UNIVERSITY OF LEEDS

Microbiology and Infection Transmission:

microbiology, pathways of infection transmission in hospitals, established and emerging pathogens

HumanIC CBT1

26th Feb 2025

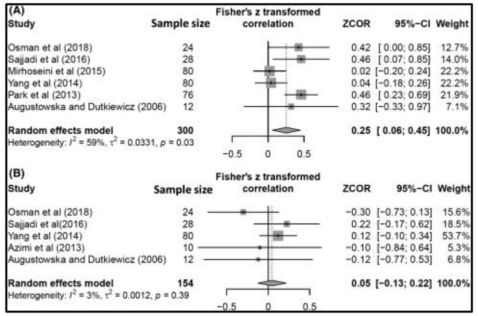
Dr Waseem Hiwar

HumanIC project has received funding from the European Union’s Horizon Europe research and innovation program under the Marie Sklodowska-Curie (HORIZON-MSCA-2022-DN-01, project no 101119726

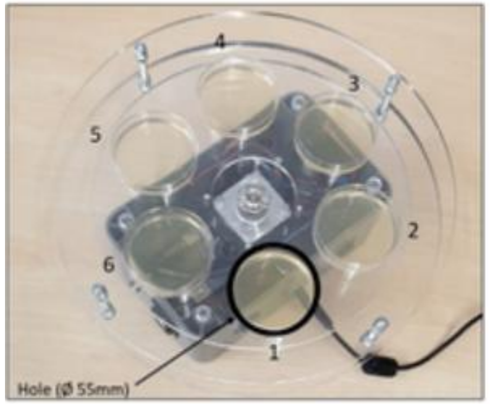
Funded by the European Union

Dr Waseem Hiwar

M.Sc. Microbiology

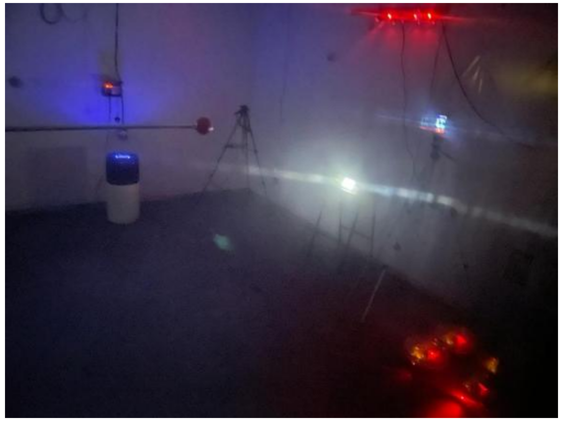


Hiwar et al. (2021), *Indoor Air, 31(5),* 1308-1322.



Hiwar et al. (2022), *Indoor Air, 32(11),* e13161.

Hiwar et al. (2025), *COBEE 2025, Eindhoven*.



Eadie et al. (2022), *Scientific Reports, 12(1),* 4373.
Hiwar et al. (2025), Building and Environment, 112734.

The PROTECT COVID-19 National Core Study on Transmission and Environment

Transport Risk Assessment for COVID Knowledge" (TRACK)

HumanIC project has received funding from the European Union's Horizon Europe research and innovation program under the Marie Sklodowska-Curie (HORIZON-MSCA-2022-DN-01, project no 101119726

Funded by the European Union

Session Objectives

- To understand the role of **microbiology** in hospital environments.
- To identify key pathways of **pathogen transmission** in healthcare settings.
- To explore **established and emerging pathogens** in hospitals.
- To examine **infection control strategies**

HumanIC project has received funding from the European Union's Horizon Europe research and innovation program under the Marie Sklodowska-Curie (HORIZON-MSCA-2022-DN-01, project no 101119726

Funded by the European Union

Obj.1/Type of Microorganisms

Bacteria are single-celled prokaryotic microorganisms found in all environments. Bacteria come in various shapes, including cocci (spherical), bacilli (rod-shaped), and spirilla (spiral-shaped), typically ranging from **0.1 to 10 µm** in size.

Bacterial Group	Main Pathogen	Primary Infections	Common Sources in Hospitals
Gram-Positive Bacteria	*Staphylococcus aureus (MRSA)*	Bloodstream infections, pneumonia, surgical site infections	**Contaminated hands**, medical devices, catheters
	Clostridioides difficile	Severe diarrhea, colitis	**Contaminated hospital surfaces**, fecal-oral transmission
	Enterococcus spp. (VRE)	UTIs, bloodstream infections, endocarditis	Catheters, **contaminated surfaces**, healthcare workers' hands
Gram-Negative Bacteria	*Escherichia coli (ESBL-producing E. coli)*	UTIs, bloodstream infections, sepsis	Urinary catheters, **poor hygiene**
	Klebsiella pneumoniae (CRE)	Pneumonia, bloodstream infections, UTIs	Hospital water sources, IV catheters
	Pseudomonas aeruginosa	Ventilator-associated pneumonia (VAP), wound infections, sepsis	Biofilms in medical equipment, humidifiers, water systems
Mycobacteria	*Mycobacterium tuberculosis (TB)*	Pulmonary TB, disseminated TB	**Airborne droplets**, infected patients, **poor ventilation**

Funded by the European Union

Type of Microorganisms

Fungi are eukaryotic organisms and exist in diverse environments. While most fungi are harmless or beneficial, a few cause human diseases, particularly skin infections. They typically range in size from **2 to 10 µm** and reproduce through spores or budding.

Fungal Group	Main Pathogen	Major Disease	High-Risk Patients	Common Sources in Hospitals
Moulds (Multicellular Filamentous)	*Aspergillus spp.*	Pulmonary/Invasive Aspergillosis	Immunocompromised (Cancer, HIV, Transplant)	Ventilation systems, damp walls, **air ducts**
Macroscopic Filamentous Fungi	*Mucorales (Zygomycetes)*	Mucormycosis (sinuses, lungs, skin)	Diabetics, transplant recipients, ICU patients	Dust, **humid hospital areas**
Yeasts (Single-Celled)	*Candida spp.*	Candidemia, Thrush, UTI, Invasive Candidiasis	ICU patients, catheter users, antibiotic-treated patients	IV catheters, urinary catheters, **ventilators**, healthcare workers' **hands**

HumanIC

Funded by the European Union

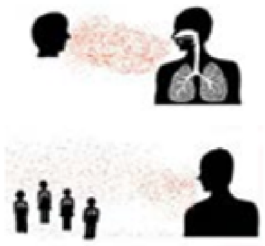
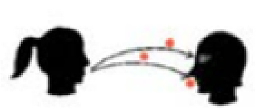
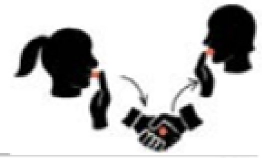
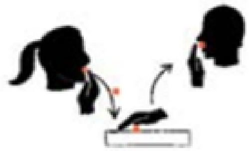
Type of Microorganisms

Viruses require a host cell to replicate. They consist of genetic material (DNA or RNA) enclosed in a protein coat (capsid), sometimes with a lipid envelope. They are much smaller than bacteria, typically ranging from **5 to 300 μm** in size.

Viral Group	Main Pathogen	Primary Infections	Common Sources in Hospitals
RNA Viruses	Influenza virus	Respiratory infections, pneumonia	Airborne droplets, contaminated surfaces, close contact
	SARS-CoV-2 (COVID-19)	Severe respiratory illness, pneumonia, multi-organ complications	**Airborne droplets**, close contact, contaminated surfaces
	Norovirus	Gastroenteritis, severe diarrhea	Contaminated food, surfaces, person-to-person
DNA Viruses	Herpes simplex virus (HSV-1, HSV-2)	Neonatal herpes, encephalitis	Direct contact, contaminated medical equipment
	Hepatitis B Virus (HBV)	Chronic liver disease, hepatocellular carcinoma	Bloodborne transmission, needlestick injuries, contaminated medical tools

Funded by the European Union

Obj. 2/Pathogen Transmission Routes

Mode of Transmission	Typical Distance from Source	Route of Transfer to Another Human	Respiratory Tract Entry Mechanism	Respiratory Tract Entry Portal	
Airborne Transmission /Inhalation	Any distance	Through the air (suspended or moving via airflow)	Inhalation	Anywhere along respiratory tract	
Direct Deposition	Short	Through the air (semi-ballistic trajectory)	Deposition on mucosa	Mouth, nose, or eyes	
Direct Contact	Short	Not through the air	Direct transfer (via touch)	Mouth, nose, or eyes	
Indirect Contact	Any distance	Not through the air (via intermediate object)	Indirect transfer (via contaminated object)	Mouth, nose, or eyes	

Funded by
the European Union

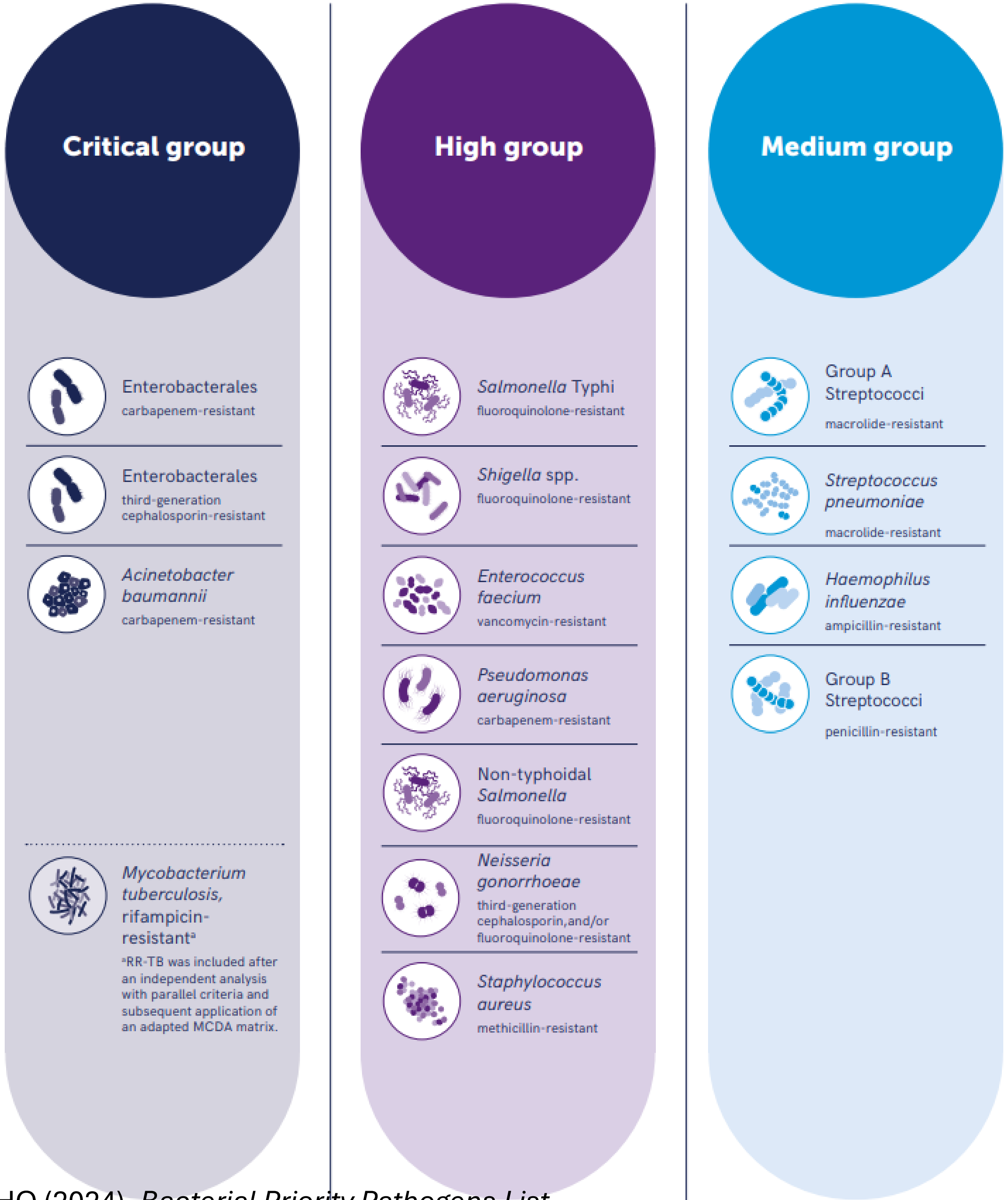
Infection Transmission Routes

Mode of Transmission	Typical Distance	Route of Transfer	Entry Mechanism	Entry Portal	Common Examples
Airborne Transmission/Inhalation	Any distance	Through the air (suspended in aerosols or moving via airflow)	Inhalation	Anywhere along respiratory tract	Tuberculosis, Measles, COVID-19 (Airborne route)
Droplet Transmission	Short	Through the air (large droplets expelled by coughing, sneezing, or talking)	Deposition on mucosa	Mouth, nose, or eyes	Influenza, Pertussis, COVID-19 (Droplet route)
Direct Contact	Short	Not through the air, direct skin-to-skin or mucosal contact	Direct transfer (via touch)	Mouth, nose, or skin	MRSA, Scabies, Clostridioides difficile (hand-to-hand contact)
Indirect Contact	Any distance	Not through the air, but via contaminated surfaces or objects	Indirect transfer (via contaminated object)	Mouth, nose, or eyes	Fomites, Contaminated medical devices, Norovirus outbreaks
Fecal-Oral Transmission	Variable	Ingestion of contaminated food, water, or hands touching infected feces	Ingestion	Gastrointestinal tract	Hepatitis A, Cholera, Rotavirus, Giardia
Vector-Borne Transmission	Variable	Via insect or animal bite from infected vectors (mosquitoes, ticks)	Vector-mediated inoculation (bite or penetration)	Skin, bloodstream	Malaria, Dengue, Lyme disease, West Nile virus

HumanIC

Funded by
the European Union

Fig 4. WHO Bacterial Priority Pathogens List, 2024



WHO (2024), *Bacterial Priority Pathogens List*.

Funded by the European Union

Summary of Epidemiological Information on Proposed Priority Pathogens

Family	Pathogen	Vector/Reservoir	Mode of Transmission	ent of Person-to-Person Transmis	Spread
Arenaviridae	Mammarenavirus lassaense	Mastomys rodents	Contact with infected rodents, person-to-person	Sufficient to cause outbreaks	Africa
Bacteria	Vibrio Cholerae (sero 01)	Aquatic environment, human hosts	Fecal-oral transmission, contaminated water sources	Some	South Asia
Bacteria	Klebsiella Pneumoniae	Humans, environmental reservoirs	Nosocomial transmission, person-to-person spread	Some	Reported worldwide
Bacteria	Yersinia Pestis (Plague)	Rodents, fleas	Flea-borne transmission, person-to-person spread	Some	Asia, Africa, Americas
Bacteria	Shigella Dysenteriae 1	Humans	Fecal-oral transmission, contaminated food/water	Sufficient to cause outbreaks	Primarily in developing countries, potential for global spre
Bacteria	Salmonella Enterica (various non-typhoidal)	Animals, environment, humans	Food-borne transmission, person-to-person spread	Sufficient to cause outbreaks	Reported worldwide
Hantaviridae	Orthohantavirus Sin Nombre	Deer mice	Inhalation of virus from rodent excreta	Little or none	Primarily confined to endemic regions in Asia
Hantaviridae	Orthohantavirus Seoul	Rats	Inhalation of virus from rodent excreta	Little or none	Primarily confined to North America
Hantaviridae	Orthohantavirus Dobrava	Ticks, rodents	Tick-borne transmission, contact with infected animals	Some	Primarily confined to endemic regions in Asia, Europe
Phenuiviridae	Bandavirus dabieense	Ticks, small mammals	Tick-borne transmission, contact with infected rodents	Some	Outbreaks in parts of Asia
Coronaviridae	Sub genus Sarbecovirus	Bats, humans	Respiratory transmission	Sufficient to cause outbreaks	Global, already caused a PHEIC
Coronaviridae	Sub genus Sarbecovirus	Bats, humans	Respiratory transmission	Sufficient to cause outbreaks	Global
Flaviviridae	Orthoflavivirus usutuvirus	Mosquitoes	Mosquito-borne transmission	Little or none	In parts of Africa and South America
Filoviridae	Orthomarburgvirus marburgense	Fruit bats, potential animal reservoir	Contact with infected bodily fluids	Sufficient to cause outbreaks	Primarily in Central and East Africa
Filoviridae	Orthobolavirus zaireense	Fruit bats, potential animal reservoir	Contact with infected bodily fluids	Sufficient to cause outbreaks	Primarily in Central and East Africa
Flaviviridae	Orthoflavivirus flavivirus	Mosquitoes, non-human primates	Mosquito-borne transmission	Little or none	Widespread in tropical and subtropical regions
Flaviviridae	Orthoflavivirus dengue1	Mosquitoes	Mosquito-borne transmission	Little or none	Outbreaks in the Americas, Africa, Asia, and the Pacific
Flaviviridae	Orthoflavivirus zikaense	Aedes mosquitoes	Mosquito-borne, potential for vertical and sexual transmission	Some	Outbreaks in parts of Asia, Africa, Europe
Orthomyxoviridae	Alphainfluenzavirus influenza H5, H7, H9, H10	Avian reservoirs, humans	Respiratory transmission, potential for zoonotic	Little or none	Outbreaks in parts of Asia and Europe
Orthomyxoviridae	Alphainfluenzavirus influenza H5, H7, H9, H10	Avian reservoirs, humans	Respiratory transmission, potential for zoonotic	Little or none	Worldwide distribution
Orthomyxoviridae	Alphainfluenzavirus influenza H1, H3	Respiratory transmission, potential for zoonotic	Respiratory transmission	Sufficient to cause outbreaks	Outbreaks in parts of Asia
Orthomyxoviridae	Henipavirus Nipah	Bats, humans	Bat-borne transmission, person-to-person spread	Sufficient to cause outbreaks	Primarily confined to Afghanistan and Pakistan
Paramyxoviridae	Enterovirus poliovirus	Humans	Fecal-oral transmission, contaminated food and water	Sufficient to cause outbreaks	Historically widespread, now confined to laboratories
Picornaviridae	Orthopoxvirus Variola	Humans	Contact with infected individuals	Sufficient to cause outbreaks	Endemic in Central and West Africa, already caused a PHE
Poxviridae	Lentivirus human6	Endemic in humans	Sexual transmission, endemic in humans	Endemic in humans	Global
Retroviridae	Alphavirus equine encephalitis	Mosquitoes, rodents	Mosquito-borne transmission	Little or none	Outbreaks in Asia, Africa, and the Americas
Togaviridae	Alphavirus Venezuelan	Mosquitoes, rodents	Mosquito-borne transmission	Little or none	Outbreaks in Central and South America

WHO (2024), *Pathogens Prioritization: A Scientific Framework for Epidemic and Pandemic Research Preparedness.*

Funded by
the European Union

Exercise 1:
Most Effective Infection Control Strategy

G1 - Ventilation

G2 - UV disinfection

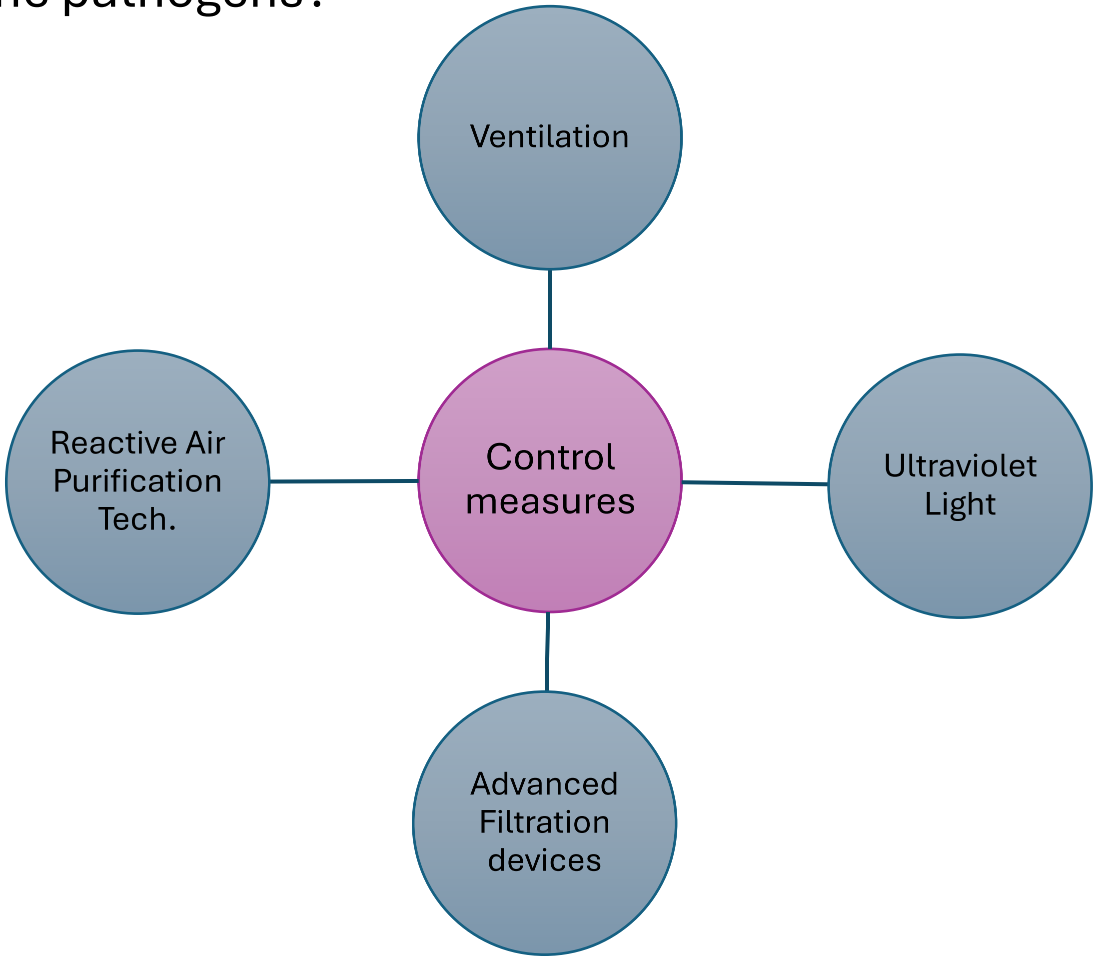
G3 - HEPA filters

- Each group must argue why their assigned strategy is the most effective (10 minutes).
- Other groups can challenge their claims (10 minutes).

Funded by
the European Union

infection control strategies

How to minimise the transmission of airborne pathogens?



Funded by the European Union

Ventilation

- Ventilation is the process of introducing and circulating clean air into indoor spaces to dilute and displace polluted air, using mechanical and natural ventilation.

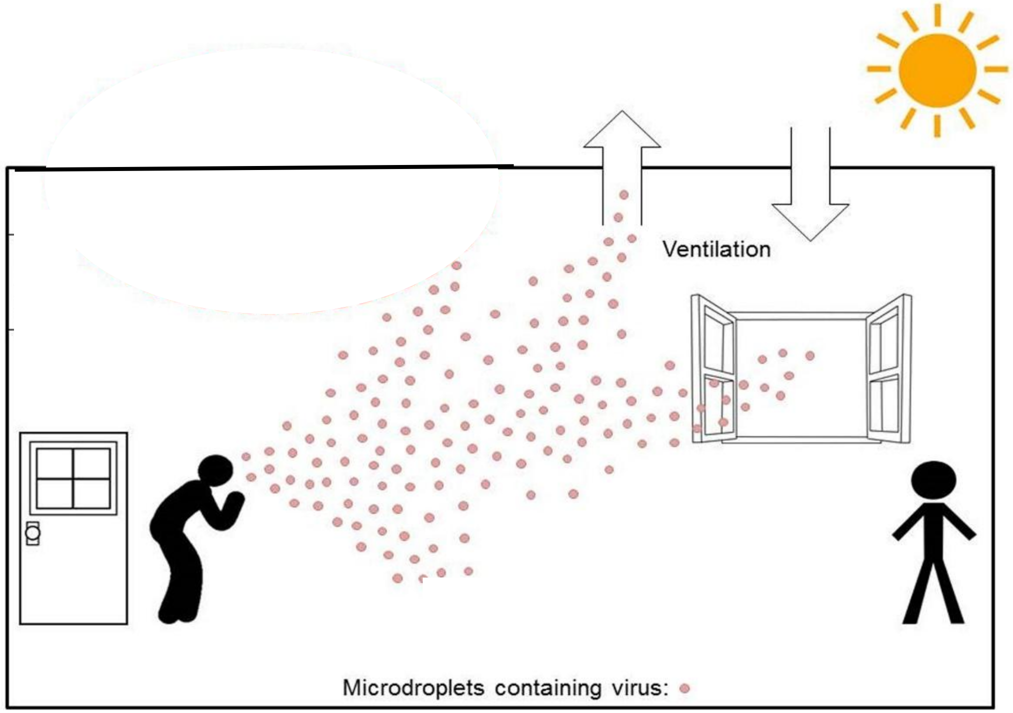


Figure 1: Airborne pathogen mitigations

Morawska, Lidia, et al. "How can airborne transmission of COVID-19 indoors be minimised?." Environment international 142 (2020).

Funded by the European Union

Type of Ventilation

Natural ventilation:

Operable windows, vents, and other openings to allow air exchange driven by natural wind and temperature differences.

Mechanical ventilation:

Like Heating, Ventilation and Air Conditioning (HVAC) to control indoor air quality by regulating airflow rates and filtration.

Hybrid systems:

Combines elements of both natural and mechanical systems to optimize energy efficiency while maintaining air quality.

Funded by
the European Union

Received: 19 August 2022 | Revised: 18 October 2022 | Accepted: 19 October 2022
DOI: 10.1111/ina.13161

ORIGINAL ARTICLE

WILEY

The impact of ventilation rate on reducing the microorganisms load in the air and on surfaces in a room-sized chamber

Waseem Hiwar[1] | Marco-Felipe King[1] | Harith Kharrufa[2] | Emma Tidswell[1] | Louise A. Fletcher[1] | Catherine J. Noakes[1]

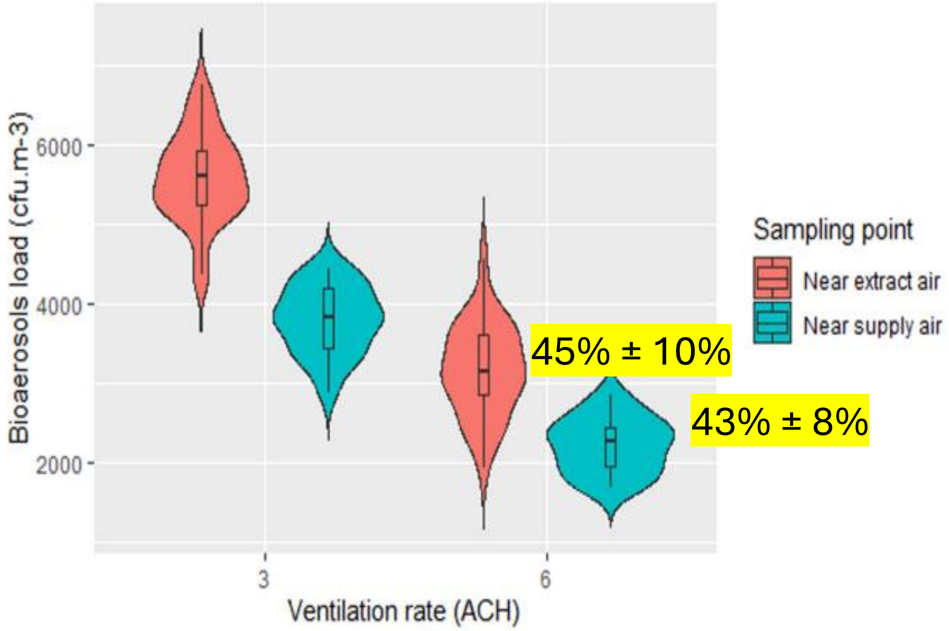


FIGURE 8: Airborne bioaerosol load under steady-state conditions at 3 and 6 ACH ventilation rates and at two locations (ventilation supply and extract) in the chamber.

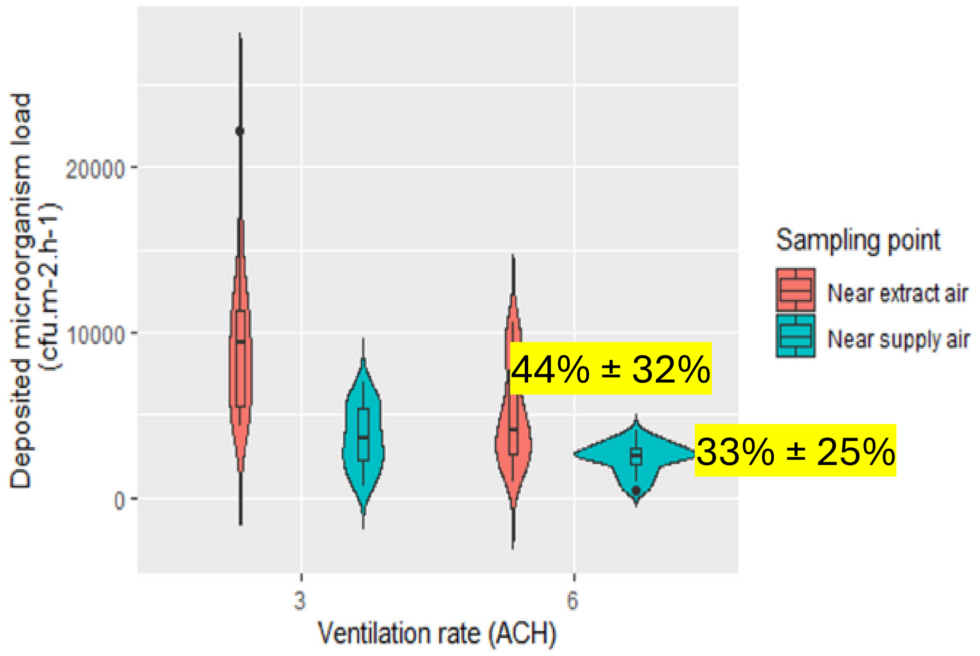
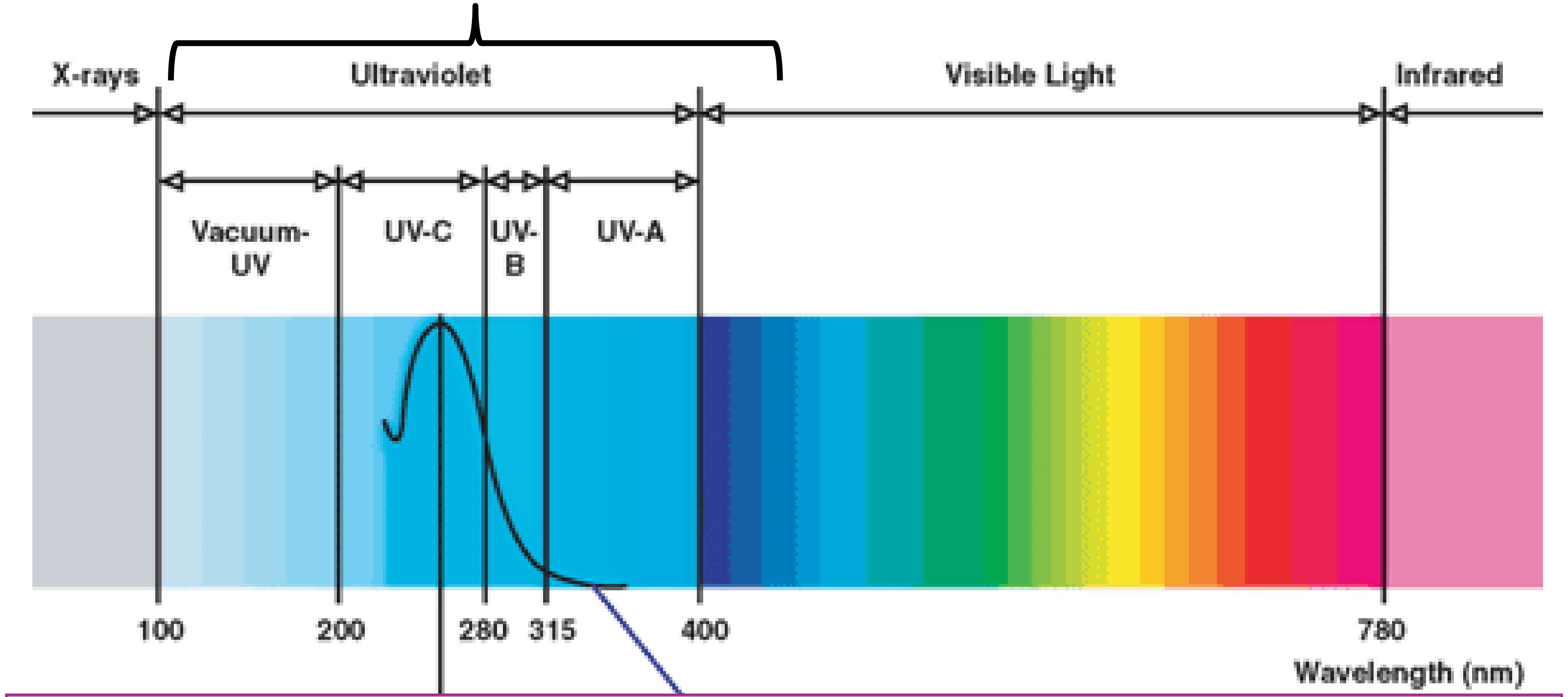


FIGURE 9: The mean deposited microorganisms load under the steady state conditions at 3 and 6 ACH ventilation rates sampled near the ventilation inlet and the outlet.

Funded by the European Union

Ultraviolet Disinfection

Electromagnetic radiation having a wavelength between 100 and 400 nm



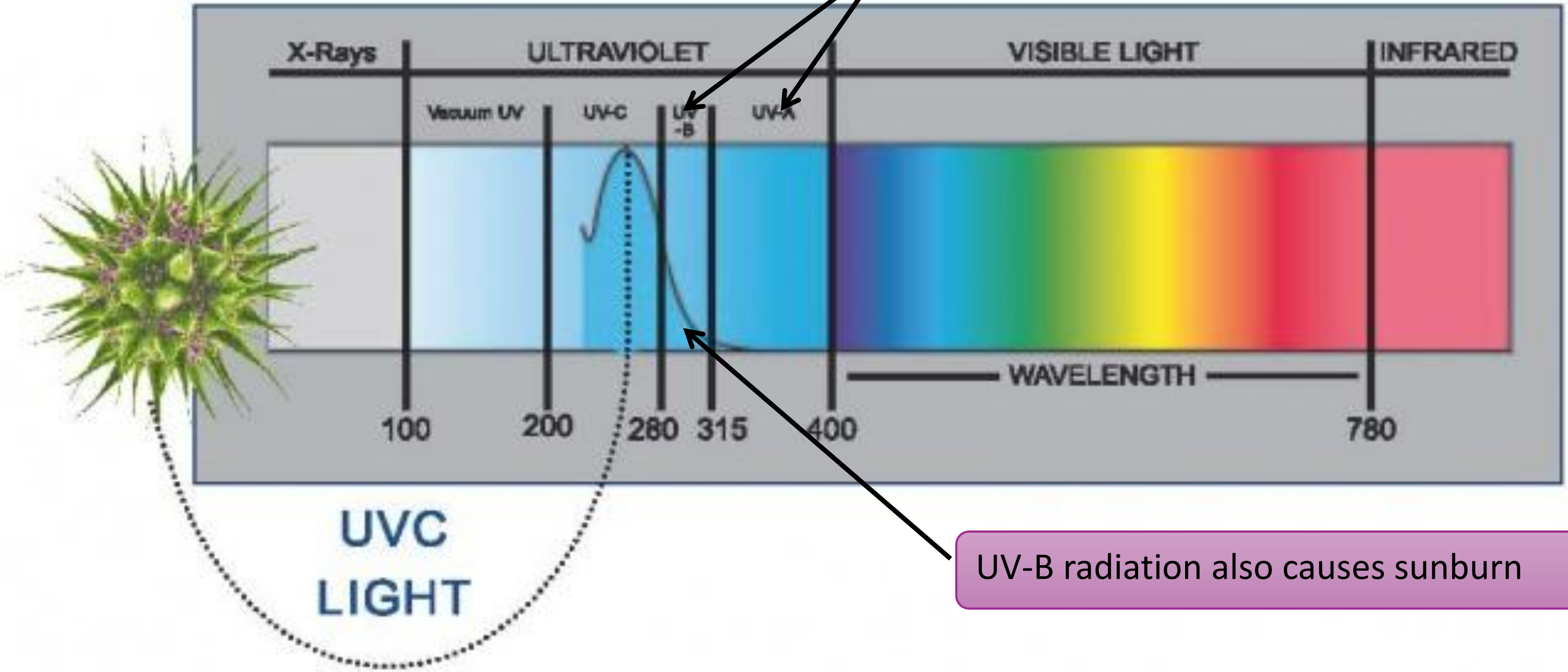
Further subdivided into 4 segments, vacuum UV, short-wave UV (UV-C), middle-wave UV (UV-B) and long-wave UV (UV-A)

https://2008.igem.org/Team:Bologna/UV_radiation/

Funded by the European Union

Ultraviolet Disinfection

UV-A and UV-B activate the melanocytes in the skin to produce melanin

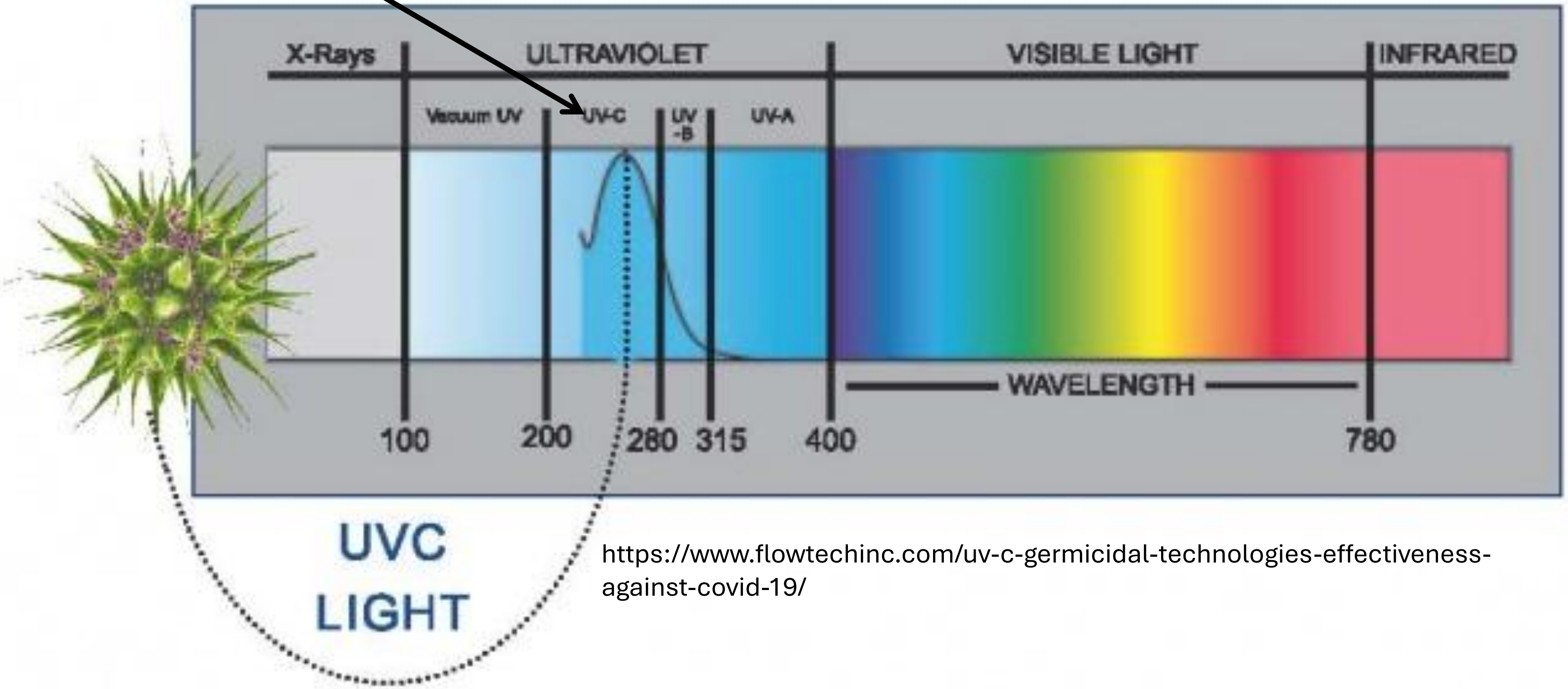


UV-B radiation also causes sunburn

Funded by the European Union

Ultraviolet Disinfection

UV-C radiation (254nm) is absorbed by the DNA and is the most likely of the three to cause skin cancer



https://www.flowtechinc.com/uv-c-germicidal-technologies-effectiveness-against-covid-19/

Funded by the European Union

History of UVGI

1930's and 40's - UV lamps used extensively in Tuberculosis (TB) wards in the USA

Numerous anecdotal accounts of the benefits of UVGI in these wards

Wells et al – Harvard University – 4 year study – UV in schools - reduced the spread of measles and chickenpox and mumps

Riley – carried on the work – looking at the control of TB

Since Riley's work there had been little work done on UV

- Reduction in TB cases due to improved drug therapies
- Difficulty in demonstrating a real health effect
- Concerns over the safety of UVGI

Funded by the European Union

<u>Renewed Interest in Ultraviolet disinfection</u>

- Increased incidence of TB
- Recognition that existing engineering controls have serious deficiencies

As a result:

- Ultraviolet germicidal irradiation is now a recognised method for inactivating a wide range of biological agents

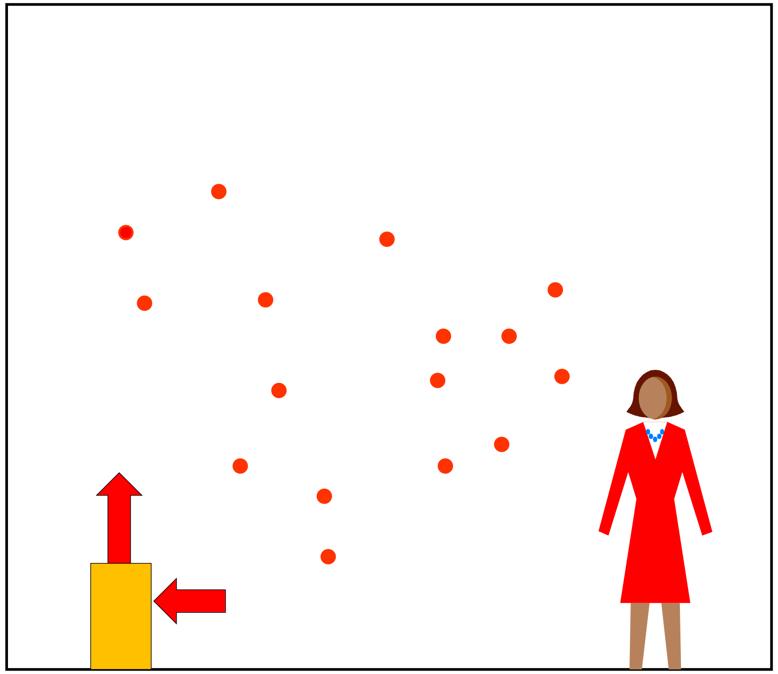
The efficacy will depend upon a range of locational and operational factors

- UV Light intensity
- Susceptibility of microorganism
- Passage of air through UV field

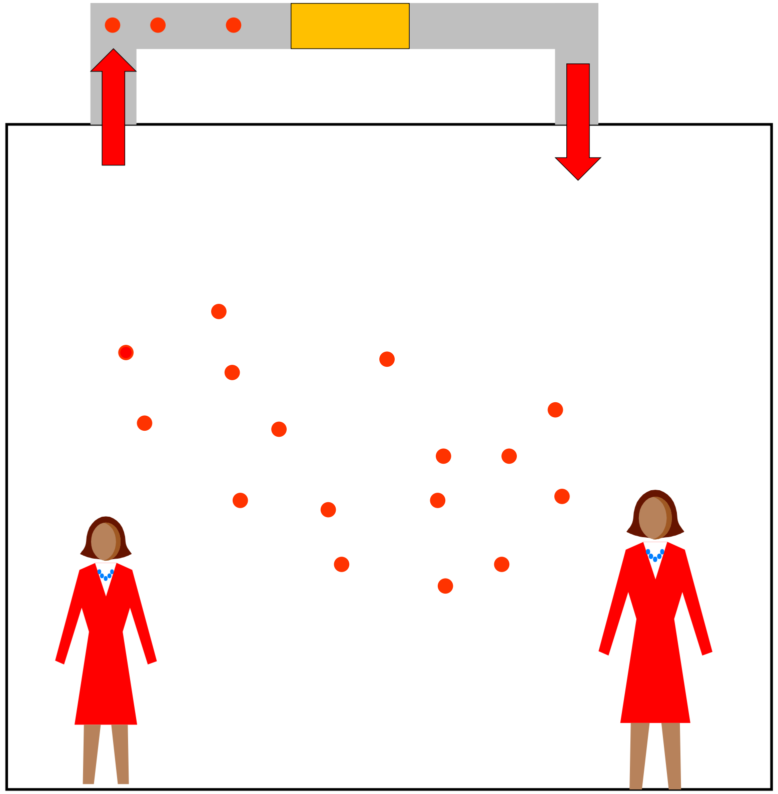
Funded by the European Union

UV Disinfection Strategies

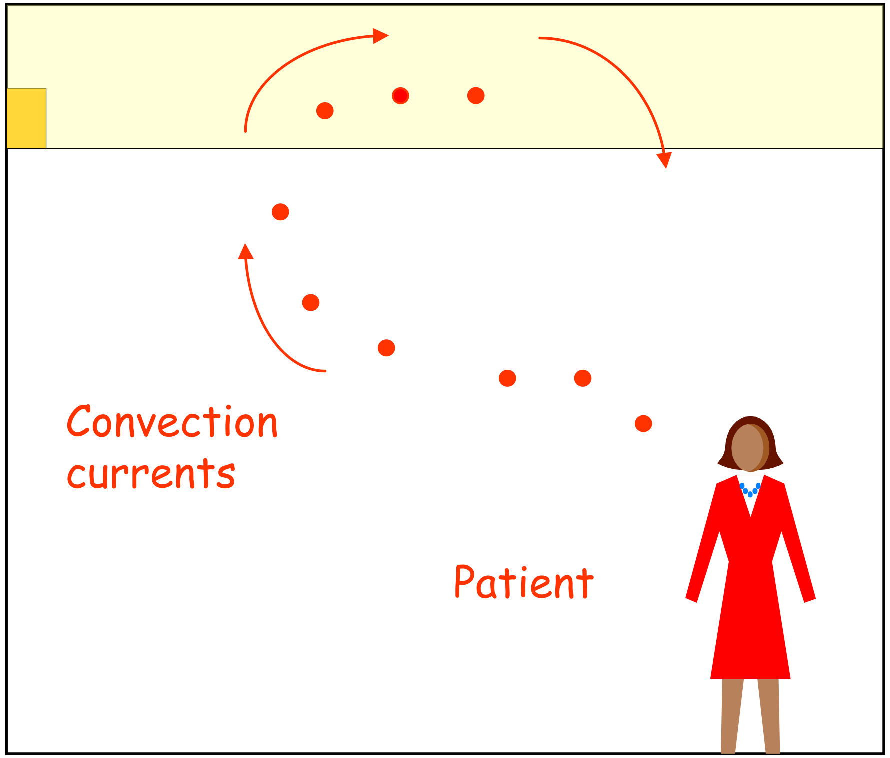
Stand-alone devices



In-duct systems

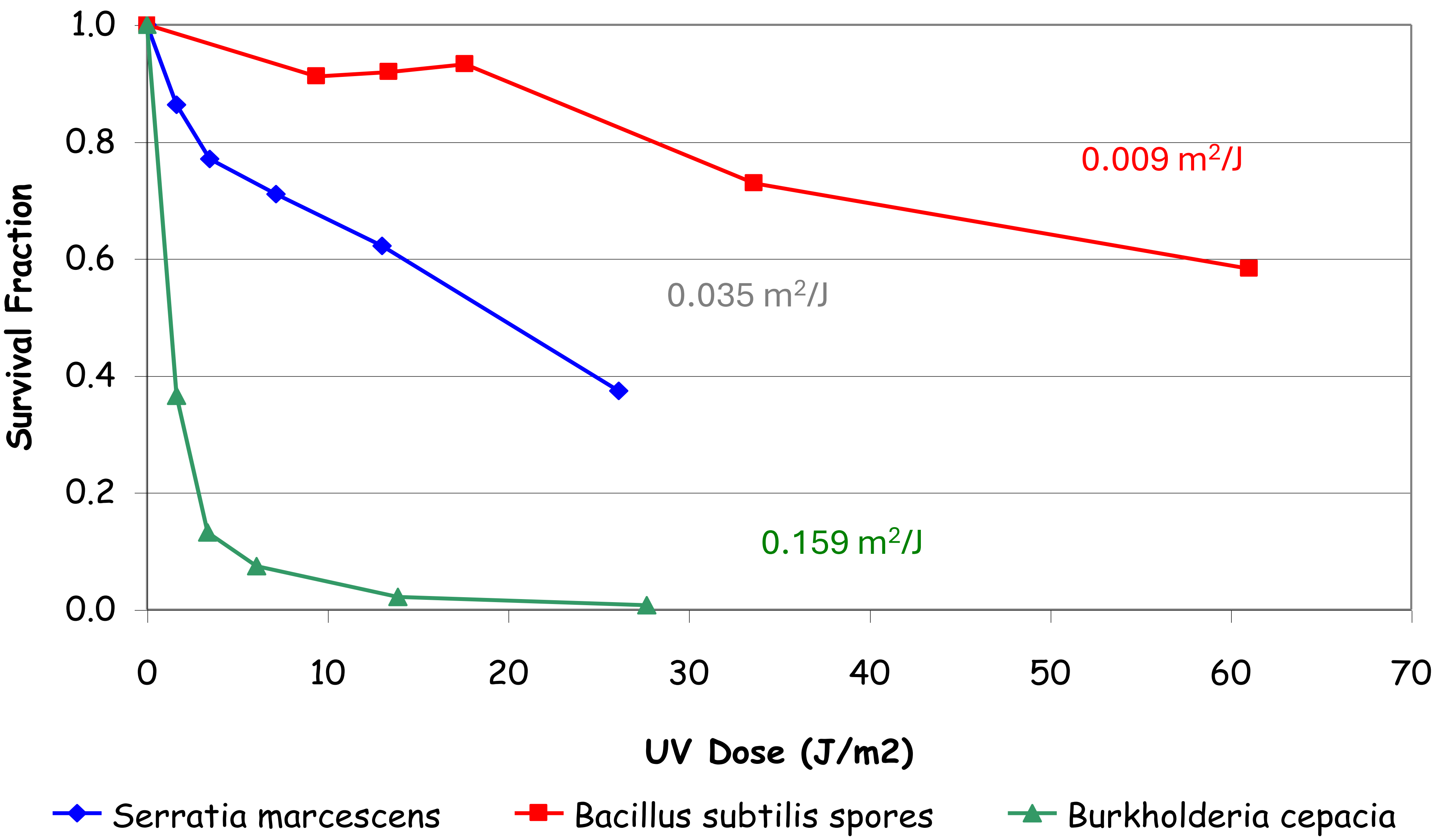


Upper Room



Funded by the European Union

Susceptibility of microorganism



Funded by the European Union

www.nature.com/scientificreports

scientific reports

Check for updates

OPEN

Far-UVC (222 nm) efficiently inactivates an airborne pathogen in a room-sized chamber

Ewan Eadie[1], Waseem Hiwar[2], Louise Fletcher[2], Emma Tidswell[2], Paul O'Mahoney[1,3], Manuela Buonanno[4], David Welch[4], Catherine S. Adamson[5], David J. Brenner[4], Catherine Noakes[2] & Kenneth Wood[6]

Funded by the European Union

- 100-280 nm (UV-C radiation)
- 250-280 nm (UVGI) at germicidal doses is potentially hazardous, biophysical
- 200-230 nm Far UV-C radiation

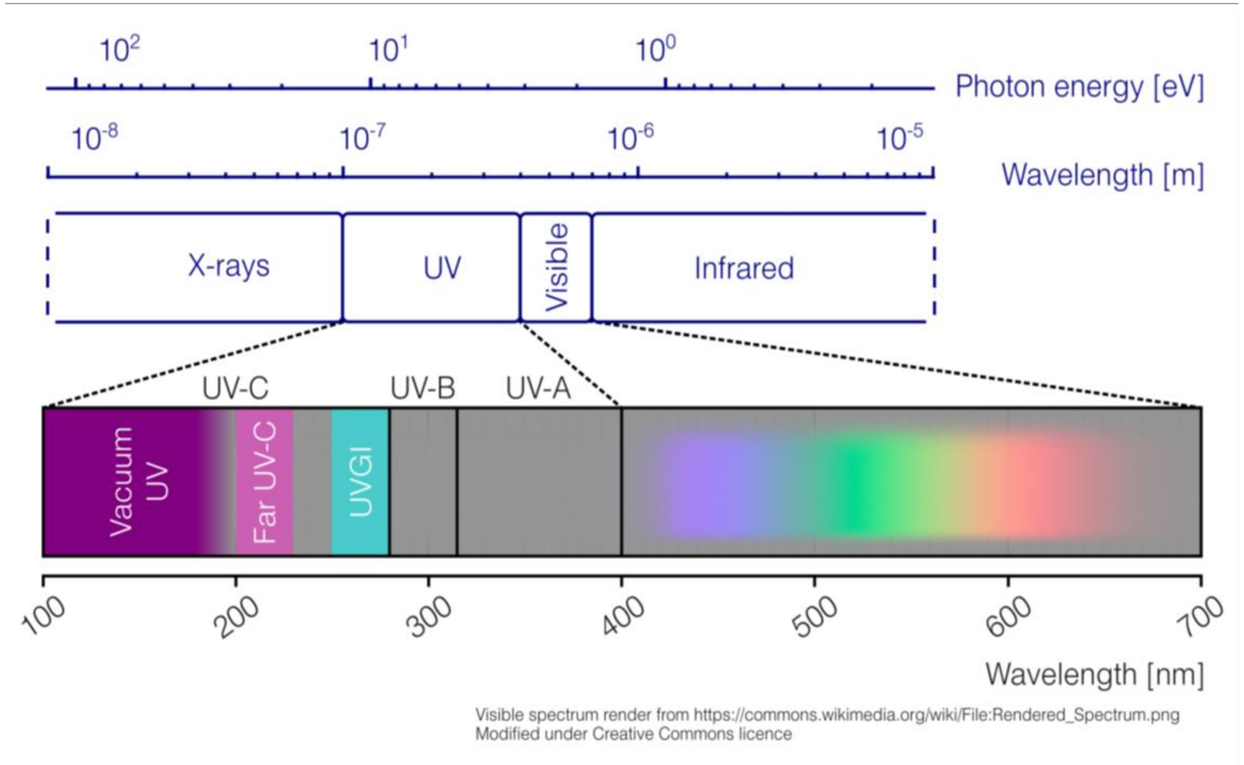
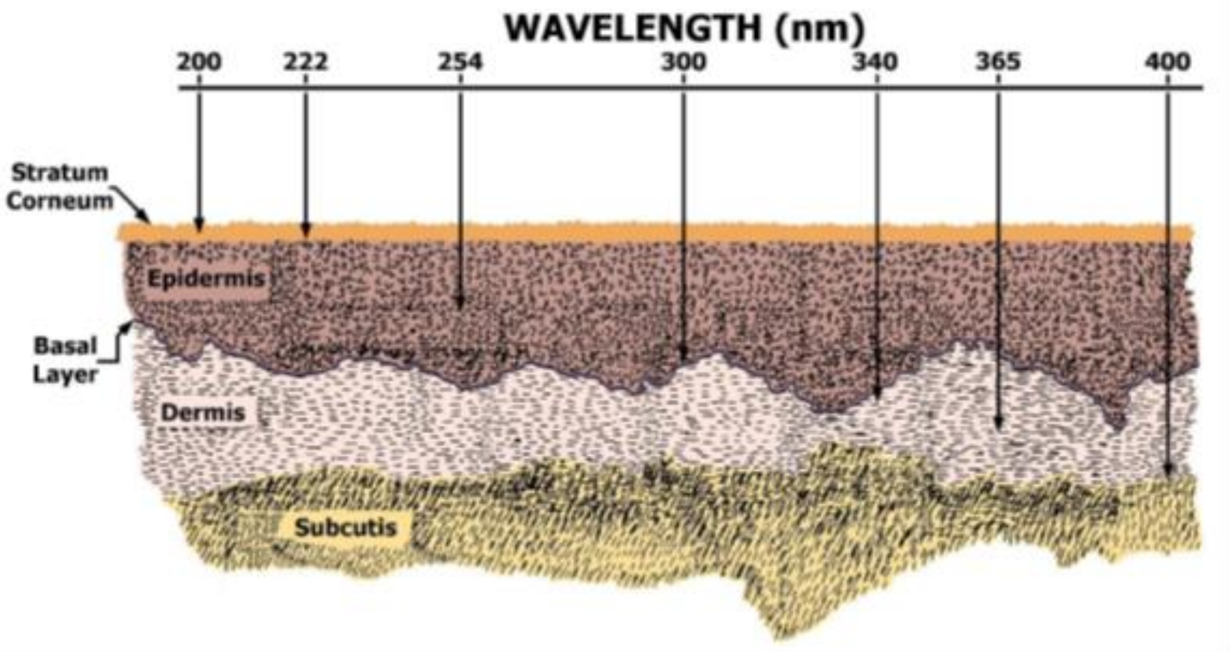


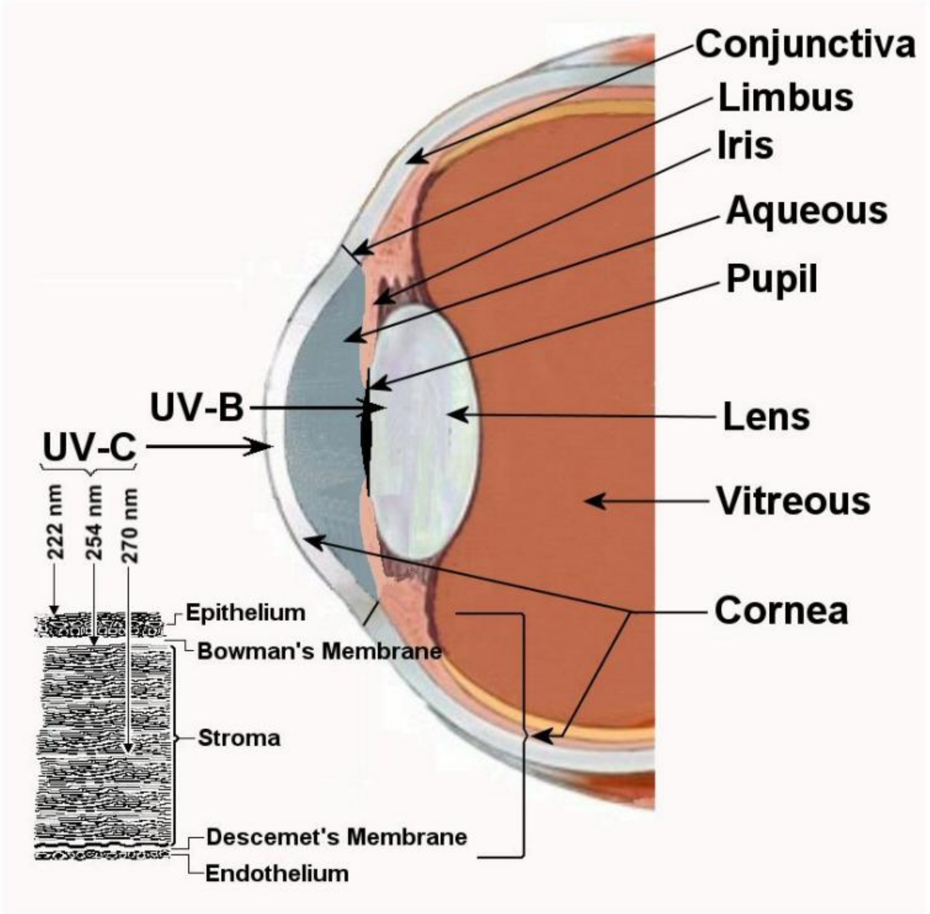
Figure 2: Far UV-C wavelength

- Nucleic acids and proteins absorb photons, making wavelengths below 230 nm efficient for deactivation.
- Airborne viral infections are commonly bound in aerosol droplets, which have high protein absorption.

Funded by the European Union



https://phys.org/news/2021-10-specific-uv-wavelength-low-cost-safe.html

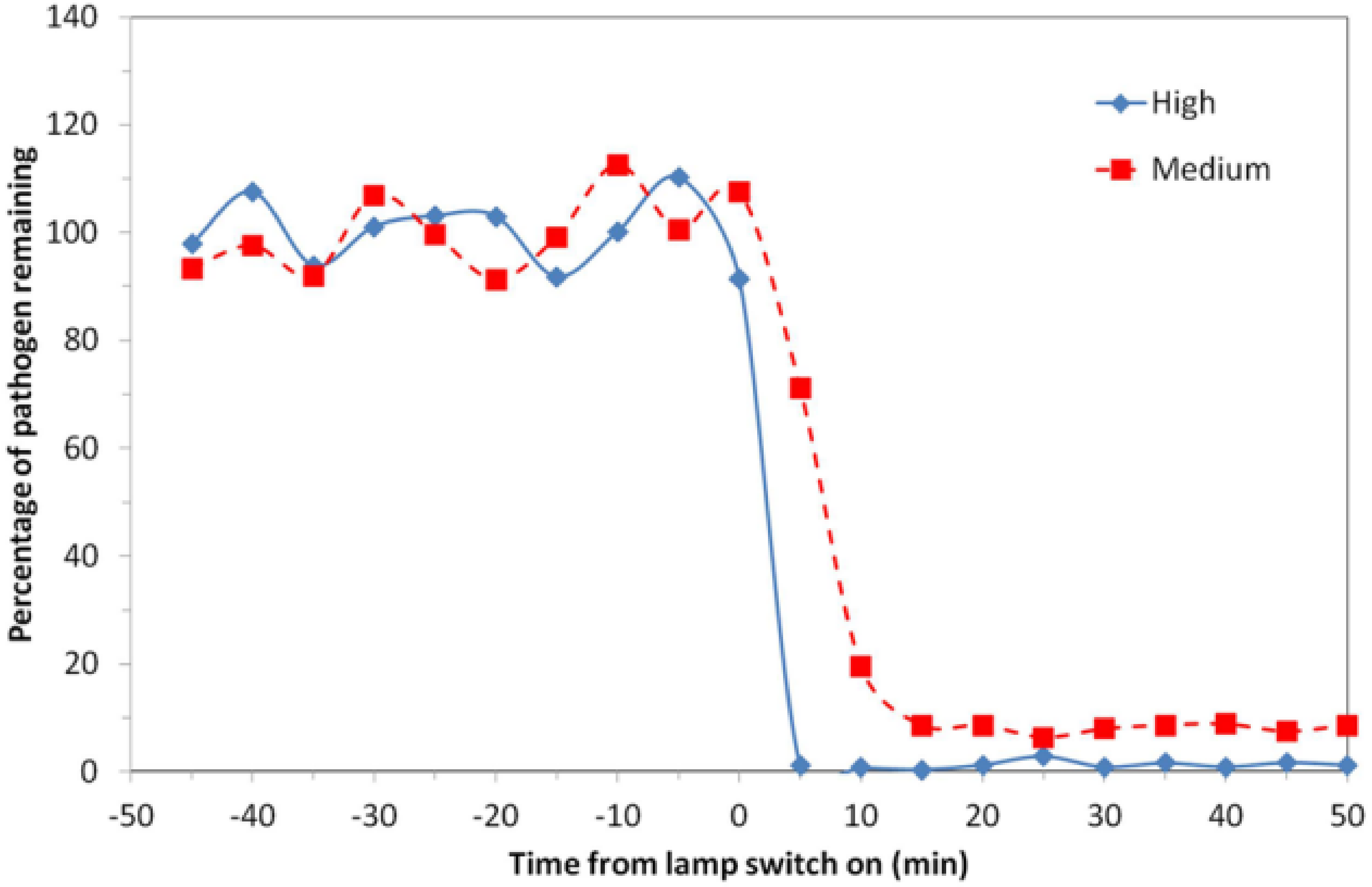


https://www.wsws.org/en/articles/2023/01/14/teda-j14.html

Funded by the European Union

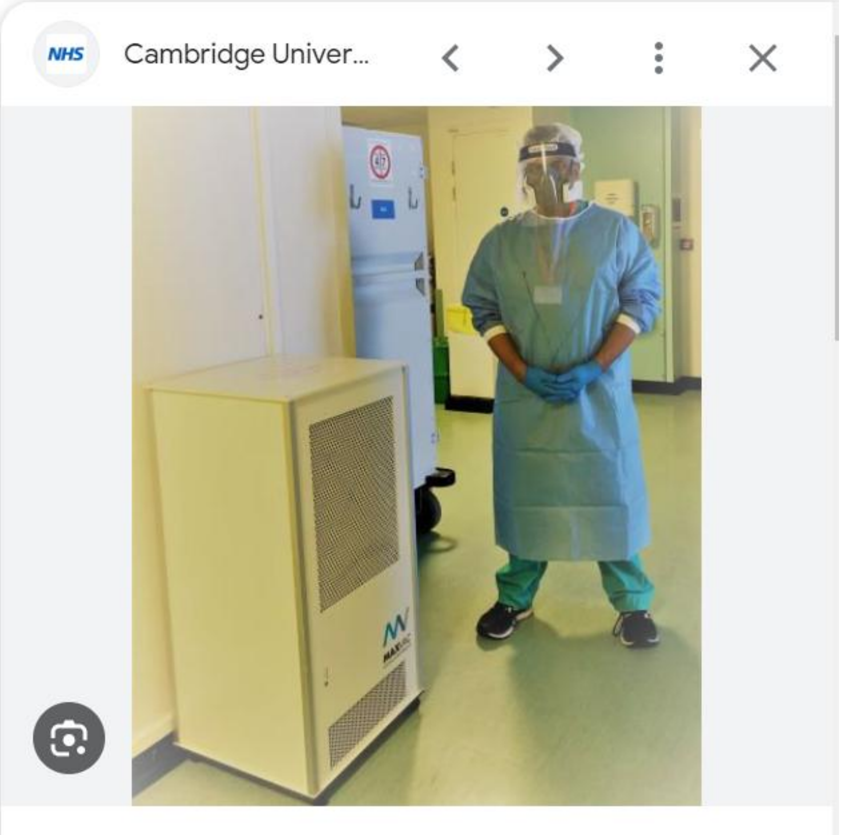
- Far-UV - typically in the wavelength range from **200 to 230 nm**
- Krypton Chloride (KrCl) excimer lamps with a primary emission wavelength of **222 nm,** and low residual emission throughout the ultraviolet region of the electromagnetic spectrum
- Have been shown in **laboratory experiments to inactivate** gram-positive and gram-negative bacteria, drug-resistant bacteria, infuenza viruses and human coronaviruses including the SARS-CoV-2 virus
- Far-UVC excimer lamps are much less likely than conventional (254 nm) germicidal UV sources to **induce acute adverse reactions on skin and eyes**, and studies to date in animal and human models have not demonstrated any long-term adverse health effects

Funded by
the European Union



Funded by
the European Union

HEPA filter unit



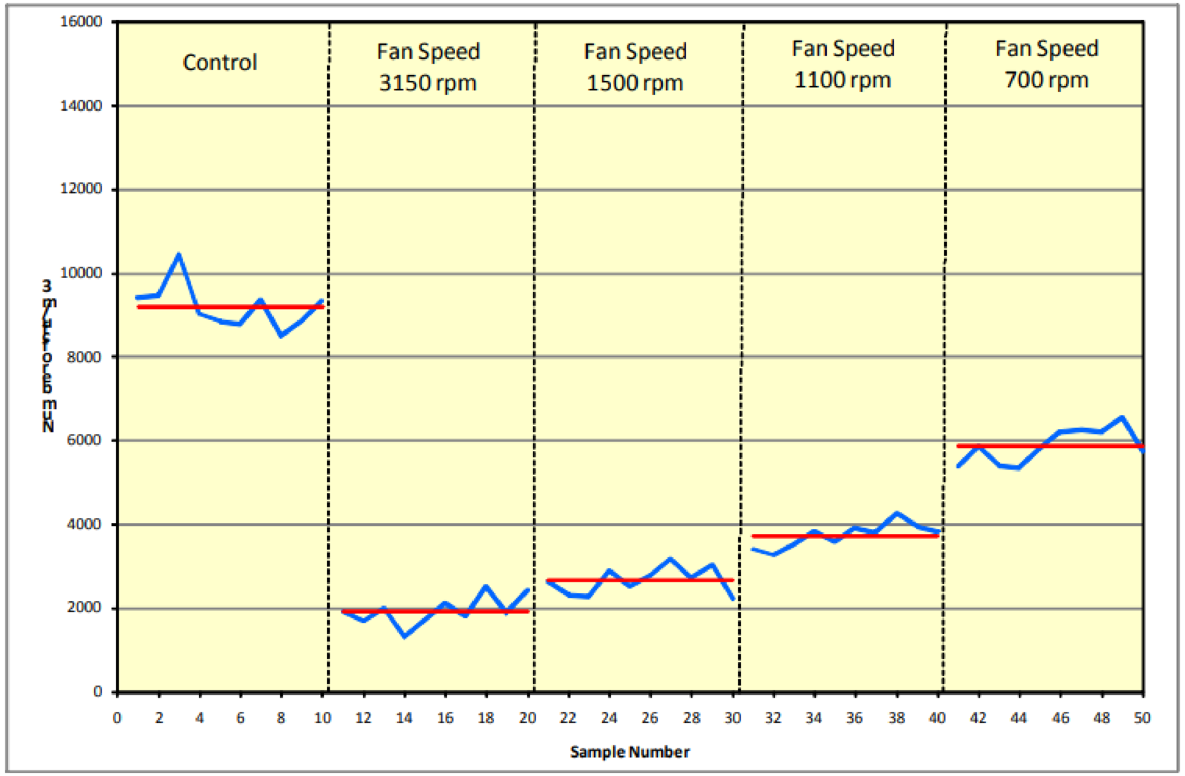


Figure 1 The performance of the air cleaning device at different fan speeds with bioaerosols of *A. fumigatus* – the blue lines represents the raw data from the ten replicate samples and the red lines are the mean concentrations over the ten replicate samples.

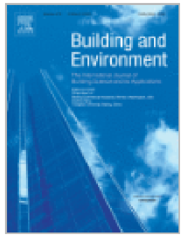
HumanIC

Funded by the European Union

ELSEVIER

Building and Environment

Volume 274, 15 April 2025, 112734



HumanIC

Experimental analysis to quantify inactivation of microorganisms by Far-UVC irradiation in indoor environments.

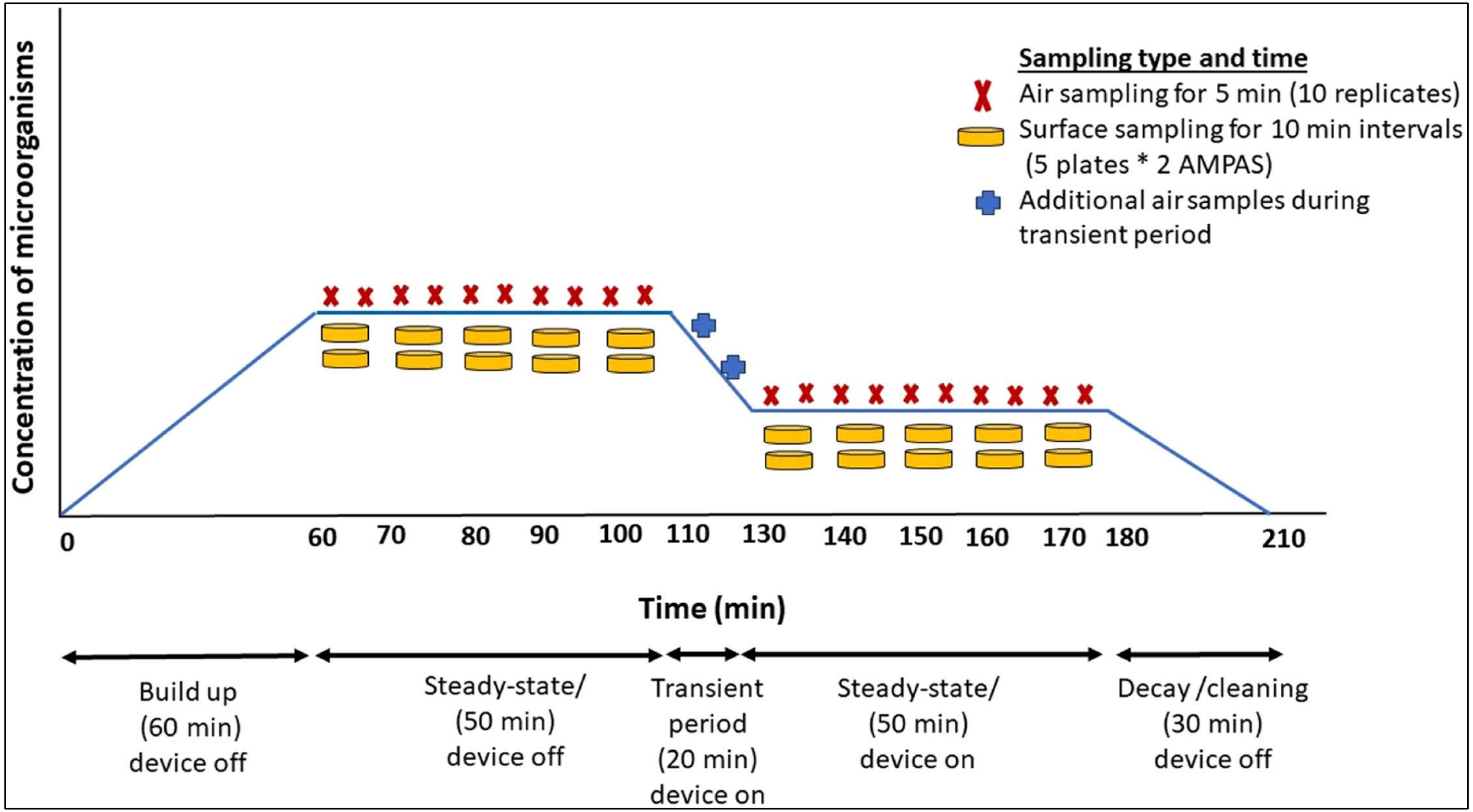
Waseem Hiwar [a], Catherine S Adamson [b], David J Brenner [c], Louise A Fletcher [a], Marco-Felipe King [a], James B. McQuaid [d], Emma Tidswell [a], Catherine J Noakes [a], Kenneth Wood [e], Ewan Eadie [f]

Funded by the European Union

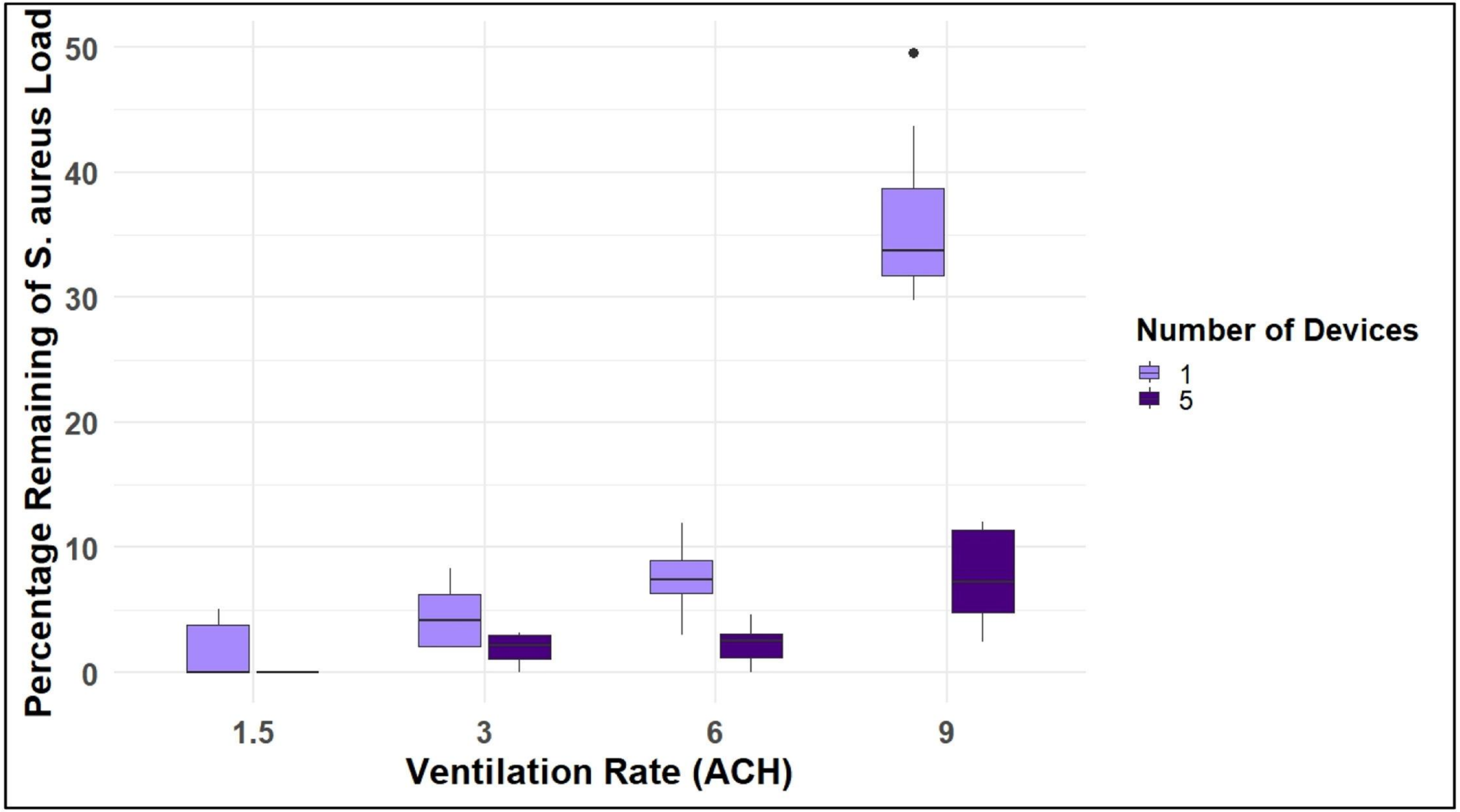
Exercise 1:

The data was obtained from controlled experiments carried out in the Leeds test chamber using *Staphylococcus aureus* over 4 days. For each experiment ten replicate samples were taken with the device switched off (control samples) and with the device switched on (test samples) and all the data is in cfu/m3. There was no sampling for the first hour, then, 10 samples were taken when the device is off, 10 samples when the device is on (at a ventilation rate of 1.5, 3, 6 and 9 ACH).

Funded by
the European Union



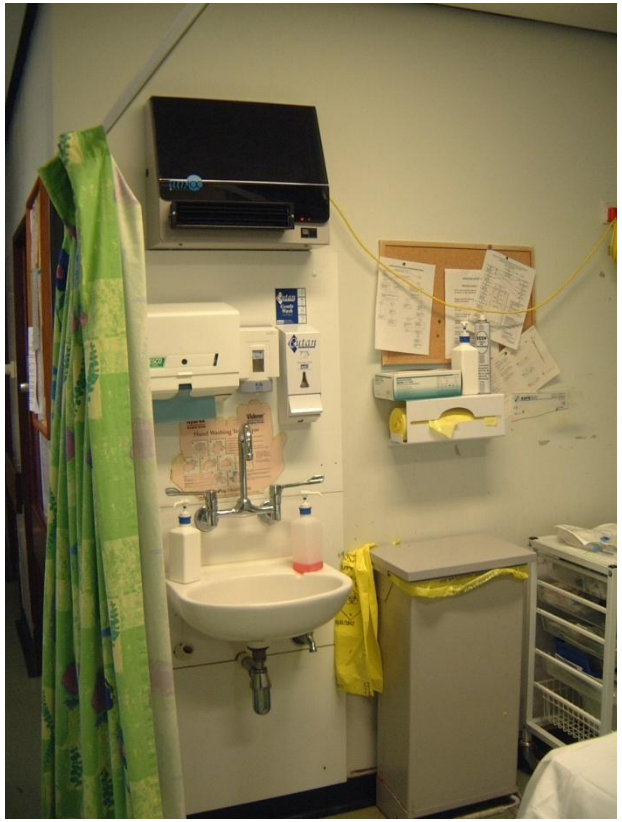
Funded by the European Union



Funded by the European Union

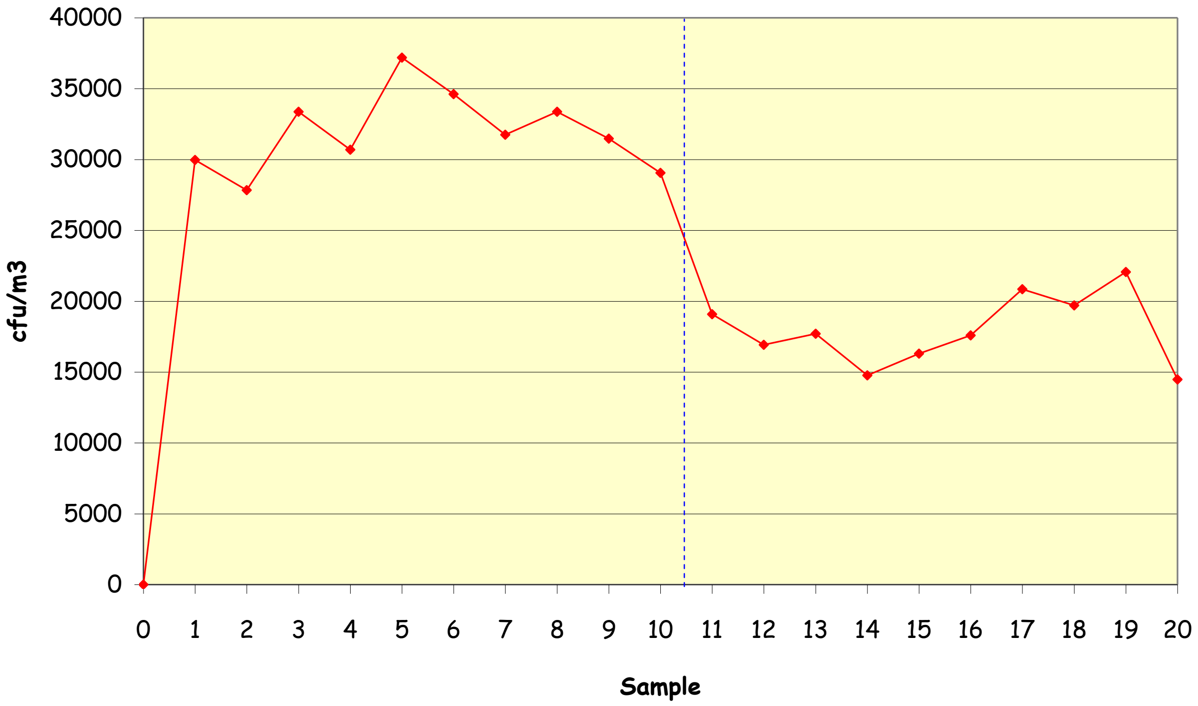
Reactive Air Purification Technology

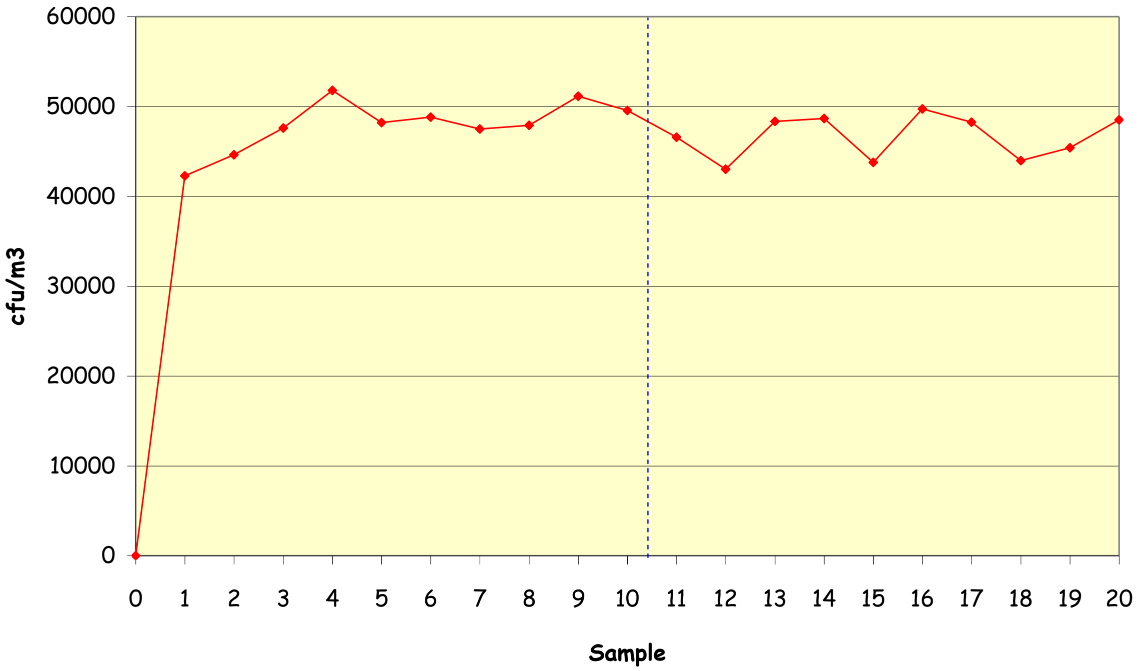
- Negative Air Ionisation



Ionisers in use in a UK Hospital

Funded by the European Union





Effect of negative ions on the airborne concentration of *Staphylococcus aureus*

Effect of negative ions on the airborne concentration of *Bacillus subtilis* spores

Funded by the European Union

Reactive Air Purification Technology

- Ozone
  - An allotrope of oxygen with **three oxygen atoms**
  - **Unstable** because the gas will readily degrade back to its stable state, diatomic oxygen
  - In air it has a **pungent odour** that is noticeable to most persons at levels above 100 ppb
  - Because it is a strong oxidant, extended exposure to ozone containing air is **harmful (**hazardous pollutant)
  - Can be generated by **photochemical**, **electrolytic** and **radiochemical methods**
  - Ozone is known to have **antibacterial activity**
  - Background levels are usually around **20 – 30 ppb**

Funded by the European Union

Reactive Air Purification Technology

- Hydroxyl Radicals

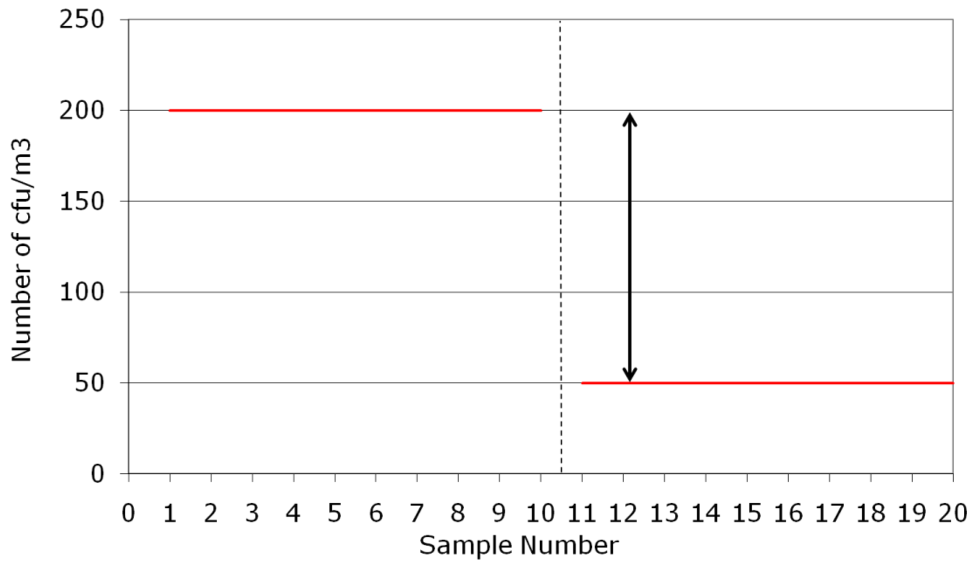
Discovered through work looking at the natural disinfection capacity of the open air – The Open-Air Factor

Patients with TB were often treated using ‘fresh air and sunshine’

Funded by the European Union

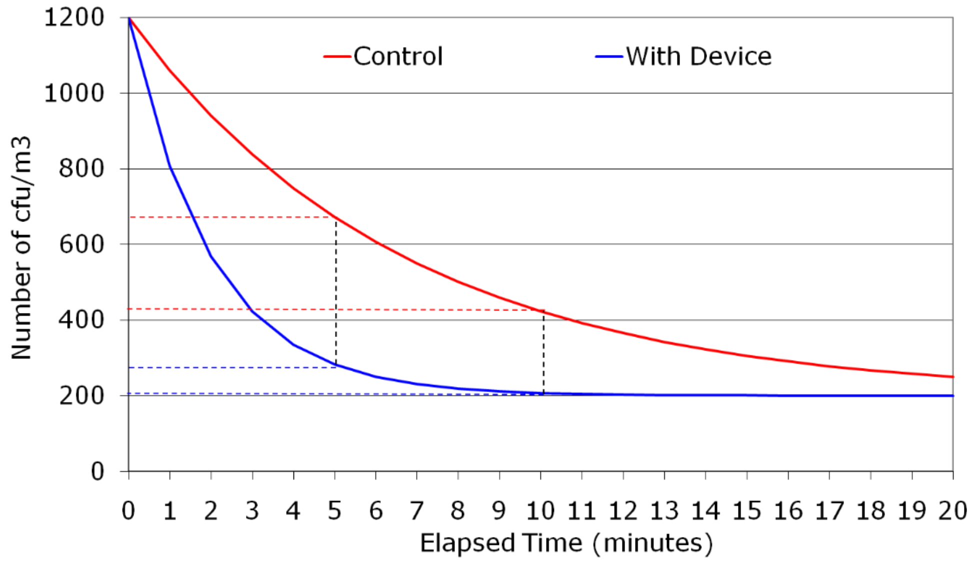
Evaluating the efficacy of air treatment devices

Controlled Environment Testing



Steady state test

- Room is subject to a continuous source of contamination
- Replicate samples are taken with the device switched off and again with the device switched on
- The difference between the two data sets is the reduction due to the device



Decay test

- Short term contamination event
- Samples are taken an set time intervals after contamination ceases with no device operating
- Test is repeated with the device switched on
- The difference in decay rate with and without the device operating indicates the efficacy of the device

Funded by the European Union

Real Environment Testing

Testing devices in real environments has **advantages** and **disadvantages.**

- It can be better to test in real environments such as hospitals etc. so you can investigate the influence of environmental conditions such as **temperature**, **relative humidity**, **ventilation rate** and the **concentration of microorganisms** which will vary over time.

- It also allows you to look at other factors such as the 'usability' of the device.
  - Does the device produce too much **noise**?
  - Does the device create a **draft**?
  - Does the device create a **smell**?
  - Do the device **get in the way**?

- If you are evaluating the performance of a device intended to be used in a hospital, by doing a full clinical trial you can also determine if the device produces a **reduction in infections** rather than just a **reduction in the level of contamination**.

- The **big disadvantage** to real environment trials is **the cost** and also the fact that they are **uncontrolled** so it can be difficult to explain differences in performance fi comparing different devices.

Funded by the European Union