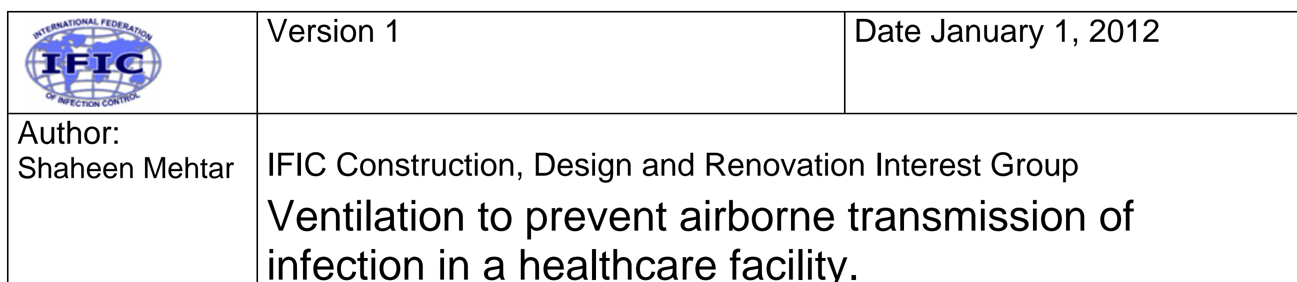


	Version 1	Date January 1, 2012
Author: Shaheen Mehtar	IFIC Construction, Design and Renovation Interest Group **Ventilation to prevent airborne transmission of infection in a healthcare facility.**	

Introduction

The aim of this document is to provide practical, evidence based (where appropriate) written materials about construction, design and renovation in health care facilities, that can be used in the co-operation between Infection control personnel, building planners and engineers

SIG recommendations are given in three levels:

- **Basic** - Even with severely limited resources, this is what you should do as a minimum
- **Standard** – this is what you should aim for in most countries
- **Ideal** – if you have the resources, this is what you could do

This document outlines recommendations for appropriate ventilation applicable to all levels and types of healthcare facilities.

Background

Transmission of pathogens in healthcare facilities is attributed mainly to hands of healthcare workers, but airborne transmission of pathogens has become more important with the occurrence of difficult-to-treat organisms especially *Mycobacterium tuberculosis*. The aim of ventilation is to dilute these microorganisms, including viruses, bacteria and fungal spores. Light and airy rooms also contribute to the general wellbeing of patients and staff.

For any type of air movement (ventilation) to happen, air has to enter and exit the area. Air supply is delivered by natural or mechanical means and removed with temperature gradients or by extract fans; ventilation could also be a mixture of both. Mechanical ventilation delivers a constant supply of air with appropriate number of air changes per hour (ACH).When the inflow of air is greater than the outflow, this is defined as positive pressure ventilation. When outflow exceeds inflow, the ventilation is defined as negative pressure in relation to the environment.

In countries with very cold climatic conditions, mechanical (controlled) ventilation is usually the norm, while in warmer climates, natural ventilation may be used. The cost of installing and maintaining air-handling units is high and often out of reach for some of the low or middle income countries. Separate ventilation is recommended for special units such as operating theatres, sterile services or isolation facilities. Large airflows require large vent sizes, fans and ducts. Clinical areas which require similar mechanical ventilation systems should be clustered if possible to reduce costs.

Natural ventilation

The WHO has published guidelines on the optimal use of natural ventilation when designing new healthcare premises or upgrading existing structures. Natural ventilation is mainly achieved by temperature differences: air flows from warmer to cooler areas in the upper part of a door or window, and from cooler to warmer areas in the lower part. Tall buildings affect air movement by creating an upward or downward draft, depending on the prevailing winds or temperatures; as warm air moves upward and is replaced by cooler air. Openings such as windows, doors and verandas capture the entry of air, directing it into the building and out to the outside atmosphere. Advantages of natural ventilation are that it is inexpensive and can be applied to most areas except where controlled ventilation is required. The disadvantages are that the air supply and removal cannot be controlled, it is dependent on weather conditions and prevailing winds, and in cold climates the air might be too cold to leave windows open. Wind turbines ('Whirly birds') that can

assist with air removal particularly from enclosed spaces are less expensive to install than fans, and require little maintenance.

Mechanical ventilation

Air inflow is directed via an air handling unit, filtered and then channelled through the health care facility via ducts. Air in- and outflow is regulated by fans. Outflow air is extracted via ducts to the outside of the building, directly or via a filtered recycling system. Windows, doors and outlets must remain closed or sealed to ensure constant and appropriate air flows. Mechanical systems deliver constant balanced, negative pressure or positive pressure, ventilation as required. Balanced ventilation means that the amount of air which is delivered to, and extracted from, the room is of equal volume and allows for constant air changes in a given space. Air handling units which can be switched between negative and positive pressure should be avoided, as errors often occur. Mechanical ventilation is suited to high income countries, where extreme weather conditions exist and regular maintenance of the systems is is an integral part of healthcare facility maintenance. The advantage is that the quality, temperature and humidity of air can be controlled with regulated air delivery and removal. The disadvantages are that it is costly to run, maintain and replace, it must be monitored regularly for optimum efficacy.

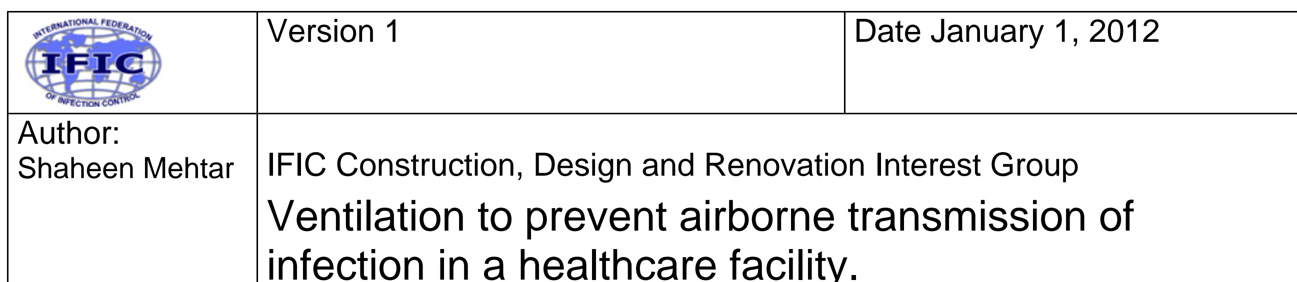
In high- technology facilities, ultra-violet germicidal light (UVG) has been considered a complement (NOT a substitute) to mechanical ventilation, but currently there is a lack of data to show that UVG prevents health-care associated infections. Practical and technical problems are common, and UVG is therefore not recommended except perhaps as an adjunct in ideal conditions.

Maintenance of mechanical ventilation

Engineers maintaining mechanical ventilation should be trained in the following:

- **Regular testing of air flow**. Air flow between rooms can be tested with smoke gas, usually titanium tetrachloride or a joss stick. Mechanical ventilation which is well designed and with fans running properly, the air flow at the inlet vents can be checked with warm-thread anemometers.
- **Replacement of filters**. When the results show a reduction in air flow, the filters should be replaced. This is particularly true in dusty, dry and hot countries where the filters frequently get clogged. In cool countries, the filters are monitored and may be changed less frequently.
- **Role of the IPC Team**. The IPC Team should be skilled in testing for airflow direction using available means. It is not an exact science but will give an idea of air movement. The recommendations range from titanium hydrochloride to joss sticks- the outcome is the same - document the direction of airflow.

Isolation facilities for airborne disease, particularly tuberculosis, should be tested for airflow prior to a patient being admitted. This is particularly important if the ventilation has been switched off or has not been in use for some time. Testing should be co-ordinated between the Engineering Department and the IPC Team. A written report with the findings and; if necessary, recommendation for remedial action should be sent to management and clinical teams. .



Application of ventilation systems in a healthcare facility

Area	**Basic**	**Standard**	**Ideal**
General wards (see IFIC SIG Design of a ward)	Natural ventilation – open windows	Natural or mechanical ventilation	Mechanical ventilation; negative pressure in bathrooms and toilets
Intensive care	Natural ventilation	Natural or mechanical ventilation	Mechanical ventilation
Burns Unit.	Natural ventilation	Natural or mechanical ventilation	Mechanical balanced or negative pressure ventilation with temperature and humidity control
Neonatal unit	Natural ventilation with heaters if required	Natural or mechanical ventilation	Mechanical balanced ventilation with temperature and humidity control
Bone Marrow Transplant- during early periods of bone marrow suppression	Natural ventilation with clean, dust free air	Mechanical filtered positive pressure ventilation	Mechanical HEPA-filtered positive pressure ventilation
Endoscopy unit.	Natural ventilation.	Mechanical ventilation	Mechanical ventilation.
Bronchoscopy unit.	Natural ventilation. Well ventilated with open spaces.	Extraction with negative pressure ventilation.	Mechanical negative pressure ventilation. 6-12 air changes/h
Specialised TB hospitals.	Natural ventilation with large open windows.	Natural ventilation with extractor fans to provide negative pressure.	Mechanical negative pressure ventilation. . 6-12 air changes/h
Isolation rooms (with en-suite washroom). PPE according to transmission based precautions	Natural ventilation	Mechanical ventilation.	Mechanical balanced or negative pressure ventilation with 6-12 air changes/h
Isolation rooms for airborne pathogens (with en-suite washroom). PPE must be worn	Natural ventilation with Extractor systems (fans or Whirly Birds) for improving negative pressure.	Mechanical balanced or negative pressure ventilation.	Mechanical balanced or negative pressure ventilation with 6-12 air changes/h. UV light as possible adjunct.

Area	Basic	Standard	Ideal
Outpatients	Natural ventilation using open windows. Reduce population of overcrowded areas. Outdoor waiting areas if weather permits	Natural or mechanical ventilation. Large and subdivided waiting rooms. Single waiting rooms for patients with long-standing cough.	Mechanical ventilation. Large and subdivided waiting rooms. Single waiting rooms for patients with long-standing cough and other suspected infection.
Primary Health Clinics and community areas	Natural ventilation	Natural or mechanical ventilation	Mechanical ventilation
Sputum booths	Open enclosed area away from other patients	Natural ventilation and Whirly Birds (if enclosed space)	Mechanical negative pressure ventilation
Sterile services decontamination	Natural ventilation.	Extraction of air using extractor fans or Whirly Birds	Mechanical negative pressure ventilation
Sterile services: Inspection, Assembly and Packaging	Natural ventilation free of dust. No open windows.	Wall mounted air conditioners with filters.	Mechanical positive pressure ventilation.
Sterile storage	Natural ventilation	Mechanical ventilation	Mechanical ventilation
Mortuaries - In the post mortem room and over dissecting table	Natural ventilation with increased airflows. Whirly Birds or extractor fans	Mechanical ventilation. Air extraction away from mortuary table preferably mechanical	Mechanical negative pressure ventilation
Laboratories.	Natural ventilation free of dust. Bio safety cabinets	Natural or mechanical ventilation. Negative pressure in TB laboratory with bio safety cabinets	Mechanical ventilation with negative pressure in TB laboratory with bio safety cabinets
Main hospital kitchen	Natural ventilation	Natural or mechanical ventilation	Mechanical ventilation with temperature and humidity control
Milk preparation room	Natural ventilation	Natural or mechanical ventilation	Mechanical ventilation with temperature control
Pharmacy and Special fluid production Unit-		Natural or mechanical ventilation with filters. clean dry air. Safety cabinets for preparation of sterile fluids and medications.	Safety cabinets- positive pressure ventilation
Operating theatres *See IFIC SIG – Design of a surgery block*			

Further Reading (References)

Ayliffe GA, Lowbury EJ. Airborne infection in hospital. J Hosp Infect. 1982;3(3):217-40.

Bagshawe KD, Blowers R, Lidwell OM. Isolating patients in hospital to control infection. Part III--Design and construction of isolation accommodation. Br Med J. 1978 Sep 9;2(6139):744-8.

Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). MMWR 2003; 52 (No. RR-10): 1–48.. The full-text version of the guidelines appears as a web-based document at the CDC's Division of Healthcare Quality Promotion's Internet site at: http://www.cdc.gov/ncidod/dhqp/gl_environinfection.html

Escombe AR, Oeser CC, Gilman RH, Navincopa M, Ticona E, Pan W, Martínez C, Chacaltana J, Rodríguez R, Moore DA, Friedland JS, Evans CA. Natural ventilation for the prevention of airborne contagion. PLoS Med. 2007;4(2):e68.

Fennelly KP. Variability of airborne transmission of Mycobacterium tuberculosis: implications for control of tuberculosis in the HIV era. Clin Infect Dis. 2007 May 15;44(10):1358-60.

Fisher-Hoch SP. Lessons from nosocomial viral haemorrhagic fever outbreaks. Br Med Bull. 2005 Dec 22;73-74:123-37.

Heating and ventilation systems. Health Technical Memorandum 03-01: Specialised ventilation for healthcare premises. *Part A: Design and validation; Part B: Operational management and performance verification.* UK Department of Health / Estates and Facilities Division, London 2007. Published by TSO (The Stationery Office) and available from: Online:www.tsoshop.co.uk

Liu JW, Lu SN, Chen SS, Yang KD, Lin MC, Wu CC, Bloland PB, Park SY, Wong W, Tsao KC, Lin TY, Chen CL. Epidemiologic study and containment of a nosocomial outbreak of severe acute respiratory syndrome in a medical center in Kaohsiung, Taiwan. Infect Control Hosp Epidemiol. 2006;27:466-72.

Memarzadeh F, Olmsted RN, Bartley JM. Applications of ultraviolet germicidal irradiation disinfection in health care facilities: effective adjunct, but not stand-alone technology. Am J Infect Control. 2010 Jun;38(5 Suppl 1):S13-24. Review.

Mehtar, S. Hospital design: ventilation. In: Mehtar S, Ed. Understanding Infection Prevention and Control. Cape Town South Africa: Juta and company Ltd 2010; 240-244.

Natural ventilation for infection control in health-care settings. 1. Ventilation — methods. 2. Air microbiology. 3. Infection control. 4. Health facilities — standards. 5. Guidelines. I. World Health Organization. ISBN 978 92 4 154785 7 (NLM classification:WX 167) World Health Organization 2009

Tang JW, Li Y, Eames I, Chan PK, Ridgway GL. Factors involved in the aerosol transmission of infection and control of ventilation in healthcare premises. J Hosp Infect. 2006;64:100-14.

Walker JT, Hoffman P, Bennett AM, Vos MC, Thomas M, Tomlinson N. Hospital and community acquired infection and the built environment--design and testing of infection control rooms. J Hosp Infect. 2007;65 Suppl 2:43-9.