Ventilation for Clinical Areas to Minimise COVID-19 Transmission

NHSE/I – Midlands Webinar

25 May 2021

12:30 – 13:30

NHS England and NHS Improvement

Welcome and Housekeeping

- **Please can you ensure that you are on mute and that your cameras are off.**
- **If you have any questions please use the chat-box function. We will use these questions to facilitate the discussion in the latter part of this session.**
- **When we are in the discussion section, please use the “hands up” button to comment or pose questions/answers to scenarios.**
- **The session will be recorded and available afterwards.**

Agenda

Timings	Session	Presenter
12:30	Welcome Introductions and Housekeeping	Kirsty Morgan
12:35	Overview and Update on work in NHS Wales	Prof. Chris Hopkins
12:40	UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?	Tony Fisher
12:50	Engineered infection controls – effective ventilation	Frank Mills
13:05	Update on Dental Ventilation Work	Peter Bill
13:10	Questions and Answers session	Panel

Ventilation for Clinical Areas to minimise COVID-19 Transmission Webinar

NHS England and NHS Improvement

UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?

Prof Tony Fisher MBE MD PhD
Consultant Clinical Scientist
Medical Physics and Clinical Engineering, Royal Liverpool Univ Hospital &
Dept of Physics, Univ of Liverpool

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Ventilation for Clinical Areas to minimise COVID-19 Transmission Webinar

NHS England and NHS Improvement

UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?

The Team … …

i. NHS colleagues Claire Greaves, Peter Bill, Chris Hopkins, Paul White

ii. Frank Mills, IMechE & CIBSE

iii. Fred Mendonca & Pawan Ghildiyal ESI Group (OpenFOAM)

Supported by UK Research and Innovation Grant

Guardian
24th May 2021

Air scrubbing-and-related technologies: use cases

- Endoscopy
- Dental theatres & surgeries

Main challenge is Aerosol Generating Procedures: AGP's (or maybe not?)

- Virus is ~100 nm max dimension
- Respiratory [0.1…5] µm: *aerosols*
- AGP's [5…25] µm: *micro-droplets*
- Dentistry 'sprays': {…500]µm macro-droplets

Ensemble particulates [0.1…500] µm
HEPA filters exclude >0.25 µm

Principal mitigation is changes of room air
(ACH: air changes per hour)

Air scrubbing-and-related technologies: use cases

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- Dental theatres & surgeries

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(ACH: air changes per hour)

Simple dilution of old air for new air using HVAC*

First order exponential clearance for a well-mixed room *viz*: removal rate is:

- 63% 1 change;
- 95% 2 changes;
- >99.5% 4 changes

Note: there is no bioburden model available to support this

*heating, ventilation, conditioning system

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Air scrubbing-and-related technologies: use cases

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Removal efficiency *w.r.t.* ACH

Principal mitigation is changes of room air (ACH: air changes per hour)

Simple dilution of old air for new air using HVAC

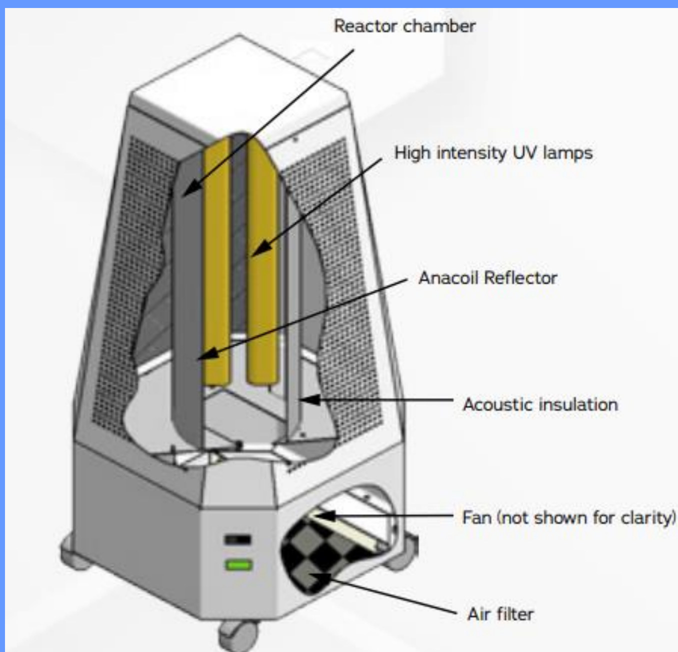
First o

- 6
- 9
- >

Air Changes per Hour, ach	Time Required for Removal Efficiency of 99%, min	Time Required for Removal Efficiency of 99.9%, min
2	138	207
4	69	104
6	46	69
8	35	52
10	28	41
12	23	35
15	18	28
20	14	21
50	6	8

Air scrubbing-and-related technologies: use cases

- Endoscopy
- Dental theatres & surgeries



$$\text{Effective ACH} = \text{ACH}_{\text{HVAC}} + \text{ACH}_{\text{AirScrubber}}$$ *assuming good mixing*

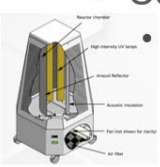
Air clearance CFD models:

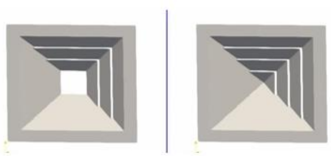
i. HVAC input grills
ii. Effect of air scrubber

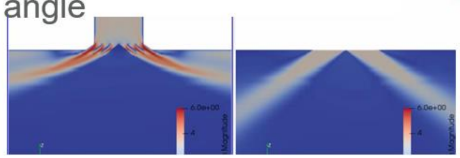
Dental Theatre: Birmingham Children's Hospital

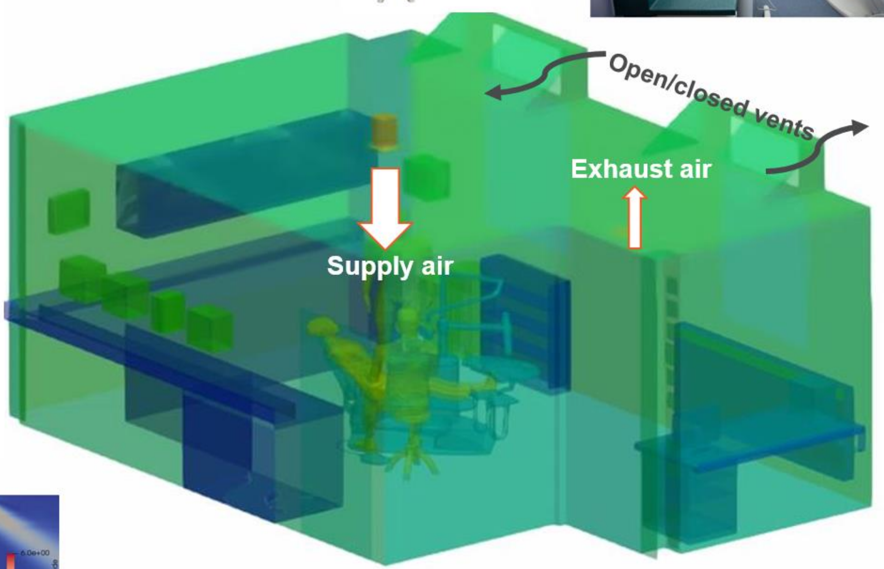
Thermally neutral operating mode

- 15th March Update – VERIFIED CFD MODEL
  - Vent air supply @ 5ACpH and extract exactly balanced
    - Treatment room volume is 44.7m^3,
    - 3 occupants/equipment included
  - Comparing
    - Effects of Air Scrubber (location and rate)
    - Dual direction
      - Roof angled
      - Central jet
    - Supply air vent angle





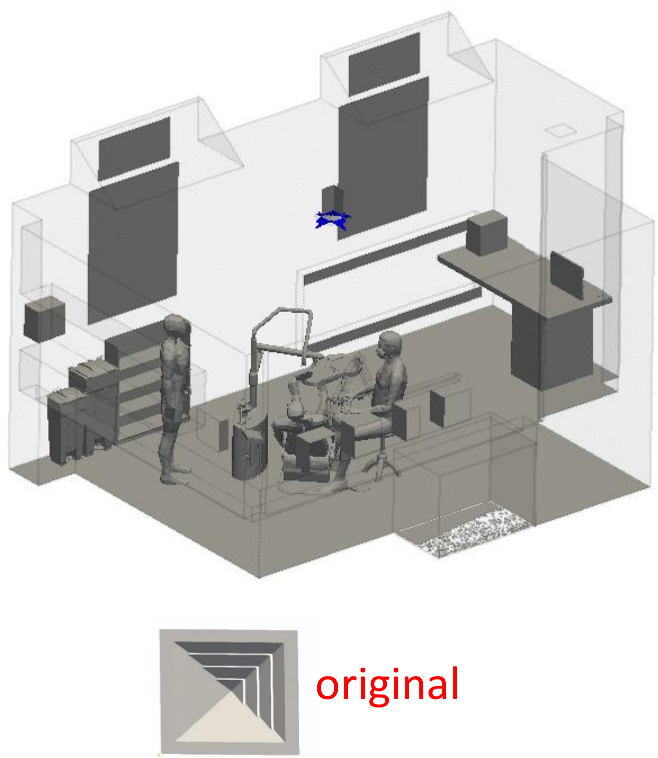




Air clearance CFD models:

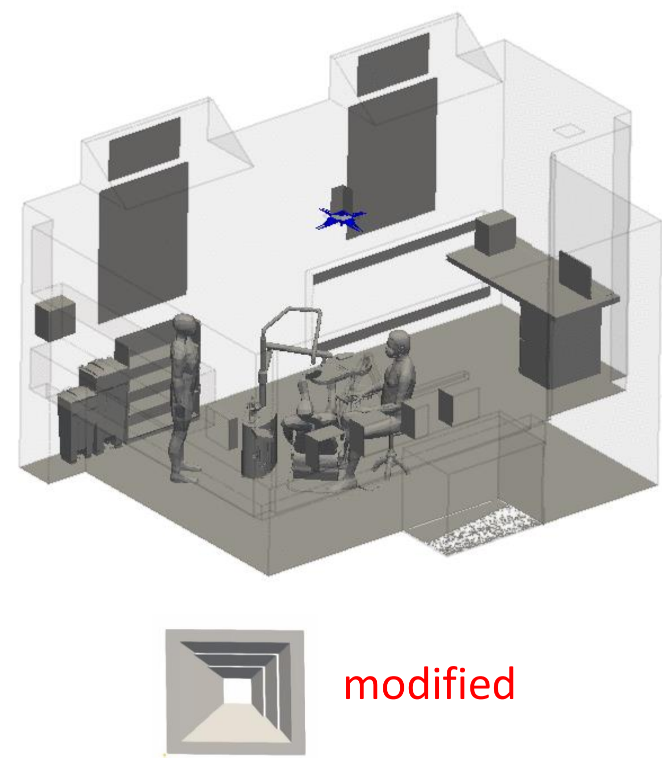
HVAC with original input grill *cf* HVAC with modified input grill

Iso Surface of Age of Air at 10 secs



original

Iso Surface of Age of Air at 10 secs

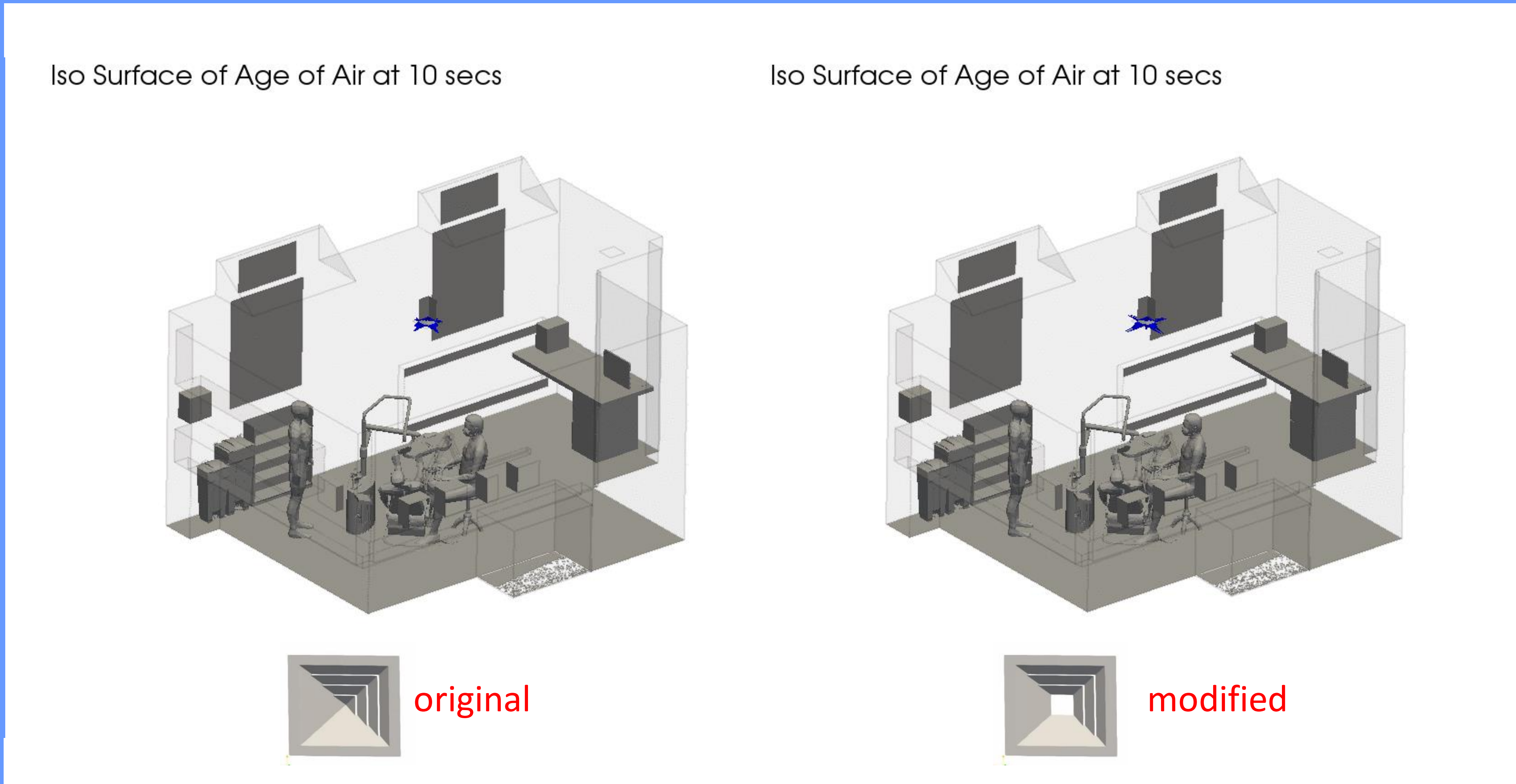


modified

UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?

Air clearance CFD models:

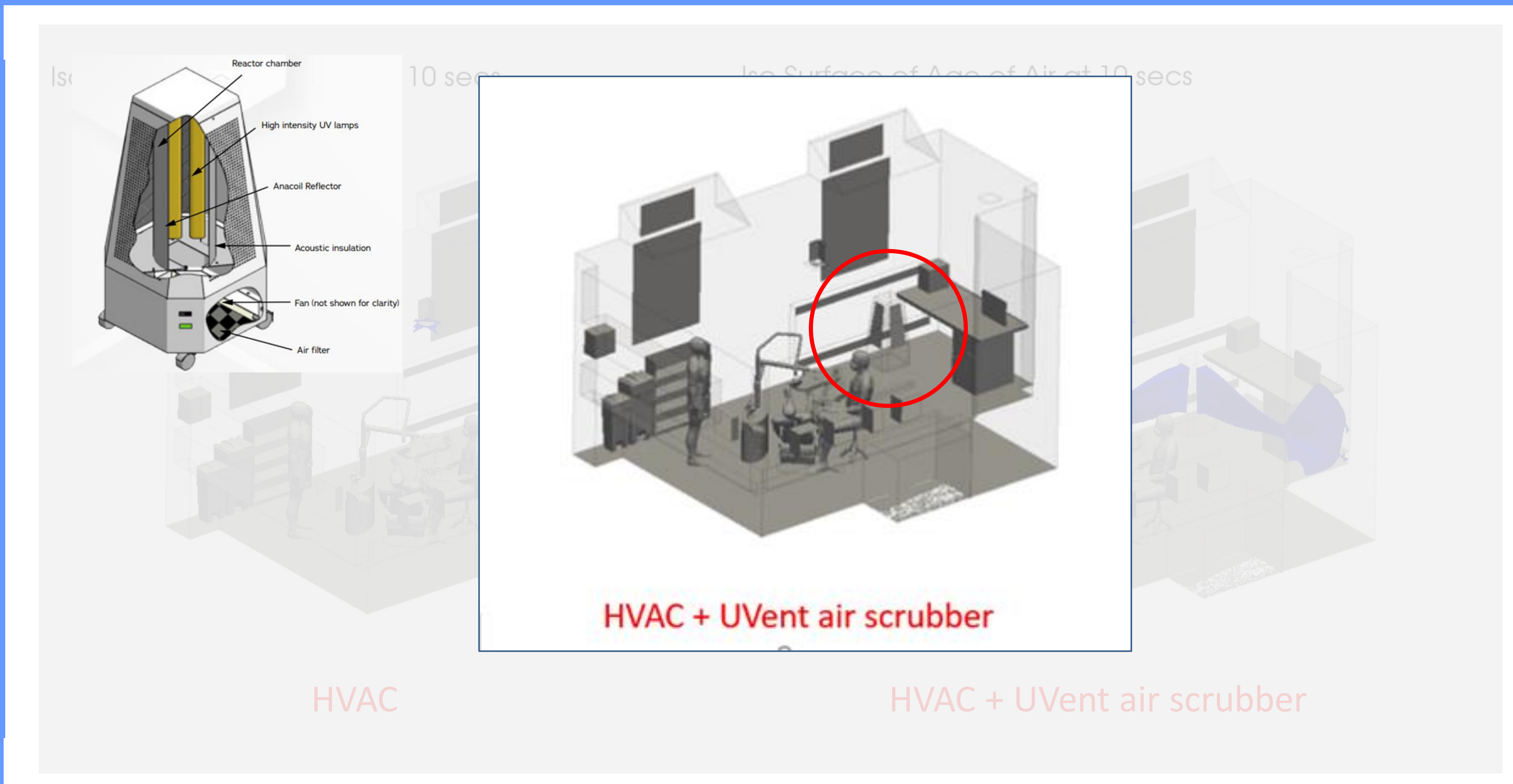
HVAC with original input grill *cf* HVAC with modified input grill



UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?

Air clearance CFD models:

HVAC with original input grill: effect of air scrubber



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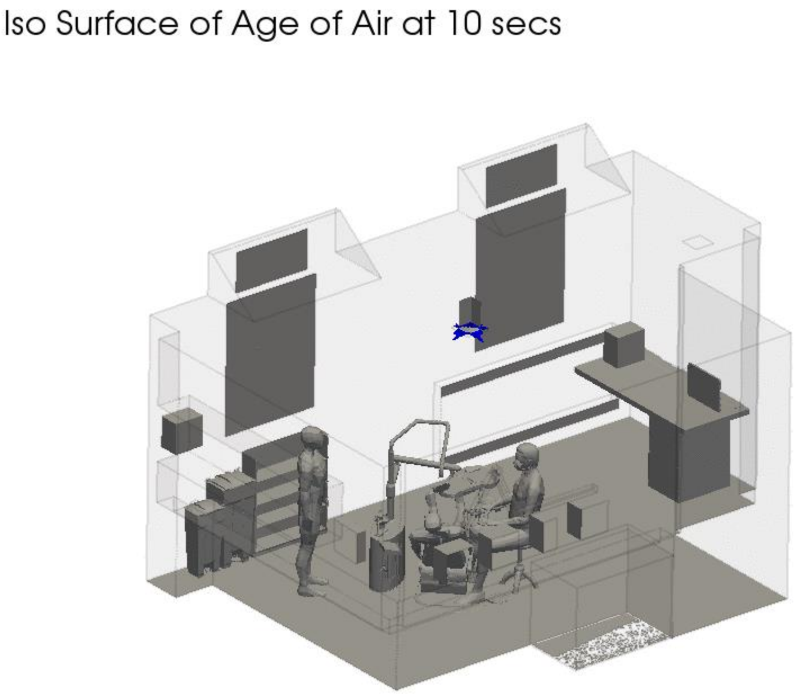
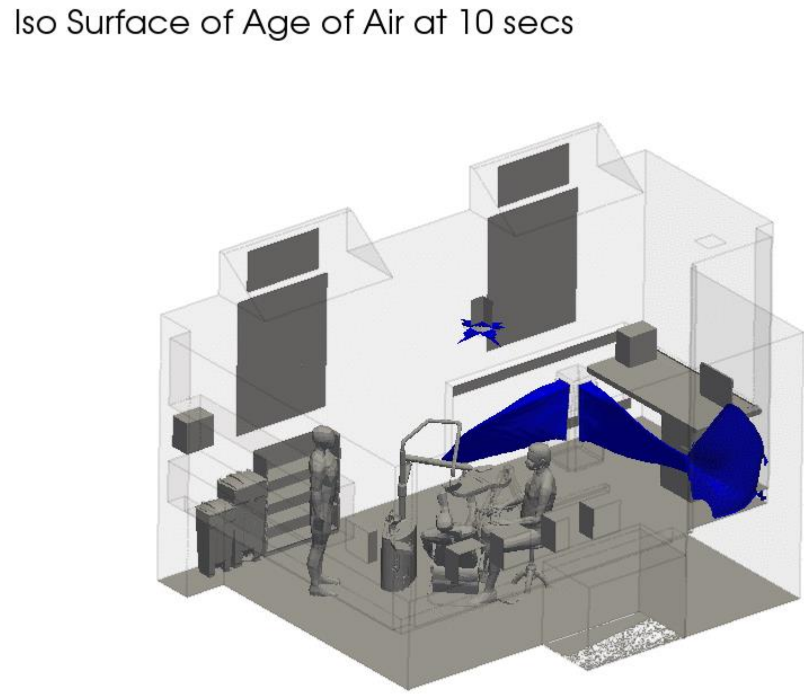
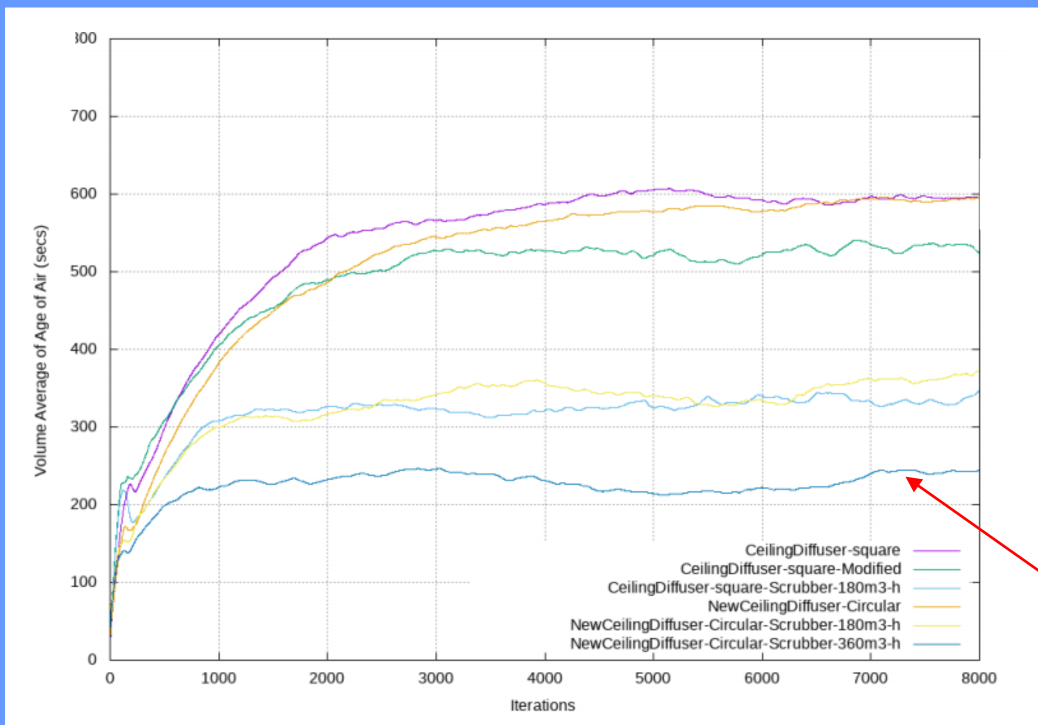


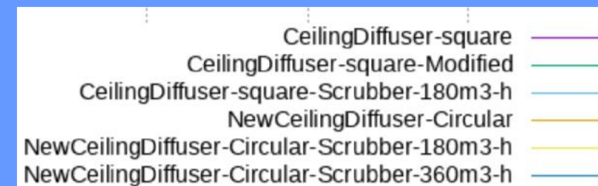
HVAC



HVAC + UVent air scrubber

UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?





New inlet diffuser + UVent air scrubber

Fallow time reduced by 75%

Air scrubbing-and-related technologies: use cases

- Endoscopy
- Dental theatres & surgeries

Air scrubber clearance calculator

1 How do I calculate the Clearance '(Effectiveness)' of air de-contamination after a Fallow Period given the Number of Air Changes per Hour?

Num air changes per hour: [ ] Info

Fallow Period[mins]: [ ] Info

Go Clearance[%]: [ ] Clear

2 How do I calculate the total Number of Air Changes per Hour for a given Clearance and Fallow Period?

Required Clearance[%]: [ ] Info

Required Fallow Period[mins]: [ ] Info

Go Num air changes per hour: [ ] Clear

3 How do I calculate the Equivalent Num of Air Changes per Hour of an Air Scrubber given the device's Flow Rate and the Room Dimensions?

Room Height[m]: [ ]

Room Length 1[m]: [ ]

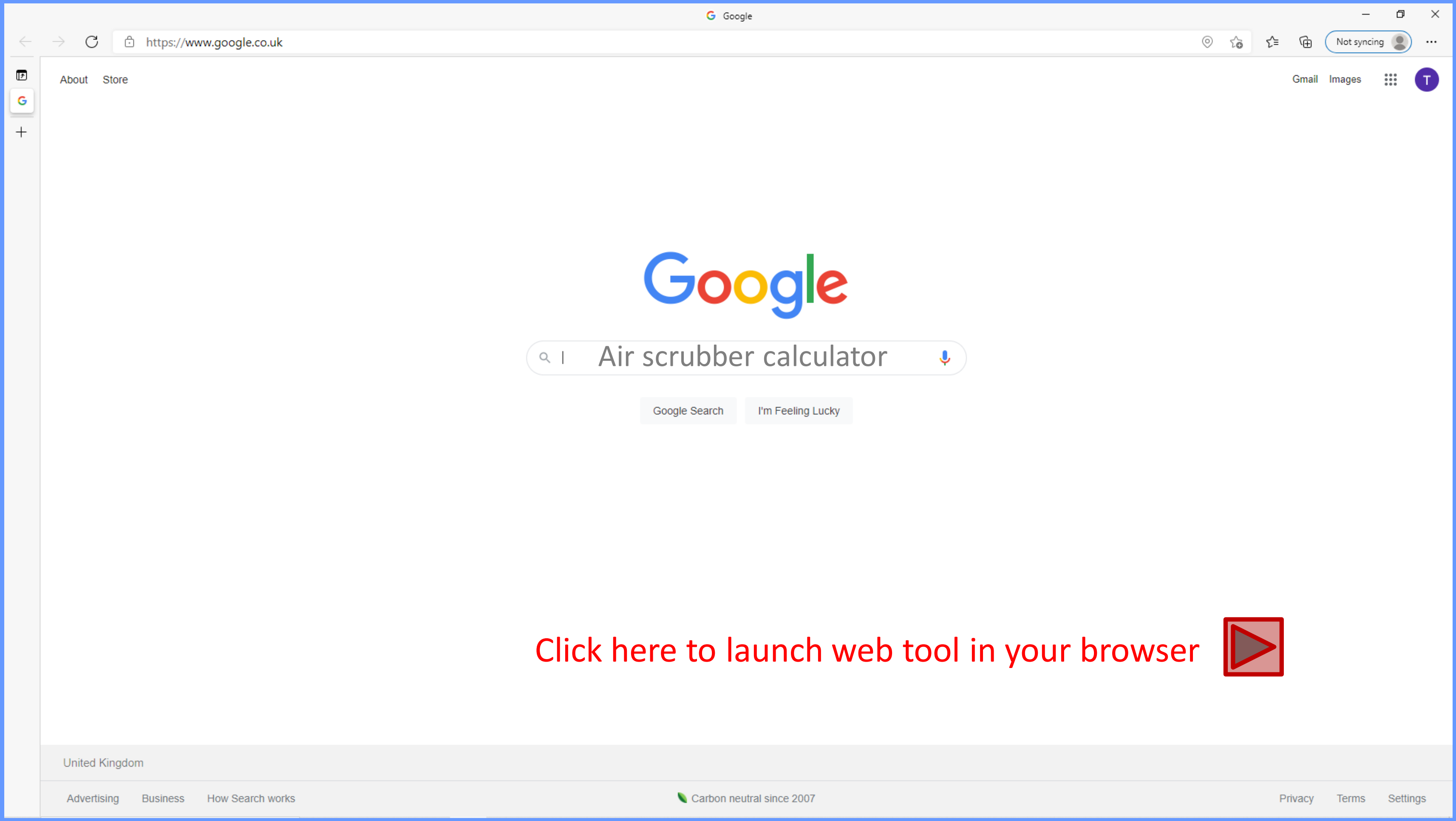
Room Length2[m]: [ ]

Air Scrubber Flow Rate[cubic m per hour): [ ] Info

Go Equivalent Num of Air Changes per Hour: [ ] Clear

Simple Air Scrubber Calculator assuming 'good mixing' and 1st order kinetics. Pls note: this code is not bombproof: MatLab code available. Tony Fisher Liverpool 26:xi:2020

UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?



Click here to launch web tool in your browser

Simple design study: effect of air scrubber

Given:

i. Existing HVAC = 5 ACH
ii. Existing 'chosen' Fallow Time = 30 minutes
iii. What is the Clearance? X … this is a target

Design for reduction in Fallow Time (30 > 10 minutes):

i. Target Fallow Period 10 minutes Y… this is a target
ii. What is the Clearance from above? X
iii. How many ACH do we need to achieve this?

$$ACH_{Total} = ACH_{HVAC} + ACH_{Air\_scrubber}$$

Calculate $ACH_{Air\_scrubber}$ (given X and Y from above)?

Is this enough to achieve our Clearance within our new 10 minute Fallow Time?

Simple design study: effect of air scrubber

Given:

i. Existing HVAC = 5 ACH

ii. Existing 'chosen' Fallow Period = 30 minutes

Fallow period decreased from 30 to 10 minutes

iii. What is the Clearance? X … this is a target

Clearance increased from 91.8 to 98.0% (bonus!)

Design for reduction in Fallow Time (30 > 10 minutes):

i. Target Fallow Period 10 minutes X … this is a target

Caution … assuming simple air mixing model

ii. What is the Clearance from above? X

iii. How many ACH do we need to achieve this?

$ACH_{Total} = ACH_{HVAC} + ACH_{Air\_scrubber}$

Calculate $ACH_{Air\_scrubber}$? Is this enough to achieve our Clearance within our 10 minute Fallow Time?

UV air scrubbing can reduce inter-patient fallow periods … Where's the evidence?

Guardian
24th May 2021

NHS

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COVID-19 engineering control measures

Frank Mills,

Chartered Engineer, FCIBSE, FIMechE, MASHRAE

Past Chair, CIBSE Healthcare Group and member of CIBSE Covid advisory group

Chair, Construction and Building Services Division, Institution of Mechanical Engineers

Founder member of Institution of Mechanical Engineers Covid 19 Task Force

Member of ASHRAE TC 9.6, Healthcare and joint lead author NZ Hospital guide

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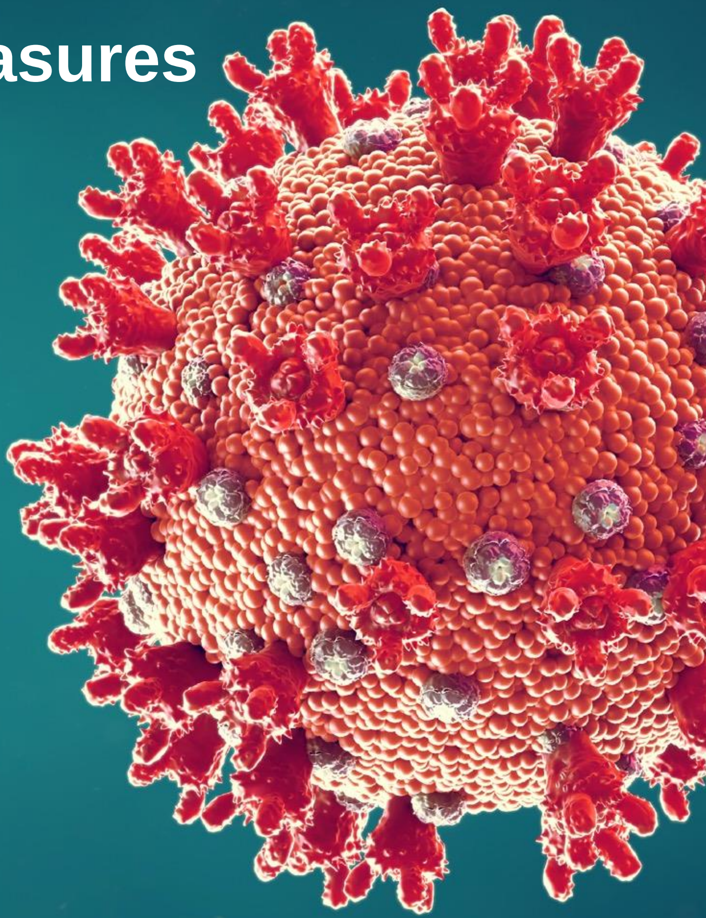
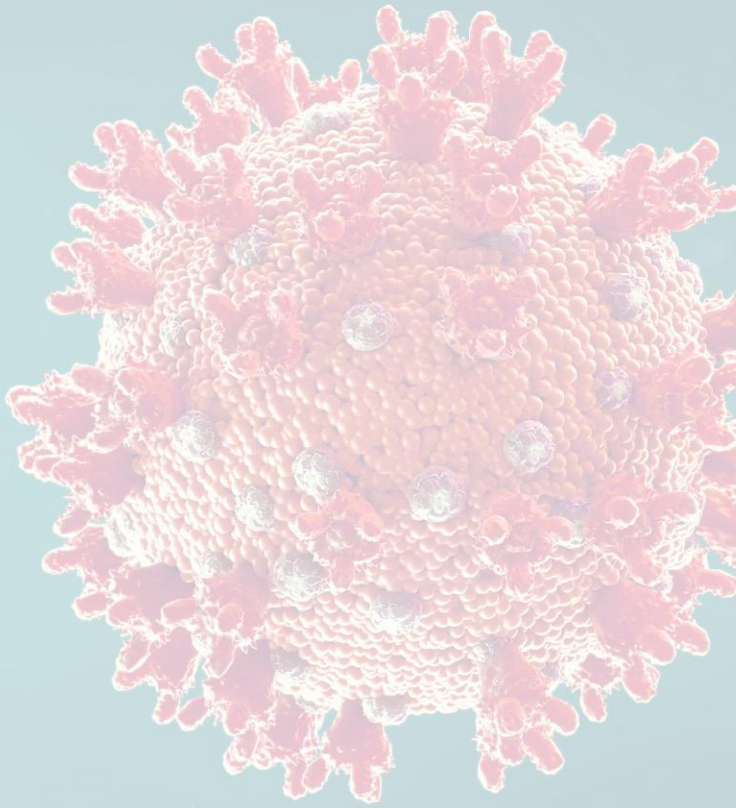


Outline / Agenda

- Engineering infection controls

- Ventilation and ventilation EFFECTIVENESS
- Natural ventilation
- Mechanical ventilation
- ‘Fresh air’
- Recirculated air

❖ Filtration options
❖ What is UV and how can we use it?
❖ Resources available to help
- CIBSE
- IMechE
- ASHRAE
- Others ….



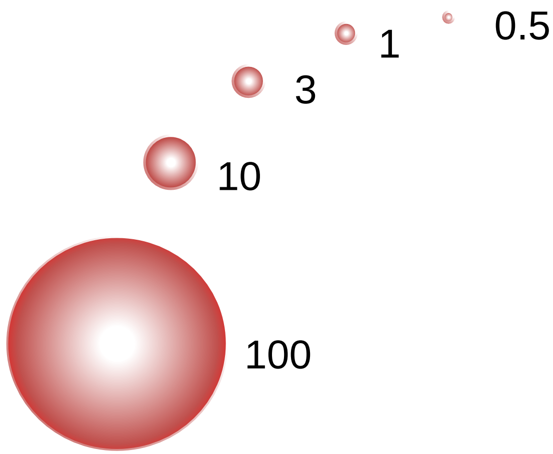
COVID infections are spread through the air…..

- Ventilation systems can spread infection – or can stop it
- Ventilation Engineers control indoor environment and therefore factors affecting airborne infection risk
- Covid 19 is spread by droplets and aerosols from mouth
- Large droplets – above 10µ– fall to surfaces within 3m and can be spread by touch.
- Small droplets and aerosols – less than 10µ – float in airstream and can drift a long way – 10m plus.
- **BUT:** large droplets can become small as they evaporate moisture and then stay floating. How far can they float ?

Droplet diameter in microns (um)

Float time

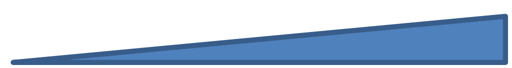
Droplets emitted from mouth vary from large – 100 micron - to very small - 0.5 micron. Large land on surfaces but small can float away and behave like an aerosol floating in airstream.



41 hours – 21 days

1.5 hours

6 seconds

Distance travelled: 1m  10m+

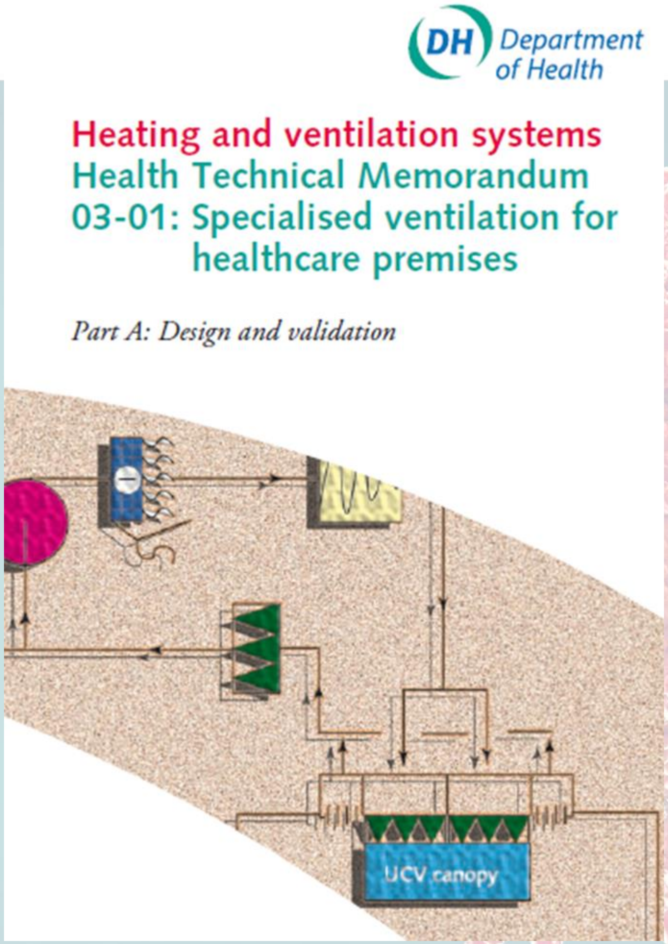
HTM 03 Ventilation for Healthcare

Sets out ventilation requirements

For Treatment rooms the MINIMUM ventilation is 10 air changes per hour.

HTM 03 still asks for FULL outdoor air.

Recirculation can only be allowed of the recirc air is CLEAN



Ventilation – Natural or Mechanical

- Ventilation for air quality, thermal comfort and infection control
- Natural Ventilation limited to normal ward area
- All other medical areas must have **mechanical** ventilation
- Treatment areas need 10 air changes
- Operating theatres need 20 to 30 ACH

High Efficiency Particulate Arresters - HEPA

Best grade of air filters
Only used in specific hospital areas such as Pharmacy
See table from HTM 03
Filter imposes a high pressure drop – so needs hefty fan power
Consequently lots of energy used
Filter collects bacteria and viruses – becomes a bio hazard
Filters get dirty and need changing – maybe as often as 6 months.
Requires very careful filter changing (treated like a bio bomb) in UNOCCUPIED area.
Fitting new filter is skilled and costly.
Should be tested using certified agent

BS EN 1822 grade (Eurovent grade)	% Efficiency at most penetrating particle size (MPPS)	Notes and typical healthcare applications
H10 (EU10)	85	Ultra-clean theatre terminal
H11 (EU11)	95	
H12 (EU12)	99.5	
H13 (EU13)	99.95	
H14 (EU14)	99.995	Pharmacy aseptic suite Category 3 room extract
U15–U17	–	Not generally used in healthcare

UVent – Air Sterilisation Systems

UVent
ultra-clean air from Mansfield Pollard

- UV-C air sterilising systems – 3 options
- Deactivates airborne pathogens through Ultraviolet Germicidal Irradiation (UVGI)
- Must present independently tested, guaranteed performance and results.

Public Health England
Porton Down

UNIVERSITY OF LEEDS

UNIVERSITY OF BRADFORD

A suite of UV-C products to suit any application and environment

ultra-clean air from Mansfield Pollard

MOBILE UNIT

- Flexible
- Portable

CEILING JET

- Compact
- Quiet

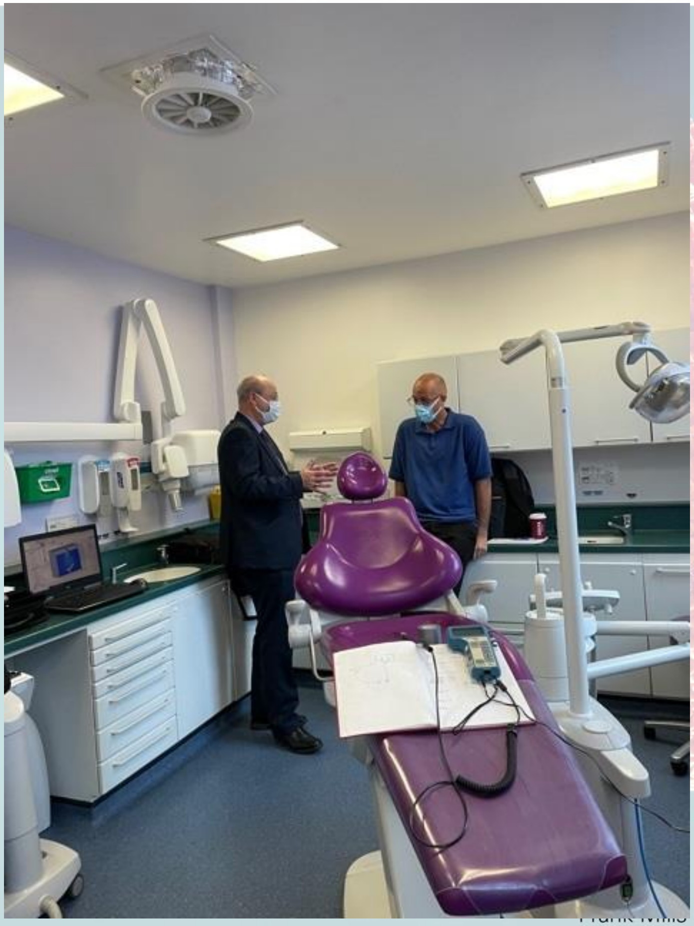
IN-DUCT

- Powerful
- Scalable

Dental surgery room 202

Chair not central due to
furniture layout
Grille offset

4 way throw ‘mixing’
grille replaced with
downflow swirl diffuser

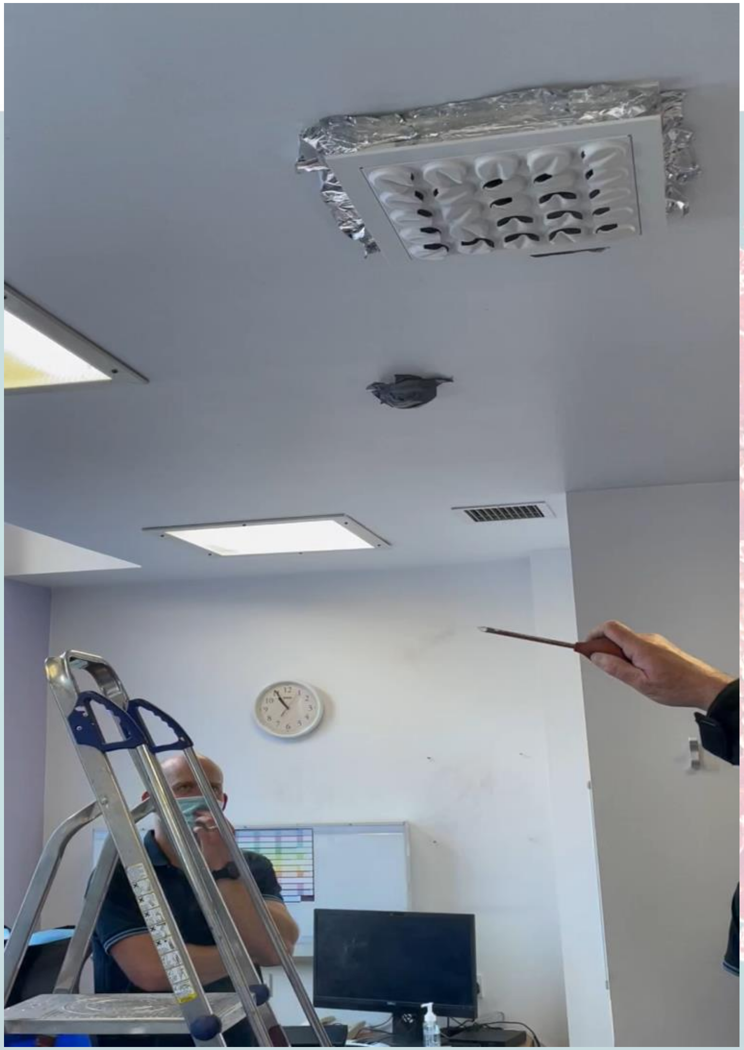


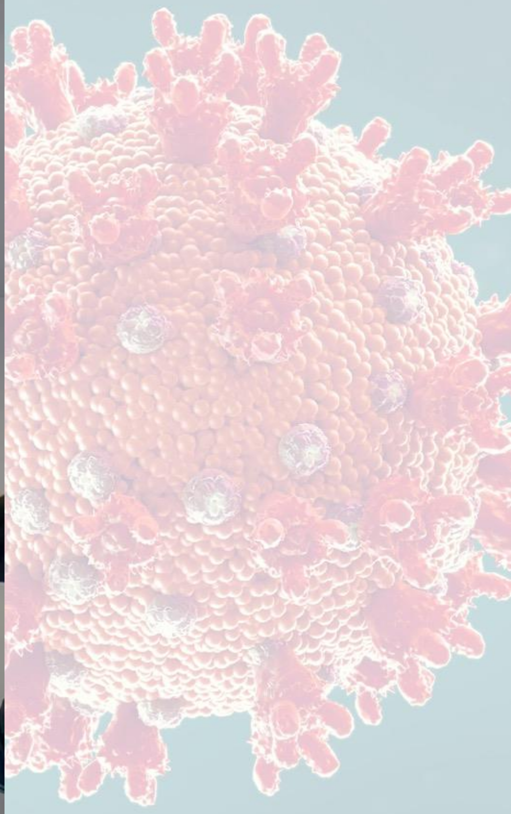
Downflow swirl diffuser – forms a vertical cone of air flow toward floor

Downflow type MN diffuser – forms a vertical flow of air toward floor

Adjustable to send air flow toward chair – about 10 degree offset

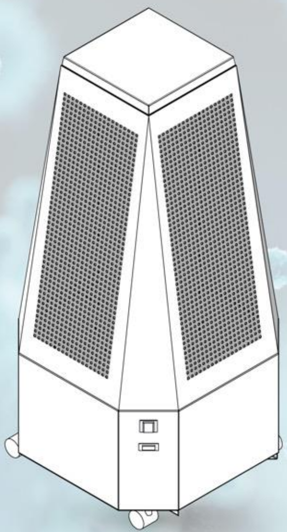
Downflow grille type MN adjusted to offset flow over chair





UVent – Mobile

UVent
ultra-clean air from Mansfield Pollard



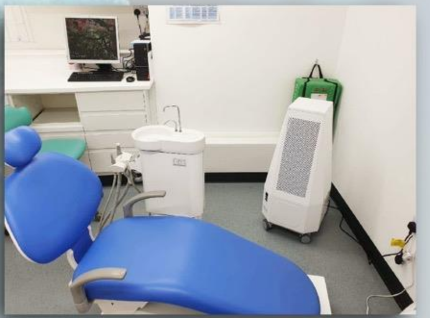
360m³/h
unit airflow capability

80m³
sterilised air distribution zone

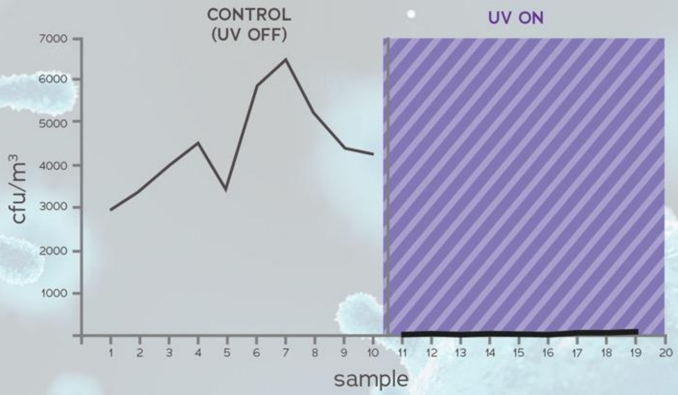
40dB(A)
ultra-quiet operation

13,000h
ultra-long lamp life

- Plug and play
- High pulse operation for immediate room purging
- Portable to sterilize any specific space



UVent – Ceiling Jet

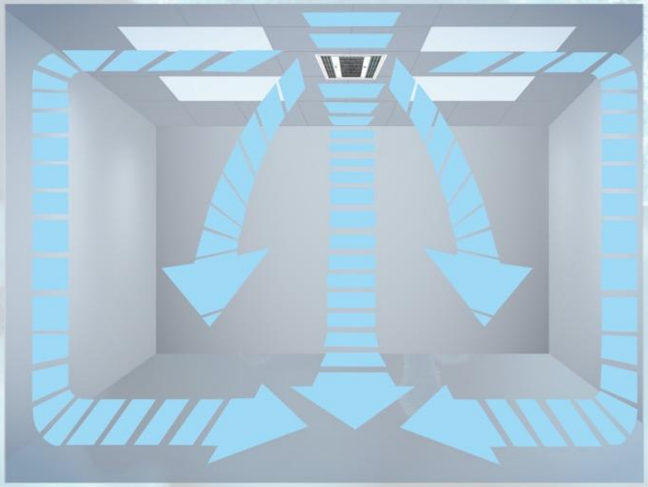


>99%
KILL PERCENTAGE

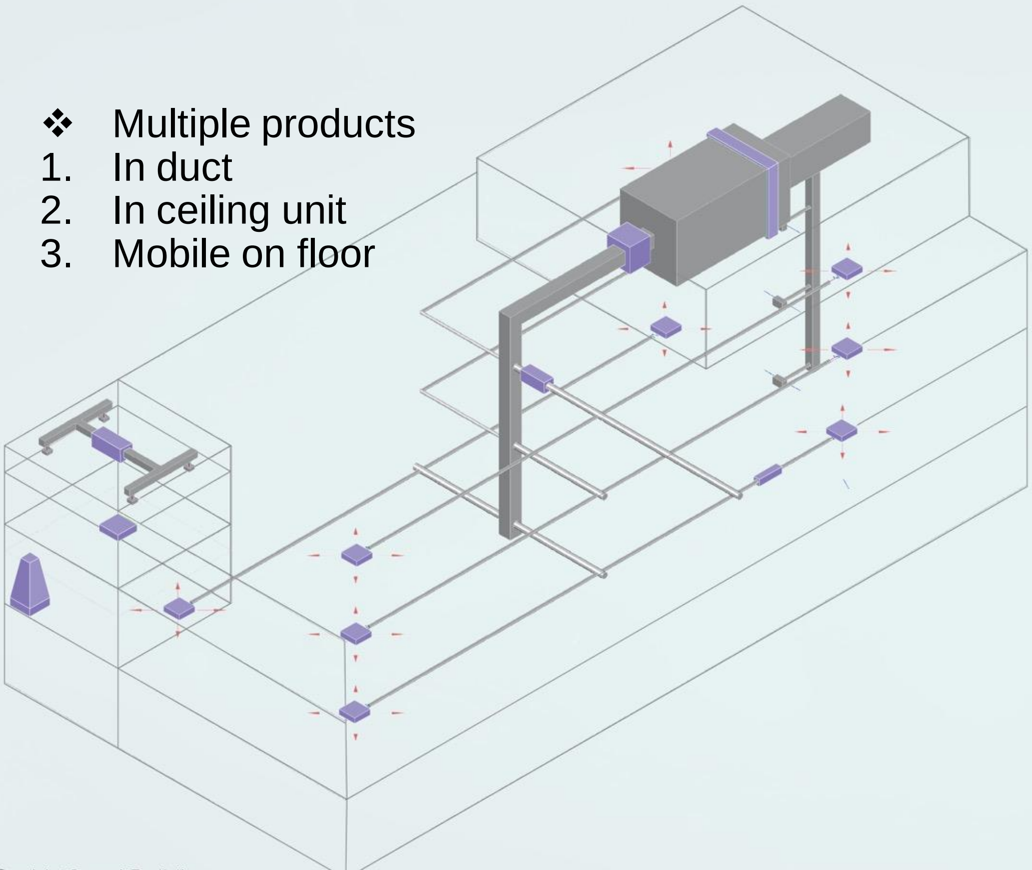
UVent
ultra-clean air from Mansfield Pollard

Performance tests carried out in partnership with ***Pathogen Control Engineering Research Group*** at the School of Civil Engineering, ***University of Leeds***

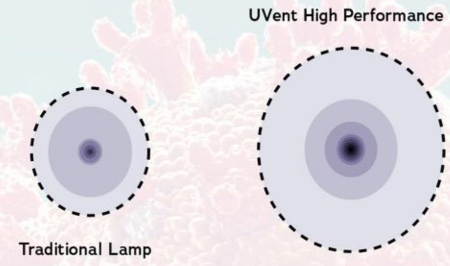
UNIVERSITY OF LEEDS



A Total Air Sterilisation System



- ❖ Multiple products
1. In duct
2. In ceiling unit
3. Mobile on floor

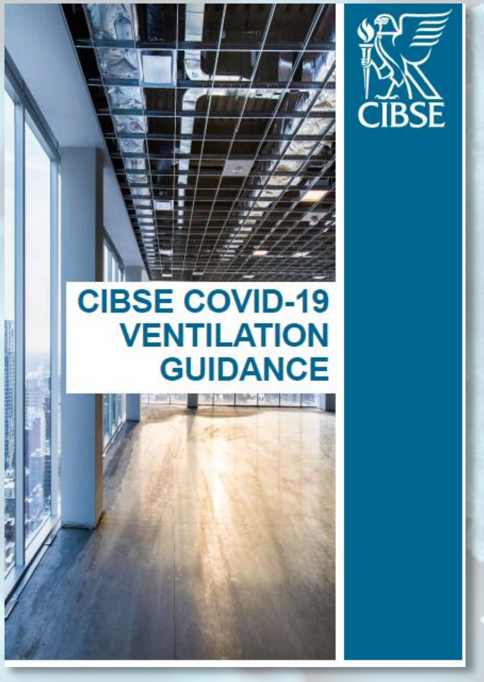


- ❖ Maximum dwell time
- ❖ Maximum kill zone

- ❖ Maximum irradiation intensity

CIBSE: Guidance on Re-opening

- www.cibse.org/Coronavirus-(COVID-19)



Residential Care Task Group

Helping Residential Care Facilities | Updated 6-9-2020

Introduction

- Extended Care
    - Nursing Homes
    - Hospice
    - Assisted Living
    - Memory Care
- Post-Acute
- Long Term

General Best Practice Recommendations

- Create Communities
- Resident Screening
- Employee/Staffing
- Risk/Quality of Life
    - Resident Isolation
    - Technology
    - Socialization
- New residents to facility
- Returning recovered resident to facility
- Facility Entry
    - Screening/Testing Room
    - Temperature
    - Touch screen & surface contaminants
    - Extra masks
    - Sanitizer

Aims & Objectives

Cleaning and Disinfection

- UVGI – Frank Mills
- Cleaning – Jane Rhode
- Hydrogen Peroxide -Jerry
- Materials and Surfaces - Jane Rhode

HVAC Solutions

- Filtration - Mike
- Positive vs Negative Pressure - Mike
- Role of an Ante-Room
- Air Device Placement
- Common vs Patient Treatment Areas
- PTAC vs other systems

Infection Control Engineer

- An infection control engineer is qualified and has experience in ventilation for safe and healthy premises.
- Understands the science – COVID virus and its transmission routes
- Knows the solutions – what to do to protect people and their spaces
- Carries out site checks and investigations
- Identifies problems & finds solutions
- Oversees and signs off works

ASHRAE Handbook UV chapter 62

- Ultraviolet light sterilises air by ‘killing’ bacteria and viruses
- UV is harmful to humans so must always be shielded from view/body
- UV performance depends on intensity and dwell time
- So air must pass close to lamps and at slow speed

CHAPTER 62

ULTRAVIOLET AIR AND SURFACE TREATMENT

ULTRAVIOLET germicidal irradiation (UVGI) uses short-wave ultraviolet (UVC) energy to inactivate viral, bacterial, and fungal organisms so they are unable to replicate and potentially cause disease. UVC energy disrupts the deoxyribonucleic acid (DNA) of a wide range of microorganisms, rendering them harmless (Brickner et al. 2003; CIE 2003). Early work established that the most effective UV wavelength range for inactivation of microorganisms is between 220 and 280 nm, with peak effectiveness near 265 nm. The standard source of UVC in commercial systems is low-pressure mercury vapor lamps, which emit mainly near-optimal 253.7 nm UVC. Use of germicidal ultraviolet (UV) lamps and lamp systems to disinfect room air and air streams dates to about 1900 (Reed 2010). Riley (1988) and Shechmeister (1991) wrote extensive reviews of UVC disinfection. Application of UVC is becoming increasingly frequent as concerns about indoor air quality increase. UVC is now used as an engineering control to interrupt the transmission of pathogenic organisms, such as *Mycobacterium tuberculosis* (TB), influenza viruses, mold, and potential bioterrorism agents (Brickner et al. 2003; CDC 2002, 2005; GSA 2010; McDeVitt et al. 2008; Rudnick et al. 2009).

UVC lamp devices and systems are placed in air-handling systems and in room settings for the purpose of air and surface disinfection (Figure 1). Control of bioaerosols using UVC can improve indoor air quality (IAQ) and thus enhance occupant health, comfort, and productivity (ASHRAE 2009; Menzies et al. 2003). Detailed descriptions of UVGI components and systems are given in Chapter 17 of the 2016 *ASHRAE Handbook—HVAC Systems and Equipment*. Upper-air (also commonly called upper-room) devices are installed in occupied spaces to control bioaerosols (e.g., suspended viruses, bacteria, fungi contained in droplet nuclei) in the space. In-duct systems are installed in air-handling units to control bioaerosols in recirculated air that may be collected from many spaces, and to control microbial growth on cooling coils and other surfaces. Keeping the coils free of biofilm buildup can help reduce pressure drop across the coils and improve heat exchanger efficiency (therefore lowering the energy required to move and condition the air), and eliminates one potential air contamination source that could degrade indoor air quality. UVC is typically combined with conventional air quality control methods, including dilution ventilation and particulate filtration, to optimize cost and energy use (Ko et al. 2001).

This chapter discusses these common approaches to the application of UVC products. It also surveys the most recent UVC design guidelines, standards, and practices and discusses energy use and economic considerations for the application of UVC systems. Photocatalytic oxidations (PCOs), another UV-based HVAC application, are not discussed in this chapter, but are addressed in Chapter 47 of this volume.

1. FUNDAMENTALS

Ultraviolet energy is electromagnetic radiation with a wavelength shorter than that of visible light and longer than x-rays (Figure 2). The International Commission on Illumination (CIE 2003) defines the UV portion of the electromagnetic spectrum as radiation having wavelengths between 100 and 400 nm. The UV spectrum is further divided into UVA (wavelengths of 400 to 315 nm), UVB (315 to 280 nm), UVC (280 to 200 nm), and vacuum UV (VUV; 200 to 100 nm) (IESNA 2000). The optimal wavelength for inactivating microorganisms is 265 nm (Figure 3), and the germicidal effect decreases rapidly if the wavelength is not optimal.

UV Dose and Microbial Response

This section is based on Martin et al. (2008).

UVGI inactivates microorganisms by damaging the structure of nucleic acids and proteins at the molecular level, making them incapable of reproducing. The most important of these is DNA, which is responsible for cell replication (Harm 1980). The nucleotide bases (pyrimidine derivatives thymine and cytosine, and purine derivatives guanine and adenine) absorb most of the UV energy responsible for cell inactivation (Diffey 1991; Setlow 1966). Absorbed UV photons can damage DNA in a variety of ways, but the most significant damage event is the creation of pyrimidine dimers, where two adjacent thymine or cytosine bases bond with each other, instead of across the double helix as usual (Diffey 1991). In general, the DNA molecule with pyrimidine dimers is unable to function properly, resulting in the organism's inability to replicate or even its death (Diffey 1991; Miller et al. 1999; Setlow 1997; Setlow and Setlow 1962). An organism that cannot reproduce is no longer capable of causing disease.

UVGI effectiveness depends primarily on the UV dose (D_{UV}, µJ/cm^2) delivered to the microorganisms:

$$D_{UV} = It \qquad (1)$$

where I is the average irradiance in µW/cm^2, and t is the exposure time in seconds (note that 1 J = 1 W/s). Although Equation (1) appears quite simple, its application can be complex (e.g., when calculating the dose received by a microorganism following a tortuous path through a device with spatial variability in irradiance). The dose is generally interpreted as that occurring on a single pass through the device or system. Although the effect of repeated UV exposure on microorganisms entrained in recirculated air may be cumulative, this effect has not been quantified, and it is conservative to neglect it.

The survival fraction S of a microbial population exposed to UVC energy is an exponential function of dose:

$$S = e^{-kD_{UV}} \qquad (2)$$

where k is a species-dependent inactivation rate constant, in cm^2/µJ. The resulting single-pass inactivation rate η is the complement of S:

$$\eta = 1 - S \qquad (3)$$

The preparation of this chapter is assigned to TC 2.9, Ultraviolet Air and Surface Treatment.

62.1

Conclusion - Dental surgery

Upgrade existing ventilation to achieve downflow across patient
Increase air change rate from 5 to 10+ by adding recirculation UV air cleaner

UV technology is the easiest and most effective way of destroying airborne pathogens including coronavirus

OVERVIEW AND UPDATE ON WORK IN NHS WALES

170 UVC Air Sterilisers purchased and installed in C&V

- Used within the Dental teaching units across Cardiff.
  - Feedback from Clinical lead is positive.

Mansfield Pollard UVent units were introduced onto our SARS-CoV-2 ward within Withybush Hospital, West Wales.

- The UVC sterilisers were strategically placed within each of the single occupancy, four bed and five bed areas with overall room volumes of less than $50m^3$.
- Initial feedback from the clinical teams.
  - Quiet to run, two settings (normal & boost).
  - Staff can still work in the bays, no impact upon nursing staff working around them.
  - Ergonomics are good.
  - Patients can sleep comfortably with them on.
  - Patients walking can see them in the bay, no trip factor for dementia patients.

Nosocomial meeting with infection control and microbiology – agreement to use within Endoscopy, Dental and High risk ward areas.

Prof. Chris Hopkins

GIG CYMRU NHS WALES | Bwrdd Iechyd Hywel Dda Health Board

TRITECH Sefydliad Institute

Midlands Dental Practice Ventilation Project

Dental treatment-room ventilation

Aim

To support community dental practices in recovery of services by modelling ventilation in clinical spaces to improve efficiency, increase clearance and reduce fallow time.

Community dental practices with calculated air changes per hour (ACH) of less than 10 and where portable air cleaning devices have been introduced.

Community dental practices with calculated ACH of less than 10.

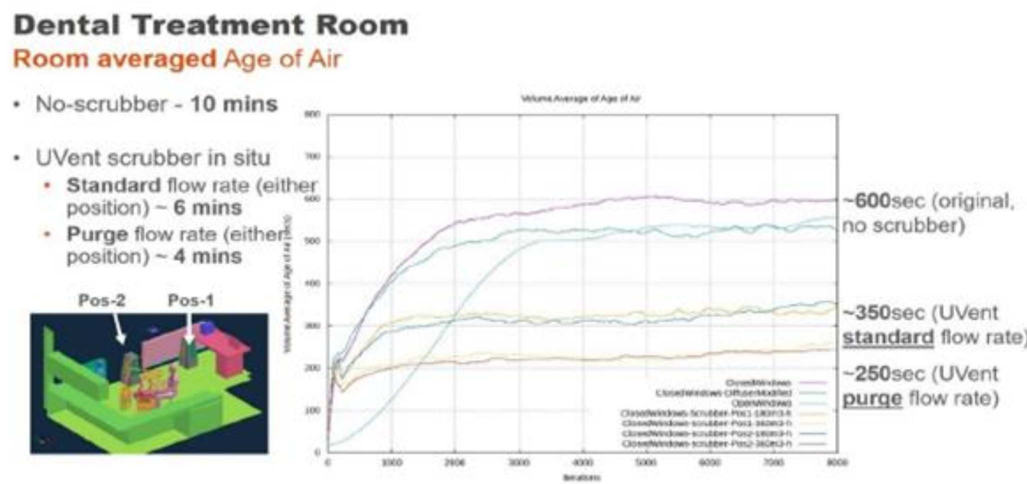
Community dental practices with no calculate ACH.

Method

- Using the Midlands dental specialty network identify 4-5 dental practices that can be enrolled into the project, prioritising facilities as described above.
- Using the national team expertise and experience to support the development of 3D models of current dental treatment rooms for each selected service.
- Air flow within the rooms will be calculated and computations fluid dynamics will be used to plot air clearance/clean air rates.
- Additional portable air cleaning devices will be introduced to the modelling to show benefits, highlight risk zones/areas of poor clearance and calculate fallow periods.
- Dental practices will be provided with an options appraisal to develop the safest environments possible using available air exchanges including access to Clinical Engineer support.
- Additional IPC advice will be available to share best practice from Trusts, General Practice and Pharmacy services, to support flow of patients and minimise risks of cross infection.
- Any changes to current practice as a result of this work will be identified, in particular improvements that result in greater patient access to dentistry

Outcomes

- Following our analysis of improvement in dental treatment room air flow management, we plan to widely disseminate the real world case studies as best practice examples for system wide learning. This will act as a Midlands blueprint to recovering safely.



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