KEMENTERIAN KESEHATAN REPUBLIK INDONESIA

BADAN STANDARDISASI NASIONAL

Sejarah Standard Ventilasi

Perumusan Performance-Based Code

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HEF 2022

Organized by: KIC

CURRICULUM VITAE

Dr. Ery Djunaedy

FOTO

Current Designation:

- Direktur Pengembangan, Sigmatech Tatakarsa
- Chief Scientist, Pusat Kinerja Bangunan dan Kota

Education Background:

- S1: Teknik Fisika, ITB
- S2: Building Science, NUS
- S3: Building Physics, TUE

Organization Experience :

- ASHRAE - Member
- IBPSA - Member

OUTLINE

01 **Sejarah Perkembangan Standard Ventilasi**

02 **Sejarah Perkembangan Standard Ventilasi**

03 **Precriptive vs Performance-Based vs Outcome-based**

04 **Prescriptive akan menaikkan konsumsi energi**

05 **Conclusion**

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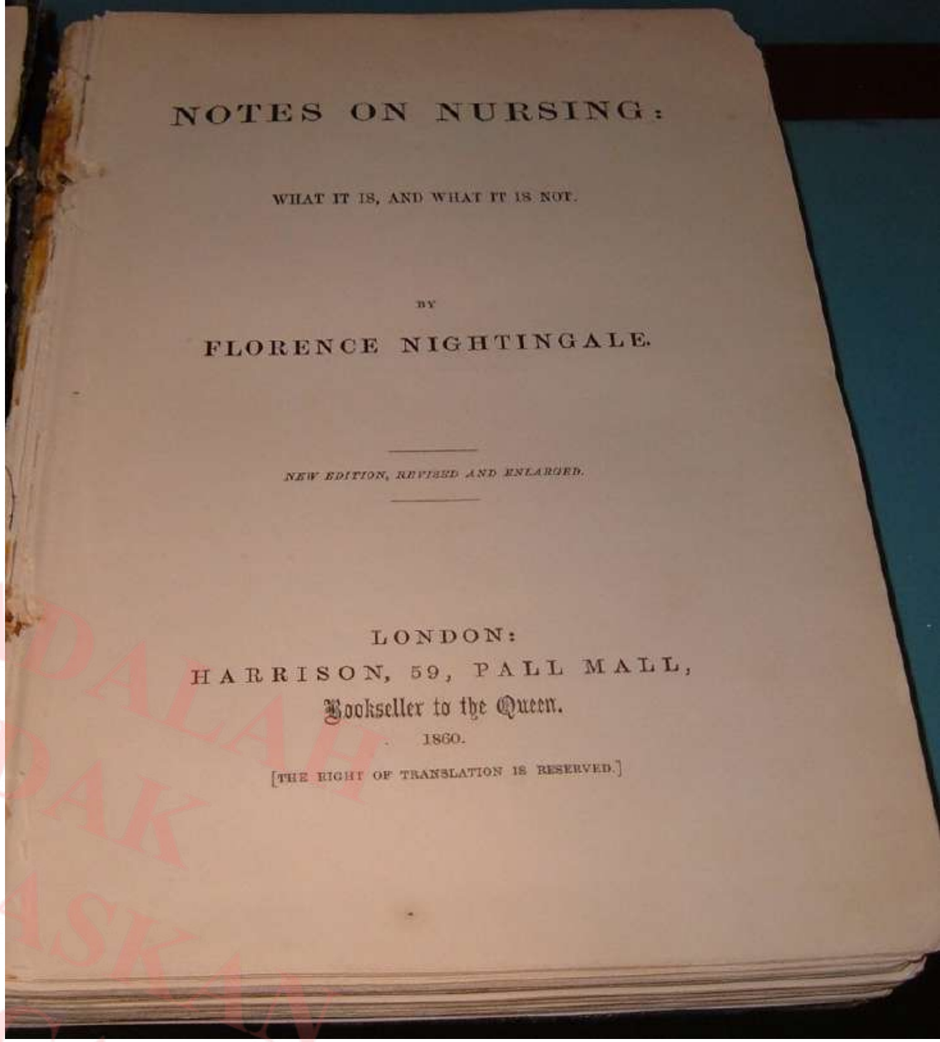
Sejarah Ventilasi di Rumah Sakit

Notes from the 19th Century

The **very first** canon of nursing, **the first and the last** thing upon which a nurse's attention must be fixed, the **first essential** to the patient, without which all the rest you can do for him is as nothing, with which I had almost said you may leave all the rest alone, is this:

TO KEEP THE AIR HE BREATHES AS PURE AS THE EXTERNAL AIR, WITHOUT CHILLING HIM.”

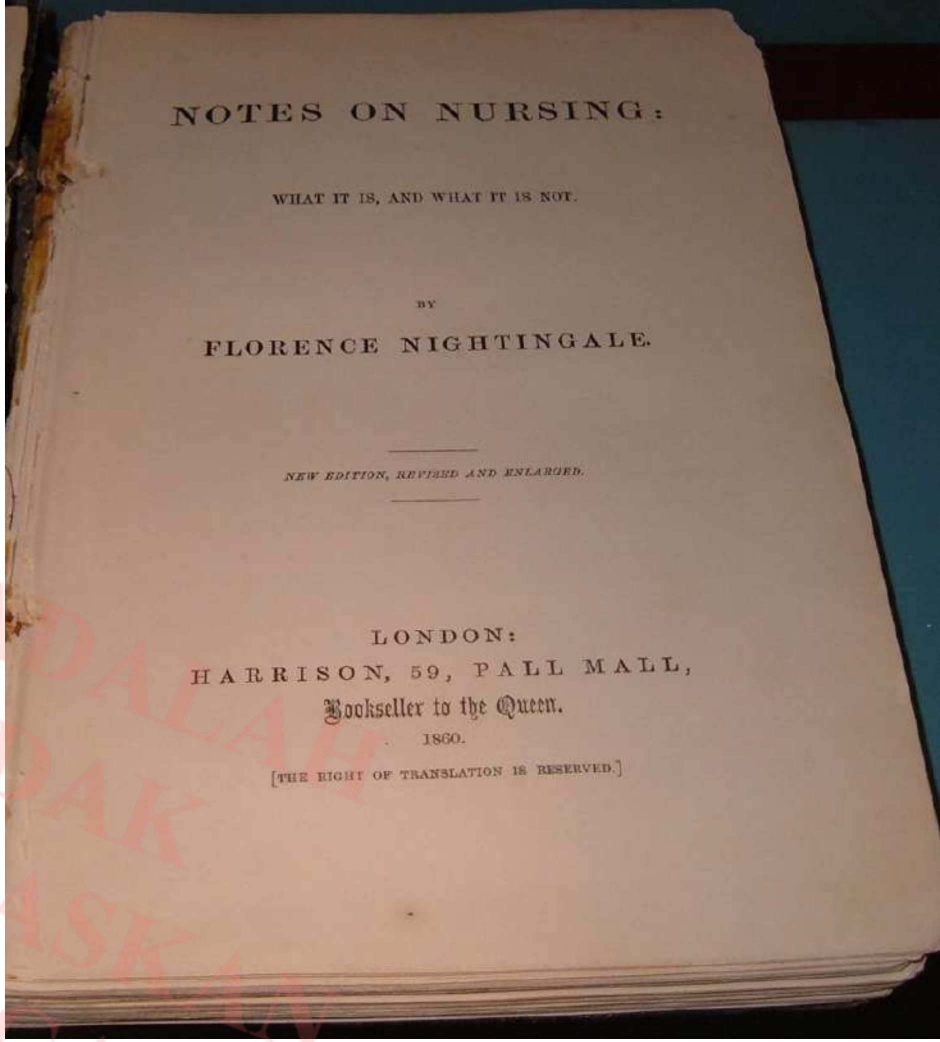


Florence Nightingale (1820-1910)
Notes on Nursing - What It Is and What It Is Not
1860.

Catatan dari Abad ke-19

- Aturan paling pertama dalam dunia keperawatan
- Hal yang pertama dan terakhir yang harus diperhatikan oleh seorang perawat
- Hal paling esensial bagi seorang pasien, yang kalau ini diabaikan, maka seluruh hal yang bisa dilakukan terhadap pasien itu seolah-olah tidak ada artinya
- Seolah-olah ingin saya katakan abaikan saja hal-hal lain

JAGALAH UDARA YANG DIHIRUP OLEH PASIEN **SEMURNI MUNGKIN MENDEKATI UDARA LUAR** TANPA MENYEBABKAN DIA KEDINGINAN



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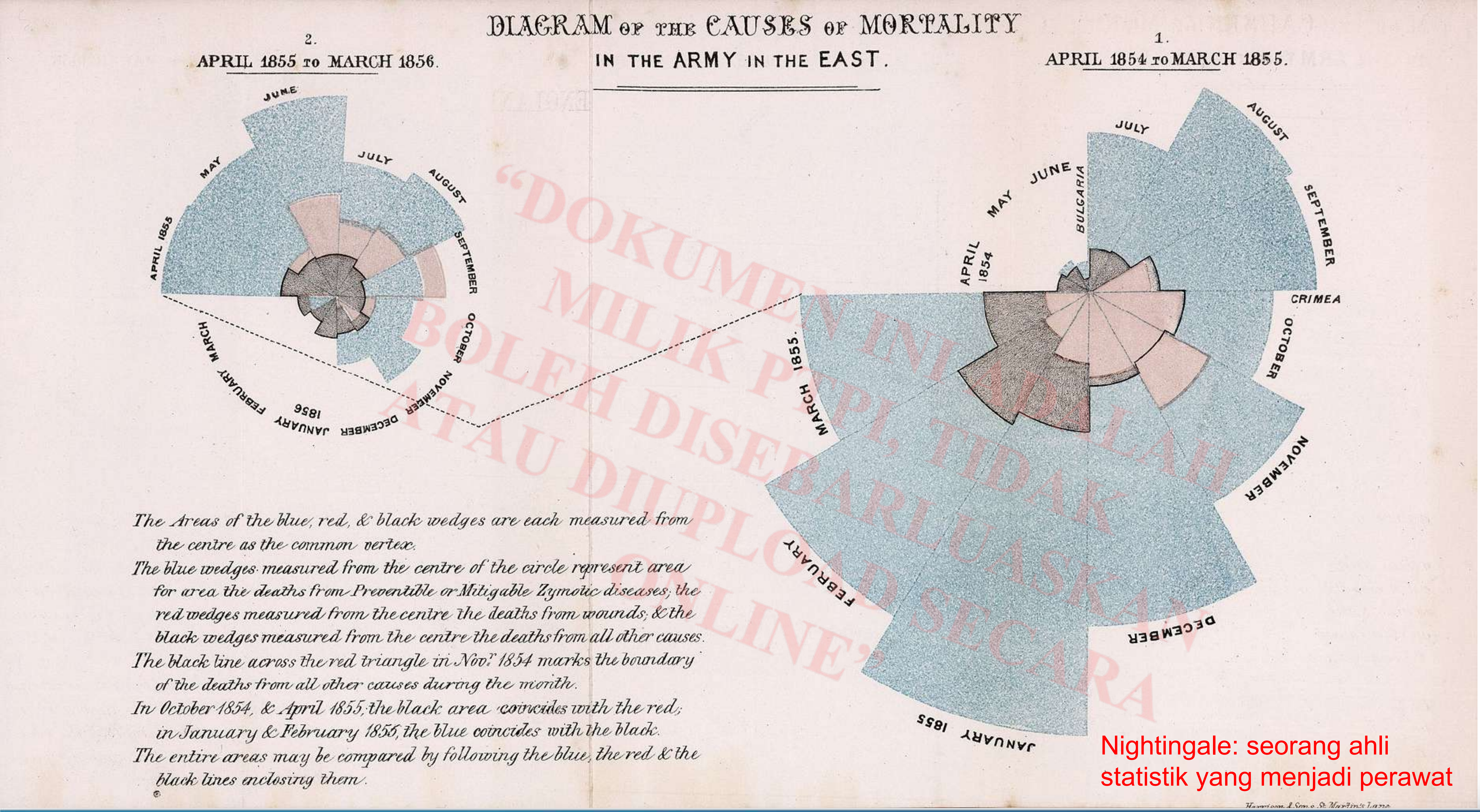
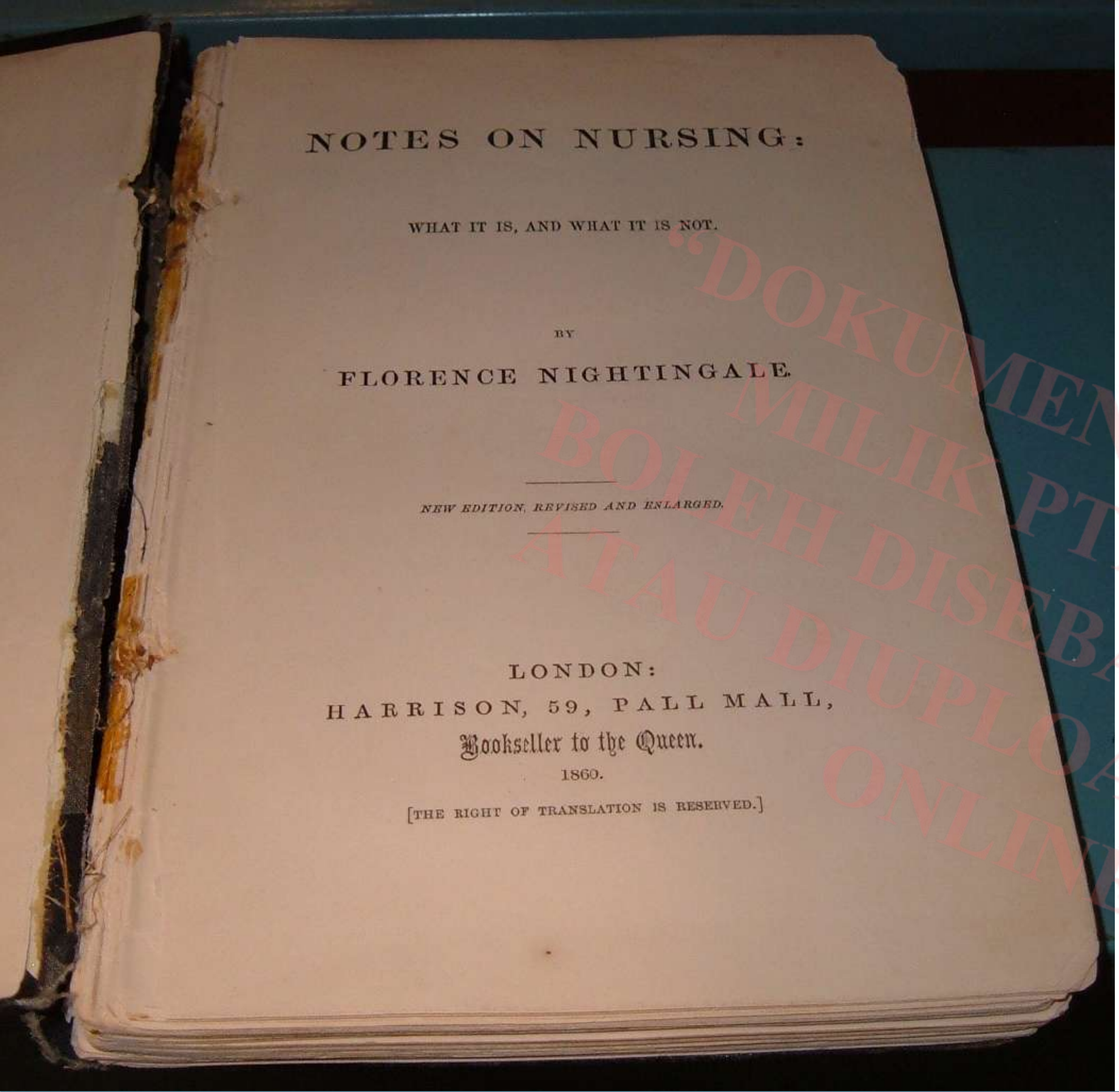


Nightingale: seorang ahli statistik yang menjadi perawat



NOTES ON NURSING:

WHAT IT IS, AND WHAT IT IS NOT.

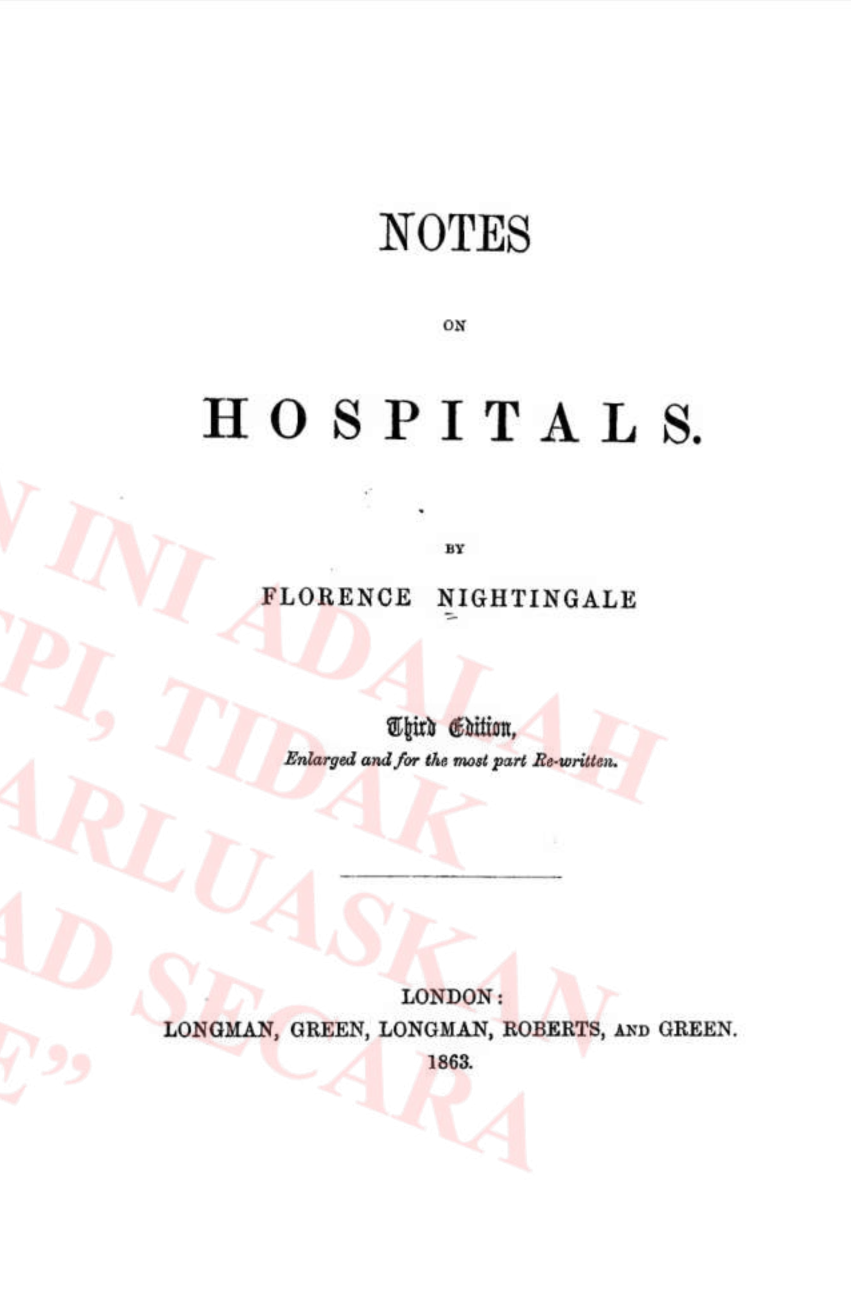
BY

FLORENCE NIGHTINGALE.

NEW EDITION, REVISED AND ENLARGED.

LONDON:
HARRISON, 59, PALL MALL,
Bookseller to the Queen.
1860.

[THE RIGHT OF TRANSLATION IS RESERVED.]



NOTES

ON

HOSPITALS.

BY

FLORENCE NIGHTINGALE

Third Edition,
Enlarged and for the most part Re-written.

LONDON:
LONGMAN, GREEN, LONGMAN, ROBERTS, AND GREEN.
1863.


Der Doctor Schna- -bel von Rom
Kleidung wider den Tod zu Rom. Anno 1656.


Florence Nightingale AN ANGEL OF MERCY. Scutari Hospital 1855
"When all the Medical Officers have retired for the night, and silence and darkness have settled down upon those miles of prostrate sick, she may be observed alone, with a little lamp in her hand, making her solitary rounds"

Table 1. Time Line

Year	Event
400 BCE	Hippocrates coins "do no harm."
1780	Ben Franklin is criticized for opening his window at night, in contrast to the popular miasma theory.
1836	Tredgold estimates ventilation rates at 4 cfm/person (2 L/s/person), to account for metabolic needs, breathing rates, and candle burning (Klauss et al. 1970).
1860	Florence Nightingale advocates access to ventilation to discourage miasma. Planners begin to use area per bed, volume per bed, and volume per bed per hour metrics.
1877	A U.K. army surgeon general report to the queen cites 108 ft^2 per bed (10 m^2/bed), one-story buildings, minimum volume per patient, and ventilation "to be changed twice every hour" (i.e. 2 ach) (Muir 1877).
1887	John Hopkins hospital is built with a "modern" architectural ventilation and heating system.
1890	Malaria is found to be transmitted by mosquitos. Often cited as the end of miasma theory. Germ theory replaces miasma in the medical field (Guillemin 2001).
1893	Billings suggests nonresidential ventilation rates at 30 cfm/person (15 L/s/person) for indoor hygiene and to prevent disease spread. Billings documents ventilation rates for hospitals at 2000 ft^3/head/h (60 m^3/head/h), 4000 ft^3/head/h (110 m^3/head/h) for fevers, and 5300 ft^3/head/h (150 m^3/head/h) in time of epidemic (Billings 1893). Other literature cites patient ward minimums at 100 ft^2/bed (10 m^2/bed), 1200–1500 ft^3/bed (34–42 m^3/bed), and 3000–5000 ft^3/h/bed (85–140 m^3/bed/h).
1905	Flugge estimates ventilation rates at 30 cfm/person (15 L/s/person) based on excessive temperature and unpleasant odor (Klauss et al. 1970).
1910	Pavilion hospitals were common: naturally ventilated "Nightingale wards" designed with minimum volumes per bed (Miller and Swensson 2002).
	Charles Chapin on air and miasma: "It may be fairly affirmed that there is no evidence that it is an appreciable factor in the maintenance of most of our common contagious diseases" (Chapin 1916). Emphasis shifts from air as a primary source of disease.
1914	ASHVE publishes nonresidential ventilation rates at 30 cfm/person (15 L/s/person) based on Billings, Flugge, and contemporaries. ASHVE manual includes a method for determining outdoor air quantities by measuring "carbonic acid" (i.e., CO_2).
1922	The pavilion hospital still in wide use. A survey in *Modern Hospital* journal lists typical volumes of 1000–2400 ft^3/bed (28–68 m^3/bed) (Webber 1922).
1925	Early U.S. codes publish nonresidential ventilation rates at 30 cfm/person (15 L/s/person) based on Billings, Flugge, and contemporaries.
1934	William F. Wells presents the droplet nucleus theory, publishes *On Airborne Infection: Study II: Droplets and Droplet Nuclei*.
1935	Lehmberg studies human occupants in airtight boxes. Beginning of the human chamber study era in ventilation research.
1936	Yaglou performs human chamber studies, and estimates ventilation rates at 15 cfm/person (7.5 L/s/person), based on odor control and considering outdoor air as a fraction of total air.
1937	Yaglou and Witheridge define ventilation effectiveness as $\varepsilon = (C_e - C_s)/(C - C_s)$.
1947	*General Standards* published for hospitals funded under the Hill-Burton program.
1957	Riley et al. demonstrate airborne spread of tuberculosis at Baltimore Veterans Hospital. Concept of a quanta introduced by Wells.
1959	ASHRAE publishes *Guide Book Chapter 8—Air Conditioning in the Prevention and Treatment of Disease*.
1960	Willis Whitfield, employee of Sandia National Laboratories, creates initial plans for a *cleanroom*, a space with measurable air cleanliness.
1960	Green and Yaglou publish separate studies of airborne bacterial counts in hospitals. Green proposes 1–2 CFU/ft^3 (35–71 CFU/m^3) for incoming supply air in health care spaces.
1963	Operating room air increased from 8 ach to 12 ach, based on Gaulin's studies.
1968	1968 Guide Book adds a table of recommended minimum ventilation rates for the various areas of the hospital, showing outdoor air ACH, total air ACH, exhaust, recirculation, and pressure requirements.
	Galson and Goddard tabulate ventilation rates based on sepsis goal of 1–2 CFU/ft^3 (35–71 CFU/m^3) in room air, recommending 13–18 ach in patient rooms (Galson and Goddard 1968).

Table 1. Time Line *(continued)*

Year	Event
1969	Operating room outdoor air reduced to 5 ach. This is "attributed [to] several factors: improvements and greater reliability of filtration of recirculated air, improvements in anesthesia, scavenger ventilation, and the imperative for energy conservation." (Wheeler 1993).
1970	Klauss et al. author "The History of the Changing Concepts in Ventilation Requirements" in the *ASHRAE Journal* (Klauss et al. 1970).
	Respiratory isolation precautions introduced for infection prevention (Siegel et al. 2007).
1971	Brachman estimates 10%–20% of endemic HAIs might be airborne (based on early National Infection Study Data).
1973	ASHRAE Standard 62 publishes ventilation rates at 15 cfm/person (7.5 L/s/person), based on Yaglou and contemporaries. Standard 62 includes 15 cfm/person in single-bed or dual-bed hospital room (7.5 L/s/person), Hospital occupant density noted at 10 per 1000 ft^2 (100 m^2).
1975	ASHRAE publishes Standard 90, on minimum energy requirements. Standard 90 prohibits constant-volume reheat in commercial buildings. However, it exempts health care facilities from ventilation conditions of Standard 90.
1977	NIOSH completes study of waste anesthetic gas exposure and proposes standard exposure thresholds (NIOSH 1977).
1976	ASHRAE publishes dust spot efficiency standard, ASHRAE Standard 52-76, for testing of filters.
1978	Wells-Riley equation published in the form $C = S\,(1 - e^{(-Iqpt/Q)})$.
1979	University of Minnesota energy and ventilation study advises most hospital ventilation rates could be reduced. Infection control review of 359 papers finds literature inconclusive on relevance of air quality in general infection prevention (DeRoos et al. 1978).
	Natural ventilation still acceptable in California, Missouri, and Oklahoma state codes (DeRoos et al. 1978).
1980	Knudsen estimates airborne spread in operating rooms accounts for 20%–24% of postoperative wound infections (Kundsin 1980).
	Riley in *Historical Perspective*: "The medical profession remains confused and, by and large, has not given its blessing to air disinfection in hospitals."
1981	ASHRAE reduces nonresidential ventilation rates to 10 cfm/person (5 L/s/person) based on energy concerns.
1983	Air contamination in operating rooms found to be correlated to subsequent infections in joint replacements (Lidwell et al. 1983).
	Survey at Duke University Hospital found 10%–12% of the 750,000 ft^2 (70 000 m^2) facility was *dirty* (air from those locations should not be recirculated). Recommended that 90% of the spaces could be ventilated using commercial standards (Chaddock 1983).
	ASTM issues *Standard Test Method for Determining Air Change in a Single Zone by Means of Tracer Gas Dilution*.
	Isolation precautions advanced to "category-specific" and "disease-specific" (Siegel et al. 2007).
1986	Woods studies operating room air (Woods et al. 1986a, 1986b).
	ACGIH recommends a limit of 283 CFU/ft^3 (10,000 CFU/m^3) total fungi.
1987	ASHRAE updates filter efficiency rating procedure to minimum efficiency reporting value in ASHRAE Standard 52.2-1987.
	AIA Guideline includes dual-filter beds, 25% efficient, 90% efficient, per ASHRAE Standard 52-1976 (AIA 1987).
	Bacterial counts (CFU/m^3) compared in high-volume operating rooms (80 ach) and conventional operating rooms (20 ach). Conventional operating room bacterial mean was 2 CFU/ft^3 (71 CFU/m^3); high-volume mean was 1.4 CFU/ft^3 (49 CFU/m^3) (Solberg 1987).
1988	WHO sets minimum recommendations for 2.8 CFU/ft^3 (100 CFU/m^3) for bacteria and 1.5 CFU/ft^3 (50 CFU/m^3) for fungi, in the report *Indoor air quality: Biological contamination*
1989	ASHRAE increases nonresidential ventilation rates to 15 cfm/person (7.5 L/s/person), based on works by Fanger, Cail, and Janssen, following sick building syndrome era (Janssen 1999). ANSI/ASHRAE Standard 62.1 also introduces the IAQ measured-performance method of design
	130–280 CFU/ft^3 (4500–10,000 CFU/m^3) suggested as upper limit for unclassified bacterial aerosols (ACGIH 1989).
1990	Raatschen publishes a literature review of DCV, clearing the way for extended applications.

Table 1. Time Line *(continued)*

Year	Event
1991	Federal Standard 209, *Airborne Particulate Classes in Cleanrooms and Cleanzones* defines clean air in a space. It requires pressurization of 0.05 in.w.g. (15 Pa) to avoid cross-contamination between spaces.
	Schaal estimates 10% of endemic nosocomial infections are airborne.
	Outbreaks of multistrain resistant tuberculosis occur in New York hospitals and jail communities.
1993	Hermans and Striefel publish table on length of stay versus risk of infection for tuberculosis.
	JCAHO bans smoking indoors in hospitals.
1994	NIST *Manual for Ventilation Assessment in Mechanically Ventilated Buildings* includes CO_2 evaluation.
	The BASE study of 100 buildings, in response to IAQ concerns, occurs (Burton et al. 2000).
	The CDC publishes *Guideline for Preventing the Transmission of TB*. Recommends 12 ach for isolation areas, ability to filter 90% of 1 µm particles.
1995	Principle of addition introduced by research to nonresidential ventilation.
	Striefel and Rhamme target 0.5 CFU/m^3 (18 CFU/m^3) of *Aspergillus* in bone marrow unit (Streifel and Rhamme 1995)
1996	FGI Guideline includes dual-filter beds, 30% efficient, 90% efficient, per ASHRAE Standard 52-1976 (AIA 1996)
	Federspiel describes "mean age of air" as a ventilation effectiveness metric (Federspiel 1999).
	Hospital isolation practices prepared and sorted into three categories: contact, droplet, and airborne (Siegel et al. 2007).
1998	ASTM publishes Standard D-6245, *Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation.*
1999	ISO 14644 classification of air cleanliness is published. Eventually supersedes Federal Standard 209 for cleanrooms.
	ASHRAE introduces rationale for demand-controlled ventilation into ANSI/ASHRAE Standard 62.1.
	ACGIH ceases publication of numerical CFU/ft^3 (CFU/m^3) exposure limits.
2000	Computational fluid dynamics study of comfort in patient rooms recommends 6 ach (Memarzadeh and Manning 2000).
	CFD study of minimizing airborne organisms in isolation rooms, modeling UV kill rates and 12 ACH in isolation rooms (Memarzadeh and Jaing 2000).
2001	AIA Guideline includes dual-filter beds, 30% efficient, 90% efficient, per ASHRAE Standard 52.1-1992. (FGI 2001)
	Development of a single-system, multiple-space methodology for outdoor air rates at a common air-handling system serving a variety of spaces.
	ANSI/ASHRAE Standard 62.1 includes 25 cfm per person in patient rooms and 15 cfm per person in recovery rooms and intensive care units.
2003	First edition of ASHRAE *HVAC Design Manual for Health Care Facilities* includes CFD Modeling Report including thermal plume theory.
2004	*Aspergillus* counts correlated to $PM_{2.5}$ measurements during a renovation, indicating $PM_{2.5}$ can be used to quickly proxy fungal spore concentrations (Mayatt et al. 2004).
	ASHRAE publishes R_p and R_a method, based on additive principle. For baseline office environment, R_p= 5 cfm/person (2.5 L/s/person), R_a = 0.06 cfm/ft^2 (0.3 L/s/m^2).
	USP 797 adopts doctrine to maintain air contamination "as low as reasonably achievable" in compounding pharmacies. Requires Class 5 and Class 7 cleanroom spaces, using ISO standards.
2005	CDC updates *Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health-Care Setting.*
	Stanke issues rationale and explanation of the science behind ANSI/ASHRAE Standard 62.1-2004 (Stanke 2006).

Table 1. Time Line *(continued)*

Year	Event
2007	Federal Standard 209 is canceled in favor of ISO 14644 for cleanrooms.
	Li et al. review ventilation and airborne transmission. "There is insufficient data to specify and quantify the minimum ventilation requirements in hospitals, schools, offices, homes and isolation rooms in relation to spread of infectious diseases via the airborne route." (Li et al. 2007).
	Use of mobile-air units demonstrated for real-time control of airborne contamination (Bergeron et al. 2007).
	CBECS reports national average in U.S. occupant density 2145 ft^2/bed (200 m^2/bed) and 586 ft^2/person (93 m^2/person) (EIA 2012).
	Kowalski estimates up to 30% of HAIs could be airborne; publishes catalogue of potential airborne pathogens, and removal efficiency of MERV 13 filters (Kowalski 2008).
	U.K. National Health Service sets energy targets for new buildings and refurbishments (Short et al. 2010).
2008	Typical practice: Occupant density, area per bed in new construction is up to 2300–2700 ft^2 (215–240 m^2) (HFMA).
	Initial publication of ANSI/ASHRAE/ASHE Standard170, *Ventilation for Health Care Facilities.*
2009	Bioaerosol concentrations reviewed in industrial settings, where heavy bioaerosols are present (e.g., agricultural, food processing) (Gilbert and Duchaine 2009).
	Romanian researchers monitor microbiological quality in health care spaces (Sirbu et al. 2009).
	WHO publishes *Natural Ventilation for Infection Control in Health Care Settings*. Includes 60 paper literature review of infection and air, finds "little evidence that increased ventilation reduces infections"; paper recommends general ventilation of 30 cfm/patient (60 L/s/patient) in all spaces.
2010	U.S. hospital energy study estimates 200 ft^2/person (19 m^2/person) occupant density in general hospital areas (Bonnema et al. 2010).
2011	Jessica Green's TED Talk *Are We Filtering the Wrong Microbes* summarizes University of Oregon research, and suggests mechanical filtration of air removes healthy bacteria in hospitals, leaving higher concentrations of pathogens.
	Bioaerosols literature review finds no consensus on biological agent concentrations, mostly due to lack of dose-response relationship (Gorny et al. 2011).
	Researchers in Asia correlate bacterial counts to RH and CO_2 in nursing care unit, and implement real-time controls of bioaerosols based on monitoring (Wu et al. 2011).
2012	DCV performance validated by ASHRAE research project RP-1547.
	CFD study of airborne transmission indicates system design (outlet and exhaust placement) may be more important than flow rates (ACH) in infectious transmission (Memarzadeh and Xu 2012).
	Kemble et al. study on microorganisms published. Shows DNA strains of airborne microbes under natural ventilation versus mechanical ventilation (Kemble et al. 2012).
	The Hospital Microbiome Project begins in Chicago to characterize microbial communities within hospitals.
2013	ANSI/ASHRAE Standard 62.1's IAQ procedure successfully implemented in six retail stores; IAQ achieved with less ventilation than required by standard calculations (Bridges 2013).
2013	Literature review, including 145 references, indicates there is "insufficient data to specify or quantify the minimum ventilation requirements in public spaces, including hospitals, office buildings, aircraft, and schools in relation to the spread of airborne infection" (Memarzadeh 2013).
2013	ASHRAE 1397-RP, *Experimental Investigation of Hospital Operating Rooms*, published. Authors did not confirm existence of thermal plumes.
	ASHRAE *170-2013* updated and published
	ASHRAE HVAC Design Manual for Hospitals and Clinics updated and published
2014	Real-time IAQ monitoring implemented in a health care setting in Taiwan, featuring controls based on CO_2, total bacteria, and particulate matter (Yang et al. 2014).
	Researchers document performance measurement and control of IAQ in a health care setting in Saudi Arabia (El-Sharkawy and Noweir 2014).

Before 1900:
Miasma
Lavoisier 1774 O_2
Lavoisier 1775 CO_2
Polluted cities Paris and London, late 18th and 19th century

After 1900:
Influenza pandemic 1918-1919
Carrier 1919 “manufactured weather”
Fanger thermal comfort
Energy crisis 1973

After 1990:
Sick building syndrome
US Indoor Air Act of 1991
Eurovent 2002
SARS epidemics 2003
WorldVent 2006

Old Health period

Comfort period

New Health period

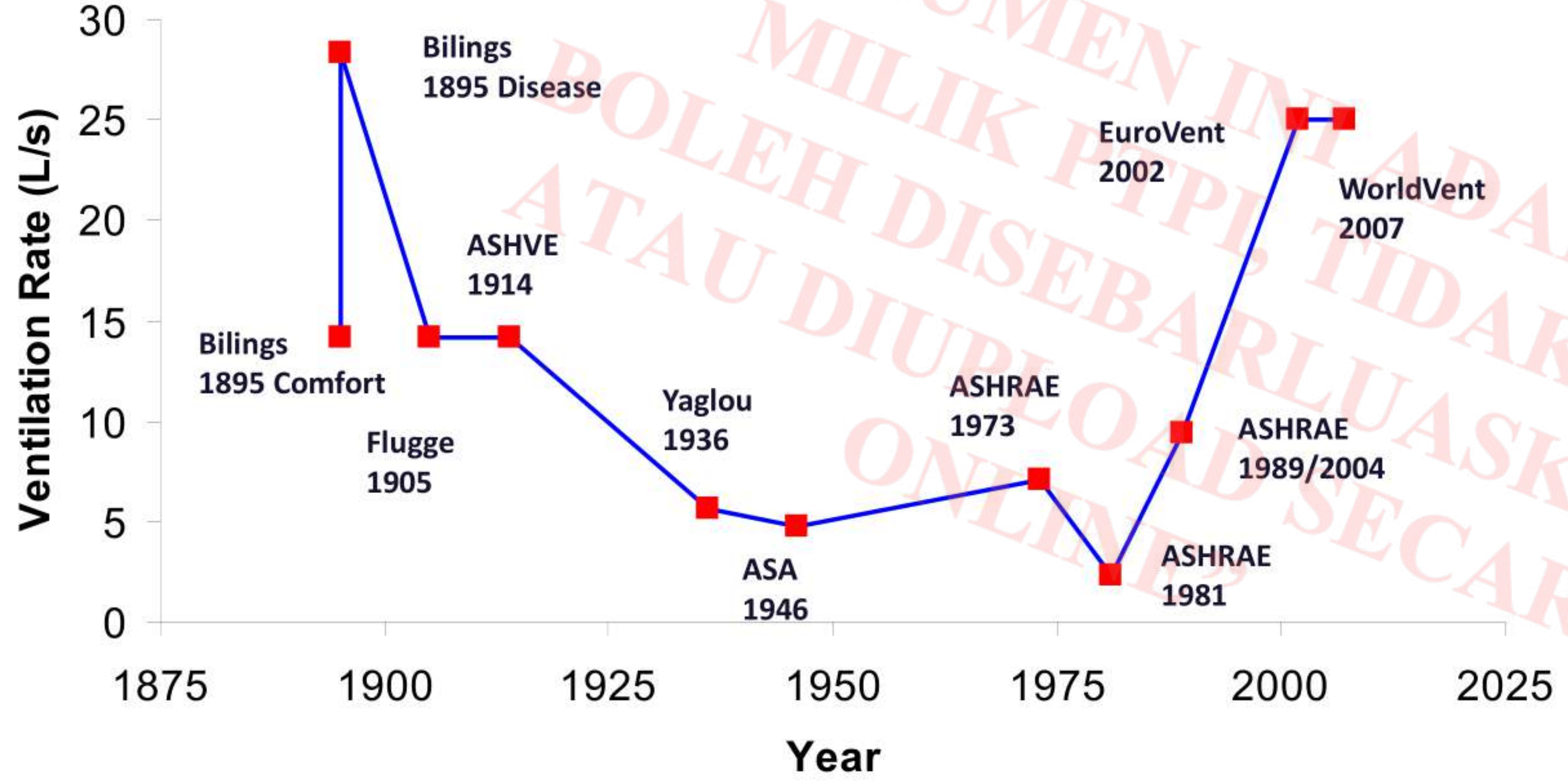


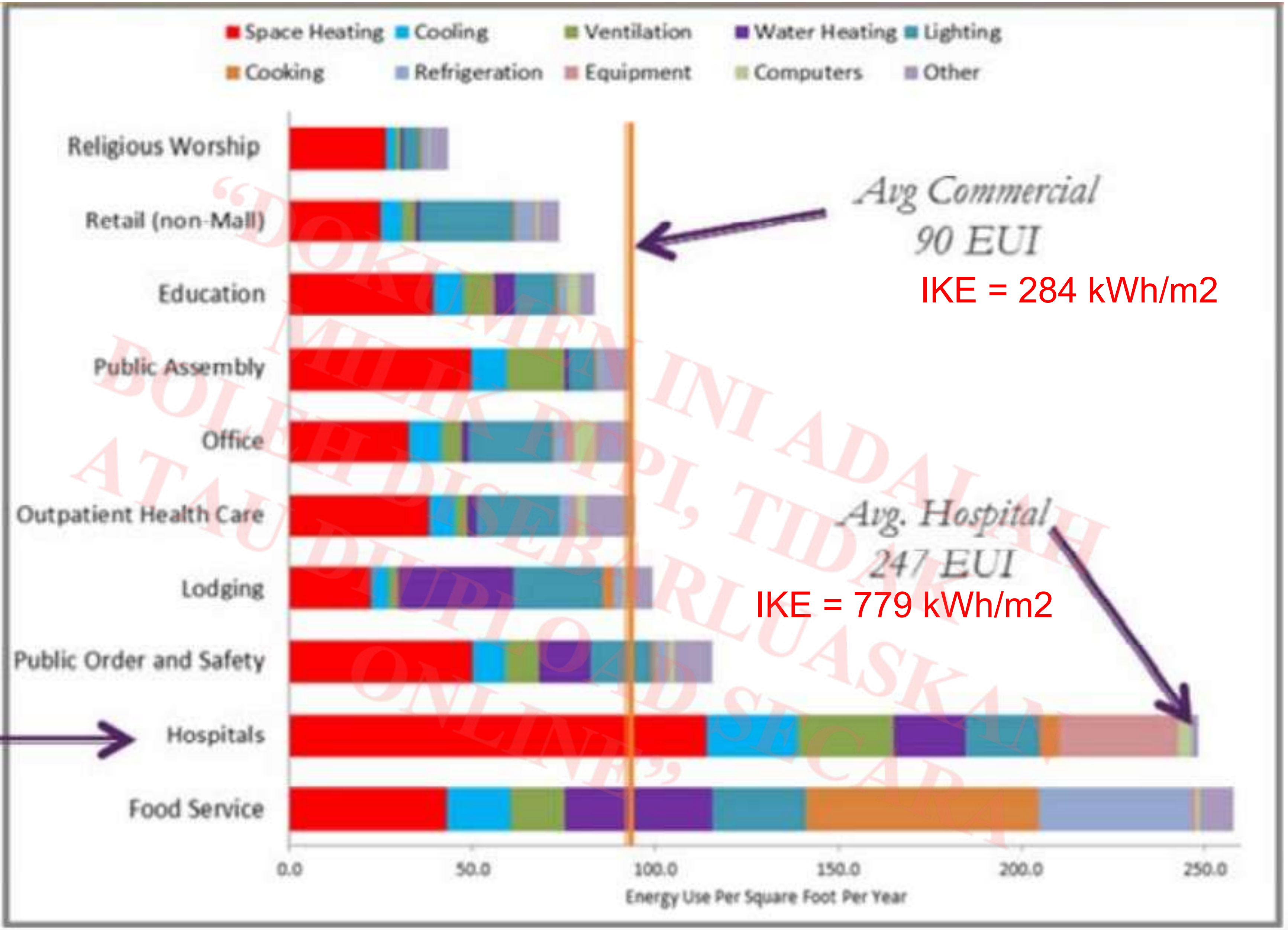
Table 2. Selected Air Change Rates Across the Years

	1959	1962	1964	1966	1968	1971	1974	1978	1982	1987	1991	1993	1997	2001	2006	2008	2013
	Source: ASHRAE Guidebooks, compiled in *Ventilation Designs* (Hermans and Streifel 1993).											Source: FGI archives (FGI 2013).				Source: ANSI/ ASHRAE/ASHE Standard 170.	
Surgery and Critical Care																	
OR: 100% OA	8-12	15	15	15	—	—	—	15	15	15	15	—	—	—	—	—	—
OR: recirculated	—	—	—	—	25/5	25/5	25/5	25/5	25/5	25/5	25/5	15/3	15/3	15/3	15/3	20/4	20/4
Delivery: 100% OA	—	15	15	15	—	—	—	—	—	—	15	—	—	—	—	—	—
Delivery: recirculated	—	—	—	—	25/5	25/5	25/5	25/5	25/5	25/5	25/5	15/3	15/3	15/3	15/3	20/4	20/4
Recovery	—	4	4	4	15/6	15/6	15/6	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2
Nursery	8-12	12	12	12	15/5	15/5	15/5	12/5	12/5	12/5	12/5	6/2	6/2	6/2	6/2	6/2	6/2
Trauma room	—	—	—	—	25/5	25/5	25/5	25/5	25/5	25/5	25/5	15/3	15/3	15/3	15/3	15/3	15/3
Anesthetic storage	2	2	—	8	8/8	8/8	8/8	8	8	8	—	8	8	8	8	8	8
Patient room	1.5	1.5	2	4/2	4/2	4/2	2/2	2/2	2/2	4/2	—	2/1	2/2	6/2	6/2	6/2	4/2
Toilet room	—	—	—	—	—	10	10	10	10	10	10	10	10	10	10	10	10
Intensive care	—	—	—	—	6/6	6/6	6/2	6/2	6/2	6/2	—	6/2	6/2	6/2	6/2	6/2	6/2
Isolation room	—	4	4	6	12/12	12/12	12/12	6/2	6/2	6/2	6/2	6/1	12/2	12/2	12/2	12/2	12/2
Anteroom	—	—	—	—	6/6	6/6	6/6	10/2	10/2	10/2	10/2	10	10	10	10	10	10
LDRP	—	—	—	—	—	—	—	—	—	—	4/2	2	2/2	6/2	6/2	6/2	6/2
Patient corridor	—	—	—	—	—	4/4	4/4	4/4	4/2	4/2	4/2	2	2	2	2	2	2
Radiology																	
X-ray surgery	—	—	—	—	—	—	—	—	—	15/3	15/3	15/3	15/3	15/3	15/3	15/3	15/3
X-ray diagnostic and treatment	—	6	6	10	6/6	6/6	6/6	6/2	6/2	6/2	6/2	6	6	6	6	6/2	6/2
Darkroom	—	10	10	12	15/6	15/6	15/6	10/2	10/2	10/2	10/2	10	10	10	10	10/2	10/2
Laboratory																	
General	—	—	—	—	—	6/6	6/6	6/6	6/2	6/2	6/2	6	6	6	6	6/2	6/2
Bacteriology	—	10	10	10	10	—	—	—	—	6/2	6/2	—	—	—	—	6/2	6/2
Biochemistry	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Cytology	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Glass wash	—	—	—	—	—	—	—	—	10/2	10	—	10	10	10	10	10/2	10/2
Histology	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Nuclear medicine	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Pathology	—	—	—	—	—	—	—	—	6/2	6/2	—	6	6	6	6	6/2	6/2
Serology	—	—	—	—	—	—	—	—	—	—	6/2	6	6	6	6	6/2	6/2
Sterilization	—	—	—	—	—	—	—	—	10	10	10	10	10	10	10	10/2	10/2
Media transfer	—	—	—	4/4	4/4	4/4	4/2	4/2	4/2	4/2	—	—	—	—	—	4/2	4/2

Table 2. Selected Air Change Rates Across the Years *(continued)*

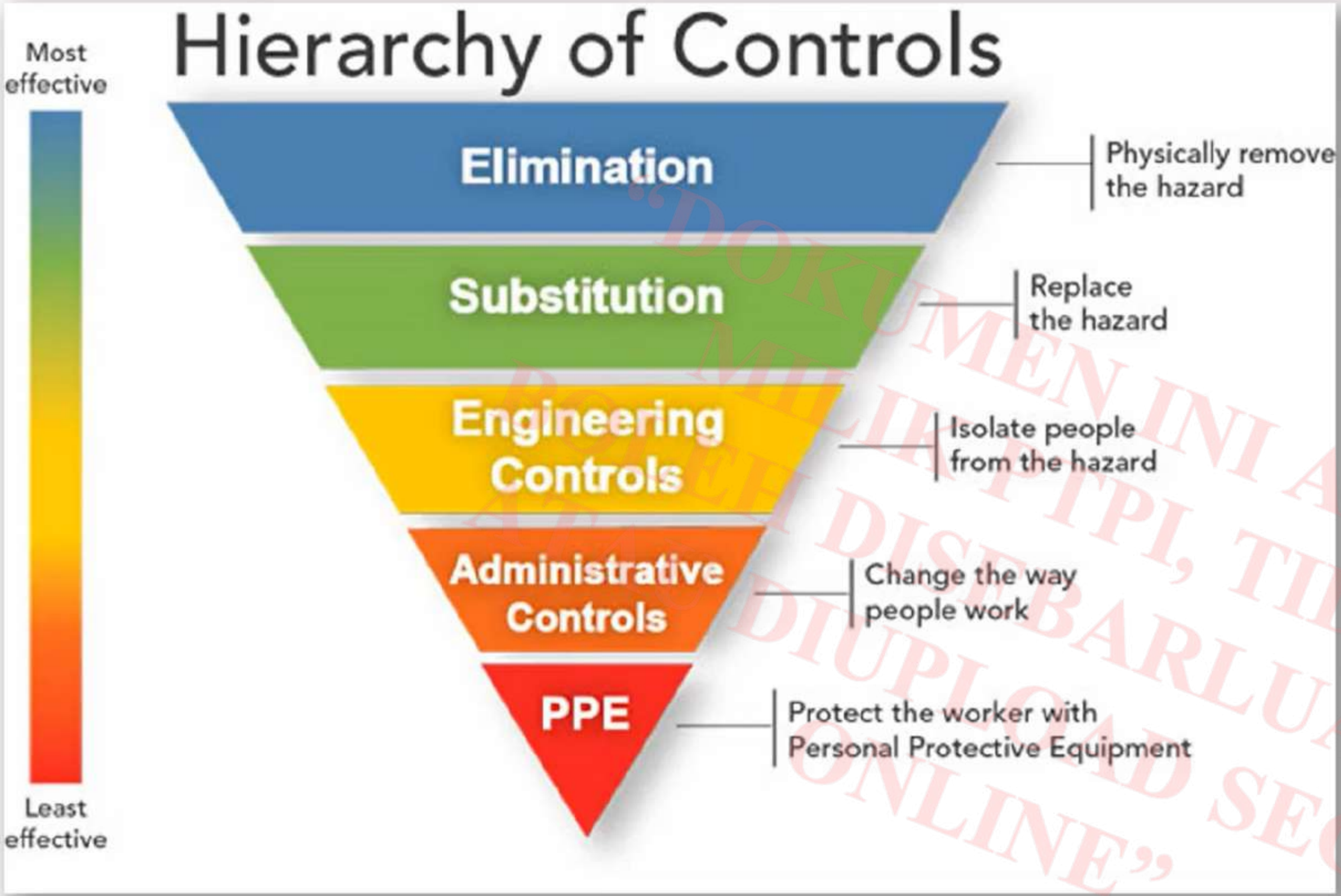
	1959	1962	1964	1966	1968	1971	1974	1978	1982	1987	1991	1993	1997	2001	2006	2008	2013
	Source: ASHRAE Guidebooks, compiled in *Ventilation Designs* (Hermans and Streifel 1993).											Source: FGI archives (FGI 2013).				Source: ANSI/ ASHRAE/ASHE Standard 170.	
Autopsy	—	10	10	15	15/6	15/6	15/6	12/2	12/2	12/2	12/2	12	12	12	12	12/2	12/2
Body holding	—	—	—	—	—	10	10	10	10	10	—	10	10	10	10	10	10
Pharmacy	—	—	—	—	—	—	—	4/2	4/2	4/2	4/2	4	4	4	4	4/2	4/2
Diagnostic and Treatment																	
Exam	—	4	4	4	12/6	12/6	12/6	6/2	6/2	6/2	6/2	6	6	6	6	6/2	6/2
Medication room	—	—	—	—	—	—	—	4/2	4/2	4/2	4/2	4	4	4	4	4/2	4/2
Treatment	4	4	4	12/6	12/6	12/6	6/2	6/2	6/2	6/2	—	6	6	6	6	6/2	6/2
Physical therapy	—	—	—	—	4/4	4/4	4/4	6/2	6/2	6/2	6/2	6	6	6	6	6/2	6/2
Soiled holding	—	3	3	4	12/4	12/4	12/4	10/2	10/2	10/2	10/2	10	10	10	10	6/2	6/2
Clean holding	—	—	—	3	12/4	12/4	12/4	4/2	4/2	4/2	4/2	4	4	4	4	4/2	4/2
Service																	
Food preparation	—	20	20	20	20/20	20/20	20/20	10/2	10/2	10/2	10/2	10	10	10	10	10/2	10/2
Ware wash	—	—	—	—	10	10	10	10	10	10	10	10	10	10	10	10	10
Dietary storage	—	—	—	—	2	2	2	2	2	2	2	2	2	2	2	2	2
Laundry	—	10	10	10	10/10	10/10	10/10	10/2	10/2	10/2	10/2	10	10	10	10	10/2	10/2
Soiled linen	—	8	8	8	10	10	10	10	10	10	10	10	10	10	10	10	10
Clean linen	—	8	8	8	2/2	2/2	2/2	2	2	2	2	2	2	2	2	2	2
Trash chute	—	—	—	10/2	10/2	10/2	10	10	10	10	—	10	10	10	10	—	—
Bedpan room	—	—	—	—	10	10	10	10	10	10	10	10	10	10	10	10	10
Bathroom	—	—	—	—	10	10	10	10	10	10	10	10	10	10	10	10	10
Janitors closet	—	—	—	10	10	10	10	10	10	10	—	10	10	10	10	10	10

- Sejak tahun 2000an terjadi lonjakan konsumsi energy RS



Source: 2002 CBECs dataset
http://www.eia.gov/consumption/commercial/

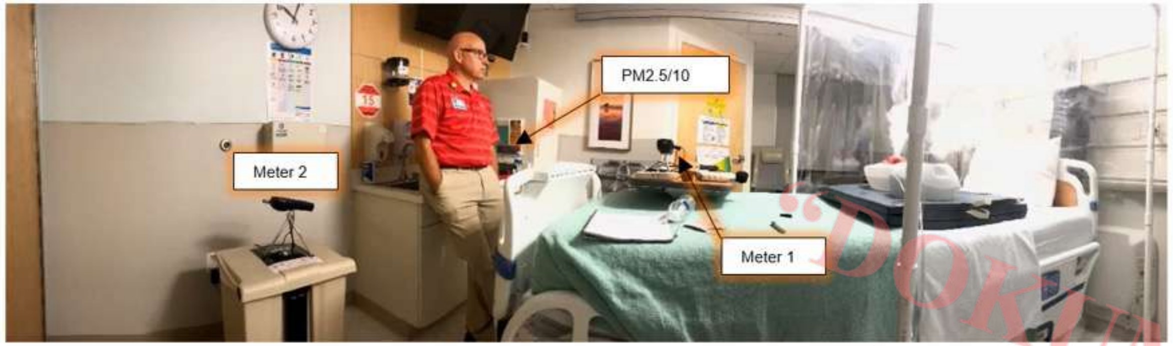
2 Engineering Intervention



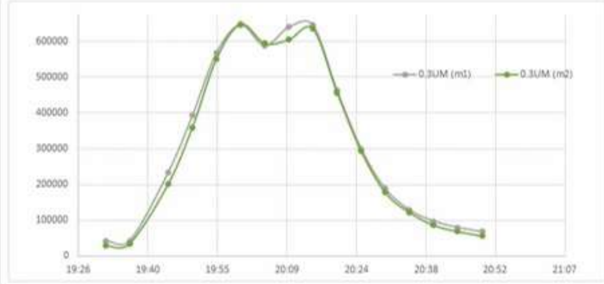
Engineering Controls

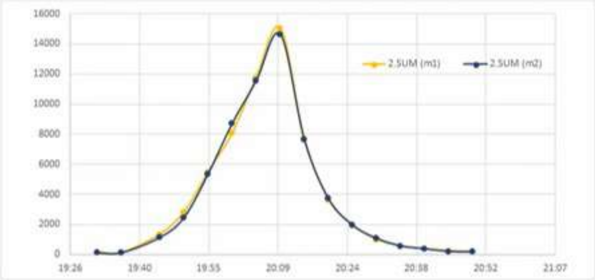
1. Capture and Removal
2. Ventilation
3. Containment

1. Capture and Removal

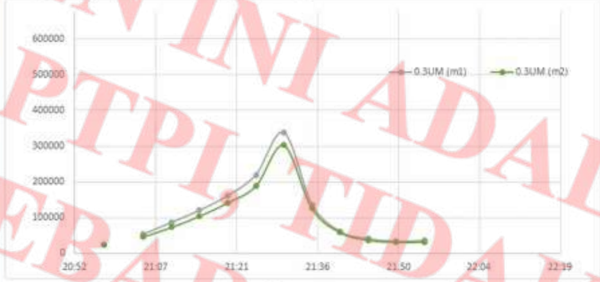


Baseline Test



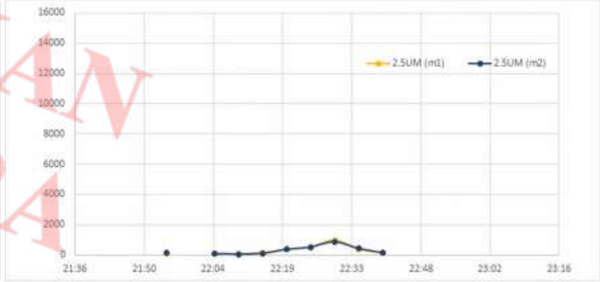


Low Speed = 65% capture.



50% Speed = 85% capture. 75% Speed = 100% capture

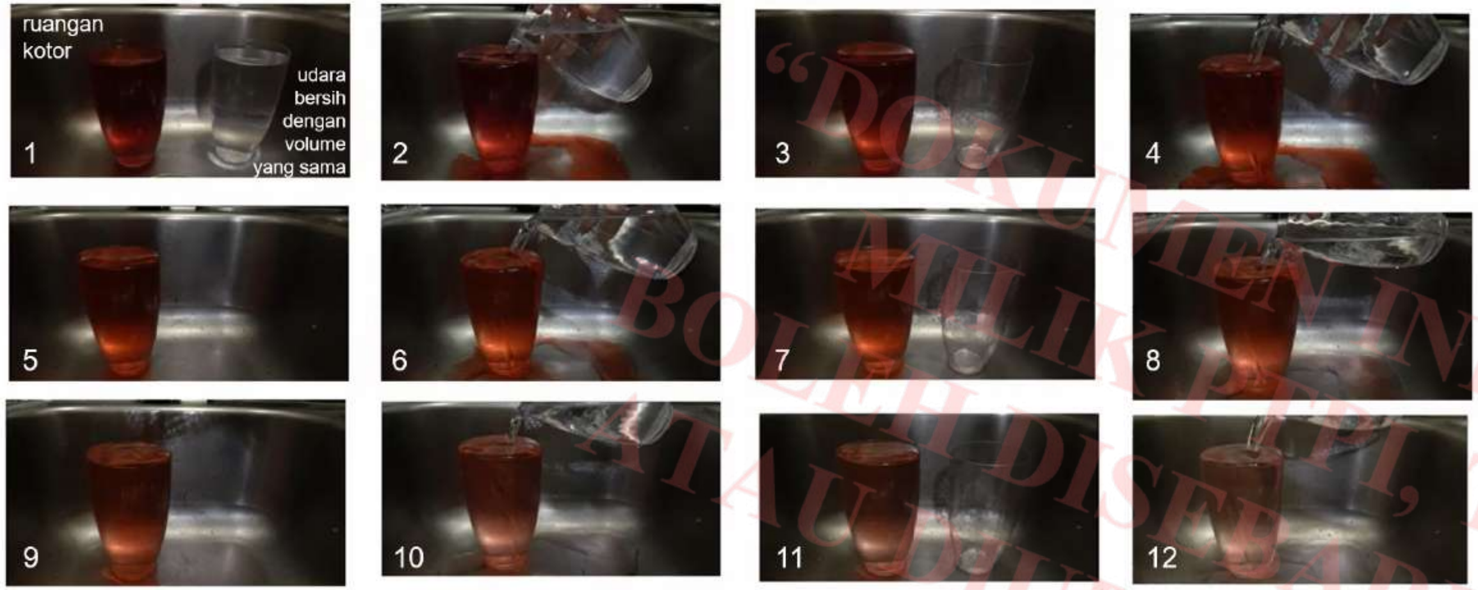
PASS!



Ventilation: Dilution

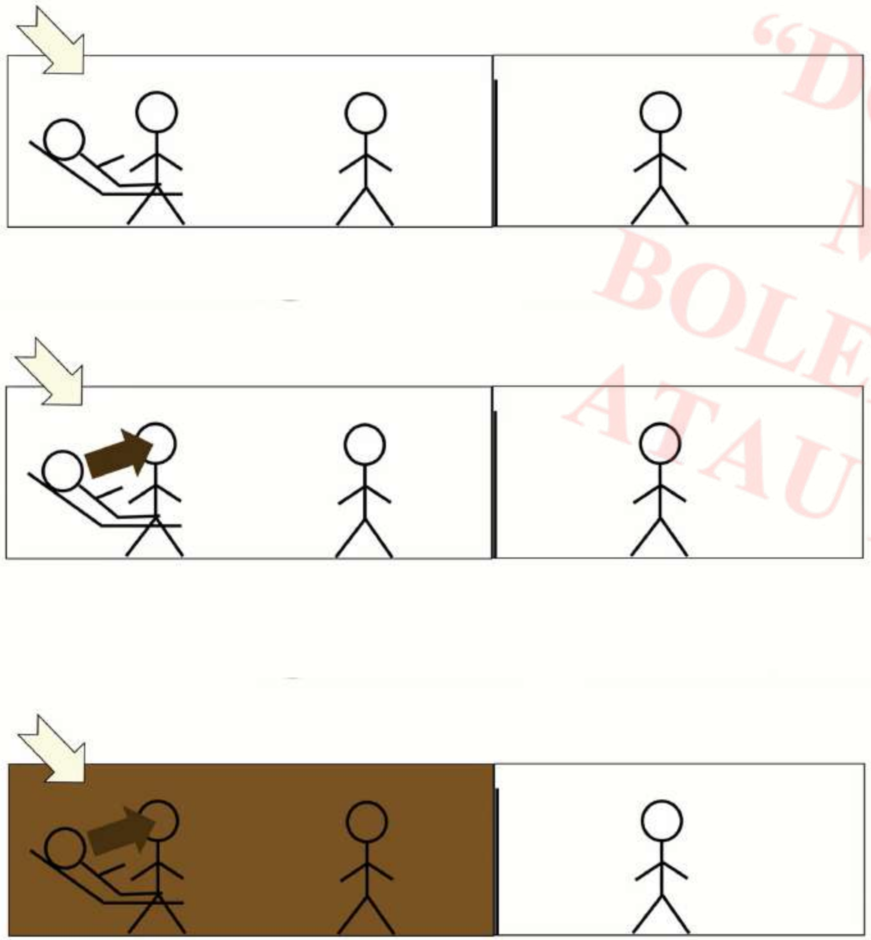
ACH adalah pergantian udara tiap jam sebanyak volume ruangan

Ventilation: Dilution



- Dilution memang tidak bisa menghilangkan seluruh polutan
- Tetapi dengan menurunkan jumlah/ konsentrasi polutan maka resiko/ potensi penularan bisa diturunkan menjadi kecil sekali, bisa diabaikan
- Jumlah pertukaran udara (ACH) menjadi penting

Containment: Negative Pressure

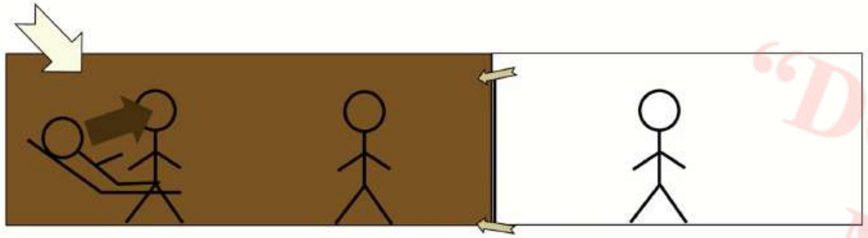


- Sebuah ruangan bertekanan negatif berbatasan dengan koridor

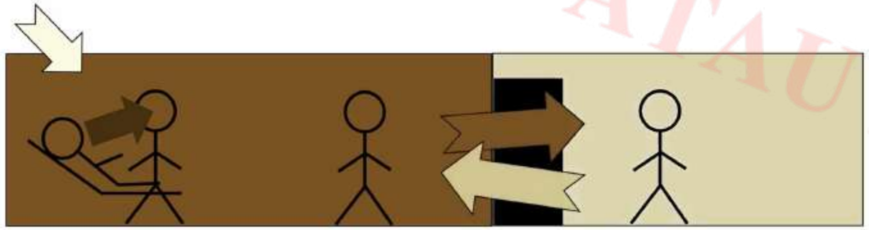
- Bila pasien mengeluarkan polutan, maka orang-orang di dalam ruangan tidak terlindungi dengan tekanan negative
- Harus mengenakan APD

- Tekanan negatif HANYA melindungi orang di luar ruangan

Containment: Negative Pressure

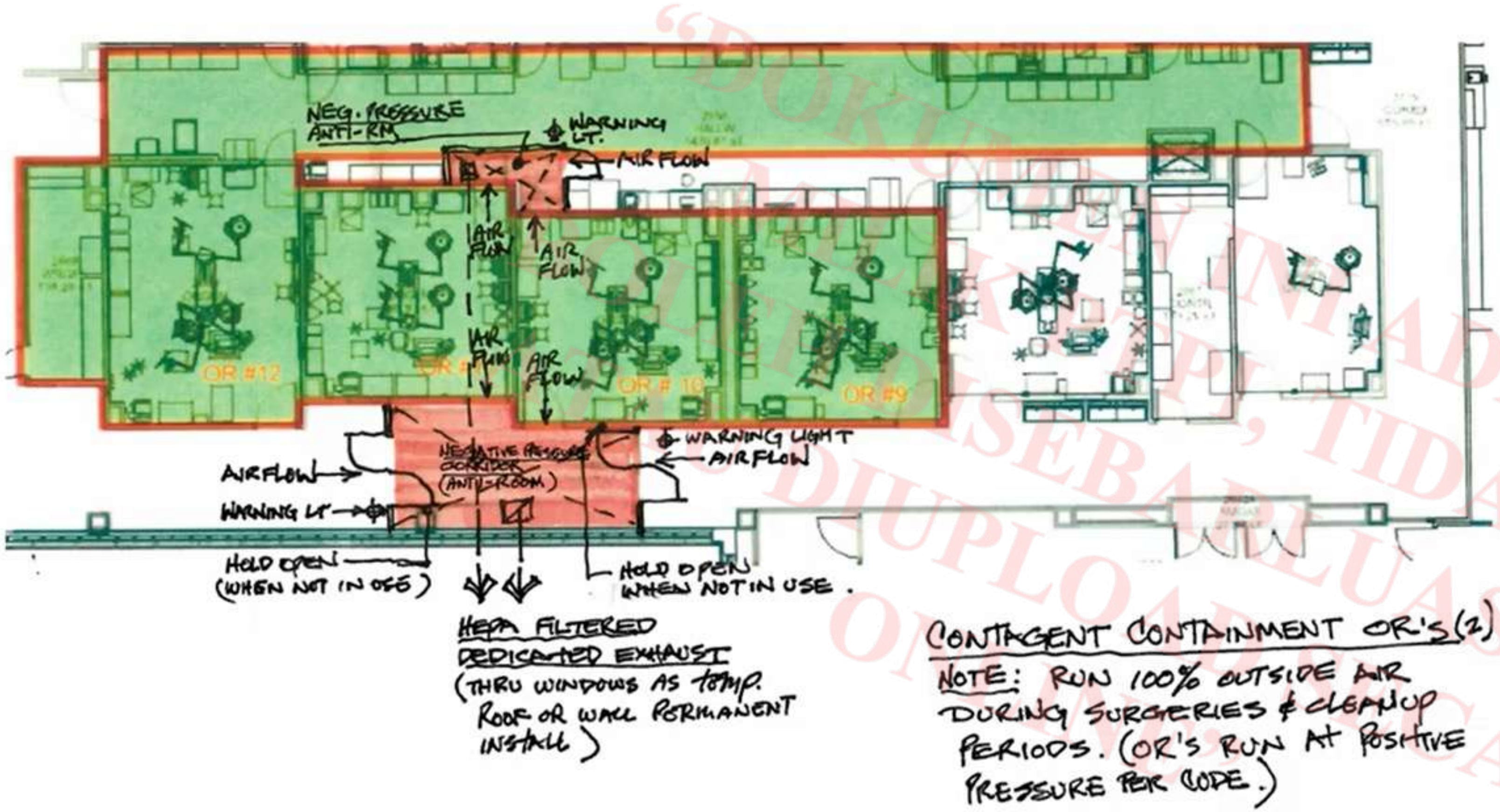


- Tekanan negatif terjaga BILA kondisi pintu tertutup
- Itupun dengan ASUMSI bahwa tidak ada kebocoran
  - Kita **<u>belum pernah</u>** melakukan leakage test terhadap ruang isolasi ataupun OK



- Kalau ada aktivitas buka/tutup pintu, maka akan terjadi pencampuran udara ke koridor
  - Solusinya: Anteroom
  - Kita **<u>belum pernah</u>** melakukan leakage test terhadap anteroom
  - Kita **<u>belum pernah</u>** melakukan uji efektivitas anteroom dalam mengurangi resiko penularan

Containment: Negative Pressure



- Never convert an OR to negative
- Never, never
- Never, never, never
- If you must, build anterooms.

Air Leakage Analysis of Special Ventilation Hospital Rooms

Andrew Geeslin **Andrew Streifel** **Gary Nelson**
Member ASHRAE

ABSTRACT

Hospitals use special ventilation (SPV) rooms to protect patients and employees from airborne infectious diseases. The room airtightness determines the effectiveness of the ventilation system at containing airborne infectious diseases. In this research, we tested SPV rooms utilizing duct pressurization equipment to determine room leakage area. The leakage testing procedure involves depressurizing the room using a fan to exhaust air out of the room at varying rates while measuring the differential pressure between the room and the adjacent corridor. Ten SPV rooms were tested and found to have significantly varying leakage areas. For airtight energy-efficient homes, the recommendation is an equivalent leakage area (EqLA) of 2.5 in^2 per 100 ft^2 of building envelope surface area (Lstiburek 2004). This study describes a method for testing room leakage area, suggests a method to trace and seal leakage sites, and makes recommendations for an airtightness standard that is achievable based on the airtightness measurements presented in this paper.

INTRODUCTION

Methods to control airborne infectious diseases in hospitals containing afflicted patients are vital to the safety of health-care workers, other patients, and visitors (Rice et al. 2001; Streifel 2003, 2006). Airborne infection isolation (AII) rooms are designed to isolate patients with a suspected airborne infectious disease and rely on special ventilation parameters to contain and filter infectious particles. Protective environment (PE) rooms are designed to protect immune-compromised patients from infectious particles.

Three environmental controls are used for special ventilation (SPV) rooms (AII and PE), including pressure management, room air changes for dilution ventilation, and filtration to remove infectious particles (Saravia et al. 2007). Pressure management refers to the use of differential pressure (patient room compared to adjacent spaces) to promote "clean to dirty" airflow. "Negative" pressure is used for AII rooms and is achieved by adjusting the exhaust/return and supply airflow rates such that the mechanically exhausted airflow is greater than the mechanically supplied air. Positive pressure is required for PE rooms and is achieved by mechanically supplying more air than is exhausted.

In practice, the relative pressure between the patient room and the corridor is most commonly used to indicate acceptable pressure control. In reality, however, the patient room must be pressurized relative to every adjacent space in order to assure that there is not airflow from any of the adjacent spaces to or from the patient room. Poorly sealed rooms require significantly higher flow differentials to establish a substantial differential pressure (Streifel 2005). In addition, greater flow differentials result in higher monetary costs of ventilation for leakier rooms. The requirement to be consistently pressurized over all six sides underscores the need for tightly sealed rooms.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) defines air leakage of a building as follows: "The air leakage area of a building is… the area of an orifice (with an assumed value of C_D) that would produce the same amount of leakage as the building envelope at the reference pressure" (ASHRAE 2005). The results in this study are presented as the equivalent leakage area, which is defined at a differential pressure of 10 Pa and a discharge coefficient of 0.611. The concept of air leakage gives designers the ability to design pressurized buildings or spaces within buildings (e.g., cleanrooms, SPV hospital rooms) to operate at a specific differential pressure under specific airflow offsets (there is a quantitative difference

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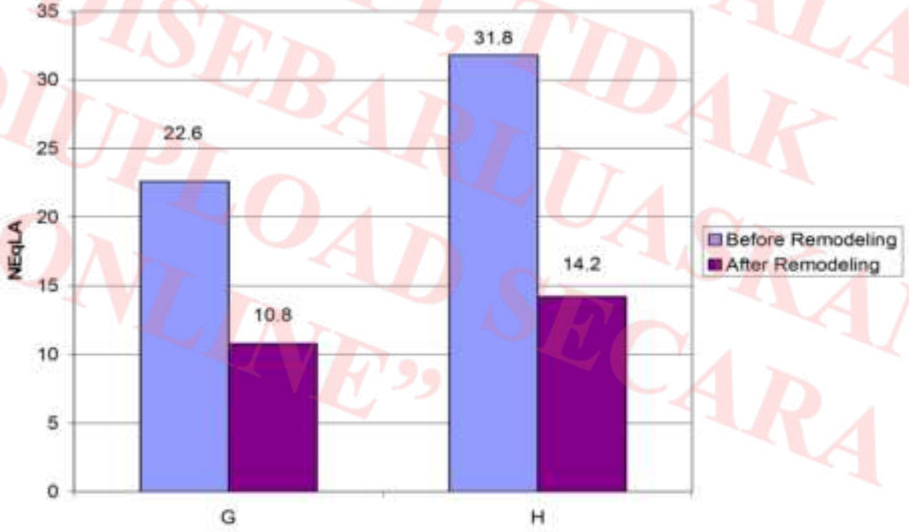


Table 1. Room, Ceiling, and Door Types for SPV Rooms Tested

Room	Room Type	Ceiling Type*	Door Type
A	PE	Solid	Single door
B	PE	Solid	Single door
C	ICU	Suspended	Double door
D	ICU	Suspended	Sliding three-panel door
E	ICU	Suspended	Sliding three-panel door
F	AII	Perforated panel	Single door
G1	AII	Perforated panel	Single door
G2	AII	Suspended	Single door
H1	AII	Perforated panel	Single door
H2	AII	Suspended	Single door

* The solid ceiling is a metal pan ceiling that was painted and completely sealed with caulk. The suspended ceiling is a special suspended ceiling with cleanable surfaces and gasketed T-bar. The perforated panel ceiling is a suspended ceiling with perforated metal panels with radiant heating coils installed above.

3

Dari mana datangnya klausul dalam standard?

TABLE 7.1 Design Parameters

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Design Relative Humidity (k), %	Design Temperatur °F/°C
SURGERY AND CRITICAL CARE							
Operating room (Class B and C) (m), (n), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Operating/surgical cystoscopic rooms, (m), (n) (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Delivery room (Caesarean) (m), (n), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Substerile service area	NR	2	6	NR	No	NR	NR
Recovery room	NR	2	6	NR	No	20–60	70–75/21–24
Critical and intensive care	NR	2	6	NR	No	30–60	70–75/21–24
Intermediate care (s)	NR	2	6	NR	NR	max 60	70–75/21–24
Wound intensive care (burn unit)	NR	2	6	NR	No	40–60	70–75/21–24
Newborn intensive care	Positive	2	6	NR	No	30–60	72–78/22–26
Treatment room (p)	NR	2	6	NR	NR	20–60	70–75/21–24
Trauma room (crisis or shock) (c)	Positive	3	15	NR	No	20–60	70–75/21–24
Medical/anesthesia gas storage (r)	Negative	NR	8	Yes	NR	NR	NR
Laser eye room	Positive	3	15	NR	No	20–60	70–75/21–24
ER waiting rooms	Negative	2	12	Yes (q)	NR	max 65	70–75/21–24
Triage	Negative	2	12	Yes (q)	NR	max 60	70–75/21–24
ER decontamination	Negative	2	12	Yes	No	NR	NR
Radiology waiting rooms	Negative	2	12	Yes (q), (w)	NR	max 60	70–75/21–24
Procedure room (Class A surgery) (o), (d)	Positive	3	15	NR	No	20–60	70–75/21–24
Emergency department exam/treatment room (p)	NR	2	6	NR	NR	max 60	70–75/21–24
INPATIENT NURSING							
Patient room	NR	2	4 (y)	NR	NR	max 60	70–75/21–24
Nourishment area or room	NR	NR	2	NR	NR	NR	NR
Toilet room	Negative	NR	10	Yes	No	NR	NR

Note: NR = no requirement

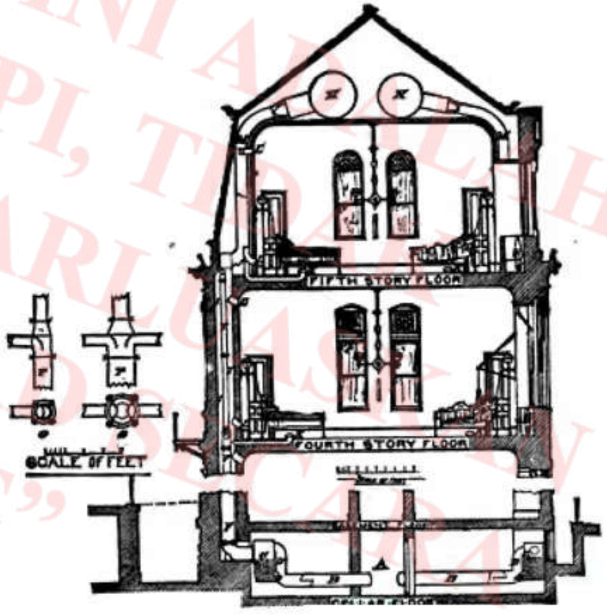
- Peraturan Ventilasi dari Standard 170
- Paling banyak: 2 ACH dan 6 ACH
- Dari mana asalnya?

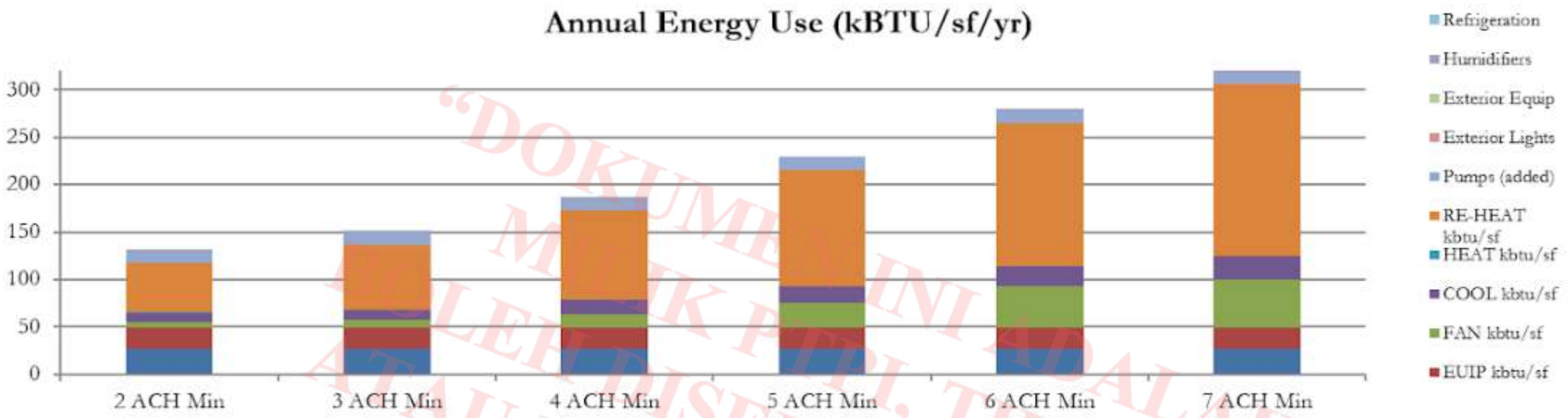
- Nightingale, 1859[1]
- Muir, 1877[2] *“Twice per hour”*
- *1879 – Thomas Edison, ‘first light bulb’*
- Billings, 1893[3]

[1] *Nightengale, F. 1859. Notes on Hospitals, 1st Edition, London: John W. Parker & Son*

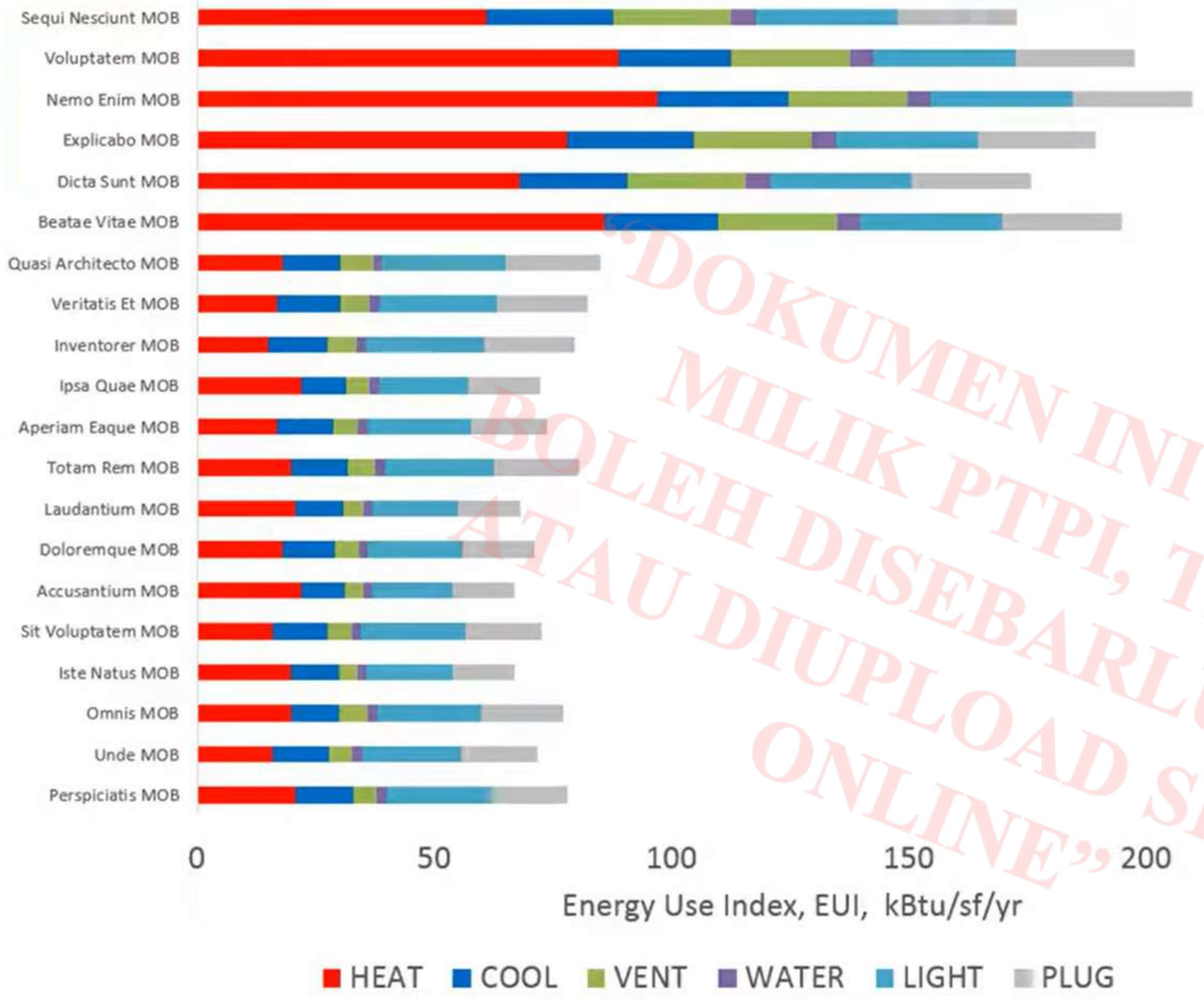
[2] *Muir, W. 1877. "Report of the Army Medical Department for the Year 1877, Volume XIX," Her Magesty's Stationary Office., London*

[3] *Billings, J. 1893. Ventilation and Heating The Engineering Record, New York*





Annual Energy Use (kBTU/sf/yr)
300
250
200
150
100
50
0
2 ACH Min
3 ACH Min
4 ACH Min
5 ACH Min
6 ACH Min
7 ACH Min
Refrigeration
Humidifiers
Exterior Equip
Exterior Lights
Pumps (added)
RE-HEAT kbtu/sf
HEAT kbtu/sf
COOL kbtu/sf
FAN kbtu/sf
EUIP kbtu/sf

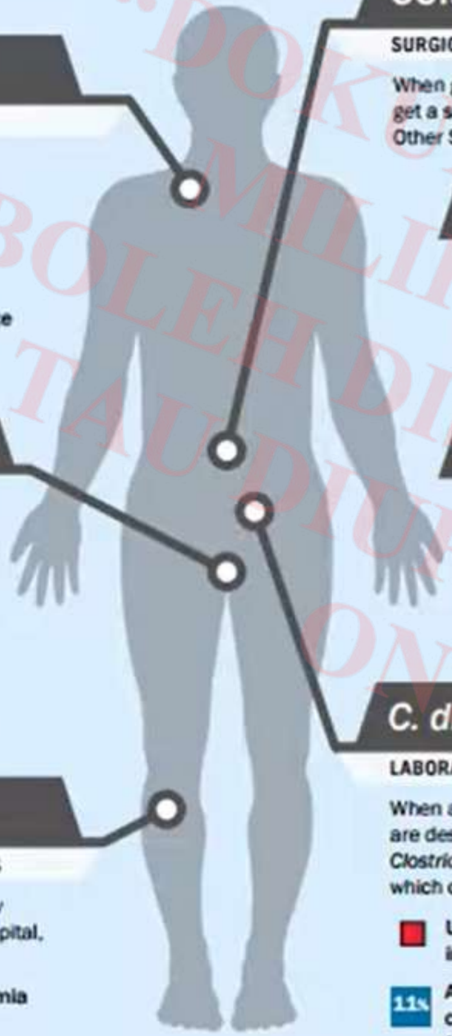

Sequi Nesciunt MOB
Voluptatem MOB
Nemo Enim MOB
Explicabo MOB
Dicta Sunt MOB
Beatae Vitae MOB
Quasi Architecto MOB
Veritatis Et MOB
Inventorer MOB
Ipsa Quae MOB
Aperiam Eaque MOB
Totam Rem MOB
Laudantium MOB
Doloremque MOB
Accusantium MOB
Sit Voluptatem MOB
Iste Natus MOB
Omnis MOB
Unde MOB
Perspiciatis MOB
0
50
100
150
200
250
Energy Use Index, EUI, kBtu/sf/yr
HEAT
COOL
VENT
WATER
LIGHT
PLUG

NATIONAL — ACUTE CARE HOSPITALS

HEALTHCARE ASSOCIATED INFECTIONS PROGRESS +

Healthcare-associated infections (HAIs) are infections patients can get while receiving medical treatment in a healthcare facility. Working toward the elimination of HAIs is a CDC priority. The standardized infection ratio (SIR) is a summary statistic that can be used to track HAI prevention progress over time; lower SIRs are better. The infection data are reported to CDC's National Healthcare Safety Network (NHSN). HAI data for nearly all U.S. hospitals are published on the Hospital Compare website.

This report is based on 2014 data, published in 2016.



CLABSIs — ⬇50% LOWER COMPARED TO NAT'L BASELINE*

CENTRAL LINE-ASSOCIATED BLOODSTREAM INFECTIONS

When a tube is placed in a large vein and not put in correctly or kept clean, it can become a way for germs to enter the body and cause deadly infections in the blood.

- U.S. hospitals reported a significant decrease in CLABSIs between 2013 and 2014.
- 10% Among the 2,442 hospitals in U.S. with enough data to calculate an SIR, 10% had an SIR significantly higher (worse) than 0.50, the value of the national SIR.

CAUTIs — 0% NO CHANGE COMPARED TO NAT'L BASELINE

CATHETER-ASSOCIATED URINARY TRACT INFECTIONS

When a urinary catheter is not put in correctly, not kept clean, or left in a patient for too long, germs can travel through the catheter and infect the bladder and kidneys.

- U.S. hospitals reported a significant decrease in CAUTIs between 2013 and 2014.
- 12% Among the 2,880 U.S. hospitals with enough data to calculate an SIR, 12% had an SIR significantly higher (worse) than 1.00, the value of the national SIR.

MRSA Bacteremia — ⬇13% LOWER COMPARED TO NAT'L BASELINE*

LABORATORY IDENTIFIED HOSPITAL-ONSET BLOODSTREAM INFECTIONS

Methicillin-resistant *Staphylococcus aureus* (MRSA) is bacteria usually spread by contaminated hands. In a healthcare setting, such as a hospital, MRSA can cause serious bloodstream infections.

- U.S. hospitals reported a significant decrease in MRSA bacteremia between 2013 and 2014.
- 8% Among the 2,042 U.S. hospitals with enough data to calculate an SIR, 8% had an SIR significantly higher (worse) than 0.87, the value of the national SIR.

SSIs

SURGICAL SITE INFECTIONS

See pages 3-5 for additional procedures

When germs get into an area where surgery is or was performed, patients can get a **surgical site infection**. Sometimes these infections involve only the skin. Other SSIs can involve tissues under the skin, organs, or implanted material.

SSI: Abdominal Hysterectomy — ⬇17% LOWER COMPARED TO NAT'L BASELINE*

- U.S. hospitals reported no significant change in SSIs related to abdominal hysterectomy surgery between 2013 and 2014.
- 6% Among the 794 U.S. hospitals with enough data to calculate an SIR, 6% had an SIR significantly higher (worse) than 0.83, the value of the national SIR.

SSI: Colon Surgery — ⬇2% LOWER COMPARED TO NAT'L BASELINE*

- U.S. hospitals reported a significant increase in SSIs related to colon surgery between 2013 and 2014.
- 8% Among the 2,051 U.S. hospitals with enough data to calculate an SIR, 8% had an SIR significantly higher (worse) than 0.98, the value of the national SIR.

C. difficile Infections — ⬇8% LOWER COMPARED TO NAT'L BASELINE*

LABORATORY IDENTIFIED HOSPITAL-ONSET *C. DIFFICILE* INFECTIONS

When a person takes antibiotics, good bacteria that protect against infection are destroyed for several months. During this time, patients can get sick from *Clostridium difficile* (*C. difficile*), bacteria that cause potentially deadly diarrhea, which can be spread in healthcare settings.

- U.S. hospitals reported a significant increase in *C. difficile* infections between 2013 and 2014.
- 11% Among the 3,554 U.S. hospitals with enough data to calculate an SIR, 11% had an SIR significantly higher (worse) than 0.92, the value of the national SIR.

*Statistically significant

CDC

Code/Standard	Min. Room Ventilation	~Air Changes	
France NF S90-351	Risk Category 3	>15 ACH	*test @ ISO 7 & 10 CFU/m^3*
England HTM-03-01	15 ACH	15 ACH	
Canada CSA	3 ACH / 9 ACH	9 ACH	
US ASHRAE-170-2013	2 ACH / 6 ACH	6 ACH	
Spain UNE-100713	15 $m^3/hr/m^2$	~4.5 ACH	
California T24 P4 Table 4A	2 ACH*	2 ACH	*when 100% OA is used*
WHO "Natural Ventilation for Infection Control in Health-Care Settings"	60 L/s/patient	~2 ACH	*General consideration; no specific L/D room requirement*
Germany DIN-1946*	40 m^3/person	~1 ACH	*General consideration; no specific L/D room requirement*

4 Perjalanan Indonesia

Dari Sub-Standard Ke Compliance Ke Performance-based

Table 2. Selected Air Change Rates Across the Years

	1959	1962	1964	1966	1968	1971	1974	1978	1982	1987	1991	1993	1997	2001	2006	2008	2013
	Source: ASHRAE Guidebooks, compiled in *Ventilation Designs* (Hermans and Streifel 1993).											Source: FGI archives (FGI 2013).				Source: ANSI/ ASHRAE/ASHE Standard 170.	
Surgery and Critical Care																	
OR: 100% OA	8-12	15	15	15	—	—	—	15	15	15	15	—	—	—	—	—	—
OR: recirculated	—	—	—	—	25/5	25/5	25/5	25/5	25/5	25/5	25/5	15/3	15/3	15/3	15/3	20/4	20/4
Delivery: 100% OA	—	15	15	15	—	—	—	—	—	—	15	—	—	—	—	—	—
Delivery: recirculated	—	—	—	—	25/5	25/5	25/5	25/5	25/5	25/5	25/5	15/3	15/3	15/3	15/3	20/4	20/4
Recovery	—	4	4	4	15/6	15/6	15/6	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2	6/2
Nursery	8-12	12	12	12	15/5	15/5	15/5	12/5	12/5	12/5	12/5	6/2	6/2	6/2	6/2	6/2	6/2
Trauma room	—	—	—	—	25/5	25/5	25/5	25/5	25/5	25/5	25/5	15/3	15/3	15/3	15/3	15/3	15/3
Anesthetic storage	2	2	—	8	8/8	8/8	8/8	8	8	8	—	8	8	8	8	8	8
Patient room	1.5	1.5	2	4/2	4/2	4/2	2/2	2/2	2/2	4/2	—	2/1	2/2	6/2	6/2	6/2	4/2
Toilet room	—	—	—	—	—	10	10	10	10	10	10	10	10	10	10	10	10
Intensive care	—	—	—	—	6/6	6/6	6/2	6/2	6/2	6/2	—	6/2	6/2	6/2	6/2	6/2	6/2
Isolation room	—	4	4	6	12/12	12/12	12/12	6/2	6/2	6/2	6/2	6/1	12/2	12/2	12/2	12/2	12/2
Anteroom	—	—	—	—	6/6	6/6	6/6	10/2	10/2	10/2	10/2	10	10	10	10	10	10
LDRP	—	—	—	—	—	—	—	—	—	—	4/2	2	2/2	6/2	6/2	6/2	6/2
Patient corridor	—	—	—	—	—	4/4	4/4	4/4	4/2	4/2	4/2	2	2	2	2	2	2
Radiology																	
X-ray surgery	—	—	—	—	—	—	—	—	—	15/3	15/3	15/3	15/3	15/3	15/3	15/3	15/3
X-ray diagnostic and treatment	—	6	6	10	6/6	6/6	6/6	6/2	6/2	6/2	6/2	6	6	6	6	6/2	6/2
Darkroom	—	10	10	12	15/6	15/6	15/6	10/2	10/2	10/2	10/2	10	10	10	10	10/2	10/2
Laboratory																	
General	—	—	—	—	—	6/6	6/6	6/6	6/2	6/2	6/2	6	6	6	6	6/2	6/2
Bacteriology	—	10	10	10	10	—	—	—	—	6/2	6/2	—	—	—	—	6/2	6/2
Biochemistry	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Cytology	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Glass wash	—	—	—	—	—	—	—	—	10/2	10	—	10	10	10	10	10/2	10/2
Histology	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Nuclear medicine	—	—	—	—	—	—	—	—	—	6/2	6/2	6	6	6	6	6/2	6/2
Pathology	—	—	—	—	—	—	—	—	6/2	6/2	—	6	6	6	6	6/2	6/2
Serology	—	—	—	—	—	—	—	—	—	—	6/2	6	6	6	6	6/2	6/2
Sterilization	—	—	—	—	—	—	—	—	10	10	10	10	10	10	10	10/2	10/2
Media transfer	—	—	—	4/4	4/4	4/4	4/2	4/2	4/2	4/2	—	—	—	—	—	4/2	4/2

- Ini peraturan prescriptive:
  - Hanya ditulis saja seperti resep
  - TIDAK DIJAMIN apakah tujuannya akan tercapai?
- Tujuan ventilasi:
  - Infection control
- Dalam aturan yang performance-based:
  - Silakan gunakan aturan ventilasi apapun
  - Yang penting aturannya tercapai
- Permen yang baru di Indonesia sudah mengandung kedua aspek:
  - Prescriptive
  - Performance-based

Prescriptive:

- Disebutkan jenis dan merek masker

Performance based:

- Terserah mau pakai masker apapun
- Yang penting kalau diuji, bisa lulus uji

Ventilation Roadmap for Indonesian Hospitals

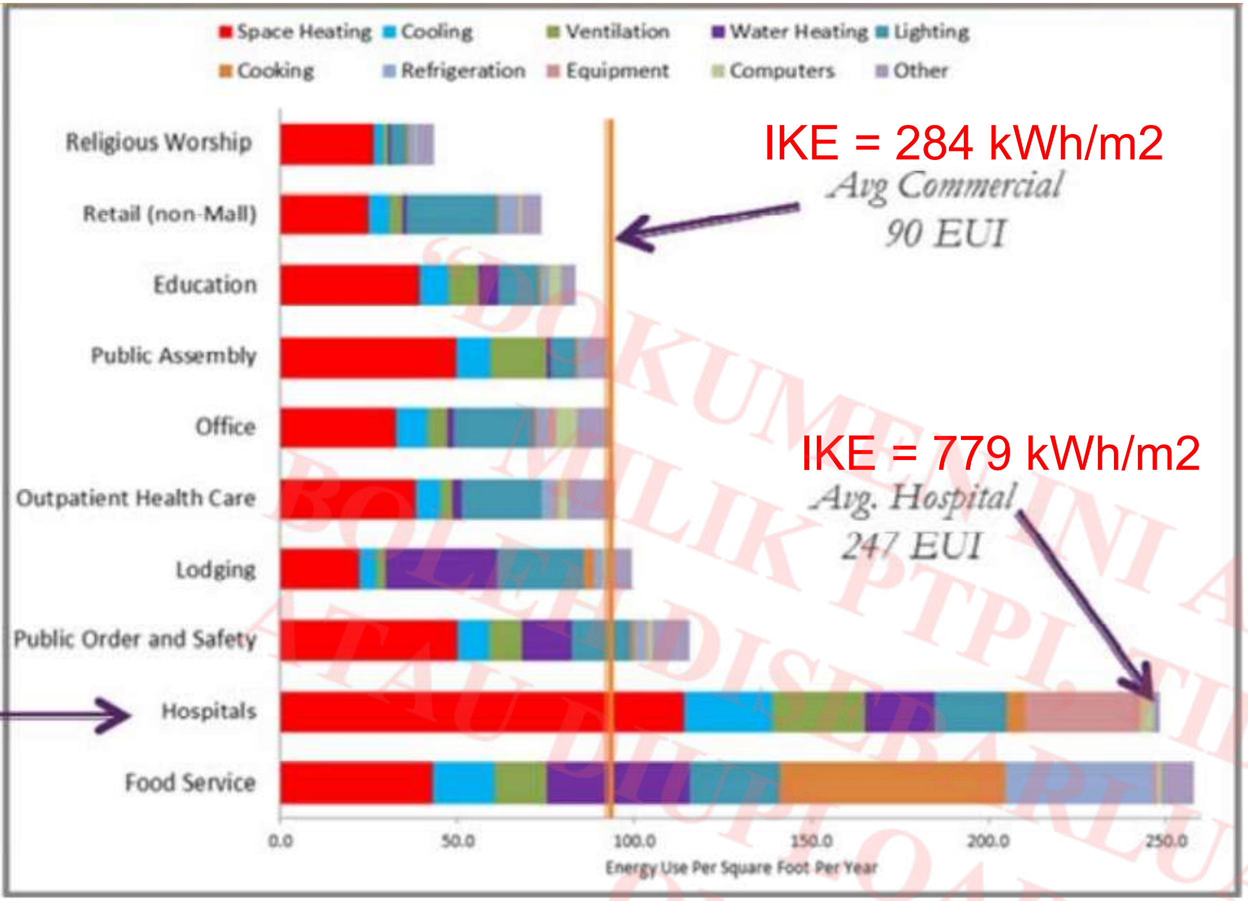
- Masih banyak yang beroperasi tidak sesuai dengan standard/ peraturan yang berlaku:
  - Masih perlu dilakukan enforcement terhadap semua RS

- Bila hal tersebut dilakukan, AKAN TERJADI peningkatan biaya listrik rumah sakit.

- Menurut saya:
  - tidak apa-apa bila terjadi kenaikan biaya listrik: BAGUS, artinya kita sudah comply dengan aturan ventilasi.

- Bila biaya listrik sudah tinggi ➔ mari kita pikirkan bagaimana caranya menurunkannya, dengan menggunakan peraturan yang performance-based.

Source: 2002 CBECs dataset
http://www.eia.gov/consumption/commercial/



Uji ventilasi:

- Mahal dan sulit dilakukan

Uji mudah dan murah

- Berapa IKE rumah sakit anda?

Kalau IKE rumah sakit anda masih setara dengan bangunan kantor, maka itu INDIKASI bahwa rumah sakit anda tidak patuh terhadap aturan ventilasi.

Bagaimana menghitung IKE?

- Mudah sekali

Klinik IKE:

- Hubungi saya untuk menghitung IKE
- pro bono/ gratis

CONCLUSION

- Perumusan standard/ peraturan prescriptive-based, berdasarkan ACH, akan meningkatkan konsumsi energi.

- Rumah sakit di Indonesia masih harus memenuhi peraturan berdasarkan prescriptive-based tadi, sekalipun ini akan meningkatkan konsumsi energi rumah sakit.

- Permen yang baru, yang memandatkan pencapaian kinerja, sudah meletakkan dasar-dasar untuk beralih ke peraturan berbasis kinerja (performance-based).

KEMENTERIAN KESEHATAN REPUBLIK INDONESIA

BADAN STANDARDISASI NASIONAL

PUKUL 13.00 s/d 17.00 WIB
SABTU, 18 JUNI 2022

TERIMA KASIH

FORUM TEKNIK PERUMAHSAKITAN 2022

Perencanaan dan Pengelolaan Sarana, Prasarana dan Alat Pengendalian Infeksi, Ruang Isolasi dan Tata Udara

HEF 2022

Organized by: KIC