 2021 (kedua)
Tanggal Analisa sampel : 1 April 2021
Area : R. Meeting Utama
Vendor : [redacted]

HASIL ANALISA

EXPOSURE

No	Area Random Exposure	TPC		M/Y	
		Before	After	Before	After
1	Area Sisi Kanan	152	44	34/0	16/0
2	Area Sisi Kiri	31	20	37/0	29/2
3	Area Tengah	31	22	32/0	20/0

SWAB

Area	Objek Random Swab	CPC		TPC		M/Y	
		Before	After	Before	After	Before	After
1	Kursi	1	0	107	10	1/0	0/0
2	Meja	0	0	>250	26	0/0	0/0
3	Papan Tulis	0	0	17	4	0	0/0

RESUME

Hasil analisa yang dilakukan di 3 titik dimana alat Ozone di pasang menunjukkan bahwa nilai mikrobiologi untuk TPC, MY , CPC berbeda dan mengalami penurunan.
Penurunan terjadi significant pada hasil analisa exposure yaitu untuk TPC dan Mould serta hasil swab untuk TPC. Sehingga berdasarkan hasil tersebut, alat Ozone yang dipasang dapat menurunkan jumlah total bakteri (TPC) dan Mould dalam area tersebut.

Jakarta, 6 April 2021

[redacted]

Fig-13: Exposure and Swab. Test results

The test is carried out by the company internally because the company has its accredited microbiology laboratory. TPC values below 100 can be considered as clean/sterile rooms and surfaces.

V. CONCLUSION

Design application of *Air & Surface Sterilizer* in a meeting room that has followed the rules of *Prevention through Design (PtD)* by placing one *nozzle* which releases 100 mg/h Ozone and with clean air entering at 680 m^3 / h, where the air removed is made to be equal as the clean air that enters, the result of Ozone concentration is 0.075 ppm. This concentration of 0.075 ppm according to OSHA, NIOSH, and ACGIH for work with medium activities (talking, debating, walking around the blackboard for presentations) is still in the safe limit for human exposure, so the right placement and concentration design has proven to be effective in deactivating or destroy the virus according to research from Fujita [5] and Israel [6] while still being safe for human exposure. According to microbiological laboratory tests, it was also known that there was a significant decrease in microorganisms (without distinguishing viruses or bacteria) after 1 month of installation. Humans will still be able to work with high productivity, while having a safe environment from the transmission of this COVID-19 virus outbreak. PtD is very important in carrying out inherent designs, to obtain a benefit for human safety while avoiding side effects and dangers.

REFERENCES

1. Main, B.W., & McMurphy, K.J. (1999). “Safety Through Design: The State of the Art in Safety Processes,” *SAE Trans.*, vol. 108, 474–481, Available: http://www.jstor.org/stable/44650643
2. “Prevention through Design | NIOSH | CDC," Feb. 21, 2020. https://www.cdc.gov/niosh/topics/ptd/default.html
3. "Modes of Transmission from Exhaled Pathogens (Adapted from a leaflet of the Office of the Prime Minister and the Ministry."
4. Baron., & Willeke. (2001). *Aerosol Measurement*. Willey.
5. Murata, T. (2020). “Test Conducted by Fujita Health University Hospital, Japan,” Aug.
6. Zucker, I. (2021). “Pseudoviruses for the assessment of coronavirus disinfection by ozone,” *Environ. Chem. Lett*, *19*(2), 1779–1785, Apr. 2021, doi:10.1007/s10311-020-01160-0.
7. “Ozone, V.S. (2013). Coronavirus: Ozone's Efficacy as a Virucidal Disinfectant.” https://www.randrmagonline.com/articles/88901-zones-efficacy-in-deactivating-coronavirus-like-pathogens *ASHRAE 62.1-2013*.