An Automatic Disinfection System for Passenger Luggage at Airports and Train/Bus Stations

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Abstract

Many researchers are working on multiple aspects of the COVID-19 pandemic including disease detection, treatment, and vaccine development. It is expected that there will be a large increase in passenger traffic at airports and railway stations and other public places. This paper proposes one solution to reduce the transmission of the disease through fomites such as passenger luggage and packages at bus/train stations and airports in the country. A tunnel system similar to the X-ray machines used for passenger luggage at airports has been proposed for disinfection of fomites. The system consists of eight 36 W T8 TUV bulbs illuminating each square meter area of the fomites on a conveyor belt for 10 s. For the standard airline luggage dimensions, 24 such bulbs will be distributed evenly on all four sides of the tunnel. The entry and exit points on the conveyor are shielded from the UV-C light leakage by placing thin plastic (such as acrylic) curtains. An optional non-foaming soap solution spray system may be used as an additional disinfection step. The toxic sodium hypochlorite solutions are not used in this design. Non-foaming soap solutions which are very effective against coronavirus and are non-toxic and biodegradable may be used as an optional disinfectant. It is to be noted that while the disinfection systems are designed to effectively mitigate the threat of coronavirus on the passenger fomite surfaces, these are purely based on theoretical calculations and have not been tested with actual viral particles. However, considering the time-sensitive emergency with COVID-19 pandemic, these systems will be very useful even without rigorous campaign of testing.

Keywords Continuous disinfection system · Passenger luggage · UV-C · COVID-19

Introduction

It has been noted in several studies that the COVID-19 viral particles can stay viable on inanimate surfaces for up to 3 days (Doremalen et al. 2020). As the current lockdown conditions are relaxed, there is a danger of second wave of infections due to inevitable increase in the movement of people. While considerable attention has been paid to social distancing, wearing facial masks to reduce the probability of infection transmission, there is a critical need to reduce the chances of infection spread through fomites such as passenger luggage and packages at the airports and train stations. The paper will describe a technology for continuous disinfection system for passengers' fomites such as luggage and packages at high-volume footfall locations such as bus/train

stations and airports. The technology consists of a UV-C-based illumination system inside an enclosed tunnel with an optional spraying system to dispense a variety of disinfectant solutions that are suitable for passenger bags and other luggage, individual packages.

The chief goal of the proposed fomite disinfection system is to minimize the spread of Wuhan corona virus (COVID-19) by disinfecting the surfaces of the luggage. The disinfection systems are very common and use one of the many of the disinfection strategies. The summary of the key disinfection agents and their utility for the current design are summarized in Table 1. Based on these characteristics, ultraviolet-C (UV-C 100–280 nm) radiation is the preferred disinfection agent. Non-foaming soap solutions are also very effective against coronavirus which has a lipid membrane (Gibbens 2020). The UV-C based disinfection technology is commonplace and is applied widely to treat surfaces in hospitals, water disinfection systems, among many applications (Philips 2020a; ICROCHEM laboratory 2020). The UV-C based disinfection works by damaging the DNA/RNA of

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Table 1 Disinfectants and their suitability

Disinfectant	Strengths	Weakness	Compatibility with materials
Natural sun light (mostly UV A and UV B)	Not very effective against viruses Does not use any chemicals	Requires long time of exposure (~ 15–30 min)	Compatible with all materials
UV-C (254 nm)	Very effective against bacteria and viruses Can be deployed at scale using the existing UV light sources that are used in the wastewater, swimming pools and medical facilities	Causes severe sunburns and is not recommended for direct human exposure at high dosages needed to inactivate the virii	Excellent: brass, stainless steel Very good: poly vinyl chloride (PVC) Good: high/low density poly ethylene (HDPE/LDPE)
Sod. Hypochlorite (bleach)	Most effective and commonly available Requires very short contact times (~ 30 s) Cheap and easily scalable	Vapors cause irritation to mucous membranes if used repeatedly and at high concentrations	Very good: HDPE, LDPE, brass Excellent: PVC, stainless steel
Liquid soap	Most effective against coronavirus Non-toxic Easily available and scalable	Leaves a residue that requires subsequent washing with water Expensive compared to sod. Hypochlorite	Excellent: HDPE, LDPE, PVC, brass and stainless steel
Ethanol solutions (> 70%)	Very effective against viruses Is a very good alternative to water-based disinfectants	Could cause drying of skin and irritation if used repeatedly Vapors pose fire hazard Expensive compared to other alternatives	Very Good: HDPE, LDPE, brass and stainless steel Fair: PVC
Isopropyl alcohol (> 70%)	Very effective against viruses Is a very good alternative to water-based disinfectants	Could cause drying of skin and irritation if used repeatedly Vapors pose fire hazard Expensive compared to other alternatives	Very good: HDPE, LDPE, brass and stainless steel Good: PVC

bacteria and viruses preventing their replication (Poepping et al. 2014; Xiaong and Hu 2013; Beck et al. 2015). Several commercial products use UV-C based disinfection technologies. For example, almost all domestic reverse osmosis systems have a UV module for an additional level of disinfection, and many of the operation theaters and laboratories use UV-C-based surface sterilization strategies.

There are two challenges with the existing commercial products as applied to the fomite disinfection:

1. Most of the designs available commercially for the disinfection of hospital rooms and other living spaces are open systems and require the movement of people out of the room when the UV-C disinfection process is carried out. This presents a practical problem when applied to the disinfection of fomites and reduces the overall effectiveness of the systems as they need to be operated with continuous supervision.
2. A second challenge with the existing systems is that most of the systems are designed outside India and are generally expensive when imported. In a price-sensitive market such as India and many other developing countries, the economic effectiveness of the strategy is essential. Additionally, it is desirable to have a system that has a wide range of uses even after addressing the immediate

need for the COVID-19 pandemic. There are very few professional open-source designs of any disinfection device that uses UV-C radiation for living spaces.

This proposed system addresses these challenges comprehensively. The proposed system is unobtrusive during its operation and can be operated even in the presence of people in the living spaces. The system design is very modular, has low capital and operating costs.

Fomite disinfection system is modeled on a tunnel-type architecture commonly seen in airports for screening passenger baggage (Fig. 1). The use of UV-C radiation for passenger luggage disinfection can be augmented with a spray system with non-foaming soap solution towards the end of the tunnel. The entry/exit of the tunnels is covered with UV-absorbing flexible plastic curtains. The technology can also be adopted by organizations such as India Posts, Flipkart, and Amazon that handle high volumes of individual packages at their distribution centers. Particular attention was paid to the use off-the-shelf components that are widely available in the market and are produced in India. The estimated timeline for the first prototype is 1 week after the delivery of the components (estimated to be one additional week). The scaleup and mass production can be achieved within 1 month.

Fig. 1 Passenger luggage disinfection tunnel

Design Criteria

The following mandatory and preferable design criteria were adopted for the design. Three levels of control system automation have been considered to enable users to deploy the systems with various levels of sophistication.

Mandatory Design Criteria

- Easy to use with no supervision.
- Easy to maintain.
- Easy to build and maintain using local materials.
- Three log reduction in the microbial loads on fomite surfaces.

Preferable Design Criteria

- Indigenous commodity scale materials used in other industries.
- Ability to handle multiple levels of automation.
- Can be repurposed for other uses, once the COVID-19 crisis passes.

Design Calculations and Rationale for Design Choices

1. Disinfectant dosage

Assumption: The dimensions of airline check-in luggage ($0.9 \text{ m} \times 0.75 \text{ m} \times 0.43 \text{ m}$) was used to estimate the total surface area of a generic passenger luggage piece as 2.8 m^2 .

- UV-C radiation dosage for inanimate surfaces: The inanimate surfaces will be disinfected with UV-C radia-

tion (100–280 nm). The disinfection action of the UV-C was modeled using the following equation for microbial inactivation.

$$\ln\left(\frac{N_t}{N_0}\right) = -k.E_{\text{eff}}t = -k.H_{\text{eff}}, \quad (1)$$

where N_0, N_t is the viral load at times zero and t , respectively, k is the microorganism-dependent rate constant (dimensionless constant), E_{eff} is the effective irradiance (W/m^2), t is the time (s), H_{eff} is the effective dose (J/m^2) ($H_{\text{eff}} = E_{\text{eff}}.t$). The values for rate constant for influenza virus (Philips Lighting 2006), $k = 0.064$, which implies an effective dose, $H_{\text{eff}} = 36 \text{ J}/\text{m}^2$ for 90% reduction (i.e., $\left(\frac{N_t}{N_0}\right) = 0.1$)

2. Number of bulbs required

$$E_{\text{eff}} = \frac{-\ln(N_t/N_0)}{k.t} = \frac{-\ln(1/1000)}{0.064 * 10} = 10.79 \text{ W}/\text{m}^2, \quad (2)$$

$$\text{Number of bulbs} = \frac{E_{\text{eff}}}{\text{TUV}} = \frac{10.79}{1.45} = 7.44 \sim 8 \text{ bulbs}/\text{m}^2, \quad (3)$$

The irradiance values for TUV 36 W T8 bulb are $1.45 \text{ W}/\text{m}^2$ as per the manufacturer's data (Philips Lighting 2020b). Assuming a treatment time of 10 s, the number of T8 bulbs required for a three-log reduction in the viral load is estimated to be eight TUV 36 W T8 bulbs/ m^2 . Since the surface area of a generic luggage piece is 2.8 m^2 , total number of bulbs will be 22.4~24 bulbs. These bulbs will be equally distributed on all four sides of the tunnel.

- Additional (optional) disinfection of inanimate surfaces: A $50 \mu\text{m}$ layer of disinfectant layer was assumed for disinfection. Based on these assumptions, a dosage of $138 \text{ mL}/\text{luggage}$ was estimated.

Conclusions

Designs for the passenger fomite disinfection were presented. A tunnel system similar to the X-ray machines used for passenger luggage at airports has been proposed for fomite disinfection. The system consists of eight 36 W T8 TUV bulbs illuminating each square meter area of the fomites on a conveyor belt for 10 s. For a standard airline luggage dimensions, 24 such bulbs will be distributed evenly on all four sides of the tunnel. The entry and exit points on the conveyor are shielded from the UV-C light leakage by placing plastic (such as acrylic) curtains. This design is purely based on theoretical calculations and the experimental validation of the designs will be conducted in future.

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Compliance with ethical standards

Conflict of interest The author does not declare any conflict of interest/competing interests.

Ethical approval All data and any information about the designs are freely available without any claims for intellectual property. Mention of brand or firm names does not constitute an endorsement by Indian Institute of Technology Indore above others of similar nature not mentioned. GM conceived the need, designed the system and prototypes, and wrote the paper.

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