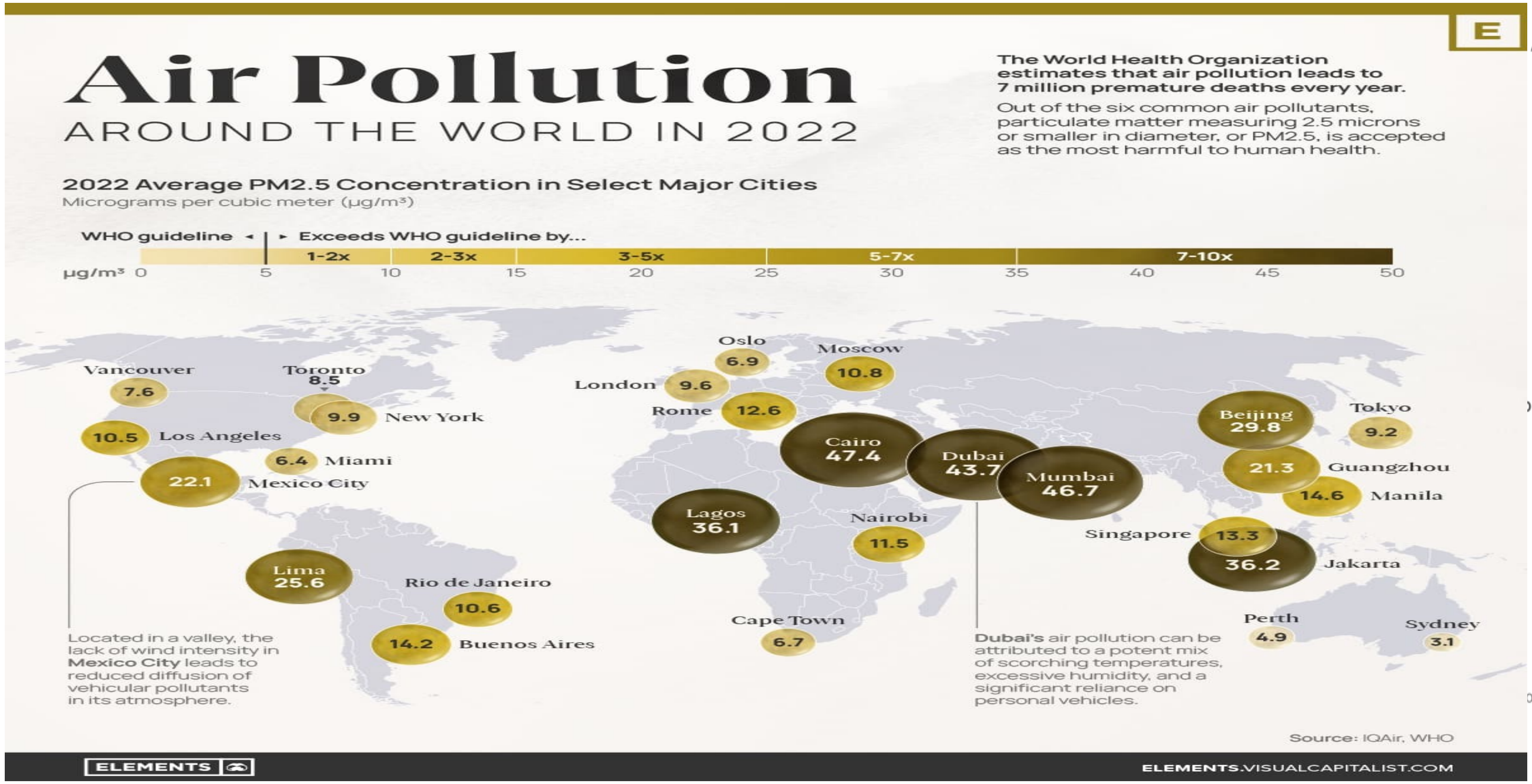
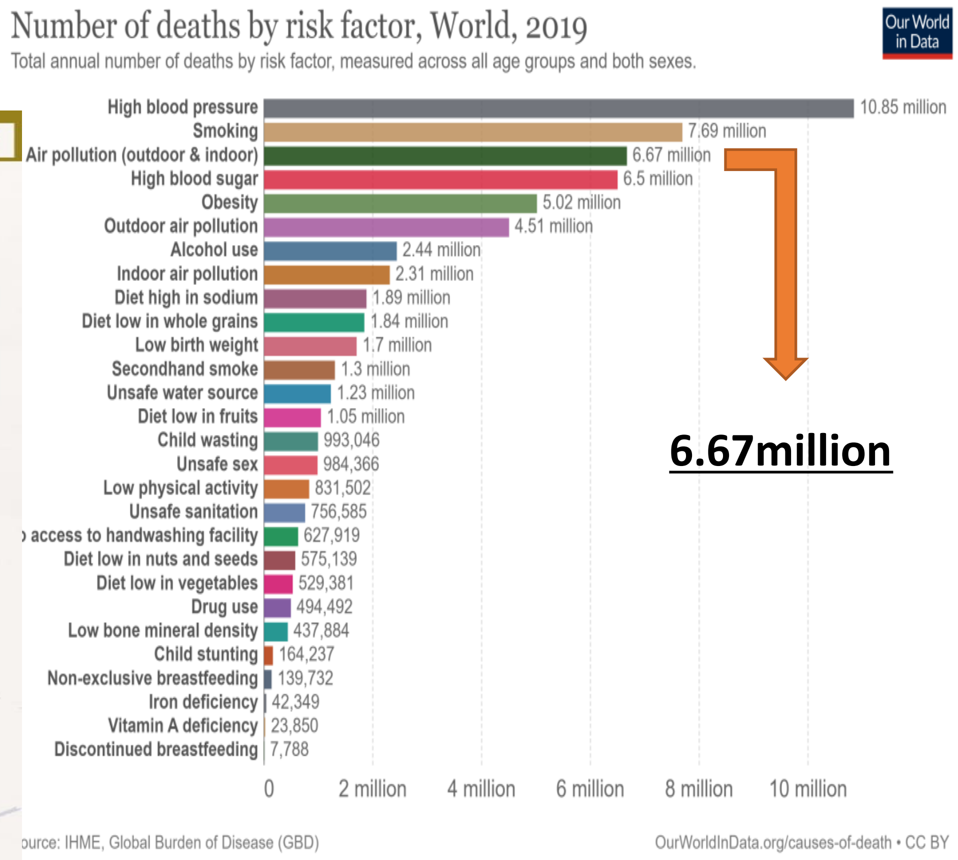
27th ETH-Nanoparticles Conference (NPC-24) and Aerosols-24 Conference
June 10 – 14, 2024, Zurich, Switzerland

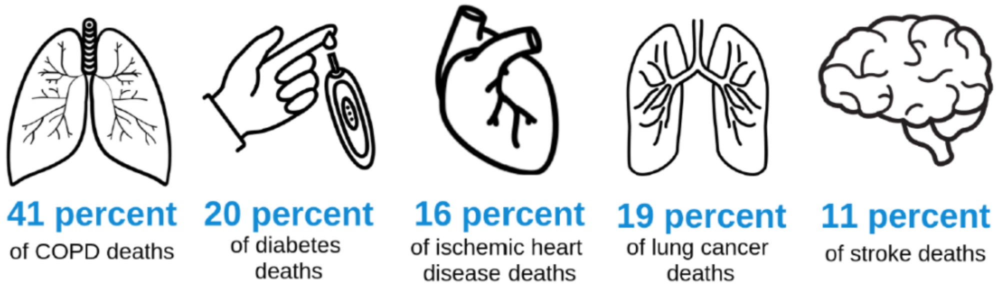
Distribution Assessment and Source apportionment of Particulate bound-PAHs in Indoor Air of south Asian precinct using IDW and PMF receptor model: *A comprehensive study*

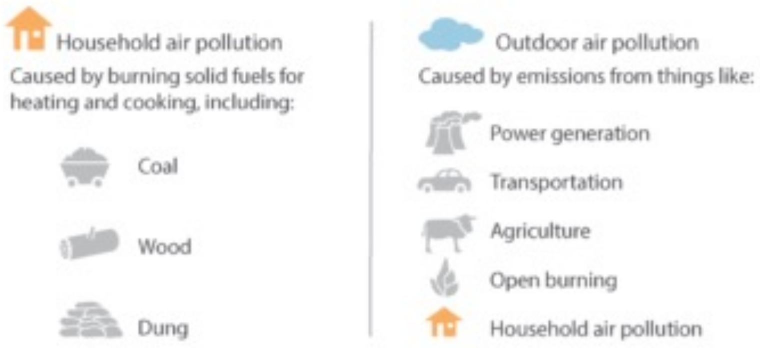
Alfred Lawrence
Department of Chemistry, Isabella Thoburn College, Lucknow, India

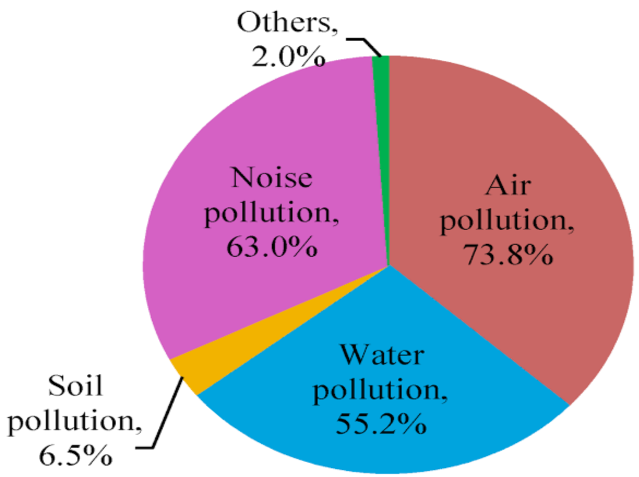
GLOBAL BURDEN OF AIR POLLUTION











ASIA

EUROPE

AMERICA

AFRICA

ASIA

EUROPE

AMERICA

AFRICA

520 Million children live in areas where outdoor air pollution exceeds international limits.

370 Million children live in areas where outdoor air pollution exceeds 2 times international limits.

60 Million children live in areas where outdoor air pollution exceeds 4 times international limits.

<1 Million children live in areas where outdoor air pollution exceeds 6 times international limits.

*https://www.who.int/health-topics/child-health#tab=tab_1

ASIA

EUROPE

130 Million children live in areas where outdoor air pollution exceeds international limits.

20 Million children live in areas where outdoor air pollution exceeds 2 times international limits.

1 Million children live in areas where outdoor air pollution exceeds 4 times international limits.

<1 Million children live in areas where outdoor air pollution exceeds 6 times international limits.

AMERICA

AFRICA

*https://www.who.int/health-topics/child-health#tab=tab_1

120 Million children live in areas where outdoor air pollution exceeds international limits.

20 Million children live in areas where outdoor air pollution exceeds 2 times international limits.

ASIA

EUROPE

AMERICA

AFRICA

1 Million children live in areas where outdoor air pollution exceeds 4 times international limits.

<1 Million children live in areas where outdoor air pollution exceeds 6 times international limits.

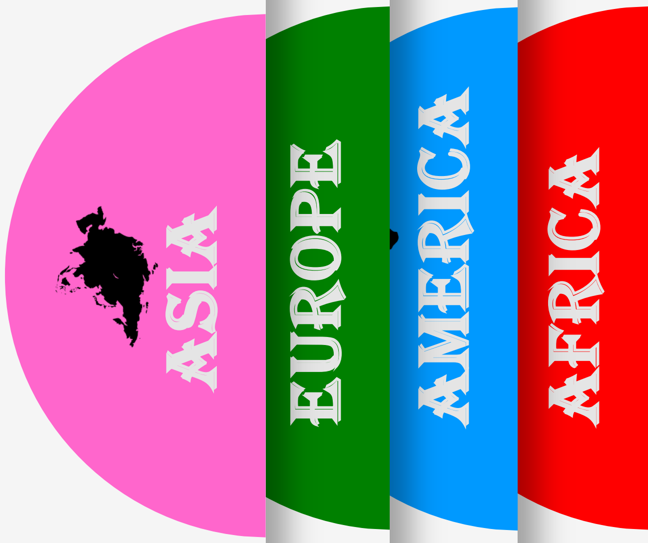
*https://www.who.int/health-topics/child-health#tab=tab_1

1.22 Billion children live in areas where outdoor air pollution exceeds international limits.

1.08 Billion children live in areas where outdoor air pollution exceeds 2 times international limits.

660 Million children live in areas where outdoor air pollution exceeds 4 times international limits.

300 Million children live in areas where outdoor air pollution exceeds 6 times international limits.



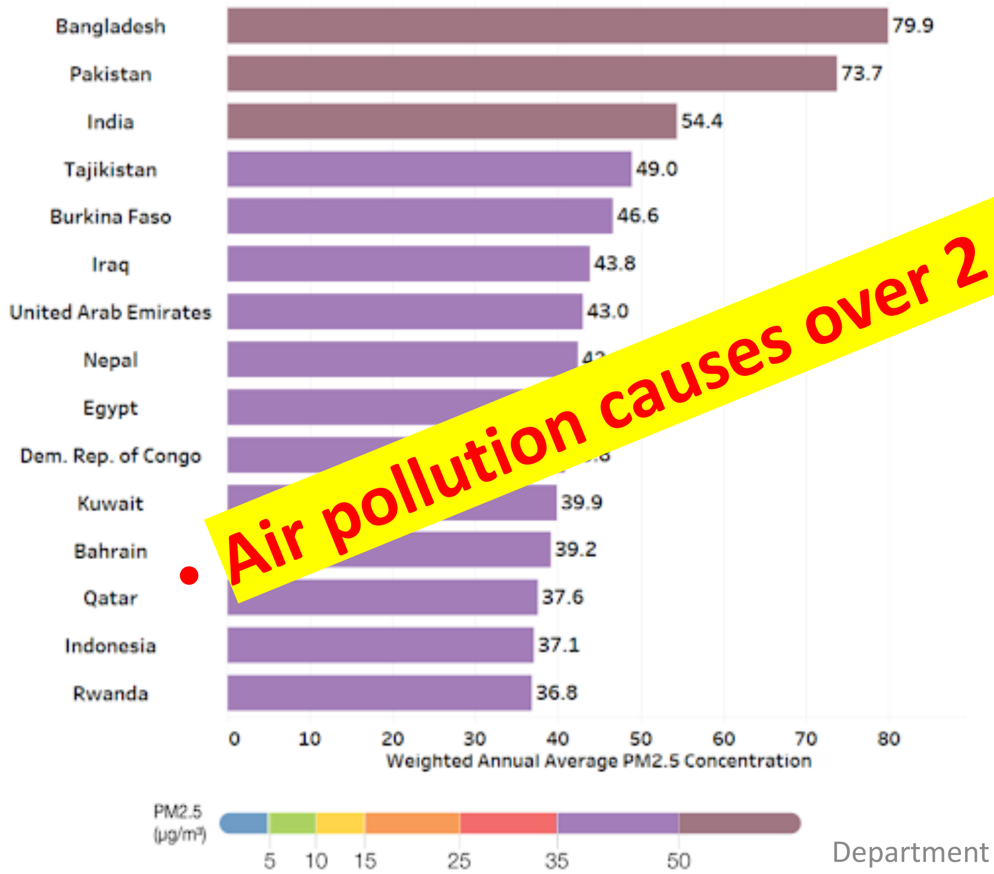
ttps://www.who.int/health-topics/child-health#tab=tab_1

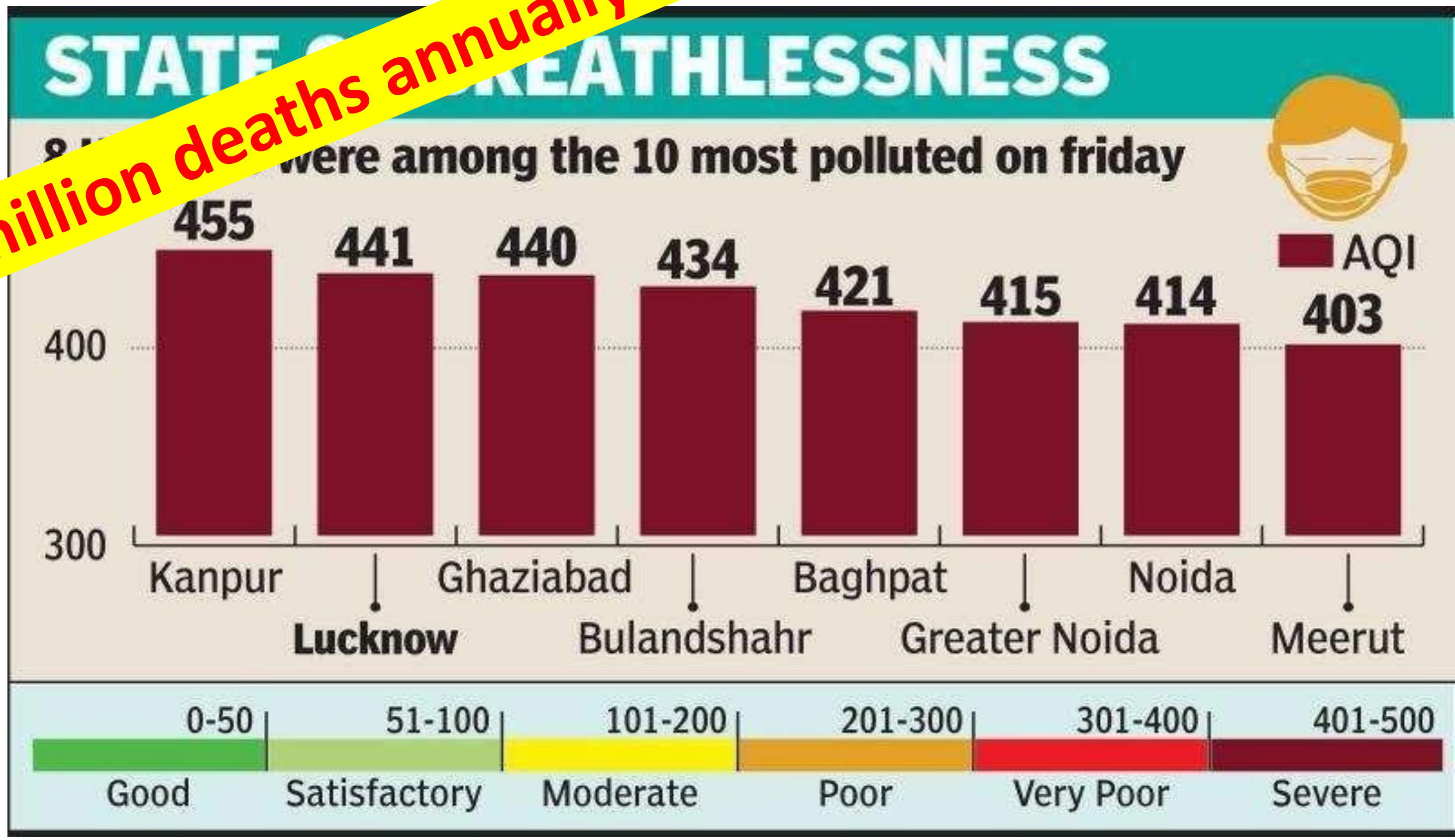
INDIA'S Storyline

1. This report, published by IQAir, which tracks air quality worldwide, reveals that a staggering 83 of these cities were situated in India, surpassing the World Health Organization's air quality guidelines by over tenfold.
2. The 6th Annual World Air Quality Report finds New Delhi to be the most polluted capital city in the world.
3. Delhi's air pollution problems often receive global attention, but Lucknow's (Capital city of the most populated state) air quality often ranks among the world's worst.

- Air pollution causes over 2 million deaths annually in India: BMJ study

Most Polluted Countries in the World in 2023





Indoor Air Pollution:
the silent killer

- India has topped a global indoor air pollution chart with the highest average annual PM2.5 levels followed by China, Turkey, UAE and South Korea.

Indoor Environment

Most Vulnerable

1

CHILDREN

The lungs and respiratory system of young children remains in developing phase as a result more inhalation of air per mass. Further, their organs are more susceptible to pollutant impacts.

2

Women and Girls

The inferior status of women is entrenched from ages. Women being the home-maker in majority of Indian households are widely exposed to air pollutants.

INDOOR ENVIRONMENT

Cooking

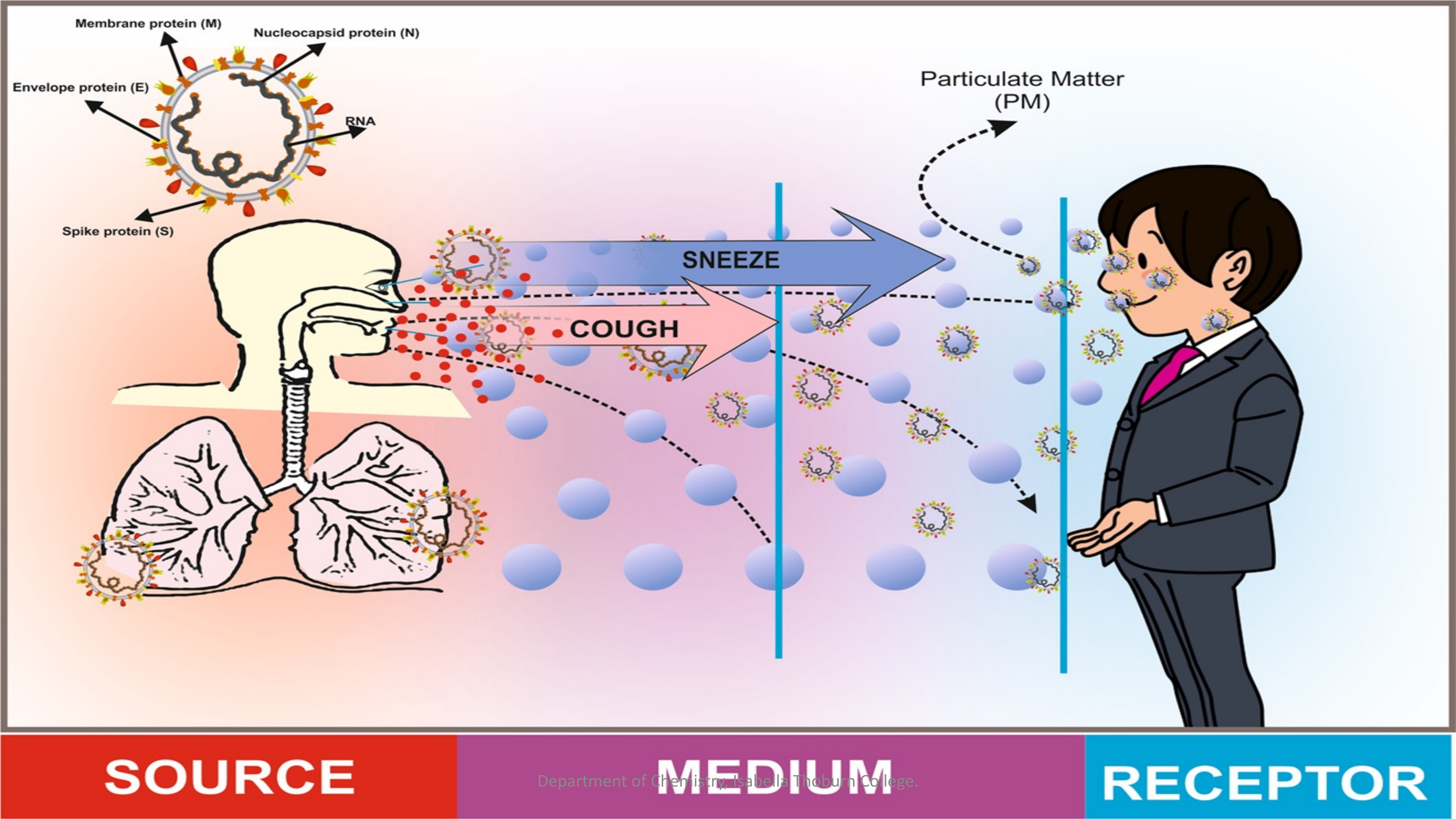
Schools

Homes

Hospitals

Workplaces

Closed public Vehicles


Membrane protein (M)
Nucleocapsid protein (N)
Envelope protein (E)
RNA
Spike protein (S)
Particulate Matter (PM)
SNEEZE
COUGH
SOURCE
MEDIUM
RECEPTOR

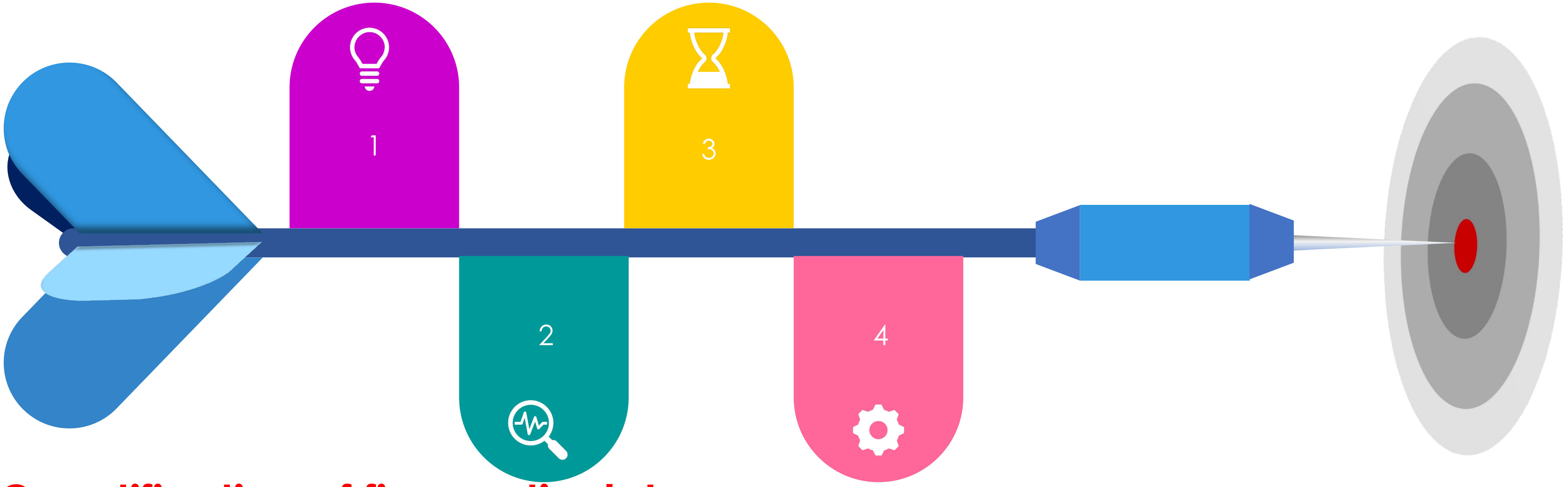
OBJECTIVES

Selection of microenvironments

Quantification of fine particulate matter in all three season namely winter , summer and monsoon in indoor air of Lucknow city.

Analysis of PM-bound Polycyclic aromatic hydrocarbons using GC-MS.

Health risk assessment using statistical and computational models.



Indoor Air Quality and its Health Impact on Children: A Survey

All personal information will remain anonymous & no personal or identifying information from the survey will be shared on any platform.

The information collected from this survey will be only used by students/teachers for research purpose.

We would appreciate your views/comments about the Indoor air quality & its possible health outcomes on your child .We would be grateful if you can give your precious 5 minutes in filling & submitting this survey.

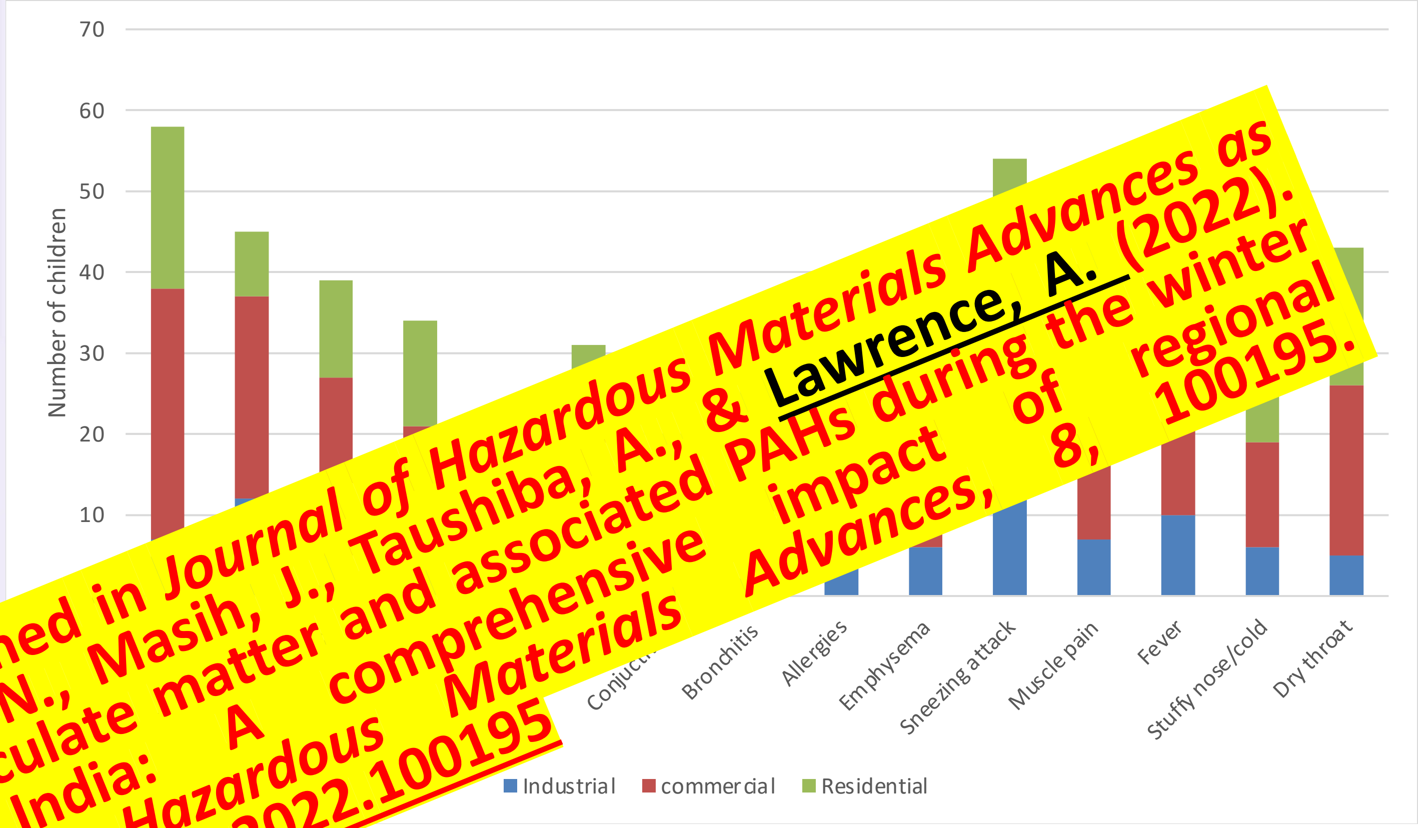
Note: The survey is conducted by Department of Chemistry, Isabella Thoburn College, Lucknow.

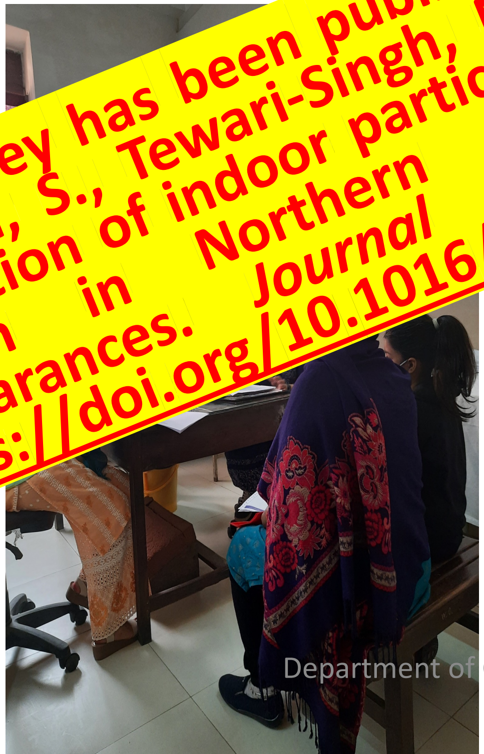
Child's Name *

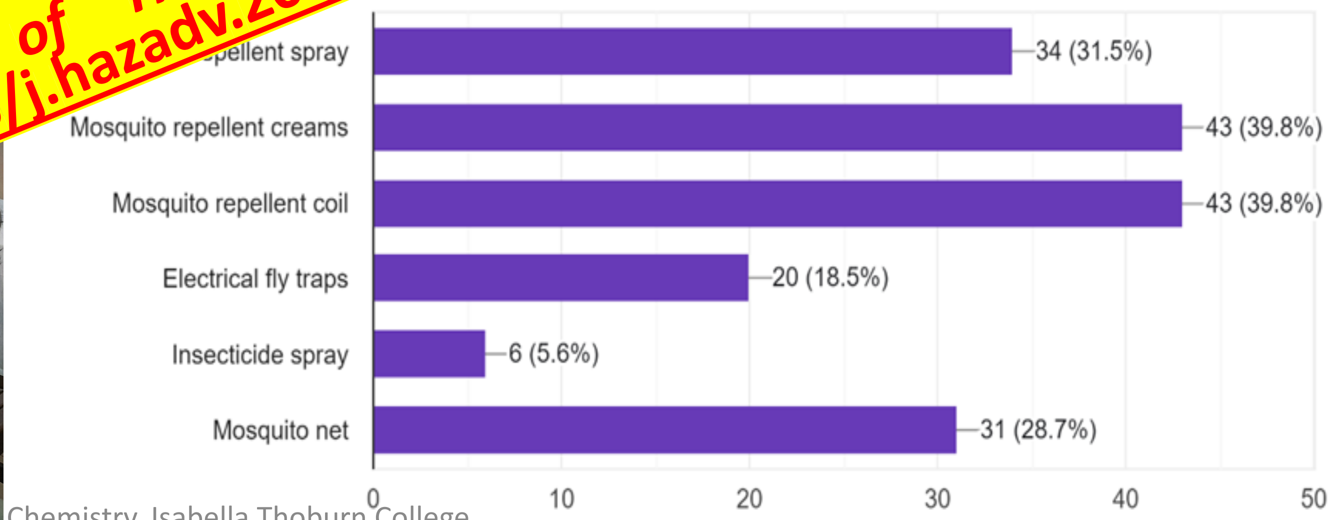
Short-answer text

Child's Age *

Short-answer text





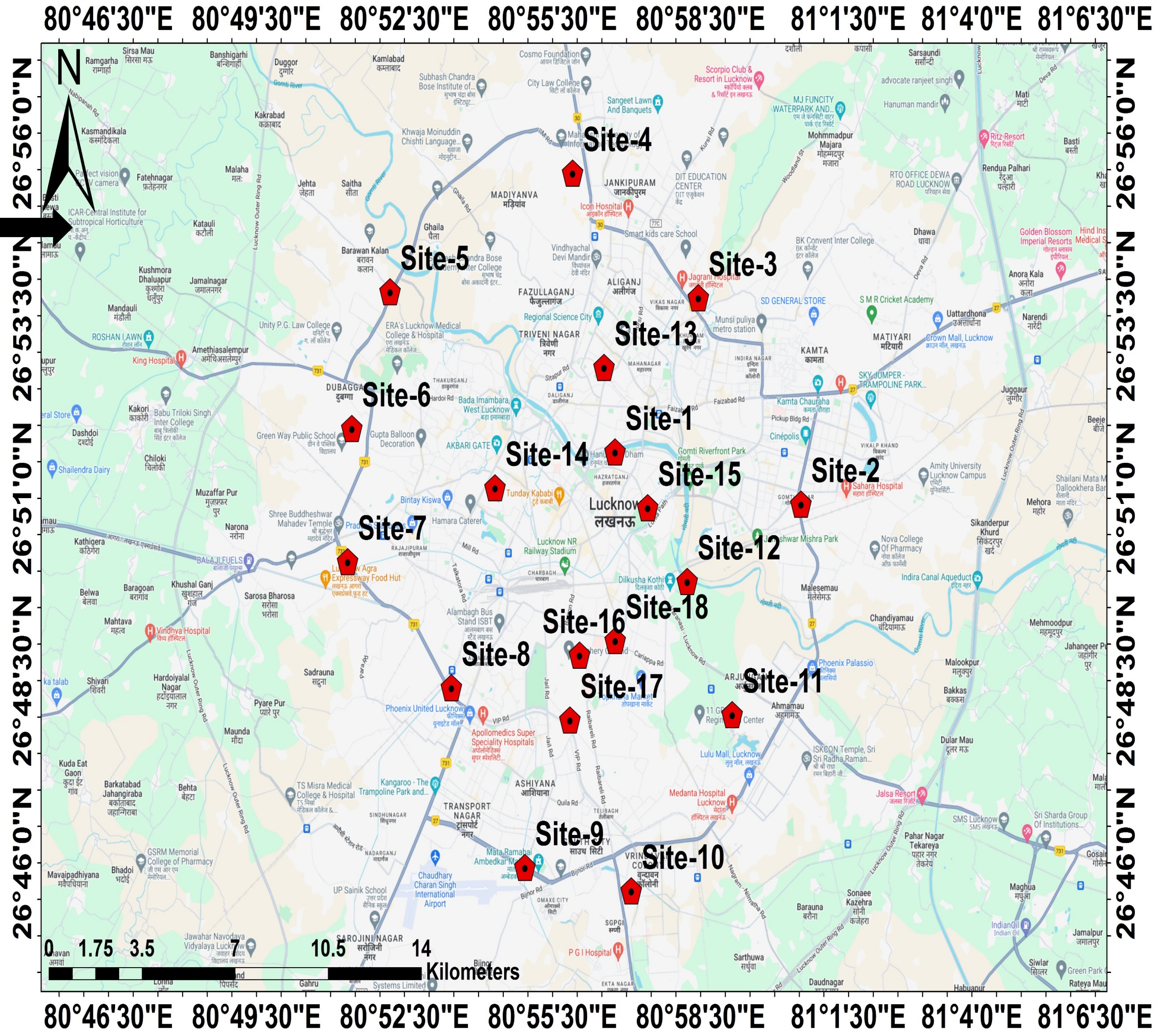


The survey has been published in Journal of Hazardous Materials Advances as Dwivedi, S., Tewari-Singh, N., Masih, J., Taushiba, A., & Lawrence, A. (2022). Evaluation of indoor particulate matter and associated PAHs during the winter season in Northern India: A comprehensive impact of regional appearances. Journal of Hazardous Materials Advances, 8, 100195. https://doi.org/10.1016/j.hazadv.2022.100195

Study Location

The study was conducted from December 2022 to November 2023.

18 Households were selected as monitoring stations.

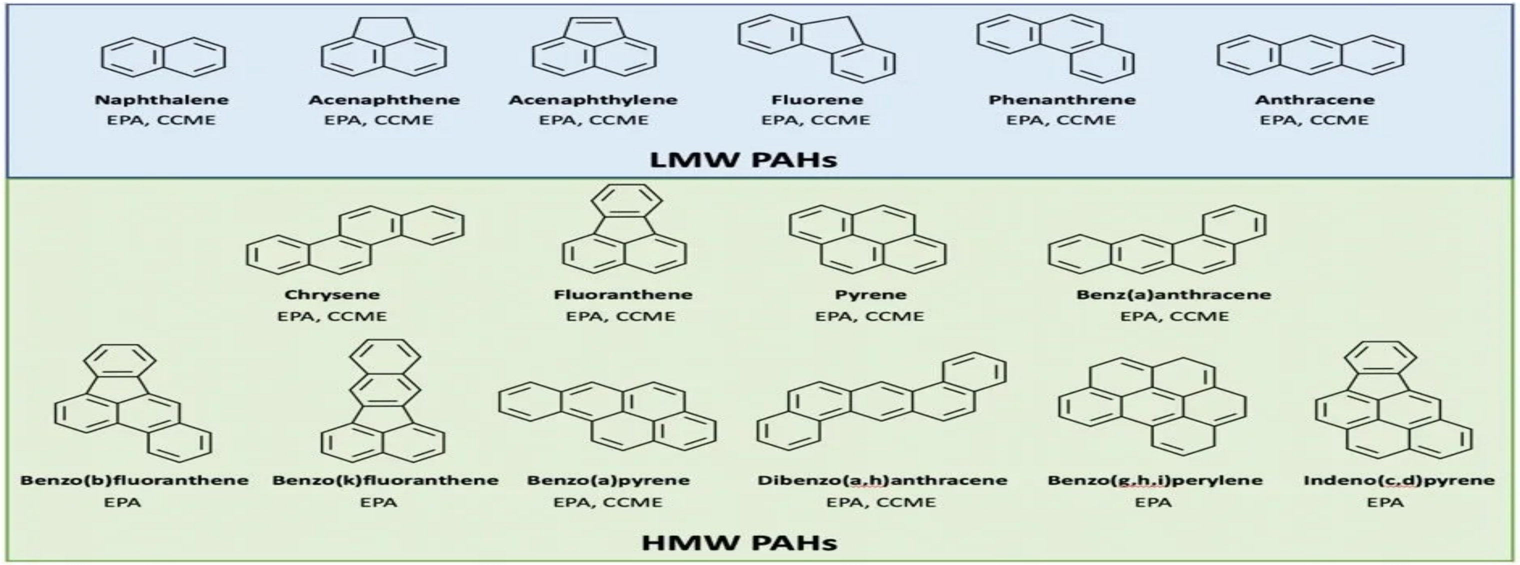


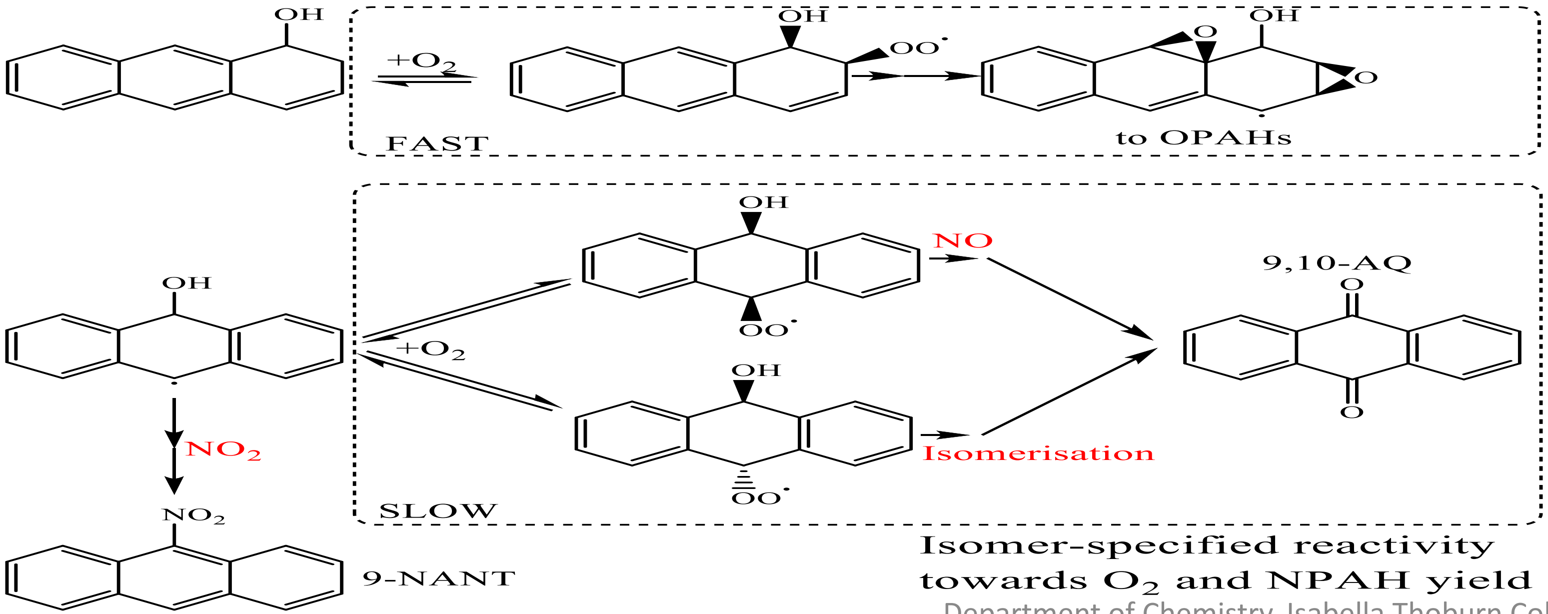
PM2.5 sampling instrument

ENVIORNTECH APM 550 set at a flow rate of 17.57lpm for 24 hours.

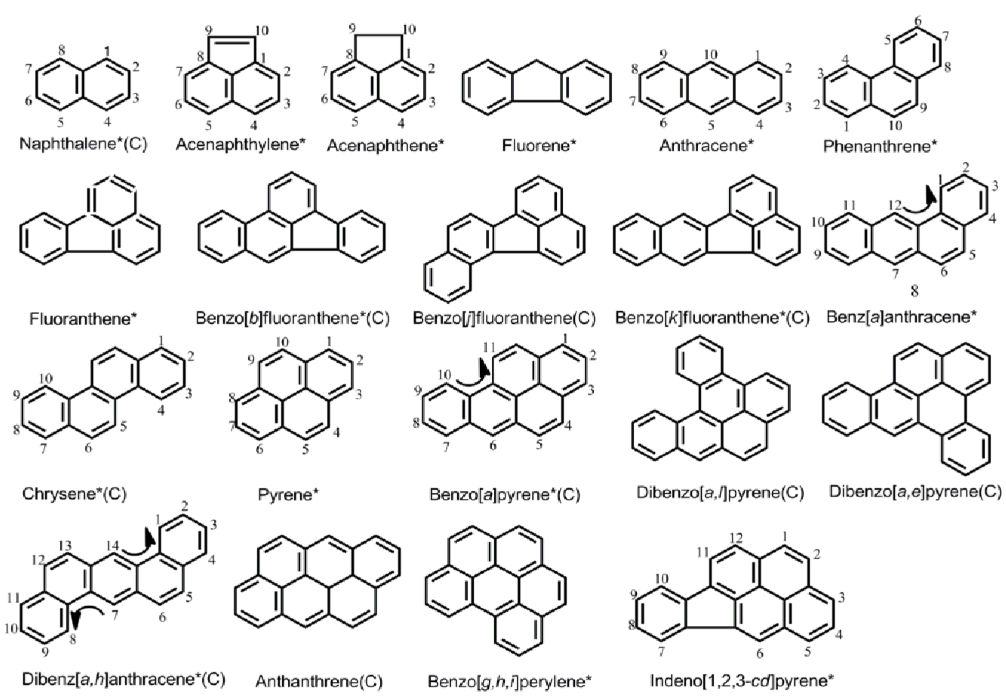
[47mm PTFE Filter paper]

PAH(s)





Isomer-specified reactivity towards O_2 and NPAH yield



An asterisk denotes a United States Environmental Protection Agency priority pollutant. (C) indicates that the compound is carcinogenic by

Analysis of PM-Bound PAHs

ASE-200
Extraction with dichloromethane
High pressure, high temperature

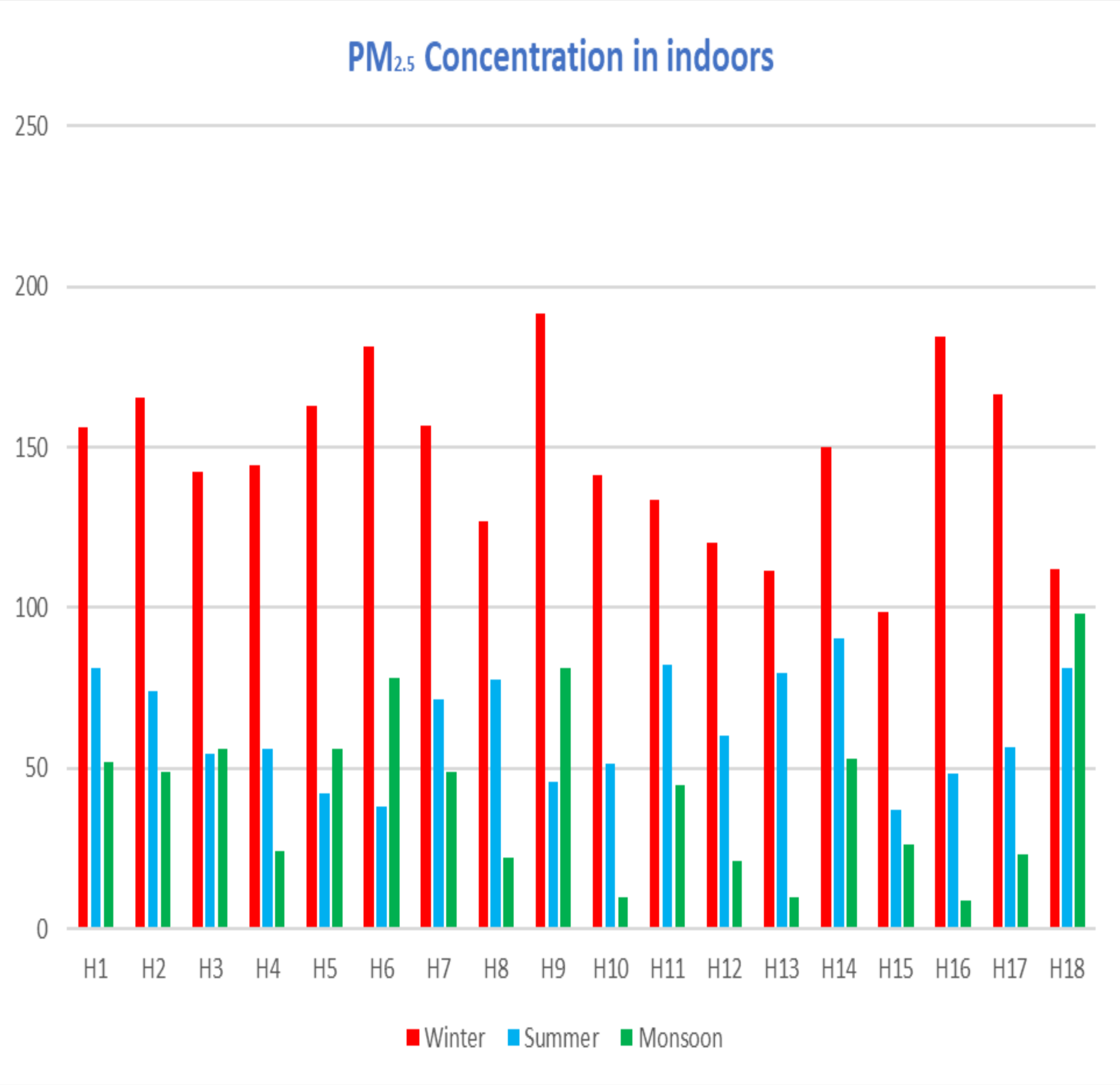
TurboVap
solvent elimination
extract concentration

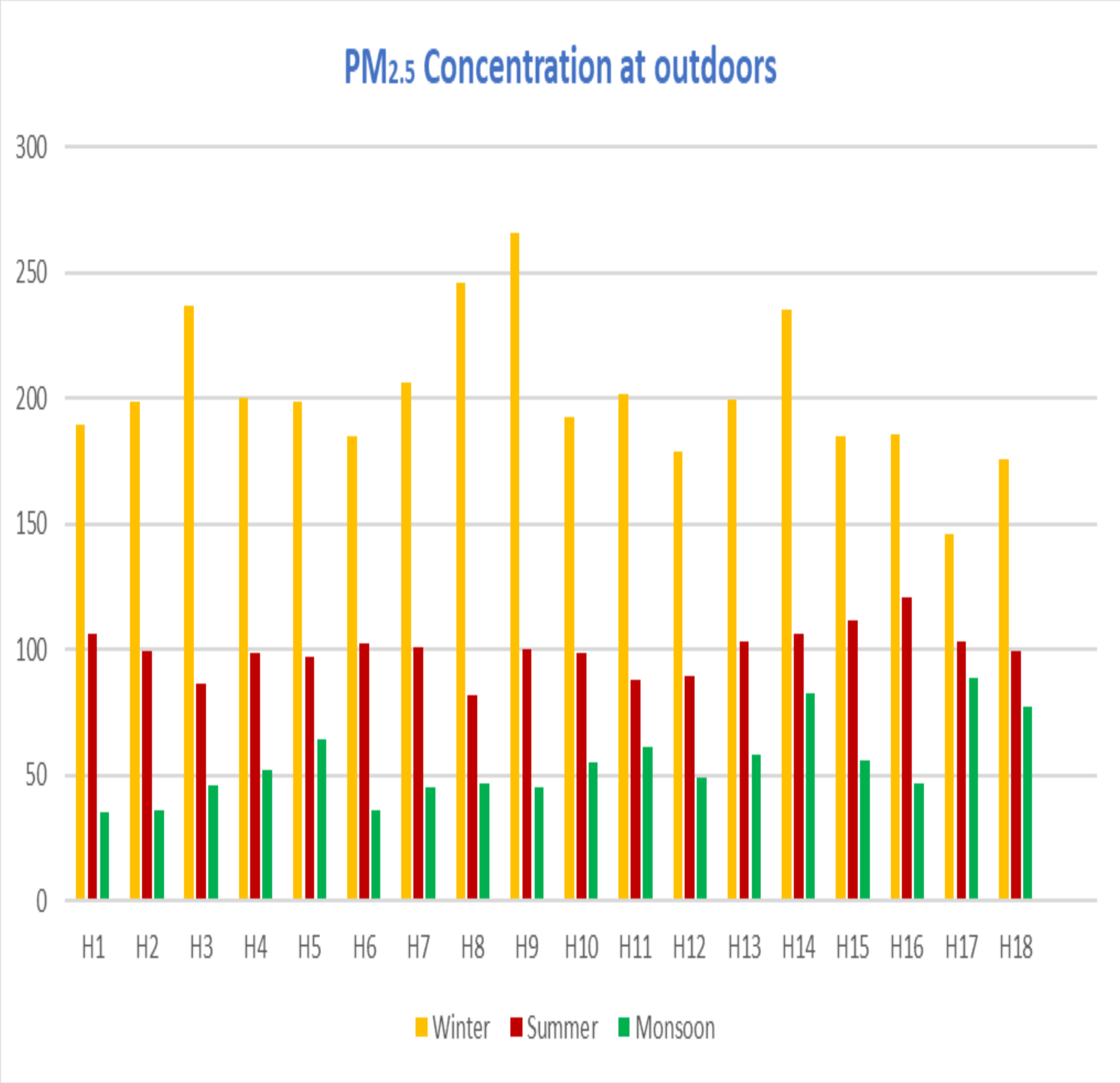
Clean up
With SPE cartridges

SpeedVac
extract concentration

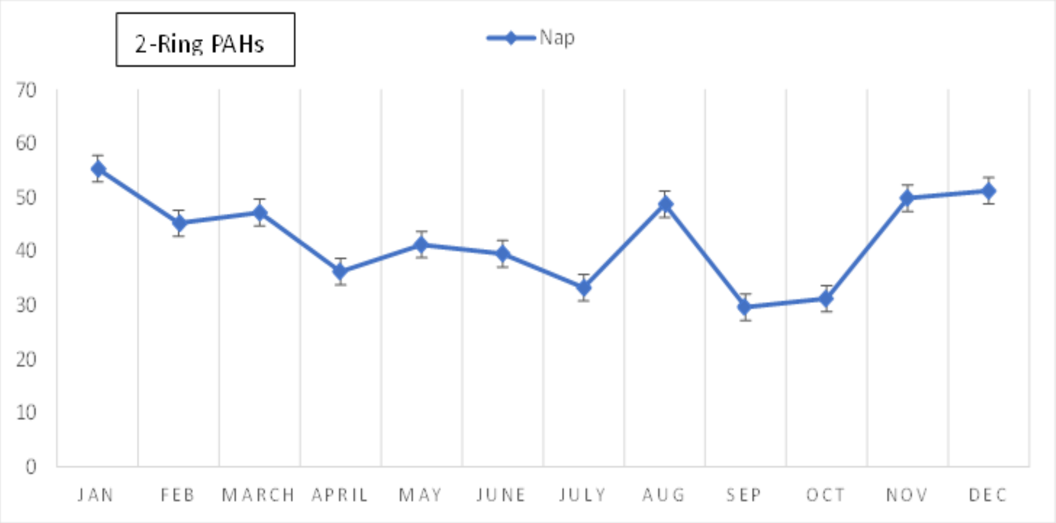
GC-MS/MS

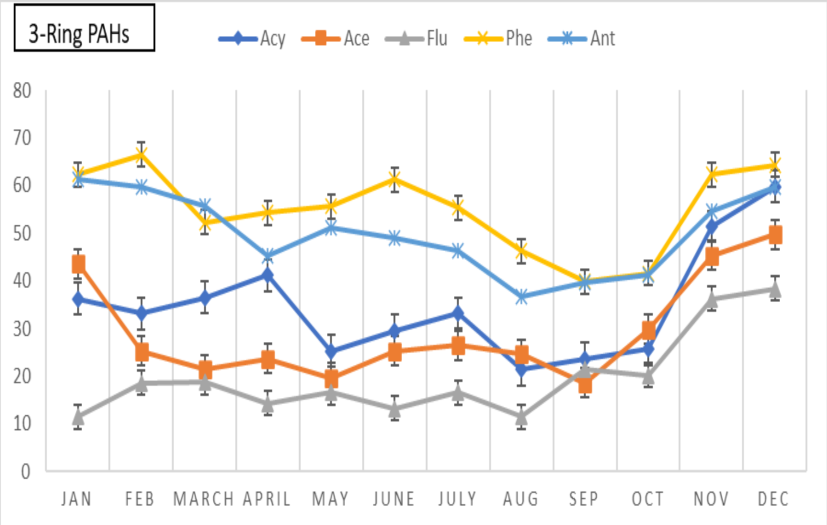
$PM_{2.5}$ Results:

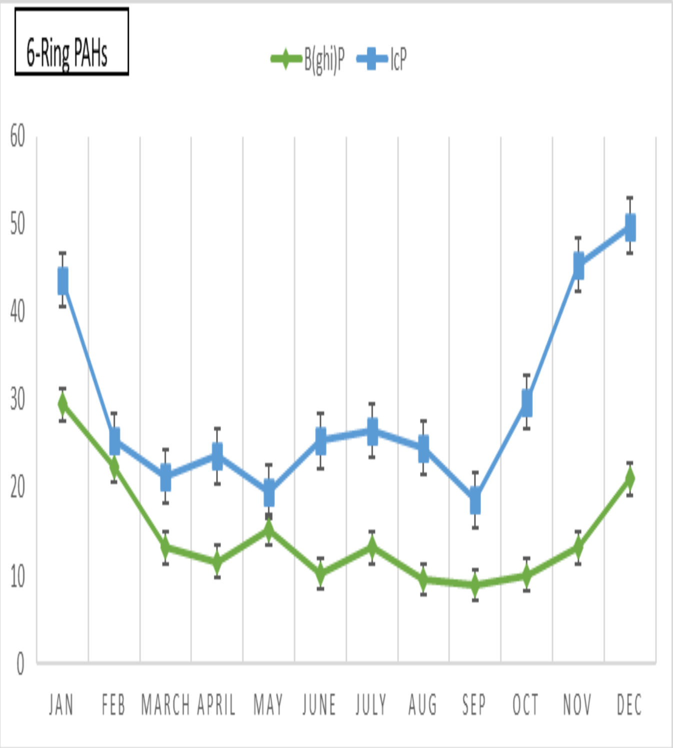


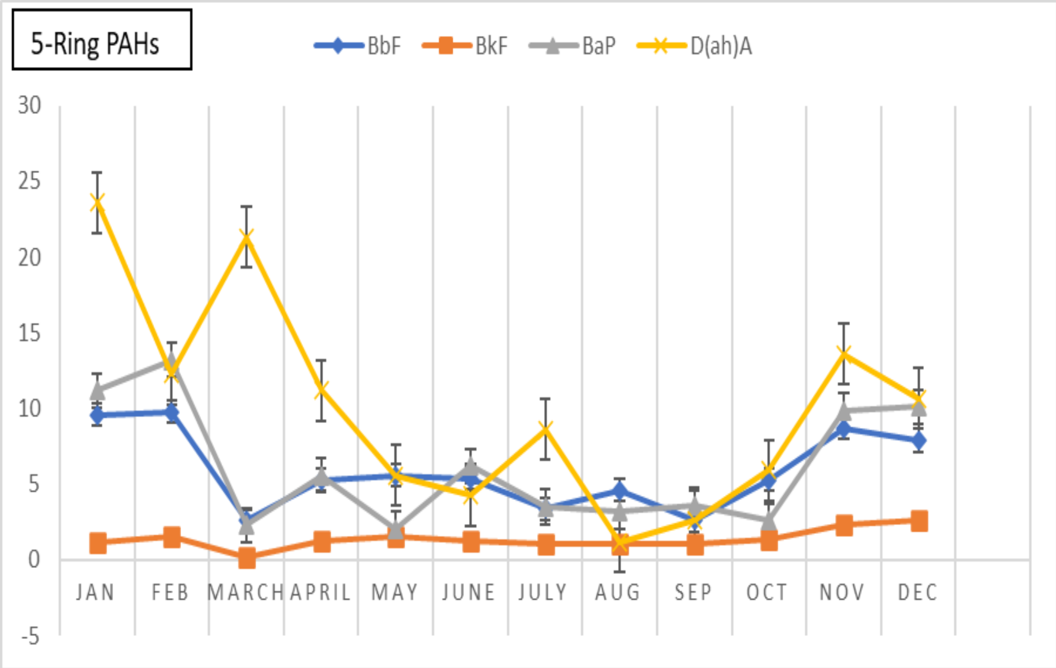


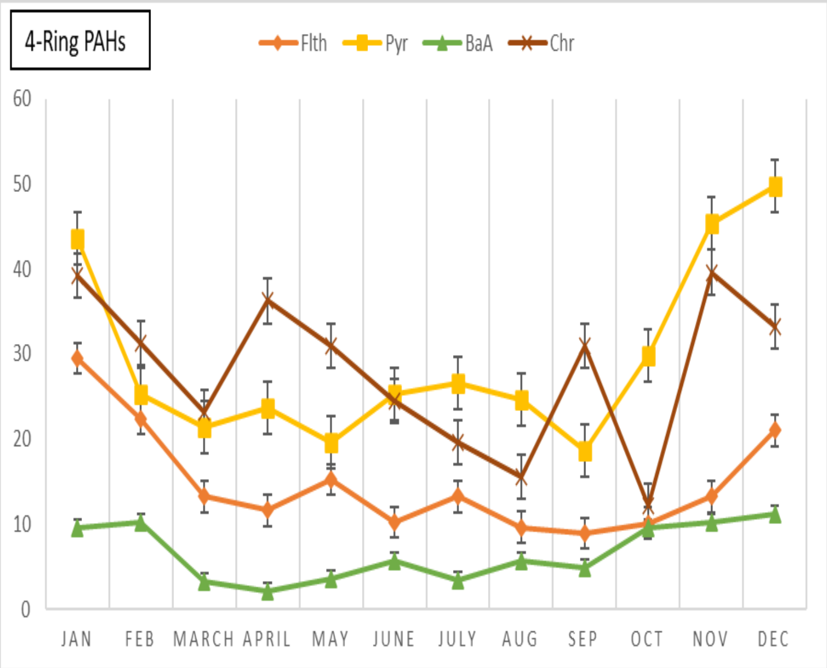
PAHs Results:



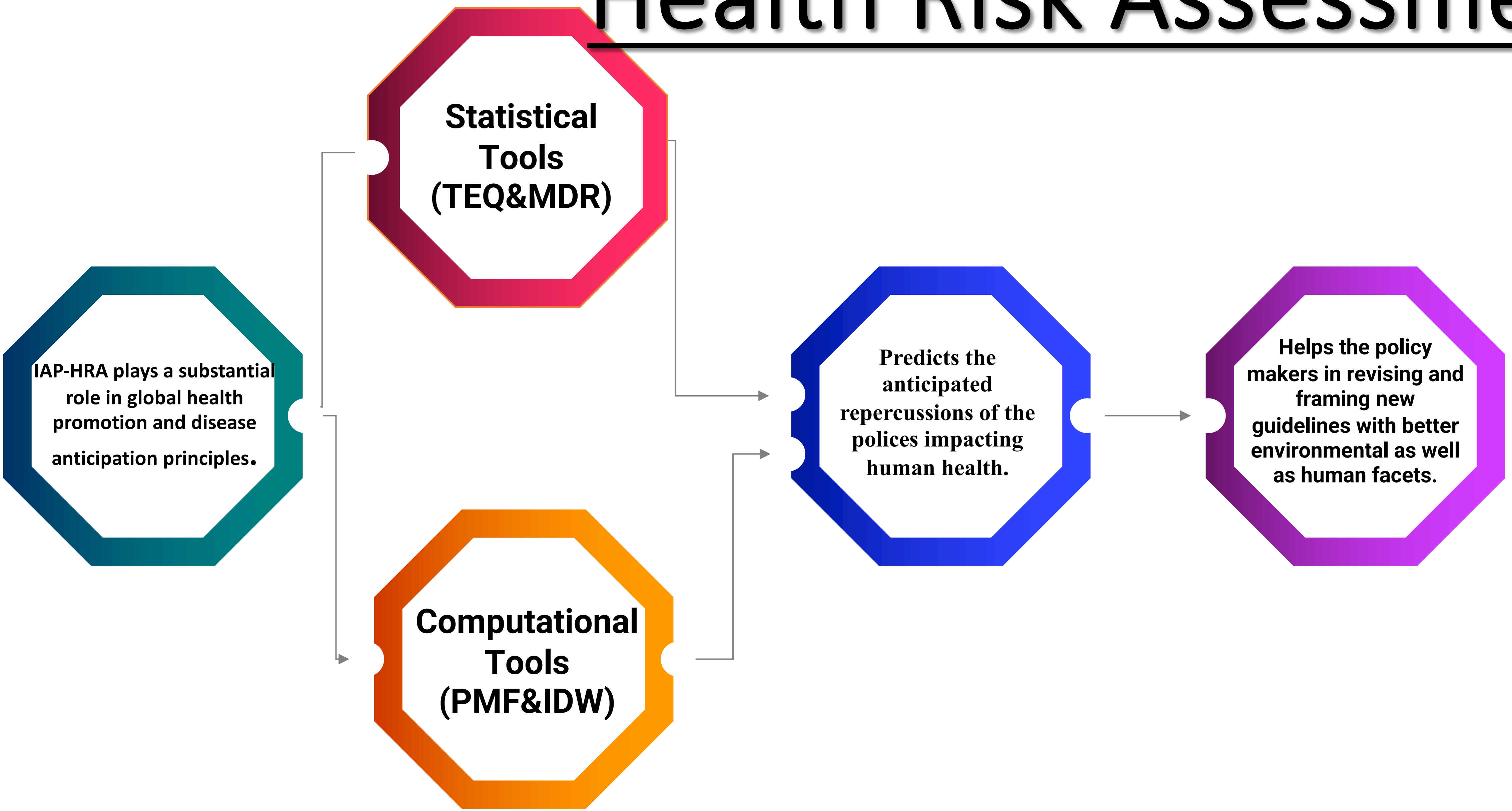








Health Risk Assessment



Toxicity Equivalent Factor

- **Toxicity and carcinogenicity of PAHs are well-known for humans as well as environment.**
- **For determination of possible carcinogenicity of individual PAHs in humans, TEQ is evaluated based on TEF i.e., toxicity equivalent factor of the respective PAHs. For calculating TEQ following equation is used-**
- $TEQ = \sum(TEF * PAH_{CONC.})$

Table TEQ assessed for individual PAH

	Winter-Outdoor	Winter-Indoor	Summer-Outdoor	Summer-Indoor	Monsoon-Outdoor	Monsoon-Indoor
AcY	0.0052	0.00336	0.00236	0.001874	0.0023	0.0010965
Nap	0.0038	0.0029235	0.0021	0.00025875	0.0023	0.000012
Ace	0.0062	0.00313475	0.0031	0.00167175	0.0016	0.00020575
Flu	0.0037	0.00217625	0.0025	0.00016325	0.0015	0.000044
Phe	0.0142	0.01146725	0.0029	0.000014725	0.0013	0.00001725
Ant	0.026	0.004615	0.076	0.052765	0.041	0.0364775
Pyr	0.0146	0.012835	0.0068	0.00424775	0.0034	0.00185925
BbP	0.00136	0.000639	0.0034	0.00177575	0.0016	0.00059125
BeA	0.0213	0.01562925	0.008	0.0066825	0.00402	0.00218
B(a)A	0.91	0.776325	1.86	0.430125	0.29	0.10475
Chr	0.196	0.1787625	0.163	0.12578	0.044	0.0335625
B(b)F	4.29	3.5911	1.54	1.309275	0.39	0.22875
B(k)F	3.25	2.775125	1.102	0.831875	0.26	0.1185
B(a)P	6.4	4.042	2.3	1.01425	1.2	0.03125
InP	8.23	7.88035	3.36	3.228325	0.401	0.253925
D(a,h)A	0.00234	0.0005643	0.0021	0.000695	0.0013	0.00005125
B(ghi)P	0.8123	0.708575	0.443	0.3925825	0.025	0.013

Molecular

<0.1 depicts a sign of unburned or partially scorched fossil fuel, whereas a ratio **>0.1 specifies towards existence of combustion causes.**

Flu/ (Flu + Pyr) exemplifies di engine releas

0.60 predict as non-ex emissions, whereas, i fraction outdoes 0.60, th can characterize tra releases.

0.21 to 0.34 shows combustion of coal, whereas, a ratio >0.35 designated towards vehicular discharges

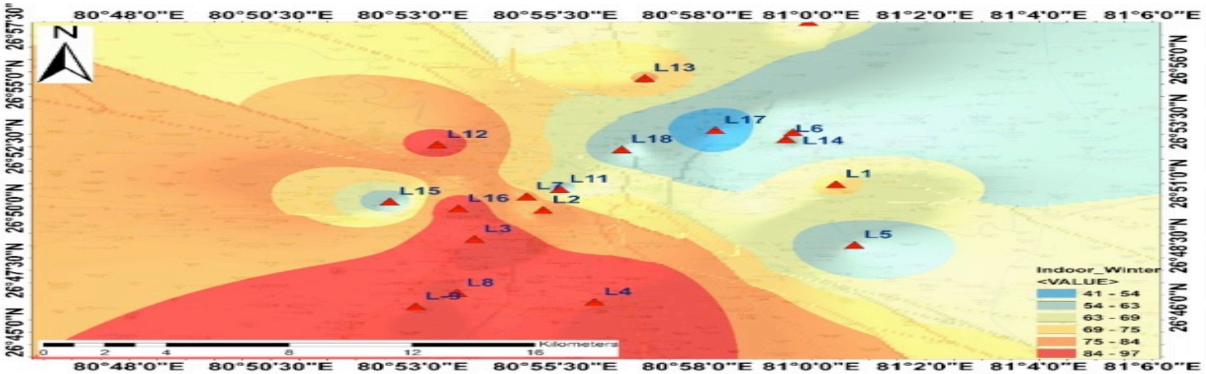
- MDR are wid ses
- MDR in this s in study time and locations.
- To our familiarity, this is the first comprehensive study to establish PAHs profiles emitted along PM2.5 in indoor and outdoor region simultaneously.
- MDR including Ant/ (Ant + Phe), BaP/ (BaP + BghiP), Flu/ (Flu + Pyr), BaA/ (BaA + Chr) were studied in this study.

Diagnostic Ratios	Ant/(Ant+Phe)	Flu/ (Flu+Pyr)	BaP/(BaP+BghiP)	BaA/(BaA+Chr)
Indoor-Winter	0.24-0.31(0.17)	0.3-0.59 (0.08)	0.3-0.21 (0.10)	0.20-0.31(0.11)
Indoor-Monsoon	0.1-0.20(0.08)	0.01-0.48(0.11)	0.2-0.16(0.03)	0.01-0.18(0.04)
Indoor-Summer	0.15-0.25(0.14)	0.06-0.63(0.26)	0.3-0.26(0.08)	0.36-0.48(0.10)
Outdoor-Winter	0.03-0.29(0.14)	0.6-0.75(0.08)	0.4-0.85(0.63)	0.34-0.59(0.31)
Outdoor-Monsoon	0.00-0.18(0.04)	0.4-0.44(0.11)	0.41-0.11(0.01)	0.02-0.26(0.09)
Outdoor-Summer	0.02-0.19(0.14)	0.7-0.83(0.26)	0.5-0.78(0.51)	0.39-0.55(0.29)

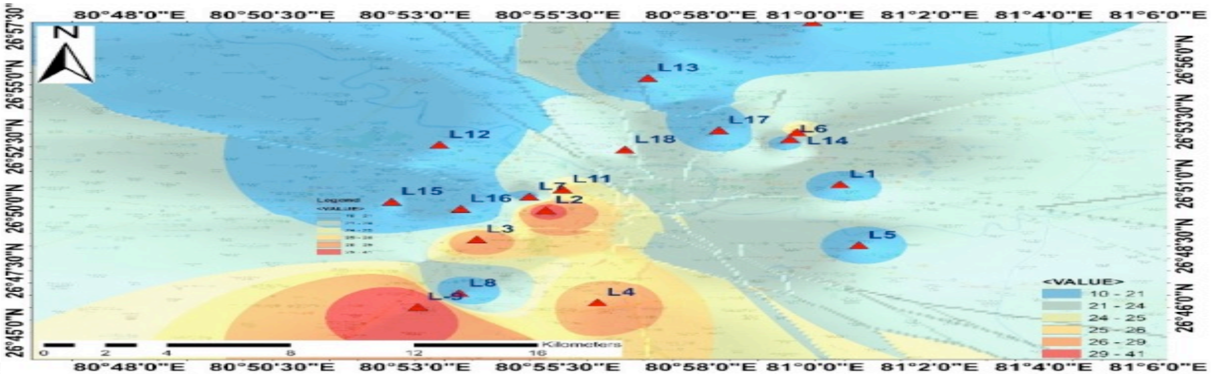
Tool Introduction

Inverse Distance Weighting (IDW)

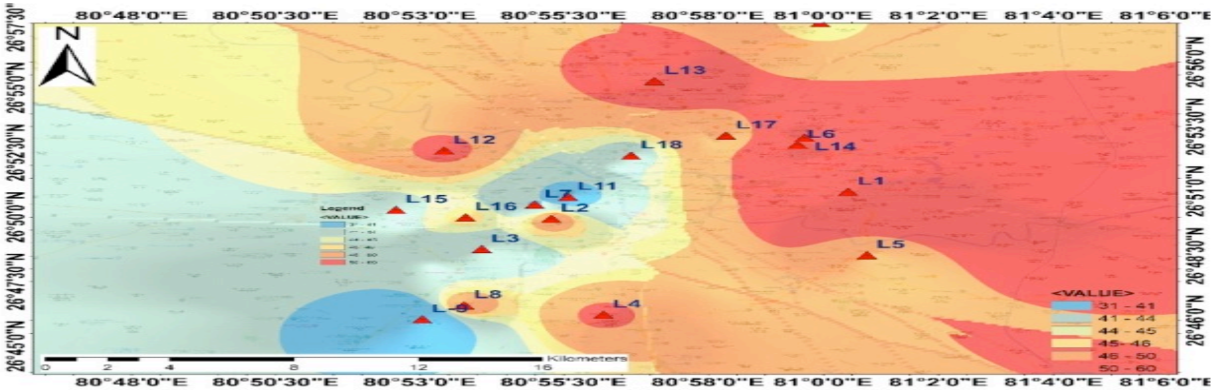
- IDW is a simple and widely used method in GIS for spatial interpolation.
- IDW designates distance as a reverse function of dependability once investigation of errors is done for prophesied results.
- Inverse distance weighing invariably involves the underlying assumption that places closer to each other will be more alike than those points that lie some distance apart. The points closest to the target location will be assigned a greater weight in IDW, and the variation in allocated weights is inversely proportional to ‘p^{th} power of distance’. Here *p* stands for the power function (*p*), which is a positive real number. Points closest to the point to be interpolated will be significantly influenced by the greater values of *p*. The summation of the product of ‘*measured values*’ and ‘*allotted weights*’ for all locations is a predicted parameter of a target location.



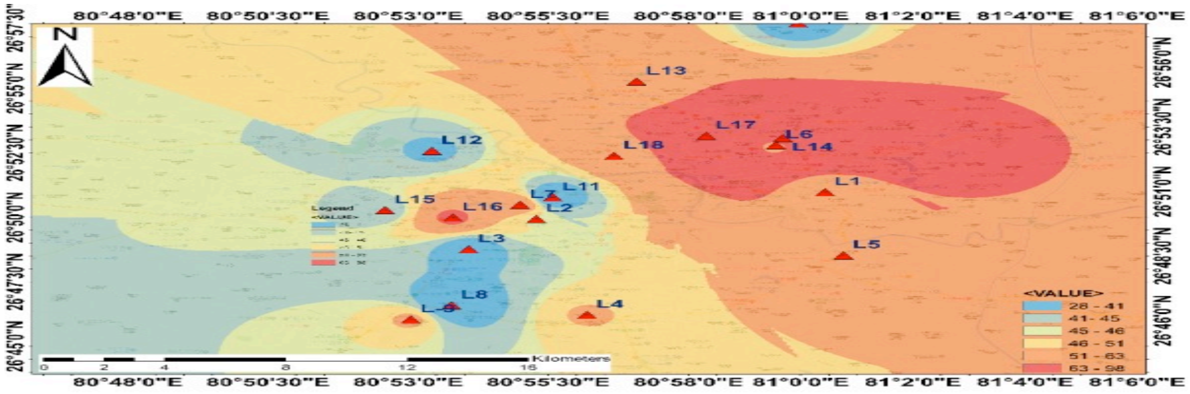
(a) Indoor Winter



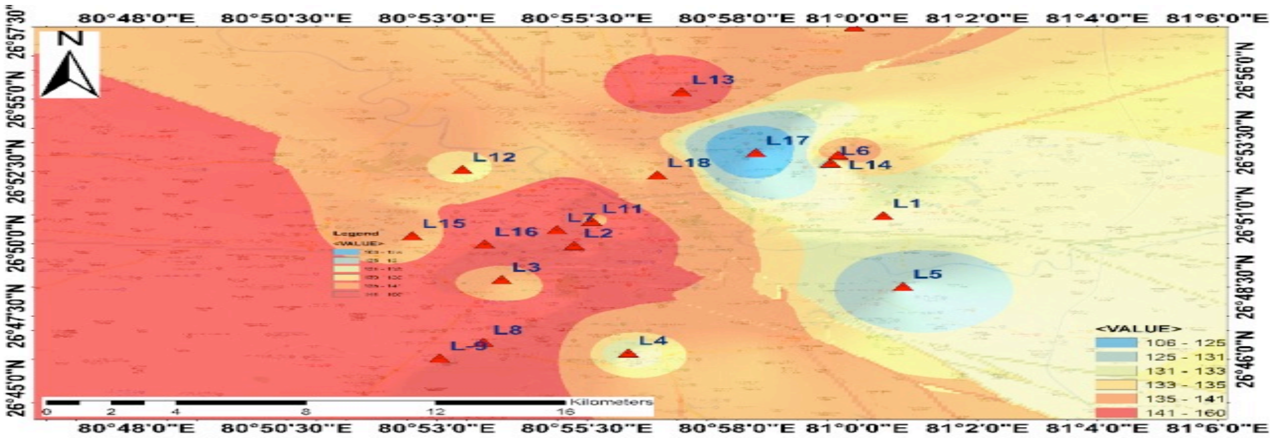
(b) Indoor Monsoon



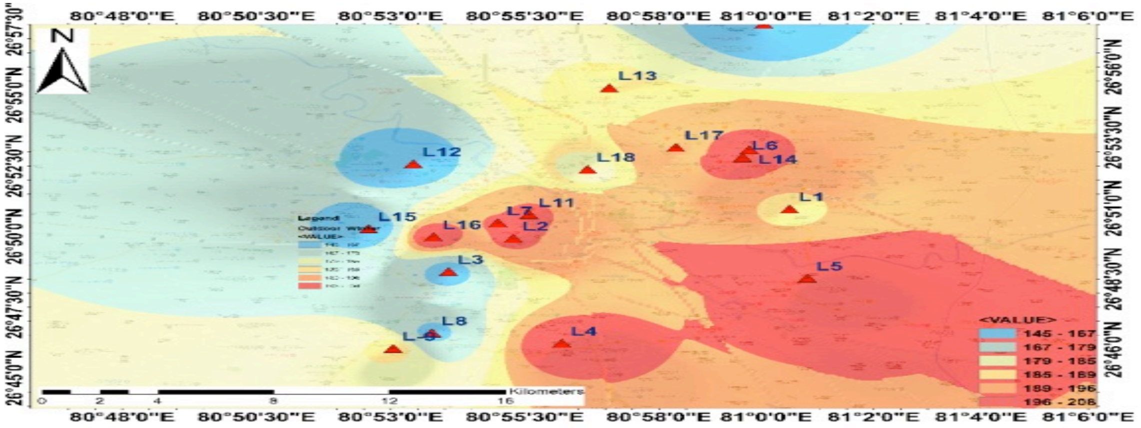
(c) Indoor Summer



(d) Outdoor Monsoon



(e) Outdoor Summer

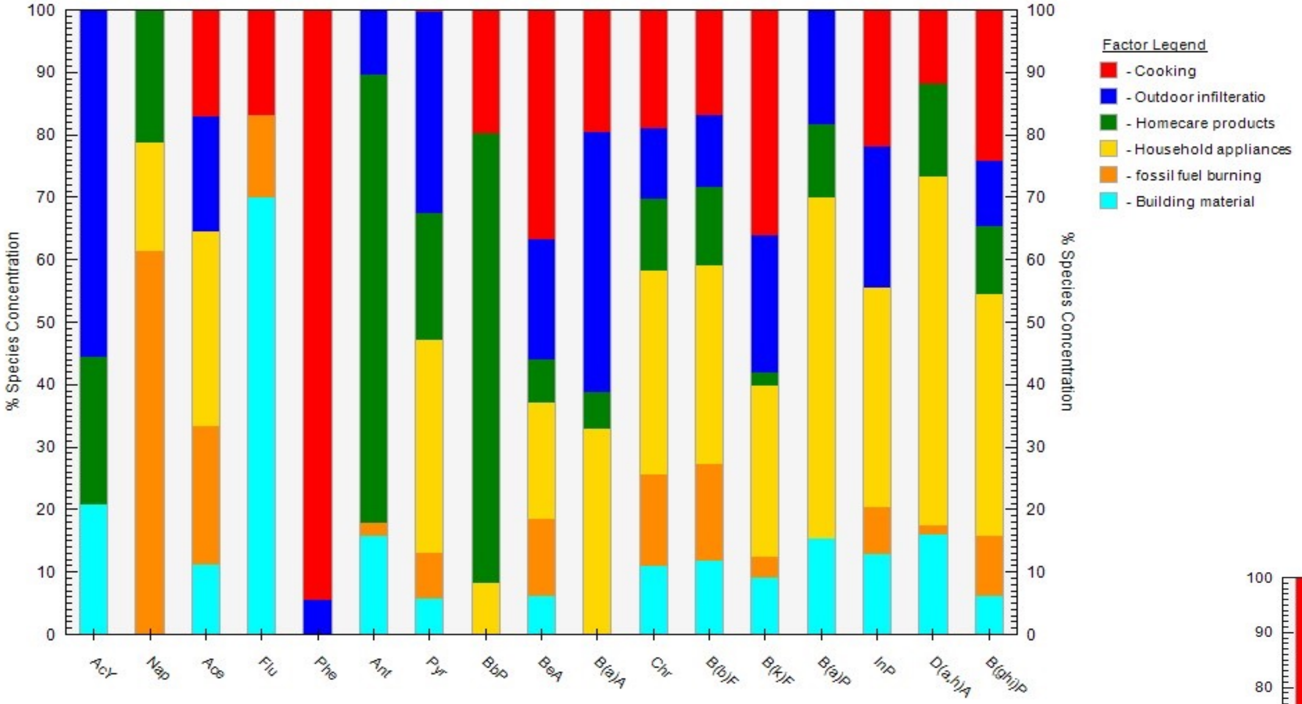


(f) Outdoor Winter

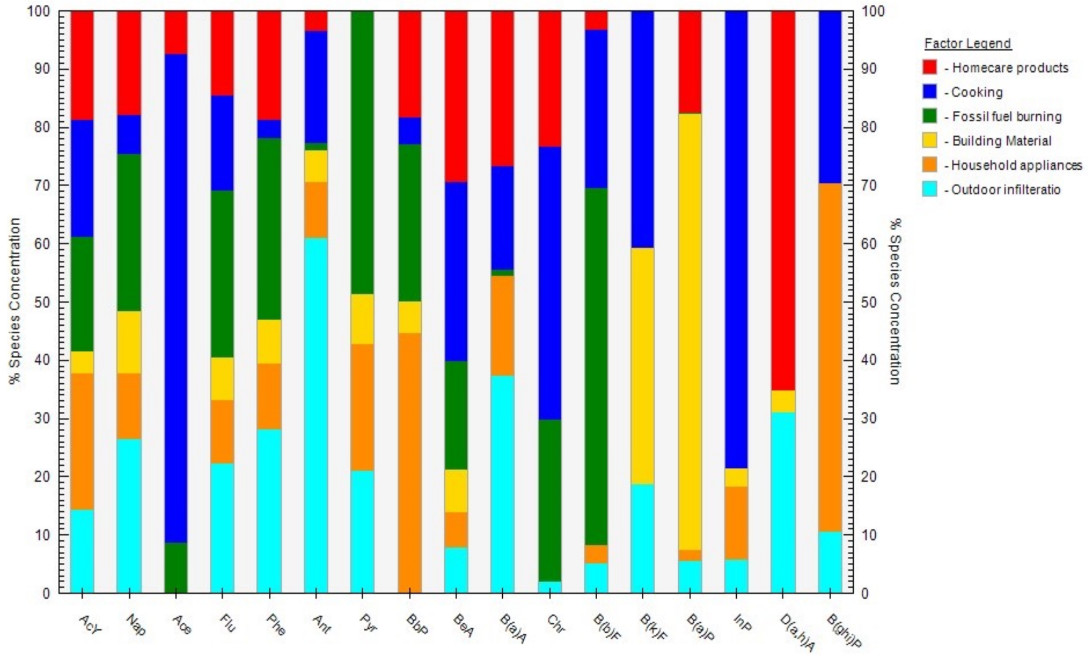
Positive Matrix Factorization [PMF]

- Positive matrix factorization (PMF) has been widely used to apportion the sources of pollutants by utilizing chemical speciation data measured at the receptor site(s).
- The concentration values used in PMF model were exclusively for indoors, as indoors are the major concern in the present study. The number of factors for the model was initially set from 1to 7, the start seed number was randomly attained, and the number of runs was 20. The most suitable number of factors was determined by assessing the minimum and most steady Q value. Lastly, it was determined that six factors resulted in good model fitting, with estimate residuals normally distributed within −3.0 to 3.0 and a prediction R^2 greater than 0.66.
- The results showed that approximately 90% of the base factors were replicated in the BS model, and no factor swaps were observed in the DISP model, indicating that the six-factor PMF solution was stable.

Factor Fingerprinting

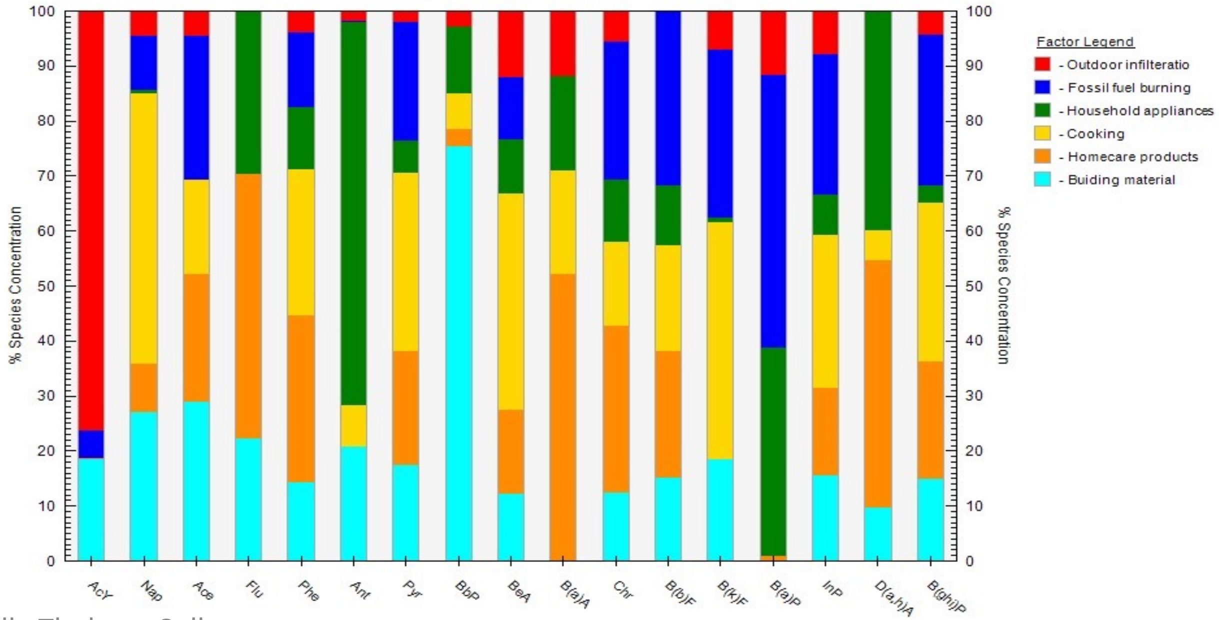


Summer Season

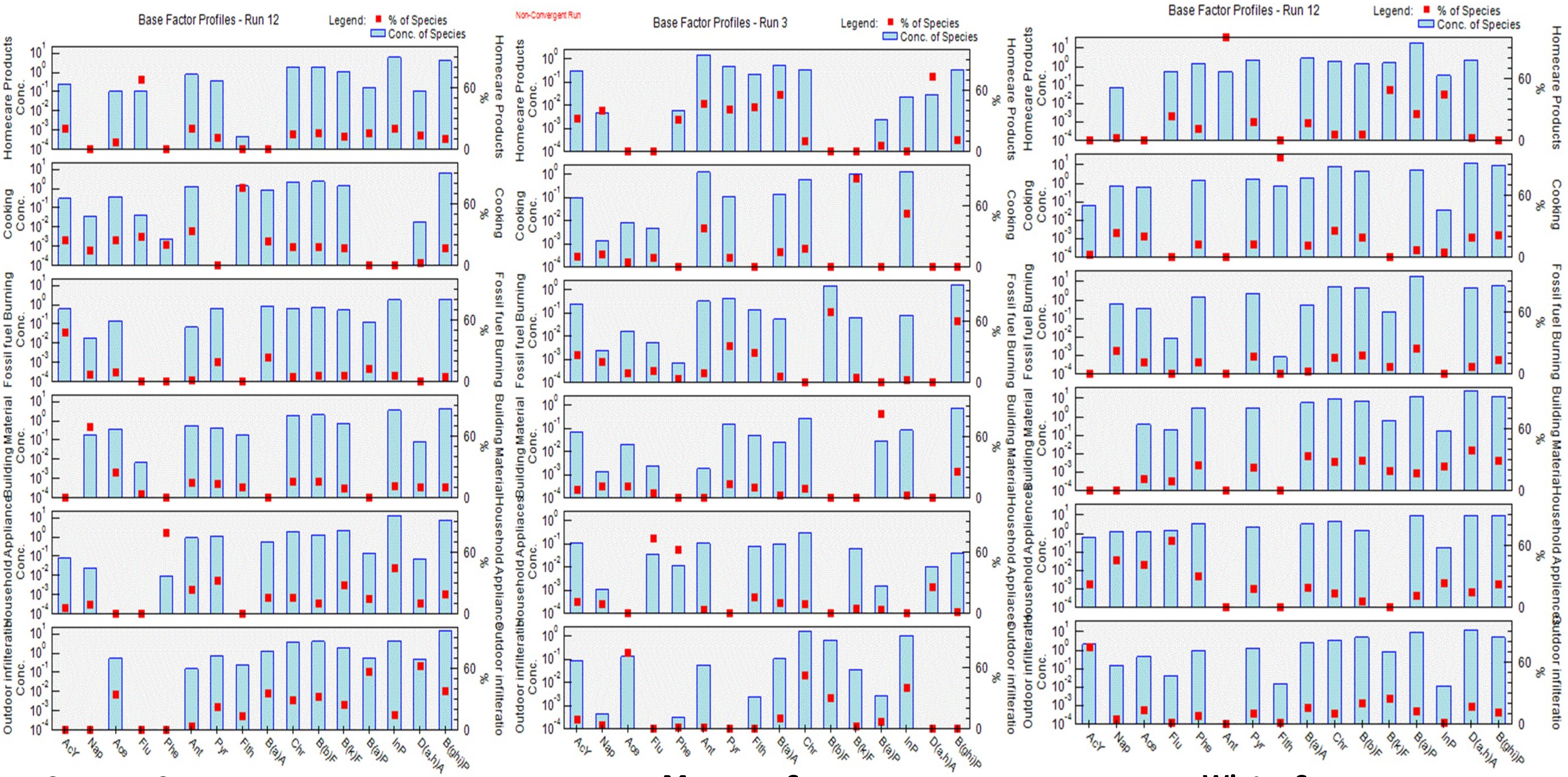


Monsoon Season

Winter Season



Cont.



Summer Season **Monsoon Season** **Winter Season**

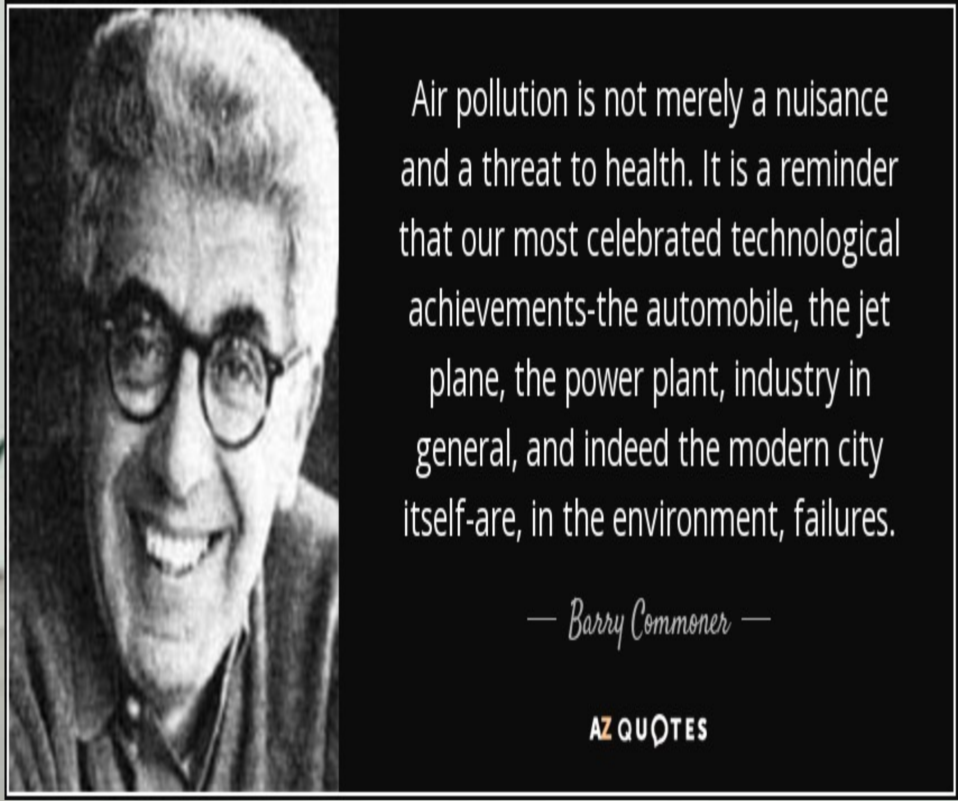
CONCLUSIONS

- Annual-average $PM_{2.5}$ concentrations surpassed WHO and NAAQS guidelines.
  The winter mean was of $PM_{2.5}$ was higher for indoors and outdoors both, however, indoor concentration was comparatively lesser than outdoor except at few households where the indoor emissions were higher than outdoors.
  In monsoon comparatively many households were detected with higher concentrations in indoors than outdoors.

- The toxicity equivalent quotient i.e., TEQ evaluated in the study demonstrations that the highest toxicity among all PAHs is exhibited by BaP followed by InP, BkF, BbF.

- Seasonal variations in the concentration of PAHs and their respective sources were also established using PMF models, which depicted In winter 3-ring PAHs contributed 42% of TPAHs straggled by 4-ring PAHs with 26.3% in outdoors, whereas, in indoors, PAHs with four-ring accounted 32% of TPAHs subsequently three-ring with 21.4%. Correspondingly, in summer two-ring accounted for 35% of the TPAHs, afterwards three-ring PAHs 27.8% and four-ring accounted 20.1% in outdoors, while, three-ring PAHs contributed 26.8% of the TPAHs, subsequently 2-ring PAHs 24.3% and 4-ring PAHs 19.6% in indoors. In monsoon PAHs with two-ring attributed 45.2% of the TPAHs, afterward three-ring with 19.8% and four-ring with 12.2% in outdoors, whereas, 2-ring PAHs contributed 38.3% of the TPAHs, followed by 3-ring PAHs 25.6% and 4-ring PAHs 21.4% in indoors.

- PAHs with high molecular weight i.e., having 3 or more rings, are more likely to be associated with PM2.5. Therefore, the sources of these PAHs specifically need to be regulated.
- As women and children spend more than 90% of their time indoors they are exposed to high concentrations of pollutants, especially women while cooking (3 – 5 hours a day) are exposed to high concentrations. Like OSHA (working place) there should be standards for kitchen.



Department of Chemistry, Isabella Thoburn College.