Hospital Environmental Management for Infection Prevention and Control

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Siriraj Hospital

Patient Infectious
- TB, chicken pox, measles, SARS, MRSA, VRE

Environmental Infectious
- Fungi, Legionella spp, Aspergillus spp., Staphylococcus spp.

Hospital Environment

Animate
- Man
  - Patient
  - HCWs
  - Visitors
- Animal
  - Pet
  - Vectors

Inanimate
- Building
  - Air - - Temp., %RH
  - Ventilation
  - Water - - Sink, Reservoir
- Equipment

Contents
- Air - Ventilation, Air cleaner, UVGI
- Environmental Services - Cleaning and Disinfecting Environmental Surfaces

Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Settings, 2005
Administrative controls/ Work practice

Engineering/ Environmental controls

Personal controls

Administrative Controls

Risk levels for HCWs: Physical areas

Risk levels for HCWs: Functional areas

1st level 2nd level 3rd level
Source Pathway Receivers

Active TB patient

Administrative control

Environment control

Personal control

Administrative Control

- Assessment of the risk
- Development of IC plan
- Adequate training of HCWs
- Patient education
- Sputum collection
- Encourage out-patient TB management
- Triage and evaluation of suspect TB patient for early diagnosis and treatment

<table>
<thead>
<tr>
<th>Location at Health Facilities</th>
<th>Low Risk</th>
<th>Medium Risk</th>
<th>High Risk</th>
<th>Very High Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative Areas: within a patient or suspect contact e.g. separate building than patient</td>
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<tr>
<td>Administrative areas: with patient or suspect contact e.g. separate building than patient</td>
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<tr>
<td>Administrative areas: same building as patient or suspect contact or an exchange from patient</td>
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<td>Intensive Care and Internal Medicine wards</td>
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<td>Emergency Rooms</td>
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<td>Intensive Care and Internal Medicine wards (intensive care)</td>
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<tr>
<td>TB Outpatient (DOT) Clinics</td>
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<tr>
<td>TB Inpatient wards</td>
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<tr>
<td>MDR-TB wards</td>
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<tr>
<td>XDR-TB wards</td>
<td></td>
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</tbody>
</table>

Procedures at health facilities

- Swab-microscopy
- Surgery (within performing clinical surgery on a TB patient or suspect)
- X-ray services
- Respiratory therapy e.g. spirometry
- Intubation
- Bronchoscopy services
- Culture and DST procedures of TB specimens
- Molecular testing with live Mtb specimen processing
- Sputum collection
- Sputum induction


Reference: IMPLEMENTING the WHO Policy on TB Infection Control, 2010
**Personal control**

- **3rd priority, least effective**
- Aim to protect HCWs from inhaling infectious droplets
- Without appropriate administrative and environmental controls

**Environmental Controls**

- **2nd priority:** Reduce droplet nuclei in the air
- Control source of infection: Local exhausted ventilation

  **Ventilation**
  - General ventilation: Natural & Mechanical ventilation
  - Proper airflow direction: Clean to less-clean air, Air pressure
  - Adequate airflow: Dilution and removal — ACH

  **Air cleaning**
  - Filtration: High-Efficiency Particulate Air (HEPA)
  - Ultra-Violet Germicidal Irradiation (UVGI)

**Personal control**

- Recognition and strict implementation of the standard manual for the prevention:
  - **Work practice**
  - Personal Hygiene: Hand wash
  - Personal Protective Equipment, PPE
Local Exhaust Ventilation (1)

- **Source control** method for capturing airborne contaminants

Local Exhaust Ventilation (2)

- **Enclosing device**: source fully or partially enclosed
  - Tents
  - Booths
  - Biological safety cabinets (BSCs)

Isolation Enclosures

Environmental Control

- **2nd priority**: Reduce droplet nuclei in the air
- Control source of infection -- Local exhausted ventilation
- Ventilation
  - General ventilation -- Natural & Mechanical ventilation

Ventilation systems

- **Natural ventilation** through open windows (simplest, least expensive).
- **Mechanical ventilation** eg. window fans, exhaust ventilation, closed recirculation filtration system.
Ventilation systems

- **Dilute** contaminated air
- **Remove** contaminated air
- **Control directional airflow** patterns in a room

Natural Ventilation

Open this window!
Fresh air fights TB

Reference: IMPLEMENTING the WHO Policy on TB Infection Control, 2010

Mechanical Ventilation

- **Dilute and remove** contaminated air and control **directional airflow** patterns in a room
- **Maintain** AII under **negative pressure**
  - Existing settings: ≥ 6 air changes/hr. (ACH)
  - New or renovated settings: ≥ 12 ACH

Reference: IMPLEMENTING the WHO Policy on TB Infection Control, 2010
Remember that propeller fans only mix the air within the room and only extractor fans move room air from within the building to the outside.

Environmental Control

- **2nd priority**: Reduce droplet nuclei in the air
- Control source of infection -- Local exhausted ventilation
- Ventilation
  - General ventilation -- Natural & Mechanical ventilation
  - Proper airflow direction -- Clean to less-clean air, Air pressure

Direction Airflow

- Clean to less clean
- Positive-Negative pressure room
Direction Airflow

- Clean to less clean
- Positive-Negative air pressure room

Air Pressure

ASHRAE 2007: >+2.5 Pa

Verifying Air Pressure

- Smoke Tube Test
- Tissue Test
- Manometer
- Velocity meter
Smoke tube testing


Air Pressure

+7.5 Pa
- Real-Time Automatic Pressure Adjustment
- Controlled by Electronic Pressure Transmitter
- Digital Differential Display
- Variable Speed Drive
- Adjustable Positive Pressure

ASHRAE 2007: +2.5 Pa

Environmental Control

2nd priority: Reduce droplet nuclei in the air

Control source of infection -- Local exhausted ventilation

Ventilation

- General ventilation -- Natural & Mechanical ventilation
- Proper airflow direction -- Clean to less-clean air
- Adequate airflow -- Dilution and removal -- ACH

Control Airborne Infected

Air Changed

Decay of target macroparticles concentration for different ventilation rates and duration of time in a room.

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>6 ACH</th>
<th>12 ACH</th>
<th>18 ACH</th>
<th>24 ACH</th>
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<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>5</td>
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<td>30.8</td>
<td>13.5</td>
<td>5.1</td>
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<td>15</td>
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<td>0.3</td>
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<tr>
<td>25</td>
<td>8.2</td>
<td>0.7</td>
<td>0.06</td>
<td>0.00</td>
</tr>
<tr>
<td>30</td>
<td>5.6</td>
<td>0.3</td>
<td>0.01</td>
<td>0.00</td>
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<tr>
<td>40</td>
<td>0.7</td>
<td>0.09</td>
<td>0.03</td>
<td>0.00</td>
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<td>60</td>
<td>0.3</td>
<td>0.03</td>
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Air Change Rate (ACH) test:

<table>
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<tr>
<th>Room</th>
<th>Air Change per Hour (ACH)</th>
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<tbody>
<tr>
<td>OR.309</td>
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<tr>
<td>OR.310</td>
<td>18</td>
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<tr>
<td>OR.311</td>
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<td>OR.312</td>
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<td>OR.313</td>
<td>20</td>
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<td>OR.314</td>
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<tr>
<td>OR.315</td>
<td>12</td>
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<tr>
<td>OR.316</td>
<td>19</td>
</tr>
<tr>
<td>OR.321</td>
<td>31</td>
</tr>
</tbody>
</table>

Clean Air System

Air Change Flow Rate (ACH) = Air flow rate (CFM) / Room Volume (ft³)

Room Volume (ft³) = 144 + 64 + 67.1 = 282.1 ft³ = 144 (CFM) x 0.01 (CFM x ft³ = ft³)
Air Changes per hour (ACH) and time in minutes required for removal efficiencies of 90, 99 and 99.9% of airborne contaminants

<table>
<thead>
<tr>
<th>Minutes required for a removal efficiency of:</th>
<th>90%</th>
<th>99%</th>
<th>99.9%</th>
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<td>20</td>
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<tr>
<td>50</td>
<td>3</td>
<td>6</td>
<td>8</td>
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</tbody>
</table>

Should remove at least 99% of particles before next patient or HCW enters

Reference: Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Settings, 2005

**NOTICE:**

- OR

- Reference: IMPLEMENTING the WHO Policy on TB Infection Control, 2010

**Table 5a.2:** Air changes per hour (ACH) and time in minutes required for removal efficiencies of 90%, 99%, and 99.9% of airborne contaminants

<table>
<thead>
<tr>
<th>ACH</th>
<th>90%</th>
<th>99%</th>
<th>99.9%</th>
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<td>267</td>
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<tr>
<td>3</td>
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<td>51</td>
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<tr>
<td>4</td>
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<td>46</td>
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<tr>
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Environmental Control

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- Control source of infection -- Local exhausted ventilation
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  - Proper airflow direction -- Clean to less-clean air
  - Adequate airflow -- Dilution and removal -- ACH
- Air cleaning
  - Filtration -- **High Efficiency Particulate Air (HEPA)**
  - Ultra-Violet Germicidal Irradiation (UVGI)

Control Airborne Infected

- Micro Pre-Filter – Disposable
- Fabric Filter Cover – Disposable
- HEPA Filter – Long lasting, Replaceable

High Efficiency Particulate Air Filter

“HEPA”

Remove at least **99.97%** of airborne particles

**0.3 μm**
Clean Air System in OR

Airborne particle 0.5 μm < 352,000 particles/m³ of air
and
Airborne particle 5 μm < 2,930 particles/m³ of air

TSI AeroTrak™ Handheld Airborne Particle Counter
Model 9306-04
Fungi threshold limits in operating room

- Total fungi spore < 15 CFU/m³ of air
- Aspergillus fumigatus < 0.1 CFU/m³ of air

Bacterial threshold limits in operating room

- Total bacteria count < 35 CFU/m³ of air (empty OT, UK)
- Total bacteria count < 180 CFU/m³ of air (activity OT, UK)

Fungi threshold limits in operating room

- Total fungi spore < 15 CFU/m³ of air
- Aspergillus fumigatus < 0.1 CFU/m³ of air

Biological Contaminants
**Fungal & Health effect**

- Allergic Reactions เมื่อได้รับสปอร์ ได้แก่ อาการไข้ บางคนมีอาการตาม น้ำมูกไหล หากสัมผัสบ่อยๆ อาจเกิดปฏิกิริยาภูมิแพ้หนักถึงกับเสียชีวิต
- โรคหอบหืด
- ปอดอักเสบจากภูมิแพ้ Hypersensitivity Pneumonitis

ก่อให้เกิดระคายเคืองต่ำต่ำ จนถึง หลอดลม ทำให้เกิดอาการปวดแสบปวดร้อน

ก่อให้เกิดสารพิษ mycotoxin ถูกสงสัยว่าเป็นสารก่อมะเร็ง

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**Environmental Control**

- 2nd priority: Reduce *droplet nuclei in the air*
- Control source of infection -- Local exhausted ventilation
- Ventilation
  - General ventilation -- Natural & Mechanical ventilation
  - Proper airflow direction -- Clean to less-clean air
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- Air cleaning
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  - Ultra-Violet Germicidal Irradiation (UVGI)

**Infection Control Technology**

"UVGI"

UltraViolet Germicidal Irradiation

UV-C Radiation used for disinfection is most effective at a wavelength of **254 nm**
**Appropriate settings**

- Large, overcrowded congregate settings where:
  - TB is often undiagnosed
  - Ventilation is insufficient
  - Highly contaminated or infectious cases in the area

**Examples**

- Emergency departments
- Waiting areas in health facilities
- Sputum induction booth

**WHO Recommendations**

- Achieving adequate ACH using ventilation systems
- Used as supplement or back-up to dilution ventilation
- Does not provide negative pressure, fresh air or directional airflow

![Contaminated air](Image)

**Upper Room system illustrating irradiation contours in the upper room above 7–8 ft**
UVGI maintenance

- Monitoring radiation levels
- Cleaning (turn off before cleaning)
- Replacing bulbs as recommended by manufacturer (~ 9,000 hr.)
- Keeping records of monitoring and maintenance activities

UVGI summary

- Reduce transmission of *M. tuberculosis* in health care settings.
- Upper air UVGI is recommended
- Adequate air circulating

Portable Air Cleaner

- Active removal pollutions
  - Plasma cluster
  - Ozone
  - Photo catalytic reactor

- Passive removal pollutions
  - HEPA filter
  - Negative ion
  - UVGI
Portable air cleaner

- **HEPA** - Not kill, only trap particles
- **Negative ion** - Not kill, refresh air only
- **Plasma cluster** - Kill, Not trap
- **Ozone** - Kill, Not trap
- **UVGI** - Kill, Not trap

- **User (nurse)**
- **ENV teams (maintenance)**
- **Occ. health teams**
- **IC teams**
- **OR**
- **Health**
- **Workplace**
  - Ventilation
  - Area decontamination

**Infection Control & Safety:**
Everyone is Responsible!

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**Education:**
- Bachelor of Science in Biology, Ramkhamhaeng University
- Master of Science in Industrial Hygiene and Safety, Mahidol University

**Position:**
- Head of Occupational Health, Siriraj Hospital

**Work Experience:**
- Special Lecturer
  - Medical Student Program, Faculty of Medicine Siriraj Campus, Mahidol University
- Specialist in Advanced Infection Control, Nursing Department, Mahidol University

**Speeches:**
- Environmental Cleaning and Room Disinfection in the 13th World Sterilization Congress, Osaka, Japan, 2012

**Other:**
- Only Thai speaker to be invited as a Guest Speaker at the 13th World Sterilization Congress, 2012.