Ventilation in healthcare settings: *A user guide*

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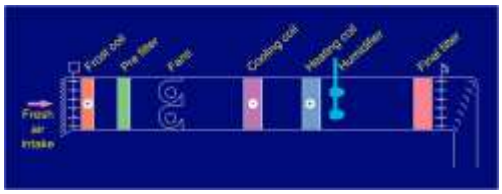
Where it all starts: the air handling unit

Air handling unit (AHU) anatomy



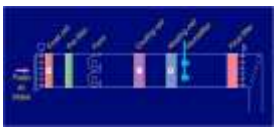
Then to a branching network of ducts. One AHU can supply a large area in a building. All that supplied air will be of the same quality.

Air filters – position

Final filters for air supplied to critical areas must be *after* the fan

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

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



The final filter controls the microbial air quality Relevant filter standards

EN 779 (Recently superseded). Based on weight percentage retention of standard dusts. Vague microbiological relevance.

ISO 16890 Filters assessed by percentage retention of particles ("PM" = particulate matter) at PM_1 (1µm), $PM_{2.5}$ (2.5µm) and PM_{10} (10µm). More microbiological relevance.

EN 1822 High efficiency particulate air (HEPA) filters. Tested at each filter's most penetrating particle size (usually around 0.2µm). Grades within this from 85 to 99.995% retention. (ISO 29463 runs in parallel with this standard).

- *Where HEPA filters really score is on their fit within their mounting, such that no air bypasses filtration. Fit can be more haphazard with other filters*.

Air filter monitoring

A filter becomes more efficient at removing particles as it blocks up (the large pores will block-up first); it just becomes less efficient at passing air.

A partially blocked filter will not be a source of air contamination.

A filter will impede airflow. This can be measured as an air pressure across the filter

As a filter blocks, this pressure will increase

- Filters are best monitored by measurement of the pressure differential across them. Manufacturers will supply a pressure range for a specific filter in use.
- The filter gets changed when the pressure across it is at, or approaches, its upper limit.

1000 litres air in empty room

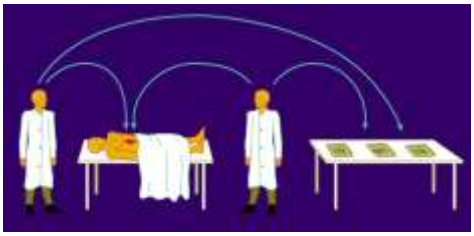
1000 litres air - person walking by sampler

Operating theatres

Aerobiologically, the dirtiest things in an operating theatre are the staff.

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

Pathways of airborne theatre wound contamination



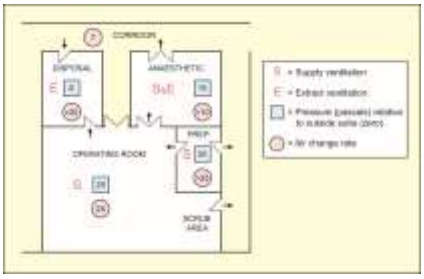
Probably around 70% of airborne microbes that end-up in a surgical wound were transferred there via surgical instruments, but highly variable.

Ventilation – operating theatres

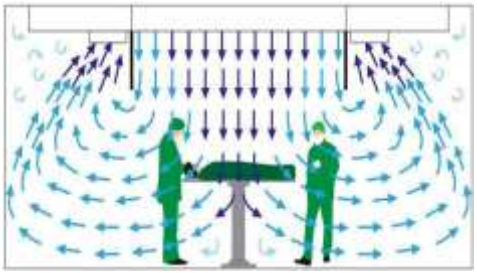
Conventional ventilation: Filtered air is supplied to the cleanest areas of the suite in high volumes, diluting contamination & flushing it out into less critical surrounding rooms. This direction of airflow prevents ingress of contaminated air.

Ultraclean ventilation: Highly filtered air is supplied in an organised ("laminar") downward flow to the central area of the theatre, rapidly removing contamination and preventing penetration of contamination from outside this clean zone.

Theatre suite – conventional ventilation



Ultraclean ventilation (UCV)



Air sampling in theatres

In new **conventionally ventilated** theatres – This should be the final part of the commissioning process.

If all the engineering is correct, it should not be necessary, but experience is that it can show undetected engineering problems.

Air sampling itself is only part of a wider validation process. It must not be used as the sole criterion of ventilation adequacy.

You should only air sample after you have been assured

- that the correct rate of air supply, in terms of air change rates, has been confirmed
- that air if flowing in the correct direction between room in the suite.

UCV theatres

Their validation is purely engineering:

- Air velocities under canopy
- Adequacy of the HEPA seal in their holders
- That the downward air flow resists ingress from the theatre periphery

How to take an air sample in a theatre

Use pre-incubated or irradiated, wrapped plates – medium of your choice

Make sure the ventilation is on and has been for at least 2 hours

Set the sampler and any air pump up on a clean surface. Good if the whole theatre is clean, but not essential

Leave the theatre and ensure it stays empty

Go to an area at lower air pressure (i.e. not the prep room)

Wait 10-15 minutes

Operate the sampler remotely (e.g. extension lead, IR zapper, pre-program …)

Retrieve the sample and ensure careful transport to incubation

Useful to take second, duplicate sample – to confirm unexpected result on the first

Only need to sample in one location – it's all the same air

Air sample results

The air supplied to the theatre (i.e. measured in an empty theatre) should have less than 10 colony forming units per cubic metre.

If more than 10:

Check sampling method. Most failed samples are from poor methods.

High fungal and/or Bacillus count: Check AHU construction and the possibility of air ingress from sources other than the supply system. Check the fit of the final filters – is air bypassing filtration? Inadequate final filter grade?

Skin flora – Mostly poor sampling technique. If not, suspect inadequate dilution - mainly inadequate air supply or short-circuiting.

Cleaning the theatre will not contribute to resolution.

Air sampling in working theatres?

There are recommendations that there should be no more than 180 cfu m^{-3} in a working **conventional** theatre.

Microbial numbers in air are a factor of the number of people in a space, their activity level and dilution.

If the dilution is OK, it will be people number and/or activity.

- If it needs X people to be in a theatre, sampling results cannot negate that need.
- If there are people in theatre who don't need to be there, you don't need sampling to tell you that is the wrong.
  - Are you really going to tell those in theatre to move around less??

What is the point of sampling?

Air sampling in working theatres?

There are recommendations that there should be no more than 10 cfu m^{-3} "*tested during surgical procedure at intervals between the time of first incision and final closure of the wound*" in an **ultraclean** theatre.

This is within 300mm of the wound – intimidating sampling.

This is just a test of that team's performance during that procedure and only at the times of sampling. It tells you nothing about more general use in the years to come. It cannot inform more general practice or engineering modification.

What is the point of sampling?

Routine air sampling?

A theatre's ventilation system will not change much year to year.

Changing filters like-for-like is not a substantial event.

- There is no need to do routine annual air sampling.

Is it often offered by external contractors as an extra to the annual engineering checks. It may not be done well and false positives may be generated.

Sampling in investigations

If high SSI rates are suspected or if there have been clusters of infection, the ventilation may often be blamed.

Ventilation is a fairly constant factor. If the ventilation rate is inadequate now, it is likely to have been so for many years. That could account for historically high infection levels, but not for a recent cluster of infection?

By all means look at the ventilation adequacy, but that alone is unlikely to be responsible – though may be part of a multifactorial pathway.

Microbiological air sampling might be useful, but only to demonstrate air quality is not the vital factor and allow focus on more productive, usually procedural, matters.

Isolation of infectious disease

Most will be contact and droplet spread – no requirement for specialist ventilation.

These just require a single room with ensuite shower/toilet. A lobby is useful space but not essential.

A few infections are know to be, or thought to be, transmissible via aerosols

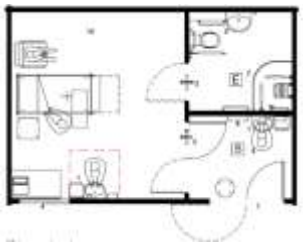
Very small, light particles that effectively form a solution in air ("aero" "sol")

Aerosols are a low efficiency mode of transmission

Two approaches to their containment

- Positive pressure ventilated lobby (PPVL) rooms
- Negative pressure rooms

HBN 4, supplement 1 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)

Airborne isolation – When?

- By guideline: MDRTB (proven or by risk assessment), TB if other patients not immunocompetent
- Other airborne infection? Varicella-zoster, viral haemorrhagic fevers, measles, sensitive TB (?), norovirus (?), (smallpox), *not pandemic flu outside specific "aerosol generating procedures"*

Other than these, controlling airflows is not thought important.

Protective isolation

Most infection would be transmitted to general "susceptible" patients by non-airborne routes

- The only relevant airborne transmission would be to highly neutropenic patients e.g. bone marrow transplants
- Here the risk is inhalation of fungal spores, usually from the outside environment
  - Significant mortality.
  - Clusters of aspergillus infection in highly immunocompromised patients also observed to coincide with building work

So all the air available for such a patient to breathe must have passed through a filter that can remove fungal spores

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.

There is no current UK guidance for such facilities

And for all specialist ventilated areas

- No opening windows