# Ventilation in Healthcare Facilities

**Peter Hoffman, Public Health England**

**A Webber Training Teleclass**

## Ventilation in healthcare facilities

**Peter Hoffman**
Consultant Clinical Scientist
Antimicrobial Resistance and Healthcare Infections Reference Unit
Public Health England

**Hosted by Martin Kiernan**
Southport and Ormskirk NHS Trust
martin@webbertraining.com





## There are many reasons for ventilation. Infection control is an unusual one.

Comfort, "fresh air"; removal of machine or solar heat gain, other temperature control

Removal of excess humidity (e.g. hydrotherapy pools), smells, toxic, flammable or explosive gases

**Control & dilute airborne pathogens** (*a very small sector of the market – few technical experts*)

 

## Ventilation & infection control

Health Technical Memorandum (HTM) 03-01 "Specialised ventilation for healthcare premises" in 2 parts: "Design & validation" and "Operational management and performance verification" (was HTM 2025 until late 2007).

HTM 03-01 "*applies to new installations and major refurbishments of existing installations*", so presumably HTM 2025 still applies to installations pre-existing (or designed before?) late 2007

*This and other Estates guidance is available at the www.gov.uk website*

 

## Ventilation

There are competing priorities in ventilation. Natural ventilation is currently encouraged (green issues). There are ways of using natural ventilation in a more sophisticated way than just open windows ("wind driven" and "stack" ventilation), but these have not yet been used in UK hospitals.

NATURAL -
*FOR*: Cheap, low carbon footprint
*AGAINST*: Lack of control of magnitude and direction.

MECHANICAL
*FOR*: Control & comfort (sometimes only in theory)
*AGAINST*: Expense (installation & maintenance)

The tendency is to use natural ventilation wherever possible and only use mechanical ventilation where control of airflows is really needed.

 

## Balanced vs cascade systems

***BALANCED***: Air is both supplied and extracted from an area. It is sometimes intended that supply exceeds extract (resulting in positive pressure) or vice versa (negative pressure). **This is how "normal" ventilation is set up**.

***CASCADE***: Air is either supplied or extracted from an area. It is arranged so that different rooms in a suite have air flowing from one to another (clean to dirty). This too will provide positive or negative pressure. **This is how systems that require a high degree of contaminant control are designed**.

 

## Filters: BS EN 779
Grades "EU" 1 – 9

Grades G1 - 4 in terms of "arrestance" - the weight of a standard dust retained on a filter

Grades F5 - 9 in terms of "efficiency"- by the passage of a finer dust through a filter (for finer filters).

*Neither of these has direct microbiological relevance.*

 

## Fine filters
BS EN 1822

HEPA: "*high efficiency particulate air*"

ULPA: "*ultra low penetration air*"

Grades H10 to H14 and U15 to U17

Uses particles of microbiologically relevant size (around 0.4µm).

Grades from 15% passage through filter (H10) to 0.000005% passage (U17)

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## Air handling unit

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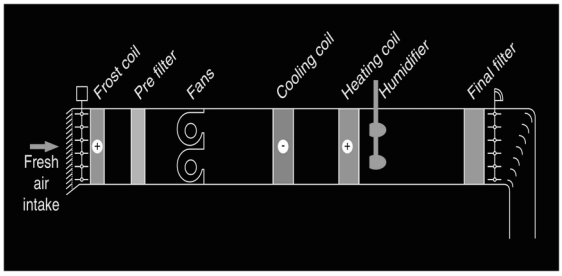
## Air handling unit

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## Air filters – position

Final filters on air supplies to critical areas must be *after* the fan

*After* the fan, the ductwork is under positive pressure; the system will tend to leak outwards. If the filter is *before* the fan, there will be strong ingress through any holes between filter and fan.

If the final filter is *before* the fan, this can lead to high fungal spore counts in the theatre supplied – ingress of outdoor air with a high fungal spores content into the air handling unit.

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## Air filters - monitoring

You can't tell how badly blocked a filter is by looking at it.

Filters are best monitored by measurement of the pressure differential across them. It should be within a range specified by the manufacturer for that particular filter

- Any holes or improper seating will result in a low pressure differential; blockage will result in a high pressure differential.

*Do not sample filters: Sampling filters just lets you know what they have retained and does not implicate them as a source.*

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## Sources of airborne contamination in operating theatres

People are constantly shedding dead skin cells ("squames"), each around 15µm in diameter.

The rate of shedding increases with movement.

A proportion of these will carry colonies of the bacteria that grow in skin.

These colonies can contain anything from 1 to 1,000 bacterial cells.

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1000 litres air in an empty room

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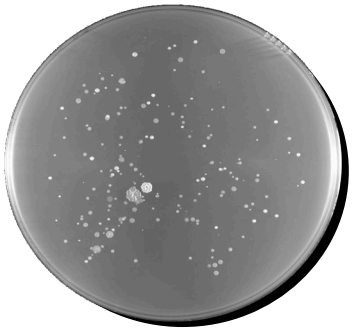

1000 litres air - person walking by sampler

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## Ventilation – operating theatres

The majority of airborne contamination in an operating theatre is generated by the staff.

The purpose of operating theatre ventilation is to prevent bacteria from settling-out in "the wound".

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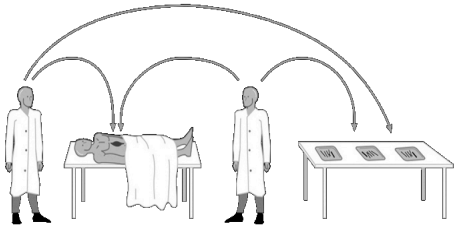
## Pathways of airborne theatre wound contamination



Probably the majority of airborne bacteria that end-up in a surgical wound, do so via exposed instruments.

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## Ventilation – operating theatres

- The purpose of theatre ventilation is to
  - Dilute contaminants generated in theatre
  - Prevent airborne ingress from surrounding areas
- This is achieved by a hierarchy of cleanliness - filtered air supplied to those areas where it is most critical, from which it is encouraged to pass to progressively less critical areas.
- In doing this, it dilutes contamination generated in the critical areas and flushes it out to less clean areas.
- As it passes out to surrounding areas, it prevents air flowing in the opposite direction, i.e. back into the theatre

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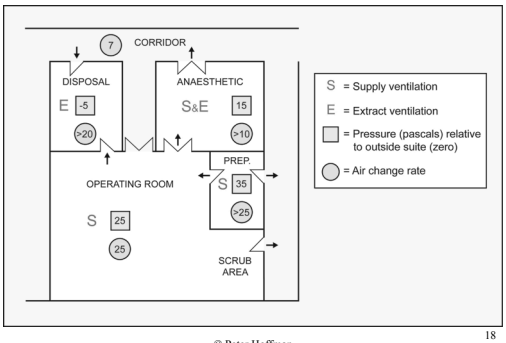
## Conventionally ventilated theatre suite

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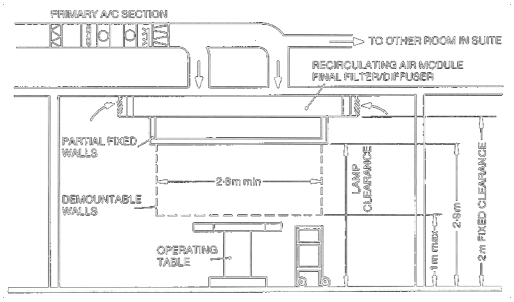
## Ultraclean ventilated (UCV) theatre






## Ventilation standards

Physical standards are based on magnitude and direction of airflow.

Microbiological standards can be used as checks on physical standards, but are secondary to them.

**The microbiology should only be done after all other commissioning tests are satisfactory**.

Microbiology cannot, of itself, assure a theatre is fit for use.



## Air change rates

Air change rate: divide the air supplied to, or extracted from, a room by the volume of the room (e.g. a 50m$^3$ room supplied with 200m$^3$ air per hour = 4 ACH).

- In new theatres: 25 ACH
- In new prep rooms: 25 ACH or greater

*This is new facilities. A 25% drop-off is allowed as the machinery ages – so should always have around 19 ACH or above*.

The magnitude of the pressure differentials is not important – just that air is flowing robustly in the correct direction.



## Microbiological standards

Air supplied to a conventional theatre (i.e. in an unoccupied theatre):

- Less than 10 CFU m$^3$ (was 35 in old guidance)

In a working theatre:

- Less than 180 CFU m$^3$ (averaged over 5 minutes)

However, if the engineering parameters are all satisfactory, failure could only be because of poor practice (too many people, doors propped open etc.). So microbiological sampling can only confirm what should be readily observable and really amounts to propaganda.

*Sampling at time of high activity will give higher counts than in quieter periods*.



## How to take an air sample for commissioning

- Use pre-incubated plates to ensure no plate contaminants
- Set the sampler up on a clean surface in the theatre
- Load the agar plate
- Go to a separate area at lower air pressure (i.e. not the prep room). No-one else to enter the theatre.
- Wait 10 – 15 minutes then operate the sampler remotely
- Retrieve the plate once the sampler motor has stopped
- Taking a sequential duplicate sample is useful to confirm an unexpected result.
- Only need sample in one position in the theatre suite – it is the same air supplied to the whole theatre suite.



## Origins of (false) air contamination in theatre commissioning

- Sampling technique
  - People being in theatre when sampling, or starting the sampler then leaving (*leave sampler in empty theatre for 15 minutes and operate remotely*)
  - Being in an area where air flows into the theatre (*i.e. do not stand in the prep room*)
  - Plates are contaminated before or after sampling (*pre-incubate and keep firmly closed before and after use*)
  - Allowing the sampler or air pump to resuspend dust from the floor (*on trolley or on a physically clean floor. Allow sampler to run empty for a while before loading plate*)
- Ventilation only just turned on after installation or work on it (*ventilation should have been running preferably for 24 hours, but at least for 3 hours*)



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## Origins of (real) air contamination in theatre commissioning

- Inadequate filtration
  - Too low a grade of filter (*should be F7 "EU7" or above – does not need to be HEPA in conventional theatre*)
  - Filter placement allowing air to bypass filtration (*filter element not abutting each other tightly, gaps between filter holder and duct, missing filter elements*)
- Improperly constructed air handling unit
  - Final filter before the fan causing ingress of air after final filter and before fan (all ductwork before the fan will be under negative pressure)
- Inadequate ventilation
  - Too low an air change rate (*not eliminating the contamination dispersed during sample setup*)
  - Air not distributed efficiently (*the right rate of air supply but short-circuiting out of the theatre and not diluting contamination*)
- Incorrect air movement between rooms
  - Contaminated air backtracking into theatre



## Unlikely explanations for theatre air contamination

- Environment not "clinically" clean
  - Sampling, if technique adequate, will only sample the air supplied, not the solid environment (*You do not sample a theatre's air after decoration work etc to prove environmental cleanliness*)
- Dirty ductwork
  - If particles in ductwork are light enough to lift into the air-stream, they will have been lifted long ago
  - If particles are too heavy to be lifted, they will not enter air stream
  - Contamination in ducts will not replicate – too dry
  - Microbiological sampling of ductwork meaningless
- Dirty filters
  - Filters have a range of pore sizes. The larger pores will let more air through and so will block up first. Thus the more filters block up, the more efficient at filtration they become; they just become less efficient at allowing air to pass . (Could possibly be a link with low air flow, but only if nearly completely blocked – cannot tell visually)

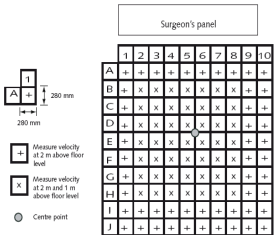


## UCV theatre validation

- Does not require microbiological sampling
- Validated by
  - Adequate air velocities under the canopy
  - Adequate fitting of the HEPA filters in the canopy such that particles cannot pass
  - Ability of the airflow under the canopy to resist ingress



## Air velocities under UCV canopy




(Diagram from guidance – misprint in column 2 – the "x"s should be "+"s)

At 2 m (+ & x squares), velocity should *average* 0.38 m/s (partial wall) or 0.3 m/s (full wall)

At 1 m (x squares), each velocity should not be *less than* 0.2 m/s



## THEATRE VENTILATION - issues

- Airing after dirty/infected operation?
  - Dilution will be rapid. Extra time may be needed for surface disinfection but not for air hygiene
  - Similarly for other disciplines wanting to use an "orthopaedic" UCV theatre
- Reducing ventilation when not in use?
  - Good economy measure to reduce or turn off ventilation. Must not happen inadvertently when theatre is in use (over-ride linked to movement sensors or theatre light). Turn on at least 30 minutes before use.



## Protective isolation

- Most HCAI would be transmitted to "susceptible" patients by non-airborne routes
- The only relevant airborne transmission would be to highly neutropenic patients
- Here the risk is inhalation of fungal spores, usually from the outside environment
- So all the air available for a patient to breathe must have passed through a HEPA filter

## Protective isolation

The only way to ensure that the only air available to breathe has passed through a HEPA filter is to ensure that all gaps in the room's integrity leak outwards, preventing ingress of unfiltered air. This is termed "positive pressure". Positive pressure is pointless without HEPA filtration.

So the filtered supply air must exceed extracted air (thus room under positive pressure), otherwise flow rates not important.

Some new BMT units have HEPA-filtered air supplied throughout the unit (with patient rooms at higher pressure), so that patients can venture outside their rooms. Central HEPA-filtration presents fewer monitoring & maintenance problems.

## Hospital MDRTB outbreak

Breathnach et al JHI (1998) **39** 111-7

- HIV-negative source patient
- Source patient in isolation room - under positive pressure
- 6 HIV-positive patients and 1 HIV-positive counsellor acquired the infection

Contact times with index patient between 33 days and less than one day

## More recent hospital TB outbreak

Jonsson et al. JHI (2013) **83** 321-6

- Sweden
- 4 patient contacts (2 with HIV) and 3 HCW (without HIV) developed TB within 10 months of death of HIV +ve patient with pulmonary TB
- Index patient isolation had been discontinued on a misdiagnosis of Pneumocystis
- Correlation between length of exposure and HCW TB acquisition

## Airborne source isolation rooms

- Prevent uncontrolled escape of pathogens (protect patients and staff outside room)
- Dilute pathogens inside room (protect staff and visitors)
- Two options currently around:
  - Negative pressure rooms
  - Positive pressure ventilated lobby (PPVL) rooms

## Isolation room guidelines

October 2012

DH Department of Health

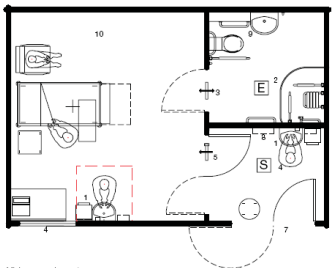
Isolation facilities for infectious patients in acute settings
**Version:1.0:England**

Describes two options.

1) Positive pressure ventilated lobby (PPVL) rooms
2) Negative pressure rooms

## PPVL isolation room




Needs to be leak tested to ensure minimal leaks on commissioning and periodically thereafter

## Negative pressure rooms

- A room where more air is extracted than supplied.
- Can leak, but leak inwards
  - Actual value irrelevant except insofar as it can be monitored. Pressures below 5 pascals cannot reliably be monitored.

Can be monitored by:

- Electronic gauge with remote (delayed) alarm (excellent)
- Mechanical gauge recorded regularly (adequate)

Need air change rate compatible with patient comfort for long-term isolation (10 air changes per hour), but less so for temporary occupation (e.g. bronchoscopy rooms) which can have higher rates.

## Air change rates and dilution

One air change removes 63% airborne contamination (assuming perfect air mixing).

| Air changes | Contamination remaining (%) |
|---|---|
| 0 | 100 |
| 1 | 36.8 |
| 2 | 13.5 |
| 3 | 5 |
| 5 | 0.67 |
| 10 | 0.0046 |

A typical bronchoscopy room for TB-risk patients has around 30 air changes per hour, equivalent to one air change every 2 minutes, five air changes (>99% removal) every 10 minutes.

## Negative pressure rooms: extracted air

- If the point of emission is not near intakes or windows, nor is in people's breathing zones, it does not need to be filtered
  - If it is filtered, care with changes of HEPA and pre-filters. These will concentrate infectious particles

## Solutions that last are either

i) simple and robust

ii) have complexity, but are monitored


*May 15* **METHODS TO EVALUATE HAND HYGIENE PRODUCTS**
*Dr. Timothy Landers, Ohio State University*
*Dr. David Macinga, GOJO Industries*

*May 26* *(Free ... Broadcast Live from IPAC-Canada Conference)*
**TOO POSH TO WASH**
*Martin Kiernan, Southport and Ormskirk NHS Trust, UK*

*May 27* *(Free ... Broadcast Live from IPAC-Canada Conference)*
**INFECTION CONTROL IN LONG TERM CARE**
*Tina MacNamara, Queen Elizabeth II Health Centre, Halifax, Nova Scotia*
*Jim Gauthier, Providence Care, Kingston, Ontario*

*June 5* **COME HELL OR HIGH WATER – INFECTION CONTROL DURING AND AFTER FLOODS**
*Gwyneth Meyers & Barbara Long, Alberta Health Services, Calgary, Alberta*

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