Case Study Review: Ultraviolet Germicidal Irradiation in Transportation

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Due to disasters such as Covid-19 virus and other contagious disease, growing concern about the surface and air contamination in the often heavily-populated means of transportation, ranging from aircraft and trains to buses and subways, sparked a heated contestation to investigate measures to address this problem. As methods of contaminants removal such as antiseptic swaps and fumigation are time consuming, hazardous and environmentally-unwise, substitutional means of disinfection seems inevitable. Meanwhile, it should be taken to consideration that unlike large cruise ships, smaller vehicles such as cars and planes create extended opportunities for infectious exchanges due to the close quarters, shared breathing air, potentially extended periods of occupancy, and the limited amount of outside air that may be brought in, especially in cold climates.

There are several studies and experiments showing Ultraviolet Germicidal Irradiation (UVGI) systems as effective disinfection tools of not only surface contamination but also airborne pathogens. Different types of UVGI systems and equipment are currently available for air and surface disinfection applications which can be used in transportation; for instance, UVGI systems can be installed in the recirculation ducts of airplanes as well as being located at individual seats. Respiratory pathogens that have been identified onboard airlines mostly including Adenovirus, Chickenpox, Coronavirus, Influenza, Measles, Mumps, Mycobacterium tuberculosis, and SARS virus; can be significantly reduced using these systems. Meanwhile, by coupling UVGI system with proper MERV filter, superior performance can be

achieved; since filtration removes most of the microbes that tend to be resistant to UVGI, and vice-versa. Furthermore, UV applications for ships include in-duct UV systems to interdict recirculated pathogens and allergens such as Norwalk virus and influenza, and surface irradiation systems to control fomites. After-hours UV systems, can also be placed in hallways, bathrooms, and other locations where occupancy is intermittent. In the rest of this article, three case studies will be investigated.

Case Study 1

Ultraviolet Germicidal Irradiation for Transit Buses, 2009

The purpose of this project was to incorporate UVGI into the Houston transit bus air conditioning systems, carry out tests and evaluate the results. This study had two main objectives. First, to evaluate improvements of air quality and reduction of harmful pathogens within the bus, which effect passengers, drivers, and employees. Second, to identify and quantify maintenance costs saving associated with the air conditioning systems.

The project included testing and evaluation of UVGI Systems on 14 transit buses, in cooperation with the Houston Metropolitan Transit Authority (Houston Metro), who provided their buses for these tests. UVGI system consists of UV Lamps were developed with special transit filaments for long life 24 Volt DC operations and 24 Volt DC ballast (power supply). End caps on the UV Lamps were redesigned to withstand the vibration of a transit bus and special UV Lamp mounting brackets were developed incorporating vibration dampers for additional protection. The selection of buses for testing included 5 older buses that have had approximately 12 years of service, 4 midlife buses with approximately 8 years of service, and 5 new buses less than one year old. All UVGI System were installed without prior cleaning of the air conditioning system to test in a "worst case scenario". Furthermore, test

period was for a 6 months period, starting July 12, 2007, and ending December 12, 2007; which represents the hottest weather and the cooler operating conditions for Houston Metro's bus fleet.

The results of this study are summarized as follows:

- The tests conducted by Biological Consulting Services of North Florida, Inc. and Dr. James W. Kimbrough, Mycologist, University of Florida, showed an effective reduction of *95% to 99%* on mold, fungi, and bacteria on the buses tested. Testing showed a *99%* reduction in common viruses.

- The UVGI System does provide substantial maintenance cost savings, enough to provide a return on investment in about 18 months. Those savings were identified in evaporator maintenance, cleaning chemicals and disposal, air filter replacement, component replacement cost, and out of service costs. Using Houston Metropolitan Transit Authority costs, those savings per 100 buses per year are estimated at approximately $129,000.

Case Study 2

UV Disinfection in Moscow Metro Public Transport Systems, Sergey Kostyuchenko, Anna Khan, Sergey Volkov, Henk Giller, 2009

In this case stuudy the effects of UV disinfection on the internal surfaces of train carriages, escalator handrails, and the air in passageways and platforms of railway stations of Moscow Metro underground railway system is investigated. As a result, LIT Technologies and the Russian Research Institute of Railway Hygiene developed a series of straight and U-shaped LPHO “Amalgam” UV lamps, coated on the inside to restrict UV depreciation, tailored especially for Metro disinfection applications. Furthermore, a special trolley was developed to disinfect the air and surfaces in metro train carriages, incorporating two 170W U-shaped amalgam lamps and equipped with a timer, to shut off the system after disinfection. Another UV system, with two LIT U-shaped amalgam 170W lamps was also developed to disinfect the surfaces of escalator handrails automatically. Moreover, a re-circulator of type AR-UF-170P-2 (with two 170W lamps inside) is mounted in a passenger passage connecting two Moscow metro stations “Paveletskaya-Radial’naya” and “Paveletskaya-Koltsevaya”. One re-circulator of type AR-UF-170-2 with a capacity of 400 m^3/h is used for every 80 m^2 of the passages and platforms. The 1260 m^2 passage of the “Paveletskaya” metro station was equipped with 16 of these UV re-circulators.

The project result can be summarized as follows:

- By means of both laboratory and field tests, the feasibility of UV disinfection for the Moscow Metro system was proven. New generations of UV equipment, fitted with effective LPHO amalgam lamps, were developed for the occasion. The microbial air quality was improved. Replacing labor sensitive, hazardous and environmentally unfriendly disinfection methods, Moscow Metro was glad to embrace the new technology. Introduction of LIT UV systems will provide an extra and reliable barrier for infectious diseases in Moscow’s congested public transport system.

Recirculator AR-UF-170-2 mounted in the passage between “Paveletskaya-Radial’naya” and PaveletskayaKoltsevaya”

UV system for interior disinfection, with two U-shaped 170 W UV lamps

UV system mounted on a handrail return stretch at the “KitaiGorod metro station

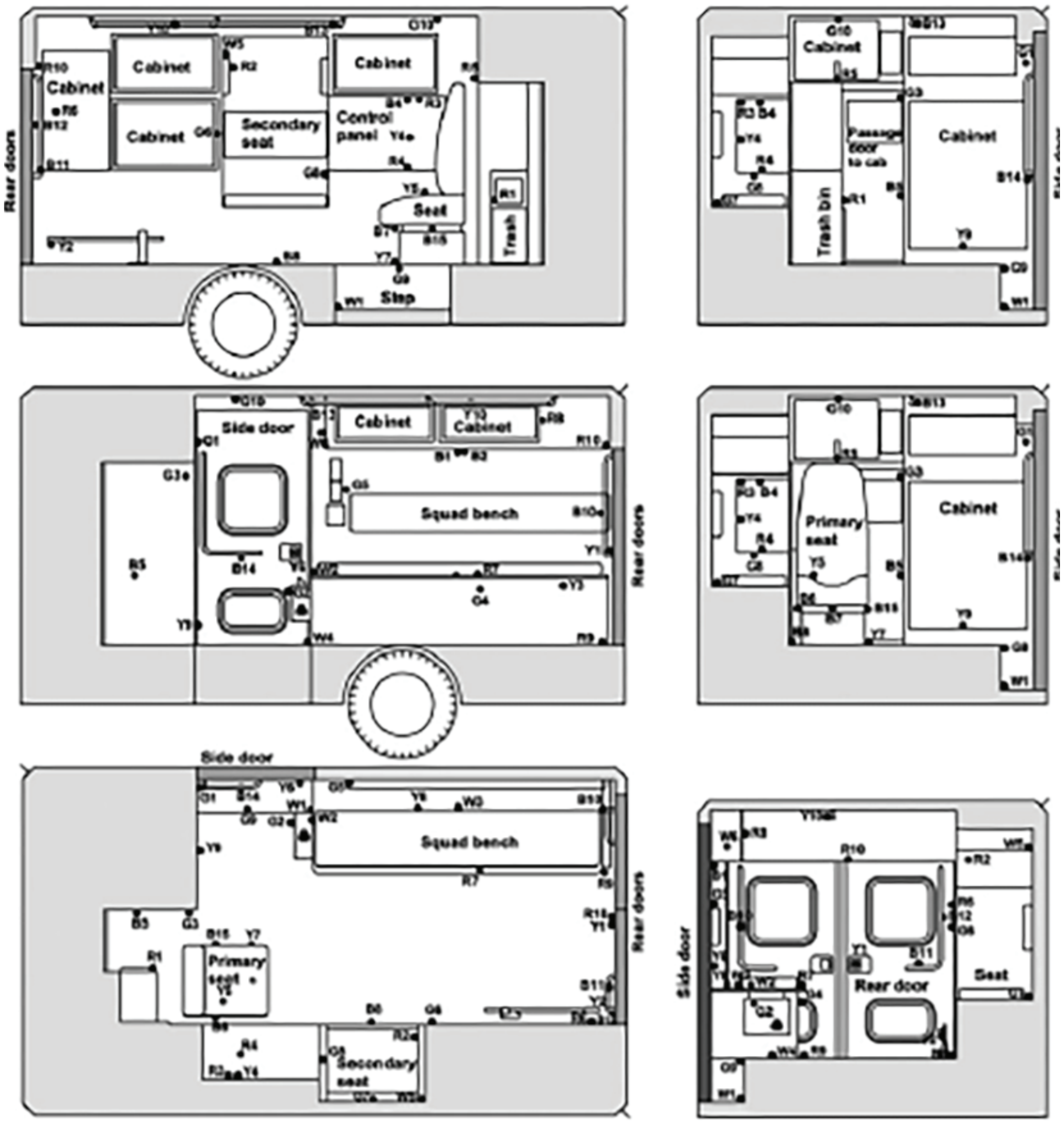
Case Study 3

Ambulance disinfection using Ultraviolet Germicidal Irradiation (UVGI): Effects of fixture location and surface reflectivity, William G. Lindsley, Tia L. McClelland, Dylan T. Neu, Stephen B. Martin Jr., Kenneth R. Mead, Robert E. Thewlis & John D. Noti, 2017

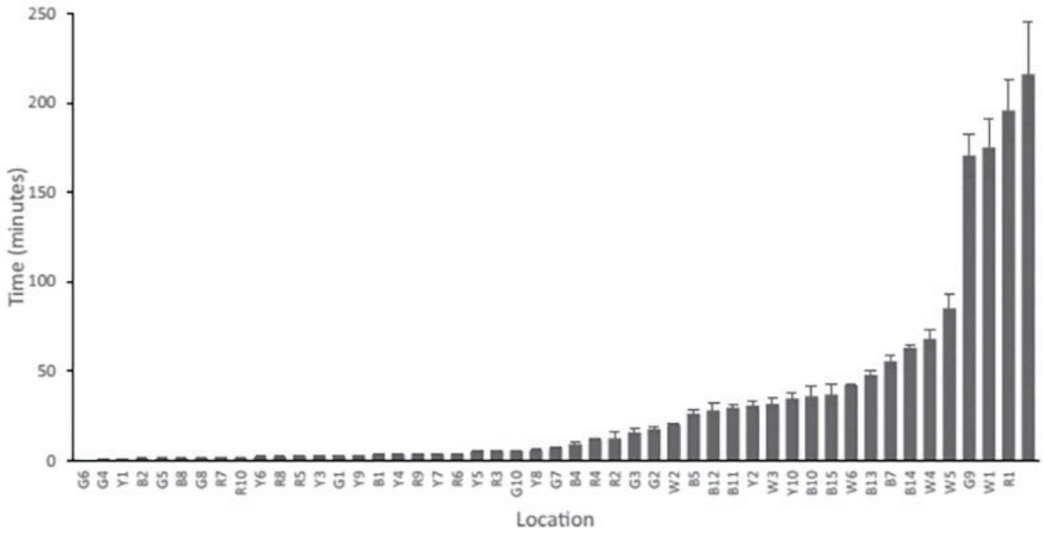
The objective of this study was to investigate the efficacy of a UVGI system in an ambulance patient compartment and to examine the impact of UVGI fixture position and the UV reflectivity of interior surfaces on the time required for disinfection. A UVGI fixture was placed in the front, middle, or back of an ambulance patient compartment, and the UV irradiance was measured at 49 locations. Aluminum sheets and UV-reflective paint were added to examine the effects of increasing surface reflectivity on disinfection time.

Disinfection tests were conducted using Bacillus subtilis spores as a surrogate for pathogens. The UVGI light fixture used in these experiments was custom-built. It consisted of ten UV-C lamps with a primary wavelength of 254 nm (TUV PL-L60 W/4P HO 1CT/25, Philips Lighting). Each lamp had a nominal wattage of 60Wand a UV wattage of 12.4W. The lamps were mounted vertically in two circles (one upper, one lower) around an 11.1cm diameter aluminum-covered post. The lamps were powered by five electronic ballasts (Pure VOLT IUV-2S60-M4-LD, Philips Lighting).

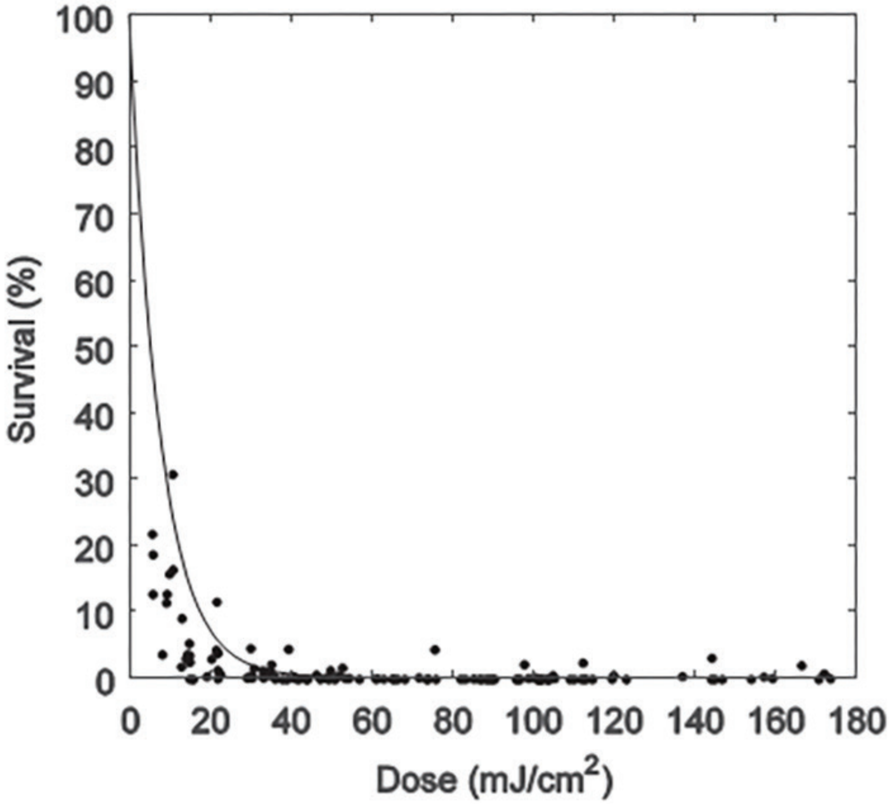
The light fixture was placed in three positions in the patient compartment for testing: Front, with the light 81cm from the left interior wall and 217cm forward of the rear doors of ambulance; Middle, with the light centered laterally between the interior walls and 132cm from the rear doors; and Back, with the light position centered laterally between the interior walls and 48cm from the rear doors.



Ambulance patient compartment showing the locations of the UVGI sensors



Surface disinfection time (exposure time required to inactivate 99.9% of Bacillus subtilis spores) at each location in the ambulance with the UVGI fixture in the middle position and with the interior surfaces in their original condition (no aluminum sheets or UV-reflective paint added). Each bar shows the average of three experiments. Error bars show the standard deviation.



Survival of Bacillus subtilis spores exposed to UVGI in the ambulance interior

The results of this study are summarized as follows:

UVGI systems are potentially a useful tool for reducing the likelihood of infectious disease transmission in ambulance patient compartments. However, when implementing a UVGI terminal disinfection system in ambulances, the following points must be kept in mind.

- The amount of UV irradiation delivered to different surface locations can be expected to vary tremendously. When evaluating a UVGI system, multiple locations should be tested.

- The time required to disinfect an ambulance compartment is governed by the exposure time needed for the least-irradiated surfaces.

- Covered and concealed locations, such as underneath seat cushions or behind cabinet doors, will not be disinfected by a UVGI system.

- The position of the UVGI fixture can have a substantial effect on the disinfection time.

- Moving the UVGI fixture to multiple locations during a disinfection cycle or using multiple fixtures can reduce the disinfection time.

- Increasing the UV reflectivity of interior surfaces can also reduce the disinfection time.

- Before putting it into service, any ambulance UVGI system should be thoroughly tested with the actual ambulance configuration for which it is to be used, and should be periodically re-tested to verify that the UVGI system's performance has not changed over time.