Comparative assessment of indoor and outdoor air quality at a semi-urban site in Delhi for observing seasonal variations and potential health effects

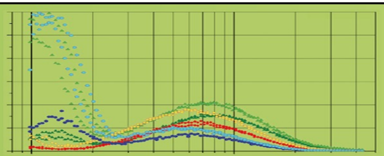
Presentation by:

Anurag Singh Chaudhary

Data Scientist, JunoTerra Technology Private Limited

contact@junoterra.com

21st June, 2022



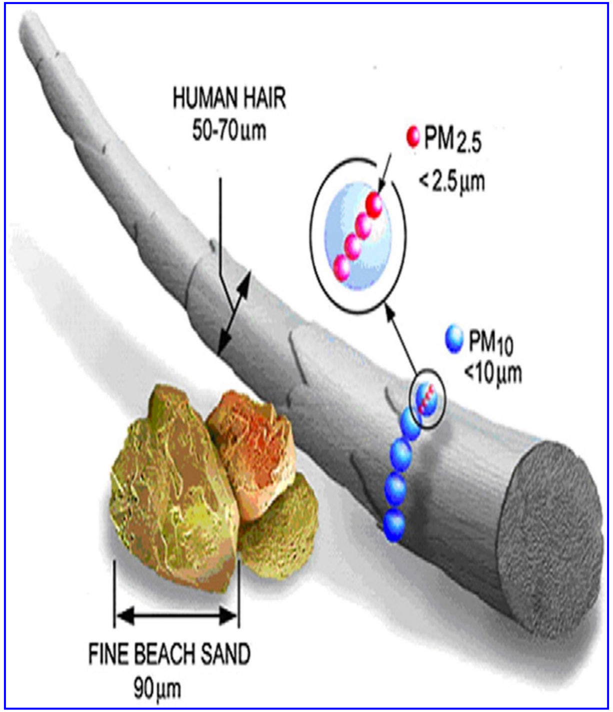
25th ETH-Conference on Combustion Generated Nanoparticles

June 21-23, 2022

PRESENTATION OUTLINE

- Introduction.
- Research Gaps.
- Objectives.
- Methodology.
- Site Inclusion Criteria.
- Device Details.
- Results.
- Potential Health Effects.
- Conclusions.
- Scientific & Social Contribution of this Research.

INTRODUCTION



Source: Guaita et al., 2011

Epidemiological studies:

Air pollution and Ambient PM ~increased hospital admission, morbidity & mortality globally.
(Dockery et al., 1993; Pope et al., 1995, Pope et. al. 2004; Meister et al., 2012; Fang et al., 2013; Bhardawaj et al., 2017a; Bhardawaj et al., 2017b)

Delhi is consistently ranked among the top air polluted cities of the world.
(Bhardawaj et al., 2016)

Global Mortality:

5.5 million people worldwide including 1.4 million in India die prematurely due to fine PM.
(AAAS, 2016).

Outdoor air pollution: 5th largest killer in India.
(Vos et al., 2015)

RESEARCH GAPS

The adverse health effects of Particulate matter and CO have been validated by studies worldwide (Peters et al., 2000; Rich et al., 2005; Liao et al., 2011; Langrish and Mills, 2014; Sade et al., 2014; Pope, 2015)

→ ??

But very few studies has been performed in Delhi, India that compares the concurrent outdoor and indoor air quality levels to relate them both with adverse health effects.

→ ??

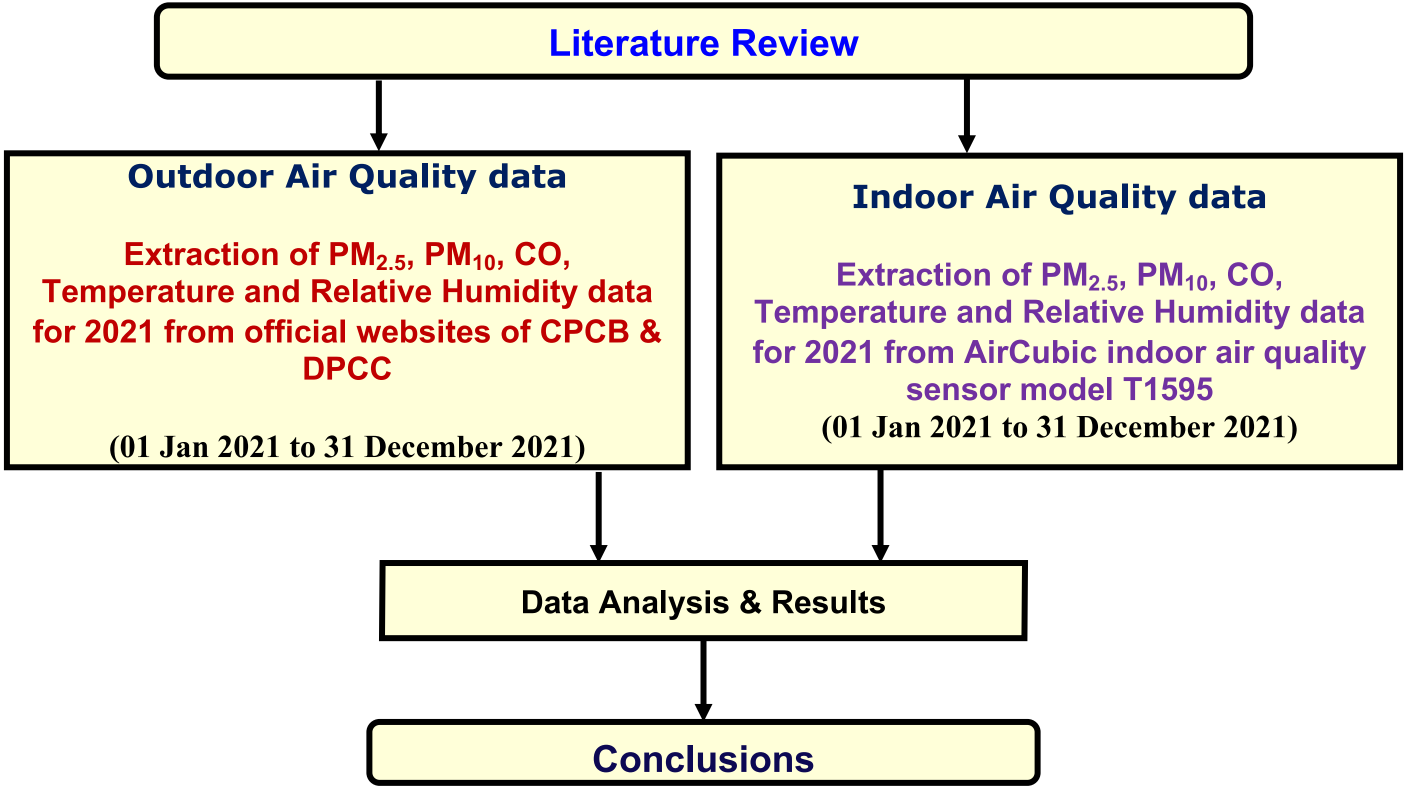
No Risk Assessment model for predicting health effects due to aerosols.

OBJECTIVES

1. To perform a Comparative assessment study of indoor and outdoor air quality at a semi-urban site in Delhi for observing seasonal variations.

1. To predict the potential health effects at the observed air quality levels theoretically using epidemiological formulas.

METHODOLOGY



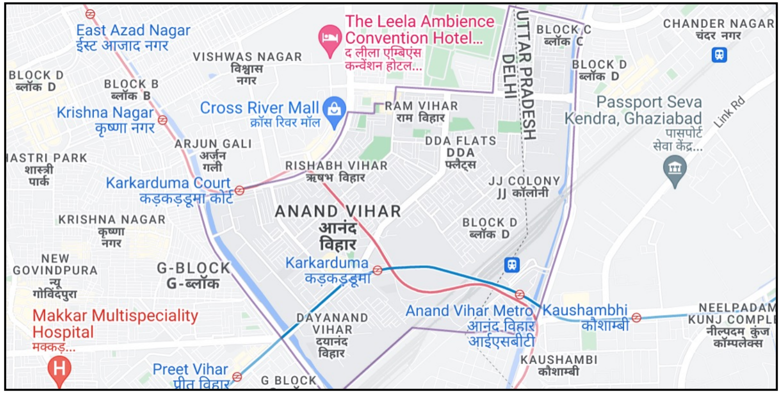
SITE INCLUSION CRITERIA

- The ***location*** selected (i.e. Anand Vihar, Delhi, India) is a ***semi-urban locality*** nearby (within 1 km) an official outdoor air quality monitoring station (28.6502° N, 77.3027° E)

- A total of ***12 houses (Code identified as A, B, C, D, E, F ,G, H, I, J, K, L)*** were selected for indoor air quality monitoring.

- Only those houses were selected that ***did not have any air purifier.***

- The ***owners of the houses*** selected were ***pre-briefed about the research*** and their ***consent taken voluntarily.***



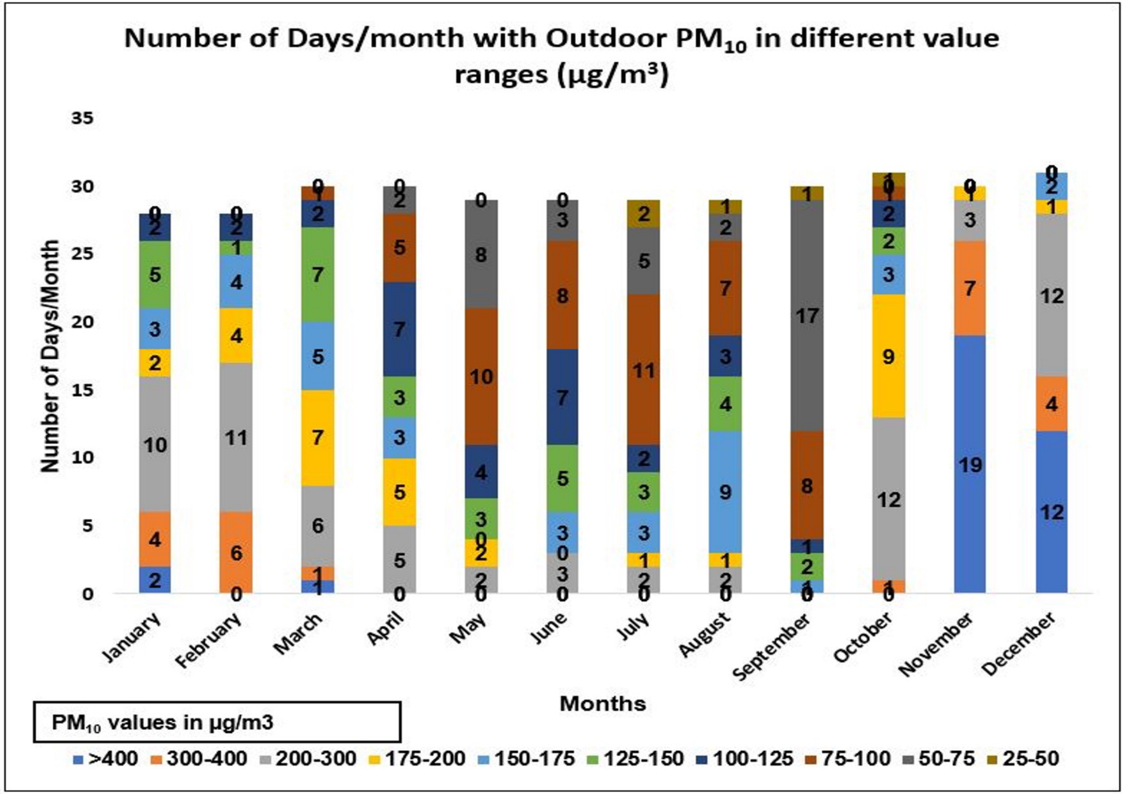
DEVICE DETAILS

- The IoT device used in this experiment i.e. AirCubic indoor air quality sensor model T1595 consists of 5 sensors has been developed by us that extracts continuous values for air quality parameters such as $PM_{2.5}$, PM_{10}, CO_2, VOC, CO, RH, Temperature & Air Pressure at set time intervals from per second to per hour as per study needs. The device also contains a small fan which act as a inlet of the air.

- Of these parameters, $PM_{2.5}$, PM_{10}, CO, RH and Temperature were included in this study recorded at five minute intervals.

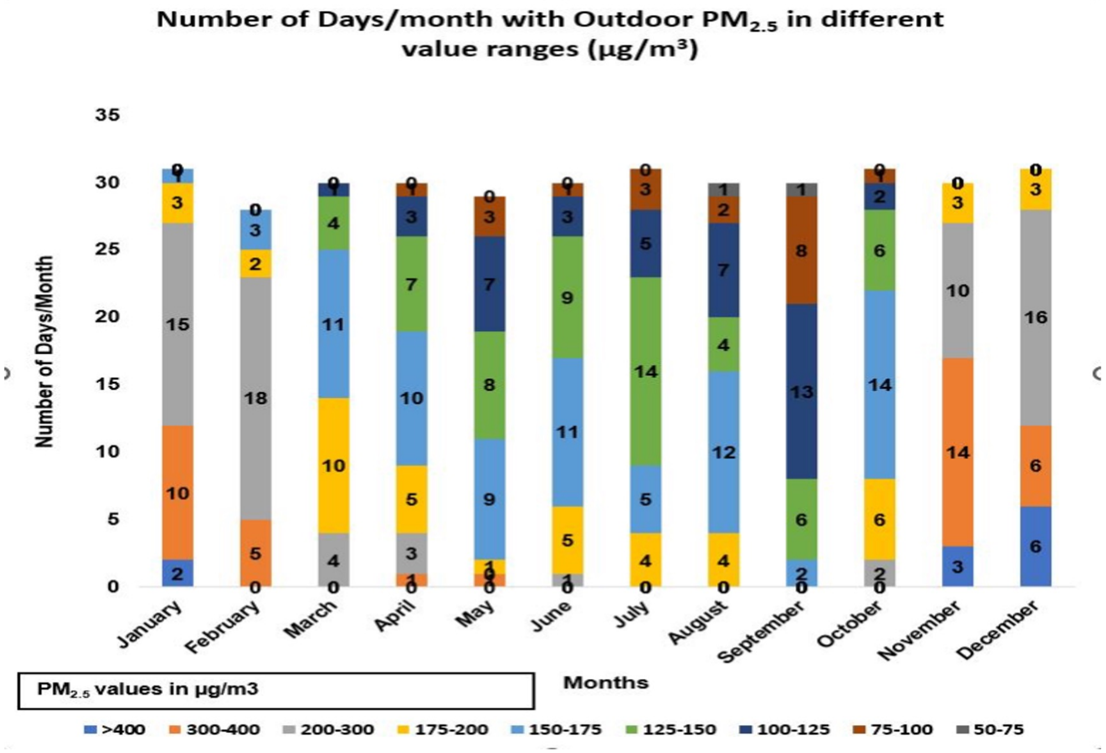
- The IoT device has a built in Microcontroller with Wi-Fi functionality which sends the continuous stream of data to the cloud.

RESULTS



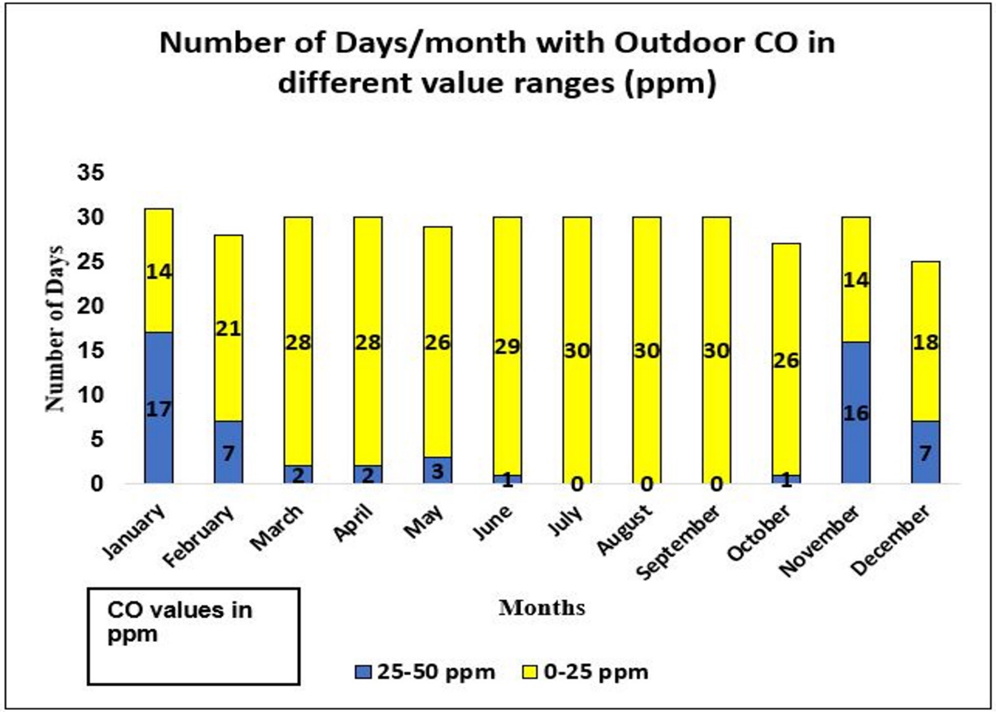
Number of Days/month with Outdoor PM10 in different value ranges (µg/m³)
Number of Days/Month
Months
January
February
March
April
May
June
July
August
September
October
November
December
PM10 values in µg/m3
>400
300-400
200-300
175-200
150-175
125-150
100-125
75-100
50-75
25-50

RESULTS

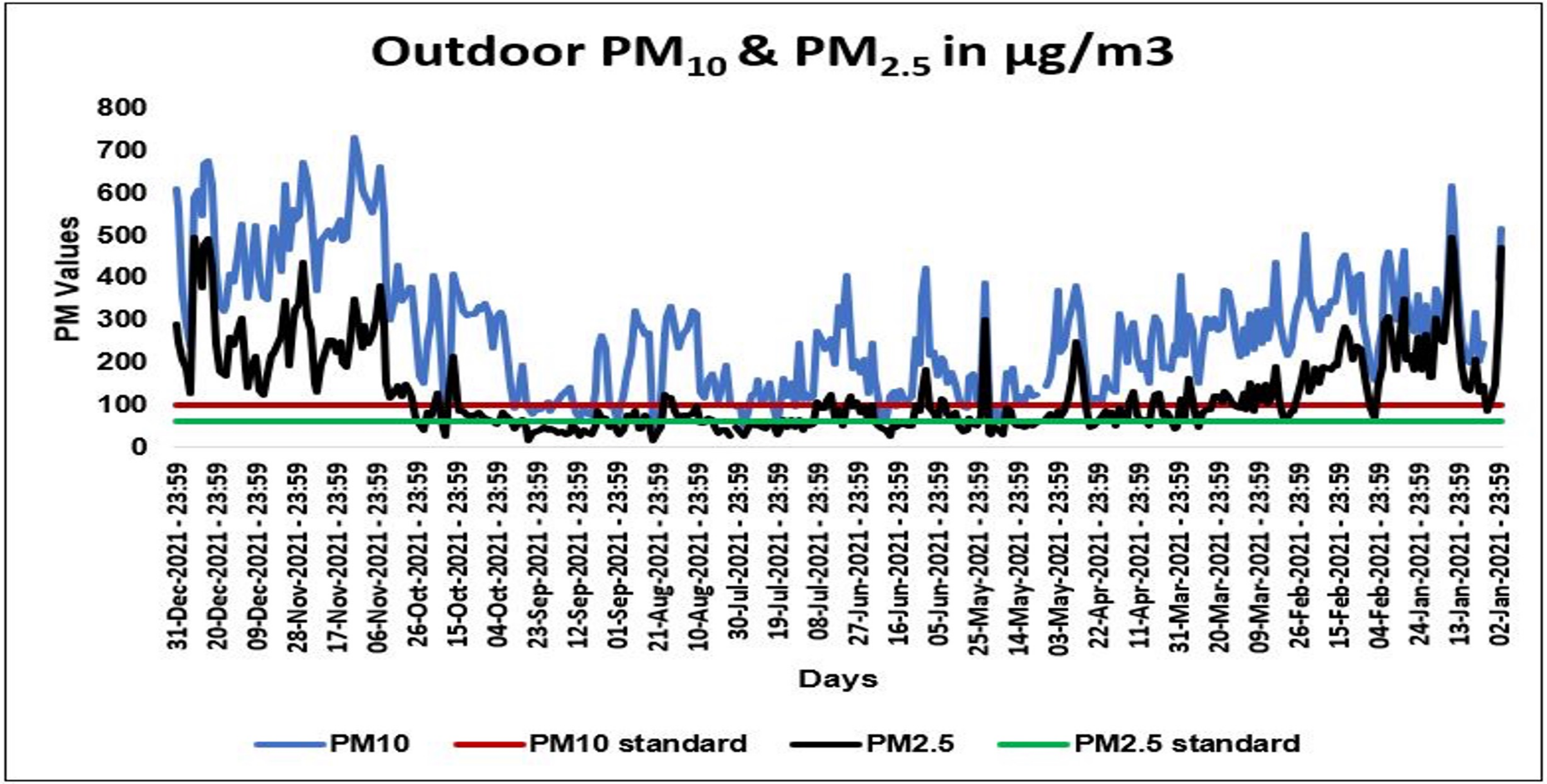


Number of Days/month with Outdoor PM2.5 in different value ranges (µg/m³)
Number of Days/Month
Months
January
February
March
April
May
June
July
August
September
October
November
December
PM2.5 values in µg/m3
>400
300-400
200-300
175-200
150-175
125-150
100-125
75-100
50-75

RESULTS

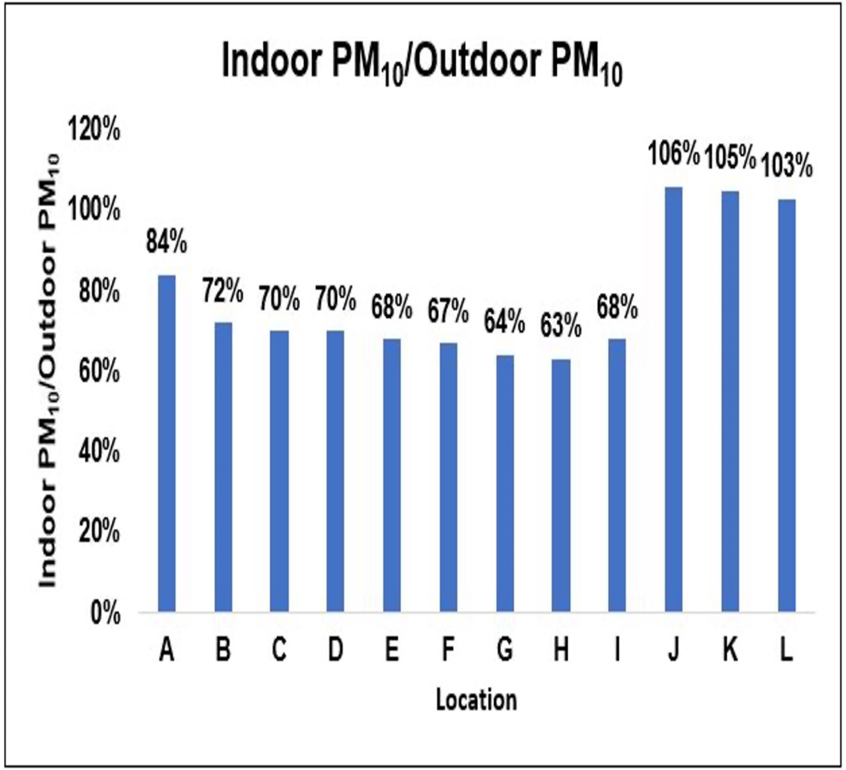

Number of Days/month with Outdoor CO in different value ranges (ppm)
Number of Days
35
30
25
20
15
10
5
0
14
17
21
7
28
2
28
2
26
3
29
1
30
0
30
0
30
0
26
1
14
16
18
7
January
February
March
April
May
June
July
August
September
October
November
December
CO values in ppm
Months
25-50 ppm
0-25 ppm

RESULTS

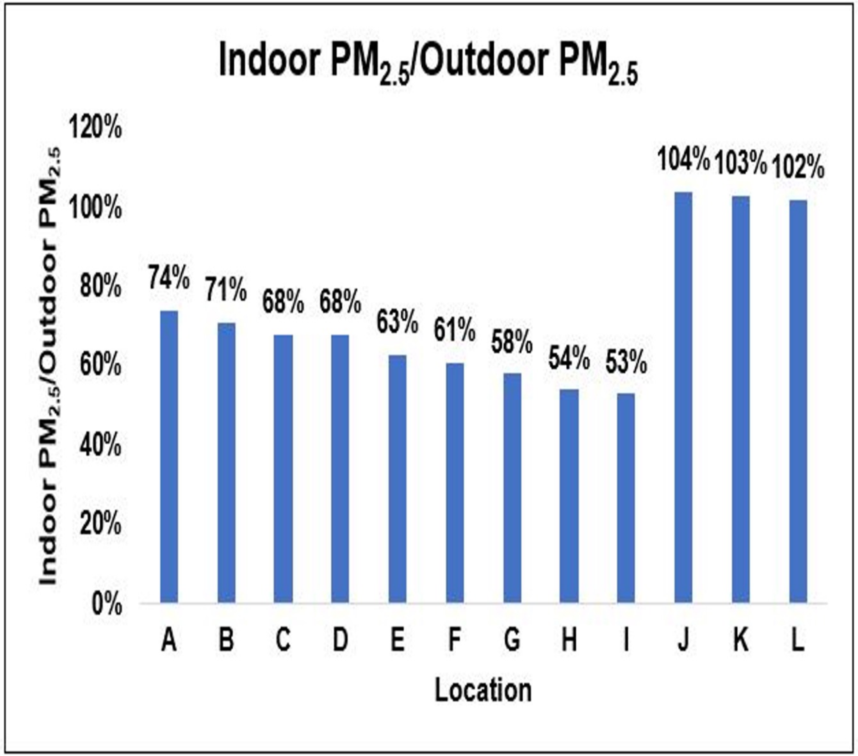


Outdoor PM10 & PM2.5 in µg/m3
800
700
600
500
400
300
200
100
0
PM Values
31-Dec-2021 - 23:59
20-Dec-2021 - 23:59
09-Dec-2021 - 23:59
28-Nov-2021 - 23:59
17-Nov-2021 - 23:59
06-Nov-2021 - 23:59
26-Oct-2021 - 23:59
15-Oct-2021 - 23:59
04-Oct-2021 - 23:59
23-Sep-2021 - 23:59
12-Sep-2021 - 23:59
01-Sep-2021 - 23:59
21-Aug-2021 - 23:59
10-Aug-2021 - 23:59
30-Jul-2021 - 23:59
19-Jul-2021 - 23:59
08-Jul-2021 - 23:59
27-Jun-2021 - 23:59
16-Jun-2021 - 23:59
05-Jun-2021 - 23:59
25-May-2021 - 23:59
14-May-2021 - 23:59
03-May-2021 - 23:59
22-Apr-2021 - 23:59
11-Apr-2021 - 23:59
31-Mar-2021 - 23:59
20-Mar-2021 - 23:59
09-Mar-2021 - 23:59
26-Feb-2021 - 23:59
15-Feb-2021 - 23:59
04-Feb-2021 - 23:59
24-Jan-2021 - 23:59
13-Jan-2021 - 23:59
02-Jan-2021 - 23:59
Days
PM10
PM10 standard
PM2.5
PM2.5 standard

RESULTS

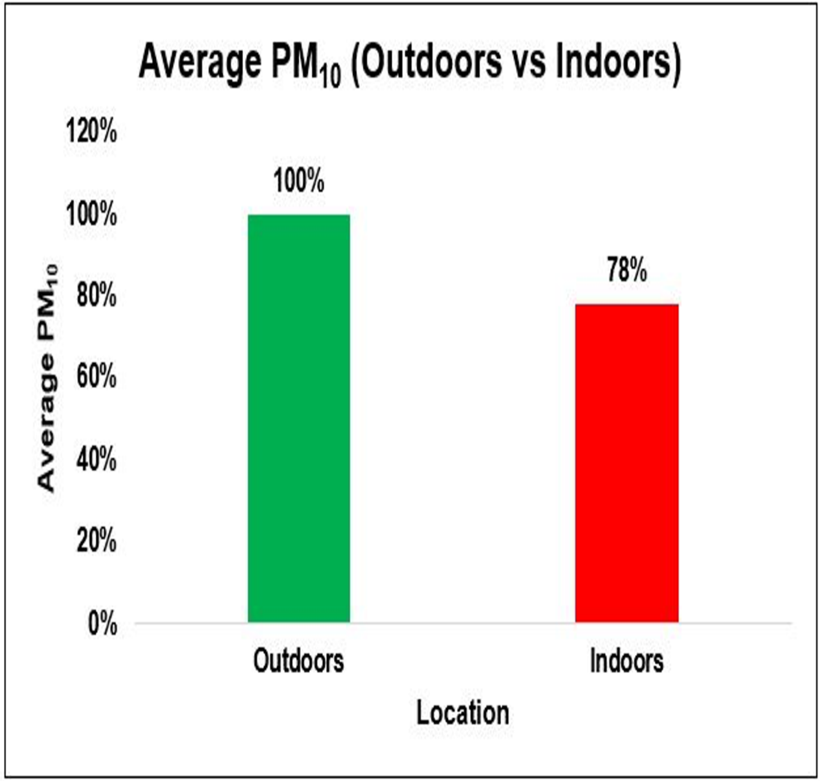


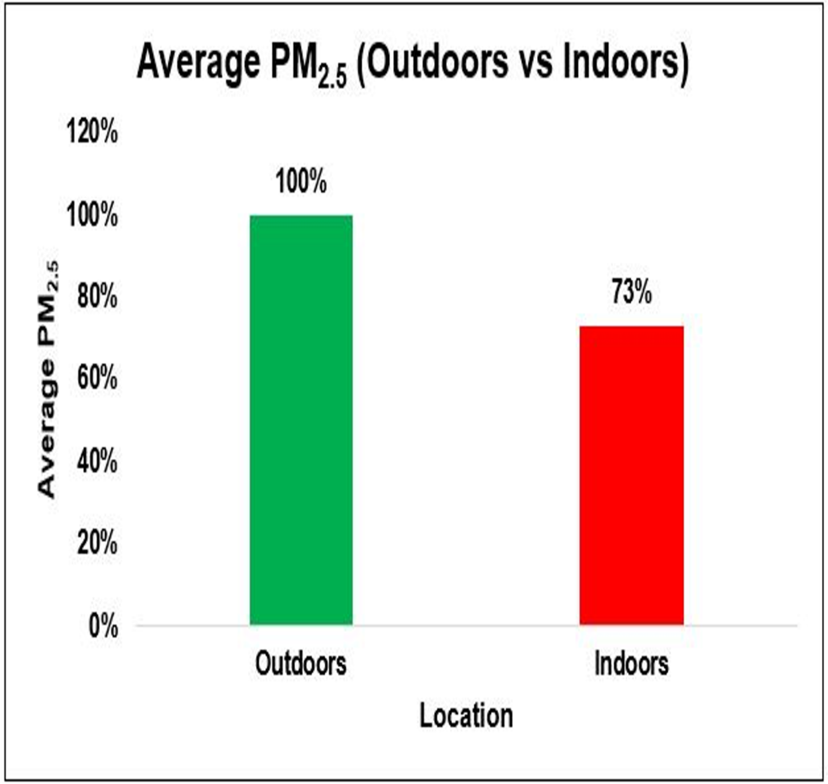
Indoor PM10/Outdoor PM10
Indoor PM10/Outdoor PM10
120%
100%
80%
60%
40%
20%
0%
84%
72%
70%
70%
68%
67%
64%
63%
68%
106%
105%
103%
A
B
C
D
E
F
G
H
I
J
K
L
Location



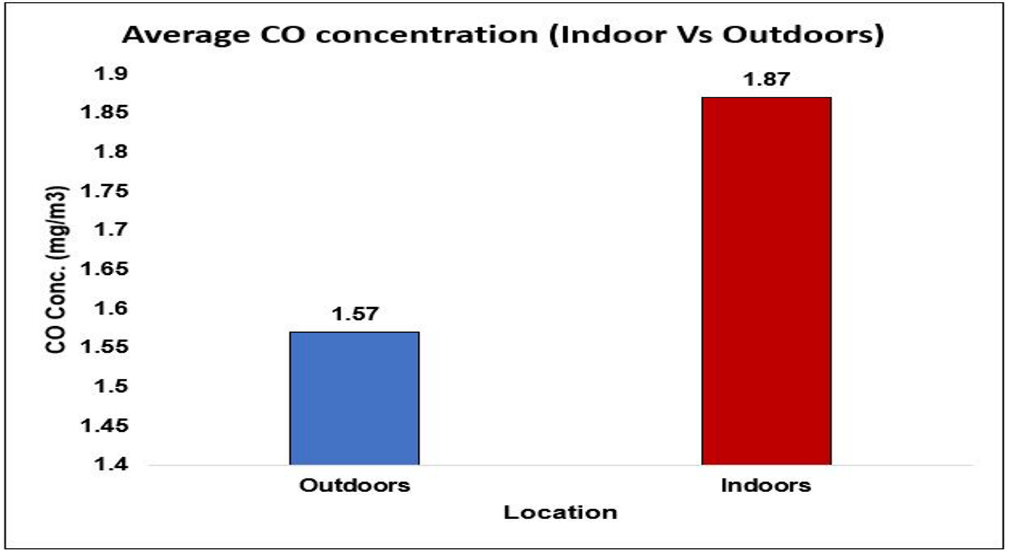
Indoor PM2.5/Outdoor PM2.5
Indoor PM2.5/Outdoor PM2.5
120%
100%
80%
60%
40%
20%
0%
74%
71%
68%
68%
63%
61%
58%
54%
53%
104%
103%
102%
A
B
C
D
E
F
G
H
I
J
K
L
Location

RESULTS


Average PM10 (Outdoors vs Indoors)
120%
100%
80%
60%
40%
20%
0%
Average PM10
100%
78%
Outdoors
Indoors
Location


Average PM2.5 (Outdoors vs Indoors)
120%
100%
80%
60%
40%
20%
0%
Average PM2.5
100%
73%
Outdoors
Indoors
Location

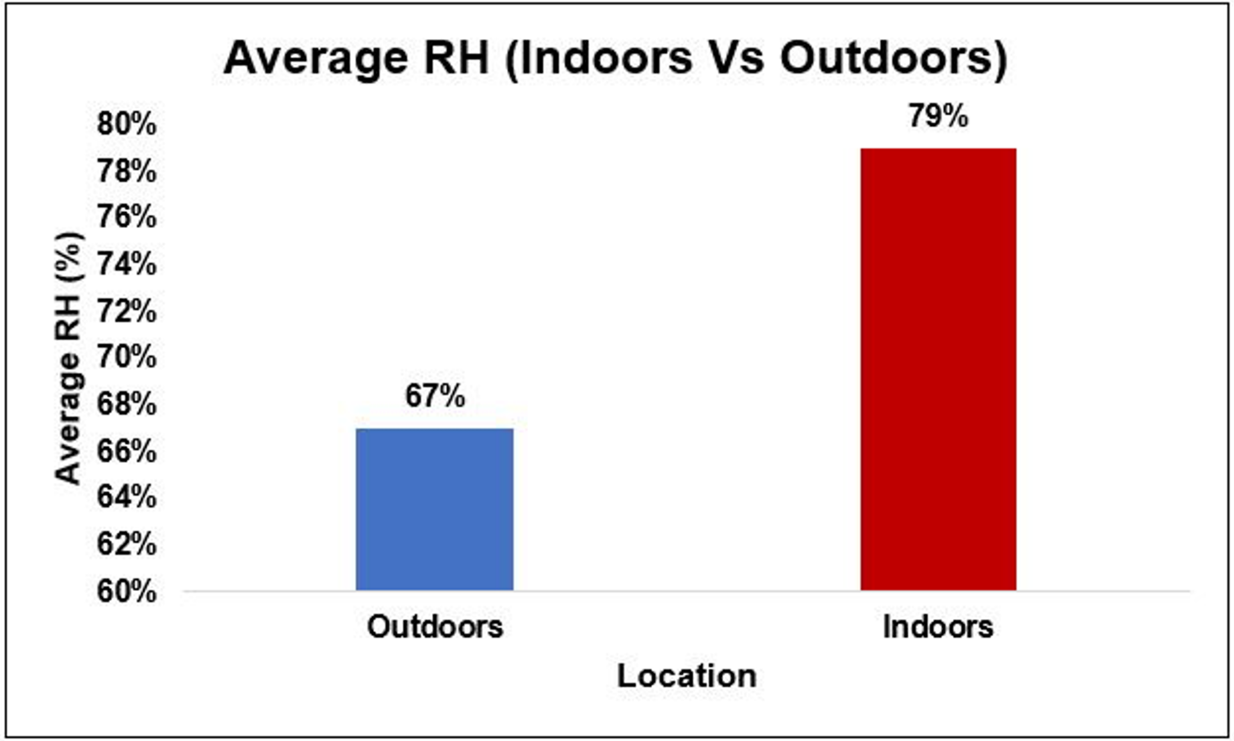
RESULTS



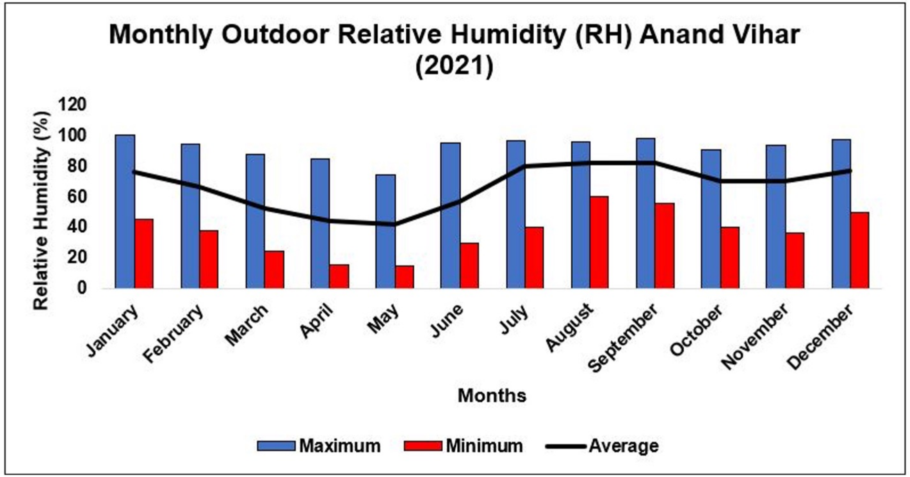
- On an average, the **CO concentration was 1.19 times more indoors than outdoors** at the select locations.

- Primary reason: **Poor ventilation.**

RESULTS


Average RH (Indoors Vs Outdoors)
80%
78%
76%
74%
72%
70%
68%
66%
64%
62%
60%
Average RH (%)
79%
67%
Outdoors
Indoors
Location

RESULTS



- **Annual Average Outdoor RH** in Anand Vihar: **67%** (2021).
- **Annual Average indoor RH** at selected locations: **79%** (2021).
- Outdoor **RH Seasonal Variation** was 42% (Summer) to 82% (Monsoon).
- **Most humid months:** September (82%) & August (81.8%).
- **Least humid months:** May (41.7%) & April (44.4%).

RESULTS

- Relative humidity (RH) affects the natural deposition process of Particulate Matter (PM).
- Moisture particles adhere to PM, accumulating atmospheric PM concentration.
- **With increasing humidity, moisture particles eventually grow in size to a point where 'dry deposition' occurs, reducing PM_{10} concentrations in the atmosphere**.
- This correlates with the air quality observed during the experimental period as the **highest RH values were observed during August & September** that also reported **the lowest PM_{10} concentrations.**

RESULTS

Hazard ratio (HR) [Outdoor]:

$$HRi = Ci/RfCi$$

Where,

HRi: Hazard Ratio

Ci: Average concentration

RfCi: Corresponding reference concentration

Pollutant	Hazard Ratio
PM_{10}	2.744
$PM_{2.5}$	2.147
CO	0.785

Potential Health Effects

- Cardiopulmonary mortality associated with long-term exposure to $PM_{2.5}$ (log - linear exposure) is expressed by the following Relative risk function for >30 years old:

$$RR = [(X + 1)/ (X_0 + 1)]^{\beta}$$

where Suggested β coefficient (95% CI) is 0.15515 (0.0562, 0.2541)

[Pope et al., 2002; Ostro et al., 2004]

X = Current pollutant concentration (μg/m^3)
Xo = target or threshold concentration of pollutant (μg/m^3)
*Recommended relationships assuming background concentration for PM_{10}=10 μg/m^3 and for $PM_{2.5}$=3 μg/m^3

- For Delhi the outdoor $PM_{2.5}$ values have been recorded as high as 999 μg/m^3. The following table presents theoretical RR values based on above formula for different ranges of $PM_{2.5}$ values:

$PM_{2.5}$ value ranges (μg/m^3)	Calculated Theoretical RR Ranges
0-100	**0-1.081**
101-200	**1.081-1.203**
201-300	**1.203-1.286**
301-400	**1.286-1.339**
401-500	**1.339-1.386**
501-600	**1.386-1.426**
601-700	**1.426-1.460**
701-800	**1.460-1.491**
801-900	**1.491-1.518**
901-1000	**1.518-1.543**

RESULTS

- Averaging across all locations, **indoor $PM_{2.5}$ & PM_{10}** in Anand Vihar locality, Delhi were **73% & 78% of outdoor air.**

- The variation in outdoor and indoor air quality parameters varied **more during winters than other seasons.** Hence the role of temperature was quite significant.

- **PM and RH values were less indoors than outdoors** whereas **CO levels were more indoors than outdoors.**

- The **theoretical Relative Risk** of **Cardiopulmonary mortality** associated with **long-term exposure to $PM_{2.5}$** (log - linear exposure) has been calculated & **varies from 0-1.543** for **$PM_{2.5}$ values 0-1000 μg/m^3.**

- In most cases the **values of CO, $PM_{2.5}$ & PM_{10} parameters obtained were above permissible limits** as per Indian & international standards which may lead to chronic and acute negative health effects, morbidity and mortality; if the exposure is for a long duration of time.

CONCLUSIONS

- There is an **urgent need for installing** a huge **web of stationary and mobile air quality monitoring stations** for observing outdoor air quality and compact sensor-based air quality monitoring devices for examining indoor air quality.

- The public in general needs to be educated more about the adverse health effects of pollution and make them understand that ***clean air is not a privilege but a right.***

Scientific & Social contribution of this Research

- It is expected that this research will help **motivate the policy makers**, **government officials** and public in general **to install more indoor air quality sensors** as a necessary health monitoring equipment and **increase the number of outdoor monitoring stations** to help the residents in planning their daily activities as per the prevailing indoor and outdoor air quality **to reduce the exposure to pollutants** and **lead a healthy life.**

References

1. American Thoracic Society, Committee of the Environmental and Occupational Health Assembly, Bascom R, et al. Health effects of outdoor air pollution. Part 2. Am J Respir Crit Care Med 1996a; 153:477–98.
2. Bhardawaj A, Habib G, Kumar A, Singh S, Nema AK. A review of ultrafine particle-related pollution during vehicular motion, health effects and control. J. Environ. Sci. Public Health. 2017;1(04):268-88.
3. Bhardawaj A, Habib G, Singh S. Ambient aerosol induced cardiovascular disease among subjects in monsoon and winter season. In AAAS Annual Meeting, Boston 2017 Feb 16.
4. Bhardawaj A, Habib G, Padhi A, Anand A, Mahala N, Singh BK. Deteriorating air quality and increased health risks in Delhi: The decisions being delayed. IIOAB Journal. 2016;7:10-5.
5. Cropper, M. L., Simon, N.B., Alberini, A., and Sharma P.K. The Health Effects of Air Pollution in Delhi, India. The World Bank Development Research Group Report, December 1997
6. Daniels MJ, Dominici F, Samet JM, et al. Estimating particulate matter-mortality dose-response curves and threshold levels: an analysis of daily time-series for the 20 largest US cities. Am J Epidemiol 2000; 152:397–406
7. Dominici, F., Daniels, M., Zeger, S.L. and Samet, J.M. Air Pollution and Mortality: Estimating Regional and National Dose–Response Relationships. American Statistical Association, Journal of the American Statistical Association, 2002, Vol. 97, No. 457.
8. http://www.dpccairdata.com/dpccairdata/display/AallStationView5MinData.php?stName=QW5hbmRWaWhhcg==
9. Hou et. al., An assessment of China's PM10-related health economic losses in 2009, Science of the Total Environment 435–436 (2012) 61–65
10. https://aqicn.org/city/delhi/anand-vihar
11. Newby et.al., Expert position paper on air pollution and cardiovascular disease, European Heart Journal, 2015; 1-13.
12. Lim et. al., A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 2012;380:2224–2260.
13. Mills et. al., Adverse cardiovascular effects of air Pollution, Nature clinical practice (Cardiovascular medicine), January 2009, Vol. 6 No. 1, 36-44
14. Pope et. al., Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. Circulation 2004;109:71 –77.

Thank You