10th GRIHA Summit
Session: Air Pollution – A call for urgent Action

Ambient Air Pollution in Delhi and Correlation with Indoor Air Quality

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Urban Air Pollution Problem

- Most of megacities in the world experience high levels of air pollution, which exceed ambient/health-based air quality standards.
- The problem is critical in megacities of developing countries like India, China.
- Delhi mega cities is also one of the most polluted cities of the world

Delhi air pollution :

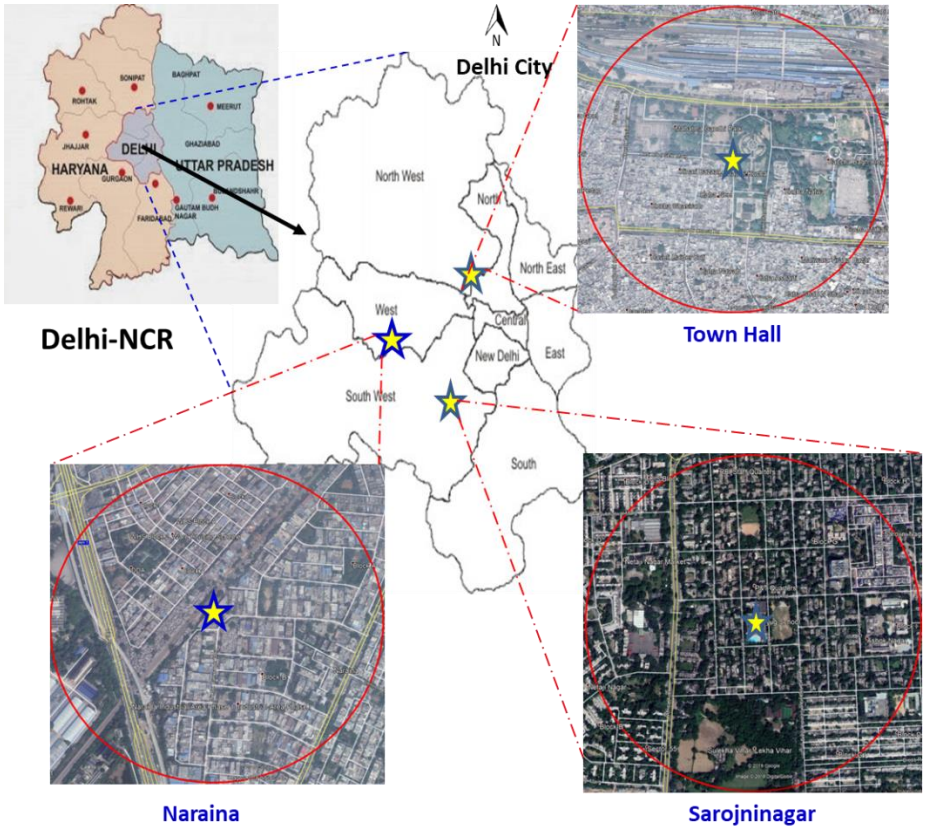
Is the current problem or past ?

Need trend analysis of historical air quality data

Monitoring Locations

Sr. No.	Location	Land Use	Surrounding Land Use Features	Direction wrt central Delhi
1	Navyug School, Sarojini Nagar	Residential	Govt. Staff Quarters, Bus depot (200 yards away), Sarojini Nagar Market (within 2 km), multi-storey buildings (EIL, HYATT Regency)	South
2	Town Hall, Chandni Chowk	Commercial	Chandni Chowk market, Old delhi Railway Station (0.4 km away), Red fort, Shishganj Gurudwara	North
3	NEERI Zonal Centre, Naraina	Industrial	Industries, Diesel Run Railway Line (Delhi-Jaipur Route), garbage dumps,	Southeast

- Air quality monitoring is being carried out as per CPCB norm under NAMP
- All three stations are part of NAMP
- Common pollutants: RSPM (PM_{10}), SO_2 and NO_2

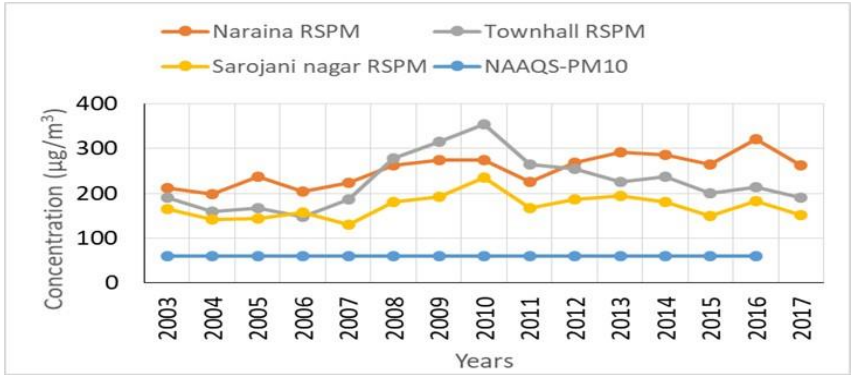


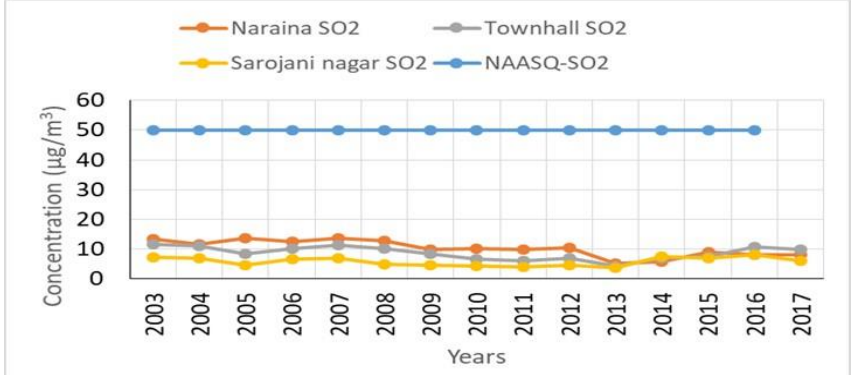
Annual Average Trend : RSPM, SO_2, NO_2

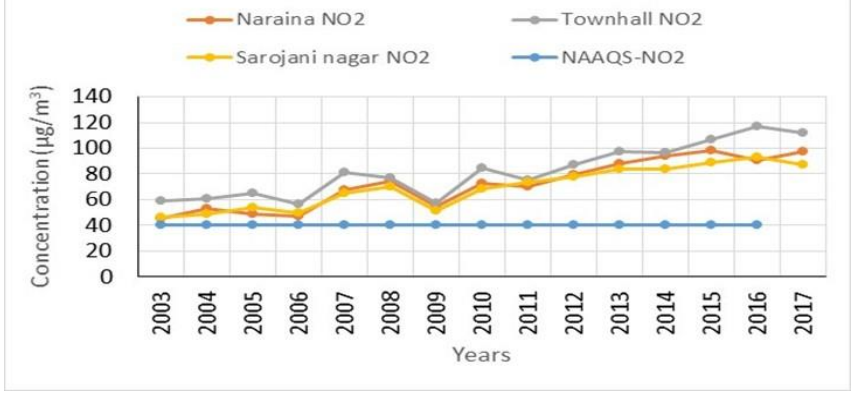
- Annual Average RSPM Concentration were found always higher than NAAQS
- Levels are increased from yr 2003 to 2017
- No clear increasing trend

- SO_2 concentration always found below the standards
- SO_2 concentration is showing decreasing trend with minimum in yr 2013-14
- SO2 not a problem in the city

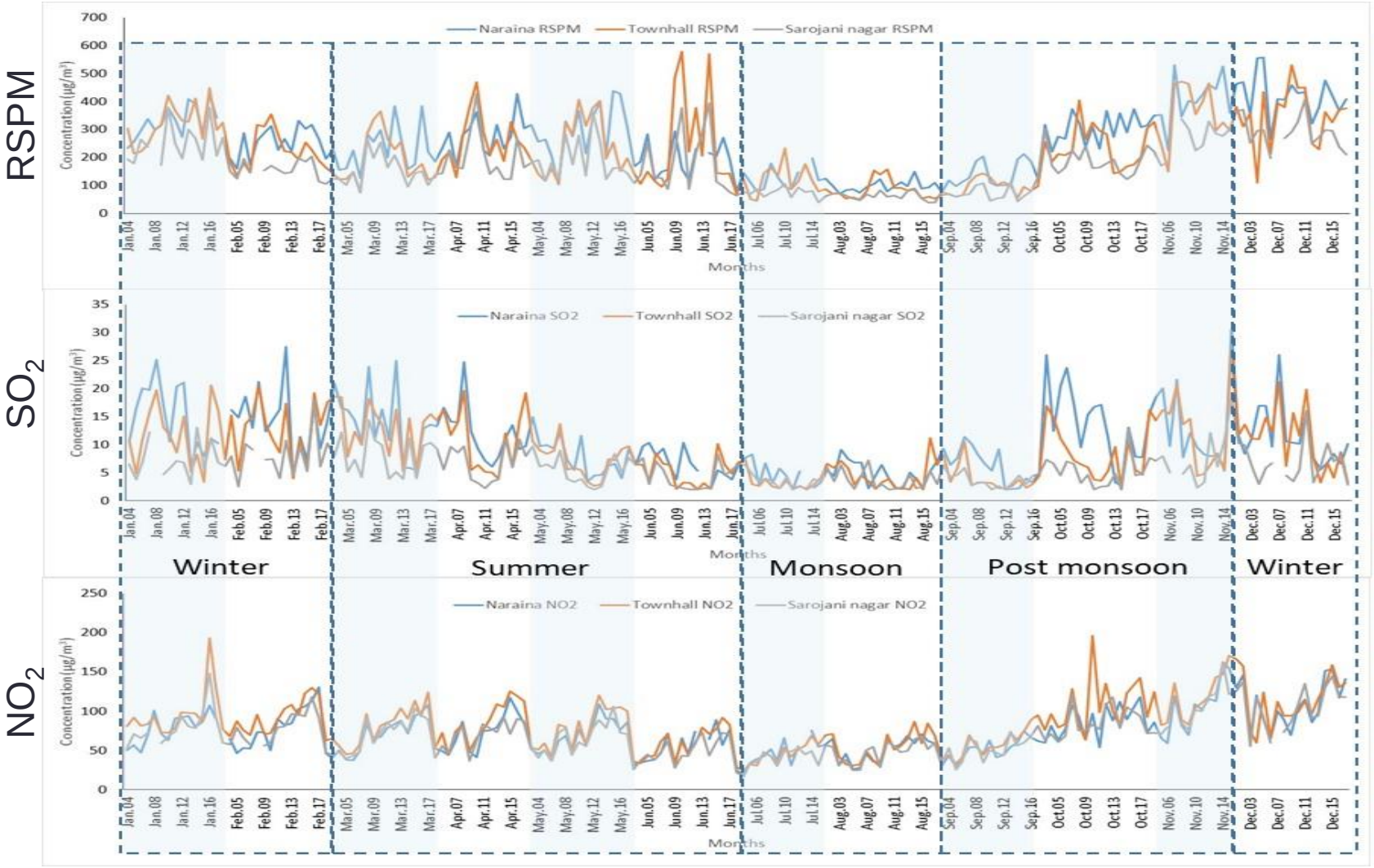
- NO_2 concentration always found above the NAAQS
- NO_2 concentration is showing increasing trend from year 2003 with slight decrease in 2005-06 and 2008-09
- Continuously Increasing







Seasonal Trend : RSPM, SO_2, NO_2



Correlation between Sites and Pollutants

Good correlations exist between

RSPM: Nariana, Town Hall and Sarojini Nagar

NO_2 : Nariana, Town Hall and Sarojini Nagar

Naraina: NO_2 and RSPM

Parameters	*Naraina- SO_2*	*Naraina- NO_2*	*Naraina- RSPM*	*Townhall- SO_2*	*Townhall- NO_2*	*Townhall- RSPM*	*Sarojani nagar- SO_2*	*Sarojani nagar- NO_2*	*Sarojani nagar- RSPM*
Naraina- SO_2	1.0								
Naraina- NO_2	0.2	1.0							
Naraina-RSPM	0.2	0.6	1.0						
Townhall- SO_2	0.5	0.2	0.3	1.0					
Townhall- NO_2	0.2	0.6	0.5	0.2	1.0				
Townhall- RSPM	0.2	0.4	0.6	0.2	0.4	1.0			
Sarojani nagar- SO_2	0.3	0.3	0.2	0.5	0.2	0.1	1.0		
Sarojani nagar- NO_2	0.1	0.7	0.5	0.2	0.6	0.4	0.3	1.0	
Sarojani nagar- RSPM	0.2	0.4	0.6	0.2	0.3	0.7	0.2	0.5	1.0

Indoor Air Quality in a Research Laboratory

- Study period: **Aug. 23-27th 2018**
- Hourly average concentration of PM_{10}, $PM_{2.5}$ and PM_1 are highest in chemical laboratory, i.e., 114±25 µg/m^3, 58±10 µg/m^3, 33 ±5 µg/m^3, respectively and lowest at un-disturbed area i.e., 42±4 µg/m^3, 33±2 µg/m^3, 22 ±2 µg/m^3, respectively.
- Ratio of $PM_{2.5}/PM_{10}$ and $PM_1/PM_{2.5}$ are found higher at un-disturbed area i.e., 0.79 and 0.75, respectively as compared to other areas.
- The daily average concentration of PM_{10} and $PM_{2.5}$ have been found in range of 81-135 µg/m^3 and 42-50 µg/m^3 respectively.

Location	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)		PM_1 (µg/m^3)	
	Ave	SD	Ave	SD	Ave	SD
Lab	114	25	58	10	33	5
Admin Office	56	11	32	5	23	3
Staff Room	50	7	33	4	22	3
Store Room	42	4	33	2	25	2
Canteen	104	28	57	9	34	3
G. House	80	23	46	3	29	5

Bio-aerosols Concentration

Fungal aerosol samples were collected from 9 different locations Reception, Basement, Terrace, Cafeteria, Conference room, Office, Chemistry lab and Toilet during the period of February-April, 2017

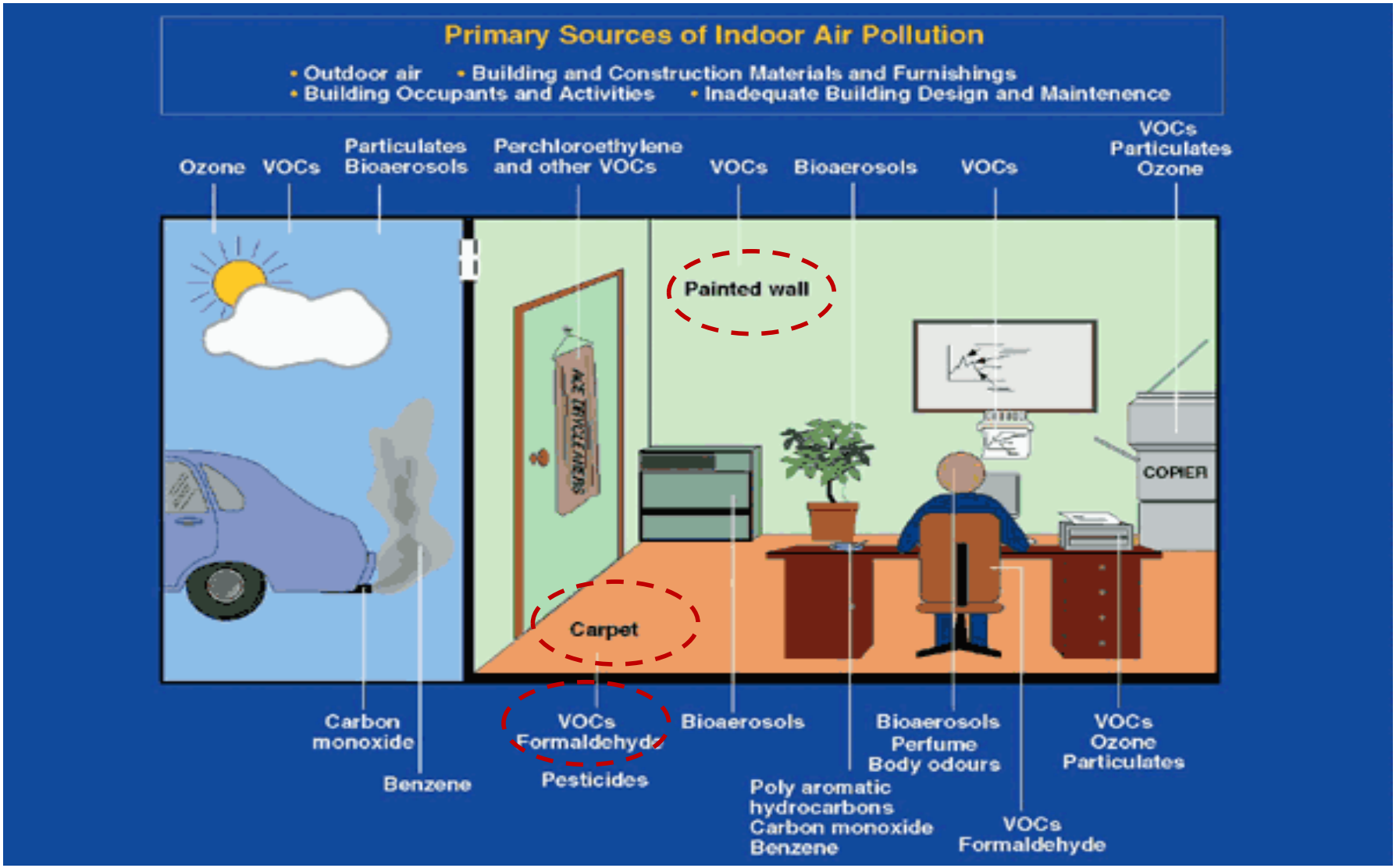
The fungal aerosols concentrations:

- 201-1139 cfu/m^3 in spring (February-March) and
- 44-172 cfu/m^3 in summer (April) season
- Maximum concentrations -Cafeteria area (793 cfu/m^3)
- Minimum concentrations -Office area (138 cfu/m^3)

Presence of dampness, moisture and organic food material were found to be the factors responsible for the fungal aerosols load in indoor micro-environments

This study gives an indication of microbial growth in the environment of modern built structures and calls for the need of further studies in various other indoor environments right from individual houses to malls, office/industrial premises. Such studies will help policy makers to formulate air quality standards for bio-aerosols in indoor environments for India.

Sources of Indoor Air Pollution in a Typical Office Building



Building materials as source of IAP

- Building materials are acknowledged as a major emission source of volatile organic compounds (VOCs) indoors (Yang et al., 2001, Xu and Zhang, 2003)
  - very-VOCs (such as formaldehyde),
  - VOCs (such as benzene, fragrance compounds),
  - semi-VOCs (such as PAHs, flame retardants)
- Building materials can also affect the transport of indoor VOCs by its sorption and desorption properties
- Sorption properties of building materials may influence indoor air quality (IAQ) during the entire service life of a building (Nielsen 1987)
- Need to estimate the adsorption and desorption properties of materials to evaluate IAQ.

Chemical Properties of VOCs

- Physiosorption is assumed as dominant mechanism in the surface sorption process
- Forced by Vander Waals interactions including:

  (a) dipole/dipole interactions between polar molecules

  (b) dipole/induced-dipole interactions between polar and nonpolar molecules

  (c) induced-dipole/induced-dipole interactions between non-polar molecules

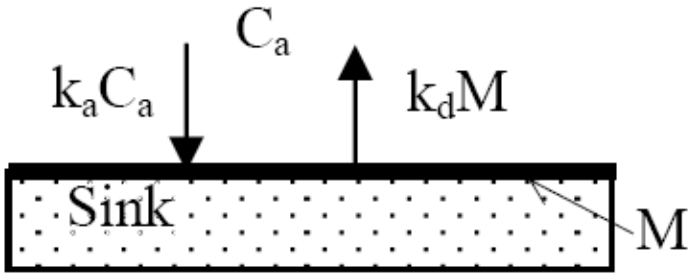
Physical properties of building materials

- Material surface roughness in terms of the specific area (SA), defined as the efficient surface area per gram material (m^2/g).
- Higher the SA- higher will be equilibrium coefficient
- Equivalent area (EqA)= specific area x weight of the sample
- Material loading factor (ratio of the surface area of the material to the volume of the test chamber)

Evaluation of sorption properties of material

Linear Langmuir model

$$dM/dt = k_aC_a - k_dM$$



Where:

dM/dt = Net mass rate of change of VOC adsorbed on the material surface

K_a = VOC adsorption coefficient on material surface (m h^{-1})
C_a = VOC concentrations in the air phase (µg m^{-3})

K_aC_a = VOC adsorption rate on material surface ((µg $m^{-2}hr^{-1}$)

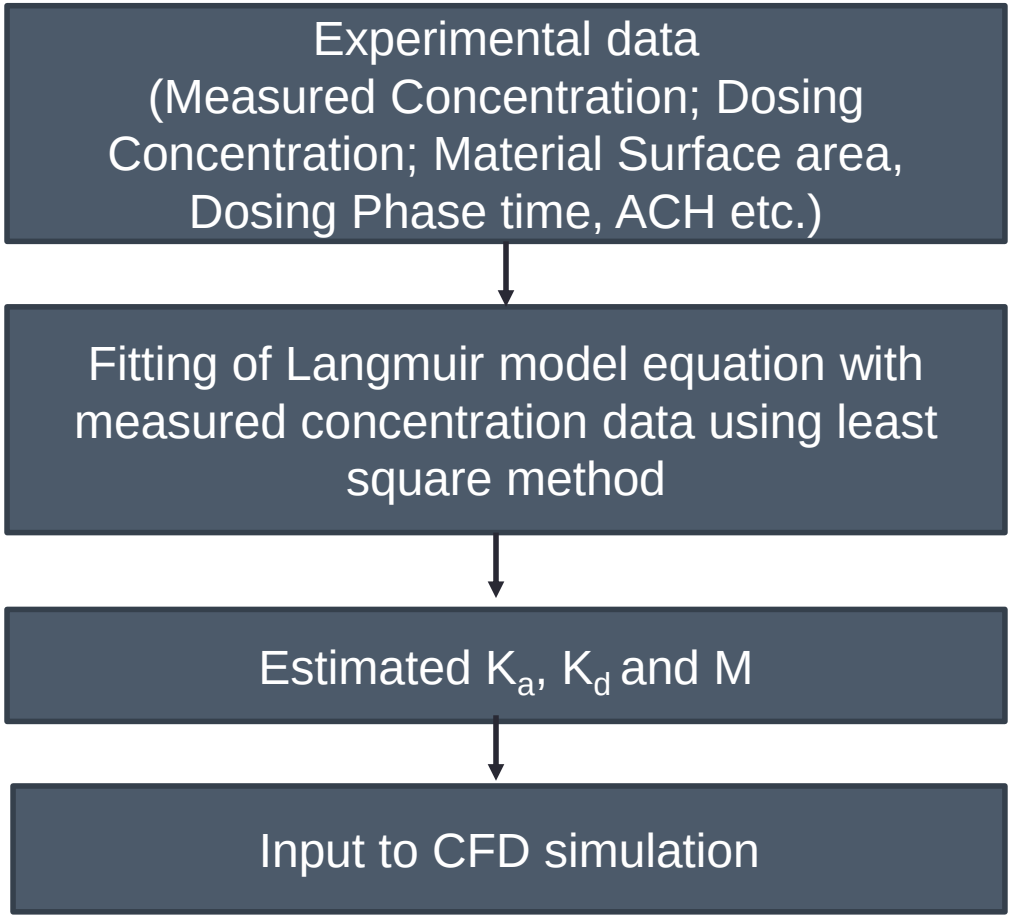
K_d = VOC desorption coefficient from the material surface (h^{-1})
M = VOC concentrations on the air material surface (µg m^{-2})

k_dM = VOC desorption rate from the material surface (µg $m^{-2}hr^{-1}$)

Assumptions/Conditions

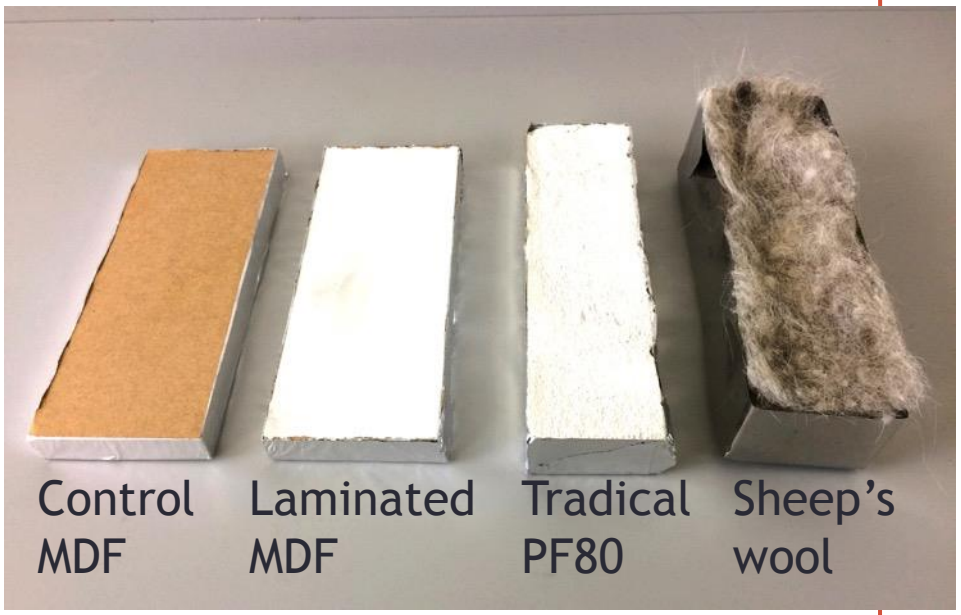
- Reversible exchange of TVOC and formaldehyde, in both air and material phases, following first order rate.
- Process of **Physi-sorption** is being modelled.
- Only surface level adsorption and desorption process is considered in the CFD simulation.
- Diffusion of TVOC and formaldehyde is not considered.
- Only one material at a time is considered for simulation of TVOC and formaldehyde.

Estimation Process*



*Part of EU funded ECO-SEE project: IIT Delhi as one of the partners outside Europe

Specimens studied inn adsorption/desorption experiments*

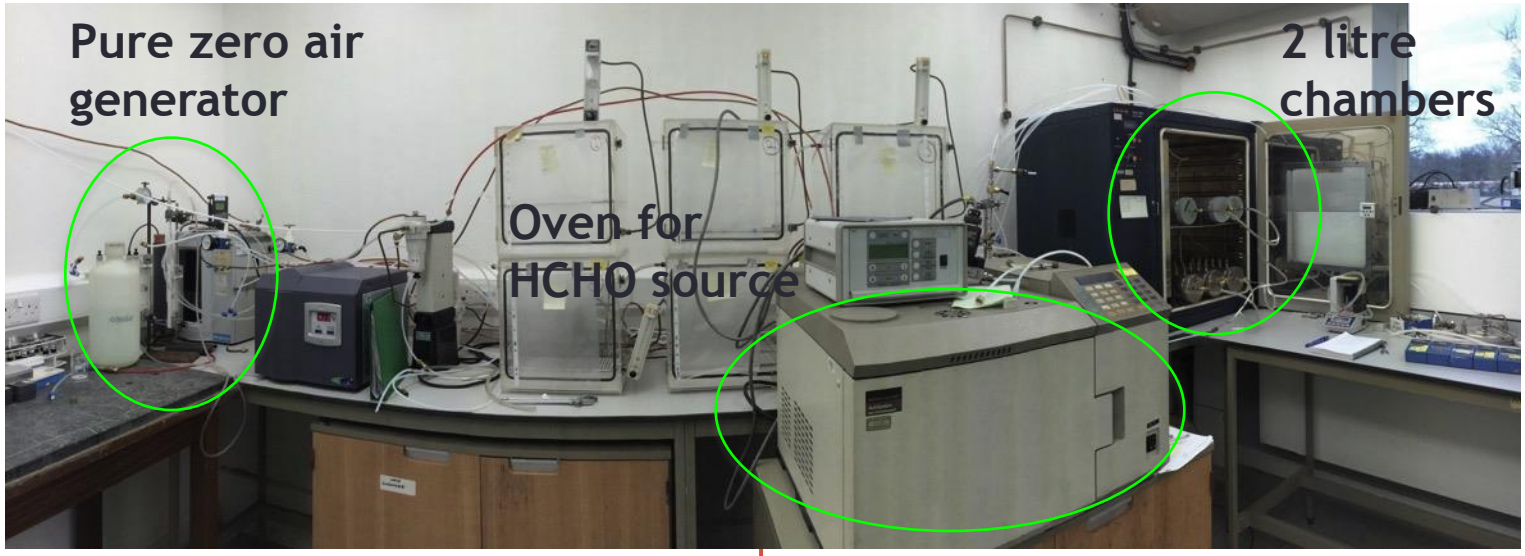


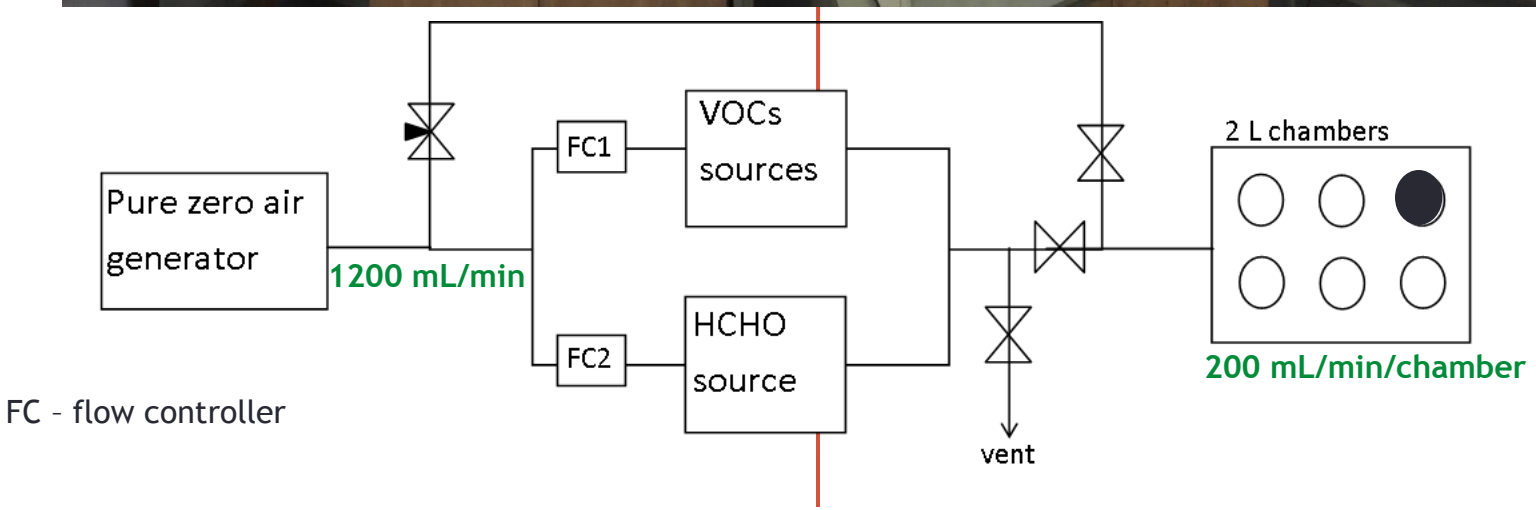
- Specimens enclosed in an aluminium boat
- Exposed area ≈ 0.016 m^2

2 liter chamber at BRE* laboratory, UK

* Partner in ECO-SEE project

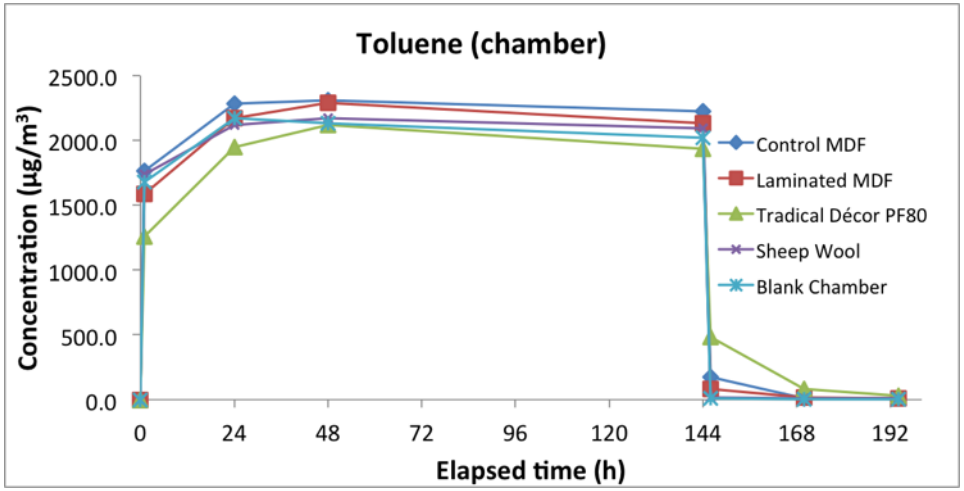
Rig for adsorption/desorption experiments: At BRE laboratory*

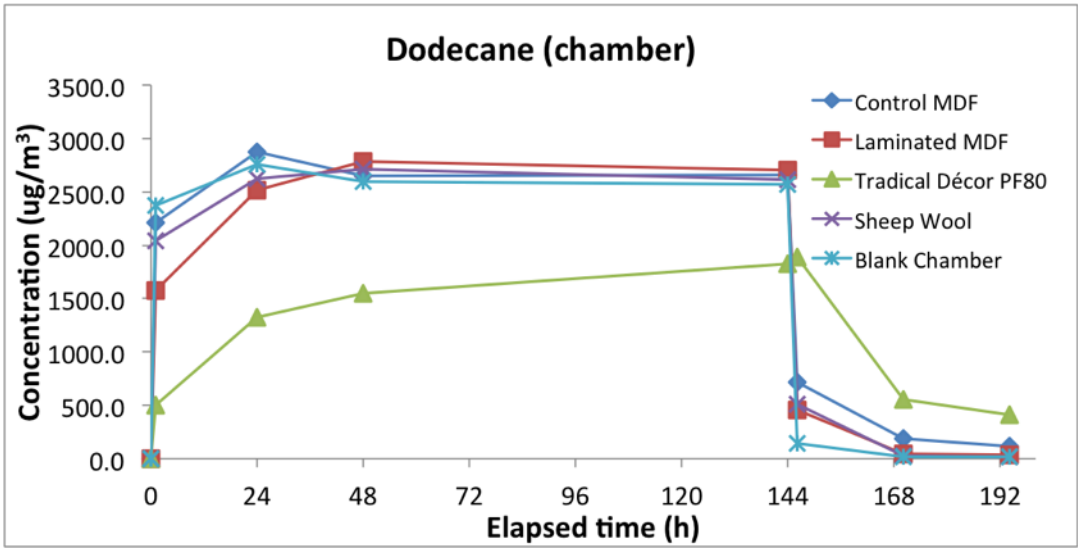




* Partner in ECO-SEE project

Materials adsorption/desorption curves

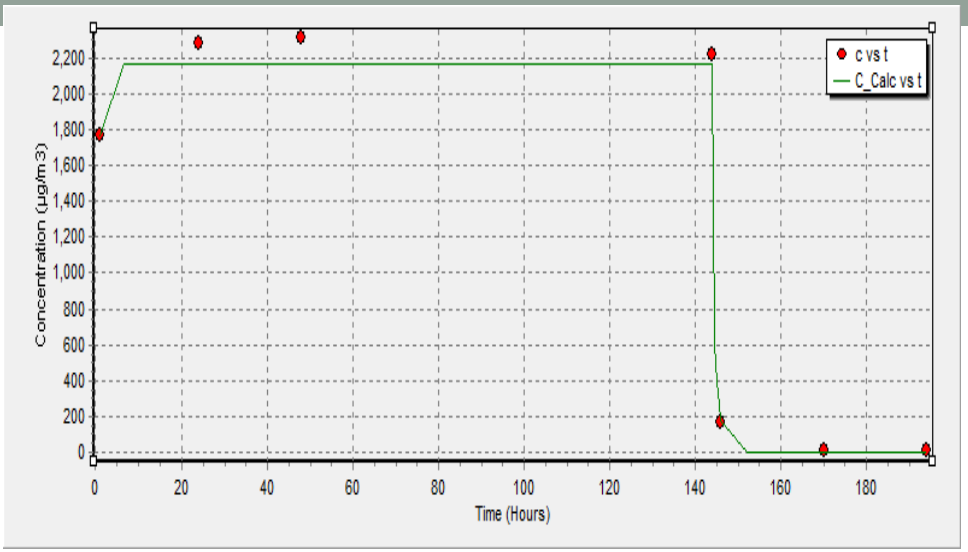




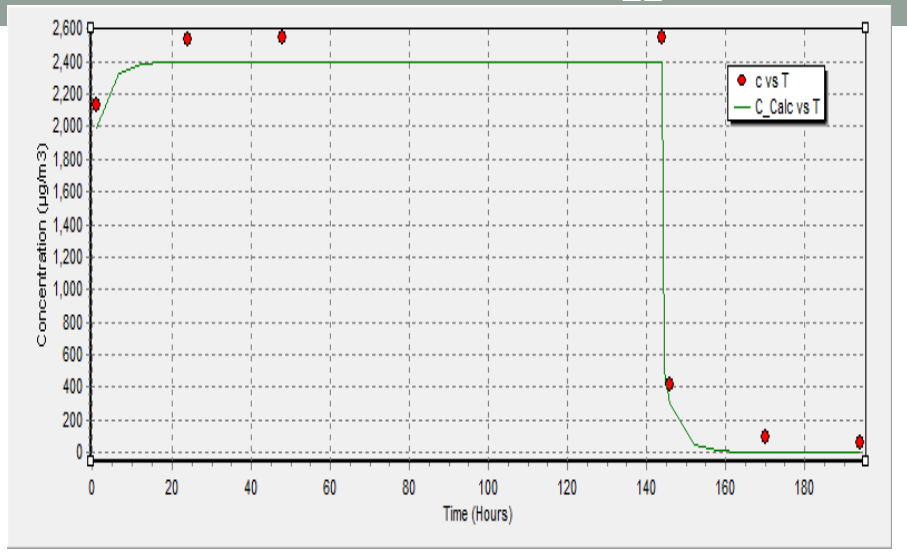
Controlled MDF

Sr. No.	Parameters	Toluene	Limonene	Dodecane	Formaldehyde
1	Chamber Volume, ($V_{0,}$ m^3)	0.002	0.002	0.002	0.002
2	ACH, ($N_{0\ ,}$ 1/h)	6	6	6	6
3	Material Surface Area, ($A_{0\ ,}$ m^2)	0.016	0.016	0.016	0.016
4	Dosing concentration, ($C_{0,}$ µg/m^3)	2169	2397	2754	779
5	Dosing time (T_stop, Hr.)	144	144	144	144

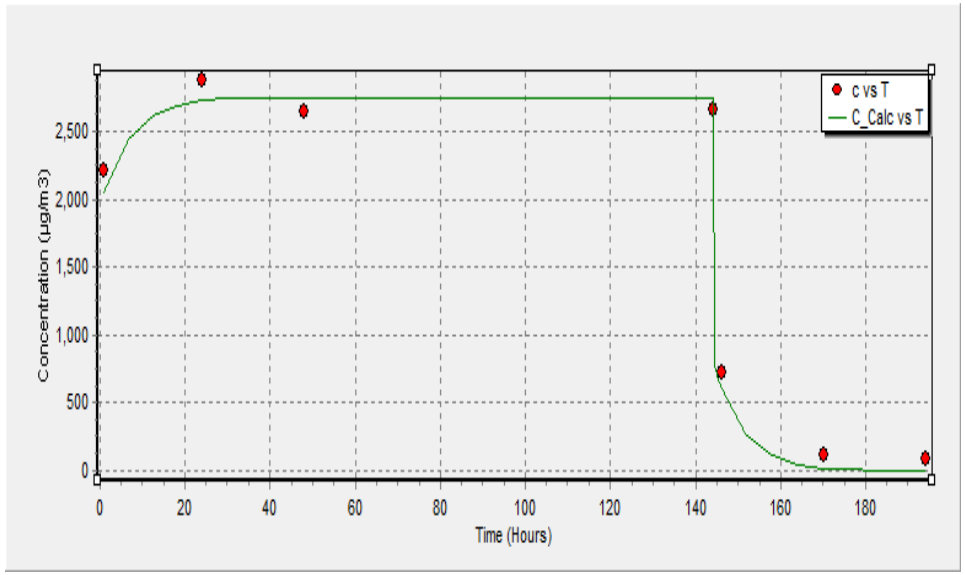
Parameters	Toluene	Limonene	Dodecane	Formaldehyde
K_a	0.398	0.200	0.297	0.904
K_d	1.297	0.382	0.200	0.673



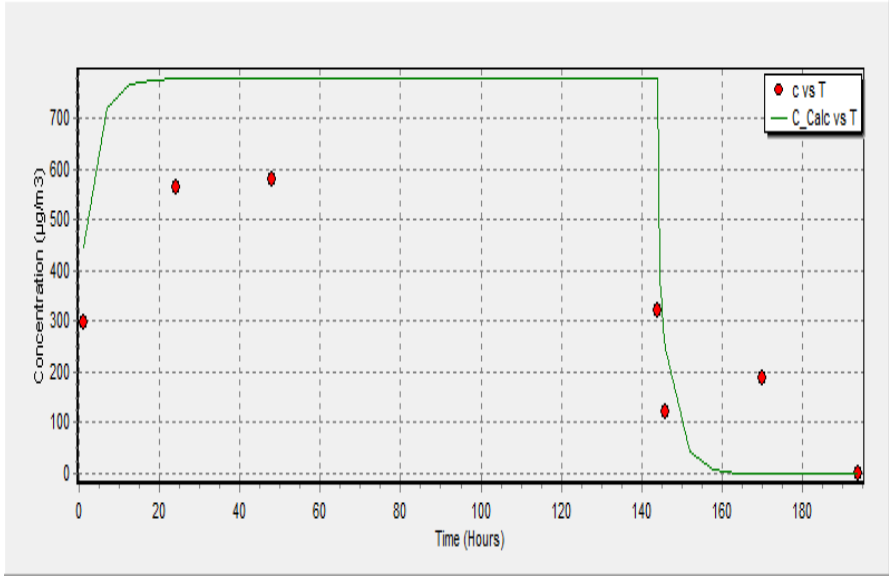
Toluene



Limonene



Dodecane



Formaldehyde

Conclusion

- Air Pollution in Delhi city is increasing gradually from last 15 years.
- PM concentrations were found always higher than standards from last 15 years,
- Sharp increase were observed in NO_x concentration.
- There is not much change in Indoor and outdoor air PM concentrations in Naraina Industrial area
- More the activity more the PM concentration which indicates re-suspension of PM due to movement
- Building materials are one of the major source of VOCs in any building
- It is necessary to evaluate the pollutant adsorption and desorption properties of the any bio-based energy efficient building materials.
- Need to develop a state of art laboratory facilities to test all types of building materials, paints, wall panels etc.
- Use of high adsorbing material for air pollutant should given additional marks for green building rating.

Thanks

ACKNOWLEDGEMENTS

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