# AIR FILTRATION – AN IDEAL SOLUTION TO HEALTHY INDOOR AIR

GRIHA 2015, 03 & 04 Feb 2015
TERI, Bangalore.

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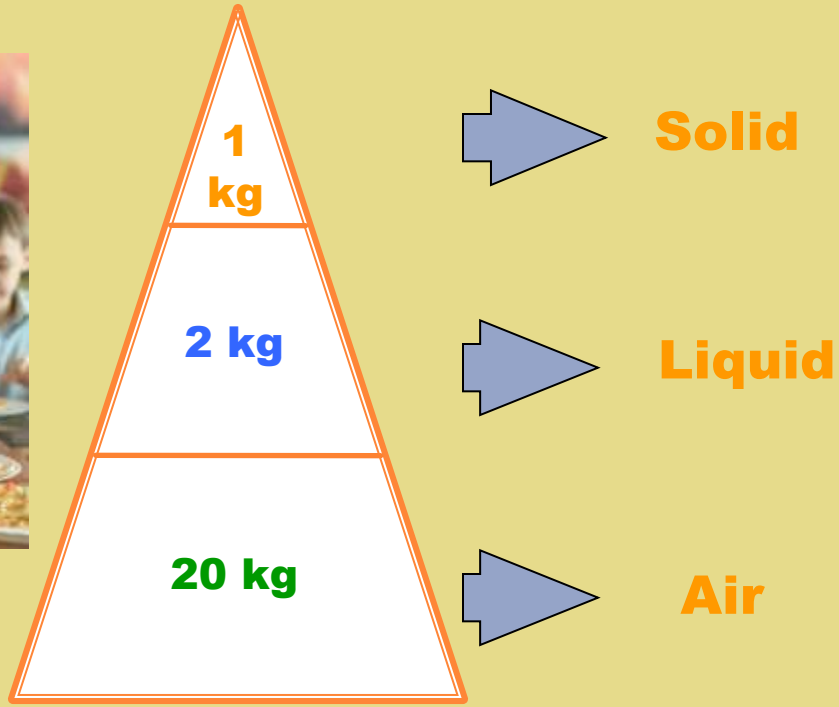
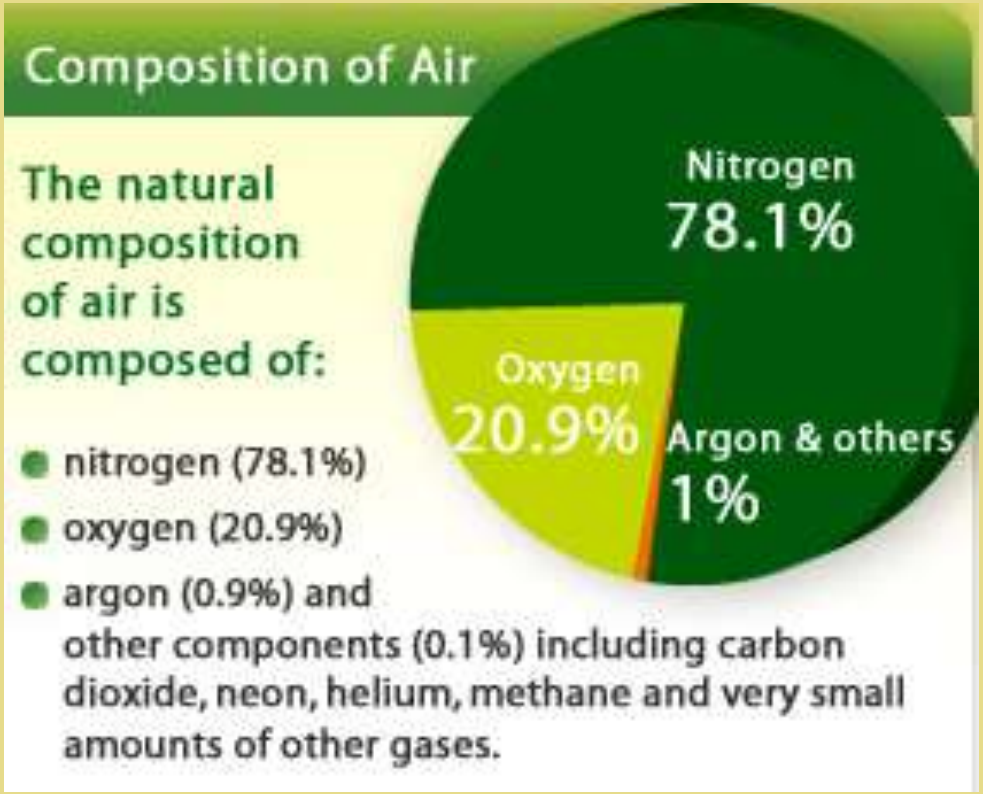
# "THINGS THAT MATTER MOST MUST NEVER BE AT THE MERCY OF THINGS THAT MATTER LEAST (LESSER)"

In this talk we consider the health and well being of the inhabitants in a space as the most important parameter.

# What do we consume every day ?



# Composition of ambient air




**IN ADDITION, AIR ALSO CARRIES WATER IN ALL THREE PHASES (water vapour, water droplets and ice crystals) AND**

**PARTICULATES**

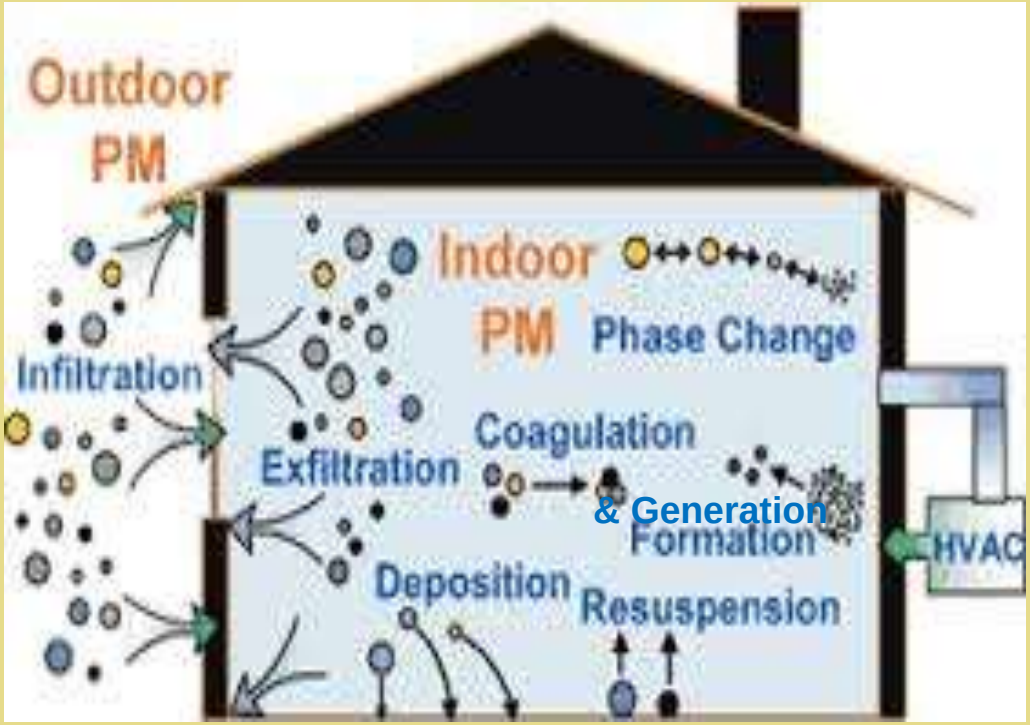
# Concentration of particles in an indoor environment - True case

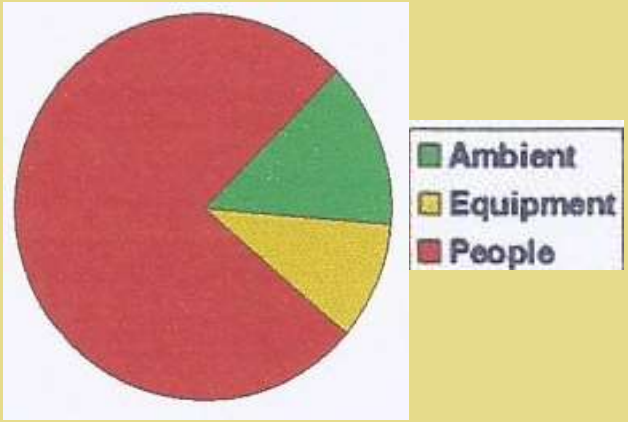
| | > 0.3 micron | > 0.5 micron | > 1 micron | > 3 micron | > 5 micron | > 10 micron |
|---|---|---|---|---|---|---|
| | ( Number of airborne particles per cubic metre ) | | | | | |
| 6" below a Hepa filter in a cleanroom area | **37** | **8** | **0** | **0** | **0** | **0** |
| At 6' below the Hepa filter in a cleanroom area under the filter | **19,595** | **12,945** | **8,984** | **3,466** | **1,662** | **53** |
| In a non air conditioned office space | **3,49,54,817** | **2,21,14,247** | **63,67,327** | **6,30,930** | **1,72,444** | **9,584** |
| In an air conditioned office space with coarse filters only. | **3,48,62,328** | **2,20,02,493** | **62,35,446** | **4,67,497** | **95,972** | **3,936** |

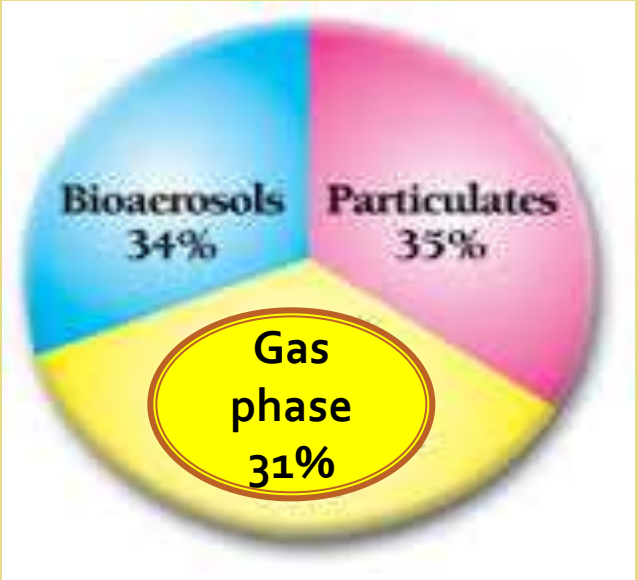
# So how much are we ingesting ?

- Assuming density of air is 1.2 Kg per cubic metre and assuming that we inhale 20 kgs of air everyday, we actually inhale 16.67 cubic metres of air every day which is 0.7 cubic metres every hour.
- Assuming indoor airborne concentration around 3.6 lakh particles per cubic metre, of size 3 microns and above, we are actually ingesting 2.5 lakh particles every hour.

# Indoor air contaminants



# Particles emitted when speaking

# Number of viable and non viable particles emitted by a person

| | Inert particles | Microbe-carrying particles |
|---|---|---|
| One sneeze | 1 000 000 | 39 000 |
| One cough | 5000 | 700 |
| Loud speaking (100 words) | 250 | 40 |

# People as a source of contamination

**Table 27.** Relationship of activity to the number of particles shed from a human body

| Activity | Number of particles generated (0.5 µm and larger per min) |
|---|---|
| Sitting or standing still | 100000 |
| Sitting, small movement of arms or head | 500000 |
| Sitting, moving arms, legs or head | 1000000 |
| Standing up | 2500000 |
| Walking slowly | 5000000 |
| Walking normally | 7500000 |
| Walking with speed (2.5 m/s) | 10000000 |
| Performing work-out | 15000000–30000000 |

# Microbial contamination

- Outer layer of human skin can host up to 1 million microorganisms per square cm
- Human saliva can host up to 1 billion microbes per mL
- Bacteria is usually primary concern, but foreign organic matter, viruses, fungi, mites, endotoxins etc are also trouble causing.
- A sneeze or a cough can release a lot of liquid droplets containing microbes. When the water evaporates, the solid content in the droplet along with the microbes form what is called a "droplet nuclei" and this can be airborne for a long time creating diseases and allergic reactions.

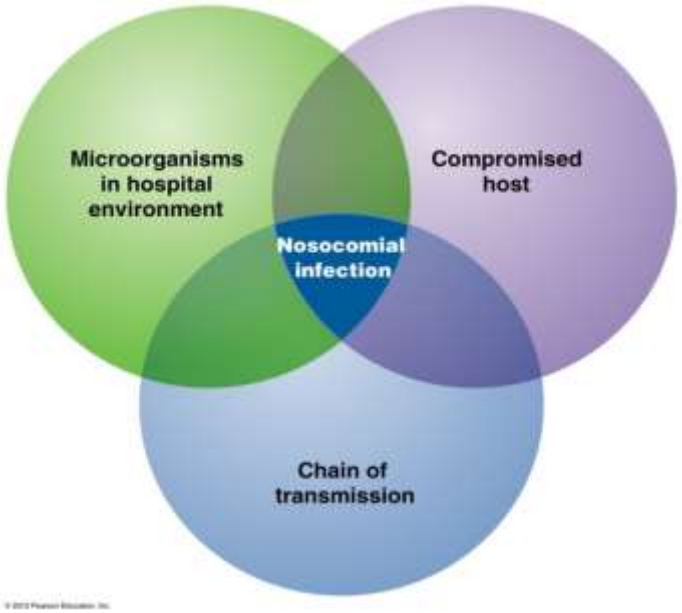
# NOSOCOMIAL INFECTIONS

- Nosocomial Infections are those infections that are acquired in hospitals and other health care facilities.
- To be classified as a Nosocomial infection, the patient must have been admitted for reasons other than the infections.
- Nosocomial infections are difficult to treat through antibiotics since the microbe in many cases would be resistant.
- It is also called as Hospital Acquired Infection ( HAI).

# Nosocomial Infections in India as per IMA statistics

- In India Nosocomial Infection rate is at over 25%.
- Frequency is 1 in every 4 patients admitted into the Hospital.
- 1/3rd of all such infections are preventable.
- Responsible for more mortality than any other form of accidental death.

# How Nosocomial infections ?



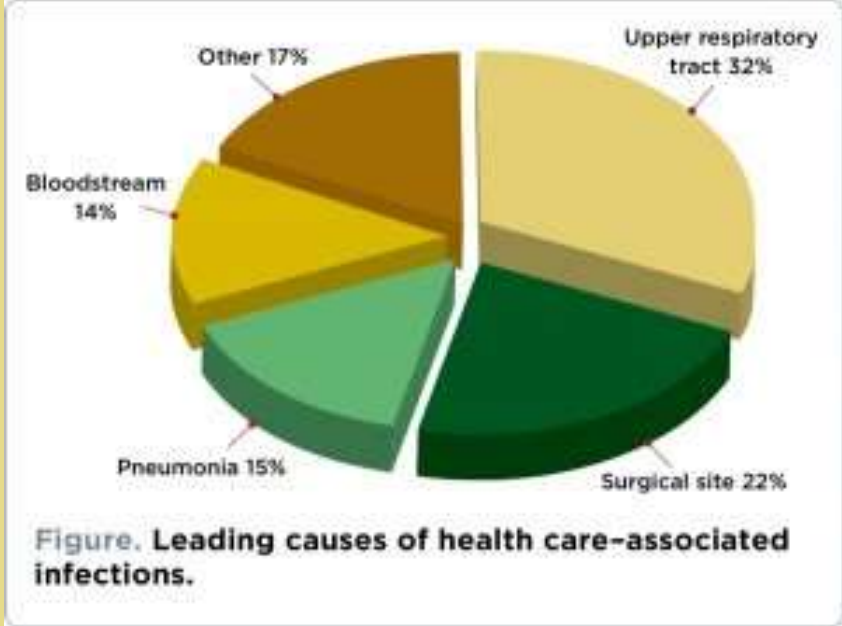
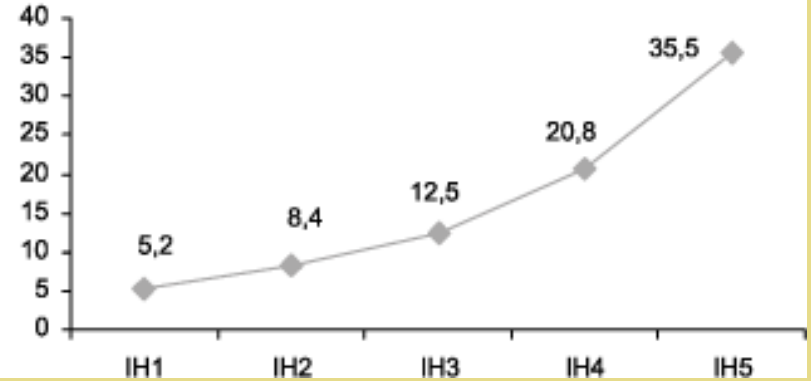




Figure. **Leading causes of health care–associated infections.**

**Figure 1.** Nosocomial infection and length of ICU stay.



# News article

**NEW DELHI:** Fungal infections kill close to 1.3 million people globally every year, matching the mortality rate of AIDS, cancer, malaria and tuberculosis, and also cause blindness to 300 million people annually.

The magnitude of the problem is particularly se-

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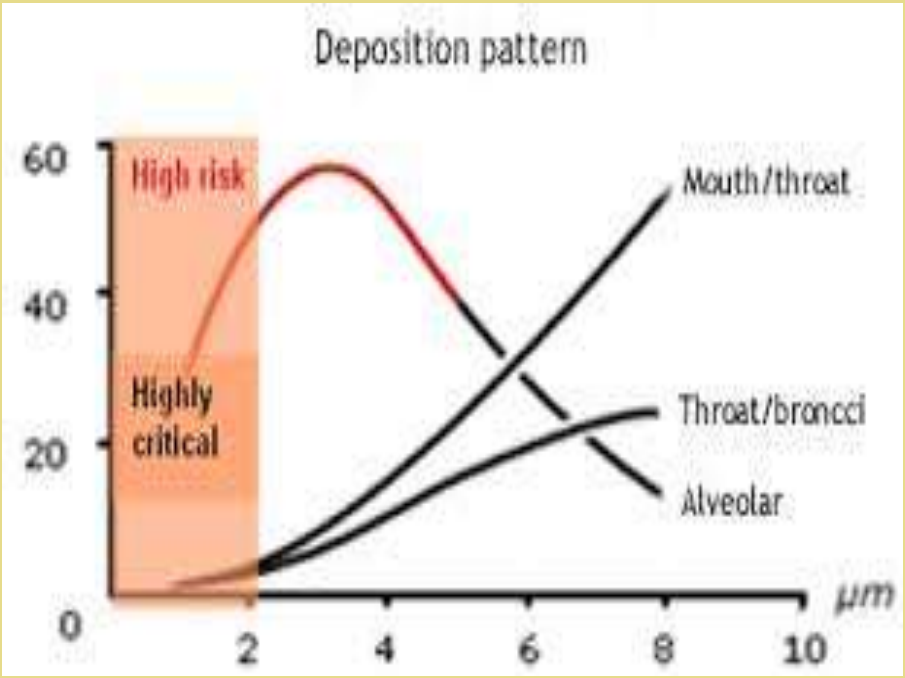
# Air borne particulates and the human respiratory system




| Particle size | Fate |
|---|---|
| 9 - 30 µm | visual pollution |
| 5.5 - 9 µm | settle in nose/throat |
| 3.3 - 5.5 µm | lodge in main breathing passages |
| 2 - 3.3 µm | lodge in small breathing passages |
| 1 - 2 µm | lodge in bronchi |
| 0.3 - 1 µm | penetrate to bronchioles and alveoli |
| 0.1 - 0.3 µm | penetrate to bronchioles and alveoli |

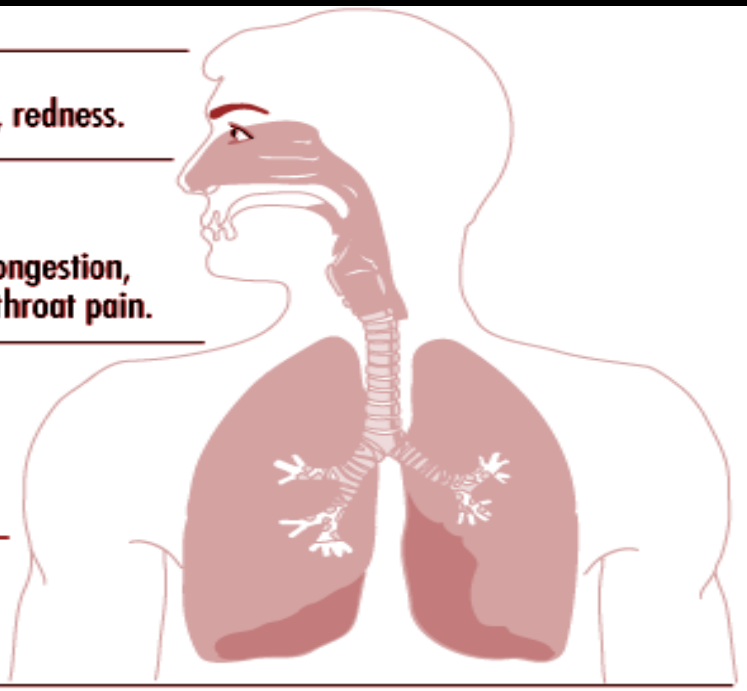
# Common symptoms of poor IAQ

**EYES**
Dryness, itching/stinging, tearing, redness.

**UPPER RESPIRATORY TRACT**
(nose and throat)
Dryness, itching/stinging, nasal congestion, nasal drip, sneezing, nose bleed, throat pain.

**LUNGS**
Chest tightness, drowning sensation, wheezing, dry cough, bronchitis.

**SKIN**
Redness, dryness, general and localized itchiness.



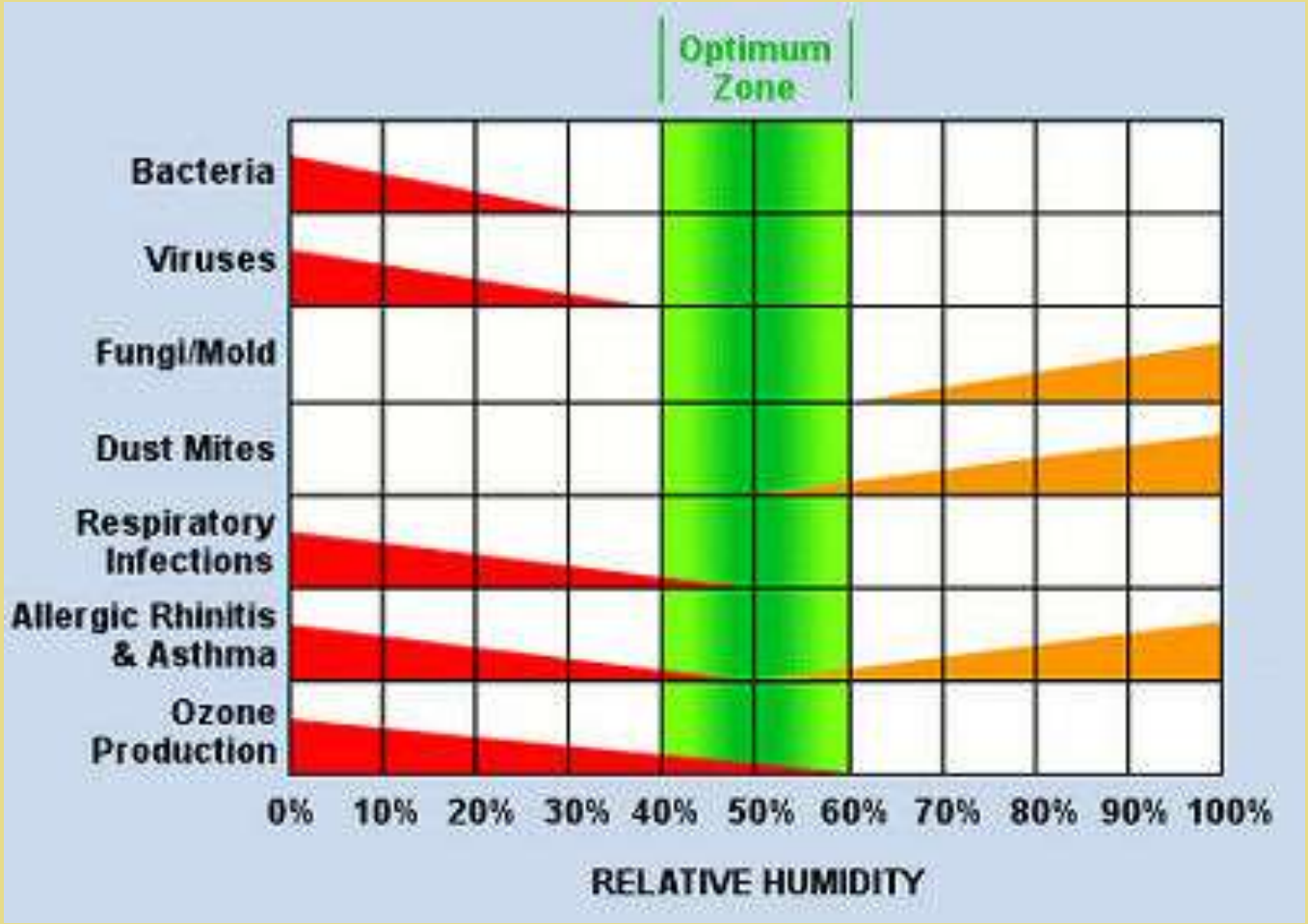
**GENERAL**
Headache, weakness, drowsiness/lethargy, difficulty concentrating, irritability, anxiety, nausea, dizziness.

**MOST COMMON ILLNESSES:**

**HYPERSENSITIVITY**
Hypersensitivity pneumonitis, humidifier fever, asthma, rhinitis, dermatitis.

**INFECTIONS**
Legionellosis (Legionnaire's disease), Pontiac fever, tuberculosis, common cold, flu.
Of unknown chemical or physical origins, including cancer.

# Effect of Humidity on Microbial growth



# Important terminologies related to poor IAQ

- Sick Building Syndrome – Symptoms disappear a certain amount of time after the person leaves the building. Symptoms appear in a good proportion of the occupants.
- Building Related Illness – Symptoms continue after leaving the building also and requires medication to subside. Symptoms are less frequent but more serious.
- Multiple Chemical Sensitivities – Specific to individual occupants.

# Tools available for removing contaminants

- Dilution with clean air.
- Particulate filtration.
- Gas phase filtration.
- Electrostatic collection.
- Photo Catalytic oxidation.
- Photo Hydro Ionisation.
- Ultra violet Germicidal Irradiation.

# Particulate Air Filters

- Works on a combination filtration mechanisms namely,
  - Diffusion
  - Inertial impaction / Impingement.
  - Interception
  - Straining / Sieving.
- Other than the above electrostatic attractive forces also come into play.

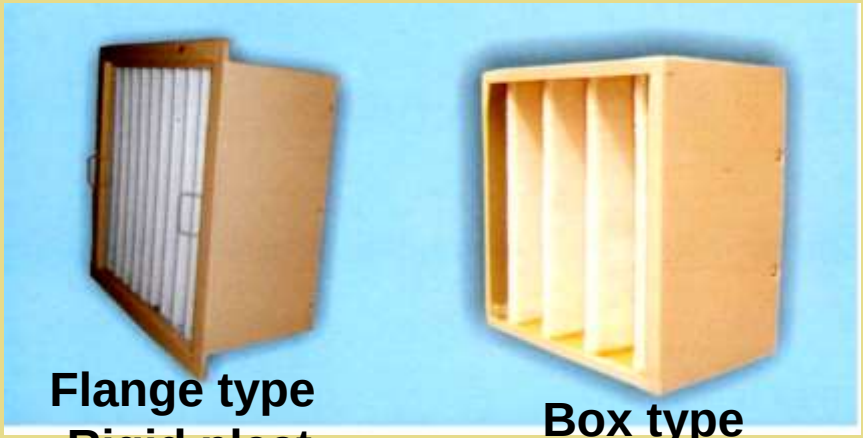
# Types of particulate Air filters

EPA and HEPA Filters

V-Bank

Melt blown pocket

Self supported pocket



Flange type Rigid pleat

Box type rigid pleat

# MERV – ASHRAE 52.2

| Group Number | MERV Rating | E1 0.3 - 1.0 Microns | E2 1.0 - 3.0 Microns | E3 3.0 - 10.0 Microns | Average Arrestance Ashrae 52.1 | Minimum Final Resistance in Pascals |
|---|---|---|---|---|---|---|
| 1 | 1 | - | - | < 20% | < 65% | 75 |
| | 2 | - | - | < 20% | 65 - 69.9% | 75 |
| | 3 | - | - | < 20% | 70 - 74.9% | 75 |
| | 4 | - | - | < 20% | 75% & > | 75 |
| 2 | 5 | - | - | 20 - 34.9% | - | 150 |
| | 6 | - | - | 35 - 49.9% | - | 150 |
| | 7 | - | - | 50 - 69.9% | - | 150 |
| | 8 | - | - | 70 - 84.9% | - | 150 |
| 3 | 9 | - | < 50% | 85% & > | - | 250 |
| | 10 | - | 50 - 64.9% | 85% & > | - | 250 |
| | 11 | - | 65 - 79.9% | 85% & > | - | 250 |
| | 12 | - | 80 - 89.9% | 90% & > | - | 250 |
| 4 | 13 | < 75% | 90% & > | 90% & > | - | 350 |
| | 14 | 75 - 84.9% | 90% & > | 90% & > | - | 350 |
| | 15 | 85 - 94.9% | 90% & > | 90% & > | - | 350 |
| | 16 | 95% & > | 90% & > | 90% & > | - | 350 |

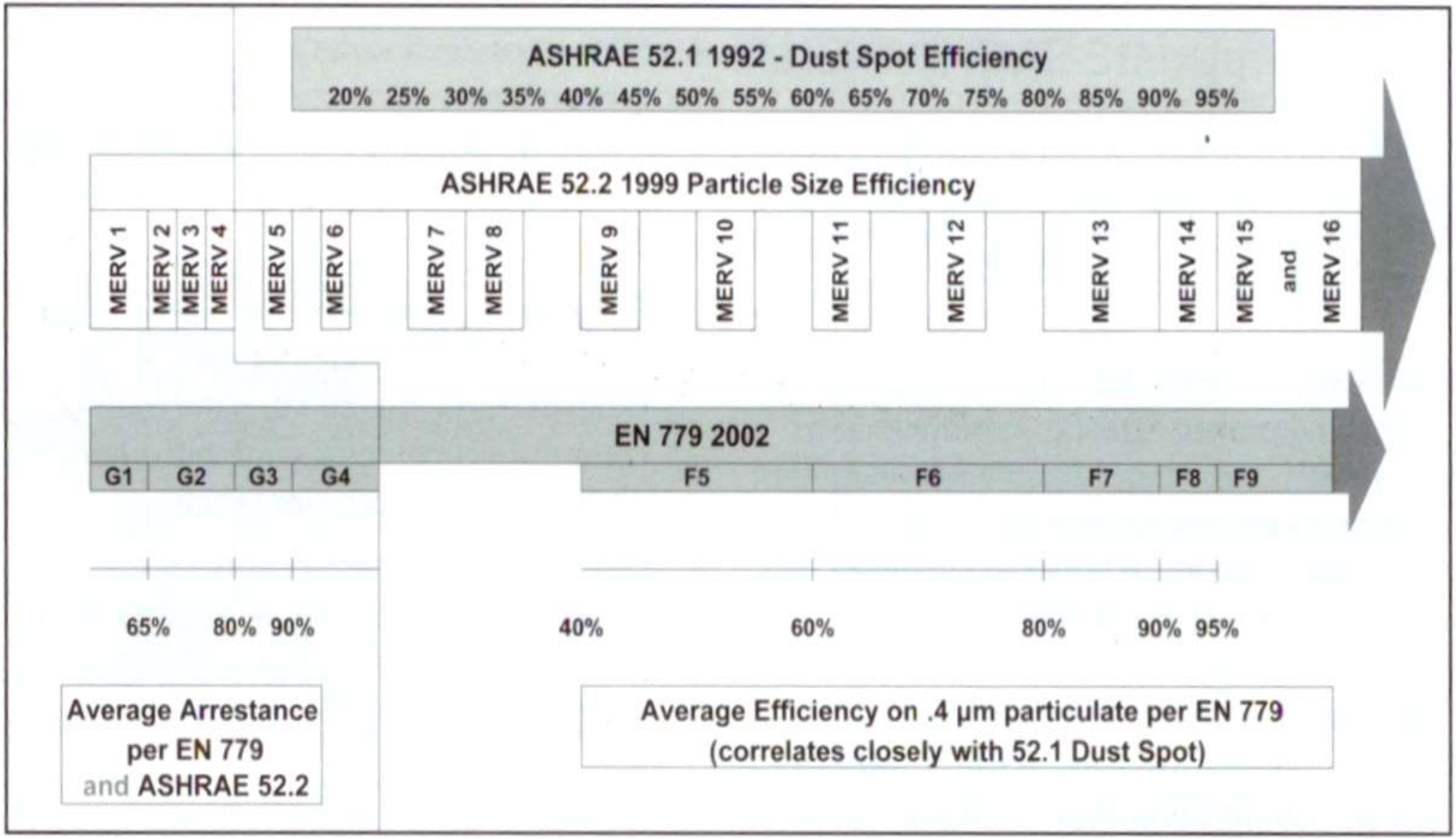
# EN 779 Air filter classification

Table 1— Classification of air filters [1)]

| Group | Class | Final test pressure drop Pa | Average arrestance ($A_m$) of synthetic dust % | Average efficiency ($E_m$) of 0,4 µm particles % | Minimum Efficiency [a] of 0,4 µm particles % |
|---|---|---|---|---|---|
| Coarse | G1 | 250 | $50 \le A_m < 65$ | - | - |
| | G2 | 250 | $65 \le A_m < 80$ | - | - |
| | G3 | 250 | $80 \le A_m < 90$ | - | - |
| | G4 | 250 | $90 \le A_m$ | - | - |
| Medium | M5 | 450 | - | $40 \le E_m < 60$ | - |
| | M6 | 450 | - | $60 \le E_m < 80$ | - |
| Fine | F7 | 450 | - | $80 \le E_m < 90$ | 35 |
| | F8 | 450 | - | $90 \le E_m < 95$ | 55 |
| | F9 | 450 | - | $95 \le E_m$ | 70 |

[a] Minimum efficiency is the lowest efficiency among the initial efficiency, discharged efficiency and the lowest efficiency throughout the loading procedure of the test.

# ASHRAE 52.2 Vs EN 779



# Advantages of using cleanable and reusable airfilters

- Pocket filters are not cleanable and reusable filters. They are of disposable type.
- Only rigid pleat filters are cleanable.
- For cleanable filters, the "pressure drop Vs time" curve over their life time is a saw tooth curve.
- For "use and throw away" the "pressure drop Vs time" curve over their life time is relatively linear.
- As a result the average pressure drop over the life cycle is lower for a cleanable and reusable type filter.

# Cleaning of air filters

- Filters must be air cleaned or water washed inside a filter cleaning booth only.
- The water that is discharged from the filter cleaning booth can be sent to the STP.
- It is necessary that the filters be made fully dry before putting it back in service.
- In the case of water washable filters, filters can be dipped in a disinfectant solution tank after cleaning and then allowed to dry before putting them in service.

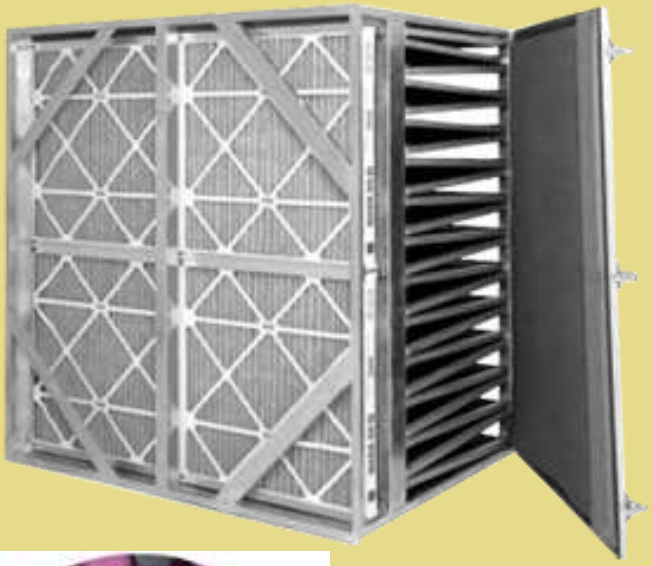
# Imperfections affect

# Gas phase Filtration

- Gas phase filtration primarily happens in 2 ways.
  - Physical Adsorption
  - Chemisorption - Physical adsorption followed by a chemical reaction.

# Tray type Gas phase filters for Out door Air intake systems

**Activated carbon granules**

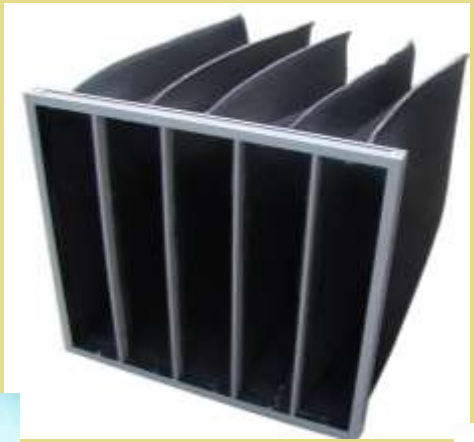


**Activated carbon pellets and $KMnO_4$ impregnated on alumina mixed together**

# Types of Gas phase filters in HVAC

Packed bed filter with Granular activated carbon and $KMnO_4$ impregnated activated alumina spheres

Activated carbon impregnated fibre media made as a pleated filter with metal mesh supports



Activated carbon impregnated fibre media made into a pocket filter

Activated carbon sandwiched media made into a mini pleat V bank filter

# Effectiveness of various adsorbents on gaseous contaminants

| Contaminant | Activated Carbon | Potassium Permanganate Impregnated Media | Caustic Impregnated Carbon | Phosphoric Acid Impregnated Carbon |
|---|---|---|---|---|
| Acetic acid | • | • | • | |
| Acetone | • | | | |
| Acrolein | • | • | | |
| Amines | | | | • |
| Ammonia | | | | • |
| Benzene | • | | | |
| Chlorine | • | | • | |
| Ethyl alcohol | • | | | |
| Formaldehyde | | • | | |
| Gluteraldehyde | • | • | | |
| Hydrogen cyanide | | | • | |
| Hydrogen sulfide | | • | • | |
| Methyl alcohol | • | • | | |
| Mercaptans | • | • | | |
| Methylene chloride | • | | | |
| Methyl ethyl ketone | • | | | |
| Nitric oxide | | • | | |
| Nitrogen dioxide | | • | | |
| Ozone | • | | | |
| Sulfur dioxide | | • | • | |
| Sulfur trioxide | | • | • | |
| Toluene | • | | | |

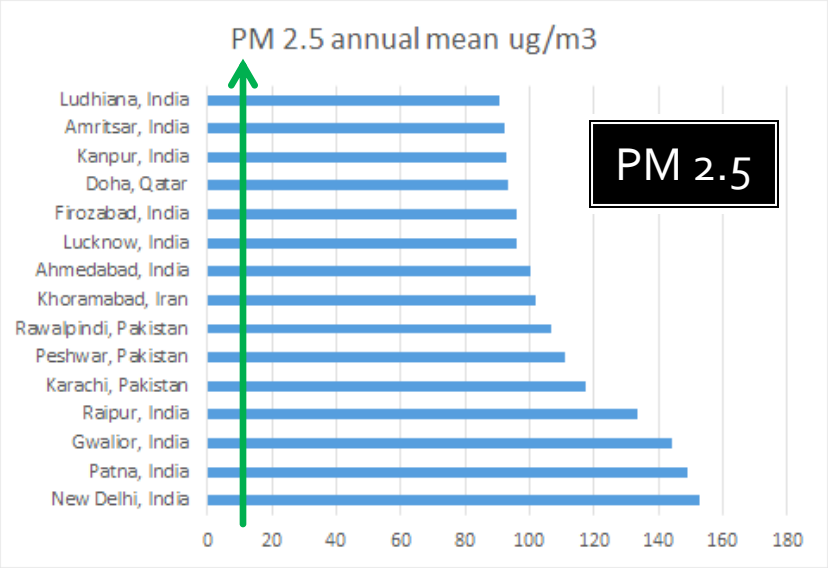
# Chemisorption media

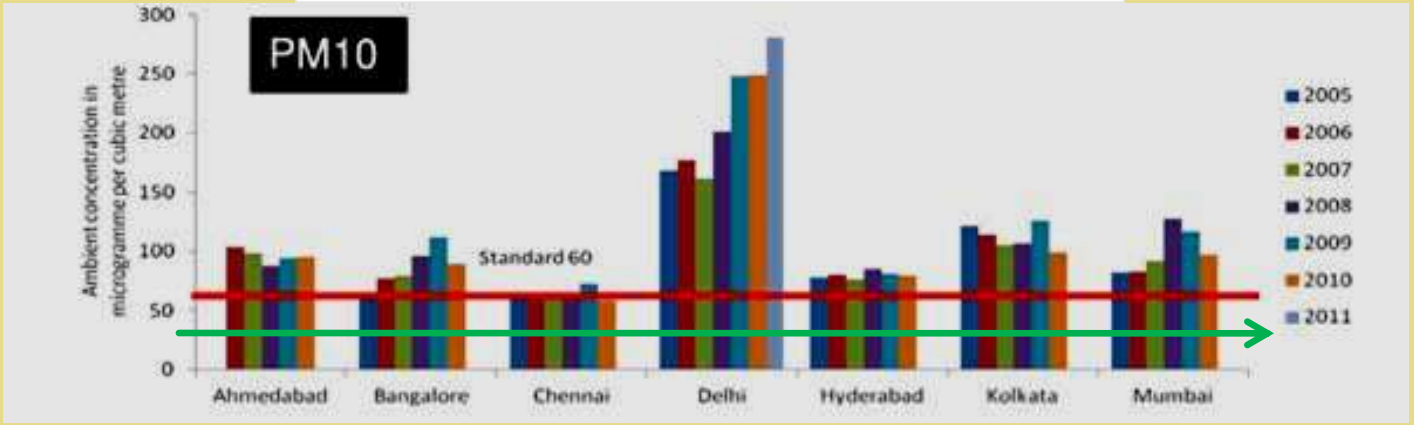
| Adsorbent | Impregnate | Effective in trapping |
|---|---|---|
| Activated Carbon | Sodium Hydroxide (or) Potassium Hydroxide | Acidic vapours like Sulphuric and Hydrochloric, Chlorine, Hydrogen sulphide etc |
| Activated Carbon | Potassium Iodide | Radio nuclides, Mercury Vapours etc |
| Activated alumina | Copper Chloride | Carbon monoxide (converts it to $CO_2$) |
| Activated Carbon | Phosphoric acid (or) Salts of copper | Ammonia |

# ODA Contaminant limits as per WHO guidelines

| Pollutant | Averaging Time | Guideline value (micro grams per cubic metre) |
|---|---|---|
| Sulphur dioxide | 24 hours | 125 |
| Sulphur dioxide | 1 year | 50 |
| Ozone | 8 hours | 120 |
| Nitrogen dioxide | 1 hour | 40 |
| Nitrogen dioxide | 1 year | 200 |
| PM 10 | 24 hours | 50 |
| PM 10 | 1 year | **40** |
| PM 2.5 | 24 hours | 25 |
| PM 2.5 | 1 year | **10** |

# Out door air conditions in India




Green arrow denotes limit as per WHO

# Guide lines for good practice EN 13779:2007 (Appendix - A)

Recommendations for filter combinations to be used

| | IDA 1 | IDA 2 | IDA 3 | IDA 4 (WORST) |
|---|---|---|---|---|
| ODA 1 | F9 | F8 | F7 | M5 |
| ODA 2 | F7 + F9 | M6 + F8 | M5 + F7 | M5 + M6 |
| ODA 3 (WORST) | F7 + GPF + F9 | F7 + GPF + F9 | M5 + F7 | M5 + M6 |

Note : GPF – Gas phase filter

# What solutions will work for us ?

Carbon dioxide emissions !!!


- Dilution with ODA
- Multi stage air filtration.
- Air filtered right from the "TFA" stage.
- Air filtered in the return air suction points.
- Air filtered before thermal conditioning equipment.
- Air filtered after thermal conditioning equipment.


# To reduce power consumption by filters…

- Design systems that will operate the filters at only 50% of its air flow capacity and replace or clean the filters when its pressure drop reaches the initial pressure drop for 100% flow.
  + Lesser pressure drop and hence lower energy costs.
  + Better efficiency.
  + Higher dust holding capacity.
  + Reduced frequency of cleaning or replacement.
  + Lower noise level due to reduced air velocity.
  - Higher initial investment.
  - Larger space requirement.

# ASHRAE 62 – Ventilation for acceptable IAQ

- Two parts –
  - Part 1 – Commercial space
  - Part 2 – Residential space.
- Two separate procedures
  - Ventilation rate procedure – Fixed ventilation rates suggested depending upon the number of people and the floor area.
  - IAQ procedure – Fix ventilation rates depending on the contaminant's measured values.

# Air filtration option for a TFA or ODAS

| Stage | Type of filter | Position |
|---|---|---|
| 1st stage | 12 mesh Stainless steel screen | At the suction point of the TFA |
| 2nd stage | G2 – Manufactured completely with water washable components, so that the filter can be washed, disinfected and reused. | Before thermal transfer equipment |
| 3rd stage | G4 – Manufactured completely with water washable components, so that the filter can be washed, disinfected and reused. | Before thermal transfer equipment. |
| 4th stage | F7 - Manufactured in such a way the filter can be air cleaned and reused. | After thermal transfer equipment |
| 5th stage | Gas phase filter – Potassium permanganate impregnated on Activated alumina. – Tray type filter. | After the thermal transfer equipment |
| 6th stage | Gas phase filter – Activated carbon – Tray type filter | After the thermal transfer equipment |

Note : For 4th, 5th and 6th stages, the position will change if the thermal transfer equipment is evaporative cooling

# Air filtration option for AHUs for commercial space

| Stage | Type of filter | Position |
|---|---|---|
| 1st stage | G3 – Manufactured completely with water washable components, so that the filter can be washed, disinfected and reused. | Before thermal transfer equipment |
| 2nd stage | M5 – Manufactured completely with water washable components, so that the filter can be washed, disinfected and reused. | Before thermal transfer equipment. |
| 3rd stage | Activated carbon sandwich filter for major Gas phase pollutants | After thermal transfer equipment |
| 4th stage | F7 or F8 or F9– Manufactured in such a way that the filter can be air cleaned and reused. | After the thermal transfer equipment |

Note : Fresh air or ODA supply to this AHU should be from a TFA as mentioned in previous slide.
For 4th stage, select F7, F8 or F9 depending on the type of space.

# Some more ideas…

- Pressurise the occupied area slightly higher than the ambient ( around 5 to 10 pascals) by balancing the supply and return air to reduce ingress of contaminants during door openings.
- Over pressure set point dampers can be provided to regulate the pressure.
- Consider usage of 3 or 4 compartment auto rotating doors to reduce loss of conditioned air due to pressurisation at all entry and exit points to the space.
- Position out door air intakes judiciously.

# And some more…

- Provide a Treated fresh air system with energy recovery systems, particulate and gas phase filtration systems for out door air intake.
- Provide ducted returns to eliminate variables in contamination addition from the attic space between the false ceiling and the RCC ceiling.
- AHU to have a mixing box to which the TFA and return air connections are made.

# Return air filters

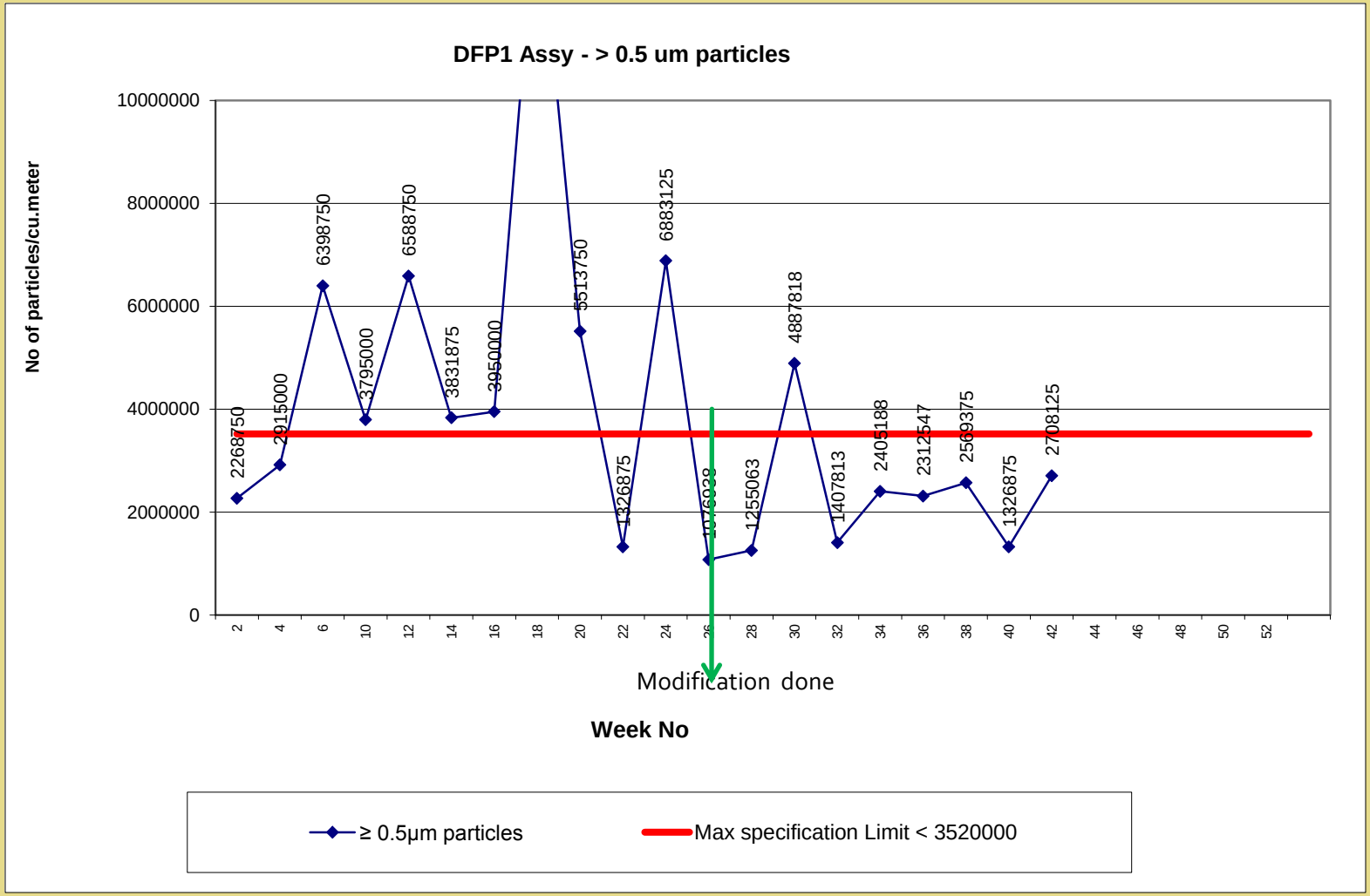
- A G3 or G4 filter can be provided at all return air suction points.
- This will reduce the dust from getting deposited in the return air ducts.
- This filter should be a completely water washable filter.

# Retrofits are possible

Before retrofit, with only G3 filter

After retrofit with water washable G4 filter and air cleanable F7 filter

# Correct choice of filters and proper installation is important




**F9 filters were used as the final stage.**

# Measurements?

- Check regularly for PM2.5
- Expose copper and silver reactive strips and coupons to check for gas phase pollutants.
- Check for carbon dioxide content on a regular basis.
- Measure pressure drops across filter at regular intervals.
- Measure air flow rates at least once a month.
- Microbiological sampling.

# Energy consumption in Air filters

Energy Consumption =

$$\frac{Q \times \Delta P \times t}{n \times 1000}$$

where:

Energy Consumption in kilowatt hours (kWh)
Q = airflow in cubic meters/second (m3/s)
ΔP = the average pressure drop across the filter in Pascals (Pa)
T = the time the fan is in operation in hours (hrs)
n = the product of the fan, motor, and drive efficiency in %

# Finally….

Improved quality of indoor air with result in

- Reduced cost of maintenance on interiors.
- Improved life of sophisticated equipments in housed in the space.
- Reduction in absenteeism of the employees on account of health issues due to poor IAQ.
- Improved performance and cognitive skills of the inhabitants on account of improved air quality.
- WHO says that a good IAQ is a person's right.

# Questions


Thank you!