



**APEX**  
ENVIRONMENTAL

## **Brain Fog: Does poor IAQ make us less Productive?**

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**DEL SA OHS Conference, 2019**



## CONFERENCE THEME:

Strategic Cooperation to Promote Decent Work and Achieve Vision Zero in Occupational Injuries and Diseases



## OBJECTIVE OF THE CONFERENCE:

To foster a collaborative approach in the achievement of “Decent employment through inclusive economic growth”.

**Co-operation . Competitiveness . Productivity . Self-regulation**

# Introduction



- The scientific community is not in disagreement when it comes to the risk factors and health effects associated with Indoor Air Quality
- IAQ is a complex subject because of the low concentrations & intra worker variability
- We know that sustained exposure to very low concentrations of chemicals and microbiologicals can have dramatic impacts on sensitive individuals
- We understand that furniture, office equipment and MVAC systems play an integral role in initiating and sustaining **incompatibility** between humans and their environment
- We know how to monitor these risk factors and which standards to compare the results to

# Pollution as a factor



The regulation of air pollution has reduced its toll on heart and lung diseases.

In the US, the Clean Air Act Amendments of 1990 helped avert an estimated 160,000 deaths and 86,000 hospitalizations in 2010 alone.<sup>1</sup>

**However**, a growing body of research suggests that polluted air also puts our brain in harm's way.

Chronic exposure to traffic-related pollutants may increase the risk of neurological disorders.<sup>2</sup>

Both short and long-term exposures have been associated with reduced human capital, including the academic performance of schoolchildren<sup>3</sup> and the productivity of workers across the adult lifespan.<sup>4</sup>

1. U.S. EPA (U.S. Environmental Protection Agency). 2011. The Benefits and Costs of the Clean Air Act from 1990 to 2020. <https://www.epa.gov/sites/production/files/2015-07/documents/summaryreport.pdf>  
2. Kilian J, Kitazawa M. 2018. The emerging risk of exposure to air pollution on cognitive decline and Alzheimer's disease—evidence from epidemiological and animal studies. *Biomed J* 41(3):141–162, PMID: 30080655, <https://doi.org/10.1016/j.bj.2018.06.001>.  
3. Ebenstein A, Lavy V, Roth S. 2016. The long-run economic consequences of high-stakes examinations: evidence from transitory variation in pollution. *Am Econ J Appl Econ* 8(4):36–65, <https://doi.org/10.1257/app.20150213>  
4. Graff Zivin J, Neidell M. 2018. Air pollution's hidden impacts. *Science* 359(6371):39–40, PMID: 29302005, <https://doi.org/10.1126/science.aap7711>. 5. U.S. EPA. Outdoor Air Quality Data: Air Data Basic Information. <https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information>

# Pollution as a factor

“The ubiquity of these less lethal impacts, revealed by emerging economic research on labour productivity and human capital accumulation, ... can add up to considerable, society-wide impacts across the globe.”

Matthew Neidell (Columbia University and Joshua Graff Zivin of the University of California, San Diego, 2018)



A house in front of the coal-fired Duvha Power Station on the outskirts of Witbank. (Mujahid Safodien, AFP)

<https://mg.co.za/article/2017-05-02-air-pollution-drives-mental-trauma>

# How does SA Rank in the world?

## AIR POLLUTION IN SOUTH AFRICA



### THE DETAILS

According to the **World Health Organisation (WHO)** South African's city pollution to well above **internationally accepted levels**.

SA IS RANKED  
**30<sup>th</sup>**  
IN THE WORLD  
for bad air quality

Overall SA has an  
exposure rate of  
**56mg**  
per cubic metre  
( $\mu\text{g}/\text{m}^3$ ) of **pollutant**  
particles in its air

**Johannesburg**  
is the worst polluted city  
in the country and  
**99<sup>th</sup>**  
IN THE WORLD

Areas with the worst air pollution in SA are: **Highveld ; Vaal Triangle, Waterberg**

The World Health Organisation (WHO) air pollution database collected data on the outdoor (or ambient) air quality of **1600 cities** from **91 countries**

# Notable Components of Outdoor (Indoor) Air Pollution



“Criteria Pollutants” in ambient air:

- Particulate matter (PM),
- Ground-level ozone,
- Sulphur dioxide,
- Nitrogen dioxide,
- Carbon monoxide
- Lead
- Benzene

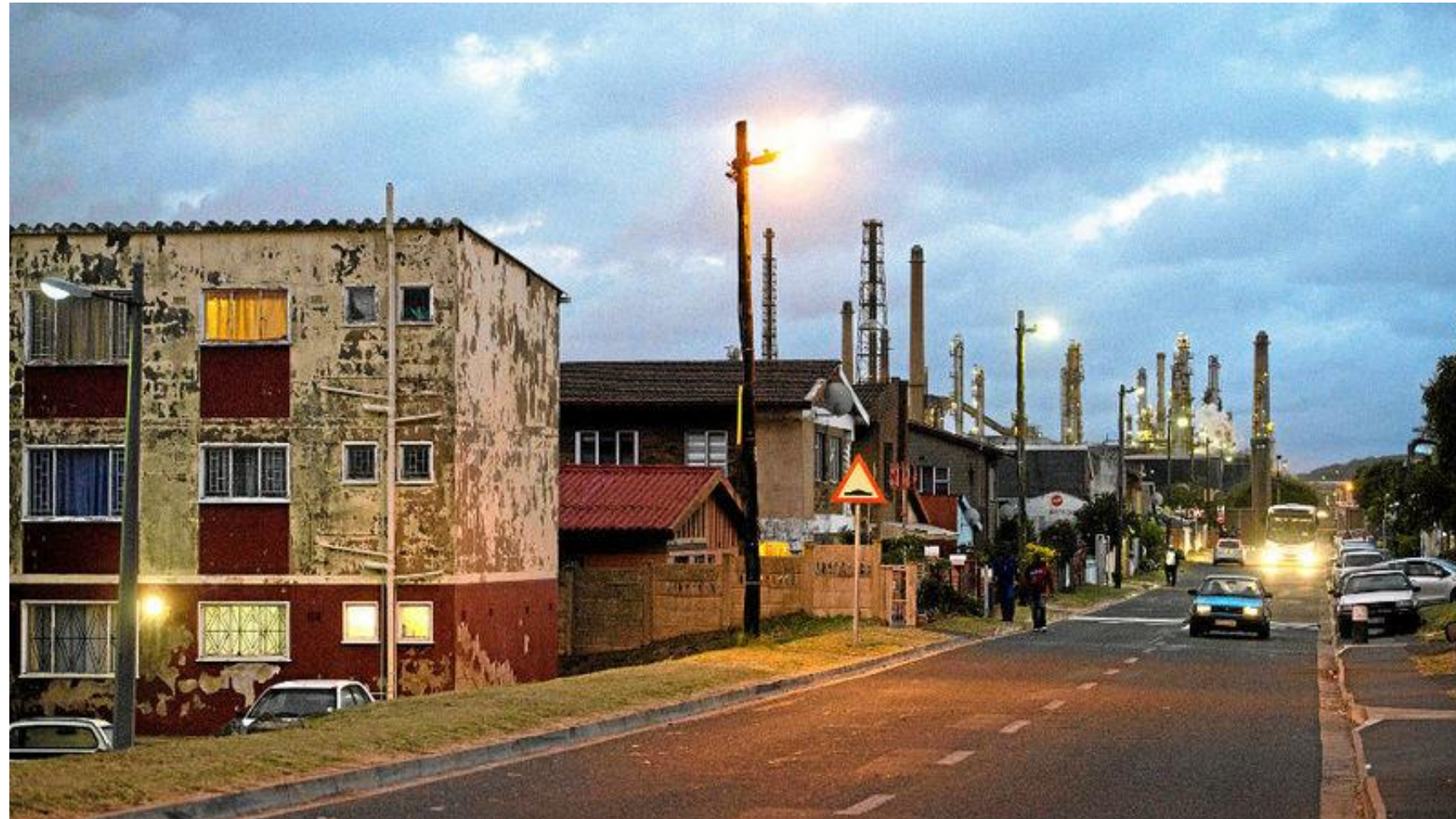
Additional pollutants from outdoor sources include methane, volatile organic compounds (VOCs), pollen, metals, and other sulphur and nitrogen oxides.

Although generated outdoors, these chemicals can travel indoors, where people spend around 90% of their day<sup>5</sup>

# Double Jeopardy - Outdoor Air **is** Indoor Air

The extent of penetration depends on building construction, ventilation rates, local meteorology, and the pollutant itself.

Another factor is whether outdoor temperatures call for open windows.....



There are about 300 smokestacks in the South Durban area. (Delwyn Verasamy, M&G)

# Indoor Air **is** Outdoor Air



Ok.... Now consider this .....

VOCs from indoor uses of chemical products make up a larger proportion of outdoor organic air pollution than they used to in urban areas.<sup>6</sup>



# Indoor Air Risk Factors



According to the 2018 State of Global Air report,<sup>7</sup> the combination of

- outdoor PM2.5
- household / office air pollution
- ozone

Make poor IAQ the fourth-leading human health risk factor globally, and;  
These three pollutants account for an estimated 11.2% of deaths in the world.

# Indoor Air **and** Brain Function



**The idea of cognitive impairment and Carbon Dioxide was catapulted into the research gate in 2012**

The study<sup>8</sup> done by researchers from the Department of Energy's Lawrence Berkeley National Laboratory

Moderately high indoor concentrations of carbon dioxide (CO<sub>2</sub>) can significantly impair people's decision-making performance

On nine scales of decision-making performance, test subjects showed significant reductions on six of the scales at CO<sub>2</sub> levels of 1,000 parts per million (ppm)

Large reductions on seven of the scales at 2,500 ppm.

The most dramatic declines in performance, in which subjects were rated as "dysfunctional," were for taking initiative and thinking strategically.

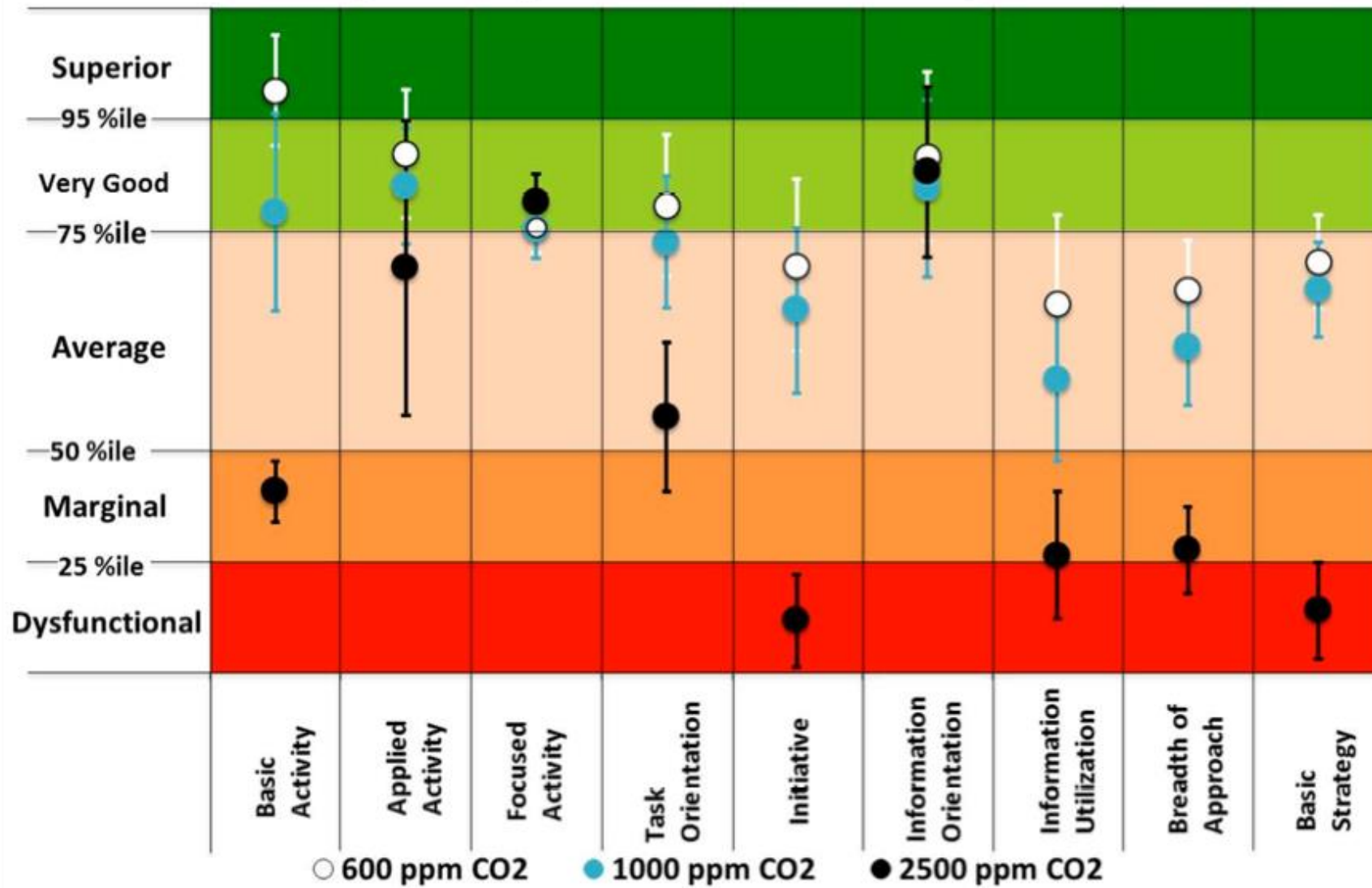
**There have been several more recent studies that correlate poor indoor / outdoor air quality to short-term impacts on productivity.**

8. Usha Satish, Mark J. Mendell, Krishnamurthy Shekhar, Toshifumi Hotchi, Douglas Sullivan, Siegfried Streufert, and William J. Fisk. 2012. Is CO<sub>2</sub> an Indoor Pollutant? Direct Effects of Low-to-Moderate CO<sub>2</sub> Concentrations on Human Decision-Making Performance. [Environmental Health Perspectives Vol. 120, No. 12](#)

# Indoor Air and Brain Function



Impact of CO<sub>2</sub> On Human Decision Making Performance



## Strategic Management Simulation (SMS) Test Results

15 percent decline of cognitive ability scores at 950 ppm

50 percent decline at 1,400 ppm

# Indoor Air **and** Brain Function



Since then, there have been several significant studies that correlate poor indoor / outdoor air quality to short-term impacts on productivity.

- White-collar office workers in the service sector (call centre employees in China)<sup>9</sup>
- Stock Brokers in the New York Stock Exchange - an increase in particle pollution of one standard deviation was associated with an 11.9% reduction in same-day returns<sup>10</sup>
- A similar association was reported for more than 100,000 investors at a German brokerage firm<sup>11</sup>

9. Chang TY, Zivin JG, Gross T, Neidell M, et al. 2019. The effect of pollution on worker productivity: evidence from call center workers in China. *Am Econ J Appl Econ* 11(1):151–172, <https://doi.org/10.1257/app.20160436>

10. Heyes A, Neidell M, Saberian S. 2016. The effect of air pollution on investor behavior: evidence from the S&P 500. NBER working paper no. 22753. Cambridge, MA: National Bureau of Economic Research. <https://www.nber.org/papers/w22753>

11. Meyer S, Pagel M. Fresh air eases work: the effect of air quality on individual investor activity. New York, NY:Columbia University, Columbia University in the City of New York, Columbia Business School Research Archive. <https://www8.gsb.columbia.edu/researcharchive/articles/25560>.

# Indoor Air and Brain Function



- Double blind study of office workers – VOCs and CO2, 2016<sup>12</sup>
- Airline pilots in flight simulator exposed to higher CO2 levels, 2018<sup>13</sup>
- 65 Elementary schools in Texas – Mould remediation and ventilation improvement<sup>14</sup>

12. Allen JG, MacNaughton P, Satish U, Santanam S, Vallarino J, Spengler JD. 2016. Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: a controlled exposure study of green and conventional office environments. *Environ Health Perspect* 124(6):805–812, PMID: 26502459, <https://doi.org/10.1289/ehp.1510037>

13. Allen JG, MacNaughton P, Cedenno-Laurent JG, Cao X, Flanigan, S, Vallarino J, et al. 2018. Airplane pilot flight performance on 21 maneuvers in a flight simulator under varying carbon dioxide conditions. *J Expo Sci Environ Epidemiol*, PMID: 30089876, <https://doi.org/10.1038/s41370-018-0055-8>.

14. Tafford TM. 2015. Indoor air quality and academic performance. *J Environ Econ Manage* 70:34–50, <https://doi.org/10.1016/j.jeem.2014.11.002>.

# Indoor Air **and** Brain Function



In a separate study, Allen's team estimated the cost of increasing building ventilation standards from the current 9.4 ls/p to 40 ls/p across a range of U.S. climate zones.

The researchers projected that the additional annual energy costs would be at most \$40 per person, but that companies would gain \$6,500 per employee from greater productivity.<sup>12</sup>

# Indoor Air **and** Brain Function



“For too long, the focus has been on energy efficiency, and health has been left out of the equation”

“Clearly, the [estimated] benefits of improved health and human productivity vastly overwhelm the costs”<sup>12</sup>

# Intervention Strategy

Promote / Develop / adopt a guidance note for use in South Africa

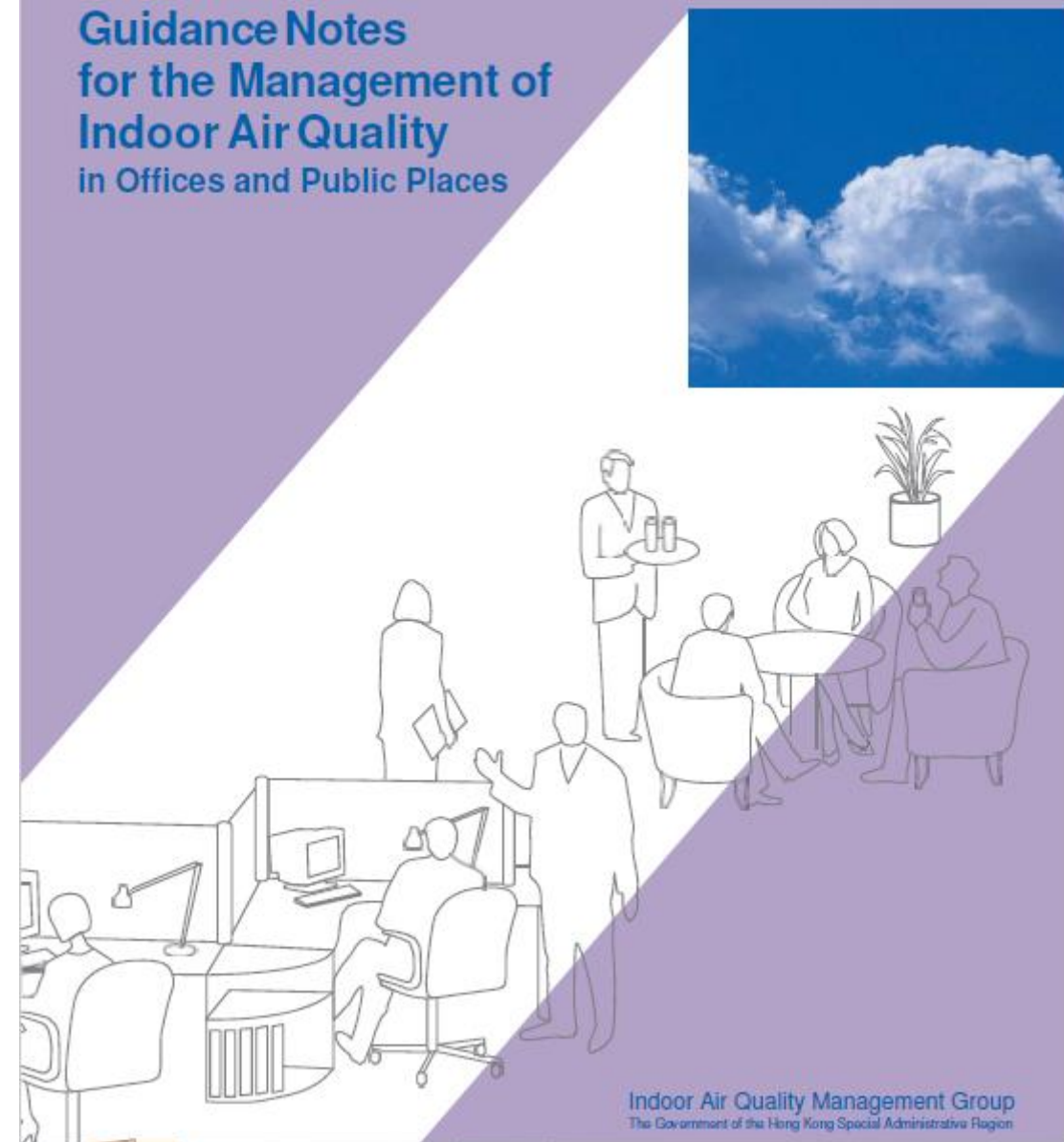
Requires Inter-disciplinary co-operation

Real-time measurements and integrated sampling

Carbon Dioxide as an indicator gas should be the first of the criteria to monitor – indicates ventilation rates

**HK std - <800 = Excellent < 1000 = Good**

But roll out the measurement of all criteria as necessary or where budget allows



# Hong Kong IAQ Objectives for Office Buildings and Public Places (Effective on 1 July 2019)



Parameter			Excellent Class	Good Class
Pollutant	Averaging Time	Unit		
Carbon Dioxide (CO <sub>2</sub> )	8-hour	mg/m <sup>3</sup>	1,440	1,800
		ppmv	800 <sup>a</sup>	1,000 <sup>a</sup>
Carbon Monoxide (CO)	8-hour	µg/m <sup>3</sup>	2,000 <sup>b</sup>	7,000 <sup>c</sup>
		ppmv	1.7	6.1
Respirable Suspended Particulates (PM <sub>10</sub> )	8-hour	µg/m <sup>3</sup>	20 <sup>d</sup>	100 <sup>d</sup>
Nitrogen Dioxide (NO <sub>2</sub> )	8-hour	µg/m <sup>3</sup>	40 <sup>c</sup>	150 <sup>e</sup>
		ppbv	21	80
	1-hour	µg/m <sup>3</sup>	100 <sup>c</sup>	200 <sup>c</sup>
		ppbv	53	106
Ozone (O <sub>3</sub> )	8-hour	µg/m <sup>3</sup>	50 <sup>b</sup>	120 <sup>f</sup>
		ppbv	25	61
Formaldehyde (HCHO)	8-hour	µg/m <sup>3</sup>	30 <sup>b</sup>	100 <sup>b</sup>
		ppbv	24	81
	30-minute	µg/m <sup>3</sup>	70 <sup>c</sup>	100 <sup>c</sup>
		ppbv	57	81
Total Volatile Organic Compounds (TVOC)	8-hour	µg/m <sup>3</sup>	200 <sup>b</sup>	600 <sup>b</sup>
		ppbv	87	261
Radon (Rn)	8-hour	Bq/m <sup>3</sup>	150 <sup>g</sup>	167 <sup>c</sup>
Airborne Bacteria	8-hour	cfu/m <sup>3</sup>	500 <sup>hi</sup>	1,000 <sup>hi</sup>
Mould	---	---	Assessment in form of prescriptive checklist (refer to <i>A Guide on Indoor Air Quality</i> )	

Compound	8-hours Average
Benzene	5.3 ppbv <sup>a</sup> (17 µg/m <sup>3</sup> )
Tetrachloroethylene	37 ppbv <sup>a</sup> (250 µg/m <sup>3</sup> )
Trichloroethylene	43 ppbv <sup>a</sup> (230 µg/m <sup>3</sup> )
Naphthalene	1.9 ppbv <sup>a</sup> (10 µg/m <sup>3</sup> )
Polycyclic Aromatic Hydrocarbons (as benzo(a)pyrene)	1.2 x 10 <sup>-4</sup> ppbv <sup>a</sup> (1.2 ng/m <sup>3</sup> )

*A Guide on Indoor Air Quality Certification Scheme for Offices and Public Places (2019)*



ENVIRONMENTAL



PPE



OCCUPATIONAL



TRAINING



STACK EMISSIONS



EQUIPMENT



ASBESTOS



# APEX

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