Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Fabrication and working of portable PPE kit sterilizer using UV Ozone Sanitization process

Gujjala Anil Babu a,b, M. Sadashiva a,b,⇑, Ranjith R. Hombal a, D. Aravinda a

a Department of Mechanical Engineering, UVCE, Bengaluru, Karnataka, India
b Department of Mechanical Engineering, PES College of Engineering, Mandya, India

ARTICLE INFO
Article history:
Available online 17 January 2022

Keywords:
Covid-19
N95 mask
Sterilization
UV Ozone Sanitization
PPE kits

ABSTRACT
Personnel protective equipment, N95 masks, and filtering facepiece respirators such as goggles, face shields, played a very important role in the safety of both virus-affected persons and as well as medical staff, health workers. As the coronavirus (Covid-19) was increasing exponentially worldwide, healthcare has been the demand for this basic equipment especially face protection shields have critical issues. There has been an effort to find out the different ways to conserve PPE kits, to use after the sterilization process. The current work focused on the fabrication of the Portable PPE Kit Sterilizer model using UV Ozone Sanitization Process to utilize for recycling of N95 masks, goggles. Due to its miniature structure, can be used in public health sectors like the hospital, research centers, schools, and laboratories also. The method adopted was cheap, reuse, well suited for mass sanitization.

Copyright © 2022 Elsevier Ltd. All rights reserved.
Selection and peer-review under responsibility of the scientific committee of the First International Conference on Design and Materials (ICDM)-2021.

1. Introduction

Sanitization was a process that involves cleaning certain surfaces and areas in such a way that develop free from bacteria and elementally clean from microbes and viruses which have infectious to the human body and lead to different kinds of diseases [1]. Different types of sanitization processes were available at the market using several working agents determined to kill bacteria, germs, and pathogenic agents which spread diseases [2]. The importance of sanitization was to stop and make the barrier to the spread of dangerous and contagious diseases. During working hours people may lead to contact surfaces in which it may be polluted with bacteria, fungi, and viruses [3]. After the unsafe contact of these surfaces may lead to actively or passively effects on the body due to viruses entering through the eyes, nose, so sanitization was important for our unfailing health [4].

Fig. 1 show the Sterilization, the process that removes or kills all forms of microorganisms. Including the spore forms of microorganisms that are usually resistant. This refers to the life forms within a fluid, mediations, and compounds such as buffers, culture media, and also the life forms on the surface [5]. Sterilization can be made with two different methods namely physical and chemical methods of sterilization. In which the Heat and Radiation those involved in physical whereas in case of chemical liquids and Gas/Vapour forms used for sterilization. This can be achieved with the combinations of chemicals, heat, high-level pressure, irradiation, and filtration [6].

Personal Protective Equipment, special equipment form a barrier between humans and germs. Due to the formation of the barrier the chance of being exposed or touching and spreading of germs can be reduced. The equipment prevents the spreading of germs and also protects from different infectious diseases [7]. Different types of PPE forms a barrier in different ways such as Gloves, masks, Goggles, Face shields, PPE Coverall, and Headcover. After the use of this equipment disposing of the PPE is very important to avoid being exposed to harmful germs. This may include special waste containers that different from other waste containers and also specially marked bags for cytotoxic PPE.

The main aim involved in designing a portable PPE kit sterilizer with the use of Ozone sanitization is to clean materials such N95 and N100 masks, goggles, PPE kits in which the pathogenic agents such as viruses, bacteria, and fungi it shown in Fig. 2. In which the concentration agents can be reduced, inactivated, and destroyed. Nowadays, the PPE kits and the mask are highly demanded by
the medical staff to deal with COVID-19 patients. Due to the wake of the covid-19 crisis, it has been forced to become scared of materials. This has made people reuse the same items. Normally washing the materials like ordinary clothes has some limitations it destroys texture [8]. The pore size and face respirators of the surgical mask will also be destroyed. Considering the sterility of the inner layer of materials, we have come up with the idea of a portable sterilizer that helps in sterilizing and cleaning the used masks and PPE by UV Ozone Sanitization method. The safe and effective decontamination and reuse of the N95 filtering facepiece respirators (FRRs) have the potential to significantly extend FFR holdings. Ozone gas appears to be effective in decontaminating FFP respirators without damaging them. The use of ozone is easy from an outlook of equipment, and it is easy to get ozone from oxygen [9].

The current work extensively focussed on relevant results of bacteria, virus disinfection by the application of the ozone sanitization method. The disinfection treatment was carried out in a sealed metallic chamber. In this regard, the present work was aimed that sterilization by using UV Ozone Sanitization can be utilized the PPE shortage by making a way for sterilizing PPE kit (includes PPE masks, PPE gloves, PPE goggles, PPE headcover, PPE coverall) to allow safe daily re-use. In this method, UV Ozone Sanitization was extensively adopted and concluded that it safe and more effective method for sterilizing compare to alternatives.

However, The following objective mainly concentrated in this research paper and were listed as:

- To design and develop of portable PPE kit sterilizer.
- Effective sterilization of PPE kit and N95 masks using UV Ozone Sanitization.
- To reduce the human effort for the sterilization process.
- To improve the safety of humans in the sterilization process.

2. Methodology

In the current situation, adopted several types of sanitization process and they were classified or determined based on agents that kill the pathogenic microorganisms which will further spread the diseases. Some of the important sanitization methods are Foam cleaning sanitization, Antimicrobial sanitization, Chemical sanitization, Pressure cleaning sanitization, and Thermal sanitization done with the steam of water.

2.1. Chemical sterilization

Chemical sterilization was that the method of using the low-temperature chemical to kill eliminate, and deduct all germs, viruses & bacteria. This may be within the type of gas or liquid chemicals.

1. Gaseous Sterilization
   - Ethylene oxide
   - Formaldehyde
   - Nitrogen dioxide
   - Ozone

2. Liquid Sterilization
   - Hydrogen peroxide
   - Glutaraldehyde
   - Hypochlorite
2.2. Ozone

The ozone was a highly reactive gas consisting of a trioxygen atom, and an inorganic molecule having the molecular formula O₃ shown in Fig. 3, pale blue gas having a pungent smell. Ozone was both a natural and man-made product that occurs in the earth’s atmosphere. From this ozone, there were both advantages and disadvantages. Ozone was obtained in both solid as well as in liquid form.

2.3. Ozone sanitization

Ozone sanitization could also be a process and should be used as a chemical disinfectant to kill bacteria and viruses with low ozone concentrations. Ozone is unstable gas consisting of three oxygen atoms. The oxygen atoms or radicals are heavily reactive and they will oxidize anything like viruses, bacteria; any microorganism in contact, ozone is a very powerful disinfectant and also a very good oxidizer.

3. Experimentation

Ozone and UV radiations were not only destroyed the bacteria cell. oxidative burst occurs which means the reaction comes when ozone approaches the cell wall. ozone weakness the cell wall and it leads to cellular rupture. Ozone kills bacteria, fungi, parasites, disease cause viruses, and microbes. There isa large number of factors that influence surface disinfection. High viral inactivation is attained when ozone disinfection treatments are applied to inert materials. Complete outer casing setup fabricated with wooden board and it was even better to construct with using hybrid composite materials in order to get high strength to weight ratio [10,11].

3.1. Ozone formation process

Ozone (O₃) is produced by the combination of an oxygen atom with another oxygen molecule (O₂). The steps for formation are:

Ozone is a highly reactive gas having a combination of three oxygen atoms. On items like polycarbonate face shields, respiratory masks, and goggles it kills or destroys the bacteria, viruses without damaging the items. The gas can move to all parts of the PPE kit to kill viruses and bacteria and to sterilize completely. Ozone was a proven disinfectant and it’s having the power to inactivate. The system can convert oxygen into ozone and it’s not having to need any other inputs.

\[
\text{UV} + \text{O}_2 = \text{O}_3
\]

For the fabrication of a portable PPE kit sterilizer using UV, Ozone sanitization was built using the following components.

3.2. Components

3.2.1. Arduino UNO

The Arduino UNO is a small MCU panel that is based on the ATmega328. Fig. 6. It consists of a different number of 14 digital input and output pins, having an analog input of 6 and a ceramic resonator of 16 MHZ, it is also having a reset button, power jack, and USB connection. **Power:** The power is supplied by using the USB connection or by using an external battery supply. Automatically the power source is selected. **Memory:** It is having 32 kb. It
also has 2 kb of SRAM and 1 kb of EEPROM. Physical characteristics, The PCB board is having a length and width of 69 and 53 mm. This board includes a power jack and USB connector that extends beyond dimension.

3.2.2. Ozone generator with air blower

Typical air blower should be portable, easy for use. Consumption of power is low, it will give efficient work and safety for use. **Working:** From the oxygen or dry air it converts oxygen into ozone by taking advantage of the power supply. Specifications of this ozone generator were: Ozone output: 10 g/h, Consumption of power: 50 W, Input source: Oxygen or air, cooling: Ambient air cooling, Size: 145 × 55 × 87 mm shown in Fig. 7.

3.2.3. Ozone sensor

MQ131 Semiconductor sensor was a gas sensor shown in Fig. 8. If the gas concentration is rising then the sensor conductivity is also higher. MQ131 sensor high sensitivity to Ozone. The character of ozone Good sensitivity to Ozone gas in a large range, Highly sensitive to ozone gas, Long life, Cost is less, Circuit is simple. Other than this some additional accessories are required for fabricating the portable sanitization unit. These were shown in Figs. 9–12.

3.3. Circuit connection

Figs. 13 and 14 shows the circuit diagram of the current model, connection and position of the component play a pivotal role to enhance the effectiveness of sterilizing. To optimize the process, circuit monitoring was crucial. Arduino PCB Board acts as a central part of the whole setup, it should control the timing of ozone generation, circulation, dispersion within the chamber, and even standby time of UV light on oxygen. The effectiveness of sanitization is majorly concentrated on overall this scenario.

The model was designed by using a wooden chamber sealed on all four sides shown in Fig. 15(a) and (b). During the working of serialization, place the PPE kit inside the chamber later close the chamber with the help of a solenoid door lock received the signal from Arduino PCB Board. Followed by the switch on the ozone generator with an air blower, it converts the oxygen into ozone by using electrical discharges.

In this phenomenon involved UV light rays were generated with help of an external electric circuit and made to fall oxygen molecules, converts effectively oxygen into ozone. The output of Ozone was measured during working noted as 10 g/h by using 50 W power and relay switches. The ozone sensor was connected to the Arduino board, ozone sensor reads the amount of discharged ozone into the chamber that same to be displayed on the LCD using signals of Arduino and once the ozone gas enters into the chamber, sterilization process starts. Fix the time set for the sterilization process for complete sanitization of objects effectively. Once standby is completed means sanitization process is completed, the buzzer will make a sound to indicate the end of the process, and finally, the solenoid door lock will be open by using a relay switch.

4. Results and conclusions

Ozone is one of the cleanest ways of deactivating bacteria viruses and can kill any microorganisms. From an equipment per-
spective, it is easy to use & get ozone from atmospheric air. The following points were outlined in the current work.

1. Successfully fabricate the portable model of the PPE Kit sanitization Unit.

Conclusion:
The PPE kit sterilizer device which works by using the UV Ozone Sanitization method it is mainly designed to sterilize or to reduce or kill the effect of pathogens like bacteria’s or viruses for healthcare workers and to reuse personal protective equipment, respirators, surgical masks, and N95 mask filtering facepiece respirators (FFRs) by using ozone sanitization, from current work concluded that Ozone gas appears to be effective in decontaminating FFP respirators without damaging them. The use of ozone is easy from an outlook of equipment, and it is easy to get ozone from oxygen, and this PPE kit sterilizer was compact in size and can be used in all medical health centers and research laboratories.

Scope for future work:
The following points will be the opportunity to enhance current work in the future.

2. The effectively use UV light as an input to convert oxygen into ozone, during the sterilization process.

3. The technical specifications of sterilizing chamber and model were achieved.

4. Recycle the PPE Kit, Gloves, and other protective equipment with minimal cost.

5. Finally to access heighten, protection from several viruses, achieved successfully.
The current model was in miniature scale, it will be construct in large dimension might help for mass sanitization.

Effective utilization of technology may reduce the risk of hazards caused by PPE kit sterilization replace UV rays.

It could be more efficient shown digital percentages outcomes of virus/bacteria vanished.

The current model runs through external electrical energy supply it may causes economically feasible. In future if attach renewable energy sources may fix this issue.

Current model constructed with wooden supports, for long run operation it can be replace by metal leads more effective.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] D. Mills, D.A. Harnish, C. Lawrence, M. Sandoval-Powers, B.K. Heimbuch, Ultraviolet germicidal irradiation of influenza-contaminated N95 filtering facepiece respirators, Am. J. Infect. Control 46 (7) (2018) e49–e55.

[2] C. Carias, G. Rainisch, M. Shankar, B.B. Adhikari, D.L. Swerdlow, W.A. Bower, Potential demand for respirators and surgical masks during a hypothetical influenza pandemic in the united states, Clin. Infect. Dis. (Suppl 1) (2015) S42–S51.

[3] M.R. Lore, B.K. Heimbuch, T.L. Brown, J.D. Wander, S.H. Hinrichs, effectiveness of three decontamination treatments against influenza virus applied to filtering facepiece respirators, Ann. Occup. Hyg. 56 (2012) 92–101.

[4] O. Dadras, S.A.S. Alinaghi, A. Karimi, M. MohsseniPour, A. Barzegary, F. Vahedi, Z. Pashaei, P. Mirzapour, A. Fakhfouri, G. Zargari, S. Saeidi, H. Mojdeghani, H. Badri, K. Qaderi, F. Behnezhad, E. Mehrlaen, Effects of COVID-19 prevention procedures on other common infections: a systematic review, Eur. J. Med. Res. 26 (1) (2021), https://doi.org/10.1186/s40001-021-00539-1.

[5] P. Rios, A. Radhakrishnan, C. Williams, N. Ramkisson, Ba’ Pham, C.V. Cormack, M.R. Grossman, M.P. Muller, S.E. Straus, A.C. Tricco, Preventing the transmission of COVID-19 and other coronaviruses in older adults aged 60 years and above living in long-term care: a rapid review, Syst. Rev. 9 (1) (2020), https://doi.org/10.1186/s13643-020-01486-4.

[6] H. Zhu, Q. Guo, M. Li, et al., Host and infectivity prediction of Wuhan 2019 novel coronavirus using a deep learning algorithm, BioRxiv (2020).

[7] COVID, Coronavirus, Global Cases by Johns Hopkins CSSE, Johns Hopkins University (JHU), 2020.

[8] World Health Organization, Coronavirus disease (COVID-19) advice for the public, 2020. <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public> (Accessed January 23, 2021).

[9] Serge P.J.M. Horbach, Pandemic publishing: medical journals strongly speed up their publication process for COVID-19, Quant. Sci. Stud. 1 (3) (2020) 1056–1067, https://doi.org/10.1162/qs_s_a_00076.

[10] M. Sadashiva, J.V. Abhishek, Characteristic evaluation of tensile properties of hybrid bio composites with different orientation of fibers, in: AIP Proceedings, 2020, pp. 030041-1–030041-5. https://doi.org/10.1063/5.0027005, ISBN:978-0-7354-4004-3.

[11] M.R. Srinivasa, Y.S. Rammohan, M. Sadashiva, Analysis of mechanical properties of graphene reinforced aluminum composites treated with shock waves, in: AIP Proceedings, 2020, pp. 030040-1–030040-7. https://doi.org/10.1063/5.0027005, ISBN: 978-0-7354-4004-3.