CAHO CONTINUING EDUCATION SERIES

HOSPITAL CLEAN AIR STANDARDS
OPERATING ROOMS, & ISOLATION ROOMS

Shankar Rajasekaran

M Tech (BITS, Pilani), CAFS, (NAFA, USA), CTP (CTCBI, UK)

Subject Matter Expert

Air Cleaning & Contamination Control Engineering

Florence Nightingale

"The very first requirement in a hospital is that it should do the sick, no harm."

— **Florence Nightingale,** [Notes on Nursing: What It Is, and What It Is Not]

PATIENT HARM IN A HOSPITAL CAN BE A RESULT OF

- MEDICAL ERRORS
- PHYSICAL INJURIES
- ACCIDENTS
- HOSPITAL ACQUIRED INFECTIONS

THE TARGET IS TO ACHIEVE REDUCTION IN OCCURANCE OF NOSOCOMIAL INFECTIONS

THE ROUTE TO MAKING A STANDARD

- Risk identification
- Risk assessment / measurement
- Risk mitigation procedures
- Validation methods
- Development of standards

WHAT WE WOULD BE TOUCHING TODAY

1. Concept of infection prevention from the engineering angle
2. Some common standards applicable for clean air environments in hospitals
3. Operating rooms
4. Isolation rooms
5. Challenges in providing clean air
6. Case study

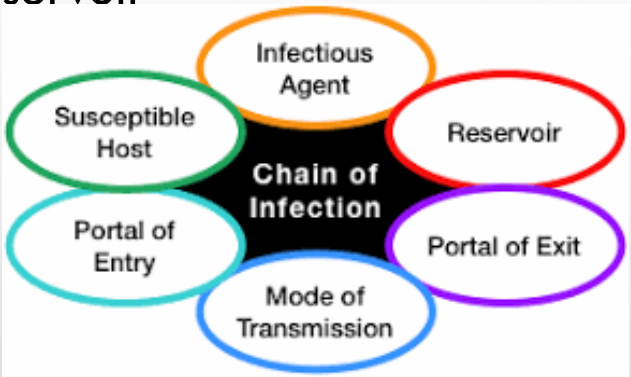
CONCEPT OF INFECTION PREVENTION FROM THE ENGINEERING ANGLE

CHAIN OF INFECTION

Contamination is avoided if this path is disconnected

Contamination is also avoided if agent dose is insufficient to trigger an infection

- Reservoir of the infectious agent
  - Human reservoirs
  - Animal reservoirs
  - Environmental reservoirs
- Portals of agent exit from the reservoir
- Modes of transmission
  - Direct contact
  - Vehicle borne
  - Airborne
  - Vector borne
- Portals of agent entry into the host.
- Susceptibility of the host for the agent dose received.



Infections occur on account of pathogens (Contaminants) entering the human body in a manner that overcomes or compromises the immune system.

In engineering terms, the key to infection prevention is contamination control

Source: :www.cdc.gov/ophss/csels/dsepd/ss1978/lesson1/section10.html

BASIC CONCEPTS IN CONTAMINATION CONTROL

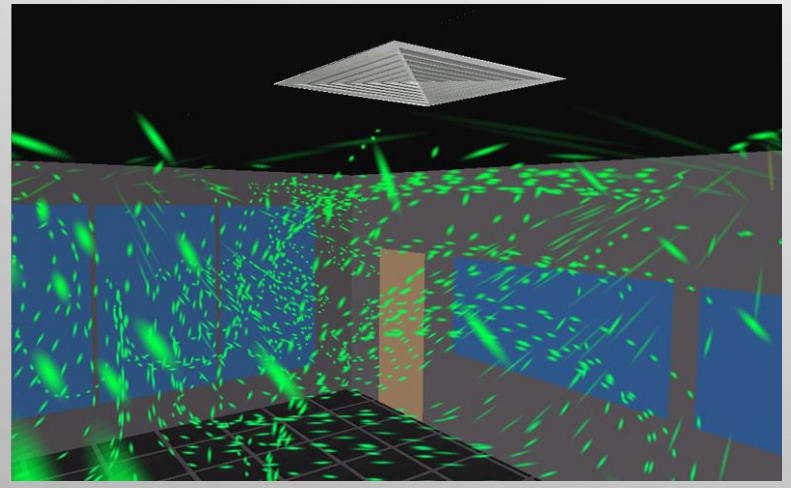
- Source limitation
  - Personnel protocols
  - Procedural protocols
- Primary (physical) barriers
  - Zoning
  - Anterooms
  - Graded isolation
- Secondary (indirect) barriers
  - Pressure differentials
  - Airflow patterns
- Purging / scavenging
  - Removing internally generated contaminants
- Dilution
  - Supplying clean air

FUNCTIONAL REQUIREMENTS OF AN HVAC SYSTEM USED FOR CRITICAL AREAS

- Maintain temperature and relative humidity requirements.
- Introduce adequate amount of contamination free out side air.
  - Fresh air intake
- Minimise addition of contaminants to very low levels.
  - Multi stage air filtration
- Remove internally generated contaminants effectively.
  - Providing streamlined airflow over critical area without eddies or swirls.
  - Suitable positioning of supply and return air points.
  - Providing adequate number of air changes.
- Control ingress / egress of contaminants from / to surrounding areas.
  - Building adequate positive / negative pressure.

AIR MOVEMENT & ITS IMPORTANCE

- Contamination free, moving air in a cleanroom is the most important functional element.
- Uniform dilution and scavenging action cannot happen effectively unless air moves in the room in a particular pattern.
- Higher magnitude of air movement results in faster removal of contaminants.

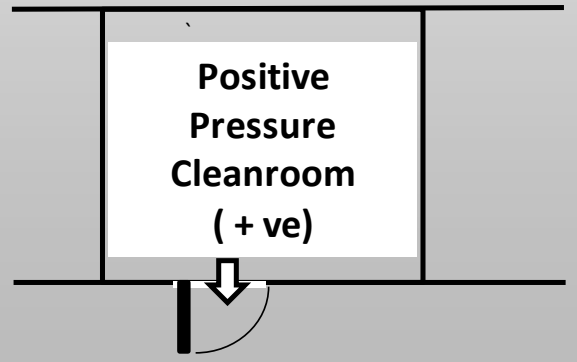


Air changes per hour	Time (mins.) required for removal 99% efficiency	Time (mins.) required for removal 99.9% efficiency
2	138	207
4	69	104
6	46	69
8	35	52
10	28	41
12	23	35
15	18	28
20	14	21
50	6	8

PRESSURIZATION

POSITIVE PRESSURIZATION

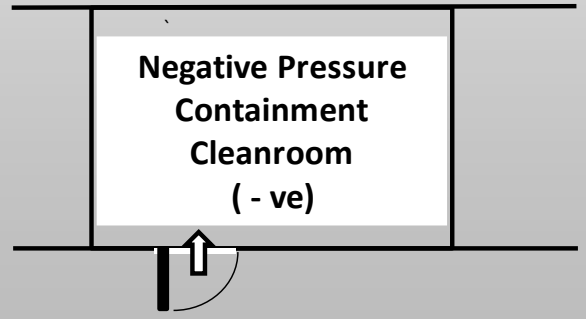
- The room is kept at a higher pressure (+ve) w.r.t. the surroundings.
- Air ex-filtrates from the room.



Less clean area

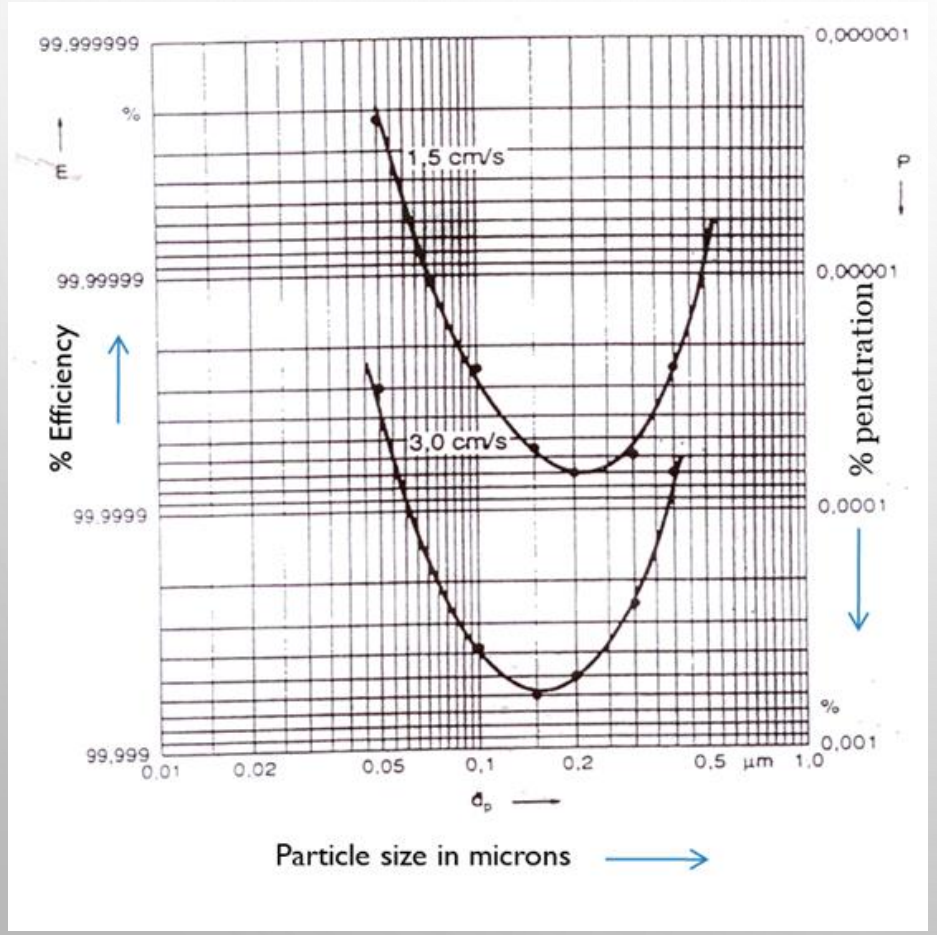
NEGATIVE PRESSURIZATION

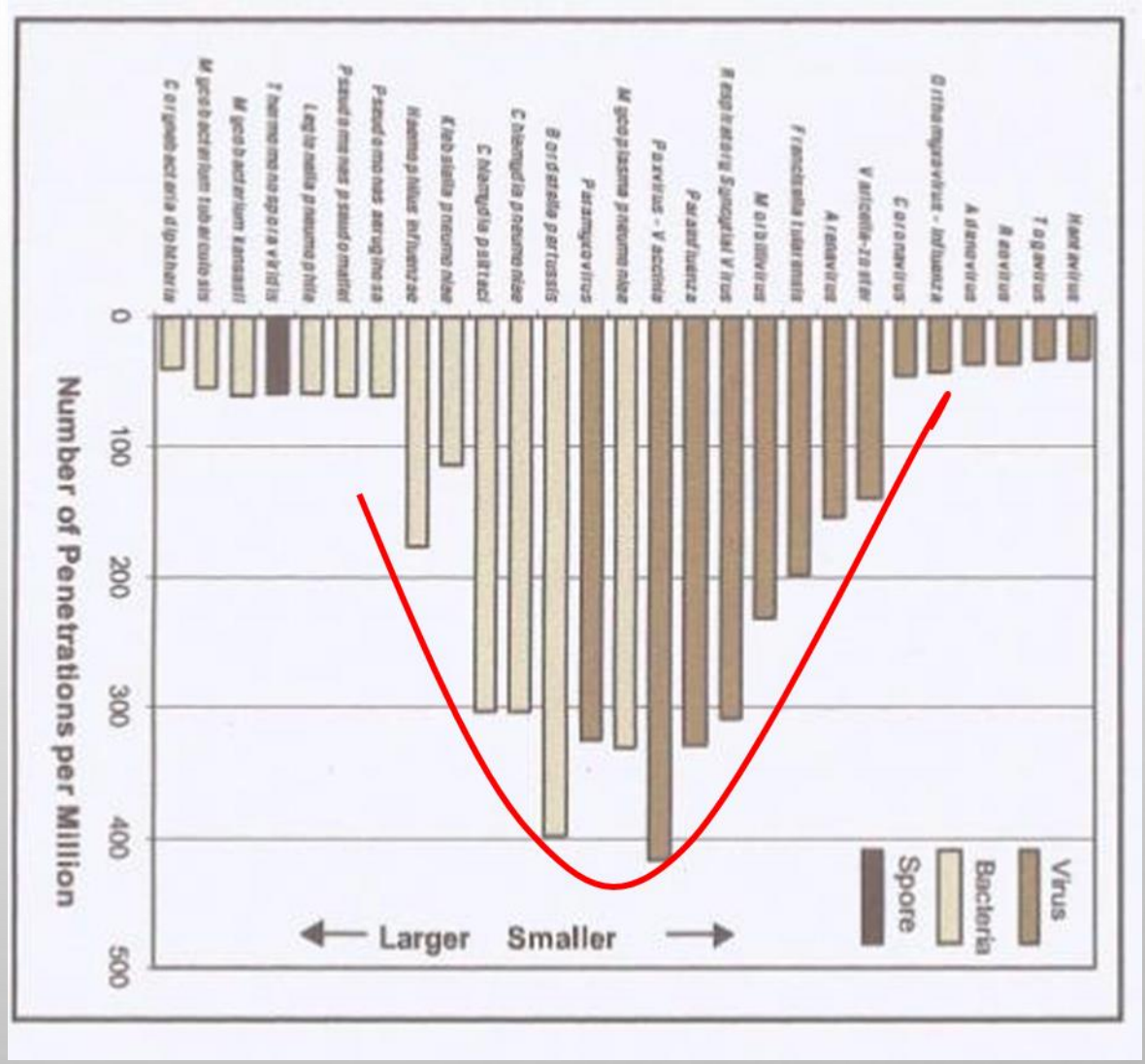
- The room is kept at a lower pressure (-ve) w.r.t. the surroundings.
- Air infiltrates into room.



Outside area

EFFICIENCY OF A HEPA FILTER



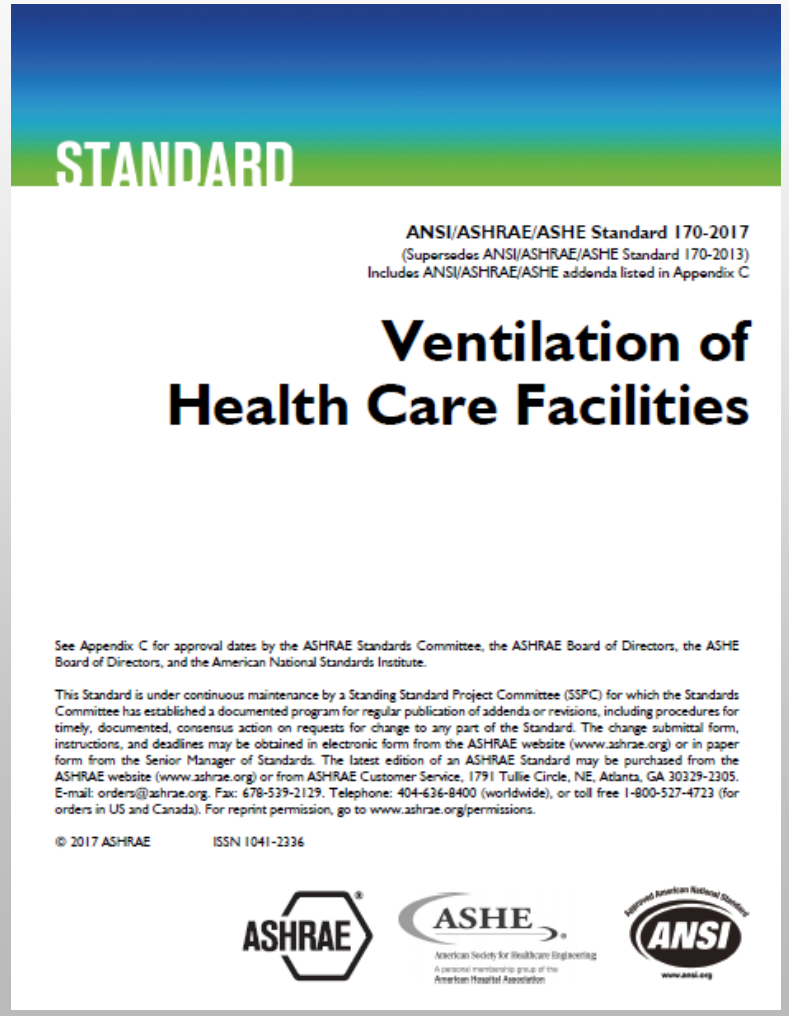


Penetration of 400 ppm = 0.04%

Equivalent to 99.96 % efficiency

SOME COMMON STANDARDS APPLICABLE FOR CLEAN AIR ENVIRONMENTS IN HOSPITALS

ASHRAE STANDARD 170


STANDARD

ANSI/ASHRAE/ASHE Standard 170-2017
(Supersedes ANSI/ASHRAE/ASHE Standard 170-2013)
Includes ANSI/ASHRAE/ASHE addenda listed in Appendix C

Ventilation of Health Care Facilities

See Appendix C for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the ASHE Board of Directors, and the American National Standards Institute.

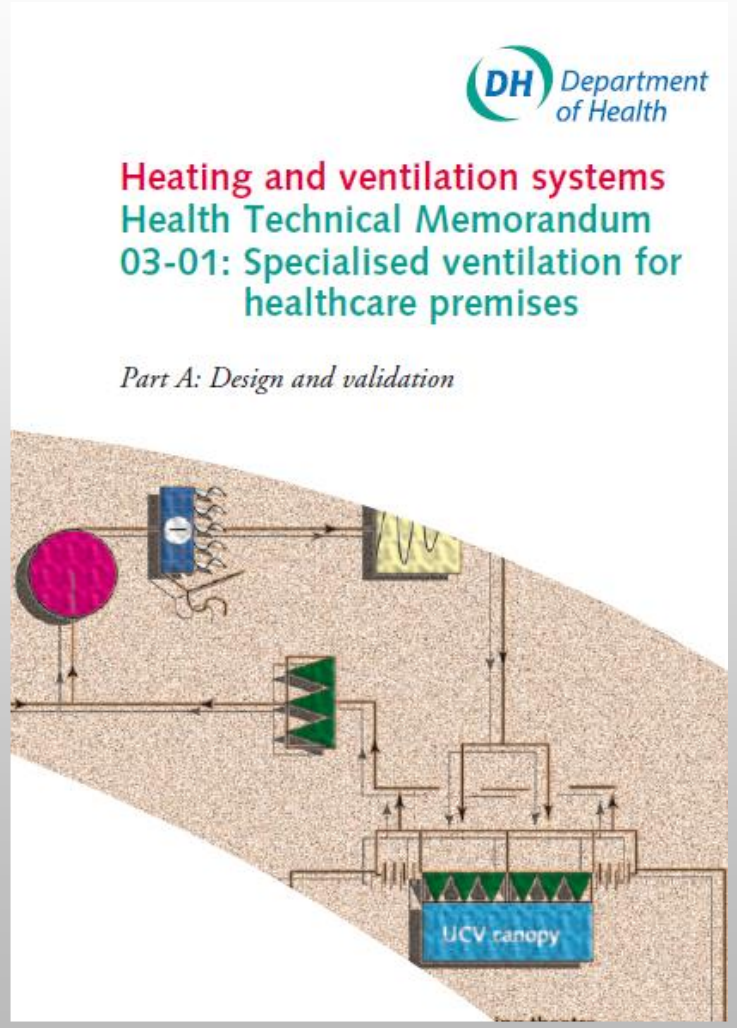
This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

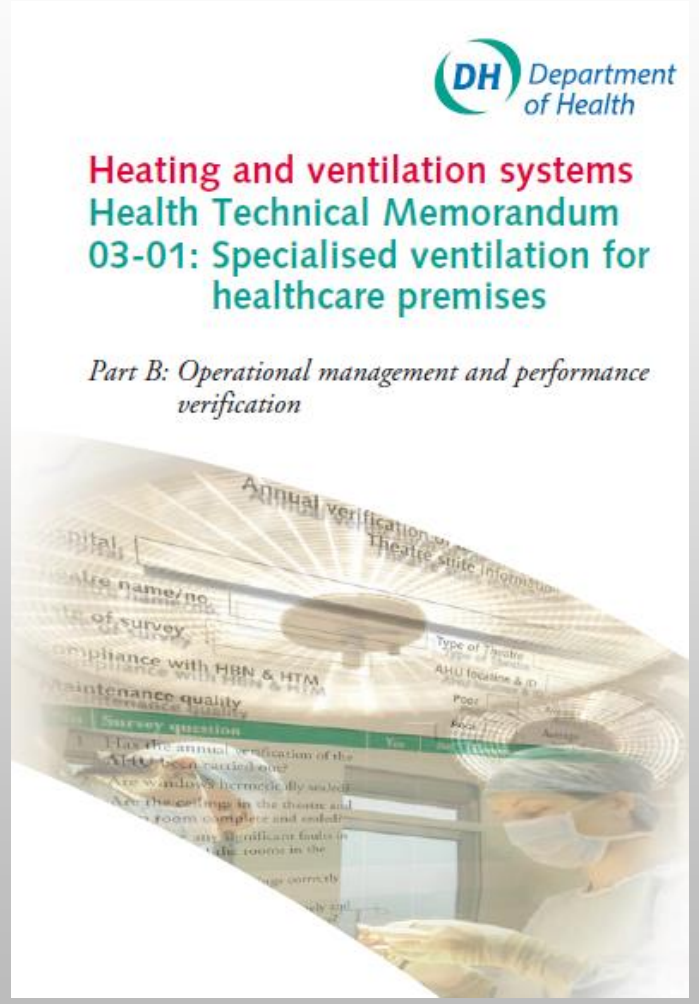
ASHRAE ASHE American Society for Healthcare Engineering A personal membership group of the American Hospital Association ANSI www.ansi.org

- A very practical and simple to use standard.
- Provides technical information regarding pressure, tempeature, RH, filtration etc.
- Covers isolation areas and operating rooms in detail.
- Provides guidance on planning construction & start up.
- Provides recommended operation and maintenance procedures as a separate appendix.

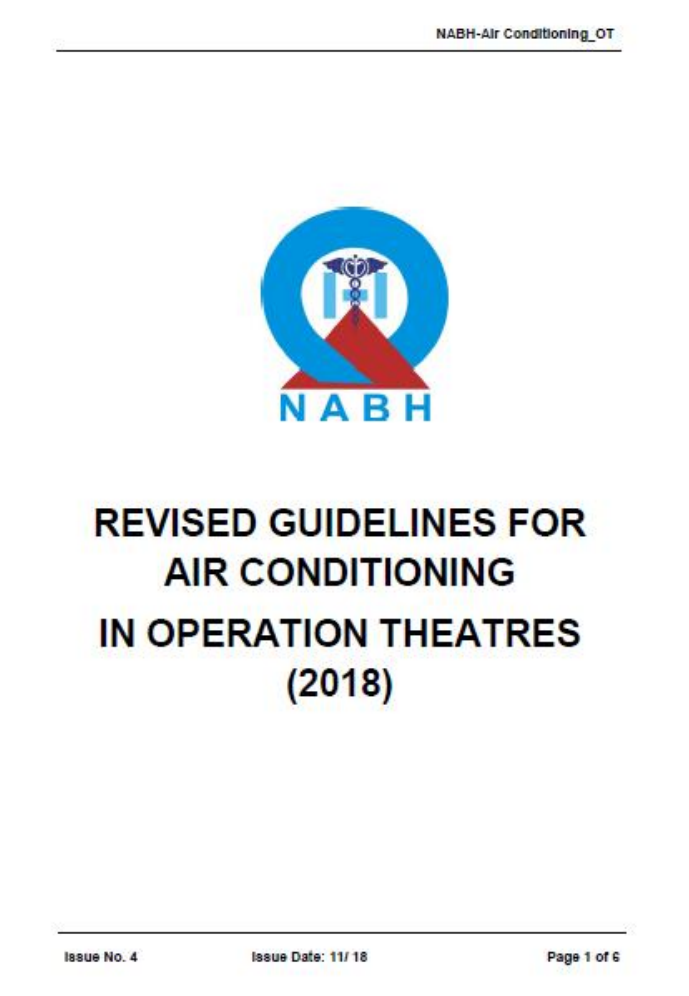
HTM – 03-01 PARTS A & B



- A prescriptive kind of standard covering all aspects of mechanical ventilation in a hospital.
- Extensive details about design concept, testing and validation.
- Covers requirements for
  - Air handling units,
  - Air distribution networks and
  - Specialized ventilation systems.
- Specialized ventilation systems cover UCV systems for Operating rooms in detail.



NABH GUIDELINES FOR OPERATION THEATRES



- Covers only operation theatres
- A simple standard allowing several practical deviations.
- Provides simple tips for operation & maintenance
- Types of tests to be conducted and the frequency is provided

LINKS FOR DOWNLOAD / PURCHASE

- https://www.nabh.co/announcement/revisedguidelines_airconditioning.pdf
- https://www.ashrae.org/technical-resources/bookstore/health-care-facilities-resources
- https://www.gov.uk/government/publications/guidance-on-specialised-ventilation-for-healthcare-premises-parts-a-and-b

OPERATING ROOMS

UDAF SYSTEM VS TURBULENT FLOW SYSTEM.

UDAF System	Turbulent flow system
Low face velocity	High face velocity
High level of velocity uniformity	Poor level of velocity uniformity
Non-aspirating flow	Aspirating flow
Low occurrence of eddies in flow	High occurrences of eddies in flow
Smooth parallel flow lines	Irregular and chaotic flow lines
Near constant velocity	Fluctuating velocity
Short recovery time	Long recovery times
Cleanses the air by action of dilution and contaminant transport	Cleanses the air by action of dilution only
Used in very critical “clean surgeries”	Used in non critical “not so clean surgeries”

UNIDIRECTIONAL AIRFLOW (LAMINAR AIR FLOW)

❖ ISO 14644 – 3 : 2003 - cleanrooms & associated controlled environments

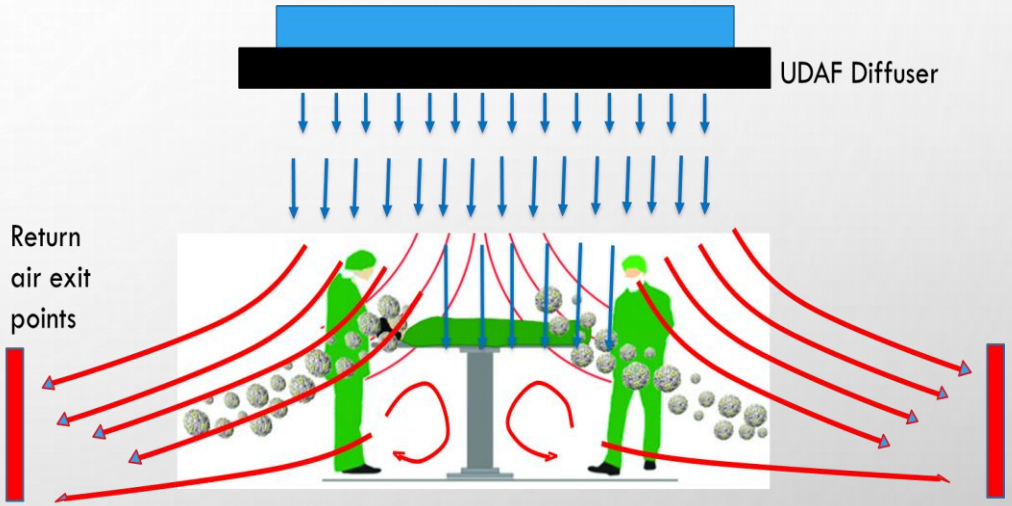
- Controlled airflow through the entire cross section of a critical zone with a steady velocity and approximately parallel streamlines.
- Airflow pattern in which the point to point readings of velocities are within a defined percentage of the average airflow velocity (typically with +/- 10 %).

❖IEST RP CC 002.3 – Unidirectional Flow Clean Air Devices

- Airflow in a single direction through a clean air device or a clean zone with essentially parallel stream lines.
- Air flow that has a velocity Relative Standard deviation [RSD = (σ/μ) x 100] of less thn 15% perpendicular to the plane of Airflow.

ILLUSTRATION OF GOOD SITE MEASUREMENT VALUES

Particle sizes in micro metres	Average Particle concentration measured on the Operating table in a Turbulent Airflow OR In particles per cubic foot	Average Particle concentration measured on the Operating table in a Unidirectional Airflow OR in particles per cubic foot	Maximum allowable particle concentration for achieving ISO Class 5 , ISO 14644-1 : 2015 in particles per cubic foot
0.3	60625	85	290
0.5	13111	45	100
1	3400	21	24
3	671	4	-
5	109	1	8
10	9	0	-



Source : National Air Filtration Association,

FINDINGS FROM ASHRAE STUDY

TABLE 1 Airflow configurations.

LAYOUT	AREA (SF)	VELOCITY (FPM)	CFM	ACH*	VELOCITY (FPM)	CFM	ACH
AC	11/3	27/93	576	7.2	NA	NA	NA
MDA	57	30	1,700	21.2	50	2,828	35.2
SLD1	57	30	1,700	21.2	50	2,828	35.2
SLD2	86	30	2,580	32.1	50	4,270	53.2

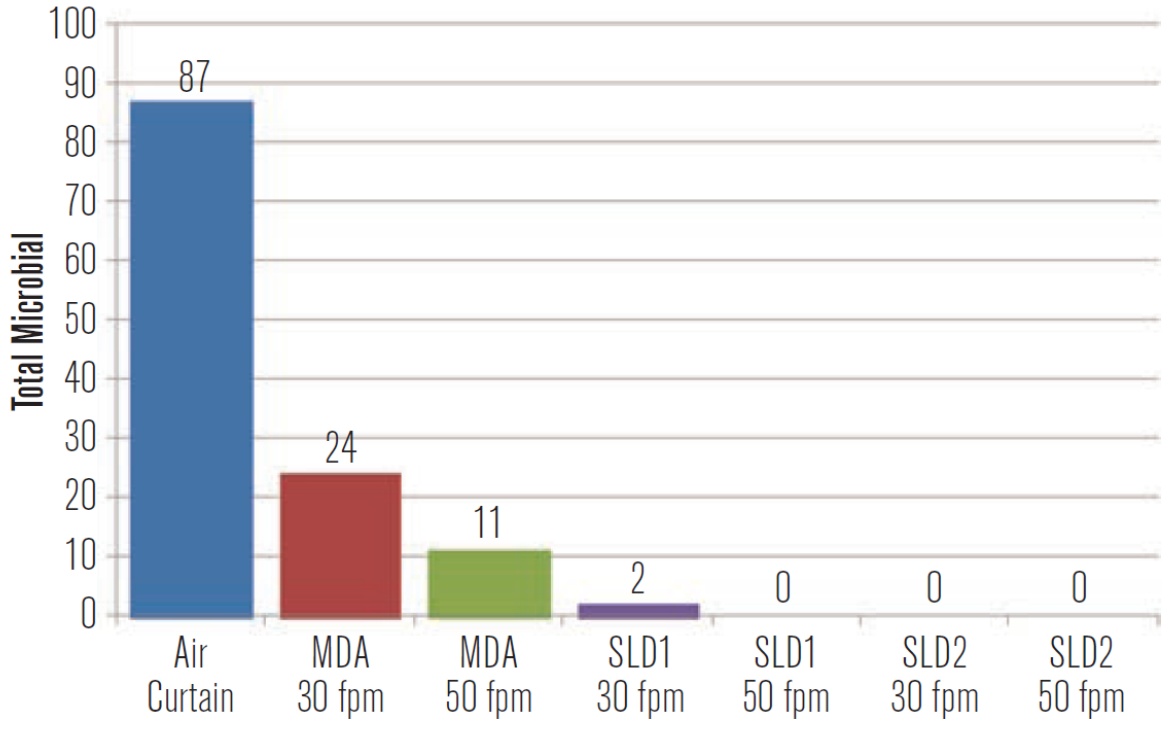


FIGURE 7 Microbial results, reported as colony forming units per cubic meter (cfu/m^3).

Source : ASHRAE Journal article Feb 2014 – Improving operating room contamination control

DIFFUSERS TO ACHIEVE UDAF

- ASHRAE STANDARD 170 : 2013 - Ventilation of healthcare facilities
  - Advises use of group “E” non-aspirating diffusers for operating rooms.
- HTM – 03 – 01 : 2007 – Specialised ventilation for healthcare premises
  - Advises use of plenum type laminar flow style diffusers. (Note : these are not true laminar flow systems in the strict sense of the word, but produce downward displacement parallel flow air distribution)
- ASHRAE HANDBOOK – HVAC Systems & Equipment (2012)
  - Defines laminar flow diffusers as those having a free area (open area of perforation for available for airflow) of less than 35%.

MEASUREMENT OF UNIDIRECTIONAL FLOW

- ISO 14644 -3 : 2005 – B.4.2.2 – Minimum number of measurement points shall be equal to square root of 10 times the area in square metres, but not less than 4 at a plane that is perpendicular to the airflow and at a distance of 150 mm from diffuser.
- HTM – 03 – 01 : 2007 - One measurement for every 280 x 280 mm square at 3 planes under the UDAF equipment, perpendicular to the airflow – 150 mm from diffuser, 2 m below diffuser and 1 m above the floor.
- NABH : 2015 – At the supply air grille face.

TARGET VALUES FOR VELOCITY IN A UDAF SYSTEM

❖HTM – 03 – 01 : 2007 –

- Minimum average velocity of 0.38 m/s at 2 m from supply air diffuser and minimum of 0.2 m/s at 1 m from the floor level.
- Average air velocity of each quadrant should not vary more than +/- 6% from the total average air velocity.

❖NABH : 2018

- Recommended to be between 25 to 35 fpm at the supply air grille face. (In the 2010 version of this standard this value was 90 to 120 fpm.)

❖ASHRAE 170 : 2017 – 7.4.1.A

- Airflow shall be unidirectional and downward flowing, with an average diffuser velocity between 25 and 35 fpm.

ALLOWED PARTICLE & MICROBIAL & LIMITS

- HTM 2025 : < 0.5 cfu / cubic metre when sampled immediately after the UDAF terminal diffuser
- HTM – 03 – 01 : < 10 cfu / cubic metre when sampled at the operating zone
- NABH 2018 : Less than 100 particles of 0.5 microns in size per cubic foot of sampled air at the supply diffuser.

ISOLATION ROOMS

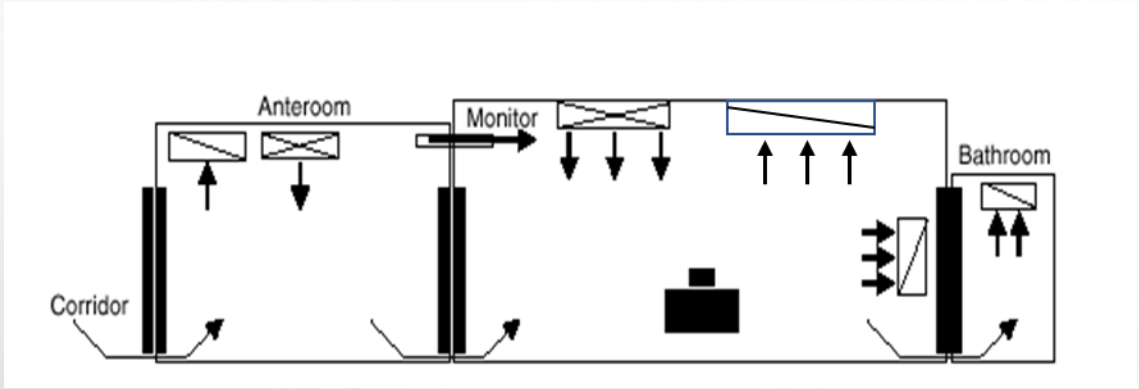
THE PRIMARY QUESTION !

- WHETHER THE PATIENT / PROCEDURE NEEDS TO BE PROTECTED FROM THE ENVIRONMENT?

- WHETHER THE ENVIRONMENT NEEDS TO BE PROTECTED FROM THE PATIENT / PROCEDURE?

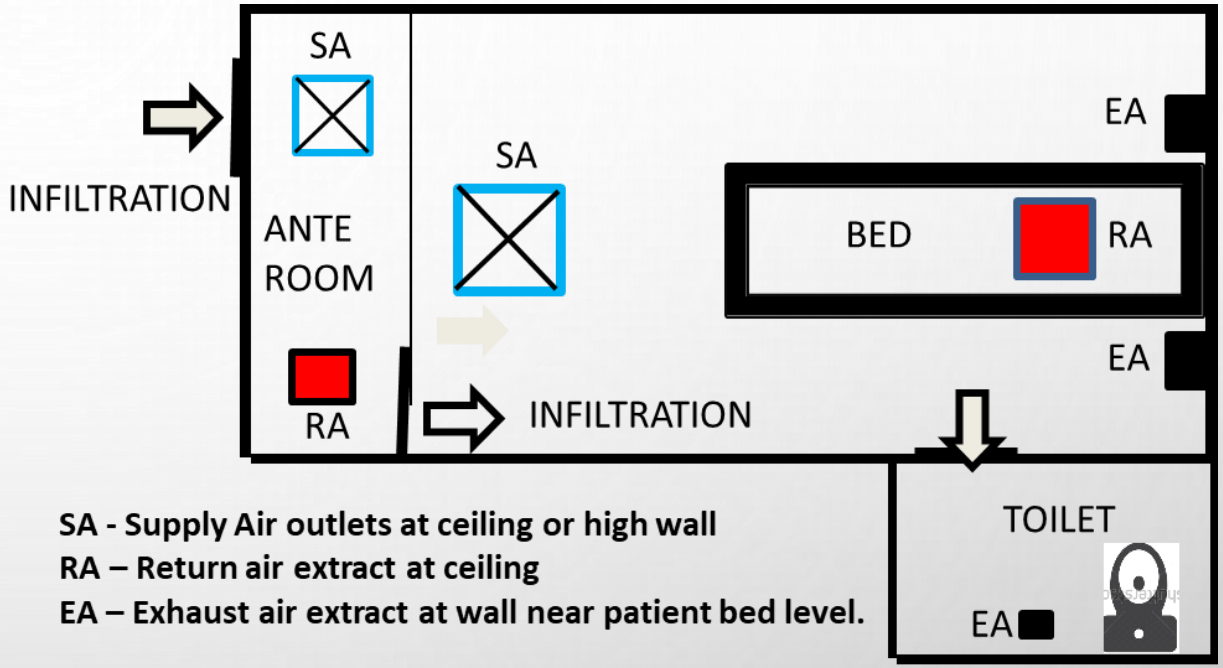
- OR BOTH ??

AIRBORNE INFECTION ISOLATION (A.I.I.) ROOMS



An All Room seeks to protect the external environment from the infection carried by the patient

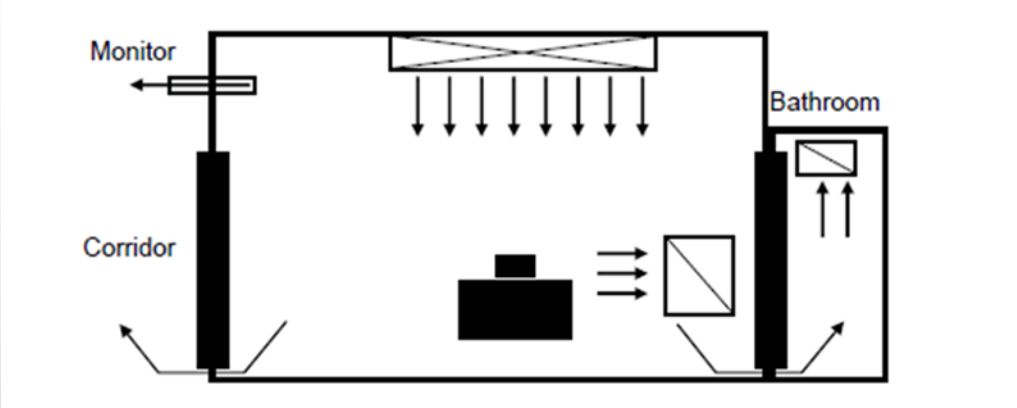
- Negative pressure.
- Clean to dirty airflow in the room: Towards the patient
- Ante room mandatory.
- Exhausts to be vented out safely or recirculated through HEPA filter.
- Use constant air volume systems.

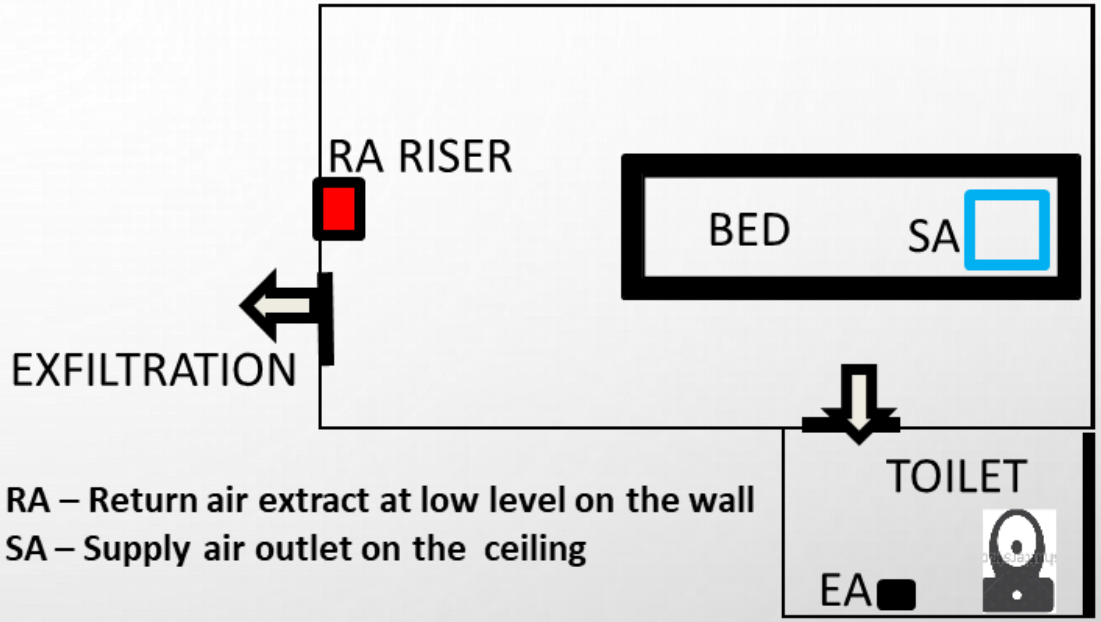


SA - Supply Air outlets at ceiling or high wall
RA – Return air extract at ceiling
EA – Exhaust air extract at wall near patient bed level.

Minimum TACPH		Minimum OACPH	Minimum Diff Pressure	Temp	RH
Patient room	Ante room	Patient room	Patient room Negative w.r.t corridor	° C	% (Max)
12	10	2	2.5 Pa	21 to 24	60

PROTECTIVE ENVIRONMENT(PE) ISOLATION ROOMS





A PE Room seeks to protect the patient from potential airborne infection.

- Positive pressure.
- Clean to dirty airflow in the room: Away the patient.
- Ante room advisable but not mandatory.
- Low velocity supply air over the patient.
- Use constant air volume systems.

Minimum TACPH		Minimum OACPH	Minimum Diff Pressure	Temp	RH
Patient room	Ante room	Patient room	Patient room Positive w.r.t corridor	° C	% (Max)
12	10	2	2.5 Pa	21 to 24	60

CHALLENGES IN PROVIDING CLEAN AIR

THINGS TO TAKE CARE OF

Grilles

Ducts

Air handling units

Filters

Water condensation from UDAF system

Microbial load in diffuser screens of a UDAF

CLASSICAL PROBLEMS AT SITE

- Damaged filters or improper filter installation – continuous and forced contamination ingress into OR.
- Improper fitment of laminar diffusers – improper airflow characteristics over the surgical table, hence higher risk of infection.
- Static charge build up on synthetic diffuser screens - contamination build up.
- Contaminated terminal filters and diffuser screens - continuous and forced contamination ingress into or.
- Improper insulation of the surgical pendent chute - condensation and water dripping over the surgical table.

CLASSICAL PROBLEMS AT SITE

- Shutting off the air handling system during hours of non use of the OR – results in contamination build up and also causes contamination on the terminal filters.
- Water stagnation in the air handling units – leads to build up of bio burden.
- Air leak in the air handling unit – leads to condensation out side the units and also loss of energy.
- Relative humidity higher than 60% - promotes growth of organisms.

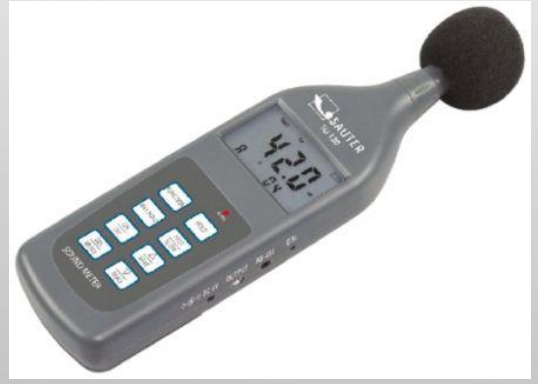
CLASSICAL PROBLEMS AT SITE

- Lack of return ducting.
- Improper sealing of surgical pendent chute - air leakage and contamination ingress.
- Duct leakage - energy wastage and possibility of contaminated air entering.
- Improper positioning and sizing of return air suction points - removal of contaminants from the critical zone is compromised.
- Improper air balancing – in sufficient or lack of positive pressure and also inadequate fresh air changes.
- Inadequate testing methods – undetected system flaws.

SOME IMPORTANT CONSIDERATIONS

- All return air paths to be ducted
- Do not allow for any crevices in the interior surfaces of rooms.
- All interior surfaces must be hard cleanable and should be non porous.
- Take adequate precautions during maintenance / retrofit / renovation
- Use “tacky mats” at various places to reduce contamination migration through traffic.
- Use pass boxes (dymanic / static) instead of opening doors each time
- Ensure ducts are leak free by conducting “duct leak tests”
- Run the AHU 24x7 without stoppage.

INSTRUMENTS FOR PARAMETRIC MEASUREMENTS



TESTING PARAMETERS FOR AIR CLEANLINESS

- Temperature
- Relative humidity
- Supply air velocity and uniformity
- Total air exchange rate
- Fresh air change rate
- Positive pressure
- Installed filter leakage test
- Particle concentration
- Flow visualisation
- Microbiological sampling

CASE STUDY

Impact of Operating Room Environment on Postoperative Central Nervous System Infection in a Resource-Limited Neurosurgical Center in South Asia

Swathi Chidambaram[1], Madabushi Chakravarthy Vasudevan[2], Mani Nathan Nair[3], Cara Joyce[4], Anand V. Germanwala[1]

RESULTS: **All 623 neurosurgical operative cases over the study period were reviewed. Four patients (0.6%) had a PCNSI, and no patients had a positive cerebrospinal fluid (CSF) culture. In the previous study, among 363 cases, 71 patients (19.6%) had a PCNSI and 7 (1.9%) had a positive CSF culture (all Gram-negative organisms). The differences in both parameters are statistically significant ($P < 0.001$). Between the 2 studies, there was no change in treatment providers, case types, case durations, antibiotic administration practices, and patient demographics.**

CONCLUSIONS: **The rates of PCNSI and positive CSF culture were significantly lower in our present cohort compared with the cohort in our previous study. The sole apparent change involves the air filtration system inside the neurosurgical operating rooms; this environmental change occurred during the 5 months between the 2 studies. This study demonstrates the impact of environmental factors in reducing infections.**

	Total number of surgeries	Post surgical central neuro system infection	Cerebro spinal fluid infection
Prior to HVAC correction	363	71	7
		19.6%	1.9%
After HVAC correction	623	4	0
		0.6%	

From the [1]Department of Neurosurgery, Loyola University Medical Center, Maywood, Illinois, USA; [2]Postgraduate Institute of Neurological Surgery, Dr. A. Lakshmipathi Neurosurgical Centre, Voluntary Health Services Hospital, Chennai, India; [3]Department of Neurosurgery, Georgetown University School of Medicine, Washington DC, USA; and [4]Department of Biostatistics, Loyola University Medical Center, Maywood, Illinois, USA

Citation: World Neurosurg. (2018) 110:e239-e244.
https://doi.org/10.1016/j.wneu.2017.10.142
*Journal homepage: **www.WORLDNEUROSURGERY.org***
*Available online: **www.sciencedirect.com***

CONCLUSION

- Contamination control through engineering systems are a sure shot protection and helps in reducing infection transmission.
- A properly designed and maintained HVAC system is a 24 x 7 tool when it comes to the fight against infection in a health care facility.
- Unidirectional air flow systems provide an aseptic environment in the critical zone only when designed, installed and tested properly. In the absence of the above, these systems cause more harm than g

THANK YOU FOR LISTENING!