ENVIRONMENTAL CONTROLS: VENTILATION, NEGATIVE PRESSURE ISOLATION ROOMS, TENTS AND BOOTHs, AIR FILTRATION AND UVGI

Ventilation

1. The risk of a person acquiring infection with M. tuberculosis depends on the concentration of infectious droplet nuclei in the air and the volume of air inhaled (which primarily depends on the duration of exposure).

2. Building ventilation, whether natural or mechanical, serves to dilute droplet nuclei in the air and is the single most important engineering control in the prevention of transmission of airborne infections. However, while ventilation is important, it is one part of, and cannot be relied upon as the only, environmental strategy for protecting building occupants against tuberculosis transmission.

3. There have been no scientific studies of the effect of various levels of general building ventilation on tuberculosis transmission and current guidance is based on the use of ventilation to control odour and other indoor air contaminants. Advice should be obtained from a ventilation engineer, preferably one with experience in hospital infection control, in cooperation with the local infection control team.

4. Effective ventilation means that dilution of the air is achieved by removing contaminated air from the room and replacing it with air free of M.tuberculosis, ie outside air, air from a low-risk area in the building, or recirculated air which has been treated to kill or remove tubercle bacilli. Ventilation is expressed in terms of the room volume as air changes per hour (ACH).

5. Air currents may transport infection within rooms and buildings. The direction of airflow is therefore important to ensure that the clean air completely mixes with ambient room air. The outflow must also be safely exhausted so that it does not flow towards other patient areas. If air is both mechanically supplied and exhausted from a room, the supply rate must not exceed the exhaust rate in order to achieve this flow. In areas where a negative room pressure is required, the exhaust rate must exceed the supply rate by a generous margin.

6. The ventilation engineer should be consulted regarding the rates of flow sufficient for effective control without causing turbulence. Engineering and construction costs, operating costs, and occupant tolerance place upper limits on the amount of ventilation that is practical.

7. There is an absolute duty under Regulation 9 of the COSHH Regulations that all local exhaust ventilation plant should be thoroughly examined and tested at least once every 14 calendar months.

Negative pressure isolation rooms.
8. Ventilation dilutes airborne infectious particles but does not contain them. This requires the physical limits of an isolation room. Where it is essential to prevent the egress of contaminated air from an isolation room through the door (or other gaps) towards other patient areas, the air in the room must be at negative pressure relative to these areas and safely exhausted.

**Direction of air flow**

9. The direction of airflow is more important than the pressure differential through which it flows, and must ensure that all air leaving the room does so through a controlled process and is discharged to the outside away from windows or ventilation inlets. It is important that the room is under negative pressure with respect to all its surroundings (except the bathroom/toilet, which itself should be under negative pressure to control smells). It is unrealistic to expect the door to be the only hole in the room through which air will flow. If other holes in the fabric of the room, for example surrounding the entry of electric cables, plumbing, pipes etc. do not exist already, or they are blocked up, they will rapidly (re)appear and can result in airflow between rooms.

**Achieving negative pressure in a room**

10. While the direction of airflow is more important, the pressure differences must be measurable. It is difficult to measure pressure differentials below 5 pascals. The USA CDC recommendation of 0.001 inch of water equates to 0.2 pascals, which is not readily measured or monitored. However, if rooms are not well sealed, it may be difficult to achieve greater differentials.

11. Extracted air volumes should exceed air supplied through the ventilation system by a large margin. (The precision with which this has to be done is open to discussion. The CDC in the USA recommends the exhaust rate from the room exceeds the intake of air by about 10-15% or 50 cubic feet per minute, whichever is greater. However, these margins are slim - it would not take much slippage in the mechanisms of the extract, the supply or both, to reverse such a slight differential, resulting in air actively blowing out of the room. There is also little practical reason to have a narrow margin: if a greater volume of air is extracted, a greater volume of incoming air will be needed. It will be supplied by air being drawn into the room (through the door and other vents), and the desired direction of flow will be obtained. With a robust flow, there should be little need for especially close fitting doors; if necessary, the pressure differential can be controlled by restricting the gap in the door-vent (which is self-sealing in the case of fire doors).

12. If the existing ventilation system is incapable of achieving the desired negative pressure, or the room lacks a separate ventilation system, steps should be taken to provide a means to discharge air from the room to the outside, such as an exhaust fan.

13. **Number of room air changes/outside air mix:** Current USA recommendations, for ≥6 air changes per hour (ACH), were empirically based on pre-existing recommended rates for non-specialised areas not related to infection control, and have only been justified for tuberculosis in retrospect. Ventilation rates between 6 and 12 ACH are likely to produce incrementally greater reductions in the concentration of bacteria in a room; airflow rates
greater than about 12 ACH may lead to complaints about draughts and higher heating costs to maintain an acceptable room environment.

**Monitoring**

14. Pressure differentials can be monitored either by a permanently-mounted magnehelic type gauge with the reading recorded regularly (eg once a day) or by an electronic micromanometer linked to a remote alarm, usually by the nurses’ station. Otherwise, monitoring may be by observing the direction of airflow, using smoke tubes. This should be done by a qualified ventilation engineer and the monitoring must itself be monitored.

15. Rooms need to be frequently checked by an appropriately trained engineer for both direction of air flow and the degree of negative pressure which has been established, and accurate and detailed monitoring records kept. (There is an absolute duty under Regulation 9 of the COSHH Regulations that all local exhaust ventilation plant should be thoroughly examined and tested at least once every 14 calendar months.) It is good practice to keep the monitoring record on the wall where it can be seen by staff. It is essential that all staff are trained in facilitating the maintenance of negative pressure by ensuring that all doors (except when persons need to enter or leave the room) and windows remain properly closed in the isolation room. A small gap (<½ inch) at the bottom of the door is sufficient to provide a controlled airflow path.

**Other features of negative air pressure rooms**

16. A negative pressure room should preferably have windows which do not open. If the room has both mechanically supplied and extracted air, these should be linked such that, should the extract fail, the supply will cut out (otherwise the room would be under positive pressure). They should be covered by emergency power generators.

17. Rooms should have their own, preferably integral, toilet room/shower facilities, and their own television/video/radio, telephone etc.

18. Ante-rooms help to reduce the escape of droplet nuclei during opening and closing of the isolation room door. They are also generally acknowledged to be a useful prompt to good infection control technique. However, given a robust ventilation system and good pressure differential, if the budget for installing a new facility is limited, an ante-room may be waived in favour of installation of a high quality negative pressure room. The isolation room should be at negative pressure relative to the anteroom. Masking and unmasking should take place in the ante-room.

**Fire precautions for negative pressure rooms**

19. In case of a fire elsewhere in the facility, all staff must be aware that patients in negative pressure rooms are at an increased risk as smoke and fire can be drawn into the negative pressure isolation room from the adjacent corridor.
**Tents and booths for sputum inducing procedures**

20. Both tents and booths should have sufficient airflow to remove at least 99 per cent of airborne particles during the interval between patients. Several factors influence the time required to do this, but in general, an ACH rate must be established which is high enough to remove 99 per cent of airborne particles within 10 minutes, e.g., 25–30 ACH$^4$.

21. A hood placed very near, but not enclosing, an infectious patient is another type of local exhaust ventilation device. Their use and airflow requirements have been described elsewhere$^4$.

22. Air from booths, tents, and hoods is preferably exhausted directly to the outside, but may be discharged into the room in which the device is located. If the latter, a HEPA filter (see below) must be incorporated in the discharge duct or vent of the device with the exhaust fan on the discharge side of the filter to ensure that the air pressure in the filter housing and the booth is negative with respect to the adjacent areas. Uncontaminated air from the room will then flow into the booth through all openings, preventing infectious droplet nuclei in the booth from escaping in the room.

**Air Filtration**

23. A large variety of portable and permanently installed air filtration devices are being used for infection control as an alternative to additional ventilation. Few have been rigorously and independently tested for their ability to clear airborne particles under field conditions. Air filtration is not a substitute for good ventilation.

24. High-efficiency particulate air (HEPA) filters remove particles down to $\geq 0.3$ µm in diameter. Such filters on exhausts to the outside are expensive to install and maintain and rarely necessary – air should be vented to a place where it will not re-enter the building. If extra filtration is required, total efficiency is not essential – it is better, cheaper and likely to be as efficacious to put a greater volume of air through a coarse filter with a lower retention.

25. HEPA filters are used to clean air which is recirculated to other areas of a facility, or recirculated within a room, for rooms where there is no general ventilation system, where the system is incapable of providing adequate airflow, or where increased effectiveness of room airflow is desired. Portable units are available. HEPA filtration may have a place as an additional measure to adequate ventilation in booths or enclosing devices designed for aerosol generating procedures. But portable HEPA filtration units have not been evaluated adequately to determine their role in tuberculosis infection control. **Recirculating air taken from areas intended to isolate a patient with tuberculosis is in any case a risk not worth taking, and is not recommended.** The consequences of a holed or improperly seated filter may be serious. The units are also expensive and need regular engineering attention.