Section 3: Environmental Control

3.1 Ventilation
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In hospitals, special ventilation systems are designed to prevent nosocomial infections in certain patient care areas. This guideline will concentrate on dealing with three common areas requiring special ventilation: airborne infection isolation room, protective environment for severely immunocompromised patients and operating theatres. Rooms with reversible provisions for the purpose of switching between protective environment and airborne infection isolation functions are not acceptable (1).

1. **Airborne Infection Isolation (AII) Rooms**

   1.1 AII room is designed with negative pressure for housing patients with suspected or known airborne infectious diseases, such as pulmonary tuberculosis, chickenpox and measles, to prevent the infectious pathogens escaping from isolation room to the surrounding areas (2, 3, 4). Pressure differential of 2.5Pa (0.01-in. water gauge) should be maintained, between the patient room and the anteroom, to prevent air leaking from the patient room to the anteroom and/or the surrounding areas (3, 5). Air flow of the AII rooms is illustrated as Figure 1 and Figure 2.

   1.2 The AII room can be constructed with or without an anteroom (3, 6). An anteroom can act as an airlock and is preferable for isolating patients requiring protective environment who concurrently have airborne infection.
1.3 Outdoor fresh air intakes shall be located not less than 25 feet, horizontal distance, from all exhaust outlets (3). The exhaust shall be discharged above roof level (3), and avoid direct exhaust towards operable windows, walkways, public areas, and parking areas.

1.4 Figure 1 and 2 below illustrate diagrams of All Rooms with and without an anteroom (7). For specific engineering, please refer Table 1.

**Figure 1. All Room with Anteroom**

![Diagram of All Room with Anteroom](image1)

**Figure 2. All Room without Anteroom**

![Diagram of All Room without Anteroom](image2)
2 **Protective Environment (PE)**

2.1 Protective environment is designed with positive pressure for accommodating severely immunocompromised patients, notably allogeneic Haemopoietic Stem Cell Transplant (HSCT) recipients. Autologous HSCT recipients with prolonged neutropenia also benefit (8). Pressure differential range of 2.5-8 Pa (0.01-0.03-in. water gauge) between the patient rooms and the surrounding areas should be maintained (3).

2.2 PE keeps airborne pathogens in adjacent space from entering the patient room, minimizes fungal spore counts and reduces the risk of invasive pulmonary aspergillosis, especially during the period of construction or renovation in patients’ vicinity (9). Air flow of the PE is illustrated as Figure 3.

2.3 High Efficient Particulate Air (HEPA) filters are preferred to be installed at point of use, such as at the end of the duct just above the diffuser, or in patient room (9).

2.4 A diagram of PE room is shown as Figure 3 below. For other details, please refer to the Table 1 for specific engineering features.

**Figure 3. Example of Positive Pressure Room (7)**
3. **Operating Theatres**

Operating theatres require special ventilation systems in order to prevent the spread of airborne infectious disease and to minimize surgical site infection. Filtration system (air handling units) designed to provide clean air should have HEPA filters installed (6).

3.1 Operating theatres should be maintained at positive pressure relative to the adjacent areas, scrub rooms and corridors (9).

3.2 All fresh and recirculated air must be filtered through HEPA filter (6).

3.3 A minimum of 15 air changes per hour shall be maintained, 3 of which must be fresh air (10).

3.4 Air is preferably introduced at the ceiling and exhausted near the floor (3). There should not be any obstruction to the exhaust grill to facilitate free exhaust of air.

3.5 Optimal temperature ranges between 20°C and 22°C and humidity between 30% and 60% (10).

3.6 Hospitals who perform surgeries on infectious patients should consider providing one or more operating rooms with a local exhaust system to capture aerosols generated during operations (8,11). HEPA filters should be installed in the exhaust duct leading from the operating room into the general circulating system if air is recirculated (3,11).

4. **Maintenance of Ventilation Systems** (5,9)

An ongoing routine maintenance of the special ventilation systems must be in place to ensure proper functioning and adequate supply and exhaust of air in the special ventilation areas. These include:

4.1 There must be a routine maintenance schedule carried out by designated personnel.
4.2 The ventilation system, such as duct, fans, exhaust grills, filters, cooling coils, drain pans, gauges, manometers etc. should be easily accessed, inspected, maintained and repaired.

4.3 The exit door of the special ventilation areas shall be kept closed and its openings including doors, windows, ceiling panels, crevices and ports of plumbing, electrical and gas connections shall be well sealed to control air leakage (3).

4.4 Water condensate should not be accumulated in the ventilation system, which may allow moisture built-up for growth of molds.

4.5 Gaskets and mounting equipment must be properly designed and installed to prevent air bypass the filters and contaminated the clean areas.

4.6 The airflow direction, air pressure differentials, filtration efficiency and air changes rates shall be tested at its initial operation and monitored periodically and recorded. Manometers, continuous monitoring device or visual indicators, such as smoke tubes and flutter strips can be used to monitor pressure differential and the air flow directions.

4.7 The efficiency of filters must be monitored and maintained to prevent change of air balance/ pressure drop due to accumulation of dust and lint on the filters. Monitoring device such as manometers or gauges can be installed to check the pressure drop across the filters.

4.8 Maintenance personnel should notify the frontline staff of the affected areas before shutting down the ventilation system for repair or routine maintenance.

4.9 All designated isolation rooms in the facility should be listed out for reference use by the healthcare workers.

4.10 Please refer to Isolation precaution section of the Infection Control Manual for details of infectious disease isolation.
5. **Air Sampling**

5.1 Routine microbiological sampling of air is unnecessary and not recommended.

5.2 Air sampling can be an additional indicator to provide evidence to support the ventilation system is functioning properly. Monitoring of engineering parameters can reflect the system meets the specification of filter installation and operations.

5.3 Air sampling surveillance may be carried out when there is a cluster / outbreak of airborne infections with evidence of an epidemiological link.
Table 1: Engineering specifications for Airborne Infection Isolation Rooms, Operating Theatres and Protective Environment (2,3):

<table>
<thead>
<tr>
<th>Engineering features</th>
<th>Airborne Infection Isolation Room</th>
<th>Operating Theatres</th>
<th>Protective Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure differentials in relation to the adjacent areas</td>
<td>Negative (≥-2.5 Pascal i.e. 0.01 inch water gauge)</td>
<td>Positive</td>
<td>Positive (≥+2.5 to +8 Pascal)</td>
</tr>
<tr>
<td>Air change per hour (ACH)</td>
<td>Minimum 6 (for existing facilities); &gt; 12 (for renovation or new construction)</td>
<td>≥15</td>
<td>≥12</td>
</tr>
<tr>
<td>Filtration efficiency of supply air</td>
<td>As per local hospital policy</td>
<td>≥90%</td>
<td>HEPA filter at 99.97% at 0.3 μm</td>
</tr>
<tr>
<td>Filtration efficiency of exhaust air</td>
<td>Not required if direct exhaust air to the outside; or HEPA filter at 99.97% at 0.3 μm for recirculated air</td>
<td>Not required if exhaust air to outside; or HEPA filters should be installed for recirculated air</td>
<td>Not required</td>
</tr>
<tr>
<td>Clean to dirty airflow</td>
<td>All towards patient and exhausted</td>
<td>From supply across patient and exhausted</td>
<td>From supply across patient and exhausted</td>
</tr>
</tbody>
</table>
References


