Disinfection System for Public Transport using Aerosolized Hydrogen Peroxide

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Abstract.

During the Covid-19 pandemic, public transportation has been debated to be associated with an increased risk of viral transmission, especially on long-distance public buses due to confined space, inadequate ventilation, and long exposure time. Effective disinfection in public transportation can minimize contact transmission. The aim of this study is to validate the disinfection efficacy of low concentration aerosolized hydrogen peroxide (aHP). Aerosolized droplets of 5% HP were generated from an ultrasonic atomizer in order to fumigate 3 intercity public buses in Trat province of Thailand. The validation process for disinfection was conducted using both a chemical indicator and spore discs biological indicator (inoculated with 10^6 *Geobacillus stearothermophilus* enclosed in glassine envelopes). The chemical and biological indicators were placed at all corners and hard-to-reach locations in the bus. The results showed that an aerosolized period of 30 minutes was effective for sporicidal 6-log reductions. The microbicidal efficacy of aHP in public buses was comparable to sterilization. The automated hydrogen peroxide aerosolized system is a highly effective and versatile method.

Keywords: aerosolized hydrogen peroxide, hydrogen peroxide fumigation, surface disinfection, surface decontamination, public transport

1. Introduction

The global pandemic of coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), began in December 2019 in Wuhan (China) and has since spread to over 200 countries. The outbreak had a significant impact on public transportation. The demand for public transport dramatic drop in ridership (40–90%) during the early stages of the outbreak (Bucsky P, 2020, de Haas M, 2020, Jenelius E, 2020, Wielechowski M, 2020). Fear of infection has resulted in decreased mobility and aversion to public transportation (Borkowski P, 2021). The researcher discovered that during the pandemic, the majority of public transportation modalities shifted to private cars (Zhang et al., (2021). This decline in ridership has contributed to transit operators' financial insecurity (Kaske M, 2020, Mehmet S, 2020, Tsang D, 2021). These effects are not only behavioural changes but also have an effect on attitudes toward public transportation. Several studies have expressed concern about the possibility that the public transport user will return to public transportation in a post-COVID-19 (Kopsidas A, 2021, Przybylowski A, 2021).

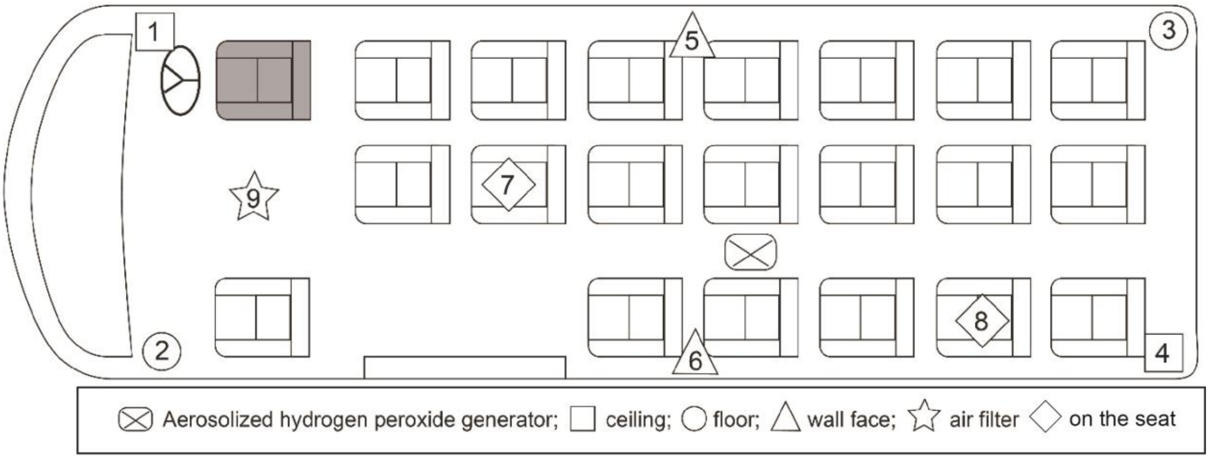
Implementing surface cleaning and disinfection is a safe strategy for mitigating the risk of disease transmission. Surface cleaning and disinfection can be achieved manually or through the use of modern automated systems. There is strong evidence that traditional cleaning and disinfection methods are ineffective at preventing and controlling the infection. According to previous research, traditional methods cover approximately 40%–60% of the surfaces that should be cleaned (Carling PC, 2006, Gordon L, 2014). Automated technologies are recommended to supplement traditional methods of cleaning and disinfection, particularly in healthcare settings (Boyce JM, 2016). These modern technologies cannot be used in place of traditional methods, as the visible dirt must be removed using a traditional method. The ultraviolet germicidal irradiation (UVGI) system and the hydrogen peroxide (H_2O_2) system are two of the most frequently used automated technologies. The UVGI system has been extensively studied and is widely used in hospitals for air and surface disinfection. UVGI has the advantage of being simple to use and leaving no residue, but the primary disadvantage is that shadowing can result in a reduction in disinfection efficacy. As a result, in complex rooms with the possibility of shadow, H_2O_2 is preferred over the UVGI system (Havill NL, 2012). On public buses, areas such as the area beneath the seat are concealed. The H_2O_2 decontamination system appears to be suitable for public bus decontamination.

The aim of this study is to validate the disinfection efficacy of low concentration aerosolized hydrogen peroxide (aHP) for public transport. A low concentration of 5% hydrogen peroxide solution was used in this experiment.

2. Materials and methods

This study was performed on 3 public buses at the public bus station of Trat City (the eastern province of Thailand). The 20-seater inter-city with an interior volume of 25.46 square meters was chosen through convenient sampling. The experiment used a generator mounted with an ultrasonic atomizer to inject 5% hydrogen peroxide into an aerosol. The aerosolized generator was placed in the center of the bus and was preset for 30 minutes aerosolized time. To validate the disinfection efficacy, chemical indicator (CI) strips (Comply™ Hydrogen Peroxide Chemical Indicator 1248, 3M, USA) and biological indicator (BI) envelopes containing 2.30 x 10^6 *Geobacillus stearothermophilus* ATCC 7953 dried on stainless-steel metal discs sealed in glassine paper (Sterind Bio-indicator *Geobacillus stearothermophilus*, Micro Biotech Inc, India) were marked by number and placed in hard-to-reach locations inside the buses on the floor, ceiling, wall faces, on the seat, and beneath the seat (Fig. 1). While injecting the aerosol, windows and doors remain closed. At the end of the process, CIs and BIs were evaluated. A CI that changed its color from blue to pink was considered exposed to hydrogen peroxide and reported as a positive test. The BI was retrieved, and the envelope was opened. A disc was transferred to culture in Tryptic soy broth at 56 °C for 7 days. Turbidity was observed for re-growth of the spores, which indicating failure or positive test

Figure 1: The location of CIs and BIs placement inside the public buses.



3. Conclusion

The aerosolized time of 30 minutes revealed effective inactive BIs in all locations, as well as all CIs exposed to H_2O_2. All three public buses in the experiment did pass the BIs and CIs tests. Three repetitive tests established the high disinfection efficacy and reliability of the aHP decontamination system.

4. Discussion

Hydrogen peroxide is a potent oxidizing agent. It is broad-spectrum microbial activity against bacteria, viruses, molds, and spores by generating free hydroxyl radicals, leading to the oxidation of the lipid membranes, protein, and deoxyribonucleic acid of microorganisms. Hydrogen peroxide in the vapor phase is a more potent protein oxidizer than hydrogen peroxide in the liquid phases (Linley E, 2012).

The BIs and CIs were placed in nine locations to represent a difficult-to-reach position. The CIs which changed color indicates that hydrogen peroxide was distributed evenly. The

BIs contain ≥10^6 *G. stearothermophilus* (ATCC 7953) spores which *G. stearothermophilus* is the most resistant microorganism to hydrogen peroxide is supported by research (Castro LCM, 2011). The BIs that were exposed to 30-min aerosolized time and found to have no pores indicated a 6-log reduction in sporicidal efficacy.

In our study, we achieved a 6-log reduction in sporicidal efficacy, which is equivalent to sterilization. The aim of this study was to determine the effectiveness of decontamination using a worst-case scenario that could be beneficial during an outbreak. The outcome, which demonstrated high effectiveness, was also beneficial in re-establishing confidence in public transportation.

The limitation of this study is that it was conducted on a single-size vehicle. A bigger vehicle may be necessary for validation, which may require the use of more than one aHP generator, or other parameters may need to be adjusted, such as the use of fans to increase distribution or a longer decontamination cycle. During the study, we observed the compatibility of materials, such as fabric seats or interior paint, and we did not find significant issues. Since we conducted this study over a short period, further long-term research is necessary to investigate the material compatibility of the public buses.

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