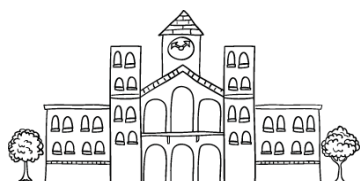


「室內空氣品質，能幫助預防結核病傳播嗎？」

Anita, Pei-Chun Chan MD. PhD.
 Medical Officer
 Taiwan CDC
 July 23, 2019



Courtesy from Carl Morrow, Paris, IUATLD 2013

Vision: **A world free of TB**

Zero TB deaths, Zero TB disease, and Zero TB suffering

Goal: **End the Global TB epidemic (<10 cases per 100,000)**

Target 1



95% reduction in deaths due to TB (compared with 2015)

Target 2



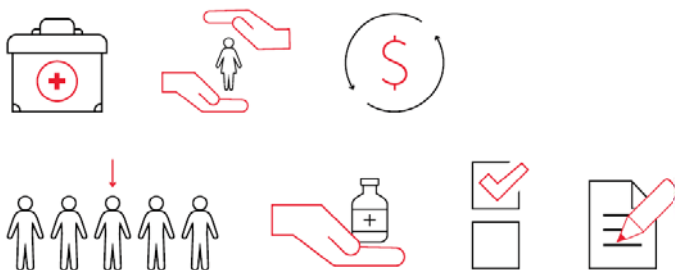
90% reduction in TB incidence rate (compared with 2015)

Target 3



No affected families face catastrophic costs due to TB

UN HIGH-LEVEL MEETING ON TB KEY TARGETS & COMMITMENTS FOR 2022



UN GENERAL ASSEMBLY HIGH-LEVEL MEETING ON ENDING TB

26 September 2018, New York



Since the UNHLM on TB, this is what I've been doing to fight TB

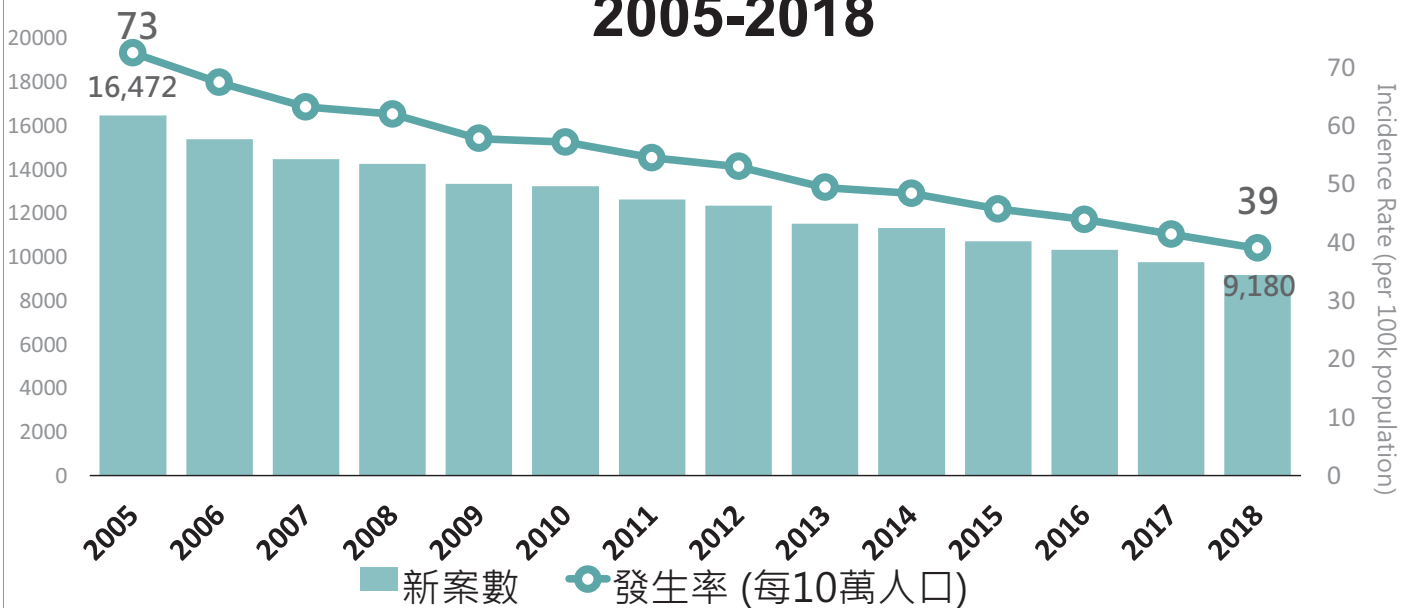
Stop TB Partnership



What did you do?

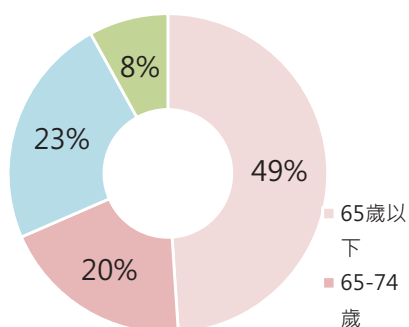


Taiwan TB Incidence Rate 2005-2018

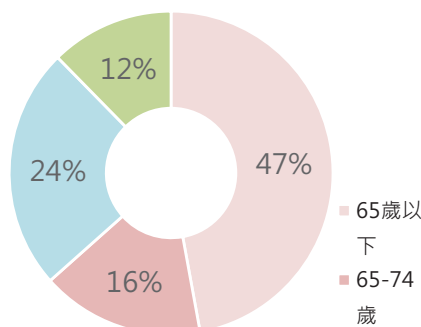


TB 年齡趨勢 2005-2018年

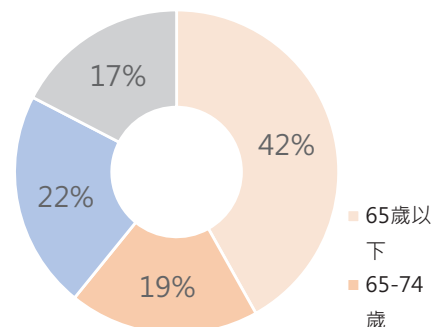
2005年



2010年

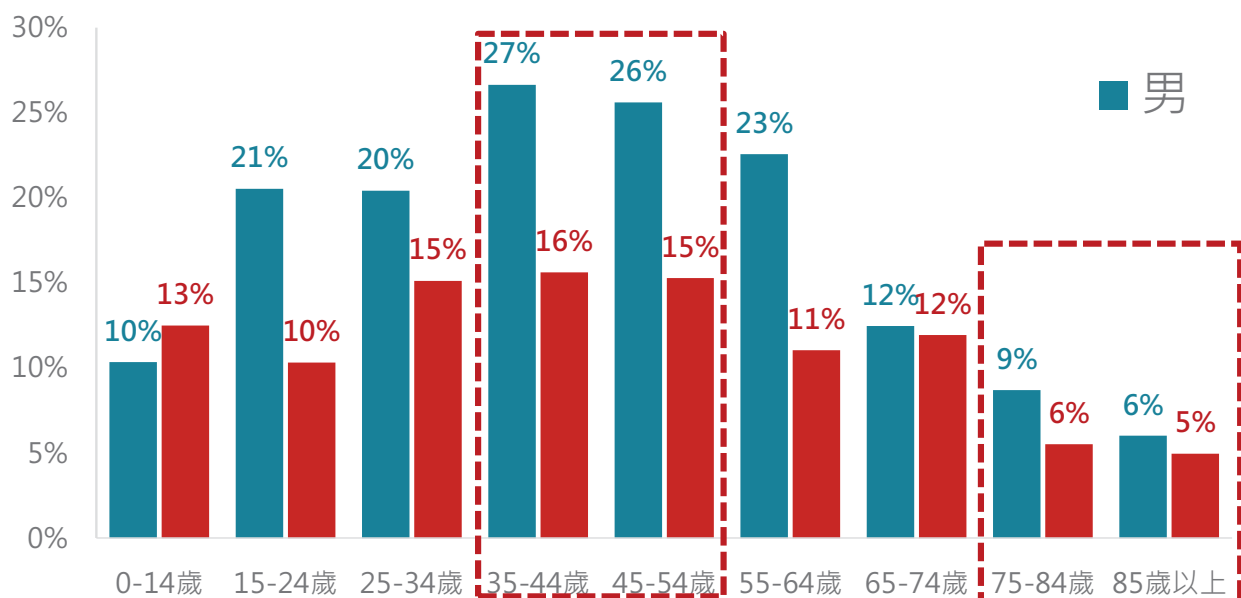


2018年



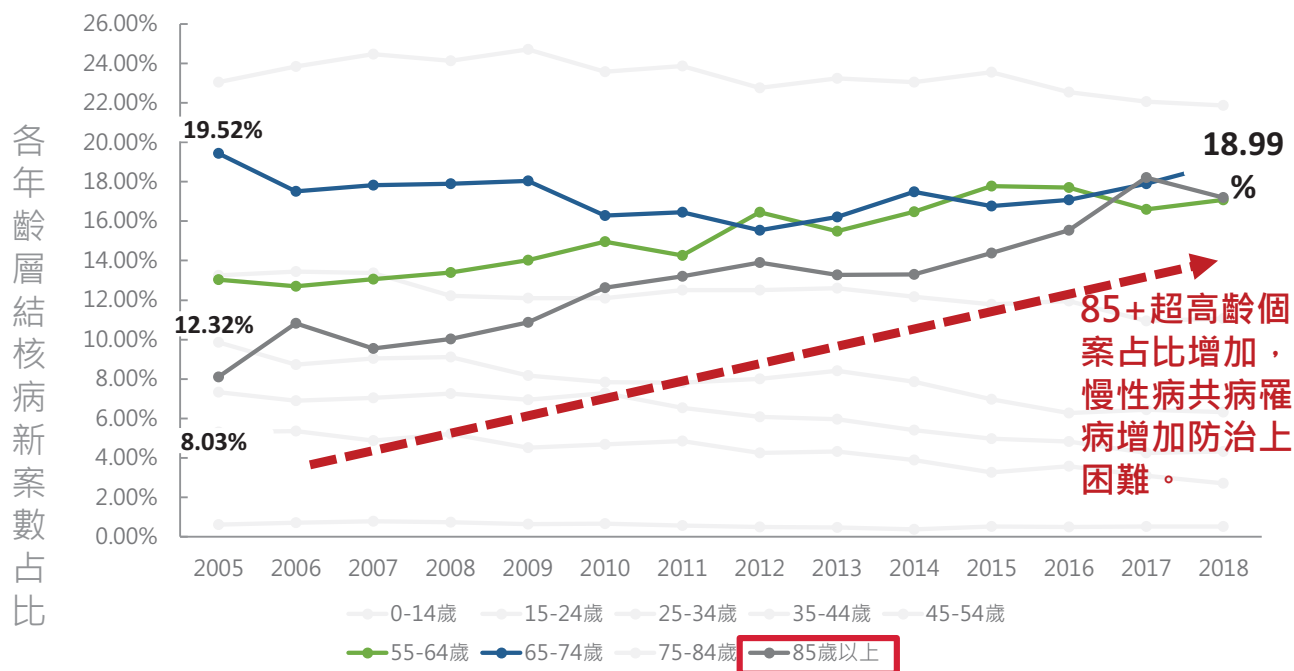
65歲及以上占比58%，由於人口老化影響，高齡個案比重逐年上升
75歲及以上更高達39%

肺空洞比例 – 性別年齡別 (2018年)



文獻上，肺空洞代表個案疾病「嚴重度較高」或「就醫、診療時間較晚」，其預後與不良結果亦較無空洞個案為高。然而，由這個統計得知，在台灣大部分的病人都是沒有開洞的，類似社區性肺炎的非典型結核病 x光型態，對於診斷的挑戰越來越險峻，對於感染控制的挑戰亦然。

各年齡層新發個案歷年同期變動趨勢



Since the UNHLM on TB,

Stop TB Partnership

What did you do?

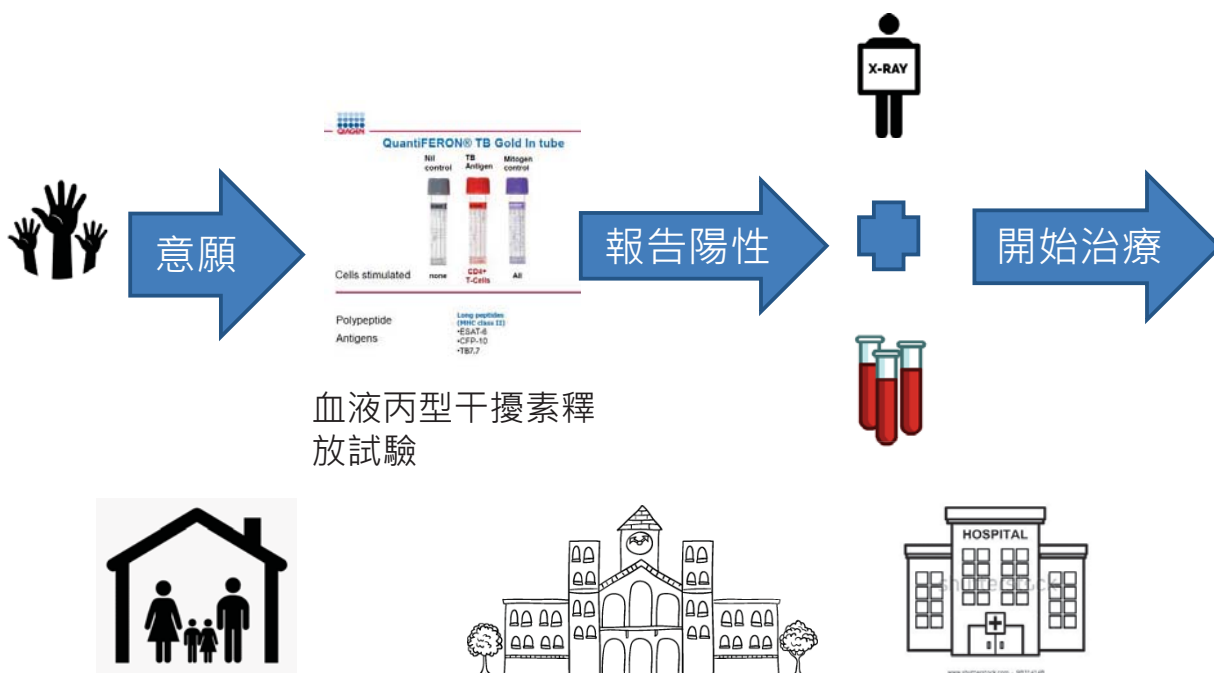
Developing of LTBI Policy in Taiwan



Latent TB infection

- 2019 ● Providing IGRA & LTBI treatment for household contacts and contacts with comorbidities exposed to S(-) and C(+) cases
- 2018 ● LTBI campaign for health care workers in community and hospital
- 2018 ● TB and LTBI control pilot program in long-term care facilities
- 2017 ○ Catch-up program for all contacts; LTBI Dx & Tx pilot projects among high risk population
- 2016 ○ Providing IGRA (>=5 years) and LTBI treatment (3HP) for all contacts of S(+) and C(+) cases
- 2015 ○ Providing IGRA & LTBI treatment for contacts of all age groups (in 6 counties/ cities)
- 2012 ○ Expansion of LTBI treatment targets: >13 years to birth cohort after year 1986 in household, school & congregate settings
- 2008 ○ Target contacts aged <13 years first

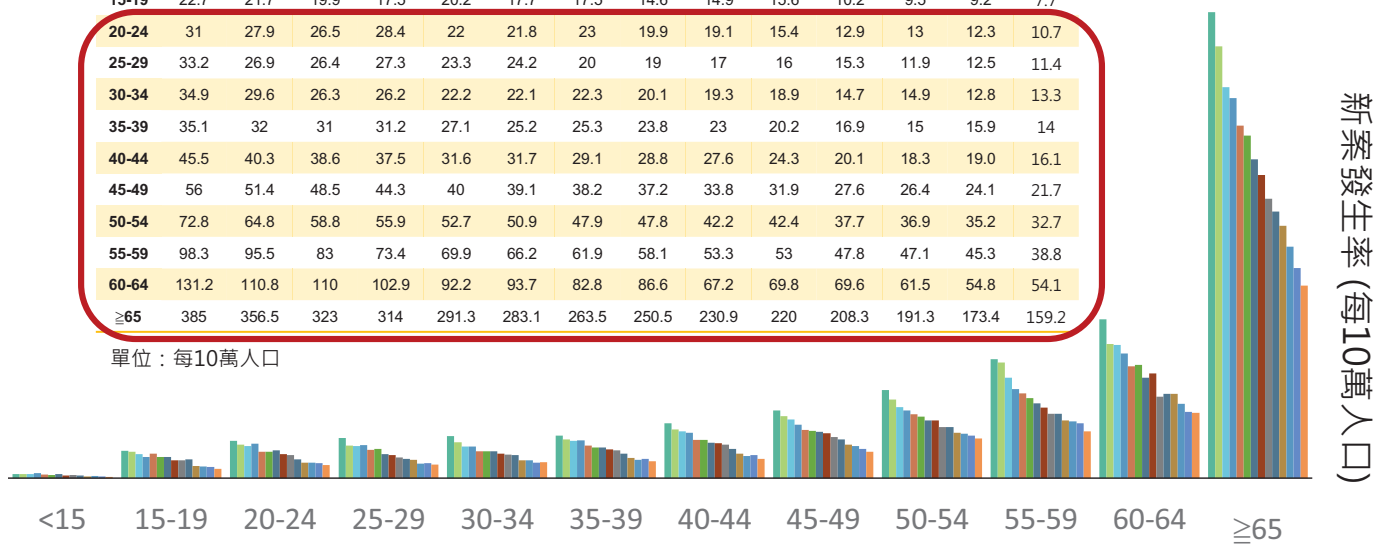
Test and Treat – 潛伏結核不傳染，篩檢治療不發病!



結核病年齡別發生率(2005-2018)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	(估計值)
<15	3.5	3.5	3.3	4	3.2	2.6	3.3	2.2	2.7	2.2	1.5	1.7	1.6	1.2	
15-19	22.7	21.7	19.9	17.5	20.2	17.7	17.5	14.6	14.9	15.6	10.2	9.5	9.2	7.7	
20-24	31	27.9	26.5	28.4	22	21.8	23	19.9	19.1	15.4	12.9	13	12.3	10.7	
25-29	33.2	26.9	26.4	27.3	23.3	24.2	20	19	17	16	15.3	11.9	12.5	11.4	
30-34	34.9	29.6	26.3	26.2	22.2	22.1	22.3	20.1	19.3	18.9	14.7	14.9	12.8	13.3	
35-39	35.1	32	31	31.2	27.1	25.2	25.3	23.8	23	20.2	16.9	15	15.9	14	
40-44	45.5	40.3	38.6	37.5	31.6	31.7	29.1	28.8	27.6	24.3	20.1	18.3	19.0	16.1	
45-49	56	51.4	48.5	44.3	40	39.1	38.2	37.2	33.8	31.9	27.6	26.4	24.1	21.7	
50-54	72.8	64.8	58.8	55.9	52.7	50.9	47.9	47.8	42.2	42.4	37.7	36.9	35.2	32.7	
55-59	98.3	95.5	83	73.4	69.9	66.2	61.9	58.1	53.3	53	47.8	47.1	45.3	38.8	
60-64	131.2	110.8	110	102.9	92.2	93.7	82.8	86.6	67.2	69.8	69.6	61.5	54.8	54.1	
≥65	385	356.5	323	314	291.3	283.1	263.5	250.5	230.9	220	208.3	191.3	173.4	159.2	

單位：每10萬人口

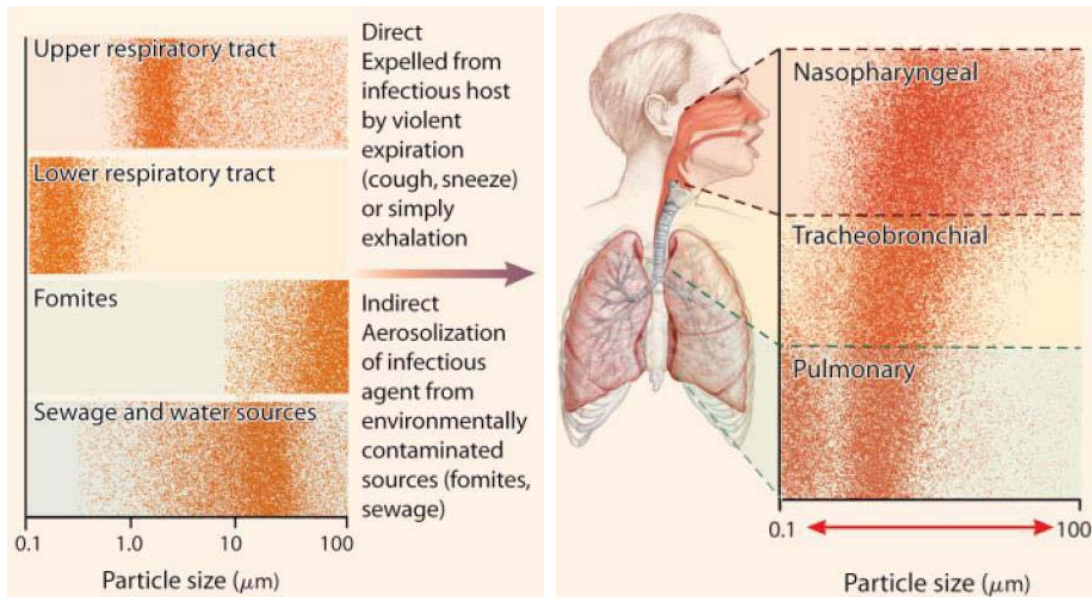


新案發生率 (每10萬人口)

室內空氣品質vs.換氣

- Characteristics of Bio-aerosols
- Control of airborne infection (environmental aspect)
- Congregate settings were high risk populations are
- Confused issues
- Regulations and standards
- Collaboration between inter-departments

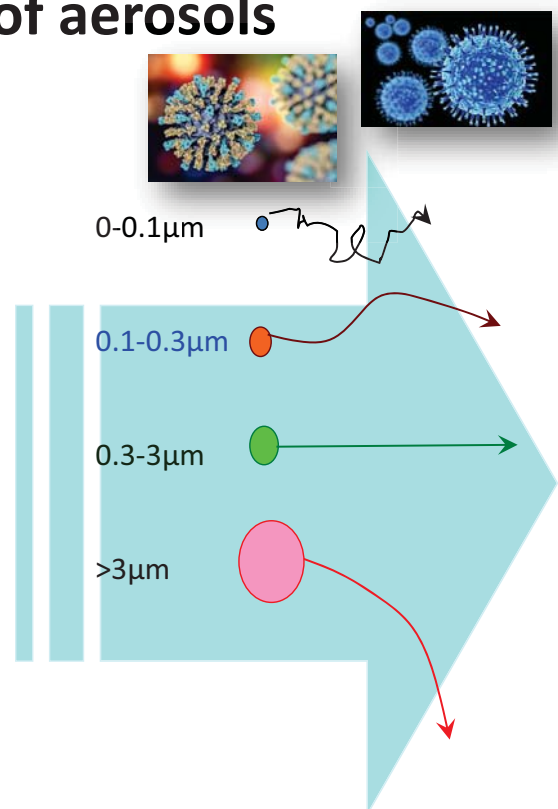
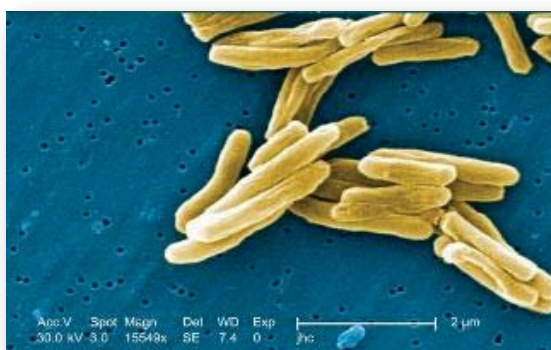
Characteristics of Bio-aerosols overview



Chad J. Roy et al., "Airborne Transmission of Communicable Infection--The Elusive Pathway", *New England Journal of Medicine*, 350;17 (2004)

Characteristics of Bio-aerosols moving characteristics of aerosols

- 0-0.3μm: random movement
- 0.3-3μm: controlled by airflow
- 3-30μm: gravitational settling
- >30μm: visible by naked eyes



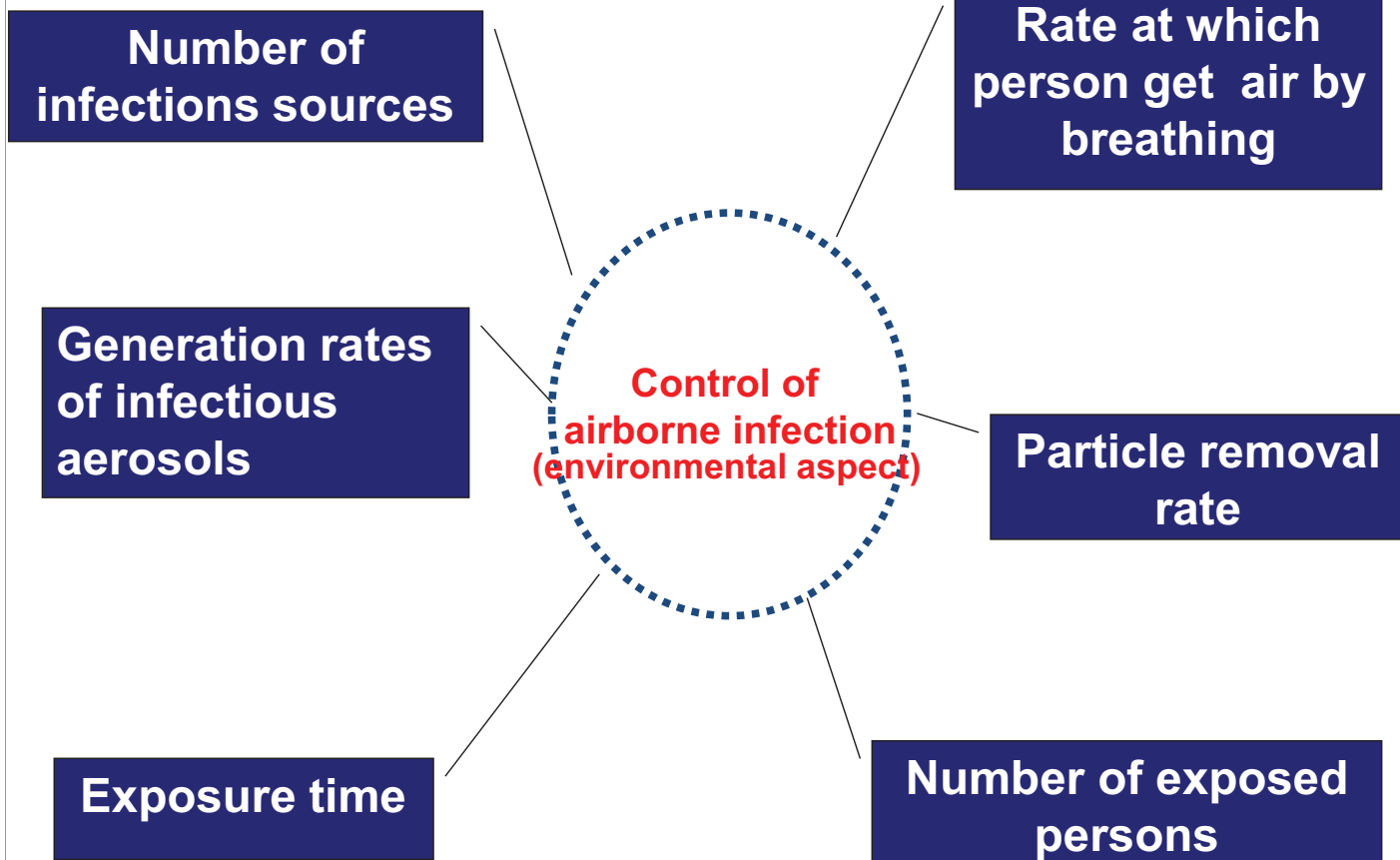


TABLE S3-1. Air changes per hour (ACH) and time in minutes required for removal efficiencies of 90%, 99%, and 99.9% of airborne contaminants*

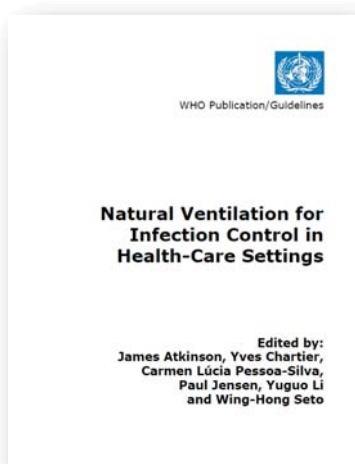
ACH	Minutes required for a removal efficiency of:		
	90%	99%	99.9%
1	138	276	414
2	69	138	207
3	46	92	138
4	35	69	104
5	28	55	83
6	23	46	69
7	20	39	59
8	17	35	52
9	15	31	46
10	14	28	41
11	13	25	38
12	12	23	35
13	11	21	32
14	10	20	30
15	9	18	28
16	9	17	26
17	8	16	24
18	8	15	23
19	7	15	22
20	7	14	21
25	6	11	17
30	5	9	14
35	4	8	12
40	3	7	10
45	3	6	9
50	3	6	8

* This table has been adapted from the formula for the rate of purging airborne contaminants (99). Values have been derived from the formula $t_1 = \frac{V}{Q} \ln \left(\frac{C_2 + C_1}{C_1} \right) + \frac{V}{Q} \times 60$, with $T_1 = 0$ and $C_2 + C_1 = (\text{removal efficiency} + 100)$, and where:

- t_1 = initial timepoint
- C_1 = initial concentration of contaminant
- C_2 = final concentration of contaminants
- Q = air flow rate (cubic feet per hour)
- V = room volume (cubic feet)
- $Q + V$ = ACH

換氣次數 (ACH) 與降低空氣有害物濃度所需時間(分)之關係

Infection risk and ventilation rate



Infection risk in 15-minute exposure for an infector in 6m x 6.7m x 2.7m enclosed space

Quanta ¹¹ generation (quanta/min)	Ventilation rate (air changes per hour) (%)			
	1	6	18	30
1	0.05	0.01	0.00	0.00
7	0.30	0.06	0.02	0.01
14	0.51	0.11	0.04	0.02
20	0.64	0.16	0.06	0.04

Source: Natural ventilation for infection control in health-care settings. (WHO, 2009)

Three principles for infection control

- Administrative measures
- Environmental controls
- Use of respiratory protective equipment



Summary of changes in the evidence-based recommendations between the 2009 and 2019 guidelines

Setting	WHO policy on TB infection control in health care facilities, congregate settings and households, 2009	WHO guidelines on tuberculosis infection prevention and control, 2019
National and subnational	<p>Activity 1. Identify and strengthen a coordinating body for TB infection control, and develop a comprehensive budgeted plan that includes human resource requirements for implementation of TB infection control at all levels.</p> <p>Activity 2. Ensure that health facility design, construction, renovation and use are appropriate.</p> <p>Activity 3. Conduct surveillance of TB disease among health workers, and conduct assessment at all levels of the health system and in congregate settings.</p> <p>Activity 4. Address TB infection control advocacy, communication and social mobilization (ACSM), including engagement of civil society.</p> <p>Activity 5. Monitor and evaluate the set of TB infection control measures.</p> <p>Activity 6. Enable and conduct operational research.</p>	<p>The Guidelines <i>Core components of infection prevention and control programmes at the national and acute health care facility level</i> were adopted in the 2019 update, to integrate 2016 evidence-based and consensus-based recommendations and good practice statements developed by the WHO Department of Service Delivery and Safety. National and subnational activities have also been adopted within the present policy guideline, and have been aligned with the core components, which provide a broader, health systems framework for the implementation of IPC.</p>
Health care facilities	<p>Control 7. Implement the set of facility level managerial activities.</p>	<p>Aligned with <i>Core components of infection prevention and control programmes at the national and acute health care facility level</i> (13).</p>
	<p>Control 8. (8a) Promptly identify people with TB symptoms (triage), (8b) separate infectious patients, (8c) control the spread of pathogens (cough etiquette and respiratory hygiene) and (8d) minimize time spent in health care facilities.</p>	<p>Recommendation 1. Triage</p> <p>Triage of people with TB signs and symptoms, or with TB disease, is recommended to reduce <i>M. tuberculosis</i> transmission to health workers, and to persons attending health care facilities or other persons in settings with a high risk of transmission.</p>

21

Setting	WHO policy on TB infection control in health care facilities, congregate settings and households, 2009	WHO guidelines on tuberculosis infection prevention and control, 2019
Health care facilities		<p>Recommendation 2. Respiratory separation / isolation</p> <p>Respiratory separation of people with presumed or demonstrated infectious TB is recommended to reduce <i>M. tuberculosis</i> transmission to health workers or other persons attending health care facilities.</p> <p>Recommendation 3. Prompt initiation of effective treatment</p> <p>Rapid diagnosis and initiation of effective treatment of people with TB disease is recommended to reduce <i>M. tuberculosis</i> transmission to health workers, persons attending health care settings or other persons in settings with a high risk of transmission.</p> <p>Recommendation 4. Respiratory hygiene (including cough etiquette)</p> <p>Respiratory hygiene (including cough etiquette) in people with presumed or confirmed TB is recommended to reduce <i>M. tuberculosis</i> transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.</p>
	<p>Control 9. Provide a package of prevention and care interventions for health workers, including HIV prevention, antiretroviral therapy and IPT for HIV-positive health workers.</p>	<p>The recommendation on preventive therapy was removed from the current policy as this is addressed in WHO LTBI and HIV policy recommendations.^{a,b}</p>
	<p>Control 10. Use ventilation systems: (10a) natural ventilation, (10b) mechanical ventilation.</p>	<p>Recommendation 6. Ventilation systems</p> <p>Ventilation systems (including natural, mixed-mode, mechanical ventilation and recirculated air through HEPA filters) are recommended to reduce <i>M. tuberculosis</i> transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.</p>

22

Setting	WHO policy on TB infection control in health care facilities, congregate settings and households, 2009	WHO guidelines on tuberculosis infection prevention and control, 2019
Health care facilities	Control 11. Use of upper-room or shielded ultraviolet germicidal irradiation fixtures.	Recommendation 5. Upper-room GUV systems Upper-room GUV systems are recommended to reduce <i>M. tuberculosis</i> transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.
	Control 12. Use of particulate respirators.	Recommendation 7. Respiratory protection Within the framework of a respiratory protection programme, particulate respirators are recommended to reduce <i>M. tuberculosis</i> transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.
Congregate settings	Extrapolation from recommendations for health care facilities.	The 2019 policy recommendations are expanded to other settings with a high risk of <i>M. tuberculosis</i> transmission, ^c where applicable.
Households	No specific recommendations, but a set of principles were outlined.	Remarks or considerations on specific interventions are made where applicable (e.g. respiratory hygiene, ventilation systems and respiratory protection).

GUV: germicidal ultraviolet; HEPA: high-efficiency particulate air; HIV: human immunodeficiency virus; IPC: infection prevention and control; IPT: isoniazid preventive therapy; LTBI: latent TB infection; *M. tuberculosis*: Mycobacterium tuberculosis; TB: tuberculosis; WHO: World Health Organization.

a Latent TB infection: updated and consolidated guidelines for programmatic management [WHO/CDS/TB/2018.4]. Geneva: World Health Organization(WHO); 2018 (<http://www.who.int/tb/publications/2018/latent-tuberculosis-infection/en/>, accessed 19 December 2018).

b Consolidated guidelines on the use of antiretroviral drugs for treating and preventing HIV infection: recommendations for a public health approach (second edition). Geneva: World Health Organization; 2016 (http://apps.who.int/iris/bitstream/10665/208825/1/9789241549684_eng.pdf?ua=1, accessed 18 December 2018).

c See definition in the Glossary.

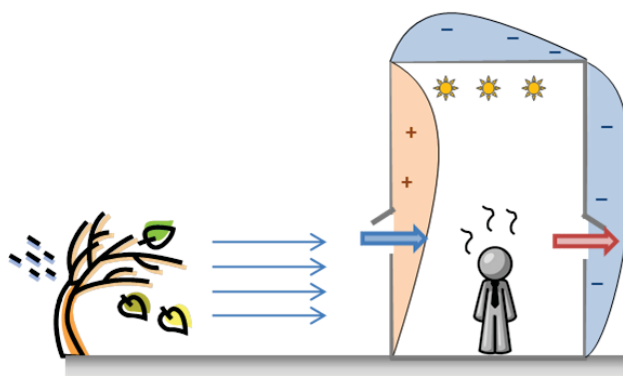
Bad Experience for PPE

- There is discomfort of using respiratory protective equipment for both health care workers and patients



Natural vs. mechanical ventilation

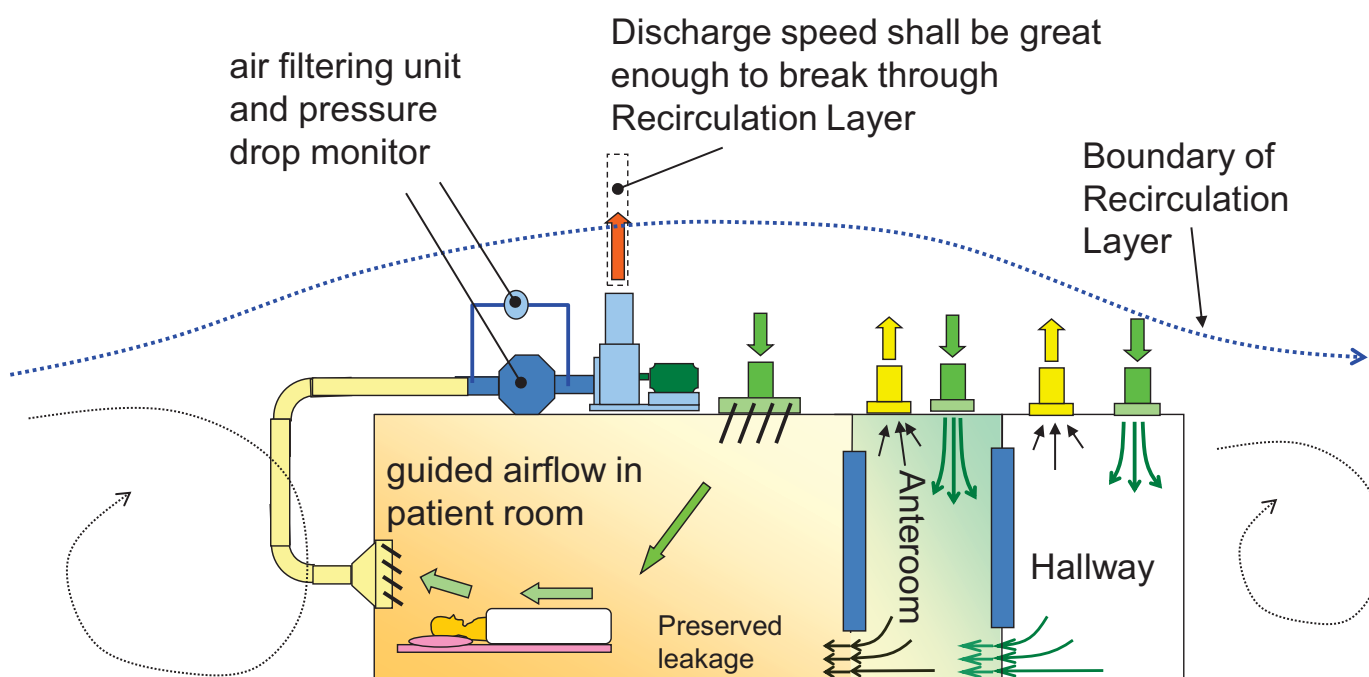
- Stabilize
 - Criteria
- Environmental
 - Urban vs rural
 - Temperature
- Energy consumption



<http://coolvent.mit.edu/intro-to-natural-ventilation/basics-of-natural-ventilation/>

High pressure Low pressure

Example of cooperation Negative Pressure Isolation Zone



Native pressure: 8 pa
ACH: 6-12

Good example of airflow pattern

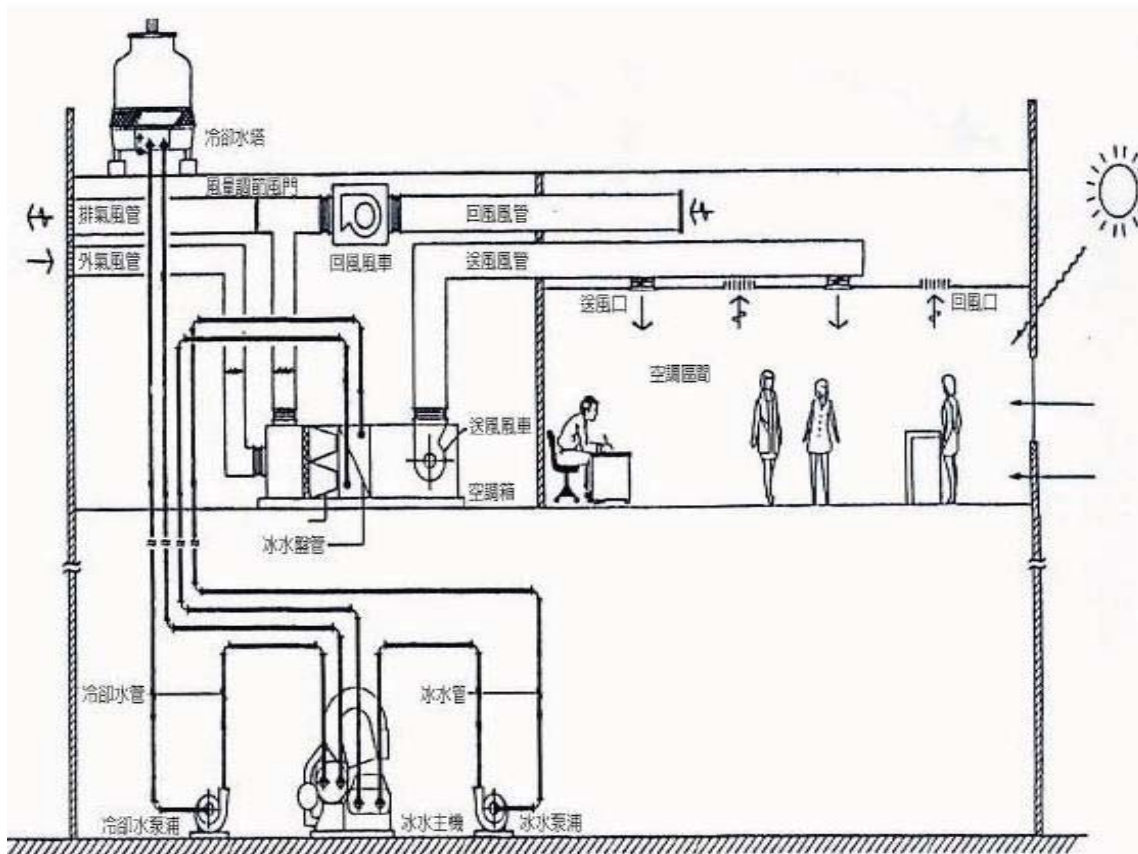


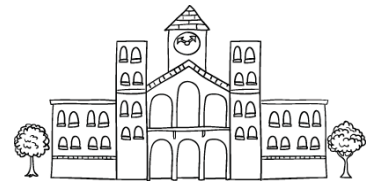
圖 4-5.2 中央空調系統之系統架構圖 (公共工程委員會)

Congregate settings were high → **END TB** risk populations are

- Congregate settings
 - School
 - Basement
 - No window
 - Long term care facility
 - Recycle fan
 - Split-Type Air-Conditioners
- High risk populations
 - Elderly
 - Nursing home
 - Long term care facility
 - Hospital

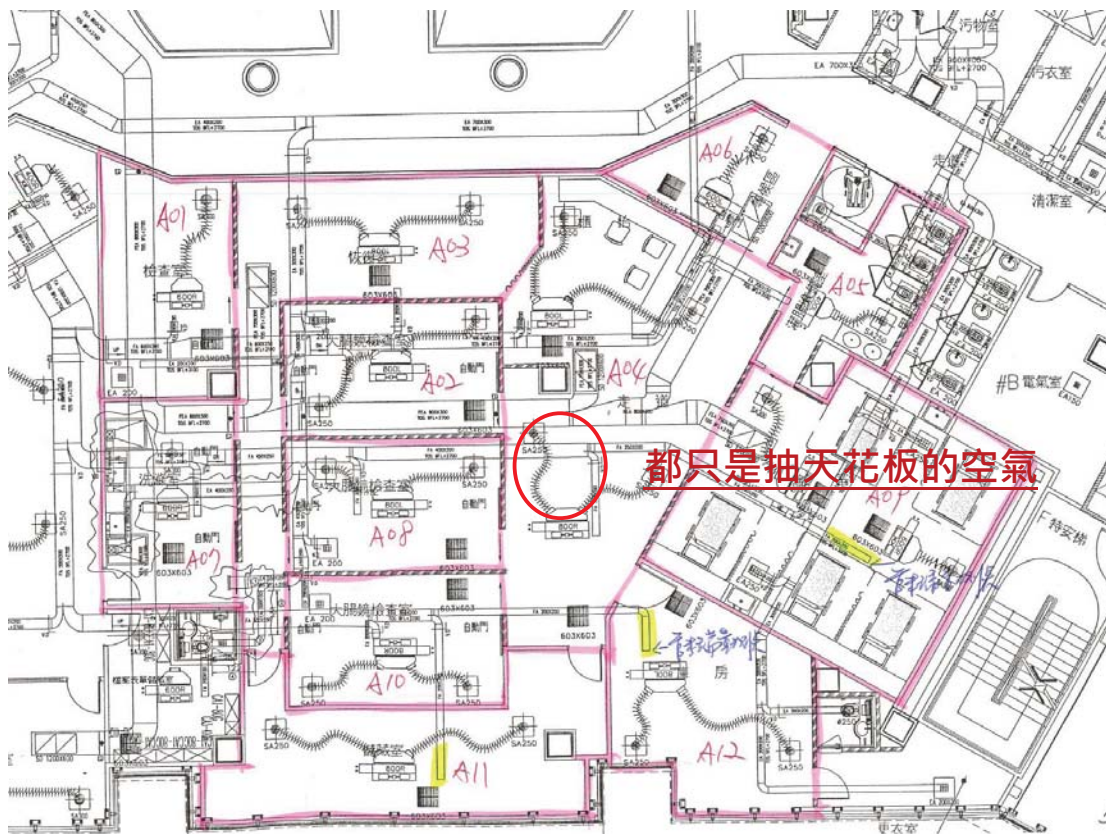
Common risks

- ✓ Crowded
- ✓ Long time shared
- ✓ Poor ventilation



29

常見錯誤樣態



30

5



地下室通風困難



分離式冷氣無換氣功能
吊扇僅有均勻效果

有沒有外氣很重要



箱型冷氣無換氣能力



窗戶無紗窗一定不會開



只會輸送冷媒

常見問題

壁扇側邊不要有空隙
氣流回抽造成無效換氣



33

管線務必保持連接



34

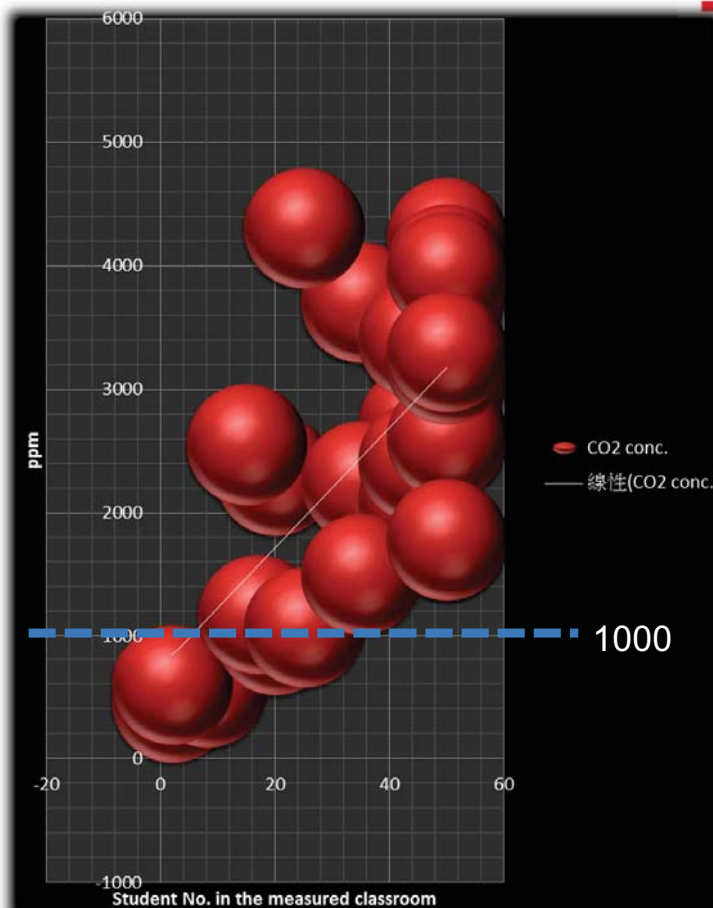
Classrooms in high-schools and colleges



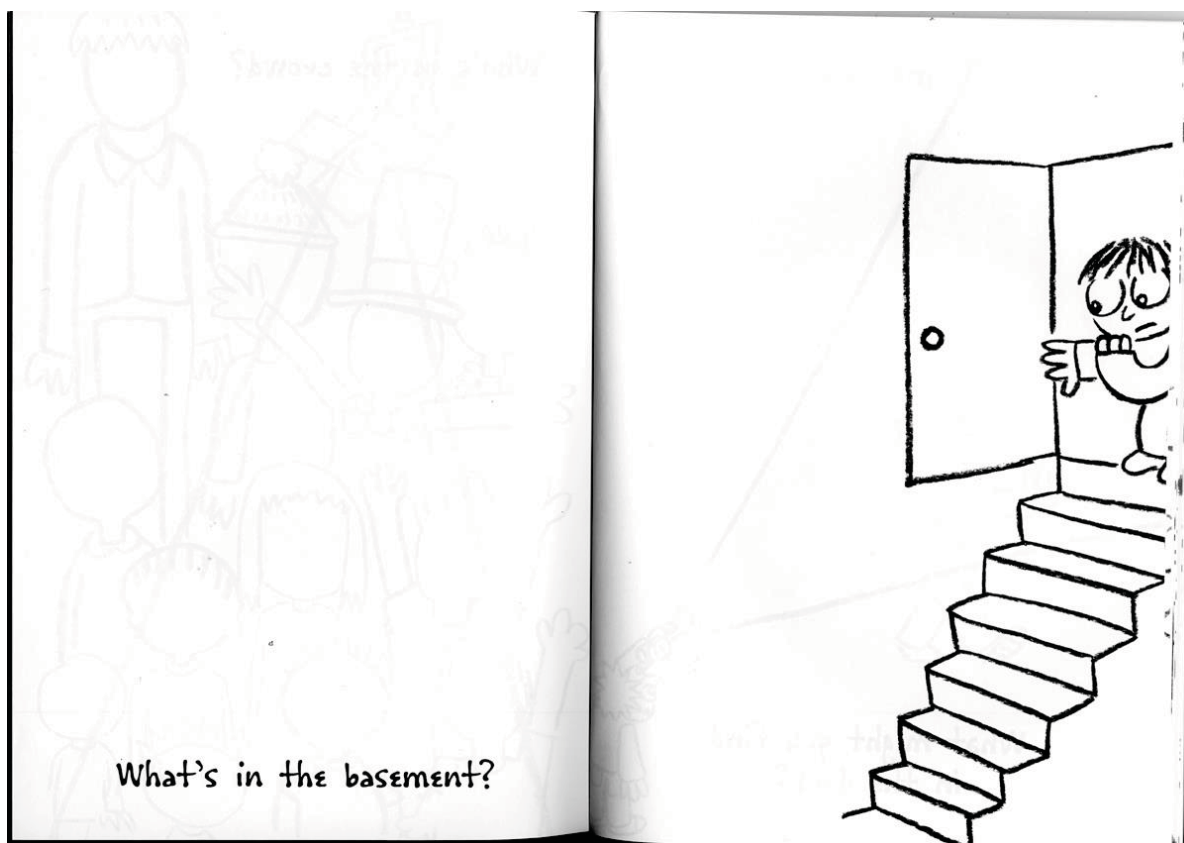
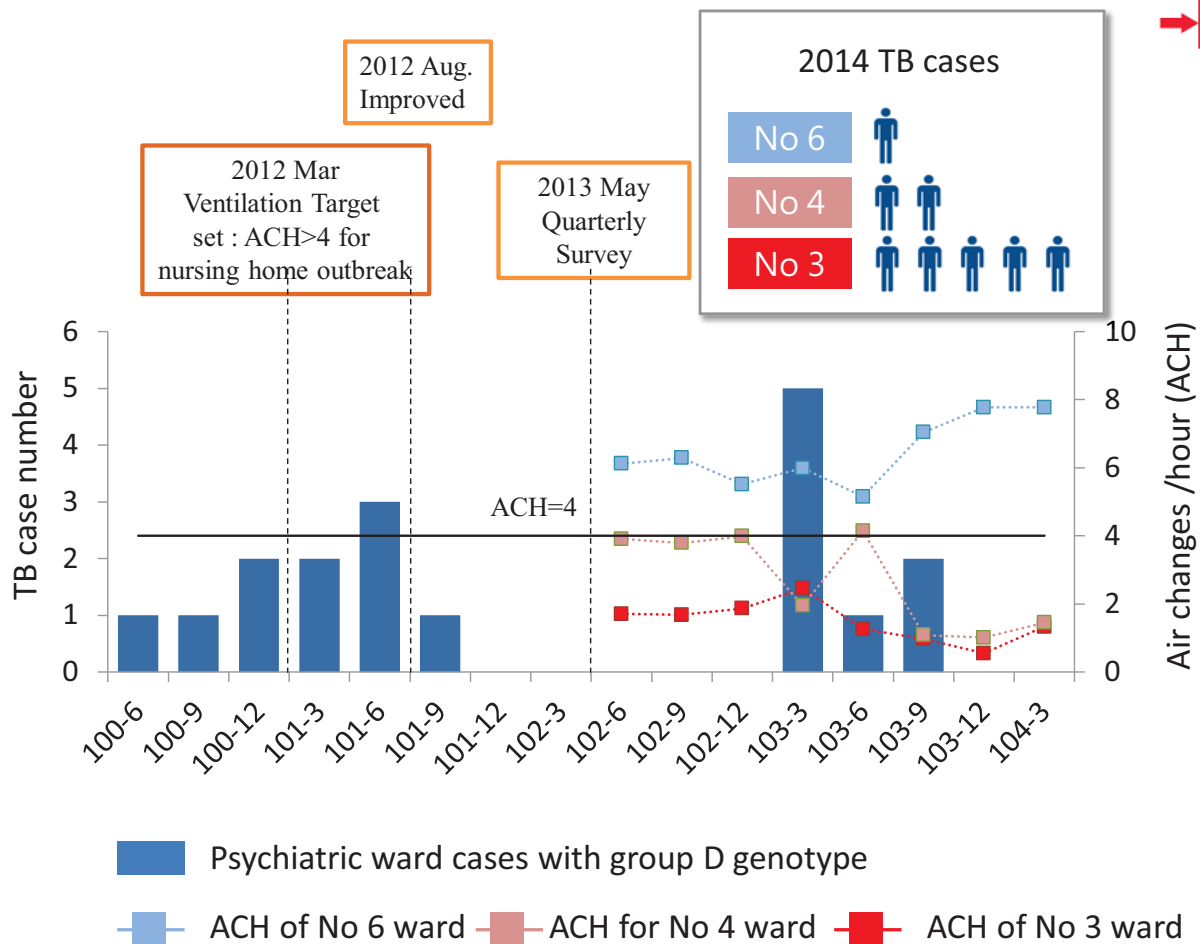
35

CO₂ concentration in 28 classrooms at the S building

- ≥ 1000 ppm: 89%
- < 1000 ppm in 3 because of < 10 students in the rooms
- This is the second set of surveillance data for CO₂ concentration gathered after the outbreak => no improvement at all



36



A校C大樓一樓門廳



側面窗均鑲有無法開啟之彩繪玻璃

39

C大廈地下樓層之進排氣改善工程

(一)、地面層出入口彩繪玻璃已依建議拆除

彩繪玻璃拆除改為紗窗後情形



(二)、已增設新鮮空氣之進排風系統

(三)、請技師進行第二次通風改善設計，於寒假進行施工

40



綜合大樓
教室兩側窗戶及
前後門打開增加
通風，以利排氣

A大樓



教室後面窗戶打開，以利通風。



教室走廊氣窗均有打
開，以利排氣，增加通
風。

Confused issue

ACH (Air Change rate per Hour)

- Source
 - Fresh Air
 - Recycle Air
- Measurement of flow rate
 - Flow rate
 - Velocity
- Flow pattern
 - Well mix
 - Shortcut
 - Substitute
 - Piston



➤ 每小時換氣次數(ACH)

某房間(容積V)內的空氣，每小時被換氣系統提供新鮮空氣所置換次數，一般使用之單位為1/hr或次/hr。

每分鐘空氣被置換次數 (1/min或次/min -
 $> Q (m^3/min)/V(m^3) * 60 \Rightarrow ACH$

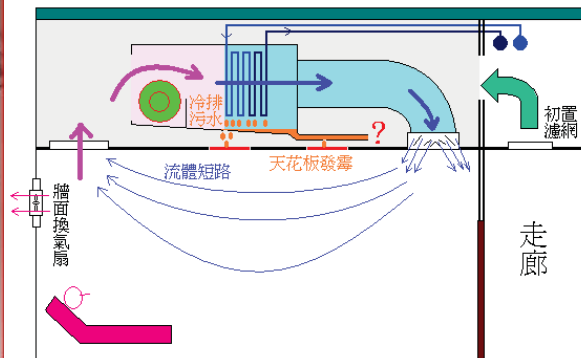
Measurement of flow rate



direct measurement (hood)



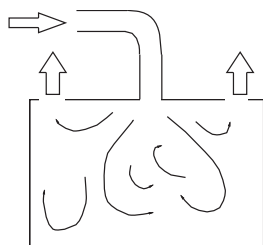
indirect measurement
(rotary airflow meter)



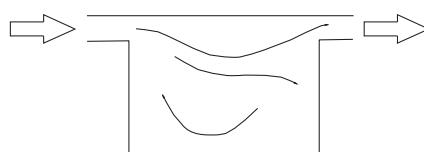
進排氣口短路

Airflow shortcut shall be prevented to reduce operational cost of air-conditioning system.

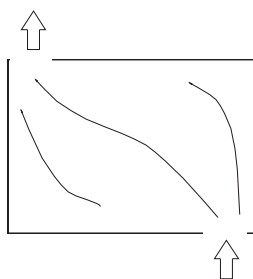
缺乏足夠換氣口



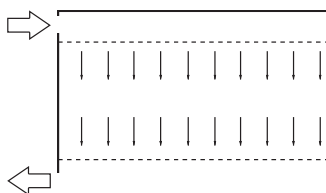
Wellmixed



shortcut



substitutue



piston

Flow pattern

建築技術規則建築設備編 102條

民國 106 年 10 月 18 日
(108/5/29修訂)

第 102 條 建築物供各種用途使用之空間，設置機械通風設備時，通風量不得小於左表規定：

房間用途	樓地板面積每平方公尺所需通風量 (立方公尺/小時)
臥室、起居室、私人辦公室等容納人數不多者。	8
辦公室、會客室	10
工友室、警衛室、收發室、詢問室。	12
會議室、候車室、候診室等容納人數較多者。	15
展覽陳列室、理髮美容院。	12
百貨商場、舞蹈、棋室、球戲等康樂活動室、灰塵較少之工作室、印刷工場、打包工場。	15
吸煙室、學校及其他指定人數使用之餐廳。	20
營業用餐廳、酒吧、咖啡館。	25
劇院、電影院、演藝場、集會堂之觀眾席。	75
廚房 營業用	60



47

如何評估室內空間之通風效率 (ACH)

• 示蹤氣體濃度衰減法 (均勻分布)

– 換氣率 (Q/V) 可由該示蹤氣體被引入之外氣稀釋，隨時間之濃度衰減曲線取對數得斜率求得。

• 定量釋放量

– 使示蹤氣體依一定速度& 量施放於實驗空間中
– 量測單位時間之濃度值並計算供給量與室內濃度時間之換氣量

$$N = \frac{G}{V \times C}$$

G：示蹤氣體釋放量

其中 V：室內有效體積(m³)

C：示蹤氣體在單位時間之平均濃度(ppm)



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台灣的室內空氣品質法規

- Environmental Protection Administration (EPA)
- << The Indoor Air Quality Act >>, announced on Nov 23, 2011 is an initiative aiming to improve indoor air quality and to protect public health.
- Enforcement Rules (along with a standard of indoor air quality and appropriate penalties) introduced on Nov. 23, 2012
- A list of prioritized public spaces related to students and the elderly— such as public schools and gatherings, elderly-care facilities and hospitals— announced in Jan 23, 2014
- The list of second wave announced in 2017

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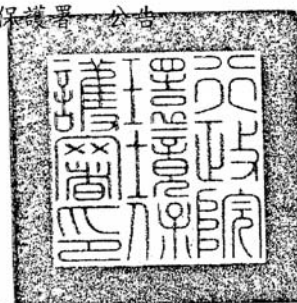
A collaboration between EPA and MOHW

The Taiwan CDC amended the standard for infection control in regards to Hospital inspection and evaluation for 2016

建議依照室內空氣品質標準來自我管理 (對於環保署尚未公告之區域及型態的醫療院所)

行政院環境保護署公告

發文日期：中華民國103年1月23日
發文字號：環署空字第1030006258號



主旨：訂定「應符合室內空氣品質管理法之第一批公告場所」，並自中華民國一百零三年七月一日生效。

依據：室內空氣品質管理法（以下簡稱本法）第六條。

公告事項：

- 一、本公告用詞，定義如下：
 - (一) 場所公告類別：指公告場所係屬本法第六條各款之公私場所業別或屬性類別。
 - (二) 管制室內空間：指公告場所應受本法管制之室內空間範圍，以公私場所各建築物之室內空間，經本公告規定適用本法之全部或一部分室內樓地板面積，並以總和計算之。
- 二、應符合本法之第一批公告場所，如附表一。
- 三、第一批公告場所之管制室內空間及應符合室內空氣品質標準之室內空氣污染物項目，公告場所所有人、管理人或使用人應依附表二規定辦理。
- 四、公告場所所有人、管理人或使用人應於中華民國一百零四年十二月三十一日前訂定室內空氣品質維護管理計畫，於一百零五年六月三十日前實施定期室內空氣品質檢驗測定、公布檢驗測定結果及作成紀錄。

署長 沈世宏



可考慮的環境監測措施：
 設立二氧化碳顯示面板
 由於二氧化碳的濃度會與換氣頻率和室內的人數有關，因此量測時應注意當時的室內人數

環保署室內空氣品質標準

項目	標準值		單位
	標準值	標準值	
二氧化碳 (CO ₂)	八小時值	1000	ppm (體積濃度百萬分之一)
一氧化碳 (CO)	八小時值	九	ppm (體積濃度百萬分之一)
甲醛 (HCHO)	一小時值	0.08	ppm (體積濃度百萬分之一)
總揮發性有機化合物 (TVOC, 包含：十二種揮發性有機物之總和)	一小時值	0.56	ppm (體積濃度百萬分之一)
細菌 (Bacteria)	最高值	1500	CFU/m ³ (菌落數/立方公尺)
真菌 (Fungi)	最高值	1000。但真菌濃度值比室內外等，不在此限。	CFU/m ³ (菌落數/立方公尺)
粒徑小於等於十微米 (μm) 之懸浮微粒 (PM ₁₀)	二十四小時值	75	μg/m ³ (微克/立方公尺)
粒徑小於等於二·五微米 (μm) 之懸浮微粒 (PM _{2.5})	二十四小時值	35	μg/m ³ (微克/立方公尺)
臭氧 (O ₃)	八小時值	0.06	ppm (體積濃度百萬分之一)

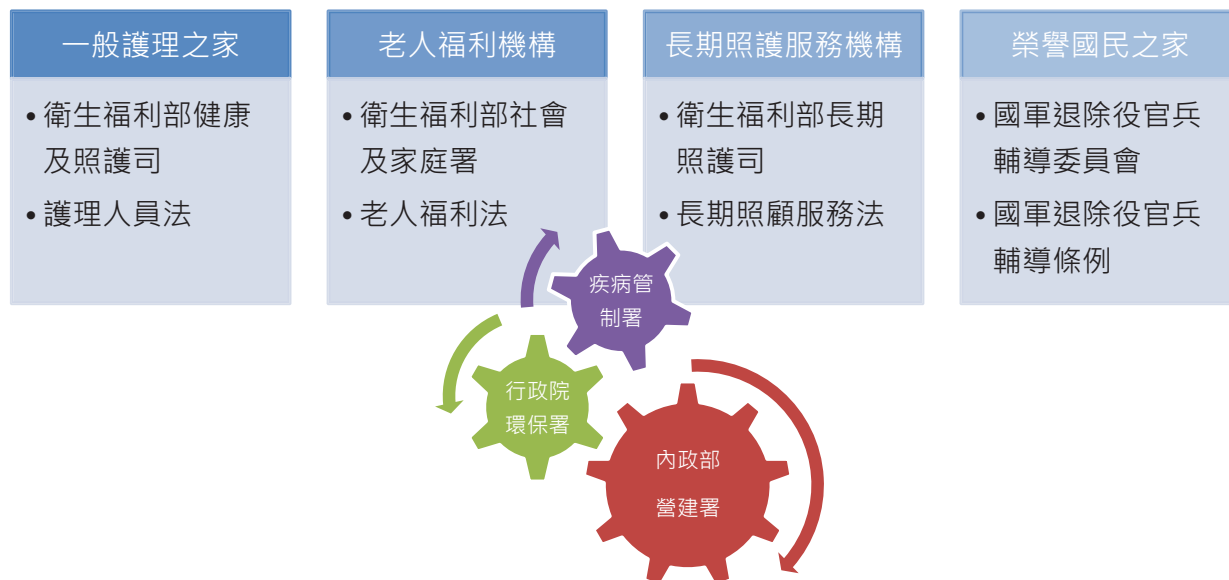
Challenges

- 病人和醫院的延遲診斷
- 當社區盛行率下降人口密集機構相對風險增加 (醫療院所亦然)
- 經營管理者很難平衡風險和資源利用



<http://www.glogster.com/nhutnibo/simpson-poster/g-6lkp3mtkjrgbo6puaa08ca0>

長照機構分類/主管機關/法規



部門間的合作

- 環保署
- 環境通風專家 (Taiwan NIOSH)
- 各事業主管機關
- 地方政府
- 醫院高層
- 疾病管制單位

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- 疾管署慢性組及國家實驗室
- 曾經群突發的醫療院所
- 相關縣市衛生局

