

Urban and Indoor Air Quality

1. Urban Air Quality

Pollutants & Indices



2. Indoor Air Quality

Radon, VOCs, SVOCs, combustion, PM

3. Air Exchange Rates



China's pollution puts a dent in its economy



NO2

O3

PM

SO2

CO

Beijing airport at noon
800 flights cancelled



<http://www.theatlantic.com/infocus/2013/01/china-s-toxic-sky/100449/>

"You literally can see the smog inside a large enough building. The airport terminal, the hotel lobby are large enough that you can no longer see clearly across the room." John Williamson

Delhi world's most polluted city

TOXIC India slips to 155 among 178 countries on environment performance index, Capital pips Beijing to be city with dirtiest air

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NEW DELHI: It's no surprise that pollution is a perpetual problem in India. But it's definitely disheartening to hear that India has slipped 32 ranks in the global Environment Performance Index (EPI) 2014 to rank a lowly 155 and its capital Delhi has earned the dubious tag of being the world's most polluted city.

A comparative study of 178 countries on nine environmental parameters released earlier this month by the US-based Yale University shows that one of the world's fastest growing economies is a disaster on the environmental front.

What's worse, India's pollution levels could be playing havoc with the health of its citizens. "A bottom performer on nearly every policy issue included in the 2014 EPI, with the exception of forests, fisheries

and water resources, India's performance lags most notably in the protection of human health from environmental harm," said a statement issued by Yale.

The study described India's air pollution as the worst in the world, tying with China in terms of the proportion of population exposed to average air pollution levels exceeding World Health Organisation (WHO) thresholds.

A deeper look at the data gathered by a Nasa satellite showed that Delhi had the highest particulate matter (PM) 2.5 pollution levels followed by Beijing. Delhi, with 810 million registered vehicles, has repeatedly beaten the Chinese capital on particulate matter pollution.

The high PM2.5 pollution caused by high vehicle density and industrial emissions is the reason for the dense smog that has been engulfing Delhi during the winter months in the last few years, with adverse

health implications. And while Beijing's infamous smog has hogged headlines and prompted government action, even led to the announcement of rewards for cutting back on pollution, the dangers in Delhi have been largely ignored.

According to a study by the Harvard International Review, every two in five persons in Delhi suffer from respiratory ailments. The Lancet's Global Health Burden 2013 report termed air pollution the sixth biggest human killer in India. The WHO last year termed air pollution carcinogenic.

Particles smaller than 2.5 microns in diameter (PM2.5 in shorthand) are fine enough to lodge deep in human lung and blood tissue and cause diseases ranging from stroke to lung cancer, the Yale study said.

CONTINUED ON PAGE 8
→ **BREATHING POISON**
IN DELHI, PG

CAPITAL BREATHES UNEASY

Tops global cities with worst air pollution



- 1 NEW DELHI, INDIA
- 2 BEIJING, CHINA
- 3 CAIRO, EGYPT
- 4 SANTIAGO, CHILE
- 5 MEXICO CITY, MEXICO

INDIA SLIPS IN RANK TOO

Is second-most polluted among its neighbours

	2014	2010
Bangladesh	169	139
India	155	123
Pakistan	148	125
Nepal	139	38
China	118	121
Sri Lanka	69	58

■ **Ranking based on 9 parameters:** Health impact, air pollution, water & sanitation, water resources, agriculture, fisheries, forests, biodiversity & habitat, climate change & energy

■ On list of 178 countries, India ranks as low as 174 on air pollution, 127 on health impact

5 CLEANEST COUNTRIES:

Switzerland, Luxembourg, Australia, Singapore and Czech Republic



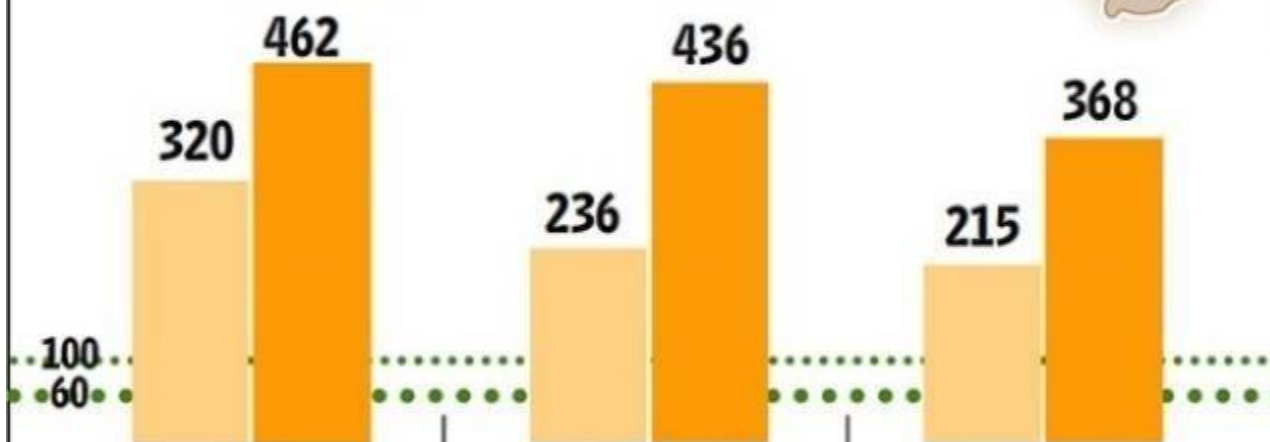
DELHI'S THREE MOST POLLUTED AREAS

Highest level in micrograms per cubic metres

PM2.5 (Particulate matter 2.5 micron size)

PM10 (Particulate matter 10 micron size)

Standard level ●●● PM2.5 ●●●● PM10



1 Anand Vihar

REASON: Anand Vihar ISBT is the hub for inter-state roadway buses which run on petrol and diesel.

2 RK Puram

REASON: Area is connected to both ring road from sectors 12 and 2. After 10pm it opens for heavy vehicles.

3 Punjabi Bagh

REASON: Location near Haryana border also a disadvantage. Residents say most homes have more than one vehicle.

US EPA Air Quality Index

O₃

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

PM

CO SO₂

NO₂

I = Air Quality Index

C = pollutant concentration

*C*_{low} = conc breakpoint < *C*

*C*_{high} = conc breakpoint > *C*

*I*_{low} = index breakpoint for *C*_{low}

*I*_{high} = index breakpoint for *C*_{high}

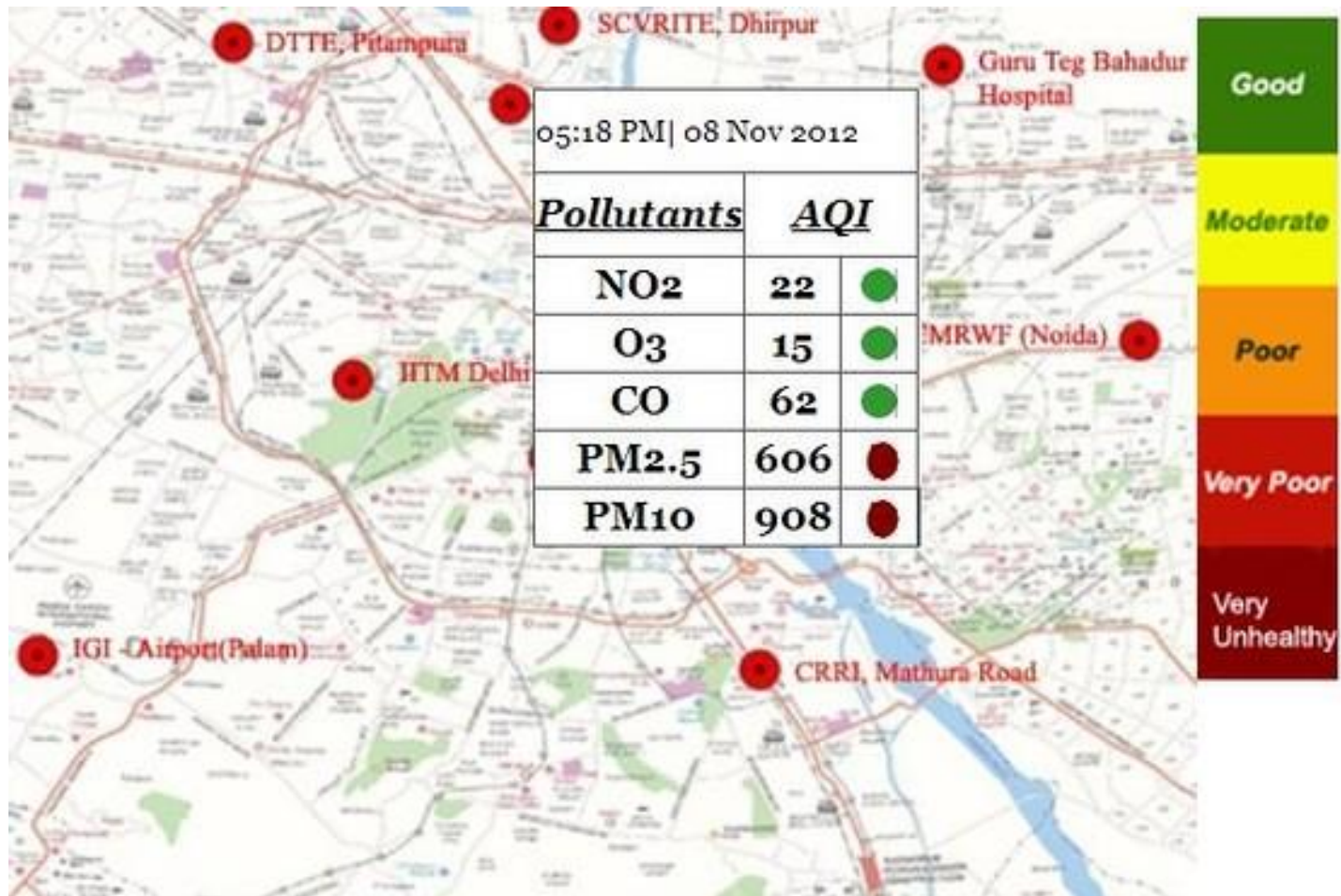
EPA's
breakpoint
table for PM2.5

Category	PM2.5 (ug/m ³)	Index Value
Good	0 – 12.0	0 - 50
Moderate	12.1-35.4	51-100
Unhealthy*	35.5-55.4	101-150
Unhealthy	55.5-150.4	151-200
Very unhealthy	150.5-250.4	201-300
Hazardous	250.5-350.4	301-400
Hazardous	350.5-500.4	401-500

Real-time AQI – China Air



AQI New Delhi



What is the AQI for NO₂, O₃ and PM_{2.5} in Nanaimo right now?

<http://www.env.gov.bc.ca/epd/bcairquality/readings/map/station.html#E229797>

Table 7.3 Air Quality Index (AQI) values and colours compared to breakpoint concentration ranges for individual pollutant species^a.

Categories	Breakpoint AQI values (colour)	Breakpoint concentration values (ppmv)			
		O ₃ (8 h)	CO (8 h)	SO ₂ (24 h)	PM _{2.5} (µg m ⁻³)
Good	0–50 (green)	0.000–0.064	0.0–4.4	0.000–0.034	0.0–15.4
Moderate	51–100 (yellow)	0.065–0.084	4.5–9.4	0.035–0.144	15.5–40.4
Unhealthy for sensitive groups	101–150 (orange)	0.085–0.104	9.5–12.4	0.145–0.224	40.5–65.4
Unhealthy	151–200 (red)	0.105–0.124	12.5–15.4	0.225–0.304	65.5–150.4
Very unhealthy	201–300 (purple)	0.125–0.374	15.5–30.4	0.305–0.604	150.5–250.4
Hazardous	301–500 (maroon)	>0.375	>30.5	>0.605	>250.5

Multi-Pollution Index (MPI)

$$\text{MPI} = (1/n) [\sum \{ (AC_i - GC_i) / GC_i \}]$$

where

AC_i is actual concentration for pollutant i

and

GC_i is guideline value for pollutant i

and

n is number of pollutants used in the index

AQHI - Canada

(3 hr average concentrations)

O₃ (ppm_v)

NO₂ (ppm_v)

PM2.5 (ug/m³)

CO and SO₂ dropped

$$AQHI = (1000/10.4) * [(e^{0.000537 * O_3} - 1) + (e^{0.000871 * NO_2} - 1) + (e^{0.000487 * PM_{2.5}} - 1)]$$

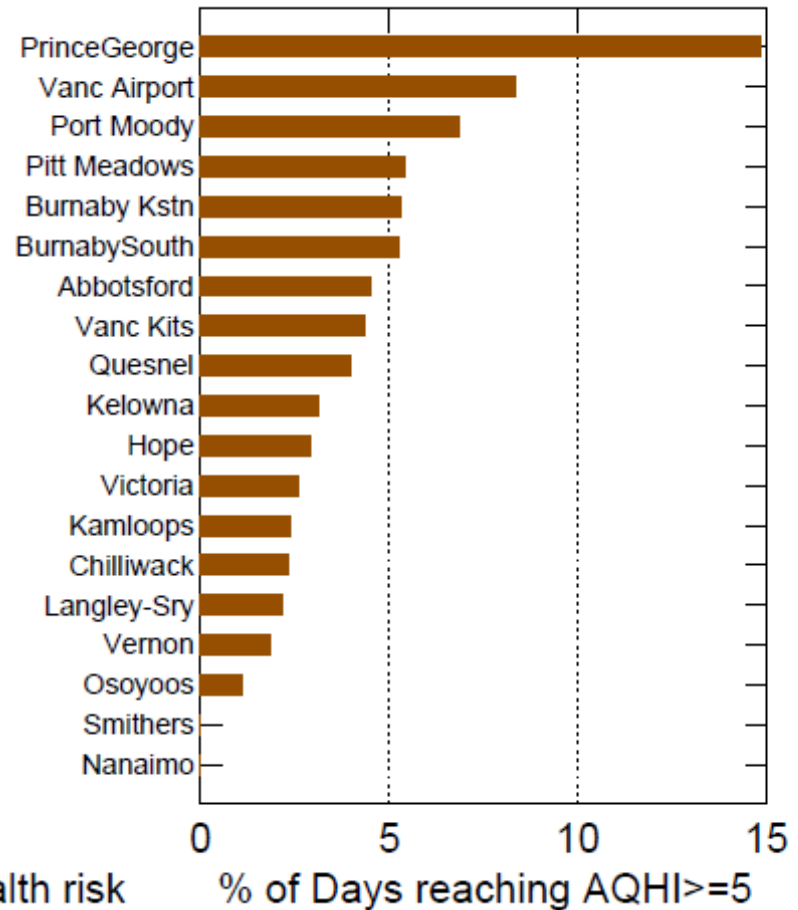
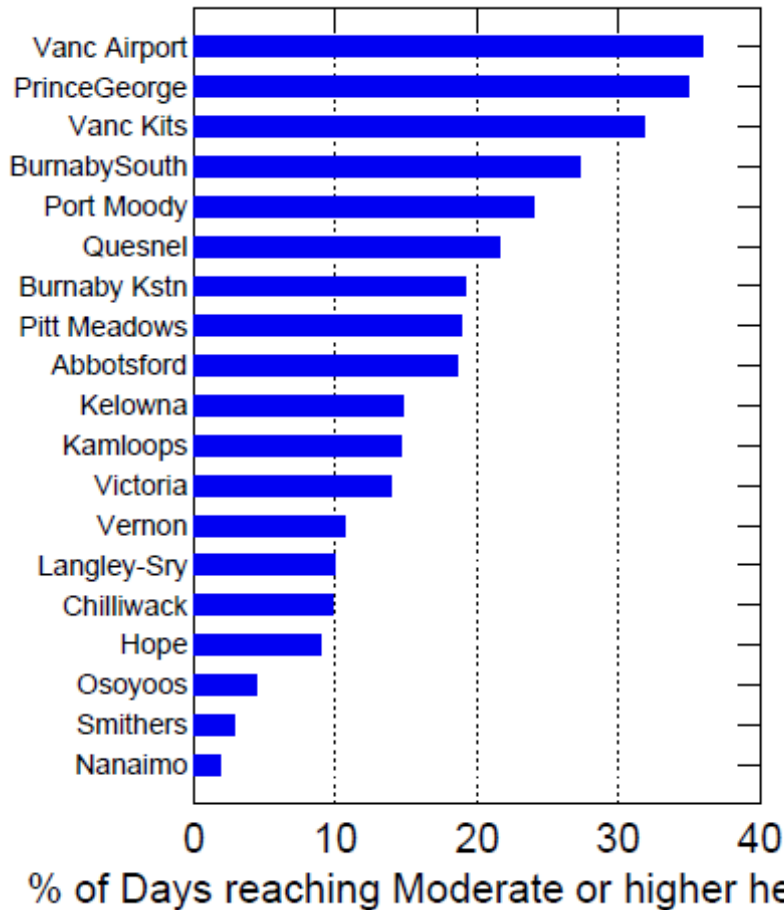


AQHI

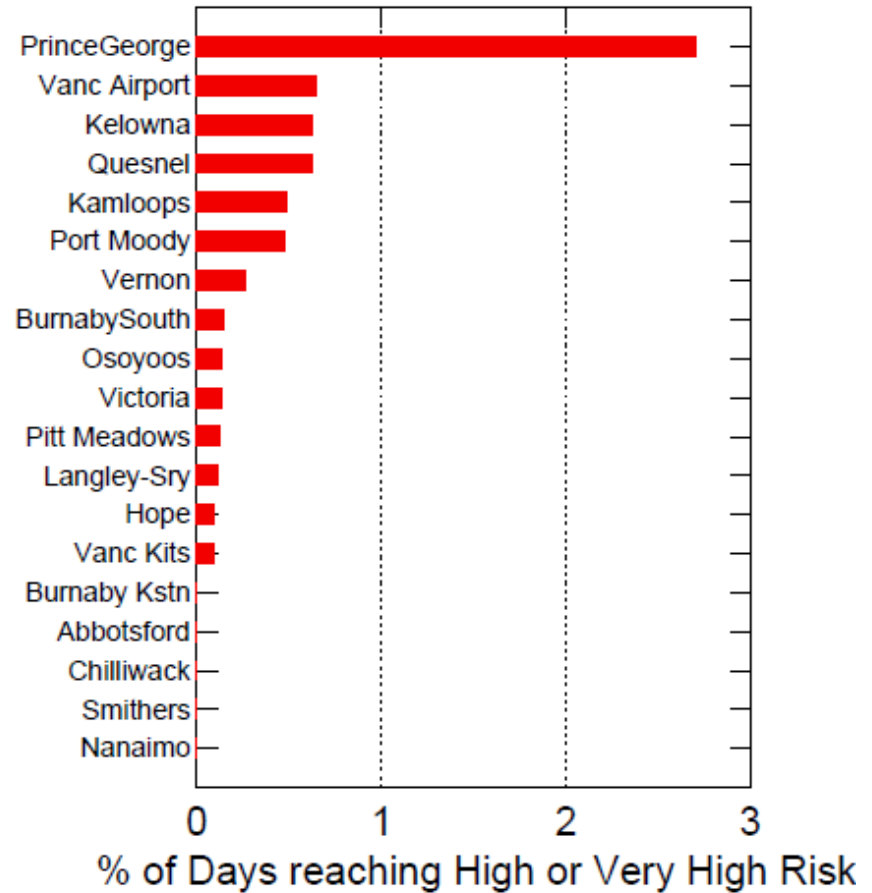
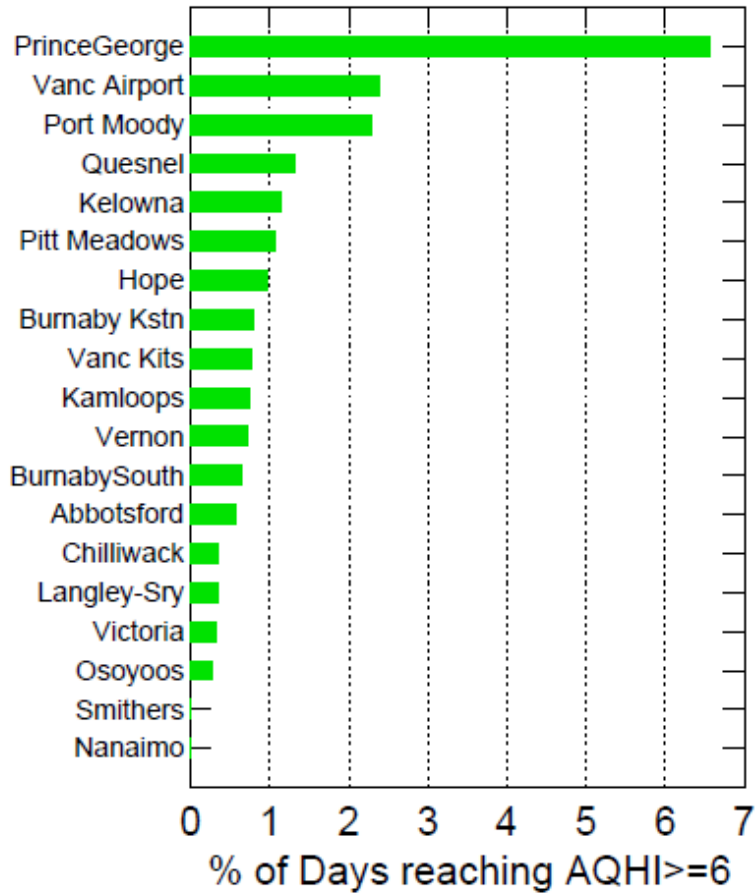
What is the AQHI for NO₂, O₃ and PM_{2.5} in Nanaimo right now?

<http://www.env.gov.bc.ca/epd/bcairquality/readings/map/station.html#E229797>

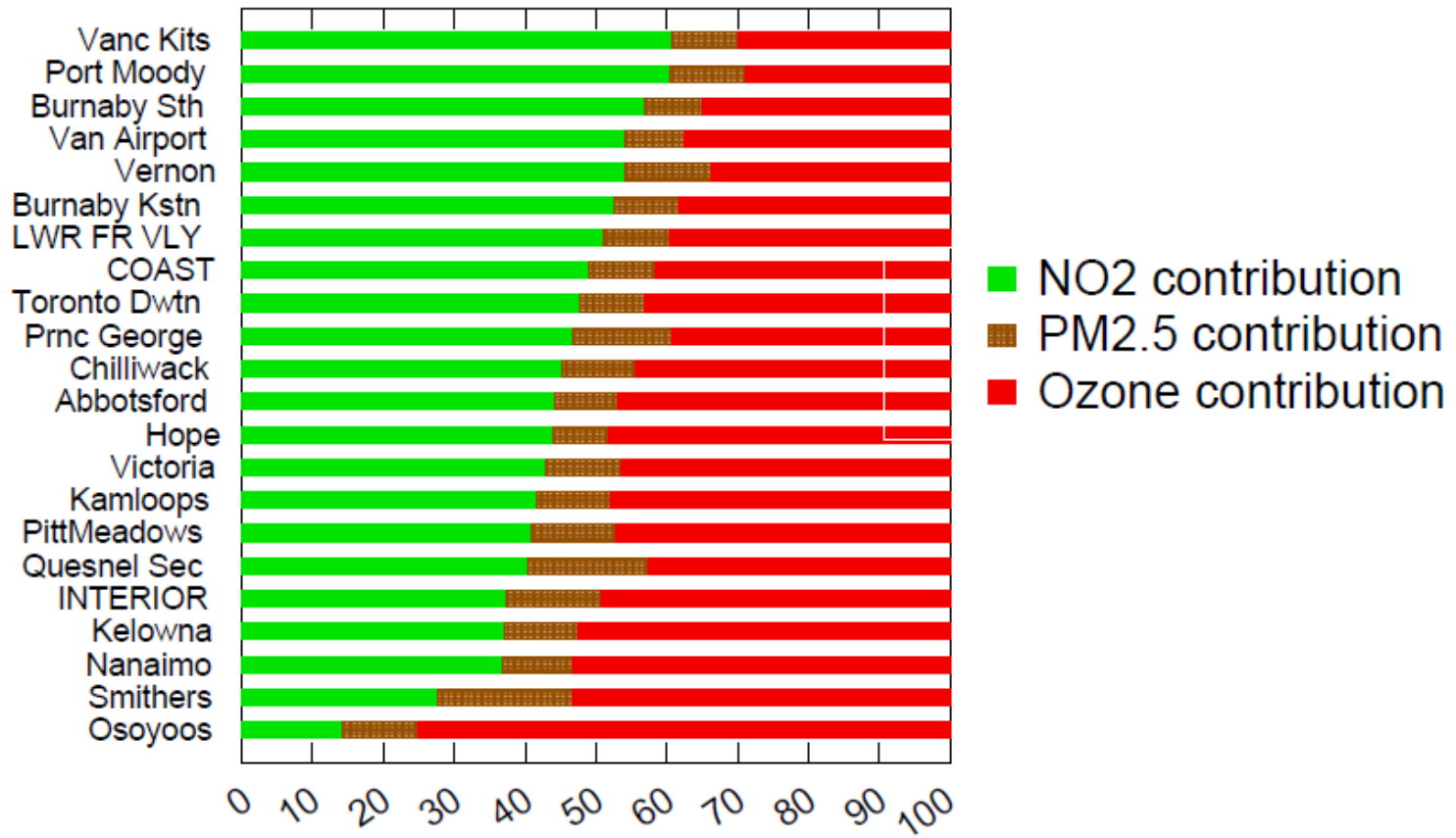
Percent of days AQHI exceedances 2000 - 2006



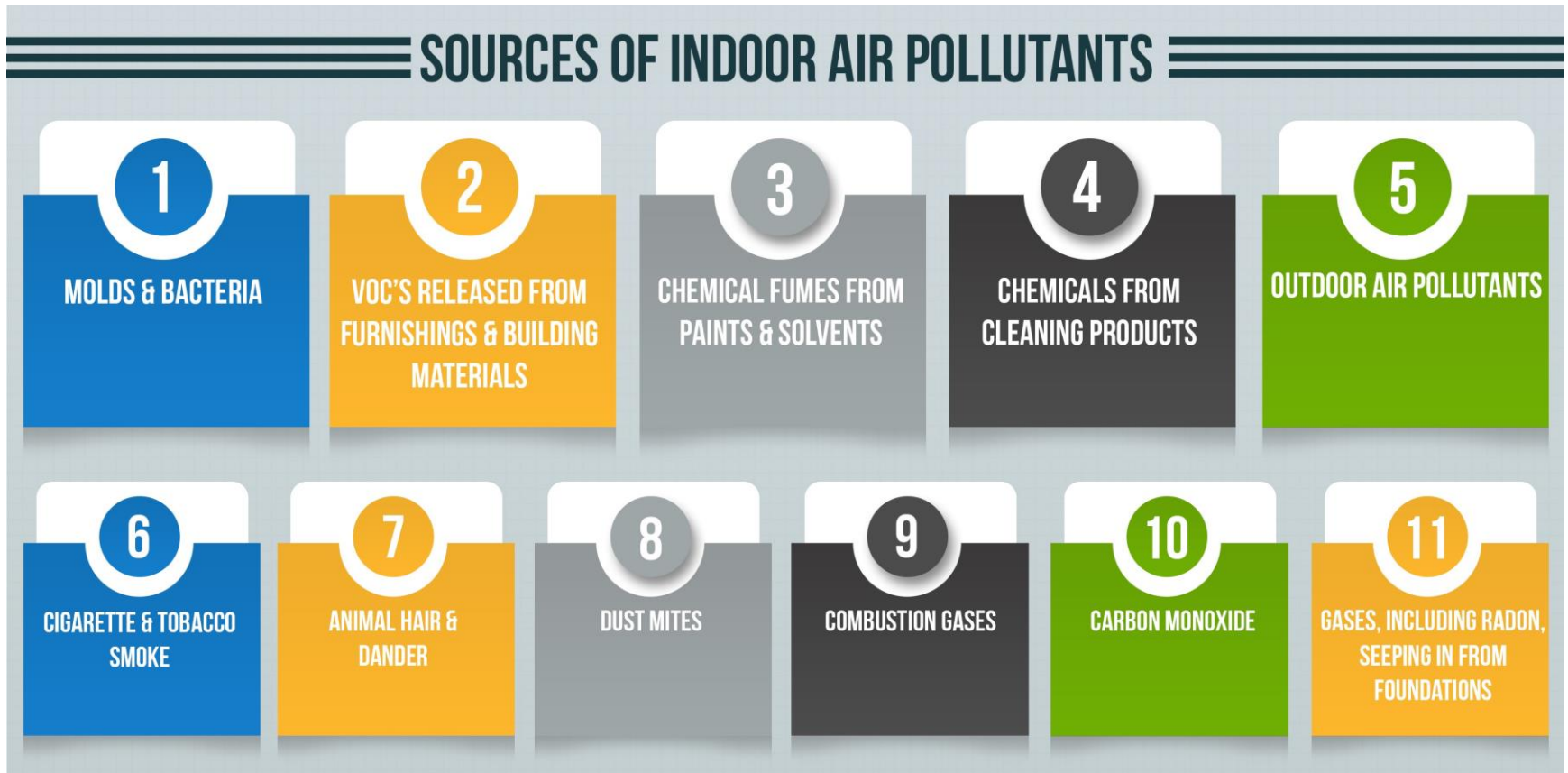
Percent of days AQHI exceedances 2000 - 2006



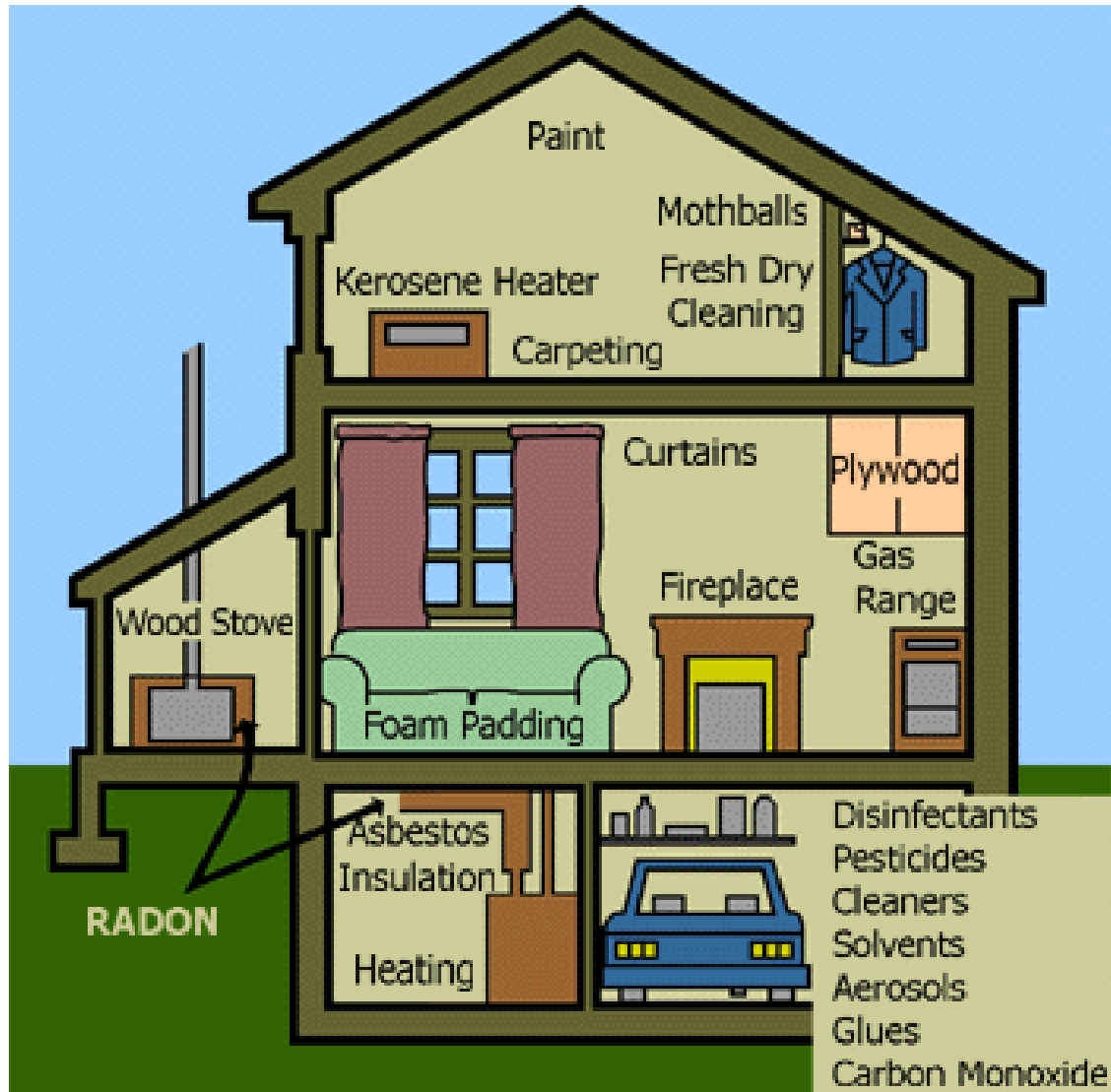
Pollutant Contributions to Health Risk

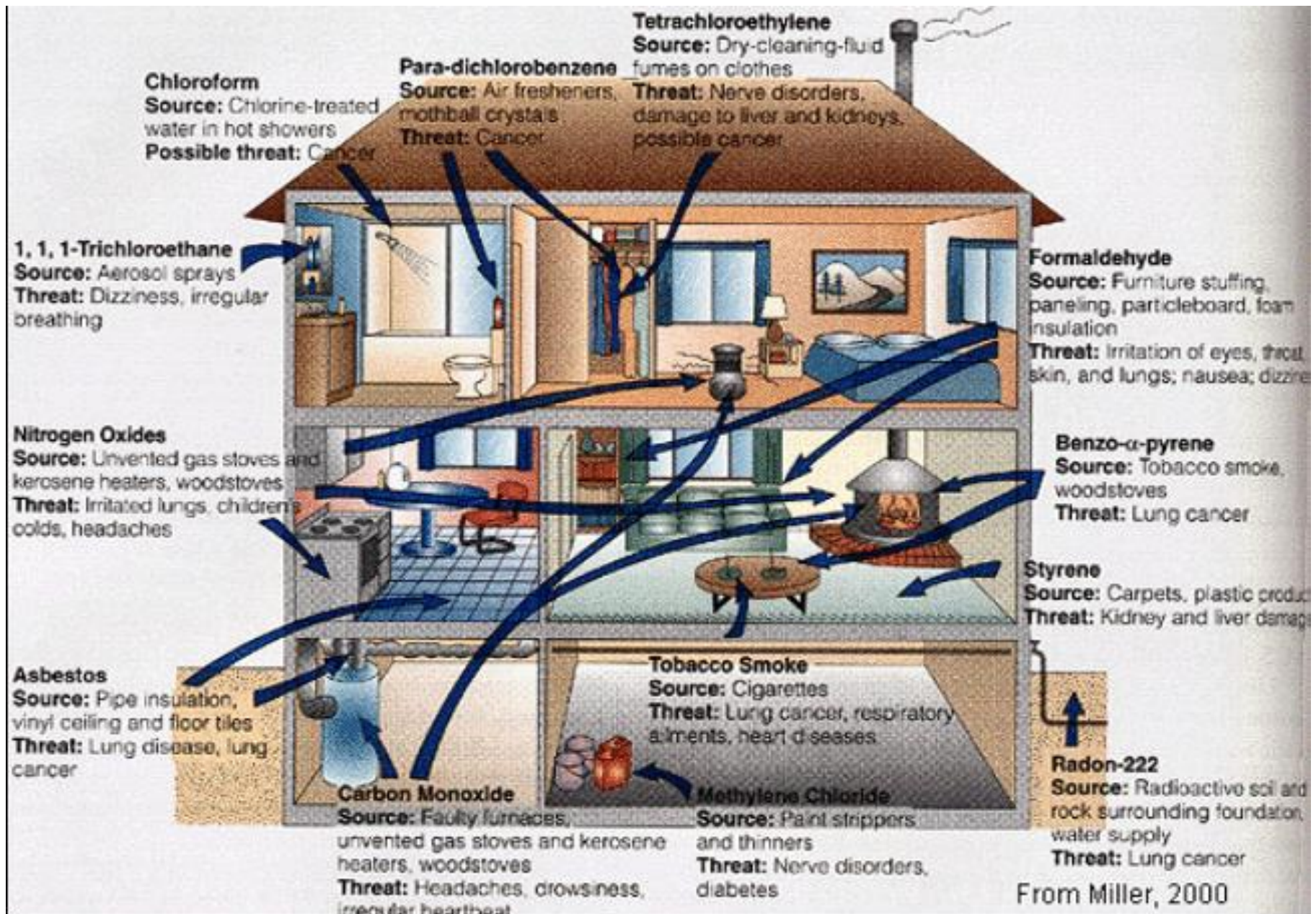


2. Indoor Air



Sources





From Miller, 2000

Indoor air quality

- Composition and exchange of outdoor air
- Indoor materials (construction, consumer goods)
- Indoor activities (cooking, heating, smoking)

→ CO, CO₂, NO_x, VOCs, PM, Rn

Specific S/VOCs of concern: H₂CO, BTEX, halocarbons, PAHs, PBDEs, PCBs, phthalates

3. Air Changes per Hour (ach)

Older homes and buildings ach $\sim 1 \text{ hr}^{-1}$

Newer homes and buildings ach $\sim 0.1\text{-}0.5 \text{ hr}^{-1}$
(i.e., one air exchange every 10 – 2 hrs)

‘ach’ is a first order rate constant (time^{-1}) $\rightarrow k_e$

Residence time of indoor air ($\tau_e = 1/k_e$)

On box models

- If there are processes, then $\tau_e = [X]_i / \text{rate of indoor prod}^n$
- At steady state, rate in = rate out
 $k_e[X]_o = k_e[X]_i$ and therefore $[X]_i = [X]_o$
if there is no indoor source or indoor chemical or physical loss of X

If there is an indoor source, then rate of X increasing indoors = $k_e[X]_o + R_i$,

where R_i is the rate of release of X from indoor source/s.

One box models (cont)

If there is an indoor chemical and/or physical loss process, then at steady state we have

$$R_i + k_e[X]_o = k_e[X]_i + k_d[X]_i$$

and

$$[X]_i = (R_i + k_e[X]_o)/(k_e + k_d)$$

where k_d is rate constant for any indoor decay process.

Indoor Particulate Concentration

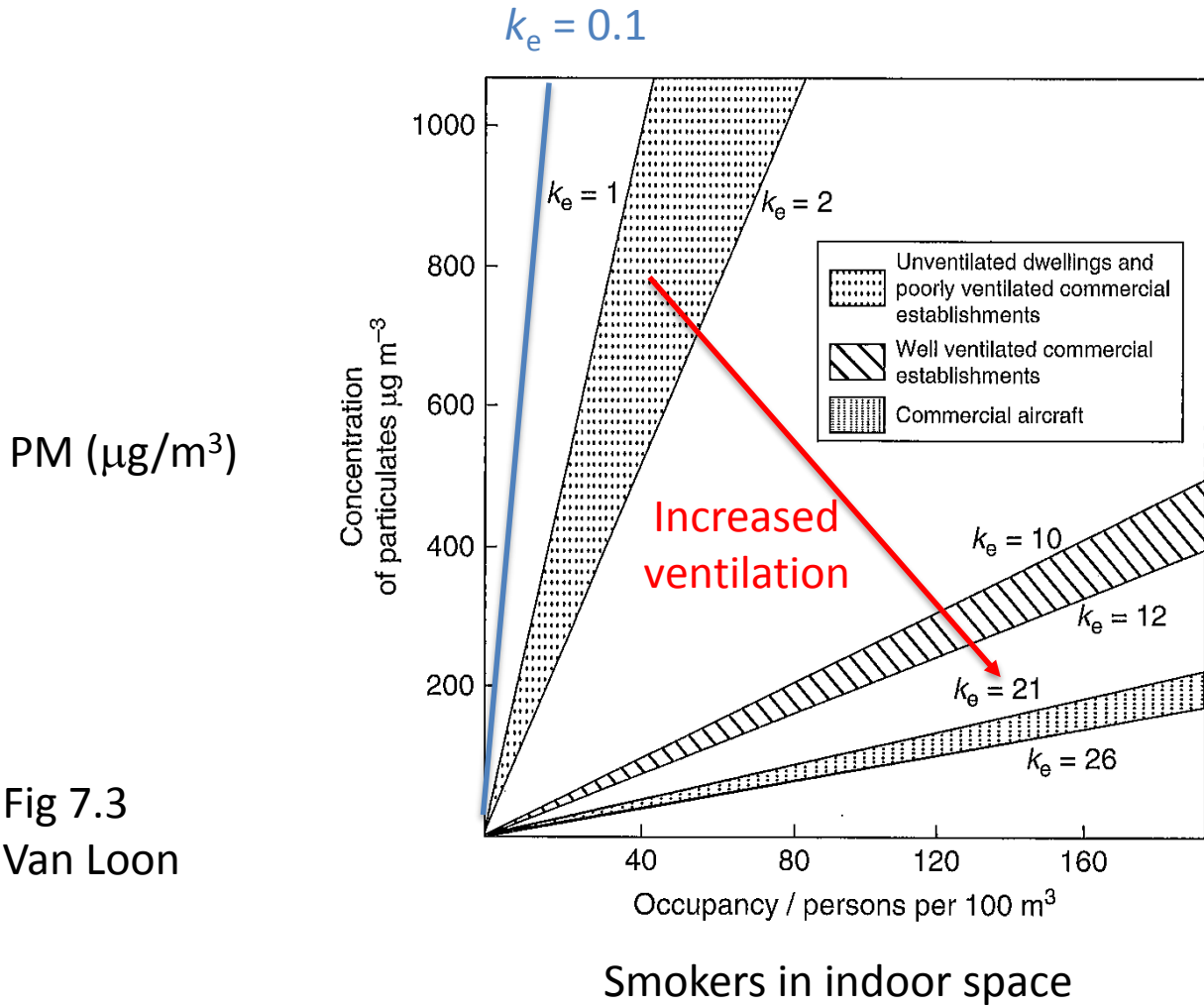


Fig 7.3
Van Loon