World Sustainable Built Environment Conference 2017 Hong Kong

Feasibility Study of Implementing an Indoor Air Quality (IAQ) Index in Hong Kong

香港室內空氣質素指數可行性研究

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BEHIND THE NEWS

Mention pollution and fingers usually point at the border. In the second of a three-part series, *Robin Kwong* examines what makes up our pollutants and who is responsible

We're off the air


Pedestrians in Mongkok cover their noses and mouths on a day of high pollution readings. Photo: Edward Wong

It has the look of an impressionist painting done with a palette of greys and murky blues. The view of Victoria Harbour a city scape rendered fuzzy as if Monet had come back to life to capture Hong Kong's skyline. It may be romantic to some, but to others it's the most visible reminder of the territory's perennial air pollution woes.

While the mountain of evidence showing that Hong Kong suffers from bad air grows each year, the problem itself has quietly transformed into just another factor of urban life in the city.

Although air quality has remained relatively steady over the past few years, one factor supporting the impression that pollution has worsened is the rise in low-visibility days. In 2004, the worst year on record, low visibility days occurred over nearly a quarter of the year at Chek Lap Kok airport.

Among Asian cities, Hong Kong clearly is not the worst – think Beijing and Shanghai, or even Mumbai and Bangkok. But neither is it one of the best – such as Singapore, Tokyo or Seoul.

Scientists have attributed the problem to four main pollutants: sulphur dioxide (SO2), nitrogen oxides (NOx), respirable suspended particles (RSP) and volatile organic compounds (VOC), which react with other pollutants under sunlight to create smog. Of these, SO2 levels have seen the largest changes in the past decade. Despite significant improvements in the early half of the 1990s, concentration levels have since crept upwards.

A basically flat line could also be drawn to show the levels of other pollutants over the past decade, although roadside pollution has improved somewhat, according to Environmental Protection Department (EPD) figures.

Usually the finger of blame is pointed at factories, power plants and cars in the Pearl River Delta (PRD), which has been widely reported as accounting for more than 80 per cent of total emissions in the region. In Hong Kong, power plants and road vehicles are the major polluters.

But according to scientists, it's not that simple. The weather, too, is an important ingredient in this potent and harmful cocktail. Further complicating the issue is the fact that the emitted pollutants often go through complex chemical reactions with other pollutants or with water droplets in the air.

"I think it would be difficult for anyone to say quantitatively [how much PRD sources contribute to Hong Kong's air pollution levels]," said atmospheric scientist and Hong Kong University of Science and Technology associate professor Alexis Lau Kai-hon.

Dr Lau and other scientists agree that the contribution of local factors would be underestimated if researchers focused solely on comparing the amount of emissions.

Dr Lau estimated that, overall, the relative contribution of PRD sources to Hong Kong's ambient air pollution to be about the same as local sources' contributions in the summer. "The PRD's contribution could reach up to 80 per cent in the winter, but only under extreme conditions," he said.

EPD assistant director Tse Chin-wan said the government treated local and regional sources as equally important, and it had long been the department's position that local sources played a significant role.

Like Dr Lau, he estimated that local sources were equally as important as PRD sources for Hong Kong's ambient air pollution levels. On roadsides, the influence of local sources rose to 60 to 70 per cent compared with regional sources. "But these are rough figures and not fully established," Mr Tse said, "which is why we could not list them officially in, for example, Legislative Council papers."

Scientists believe that roadside pollution has been underestimated.

Professor Fang Ming of the Institute for the Environment at the Hong Kong University of Science and Technology, whose team has taken the Mobile Real-time Air Monitoring Platform (MAP), a van fitted with monitoring equipment, to the streets of Hong Kong for the past four years, said that the concentration of pollutants on busy roads could be substantially higher than ambient air pollution levels.

"The most extreme example would be the accumulation of pollutants in tunnels," Professor Fang said. Pollutants near the southbound exit of the 3.8km-long Tai Lam Tunnel reached five to 10 times that of the air at the entrance, he said.

The worst readings were for fine suspended particles (PM2.5), which could penetrate the "filters" in the respiratory system and become lodged deep within the lungs.

The highest average concentration in the tunnels was more than 250mcg/m3 (250 micrograms per cubic metre), far higher than our air quality objectives of 180mcg/m3 for 24-hour exposures to respirable suspended particulates (PM10).

Hong Kong doesn't yet have a standard for acceptable concentrations of PM2.5, although the US has set a 24-hour objective of 65mcg/m3.

Professor Fang said the health risk was mitigated by the fact that people usually spent only a short time in a tunnel, and that concentrations of known carcinogens were found to be low enough that acute effects were unlikely.

Given the fact that such pollution is often highly localised, most people would find it possible to limit the worst effects of roadside pollution.

However, although most Hongkongers spend about 70 per cent of their time indoors, it does not mean they are protected from the pollutants outside.

Horace Mui Kwok-wai, assistant professor of Polytechnic University's Department of Building Services and Engineering, said certain high-grade filters for air ventilation systems could filter out RSPs, but these were more likely to be found in labs than in office buildings.

"As for other pollutants such as sulphur dioxide or nitrogen oxide, they pass right through because they're gases. I wouldn't say that the concentration levels for these pollutants are exactly the same inside as outside all the time, but there's certainly a very high correlation," he said.

In homes, in particular, it is almost impossible to block out pollution from the outside. "Even if you turn up the air-conditioner and close all the windows, there are still cracks where outside air can infiltrate the home," Dr Mui said.

Medical experts also warn that the air pollution index (API), and its associated health advice may not be of much help.

"It's the single most misleading piece of public health information our government has put out," said Anthony Hedley, chair professor of the department of community medicine at the University of Hong Kong. "They are not protective for health."

Hong Kong's API reflects the level of pollution relative to the acceptable concentration level set out in our air quality objectives (AQO).

An API of 100, for example, corresponds with pollutant levels at the AQO limit. Environmentalists and medical experts such as Professor Hedley have long campaigned for a review and tightening of the AQO levels, which were established in 1987.

EPD assistant director Tse Chin-wan said that Hong Kong's present AQOs were comparable to US national standards. The API and its associated health advice was also reviewed in 1998, with input from medical professionals, he said.

The likely situation is that pollutants in Hong Kong's ambient air, on any given day, could come from a range of locations – a variety of local sources, from the Pearl River Delta, or from even further inland on isolated days – all depending on weather conditions.

The picture of how air pollution works is arguably much like our harbour view on a bad day – we see the outlines, but the details remain fuzzy. One message that's clearly in focus, is that much more work needs to be done if we're to fix, rather than just arrest, the problem – and stepping up efforts to clean our own house would certainly help.

● *The final part of the series tomorrow examines what more needs to be done to address Hong Kong's pollution problem.*

THE FOUR MAIN OFFENDERS

		Source (%) of total emissions in 2003
Sulphur dioxide (SO2)	Can affect breathing and make existing respiratory ailments worse	Power generation (92), marine vessels (4), non-transport fuel combustion (4)
Nitrogen oxides (NOx)	Mainly produced during fuel combustion. Can lower resistance to respiratory infections	Power generation (57), road transport (21), marine vessels (14), others (4)
Respirable suspended particles (RSP or PM10)	Tiny particulates from fuel combustion or chemical reactions with other pollutants. The tinier the particulate, the more health damage it can cause	Power generation (44), road transport (28), Non-combustion i.e. construction (16), others (10)
Volatile organic compounds (VOC)	React with other pollutants to form ozone (smog). Ground-level ozone irritates the eyes, nose and throat	Consumer products, paints, printing, etc (81); road transport (17); others (2)


SCMP Graphic

DANGERS IN THE OFFICE

Internal pollution is increasingly seen as a problem in homes and offices, with unclean air causing headaches, nose and throat irritations and respiratory difficulties, experts say. Poor air may also lower a person's resistance to infectious diseases.

Environmental tobacco smoke, where present, is the single largest source of indoor pollutants. Tests have shown particle levels in smoking areas are typically 2½ times the level graded as "good" by the Environmental Protection Department (EPD), which mems they exceed 180 micrograms per cubic metre.

Assistant professor of Polytechnic University's Department of Building Services and Engineering, Horace Mui Kwok-wai, said tests on 422 office buildings carried out from 2000-2003 showed other sources of indoor air pollution also plagued most offices.

Overall, only 3 per cent of the surveyed buildings met the "excellent" levels for the EPD's Indoor Air Quality Certification Scheme, and only a quarter met the "good" levels, Dr Mui said.

Just over half of the buildings surveyed had airborne bacteria levels that met the "excellent" levels as set by the EPD scheme.

"While the bacteria are not a severe health risk in themselves, they serve as an indication of how clean the ventilation system is," he said.

Robin Kwong

CLP the worst local polluter

It is impossible to talk about local sources of air pollution without mentioning our power plants. CLP Power – which owns one gas-fired and one coal-fired power plant on the west side of Kowloon, as well as a small oil-fired plant at Penny's Bay on Lantau Island – is Hong Kong's single largest polluter. In 2003, its power plants pumped roughly 51,000 tonnes of sulphur dioxide, 38,000 tonnes of nitrogen oxide, and 1,700 tonnes of respirable suspended particles into the air.

In total, power plants accounted for 92.2 per cent, 57.2 per cent, and 45.9 per cent of total 2003 emissions in Hong Kong of sulphur dioxide, nitrogen oxide, and respirable suspended particle respectively, according to the Environmental Protection Department.

CLP's decision on its fuel mix also has a significant impact on the amount of pollutant emissions in Hong Kong – particularly sulphur dioxide. An increase in the city's sulphur dioxide emissions from 67,500 tonnes in 2002 to 94,800 tonnes in 2004 could almost entirely be explained by a similar increase in CLP's emissions.

CLP's 2004 Social and Environmental Report said the company burned greater amounts of coal in 2003 because there were less reserves at its Yacheng gas field, off Hainan Island, than expected. CLP reduced the amount of coal burned in 2004, but sourced "coal with higher sulphur and ash content than in 2003".

Uncertainty lingers over the extent to which power plant emissions affect Hong Kong's air quality. On the one hand the plants, with their tall stacks, are all located on the west and south side, which allows the northeasterly monsoon in winter to blow pollutants out of Hong Kong.

But research by the Hong Kong University of Science and Technology has shown that under the southwesterly winds usually in summer and early autumn, pollutants could reach ground levels in most areas of Hong Kong.

Robin Kwong


By using more coal, CLP is adding to air pollution. Photo: Dustin Shum

Air and sea ports make impact

The Pearl River Delta is serviced by five airports – Hong Kong, Guangzhou, Macau, Zhuhai and Shenzhen – each with their own airspace procedures. Pilots approaching from the north must navigate through each airspace before landing at Hong Kong's International Airport, which means extra flight time – and more fuel being burned.

Captain Russell Davie, airline operations manager for Cathay Pacific, says these restrictions result in an extra 25,000 tonnes of fuel burned each year by Cathay flights alone.

Giovanni Bisignani, director-general of the International Air Transport Association (Iata), priced the inefficiency at US$400 million, reported earlier by trade magazine *Orient Aviation*. "This unnecessary cost to airlines and the environment is not acceptable. Iata is working closely with all parties to rationalise the situation."

Given the high altitude at which jet fuel burns and its relatively high quality, the impact of this inefficiency on Hong Kong's air pollution is tenuous at best. The carbon dioxide emitted as a result, however, does have implications on global warming.

There is also increasing attention paid to the pollution that shipping generates, given 172,000 vessels arrived in the city in the first nine months of last year. Under present international regulations, the sulphur content of bunker fuel could be as high as 4.5 per cent. Hong Kong's diesel for road vehicles has a sulphur content of 0.005 per cent.

Government statistics for 2003 showed "navigation" accounted for just 4 per cent of sulphur dioxide emissions and 15.7 per cent of nitrogen oxide emissions. But environmental groups say the toxic fumes are emitted close to ground level, and pollutants blow directly into heavily populated areas.

Robin Kwong


Iata chief Giovanni Bisignani. Photo: Bloomberg News

Newspaper clips on IAQ Issues

"South China Morning Post, 23 Feb 2006"

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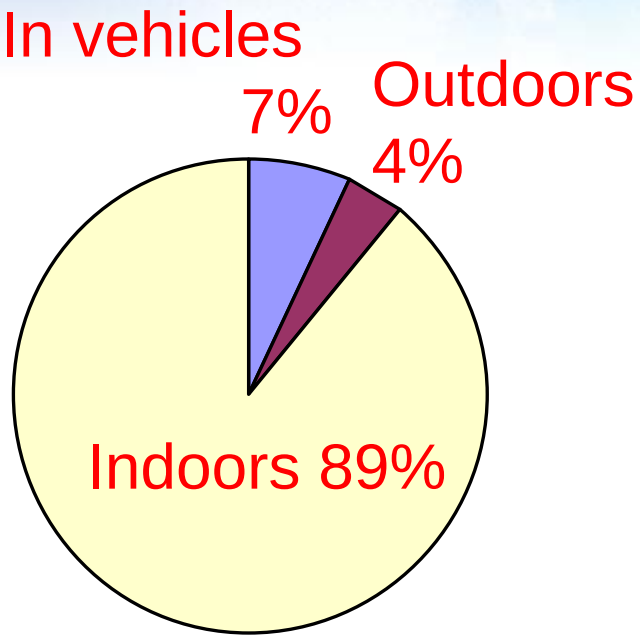
Why should we concern about IAQ?

- **Indoor Air Quality (IAQ):**
  - **Exposure: People spend >85% time indoor**
  - **Concerns of health and comfort**
    - **e.g. Sick leave, low productivity, money loss**
  - **Impact on energy use**



Where do we spend most of our time?

Prepared by K.W MUI
(BSE, PolyU)

Health concerns of IAQ

- 3.8 million premature deaths (WHO,2014)

Pathogenic
- Long term effects (chronic)
- Short term effects (acute)

Annoyance
- Odour
- Irritation (eye, nose and throat)

- What is acceptable air quality?
  - No more than 5% occupants complaint
  - No known pollutants exceed existing IAQ standard

World Health Organization. (2014). Burden of disease from Household Air Pollution for 2012. Retrieved from: http://www.who.int/phe/health_topics/outdoorair/databases/HAP_BoD_results_March2014.pdf?ua=1.

Prepared by K.W MUI
(BSE, PolyU)

Economic concerns of IAQ

↓Productivity + ↑Sickness absence

= ↑ Labour and production costs

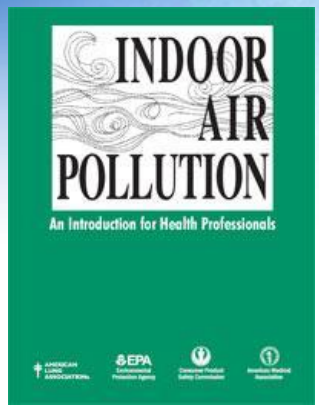
- 2% decrease in productivity due to SBS symptoms would cost USD 60 billion annually (Fisk, 2000a; Fisk 2000b)

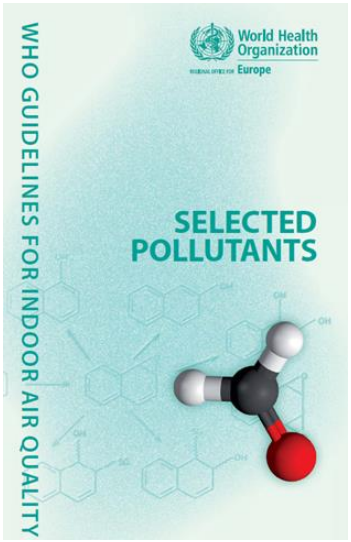
- Fisk, W.J. (2000a). Health and productivity gains from better indoor environments and their relationship with building energy efficiency. Annual Review of Energy and the Environment, 25(1):537-566. doi: 10.1146/annurev.energy.25.1.537
- Fisk, W.J. (2000b). Estimates of potential nationwide productivity and health benefits from better indoor environments: An update. Chapter 4 in Indoor Air Quality Handbook, eds: Spengler, J.D., Samet, J.M., McCarthy, J.F. New York: McGraw Hill.

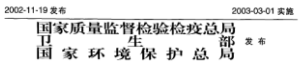
Prepared by K.W MUI
(BSE, PolyU)

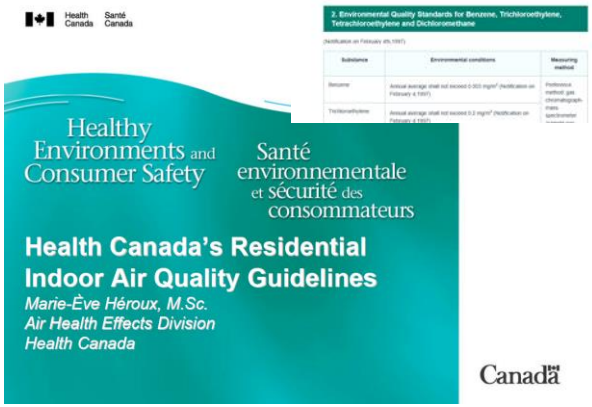
International Responses …

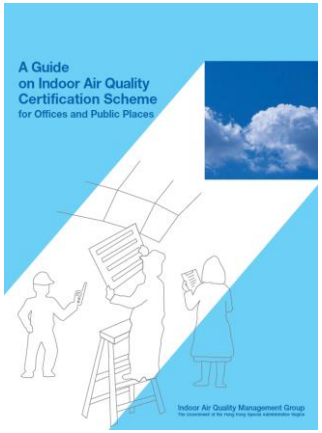
- Australia
- China
- Europe
- Japan
- Taiwan
- South Korea
- USA
- HK
- WHO
- …





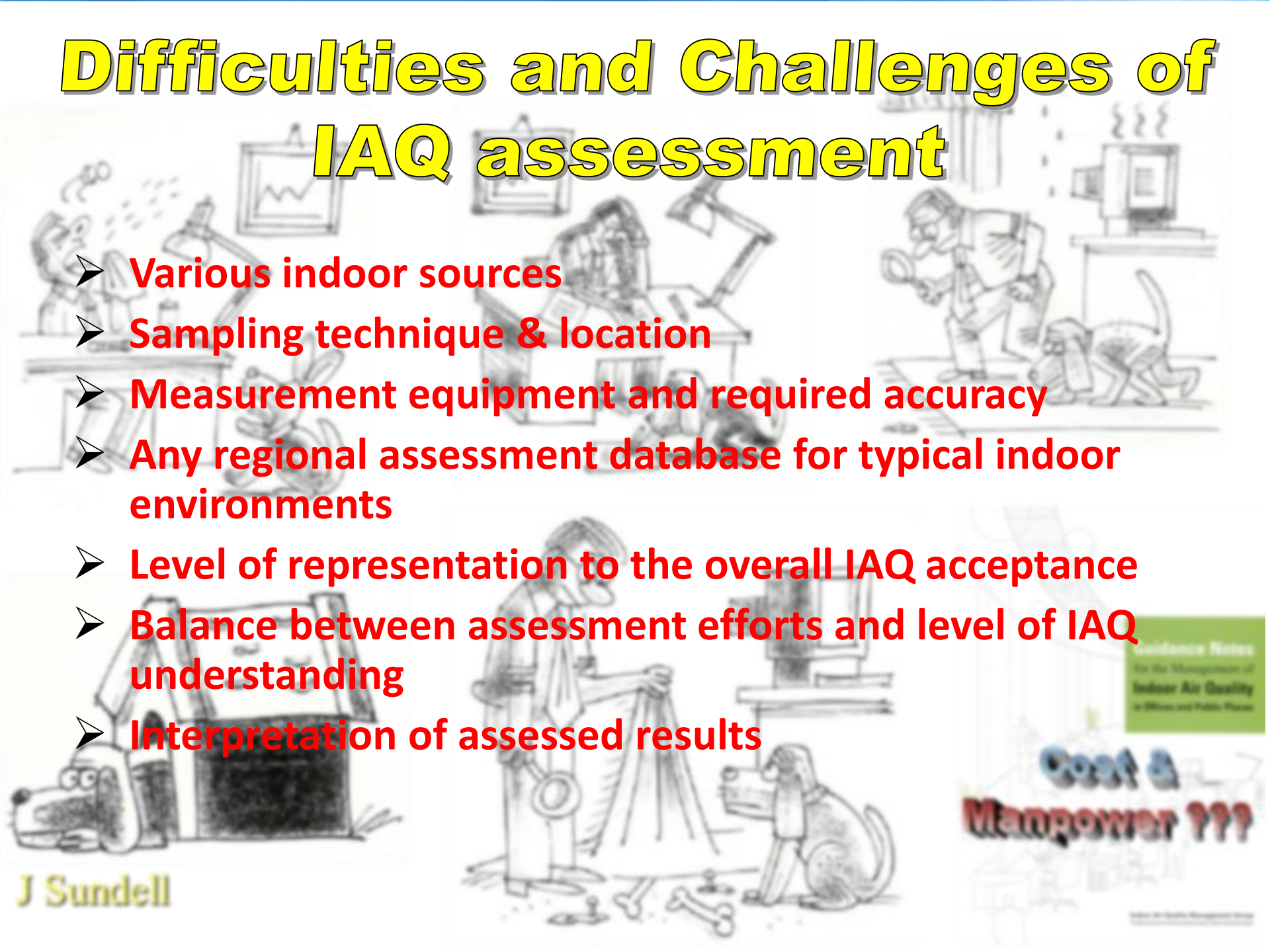


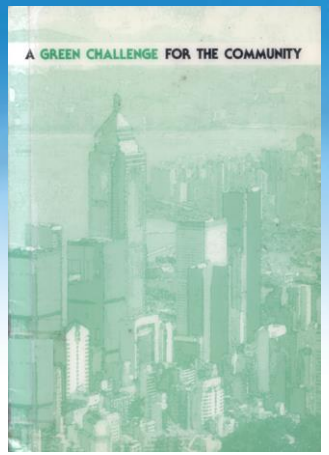




Difficulties and Challenges of IAQ assessment

- Various indoor sources
- Sampling technique & location
- Measurement equipment and required accuracy
- Any regional assessment database for typical indoor environments
- Level of representation to the overall IAQ acceptance
- Balance between assessment efforts and level of IAQ understanding
- Interpretation of assessed results



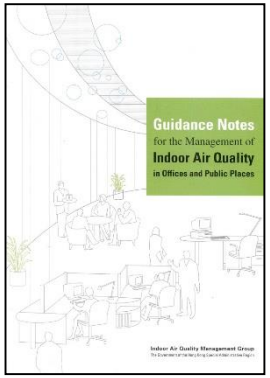


1990
Pilot study on IAQ in 35 air-conditioned office

1993
Second review of the "1989 White Paper on Pollution in Hong Kong"

1994
Interim IAQ Guidelines

1995
Consultancy study on Indoor Air Pollution in Offices and Public Places in Hong Kong



1998
Indoor Air Quality Management Group (IAQMG)

1999
IAQ Management Programme

since 2000

- IAQ Objective
- Public education and publicity campaign
- IAQ Information Centre

since 2003

- IAQ Certification Scheme for Offices and Public Places
- Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places

IAQ development in Hong Kong

Prepared by K.W MUI
(BSE, PolyU)

Prepared by K.W MUI
(BSE, PolyU)

Parameters in IAQ Scheme

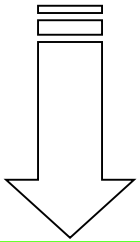
- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Respirable Suspended Particulates (RSP)
- Nitrogen Dioxide (NO_2)
- Ozone (O_3)
- Formaldehyde (HCHO)
- Total Volatile Organic Compounds (TVOC)
- Radon (Rn)
- Airborne Bacteria
- Room Temperature
- Relative Humidity
- Air Movement

Prepared by K.W MUI
(BSE, PolyU)

Validity of GN (Guidance Notes)?

Trend of IAQ?

Assessments of IAQ??



4 Assessments

A B C D

1990
Pilot study on IAQ in 35 air-conditioned office

1993
Second review of the "1989 White Paper on Pollution in Hong Kong"

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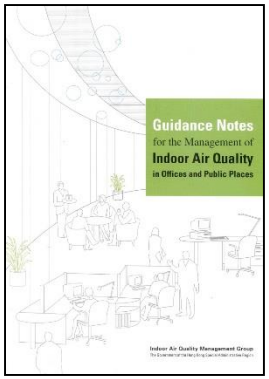
Consultancy study on Indoor Air Pollution in Offices and Public Places in Hong Kong

Assessment A



1998
Indoor Air Quality Management Group (IAQMG)

1999
IAQ Management Programme

Assessments B, C & D

since 2000

- IAQ Objective
- Public education and publicity campaign
- IAQ Information Centre

since 2003

- IAQ Certification Scheme for Offices and Public Places
- Guidance Notes for the Management of Indoor Air Quality in Offices and Public Places

Prepared by K.W MUI
(BSE, PolyU)

- **Assessment A:**

  First extensive IAQ study for Hong Kong carried out by an independent consultant. The sampling protocol based on the US Environmental Protection Agency's BASE (Building Assessment Survey and Evaluation) study and modified as necessary to cope with the local constraints

- **Assessment B:**

  Three government office measurements were also performed in a trial run to verify the validity of the GN (Guidance Notes)

- **Assessment C:**

  Four of the HKEPD listed indoor pollutants, namely CO_2, HCHO, RSP and ABC, were measured in 10 typical air-conditioned offices installed with mechanical ventilation systems

- **Assessment D:**

  A regional cross-sectional measurement of pollutant levels was conducted in 422 air-conditioned offices in Hong Kong

Predicted Satisfactory Office Environment in Hong Kong from 1996 to 2003

Prepared by K.W MUI
(BSE, PolyU)

(a) At excellent level

Parameters		CO_2 (ppm)	CO ($\mu g\ m^{-3}$)	RSP ($\mu g\ m^{-3}$)	NO_2 ($\mu g\ m^{-3}$)	O_3 ($\mu g\ m^{-3}$)	HCHO ($\mu g\ m^{-3}$)	TVOC ($\mu g\ m^{-3}$)	Rn ($Bq\ m^{-3}$)	ABC ($CFU\ m^{-3}$)	T (°C)	RH (%)	V (ms^{-1})
Criteria for 'Excellent'		<800	<2,000	<20	<40	<50	<30	<200	<150	<500	20-25.5	40-70	<0.2
Source of data	**Sample size**	Predicted satisfactory rate (%)											
Assessment A	40	28%	99%	34%	97%	73%	16%	--	--	33%	100%	98%	100%
Assessment B	3	56%	100%	14%	96%	100%	31%	15%	100%	61%	79%	100%	100%
Assessment C	10	52%	--	53%	--	--	93%	--	--	76%	--	--	--
Assessment D	422	82%	100%	35%	84%	82%	42%	26%	98%	51%	88%	86%	93%

(b) At good level

Parameters		CO_2 (ppm)	CO ($\mu g\ m^{-3}$)	RSP ($\mu g\ m^{-3}$)	NO_2 ($\mu g\ m^{-3}$)	O_3 ($\mu g\ m^{-3}$)	HCHO ($\mu g\ m^{-3}$)	TVOC ($\mu g\ m^{-3}$)	Rn ($Bq\ m^{-3}$)	ABC ($CFU\ m^{-3}$)	T (°C)	RH (%)	V (ms^{-1})
Criteria for 'Good'		<1,000	<10,000	<180	<150	<120	<100	<600	<200	<1,000	<25.5	<70	<0.3
Source of data	**Sample size**	Predicted satisfactory rate (%)											
Assessment A	40	56%	100%	100%	100%	100%	75%	--	--	69%	100%	98%	100%
Assessment B	3	88%	100%	100%	100%	100%	98%	22%	100%	100%	100%	100%	100%
Assessment C	10	61%	--	100%	--	--	100%	--	--	96%	--	--	--
Assessment D	422	97%	>99.8	>99.8	>99.8	95%	94%	84%	100%	85%	98%	88%	98%

Validity of GN?

Trend of IAQ?

- From 1999 to 2003, with the implementation of the GN
  - Predicted satisfactory rates of CO_2, HCHO, TVOC and ABC were enhanced
  - Predicted satisfactory rates for RH and T were decreased.
    - It could be explained by the fact that most existing air-conditioned systems had not yet been renovated to cater for the increased fresh air loads.
  - Some of the parameters seldom exceeded the recommended criteria, e.g. CO
  - Some contributed to a relatively low unsatisfactory rate, e.g. Rn and V

Problems and Limitations

- **Low participation number: 996 premises (Nov, 2015)**
- **Certified locations: > 60% in common areas**
- **Voluntary basis**
- **Stringent IAQ standards**
- **High implementation cost and improvement cost**
- **Lack of flexibility in measurement procedures and subsequent monitoring**
- **Outdated?**

Indoor Air Quality Information Centre, Hong Kong Environmental Protection Department (HKEPD), Government of the Hong Kong Special Administrative Region. (2015). Certified premise list. [online] Available at: http://www.iaq.gov.hk/en/iaq-certification-scheme/certified-premises-list.aspx [Accessed 10 Nov. 2015].

But....

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Universal Declaration of Human Rights

The Universal Declaration of Human Rights

The Universal Declaration of Human Rights (UDHR) is a milestone document in the history of human rights. Drafted by representatives with different legal cultural backgrounds from all regions of the world, the Declaration was proclaimed by the United Nations General Assembly in Paris on 10 Decem 1948 (General Assembly resolution 217 A) as a common standard of achievements for all peoples and all nations. It sets out, for the first time, fundamental human rights to be universally protected and it has been trar into over 500 languages.

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ILLUSTRATED VERSION

Article 24.

Everyone has the right to rest and leisure, including reasonable limitation of working hours and periodic holidays with pay.

Article 25.

(1) Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control.

(2) Motherhood and childhood are entitled to special care and assistance. All children, whether born in or out of wedlock, shall enjoy the same social protection.

Article 26.

(1) Everyone has the right to education. Education shall be free, at least in the elementary and fundamental

Preamble

Whereas recognition of the inherent dignity and of the equal and inalienable rights of all members of the family is the foundation of freedom, justice and peace in the world,

Whereas disregard and contempt for human rights have resulted in barbarous acts which have outrage

Prepared by K.W MUI
(BSE, PolyU)

Do we need to establish something on indoor air quality?

Prepared by K.W MUI
(BSE, PolyU)

IAQ Pre-assessment tools

- Two approaches:
  - Health-risk approach

IAQHI

  - Indicator approach

IAQSI

IAQ Health Index (IAQHI)

Based on Air Quality Health Index (AQHI) (Wong *et al.* 2013):

- **Health risk-based air pollution index**
- **Estimate the short-term risk of respiratory diseases associated with exposure to 4 criteria air pollutants**
  - **SO_2**
  - **NO_2**
  - **O_3**
  - **PM_{10}**

Index Calculation

Wong *et al.*, 2013

- **Sum of the percentage added health risk (%AR) of daily hospital admissions attributable to the 3-h moving average concentrations of the four air pollutants (SO_2, NO_2, O_3, PM_{10})**

$$\%AR = \sum \%AR(c)$$

- **%AR of each pollutant depends on its concentration and a risk factor correlated with local health statistics and air pollution data (*Wong et al.*, 2013)**

$$\%AR(c) = \{\exp[\beta(c) \times C(c)] - 1\} \times 100\%$$

Wong, T. W., Tam, W. W., Yu, I. T., Lau, A. K., Pang, S. W., & Wong, A. H. (2013). Developing a risk-based air quality health index. Atmospheric Environment, 76, 52-58. doi:10.1016/j.atmosenv.2012.06.071

Can we consider to use it in indoor environment?

- Industrial standards are set for healthy adults in the 8 hour-shift work place
- General population, age, health status vary
- Exposure-time are different:
  - Intermittent, continuous
- Effects of long term low level exposure not known

Proposed Development of IAQHI

- Addition of indoor surrogate parameters into the calculation
- Daily environments may be divided into two distinct groups:
  1. Indoor spaces served by MVAC systems; and
     - CO_2, VOCs (including HCHO) and $PM_{2.5}$
  2. Outdoor spaces (including enclosed places with windows for natural ventilation)
     - VOCs (including HCHO) and $PM_{2.5}$

Difficulties in Developing IAQHI

- At preliminarily stage
- Identification of health risk of individual chemical takes extensive health-based research and collective health assessment study
- Limited knowledge on combined exposure to multiple pollutants
- Individuals respond to chemical exposures in different ways
- age, gender, health status and genetics

Ultimate Goal ??

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3 common IAQ control strategies

IAQ Index with Surrogate Indicators (IAQSI)

- **Surrogate indicators (Wong *et al.*, 2006)**
  - **CO_2: Surrogate indicator for ventilation & occupant load**
  - **RSP: Dominant outdoor air pollutant; indicator of the filtration performance**
  - **TVOC: Indicator of indoor air pollutants emitted from building materials, finishes and human activities**

Wong, L. T., Mui, K. W., & Hui, P. S. (2006). A statistical model for characterizing common air pollutants in air-conditioned offices. Atmospheric Environment, 40(23), 4246-4257. doi:10.1016/j.atmosenv.2006.04.005

IAQ Index with Surrogate Indicators (IAQSI)

- "IAQ index" θ
  - Average fractional dose ϕ_j^* of the average level ϕ_j to the exposure limit $\phi_{j,0}$ of Good Class in the Scheme for N selected surrogate parameters j (Wong *et al.*, 2007)

No.	Air pollutant	HKEPD recommended maximum level
1	CO_2 (ppm)	1000
2	CO ($\mu g\ m^{-3}$)	10000
3	RSP ($\mu g\ m^{-3}$)	180
4	NO_2 ($\mu g\ m^{-3}$)	150
5	O_3 ($\mu g\ m^{-3}$)	120
6	HCHO ($\mu g\ m^{-3}$)	100
7	TVOC ($\mu g\ m^{-3}$)	600
8	Rn ($Bq\ m^{-3}$)	200
9	ABC ($CFU\ m^{-3}$)	1000

$$\theta = \frac{1}{N}\sum_{j=1}^{N}\phi_j^* \qquad \phi_j^* = \frac{\phi_j}{\phi_{j,0}}$$

ϕ_j: assessed average pollutant level

$\phi_{j,0}$: exposure limits

Existing standards used as a reference

Wong, L. T., Mui, K. W., & Hui, P. S. (2007). Screening for Indoor air Quality of Air-Conditioned Offices. Indoor and Built Environment, 16(5), 438-443. doi:10.1177/1420326x07082159

IAQ Index with Surrogate Indicators (IAQSI)

Based on the feasibility study conducted by Mui *et al.* (2011), effect of using different combinations of surrogate IAQ parameters in IAQ index "*θ*" for predicting unsatisfactory IAQ in office is investigated by Wong *et al.* (2016).

Combination (Wong *et al.*, 2016)

1. IAQ index θ_1 - CO_2
2. IAQ index θ_2 - CO_2 and RSP
3. IAQ index θ_3 - CO_2, RSP and TVOC

Wong, L., Mui, K., & Tsang, T. (2016). Evaluation of Indoor Air Quality Screening Strategies: A Step-Wise Approach for IAQ Screening. International Journal of Environmental Research and Public Health, 13(12), 1240. doi:10.3390/ijerph13121240

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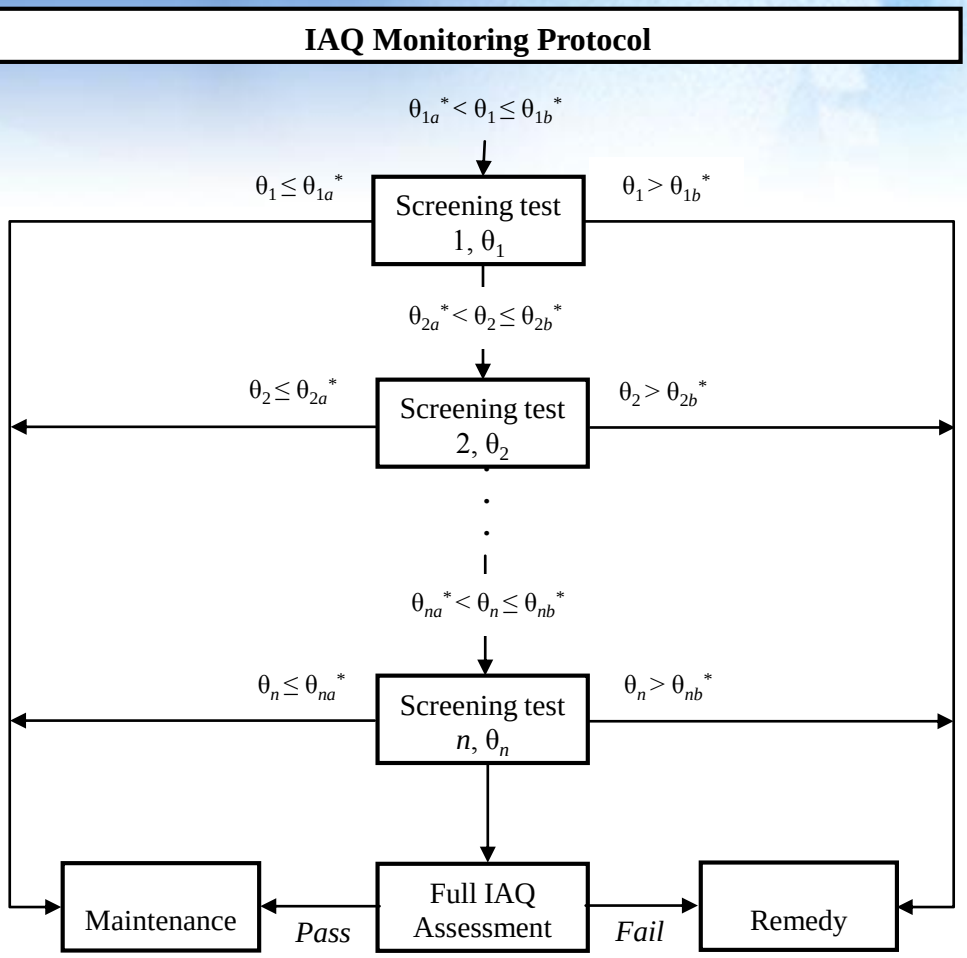
Proposed Step-wise Screening Protocol

Wong *et al.* 2016

- For decision making in practical IAQ management
- Testing threshold and test-treatment threshold are set according to facility management strategies
- Balance between resources and effectiveness

Framework of the screening



Ref: Int. J. Environ. Res. Public Health **2016**, 13, 1240

How Likely the Test is Telling the Truth?

- Further to that, likelihood ratio L_r is used to provide information about the reliance of the test result
  - i.e. how likely a positive result in a test is indicating a true problematic case.
- Based on the testing thresholds, three indices were categorized into five screening levels
  - i.e., multilevel likelihood ratios with an order of magnitude L_r = 10 or 0.1 used in a medical test for diagnosing a disease.

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How to Use?

- **Likelihood ratio (概似比)** of an IAQ index in diagnosing unsatisfactory IAQ can be determined:
  - ***TP*: fail counts (of the scheme)** against the screening test parameters $\theta<\theta_a^*$ and $\theta>\theta_b^*$
  - ***TN*: pass counts (of the scheme)** against the screening test parameters $\theta<\theta_a^*$ and $\theta>\theta_b^*$
  - n_{TP}: **total fail counts**
  - n_{TN}: **total pass counts**

$$L_r = \frac{TN}{TP}\frac{n_{TP}}{n_{TN}}$$

For example, if we measure CO_2 and RSP; the IAQ index is 0.7

It summarizes the screening results and their corresponding likelihood ratios for IAQ indices θ_1, θ_2 and θ_3

k	Screening Level for θ_1, θ_2, θ_3	Likelihood Ratio, L_r		
		θ_1	θ_2	θ_3
1	< 0.32	/	0.3	0.1
2	0.32 – 0.42	0.2	0.8	0.4
3	0.43 – 0.53	0.7	1.4	0.8
4	0.54 – 0.64	0.9	2.6	1.7
5	≥ 0.65	1.3	4.3	25

k is the order of screening level, where $k = 1$ when $\theta_n < 0.32$; $k = 2$ when $0.32 \le \theta_n \le 0.42$; $k = 3$ when $0.43 \le \theta_n \le 0.53$; $k = 4$ when $0.54 \le \theta_n \le 0.64$; and $k = 5$ when $\theta_n \ge 0.65$.

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Probability of Having Poor IAQ

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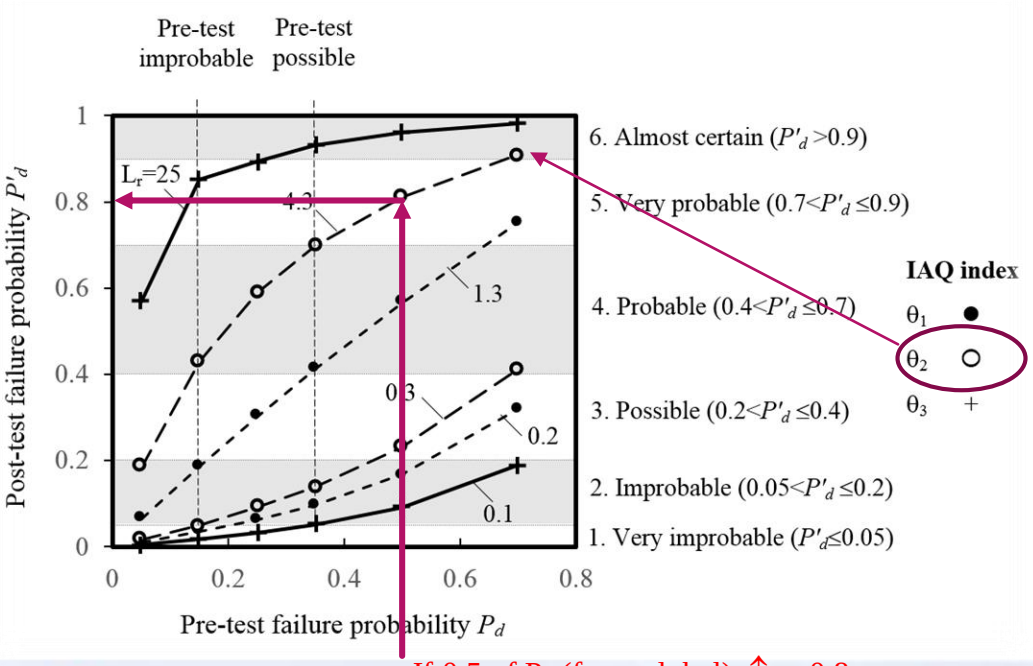
- Pre-test probability P_d and L_r are required for calculating the post-test probability P'_d of having poor IAQ.
- Prevalence of unsatisfactory IAQ (i.e. P_d) in HK can be acquired from collective IAQ assessment of similar buildings.
  - P_d: pre-assessment probability
  - O_d: pre-assessment odds
  - O'_d: post-assessment odds
  - P'_d: post-assessment probability
  - N_d: the number of unsatisfactory IAQ samples in N regional IAQ samples

$$P_d = \frac{N_d}{N} \quad O_d = \frac{P_d}{1-P_d} \quad P'_d = \frac{O'_d}{1+O'_d} \quad O'_d = O_d \times L_r$$



If 0.5 of P_d (from global), ↑ to 0.8
Probable to Very probable

IAQ index θ_1

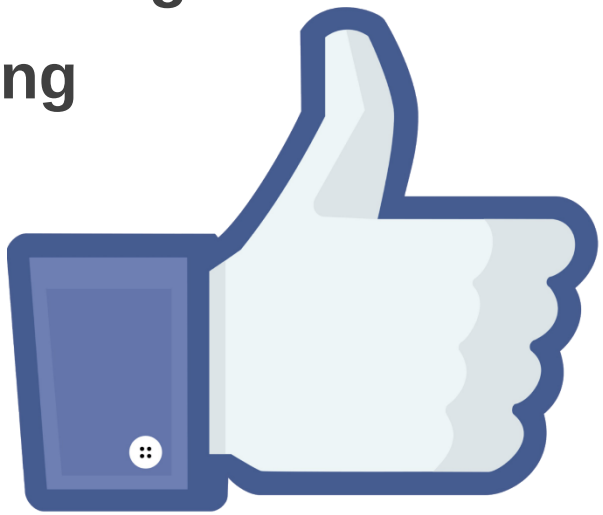
- Low resolution
- Can identify lower risk group

IAQ index θ_2 and IAQ index θ_3

- High resolution
- Can identify lower risk and higher risk group

Advantages of IAQSI

- Reduce cost and the investment of massive resource
- Can be applied to general indoor environments
- Suitable for territory-wide IAQ screening
- Suitable for real-time IAQ monitoring



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Suggestions on IAQ Policy Development in Hong Kong

Short term …

- Improving IAQ objective
  - Should be consistent and expanded to cover all indoor environments.
  - All reference standards should be relevant and up to date.
  - Evaluation of the standards should be conducted to give a set of air pollutant limits that is attainable, while protecting people's health and the environment.
- To preliminarily identify places having potential IAQ problems, a territory-wide IAQ screening programme should be conducted for a variety of indoor environments.
  - Using IAQSI together with step-wise screening protocol.

Suggestions on IAQ Policy Development in Hong Kong

Long term …

- Establish a comprehensive framework that provides new knowledge towards an integrated approach to assessing health risks from indoor air pollution, focusing on both existing and new buildings.
- Raising public awareness.
- Conducting educational seminars and exhibition on the importance of good IAQ.

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Public Dissemination: IAQ benchmarks

- Overall IAQ situation in Hong Kong can be monitored and improved, a territory-wide IAQ database should be maintained.
- An IAQ profile exclusively for Hong Kong can be generated through extensive IAQ assessments in major local buildings.
- Based on the data collected, a 5-star IAQ benchmarking system can be established.

- For regular updating of the profile, the HKSAR Government may consider annual IAQ data collection.

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Thank you very much!