

HVAC challenges ahead, a consultant's perspective:

Managing Indoor Air Quality of Buildings Located in Polluted Areas

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When Indoor Air Quality is Poor...

...open a window or increase ventilation!

...reduce pollution sources!

But what if all these leads to poorer IAQ?

WHO: Ambient air pollution in cities database 2016

PM_{2.5} Annual average 2012...2014 (µg/m³)

WHO AQG level: < 10 µg/m³

- **Top 5 most polluted cities in India:**

– Gwalior	176
– Allahabad	170
– Patna	149
– Raipur	144
– Delhi	122

12-18 times higher

Above 10: 121/122

99%

- **Top 5 most polluted cities in USA:**

– Visalia-Porterville, CA	18
– Hanford-Corcoran, CA	16
– Portola, Plumas, CA	16
– Fresno, CA	15
– Elkhart-Goshen, IN	15

2 times higher

Above 10: 38/372

10%

- **Top 5 most polluted cities in Europe:**

– Tetovo, Macedonia	81
– Batman, Turkey	67
– Hakkari, Turkey	67
– Gaziantep, Turkey	66
– Tuzla, Bosnia and Herzegovina	65

6-8 times higher

Above 10: 1340/1713

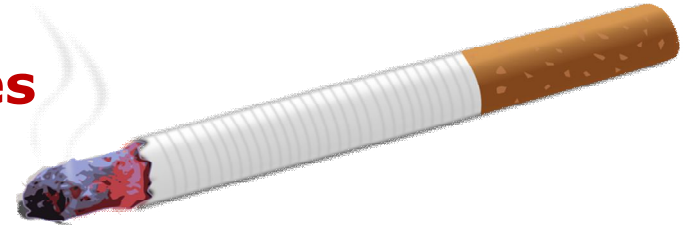
78%

Air Pollution and Cigarette Equivalence

PM2.5 level of 22 $\mu\text{g}/\text{m}^3$ is equivalent of one cigarette per day (Berkeley Earth)

	$\mu\text{g}/\text{m}^3$	cigarette/day
– Gwalior	176	8.0
– Allahabad	170	7.7
– Patna	149	6.8
– Raipur	144	6.5
– Delhi	122	5.5
– Tetovo, Macedonia	81	3.7
– Batman, Turkey	67	3.0
– Hakkari, Turkey	67	3.0
– Gaziantep, Turkey	66	3.0
– Tuzla, Bosnia and Herzegovina	65	3.0

300 $\mu\text{g}/\text{m}^3$ = 1/2 pack of cigarettes



Main Ambient Air Pollution in India

- **Particulate matter (dust, fine and ultra-fine):**
 - Traffic (especially diesel cars);
 - Energy production (especially coal power plants);
 - Chullahs and other open fire cooking;
 - Construction work;
 - Stubble burning;
 - Burning of waste;
 - Industrial process emissions.
- **Gases (NO₂, O₃, etc.)**
 - Traffic;
 - Industrial processes;
 - Open sewage systems.



Indoor Air Pollution

- **Outdoor air is the biggest indoor air pollution source - if air is not properly filtered and purified before taken indoors;**
- **Other indoor air pollution sources are:**
 - Tobacco smoking;
 - Copy machines and printers;
 - Cleaning products;
 - Moisture damages and mould growth;
 - Paints, solvents and other construction
 - New furniture;
 - Scents (perfumes, temple sticks, etc.);
 - Other people.



Particulate matter is classified as carcinogenic to humans (group 1) in 2014.

Source: IARC & WHO

About 1.4 million lives were lost in India due to air pollution in 2013.

Source: WHO

Nearly HALF of Delhi's children suffer 'severe' lung problems due to air pollution (2015).

Source: HEAL Foundation and Breathe Blue

Air pollution is the third largest cause of stroke.

Source: Lancet Neurology

Air pollution particulates are found inside the human brains and are linked to be a potential risk for Alzheimer's disease.

Source: Lancaster University

Air pollution can increase the diabetes risk.

Source: German Research Center for Environmental Health

Exposure to air pollution increases a person's risk of lung cancer, stroke, heart disease and chronic bronchitis.

Source: WHO

Long-term exposure to air pollution is likely to cause damages to the kidneys.

Source: Journal of the American Society of Nephrology

It is estimated that air pollution cost the Indian economy
USD 0.5 trillion (INR 100,000 per family) in welfare losses.

Source: OECD



Average annual income per family is INR 89,000

ISHRAE launched 7.10.2016

Indoor Environmental Quality Standard
ISHRAE Standard- 10001:2016
An ISHRAE initiative

Indoor Environmental Quality Standard

ISHRAE Standard - 10001:2016
First Version: 2016-2017

What to Measure / Benchmark

Parameter	Unit	ISHRAE standard A-class	ISHRAE standard B-class	ISHRAE standard C-class	WELL building standard	ACGIH TLV	OSHA PEL
T (summer)	°C	24±2.5	24±2.5	24±2.5	ASHRAE 55	-	-
RH	%	30-70	30-70	30-70	30-50	-	-
CO ₂	ppm	Ambient +350	Ambient +500	Ambient +700	<800	<5,000	<5,000
CO	ppm	<2	<9	<9	<9	<50	<50
PM ₁₀	µg/m ³	<50	< 100	<100	<50	-	-
PM_{2.5}	µg/m³	<15	<25	<25	<15	<3,000	<5,000
TVOC (equiv. isobutylene)	µg/m ³	<200	<500	<500	<500	Individual VOCs only	<230,000
CH ₂ O	µg/m ³	<30	<30	-	<32	<1,230	<1,230
SO ₂	µg/m ³	<40	<80	-	-	<5,200	<13,000
NO ₂	µg/m ³	<40	<80	-	<100	<5,700	<9,300
O ₃	µg/m ³	<50	<100	-	<109	<100	<200
Total Bio-burden	CFU/m ³	Indoor < outdoor	Indoor < outdoor	-	<500	-	-
User satisfaction		>90%	>80%	-	-	-	-

Indoor Air Quality and Ventilation Rate

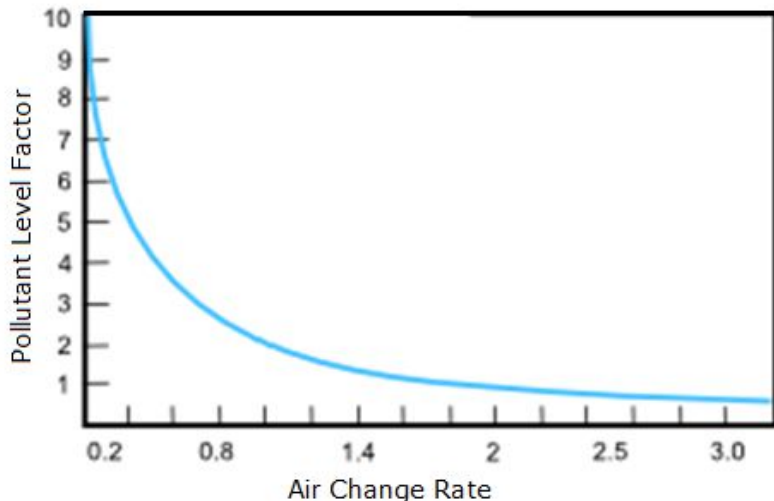
ASHRAE 62.1 and EN 15251 specifies the ventilation rate for office building

Occupancy	Standards									
	ASHRAE 62.1	EN 15251								
		Category I			Category II			Category III		
Minimum ventilation for occupants (l/s person)	2,5	10			7			4		
Additional ventilation for building (l/s-m²)	0,3	A	B	C	A	B	C	A	B	C
		0,5	1	2	0,35	0,7	1,4	0,3	0,4	0,8

A – Very Low Pollution **B** – Low Pollution **C** – Not Low Pollution

Standard	1 person per 7 m ²	l/s,m ²	ac/h
ASHRAE	$(2.5 + 0.3 \cdot 7) / 7$	0.7	0.8
LEED (ASHRAE +30%)	$0.7 \cdot 1.3$	0.9	1
EN15251, category I, non-low polluting materials	$(10 + 2 \cdot 7) / 7$	3.4	4
EN15251, category I, very low polluting materials	$(10 + 0.7 \cdot 7) / 7$	2.1	2.5
EN15251, category III, non-low polluting materials	$(4 + 0.8 \cdot 7) / 7$	1.4	1.7

Good IAQ by Diluting Indoor Pollutants



**Air change rate of 0.5 ac/h
reduces indoor pollutants 60%.**

**To achieve 90% reduction, the air
flow rate of 2 ac/h is required.**

- The minimum outdoor air flow rate in ASHRAE standard 62.1 and EN 15251 is specified so that outdoor air supply both dilutes the human emissions (**CO₂**, moisture, odours) and emissions from the structures, furniture etc.
- The ASHRAE outdoor air flow rate (5 cfm/person + 0.06 cfm/ft²) replaces the indoor air once in every 2 h (0.5 ac/h).
- The EN 15251 based outdoor air flow rate with low polluting building materials and IAQ target level of B-class replaces the indoor air once in every 30 min (2 ac/h).

Filter Recommendations According EN 13779 (performance testing EN779:2012)

<i>Category of outdoor air</i>	<i>Description</i>	<i>Concentration levels</i>				
		<i>CO2 (ppm)</i>	<i>CO2 (mg/m2)</i>	<i>NO2 (µg/m2)</i>	<i>SO2 (µg/m2)</i>	<i>PM10 (µg/m2)</i>
ODA1	Rural areas	350	< 1	5 - 35	< 5	< 20
ODA2	Smaller towns	400	1 - 3	15 - 40	5 - 15	10 - 30
ODA3	City centres	450	2 - 6	30 - 80	10 - 50	20 - 50

<i>Category of indoor air</i>	<i>Description</i>	<i>CO2 –level</i>	<i>Rate of outdoor air</i>		
		<i>(ppm)</i>	<i>(m3/h, person)</i>	<i>(l/s, person)</i>	<i>(cfm/person)</i>
IDA 1	High IAQ	< 400	>54	>15	>32
IDA 2	Medium IAQ	400 – 600	36 - 54	10 - 15	22 - 32
IDA 3	Moderate IAQ	600- 1000	22 - 36	6 - 10	13 -32
IDA 4	Low IAQ	> 1000	< 22	< 6	< 13

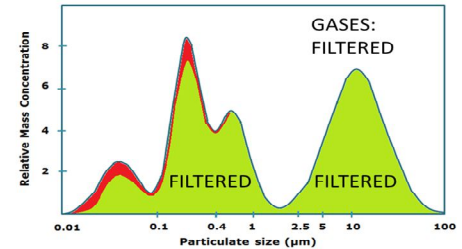
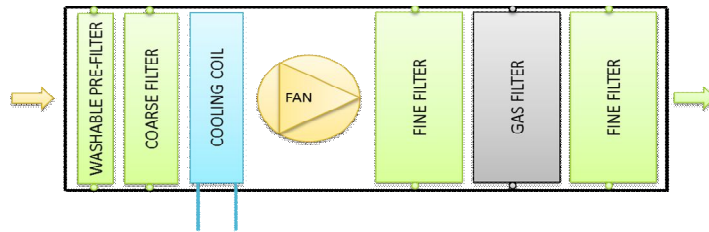
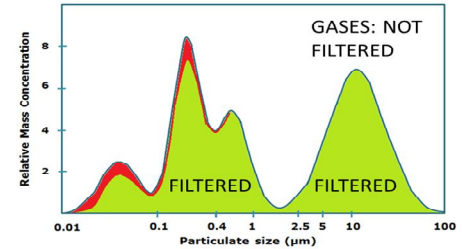
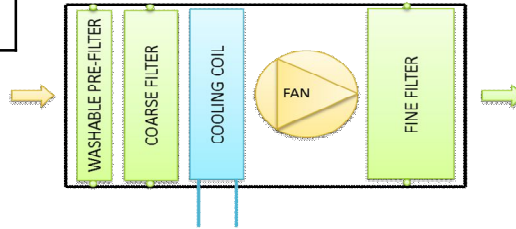
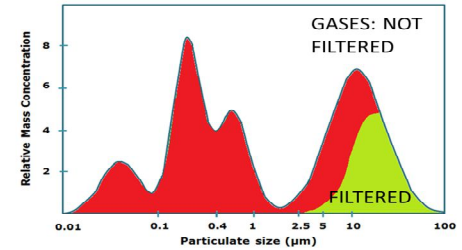
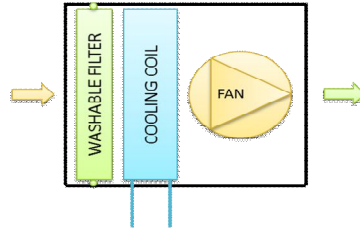
<i>Outdoor Air Quality</i>	<i>IAQ (Indoor Air Quality)</i>			
	<i>IDA 1 (High)</i>	<i>IDA 2 (Medium)</i>	<i>IDA 3 (Moderate)</i>	<i>IDA 4 (Low)</i>
ODA1	F9	F8	F7	M5
ODA2	F7 / F9	M6 / F8	M5 / F7	M5 / M6
ODA3	F7 / GF / F9	F7 / GF / F9	M5 / F7	M5 / M6

Examples of Air Filtration Solutions

EU	Efficiency (0.4 μm)	ASHRAE	Efficiency (0.3-1 μm)
F9	>95%	MERV 15	>95%
F8	90-95%	MERV 14	90-95%
F7	80-90%	MERV 13	80-90%
M6	60-80%	MERV 11-12	60-75%
M5	40-60%	MERV 9-10	40-55%

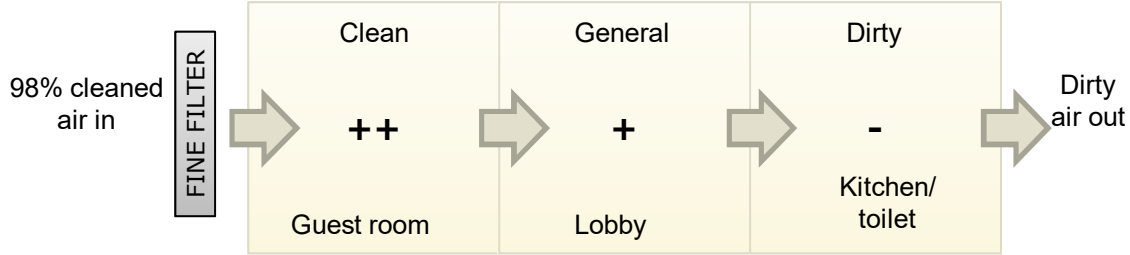


F9 / MERV 15 Fine filter

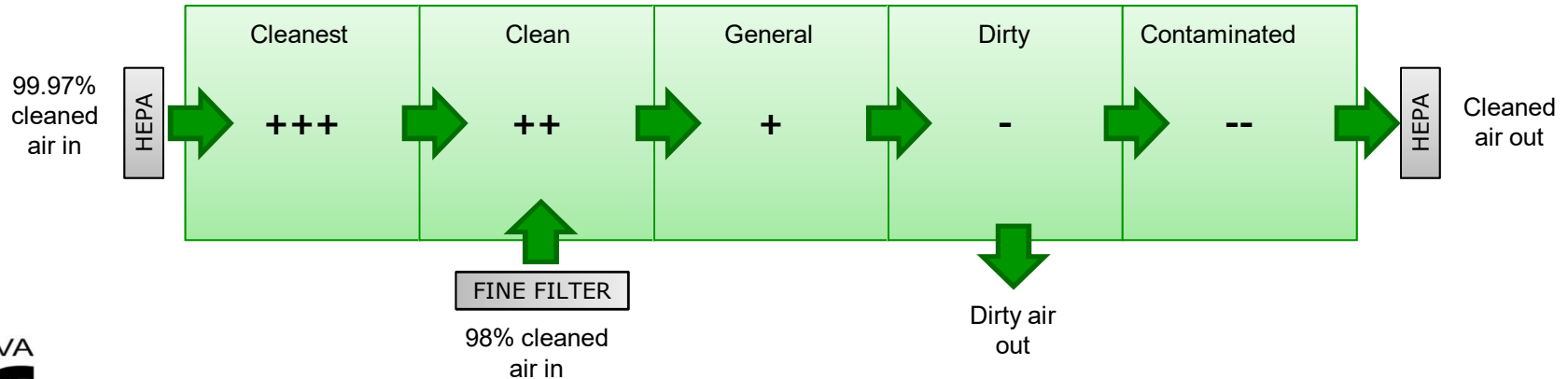


Pressurization (POSITIVE) with Clean Air

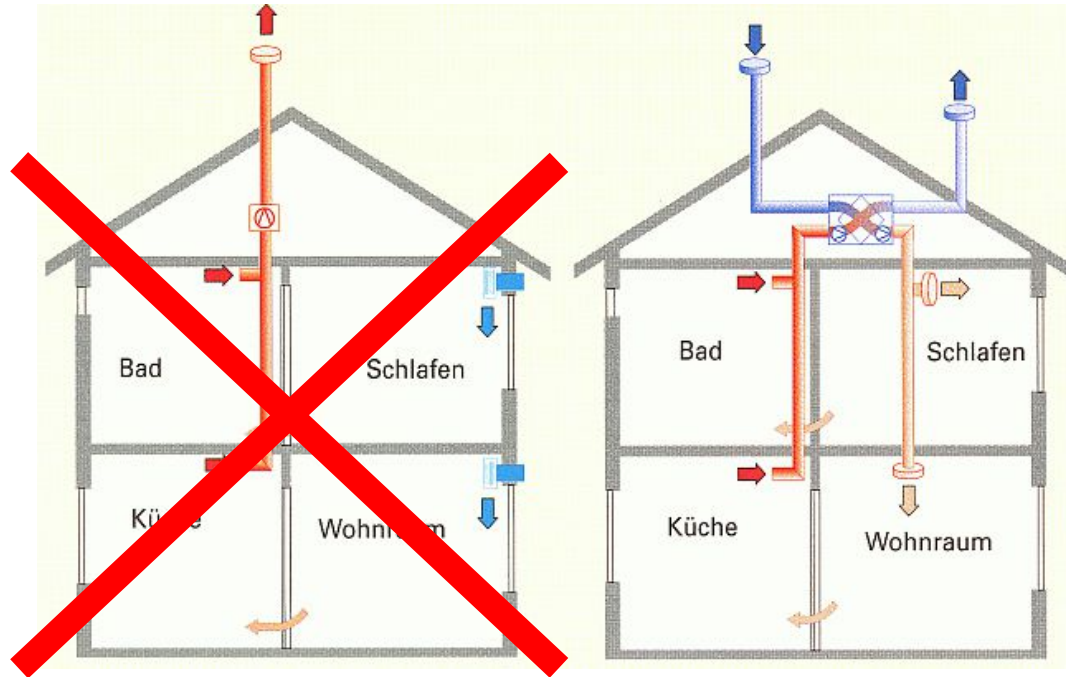
COMMERCIAL BUILDINGS e.g. HOTEL



HOSPITALS



Typical Residential Ventilation Systems



Mechanical exhaust

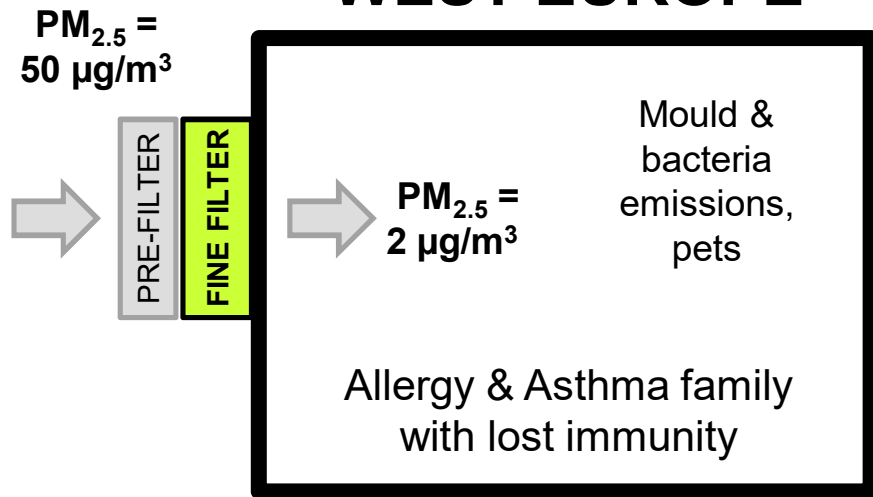
**Energy recovery with
mechanical exhaust & supply**

Demand Based Control

- Fan (EC) speed control or motorized dampers in each zone;
- Based on:
 - Occupancy (occupancy sensor, CO₂);
 - Air quality (CO₂, PM_{2.5}, TVOC);
- Ensure positive pressure in all operation modes;
- Balancing of ductwork becomes very important both in terms of control and positive pressure;
- Saves energy, improves comfort, allows use of higher air exchange rate when required.

Room Air Purifiers

WEST EUROPE

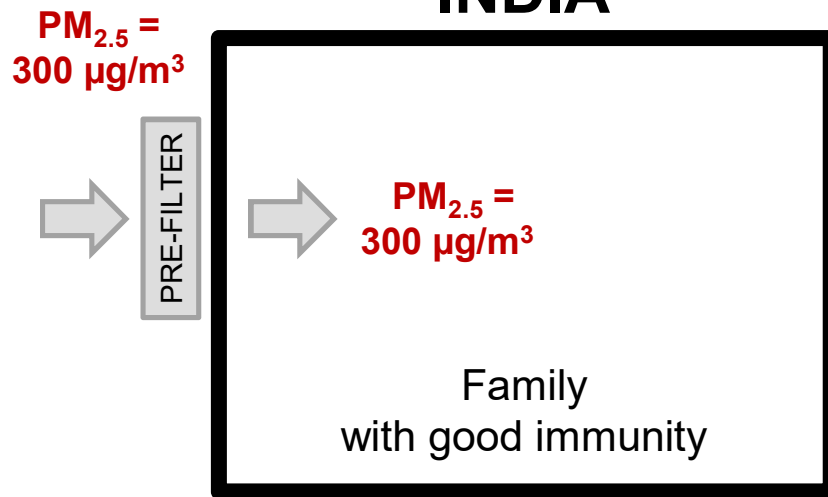


Room air

purifier with:

HEPA FILTER AND UVGI

INDIA



PRE AND FINE FILTER

- **Protection of immunity of healthy population;**
- **How often filters need to be changed? Once in every 6-8 weeks or once a year.**

Holistic Indoor Air Quality Management

FILTRATION – DILUTION – PRESSURIZATION - CONTROL - MONITORING



Ambient Air Purifier



AIRwala smart Controller (C),
Indoor (IAM) and Outdoor
(OAM) Air Quality Monitoring

