Reducing Indoor Infections: The Economic Potential

A Cost-Benefit Analysis of Far-UVC Lamps

analytical. quantitative. tech.

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Content

Reducing Indoor Infections: The Economic Potential, September 2024

01. Introduction

Indoor environments are particularly conducive to the transmission of airborne pathogens, contributing to the propagation of infectious diseases. Since most people spend the majority of their time indoors[1], technologies like air filtration, ventilation, and UV radiation are essential for managing indoor air quality and preventing transmission of airborne pathogens.[2] Among these, germicidal ultraviolet-C (UVC) light is a promising approach for real-time infection mitigation.

Far-UVC, a specific wavelength within the UVC spectrum, can enhance indoor air quality by complementing ventilation and air filtration.[3] While ventilation exchanges indoor and outdoor air, and filtration removes particle matter, far-UVC disinfects contaminated air and surfaces by inactivating viruses and bacteria. The increasing likelihood of pandemics[4], the COVID-19-pandemic and seasonal epidemics of respiratory infections underscore the importance of such technologies to mitigate and prevent the risk of transmission in indoor settings like offices, transportation, bars, and restaurants.

The COVID-19-pandemic highlighted the limitations of non-pharmaceutical interventions, such as masks and disinfectants, due to issues like human error and societal acceptance. Far-UVC technology can offer a more reliable and less intrusive solution for mitigating indoor pathogen transmission. As part of a comprehensive approach, far-UVC effectively complements other public health measures in prevention, detection, and response efforts to disease outbreaks. This study addresses the need to also understand the economic implications of far-UVC installations in indoor settings.

Far-UVC light: characteristics

- Far-UVC light refers to wavelengths between 200 and 235 nm, making it invisible to the human eye.

- Far-UVC radiation is effective at inactivating airborne viruses like influenza and SARS-CoV-2 by damaging their nucleic acids and proteins.[5] Far-UVC also shows promise for reducing transmission of antibiotic-resistant bacteria.[6] In contrast to regular UVC light and depending on the dose, it does no or less harm to human tissue since it is almost fully absorbed by the first non-living layers (stratum corneum) of human skin and the tear layer of the eye.[7]

1 N. P. Saravanan, Reason, 2004 [LINK]; M. Simoni et al., Eur. Respir. J., 2003 [LINK]

2 R. Moreno et al., Publications Office of the European Union, 2024 [LINK]

3 "Clean air in the context of pathogen circulation" issued by the Swiss Scientific Advisory Panel COVID-19, 2023 [LINK]

4 M. Mahon et al., Nature, 2024 [LINK]

5 D. Welch et al., Sci. Rep., 2017 [LINK] ; G. Buonanno et al., Environ. Int., 2020 [LINK]; K. Naito et al., Sci. Rep., 2022 [LINK]; K. R. Wigginton et al., Environ. Sci. Technol., 2012 [LINK]

6 S. Rattanakul and K. Oguma, Water Res., 2018 [LINK]; M. Raeiszadeh and F. Taghipour, Chem. Eng. J., 2020 [LINK] ; J. Glaab et al., Sci.Rep., 2021 [LINK]

7 M. Buonanno et al., Sci Rep., 2020 [LINK]; H. Claus, Photochem. Photobiol., 2021 [LINK]; J. L. Cadnum et al., Pathog Immun, 2020 [LINK]; R. P. Hickerson et al., Br J Dermatol, 2021 [LINK]; H. Kitagawa et al., Am. J. Infect. Control, 2021 [LINK], L. Finlayson et al., Photochem. Photobiol., 2021 [LINK]

Ensuring Safety: Challenges and Considerations

- The effects on the skin microbiome and potential impacts on allergies and autoimmunity from far-UVC exposure remain unexplored and require further research.[8]

- Far-UVC light can interact with atmospheric molecules like ozone[9] and volatile organic compounds[10], leading to the formation of harmful radicals indoors.[11] Hence, filtration and ventilation are recommended when using far-UVC. Initial data suggests that minimal ventilation is required to mitigate the effects of far-UVC on indoor particulate matter[12], but the precise level of ventilation required to mitigate all risks is currently unclear.

Regulatory Status Quo

- The International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommends an exposure dosage limit for 222 nm far-UVC light of 240 J/m^2 (24 mJ/cm^2), with an exposure time limit of 8 hours per day and 40 hours per week. This forms the basis of the European standards.[13]

- Directive 2008/50/EC mandates ozone concentration limits of less than 120 $\mu g/m^3$ over an 8-hour average period. Monitoring of ozone precursors like nitrogen oxides and volatile organic compounds is required to ensure air quality compliance.

Adherence to the ICNIRP limits for far-UVC usage in combination with ventilation appears reasonably safe based on current understanding.

Pathogen inactivation with far-UVC light

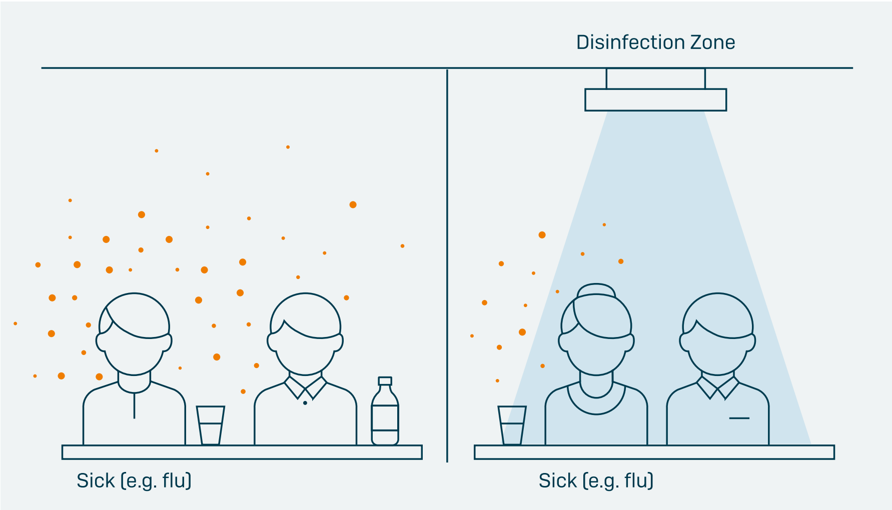

Figure 1: Schematic depiction of far-UVC light for pathogen inactivation in an indoor setting

8 E. Maverakis et al., J. Autoimmun., 2010 [LINK]; J. D'Orazio et al., Int. J. Mol. Sci., 2013 [LINK]; V. Patra et al., Nutrients, 2020 [LINK];

9 Far-UVC light can generate O3 from O2 via photochemical reactions.

10 Like limonene which is found as an additive in many cleaning products.

11 F. Graeffe et al., Environ. Sci. Technol. Lett., 2023 [LINK]; M. Link et al, Environ. Sci. Technol. Lett., 2023 [LINK]; Z. Peng et al., Environ. Sci. Technol. Lett., 2023 [LINK]

12 F. Narouei et al., ChemRxiv, 2024 [LINK]

13 "Fact sheet on UV-C disinfection lamps for home use" issued by Swiss Federal Office of Public Health, 2021 [LINK]

02. Methods

In this cost-benefit study, we analyze the incurred costs of implementing far-UVC devices in several indoor settings and the benefits that could be achieved by this intervention.

- The study uses the CERN Airborne Model for Indoor Risk Assessment (CAiMIRA) to model infection risk reduction by far-UVC lamps in specific settings, considering room size, occupancy, and ventilation rates. The chosen settings were different restaurants, offices as well as waiting rooms in hospitals and doctors' offices. Our selection was based on the undesirability or impracticality of mask usage.

- The efficacy of the lamps was translated into equivalent air changes per hour (eACH) based on empirical data presented by Eadie et al.[14] Using CAiMIRA, we determined the difference in infections with and without far-UVC lamps, computing the number of avoided infections in each setting per scenario.

- We distinguished between three potential scenarios including a normal winter with mainly influenza and common colds lasting 22 weeks, a COVID-19-like pandemic with a wave lasting 4 weeks, and a more severe pandemic with a wave duration of 8 weeks.

- The study evaluates the monetary benefits of avoiding infections, categorizing them into healthcare cost savings, national economic productivity gains, and monetized health benefits through avoided quality-adjusted life years (QALY) lost per infection.

- Costs include initial purchase and installation, maintenance, and energy expenditure.

03. Key Findings

- In our study, the benefits from the deployment of far-UVC lamps in restaurants, waiting rooms, and offices strongly outweigh the costs in a normal winter and both considered outbreak scenarios, see Table 1.

Benefits / cost ratio	Restaurant	Waiting room	Office
Normal winter	290	100	30
COVID-19-like pandemic wave	430	170	65
Severe pandemic wave	20'500	6'700	2'300

Table 1: Benefits to costs ratio for installing far-UVC lamps in the indicated settings. Benefits are summed over all three types and divided by the annual cost of the installed lamps.

14 E. Eadie et al., Sci. Rep., 2022 [LINK]

■ For the example of Switzerland, one franc invested in indoor air quality yields a benefit of up to 290 francs per winter season.

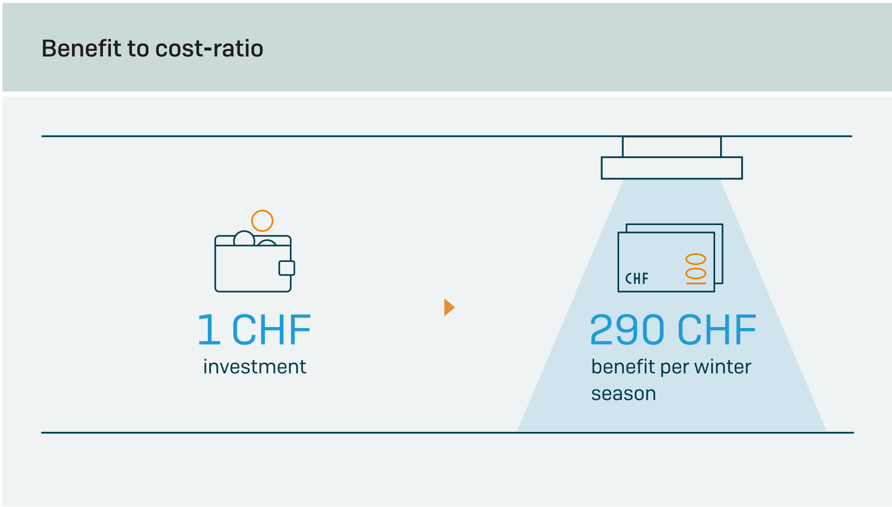

Figure 2: Key finding that far-UVC has a benefit to cost-ratio of up to 290 in a normal winter

■ Introducing far-UVC in all restaurants, waiting rooms, and offices in Switzerland can result in CHF 1'400 net benefits per person and avoid 2.4 sick days per person each year during a normal winter. A reduction of 2.4 days equates to a decrease of approx. 40% in health-related absences or 25% in overall work absences. In total, roughly 21 million sick days could be avoided in a normal winter.

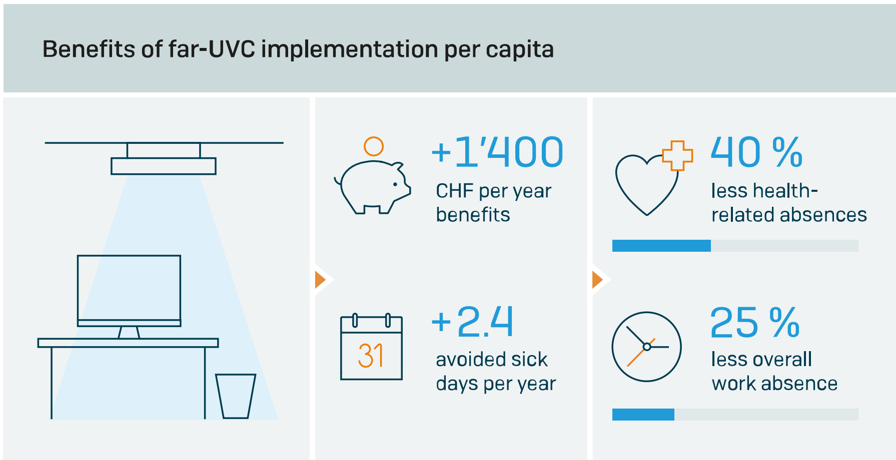

Figure 3: Key finding of net benefits per capita in a normal winter for far-UVC implementation throughout Switzerland

■ A large office space (approx. 100m²) in Switzerland equipped with far-UVC achieves benefits of up to CHF 3.1 million in a severe pandemic wave and around CHF 40'000 in a normal winter.

■ During winter, far-UVC lamps in a single busy pub can prevent around CHF 600'000 in losses related to the health care costs, work absences, and ill health.

■ In a COVID-19-like pandemic wave, the estimated net benefits would be approx. CHF 19 billion for all settings in Switzerland together. In an even more severe pandemic scenario, net benefits would increase to CHF 860 billion across all settings.

- Our results indicate that far-UVC lamps are a cost-saving technology for the Swiss society both in an average winter and a more severe pandemic situation like COVID-19 or other potentially emerging pathogens.

- In the considered scenarios, far-UVC lamps were at least as efficient as HEPA filters and comparable in cost. The lower energy consumption (11 W vs. 60W) as well as the absence of noise from filtration are in favor of far-UVC lamps.

21 MIO

sick days avoided in a normal winter

40 K

CHF benefits in a large office in a normal winter season

19 BN

CHF net benefits in Switzerland in a Covid-like pandemic

04. Policy Recommendations

Given the cost efficiency of far-UVC light, the following recommendations are made to aid public health and pandemic preparedness. However, the implications of implementation require further analysis.

Private Sector

- Enhance infection protection through monitoring and air quality improvement

Regular air quality measurements and installing systems to manage indoor air are recommended for the private sector. This helps businesses ensure safer environments and promote well-being for customers and employees. Far-UVC can strongly contribute to the goal of decreasing disease transmission if implemented within the current European guidelines and in combination with ventilation.

Public Institutions

- Conduct real-world and feasibility studies of far-UVC

Real-world studies are necessary to assess the practical applicability, long-term safety and efficiency of far-UVC light. Research could be commissioned by public health offices or national research programs.

- Monitor indoor air quality and ensure transparency

Comprehensive data on indoor air quality is lacking in countries like Germany and Switzerland. Surveys and public reporting can identify problem areas and define targeted measures for improvement.

- Anchor the state's position as a role model

By setting air quality standards for public buildings, the government promotes public health and encourages other sectors.

- Create incentives to improve indoor air quality

Financial incentives can play a significant role in encouraging implementation of public health measures.

- Equip critical infrastructure with far-UVC technology for pandemic response

Facilities critical during pandemics, such as hospitals and government buildings, should consider long-term far-UVC installations as part of their pandemic response plans.

Conclusion

Far-UVC technology presents a cost-effective method for improving indoor air quality and reducing health care costs associated with infectious diseases. Its integration into public health and private sector can enhance community resilience and preparedness for future pandemics. Further research is needed to optimize its use and ensure safety.

Appendix

Pour Demain is a European think tank working towards a safe and positive future for our children, grandchildren and their descendants. Biosecurity and pandemic preparedness are among its focus areas. Pour Demain is committed to effective and science-based policy.

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For further details on our methodology, more in-depth results, context and limitations of the study, a longer version can be requested at: info@pourdemain.ngo