2020

COVID-19 Personal Protective Equipment Sterilization System

Uwe Reischl
Boise State University

Publication Information

Reischl, Uwe. (2020). "COVID-19 Personal Protective Equipment Sterilization System". In Y. Li, M. Zhu, and X. Zeng (Eds.), *13th Textile Bioengineering and Informatics Symposium Proceedings (TBIS 2020): Combatting COVID-19 Pandemic with Science and Technology Innovations* (pp. 10-14). Textile Bioengineering and Informatics Society Limited.

COVID-19 Personal Protective Equipment Sterilization System

Uwe Reischl[1]

[1]*Boise State University, 1910 University Dr., Boise, Idaho 83725, USA*

[*]Corresponding author's email: ureischl@boisestate.edu

Abstract

A portable system based on a non-destructive sterilization method was developed that consists of a chamber producing ozone concentration levels reported in the scientific literature to deactivate 99.9% of all microorganisms. The system includes a small cordless 30mg/h ozone generator placed inside a 20L enclosed chamber. Personal protective equipment is loaded into the chamber and automatically exposed to an ozone concentration up to 18 ppm for 30 minutes. PPE is then removed and ventilated in open air to allow residual ozone to degrade to oxygen. The paper describes the design and performance characteristics of this technology.

Keywords: PPE; Sterilization; Ozone; Face Mask Reuse

1. Background

The current coronavirus pandemic has sparked global efforts to develop new and creative approaches to solve shortages of personal protective equipment. This includes facemasks, coveralls, gloves, shoes, and other devices used by medical workers treating COVID-19 patients and by the public to reduce the spread of the virus within the community. While most currently available personal protective equipment is intended for single-use, safe and effective disinfection will allow the personal protective equipment to be reused multiple times, thus addressing equipment shortages.

Ozone is a disinfectant known to kill bacteria and viruses upon contact [1-11]. Ozone (O_3) is an unstable gas that degrades back into its original stable state of Oxygen (O_2) by forming a reactive free oxygen atom that oxidizes organic and inorganic compounds. Ozone gas can reach poorly accessible spaces such as dense textile materials that other methods such as hydrogen peroxide vapors, laser light or UV radiation, etc., cannot. Ozone gas does not produce harmful residues since residual ozone always converts back to oxygen (O_2) within a few minutes. Therefore, this method provides an ideal solution for sterilizing personal protective equipment against the COVID-19 virus.

A portable ozone sterilization system was developed. The system consists of a cordless 30mg/h capacity ozone generator placed inside an enclosed chamber. Personal protective equipment can then be loaded into the chamber and automatically exposed to an ozone concentration capable of deactivating the pathogens. After exposure, the personal protective equipment is removed and ventilated in open air to allow residual ozone to degrade to oxygen.

2. Methods and Procedures

2.1 Instrumentation

A cordless (re-chargeable battery powered) ozone generator was used for all tests. The generator is commercially available for use in cleaning Continuous Positive Airway Pressure (CPAP) mask systems. A digital ozone detector, including a sampling pump and probe, was used to measure the ozone concentrations inside the enclosed chamber. The equipment components are shown in Fig.1.

2.2 Equipment Specifications

The equipment used in this study including the ozone generator and monitor and associated performance specification are summarized in Table 1.

Table 1. Summary of equipment performance specifications

System Components	Specifications
Ozone generator	o Rosa Rugosa (RR) o CPAP cleaner Model S4 Plus o Output: 30mg/h o Flow rate: 34 L/min o O_3 Output Concentration: 7 ppm
Ozone monitor	o Forensics Inc. (FI) o Sampling pump: 500 mL/min o O_3 Detector: Model FD-90A o Sensitivity: 0.1 ppm o Detection range: 0-20 ppm

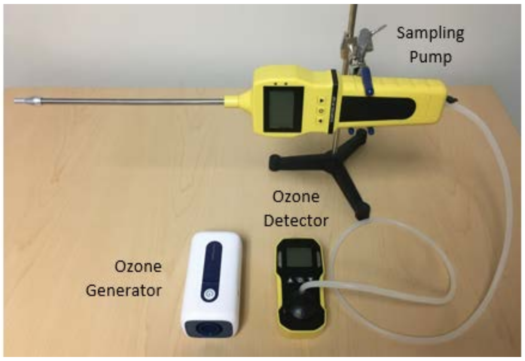

Fig.1 Illustration of equipment used in tests: Ozone generator; Ozone detector and Air-sampling pump

2.3 Ozone Generator Placement

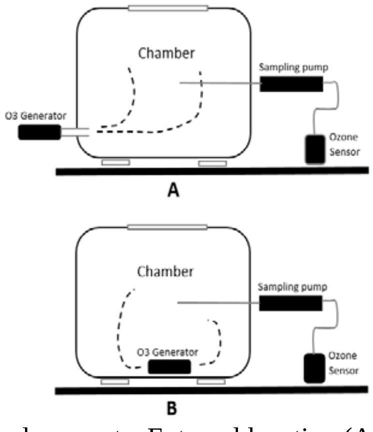

Fig.2 Ozone generator placements: External location (A) Internal location (B)

Initial tests were conducted to evaluate the effect of ozone generator placement on equilibrium concentration achieved inside the chamber. Two configurations were examined. The first configuration consisted of the ozone generator being placed outside of the chamber and connected to the chamber by a tube. The second configuration consisted of the ozone generator being placed inside the chamber. The two placement configurations are illustrated in Fig.2. The objective was to determine whether the placement of the ozone generator will influence the equilibrium ozone concentrations obtained inside the chamber.

3. Results

3.1 Ozone Generator Placement

Significant differences in the ozone equilibrium concentrations were observed between the external ozone generator placement and the internal placement. The equilibrium ozone concentration achieved for the external placement was 4 ppm while the equilibrium ozone concentration achieved for the internal placement was 17 ppm. The results are illustrated graphically in Fig.3.

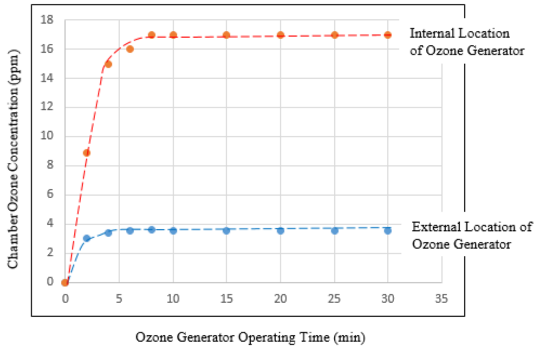

Fig.3 Ozone equilibrium concentrations observed inside a 20L chamber with an internal placement of the ozone generator and with an external placement of the ozone generator.

3.2 Chamber Size Effects

Five chamber sizes were evaluated including the following: 20L, 28L,45L, 57L and 96L. The geometry of all of the chambers was symmetrical, i.e., all six sides of a chamber were equal in size (area).

Significant differences in ozone equilibrium concentrations were observed. Smaller chambers reached higher ozone concentrations than larger chambers. The 20L chamber reached 18 ppm, the 28L chamber reached 11 ppm, the 45L chamber reached 7ppm, the 67L chamber reached 4 ppm and the 96L chamber reached 3 ppm. The results are summarized graphically in Fig.4.

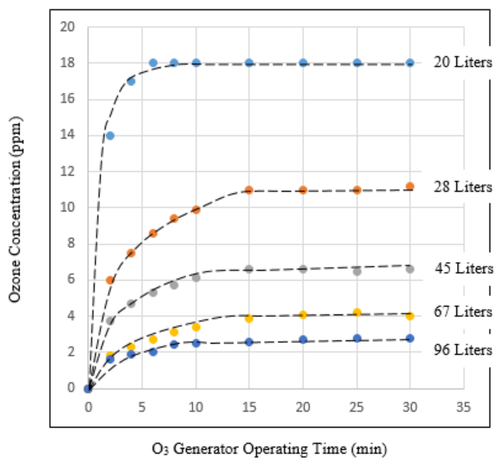

Fig.4 Relationship between chamber size (volume) and equilibrium ozone concentrations (ppm) observed for five chambers. The ozone generator was located inside the chamber in all tests.

4. Discussion

The multiplicative effect observed when the ozone generator was placed inside the chamber resulted in equilibrium concentrations significantly higher than when the ozone generator was located outside of the chamber due to the re-circulation of the ozonized air inside the chamber. This effect was observed for all of the five volume configurations tested. The relationship between chamber volume and the equilibrium ozone concentrations is illustrated in Fig.5. This relationship is believed to be associated with the half-life characteristics of ozone inside the chamber. It is known that the half-life of ozone ranges between a few seconds and minutes, depending on chamber enclosure material, temperature, and humidity. Furthermore, as the chamber volume is increased, the time needed for the chamber air to be re-circulated through the ozone generator is also increased. Subsequently, the concentration of the ozonized air re-entering the generator decreased.

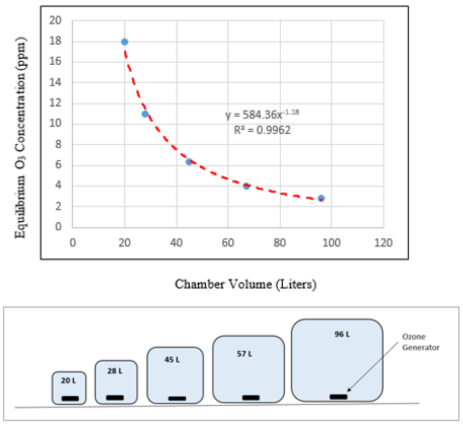

Fig.5 Relationship between chamber size (volume) and equilibrium ozone concentrations for an internal placement of the ozone generator.

5. Conclusion

The results of the tests show that ozone concentrations needed to disinfect facemasks and other personal protective equipment (PPE) can be achieved easily by using a 30mg/h ozone generator placed inside a 20L chamber. Although the effectiveness of the system decreases as the volume of a chamber is increased, a lethal ozone concentration can also be achieved using larger chamber volumes. The simplicity of the design allows individuals and families to assemble sterilization kits for personal use.

Fig.6 illustrates an example of such a solution. The system consists of a 20-Liter plastic container available in most department stores. The ozone generator can be purchased online from retailers such as Amazon, eBay, Alibaba, and others. The tests have shown that the system can offer effective sterilization of personal protective equipment and protect users against exposure to pathogenic bacteria and viruses that may have accumulated inside the mask during previous uses.

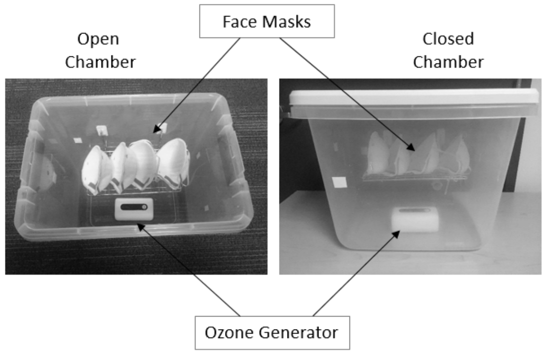

Fig.6 Illustration of a simple and practical low-cost ozone disinfection kit for use by families.

6. Acknowledgements

Sincere appreciation is extended to Mr. John Schiff of Obtainium, LLC. and Mr. Steven Rodoletz of Reuseum, Inc. in Boise, Idaho, USA. Both gentlemen provided valuable technical and logistical support for this project.

References

[1] Tseng C, Li C. Inactivation of Surface Viruses by Gaseous Ozone. J Env Hlth: 2008; 70: 10: 56-63.
[2] Li CS, Wang YC. Surface Germicidal Effects of Ozone for Microorganisms, AIHA J: 2003; 64: 4: 533-537.
[3] Dubuis ME, Dumont-Leblond N,Camille Laliberté C, Veillette M, Turgeon N, Jean J, Duchaine C. Ozone Efficacy for the Control of Airborne Viruses: Bacteriophage and Norovirus Models. National Library of Medicine: 2020: 10; 15 (4): e0231164.
[4] Tseng C, Li, C. Ozone for Inactivation of Aerosolized Bacteriophages. Aero Sci Tech; 2006; 40:9; 683-689.
[5] Roy D, Wong PK, Engelbrecht RS, Chain ES. Mechanism of Enteroviral Inactivation by Ozone. Appl Env Microbiol: 1981; 41: 3: 718-723.
[6] Katzenelson E, Koerner G, Biedermann N, Peleg M, and Shuval HI. Measurement of the Inactivation Kinetics of Poliovirus by Ozone in a Fast-Flow Mixer. Appl Env Microb: 1979; 37: 4; 715-718.
[7] Karpendale MTF, Freeber JK. Ozone Inactivates HIV at Noncytotoxic concentrations. Antiviral Res: 1991; 16: 3: 281-292.
[8] Khadre MA, Yousef AE. Susceptibility of Human Rotavirus to Ozone and High Pressure and Pulsed Electric Field. J. Food Protection: 2002; 65: 1441-1446.
[9] Sharma M, Hudson JB. Use of Ozone to Reduce Moulds in a Cheese Ripening Room. Amer. J. Infect Control: 2008; 36: 559-563.
[10] Shin GA, Sobsey MD. Reduction of Norwalk Virus, Poliovirus 1 and Bacteriophage MS2 by Ozone Disinfection in Water. Appl. Environ. Microbiol: 2003; 69: 3975-3978.
[11] Cataldo F. Ozone Degradation of Biological Macromolecules: Proteins, Hemoglobin, RNA, and DNA. Infection. Ozone: Sci. Eng: 2006; 28: 317-328.