Measurement and Analysis of Toxic Metals Concentration Influencing Continental Atmosphere

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Sources of Ambient Particulate Matter

Construction Equipment Power plants

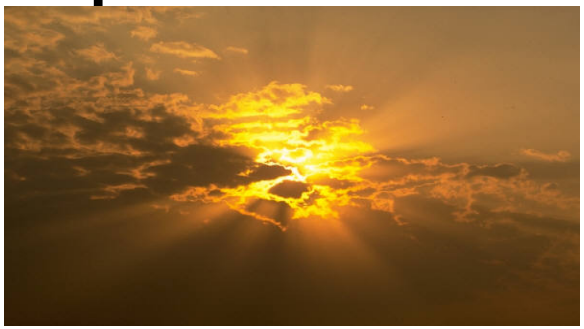
Woodstoves Wildfires

Diesel trucks and buses

Chemical reactions in the atmosphere

Particulate Matter – Origin?

Atmospheric Conditions



Emissions

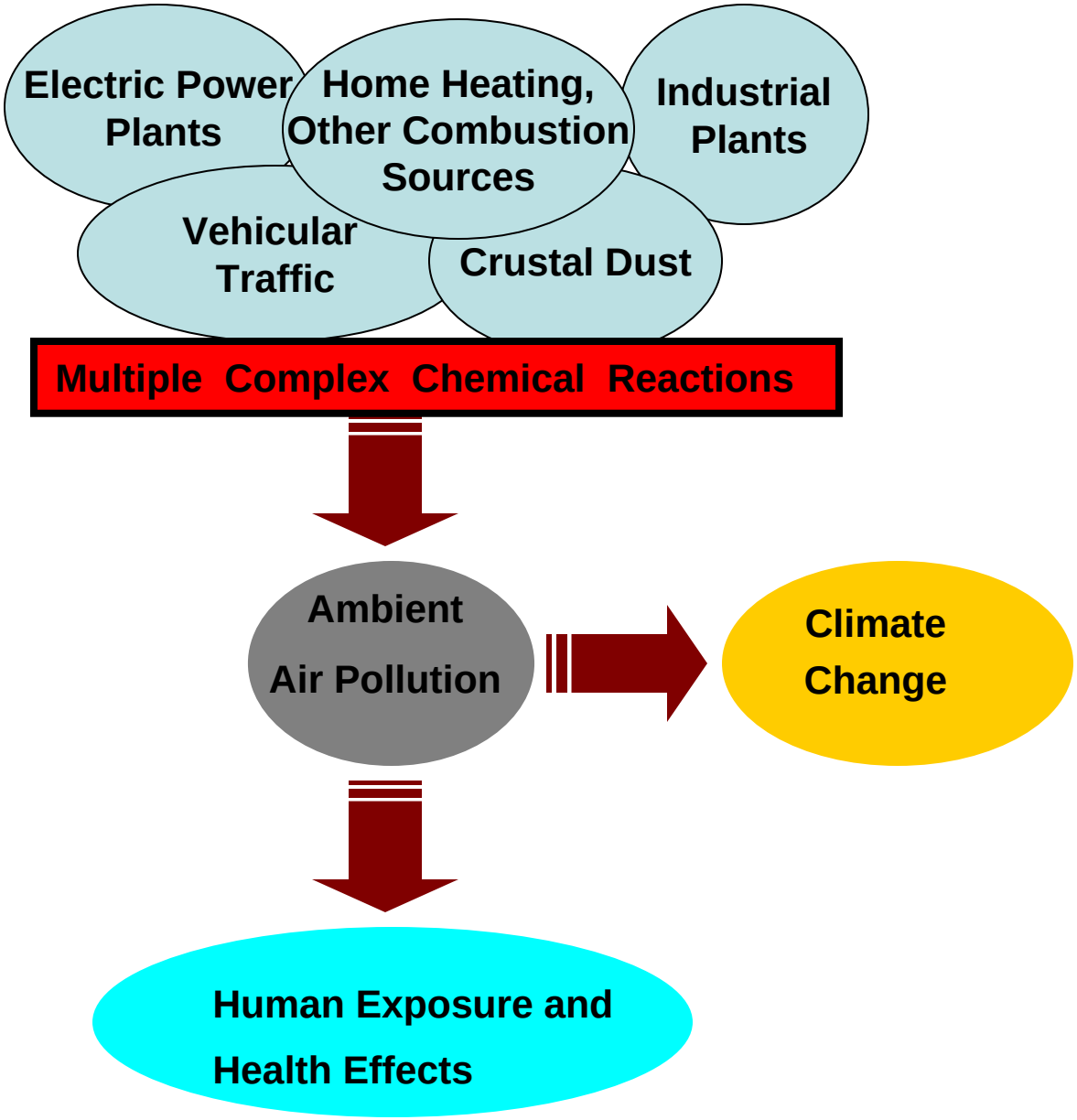
Oxidant ($OH^{\cdot}$)

NH_3

Hydrocarbons

Secondary Aerosol

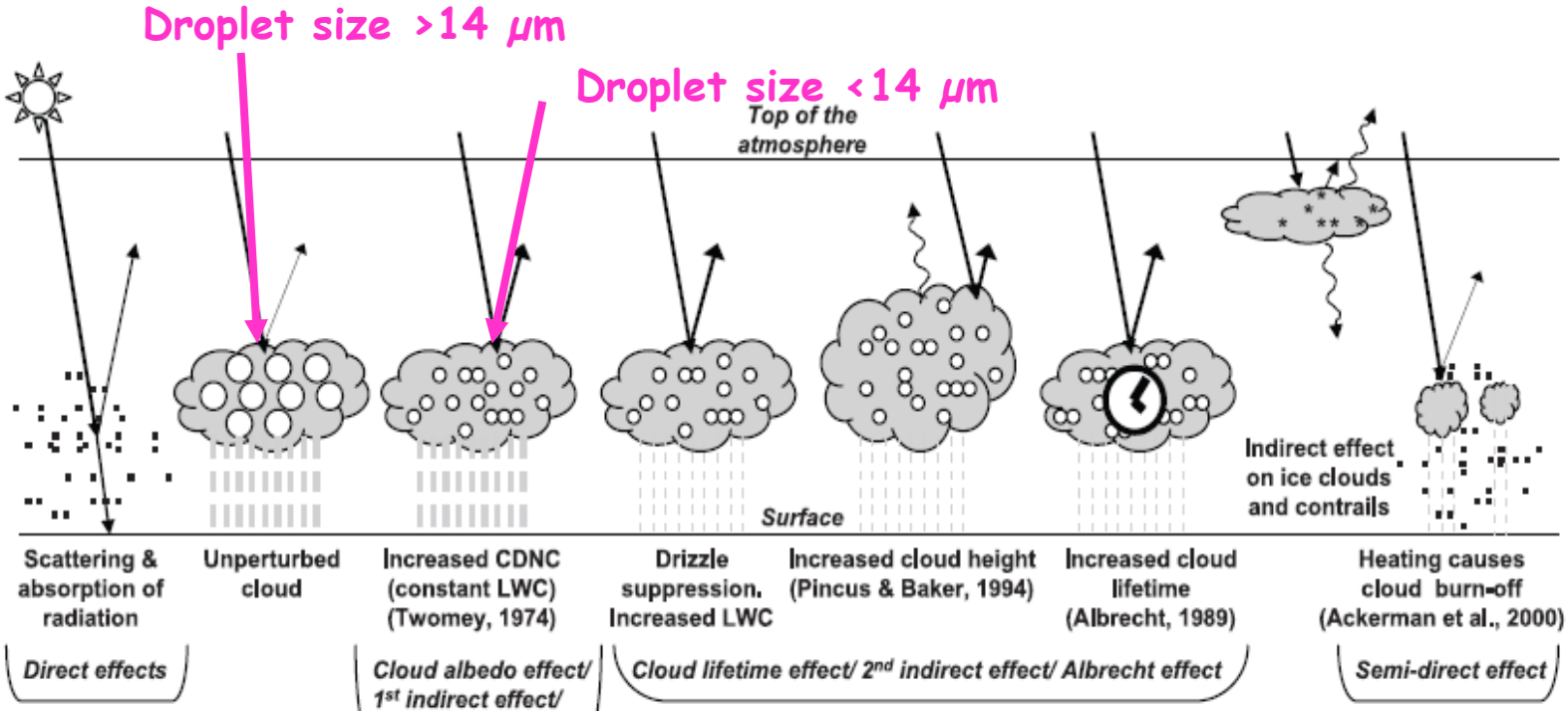
Air Pollution and Effects: Basics



Atmospheric Haze

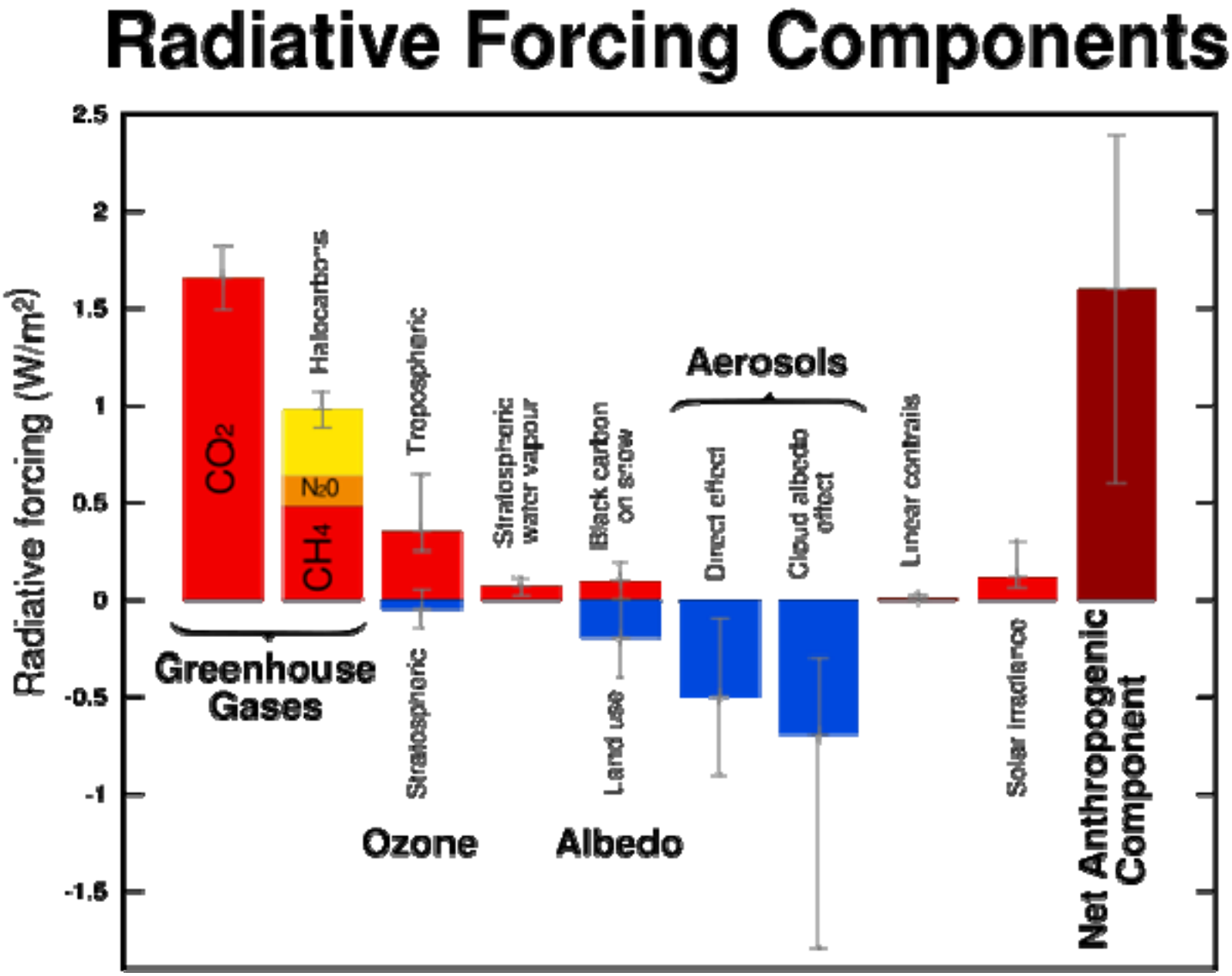
- Tiny particles at high concentrations that scatter and absorb sunlight
- Diminished horizontal visibility
- Natural and anthropogenic sources
- Factors such as **prolonged dry weather**, **a stable atmosphere**, and an **abundant supply of pollutants**.

Role of Aerosol in Climate Change



Modified after IPCC Report, 2007
based on Ramanathan et.al, Science, 2001
Twomey(1974), Atm. Env.
Albrecht (1989), Science

Role of Aerosol in Climate Change



Outdoor Sources for Metals

Arsenic (As) : stationary combustion of fossil fuel, coal burning, metallurgical industry.

Cadmium (Cd) : gasoline, car parts corrosion.

Chromium (Cr) : coal combustion, vehicle exhaust, crustal dust.

Copper (Cu) : vehicle exhaust.

Mercury (Hg)) : coal power plants, smelters, cement production, steel making.

Nickel (Ni) : industrial oil combustion, road transport.

Lead (Pb) : metal industry, incinerator, refineries.

Iron (Fe) : metal industry, crustal dust.

Indoor Sources for Metals

Arsenic (As) : space heating by coal or oil burning.

Cadmium (Cd) : tobacco smoking.

Chromium (Cr) : pigments.

Copper (Cu) : wood burning.

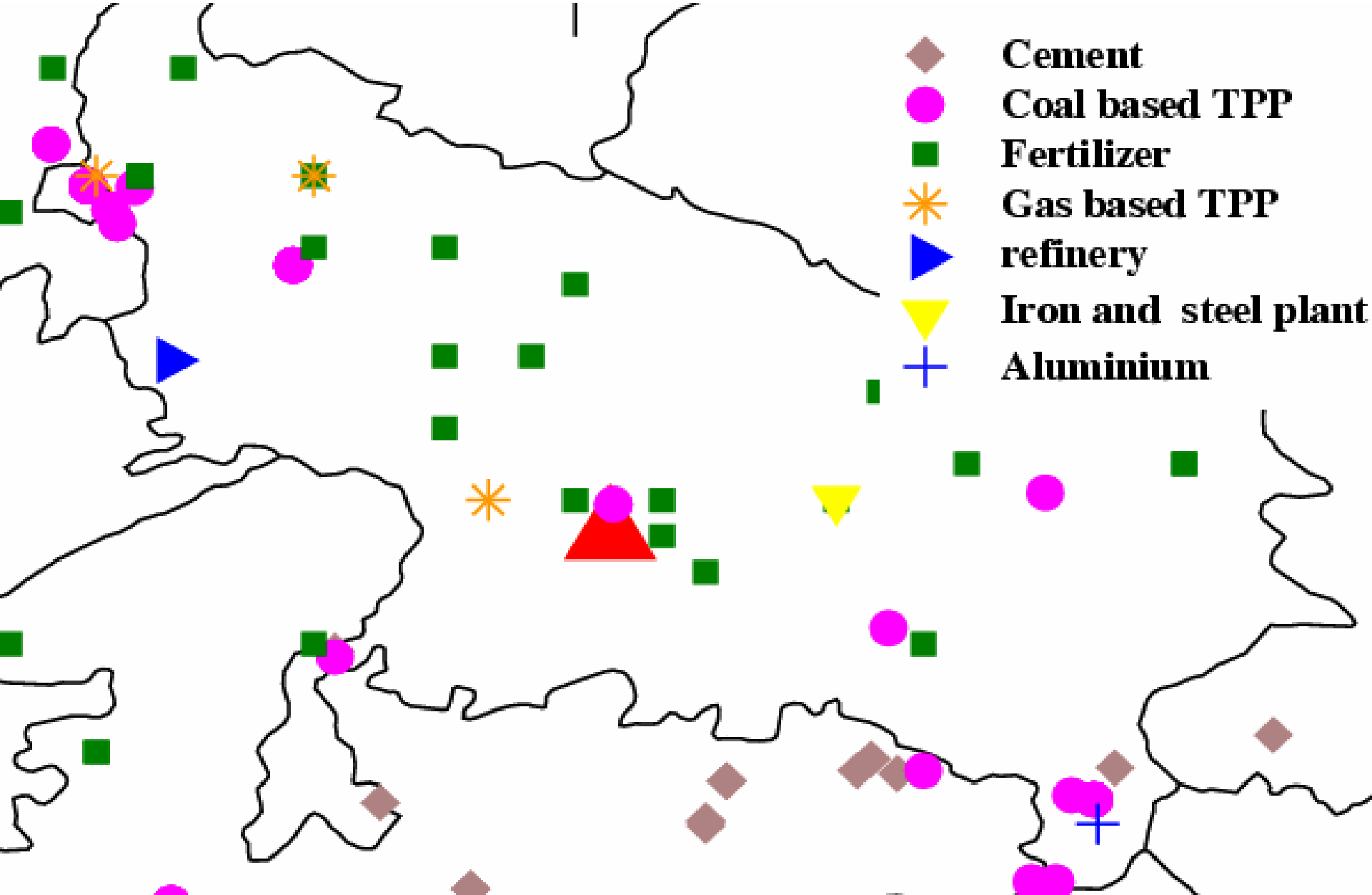
Mercury (Hg) : fluorescent light bulbs.

Nickel (Ni) : tobacco smoking.

Lead (Pb) : indoor paints, wood burning.

Iron (Fe) : smoke from biomass fuel burning.

Industries in and around Kanpur



Ground Based Measurement: Kanpur

Parameter	Load in kg/hour
SO_2	33.7
PM	42.2
NOx	408
CO	2307
HC	757

More than 0.3 million vehicles in Kanpur!

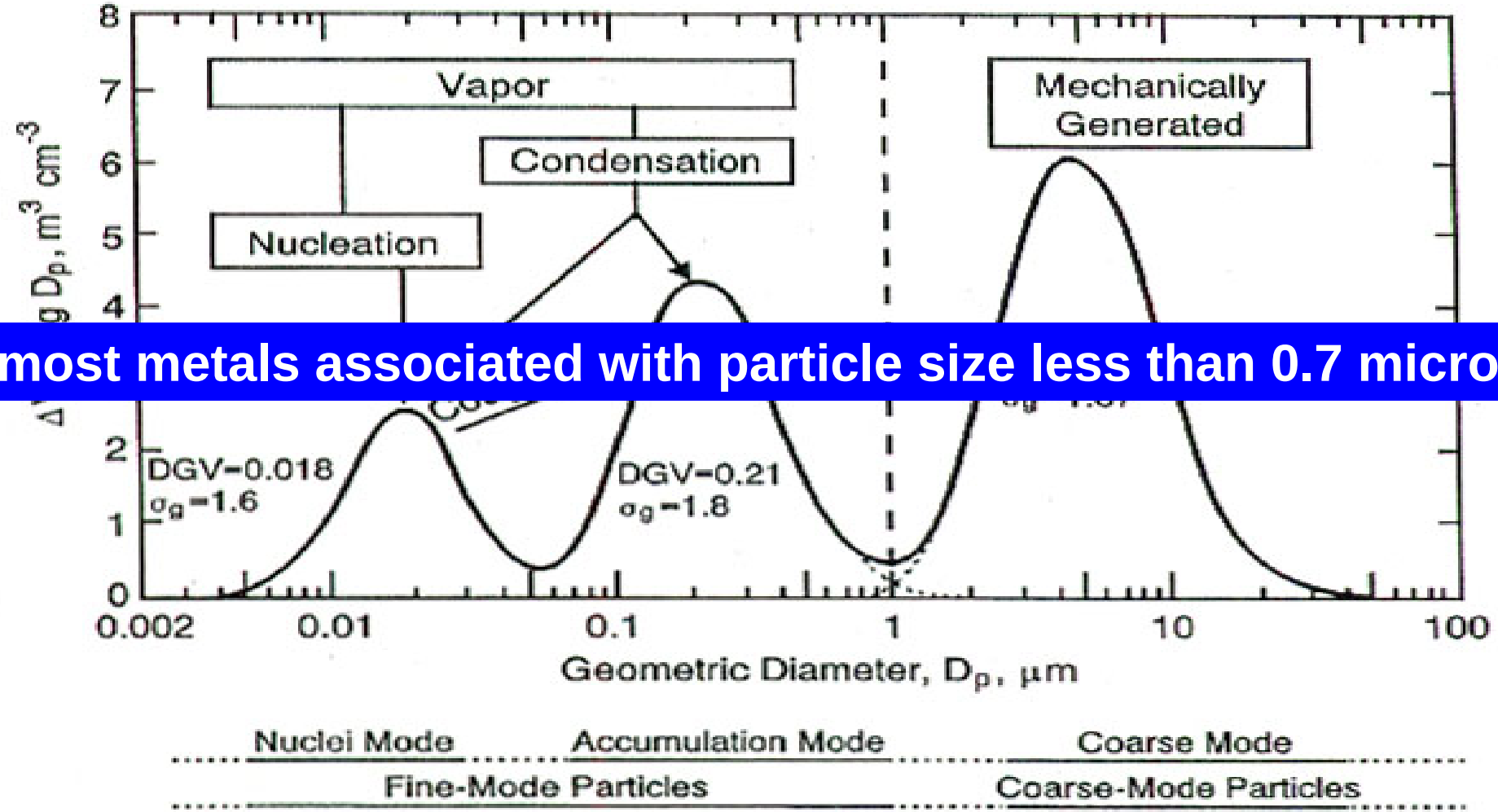
Emissions from Fuels in Kanpur

Domestic Emission Sources		Emission Rate (kg/day)			
Type of fuel	Consumption/day	PM	SO_2	NOx	CO
Coal	70 t	350	532.00	104	3132
kerosene	105 kl	213	357.00	163	21
LPG-	911	38	0.04	164	40
Wood& related fuel	30 t	205	15.00	150	30

Ground Based Measurement: Kanpur

Point Source Emissions (in kg/hr)			
Source	**SO_2**	**NO_2**	**SPM**
Fazalganj industrial	71	28	585
Dada Nagar ind. Area	134	101	180
Panki ind. Area.	254	112	2600
Jajmau ind. Area.	55	50	607
Industrial Estate	21	9	195
Fertiliser Unit	91	62	162
Power plant, Panki	1090	751	3900
Textile Mills	63	44	682
Lal Imli	5	6	97
Ind.At Sarvodaya nagar	3	2	65

Ambient Aerosol Size Distribution



most metals associated with particle size less than 0.7 micron

SOURCE: Wilson WE, Spiller LL, Ellestad TG, Lamothe PJ, Dzubay TG, Stevens RK, Macias ES, Fletcher RA, Husar JD, Husar RB, Whitby KT, Kittelson DB, Cantrell BK. (1977) General Motors sulfate dispersion experiment: summary of EPA measurements. *J Air Pollut Control Assoc.* 27:46-51.

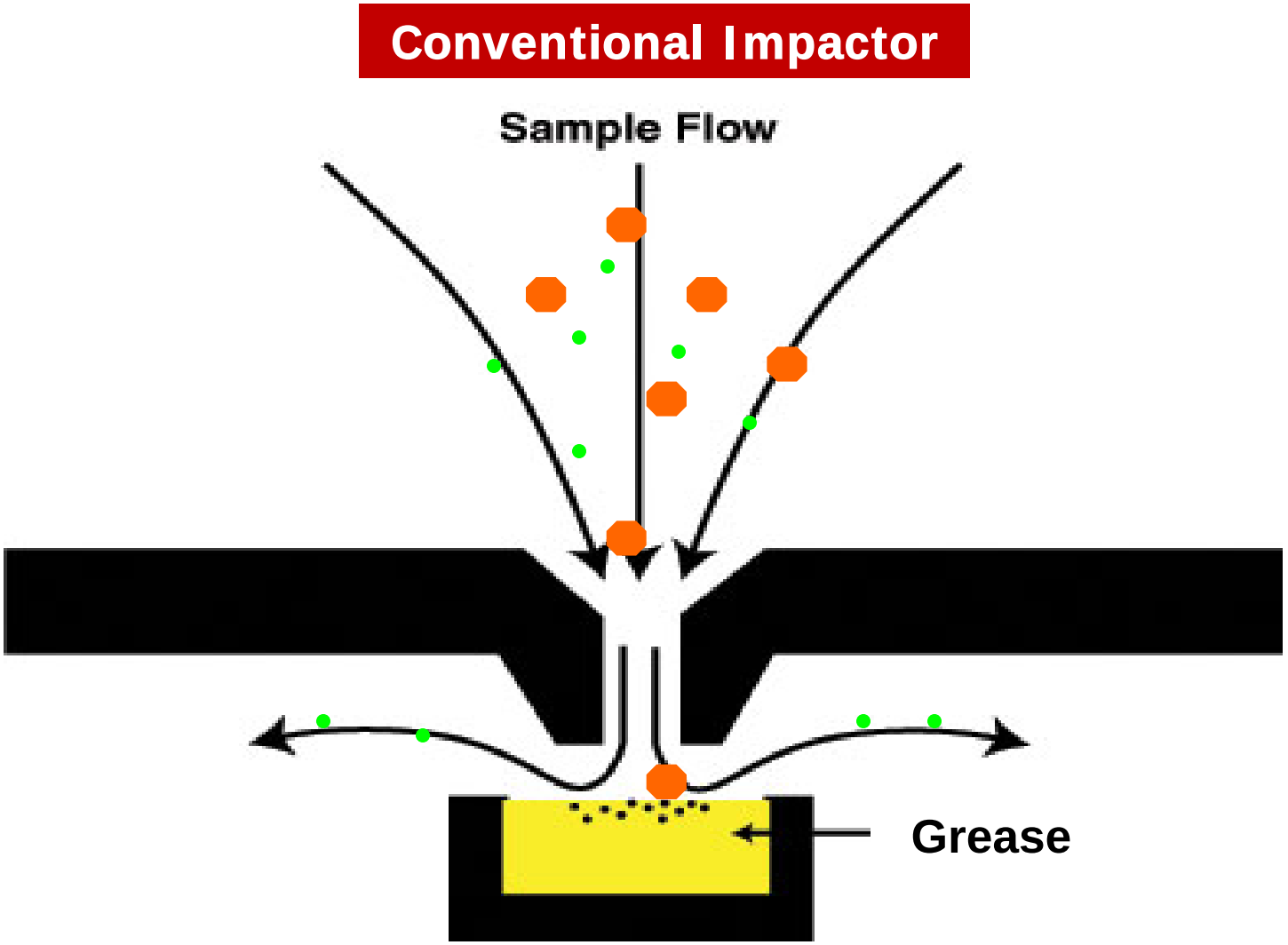
Study Objectives

(a)To design and fabricate a submicron ($PM_{1.0}$) particulate air sampler

(b) To sample outdoor air throughout an year followed by elemental analysis.

(c) Use of source apportionment models for this dataset in order to determine the important sources for submicron aerosol in this part of Indo-Gangetic plains.

Impaction Theory



Theoretical Design Considerations

Key governing parameter for Impaction is the dimensionless Stokes number (Stk):

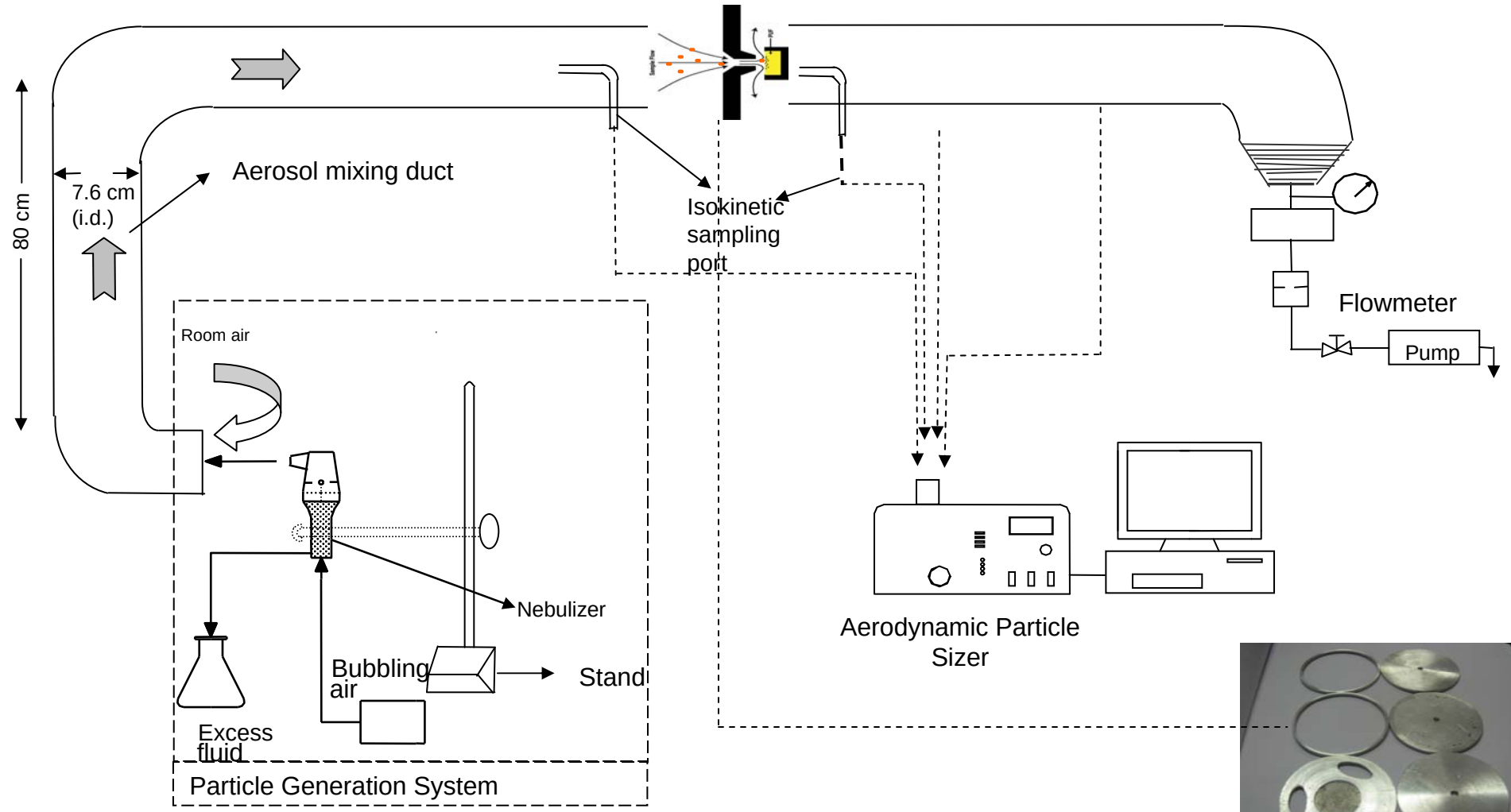
$$Stk = \frac{\rho_p d^2{}_p U C_c}{9\eta W} \qquad \text{(i)}$$

Calculation of the theoretical cut point diameter(d_{50}):

$$d_{50}\sqrt{C_c} = \left[\frac{9\pi\eta D^3{}_j (Stk_{50})}{4\rho_p Q}\right]^{1/2} \qquad \text{(ii)}$$

(Hinds, 1999)

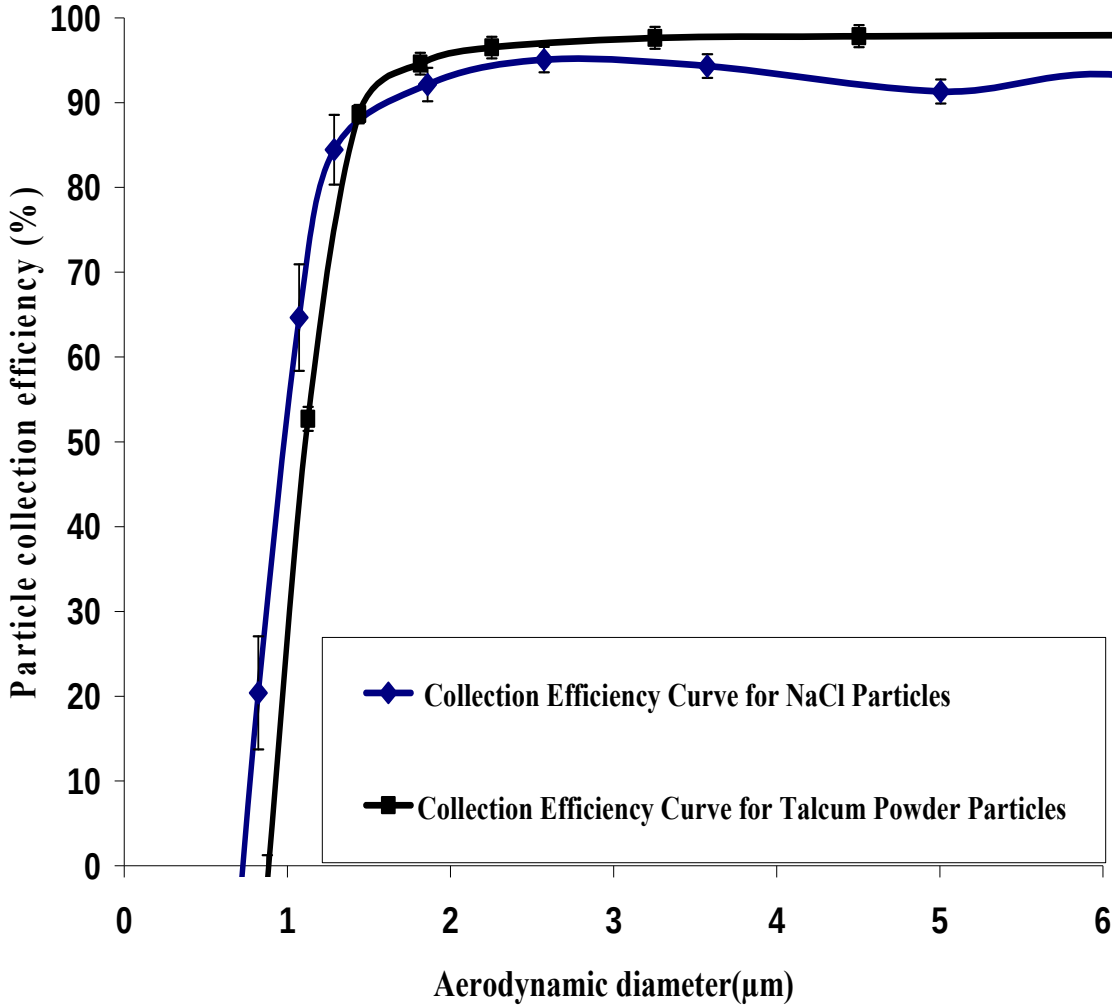
Experimental Setup



Parts of Impactor

Experimental Setup

Developed Submicron (PM_1) Sampler

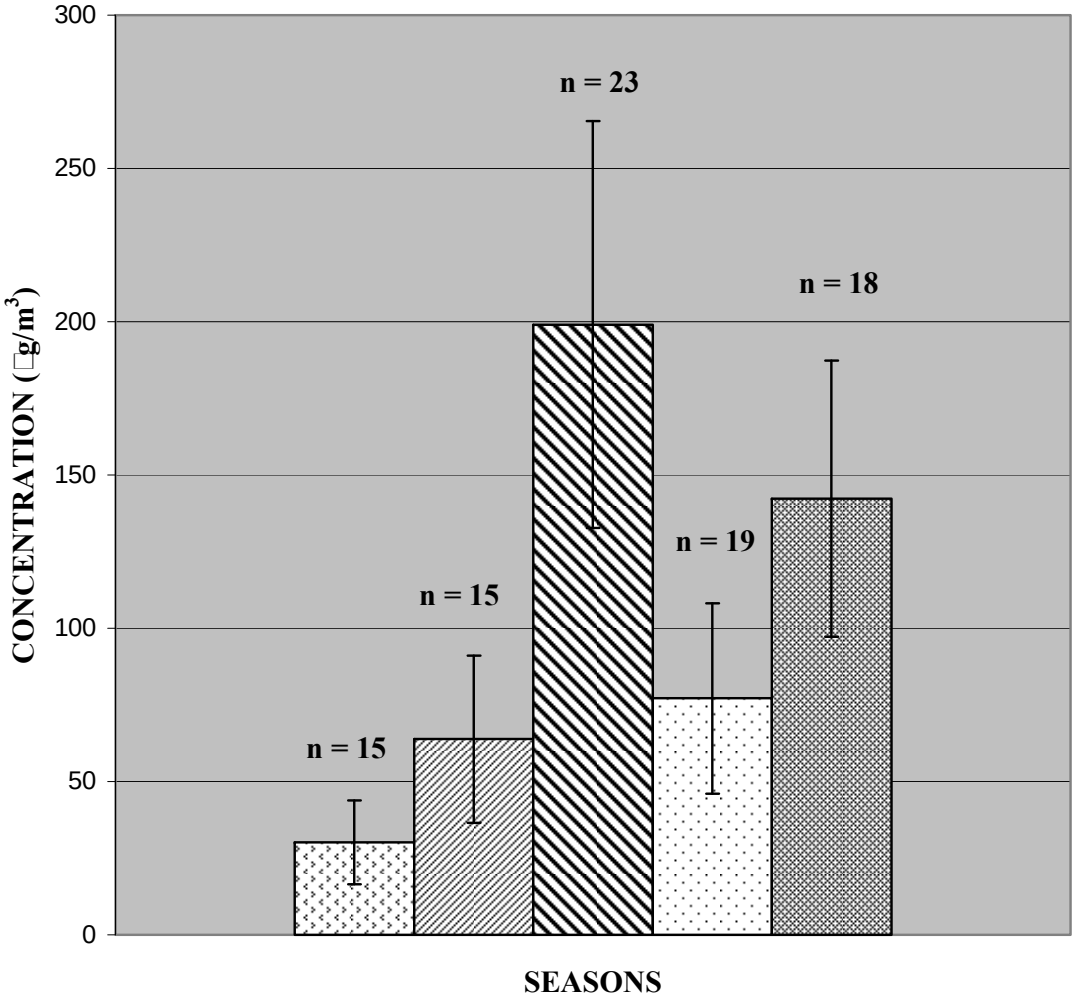


- **all aluminum based weighs 500 g, uses silicone vacuum grease as an impaction substrate.**
- **It has a 1.0 μm cutpoint at an air flow rate of 10 LPM.**

Outdoor PM Measurement

- PM_1 sampler used to collect 100 samples (8 h long) over a one year period at IITK.
- Filters were subjected to chemical analyses for anions and elements.
- The samples were analyzed for 13 trace metals-As, Ca, Co, Cr, Cd, Mg, Fe, Ni, Pb, Cu, Zn, V, Se and 5 anions- F^-, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}

PM_1 Concentrations



Monsoon 30.1 ± 13.7

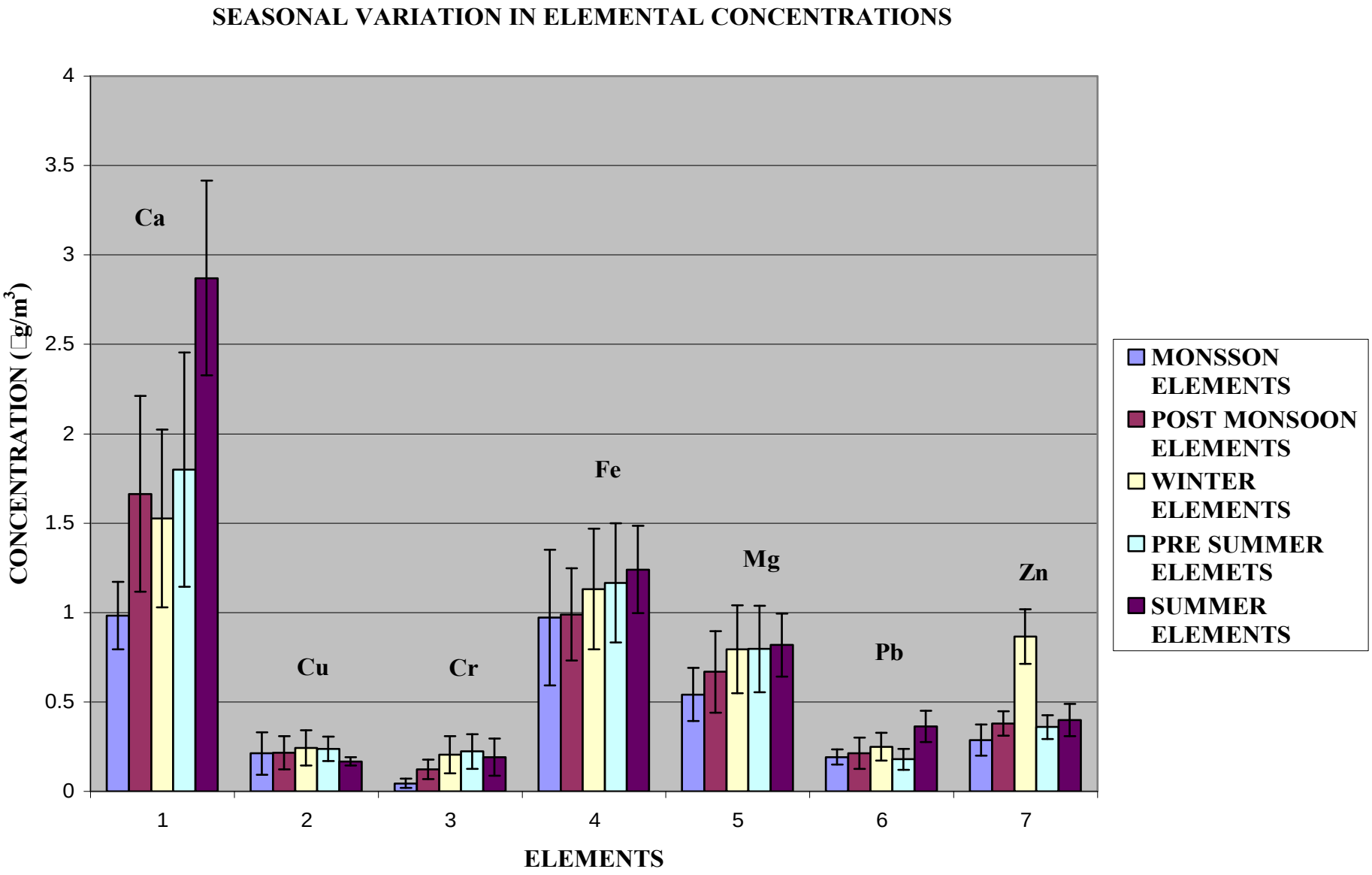
Post monsoon 63.8 ± 23.7

Winter 199 ± 66

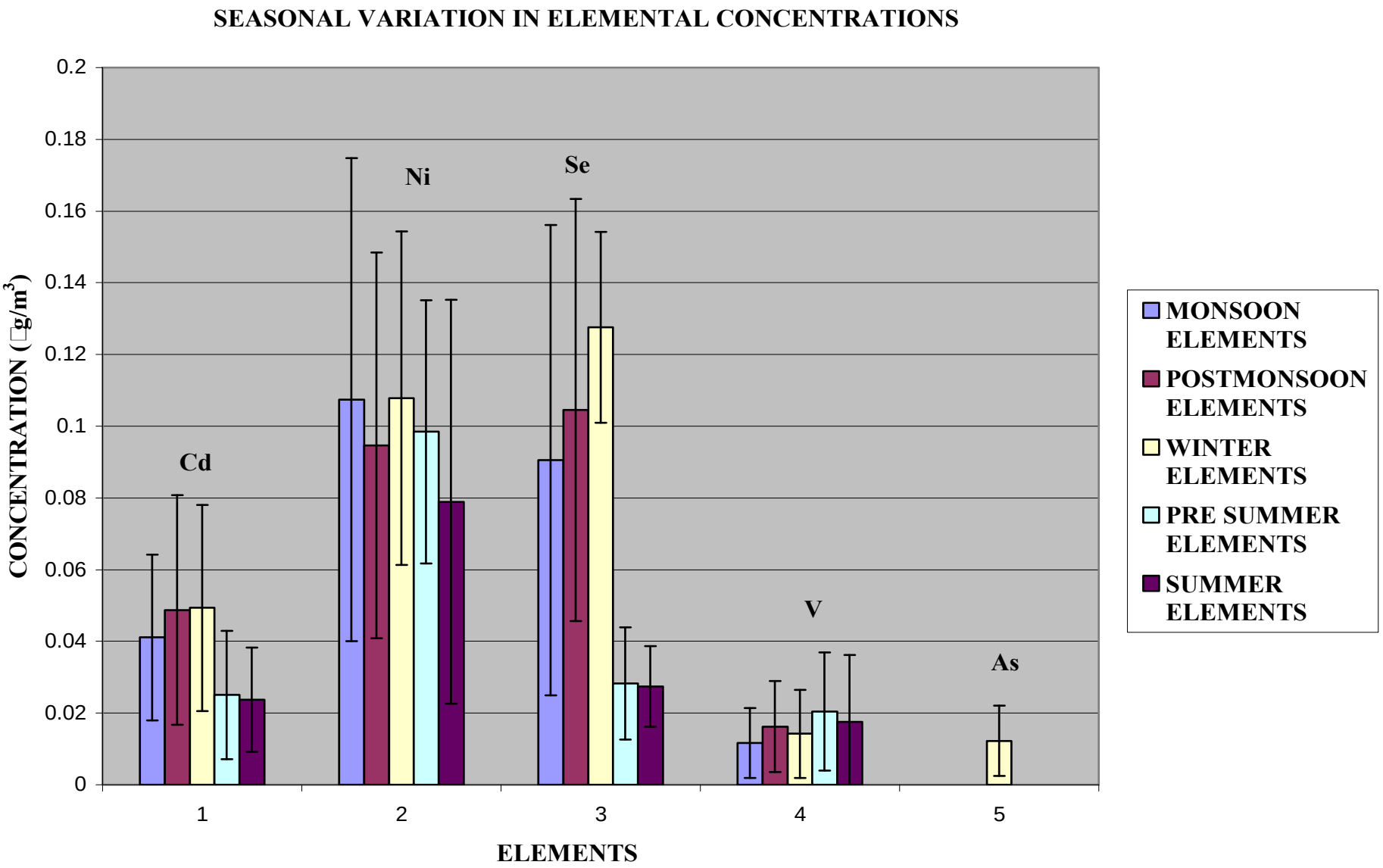
Pre summer 77.1 ± 31

Summer 142.3 ± 45

Elemental Profile



Elemental Profile



Trends in Elemental Concentrations

- In summer season crustal (Ca,Fe,Mg) element concentrations were relatively higher than other season.
- Lead was found in significant amount even after introduction of CNG.
- Zn, Cu, Cd, Cr, Se shows higher concentrations during winter season, indicating to their possible anthropogenic origin.
- As (Arsenic) was detected only in winter season, may be due to lower ambient temperature it transforms from vapor phase to particle phase.
- Co was never detected in any of the samples may be due to it's mainly associated with coarser particles.

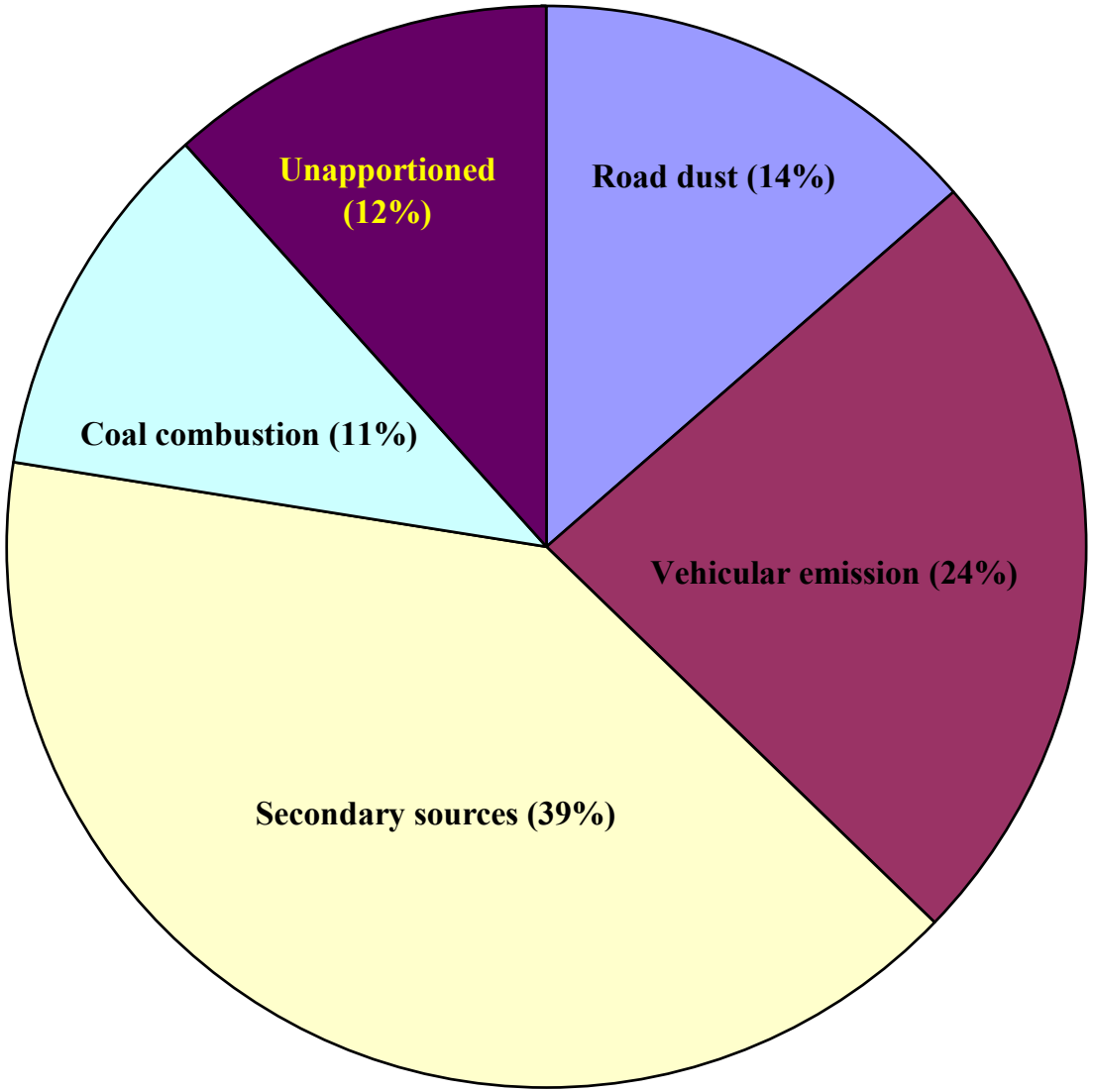
Source Apportionment

UNMIX

Species	Source 1	Source 2	Source 3	Source 4
Ca3933	0.972	1.360	-0.443	-0.064
Cd2288	0.006	0.003	0.016	0.016
Cr2835	0.042	0.178	-0.011	-0.041
Cu3247	0.042	0.082	0.015	0.079
Fe2599	0.407	0.460	-0.041	0.241
Mg2795	0.285	0.274	0.027	0.125
Ni2216	0.028	0.028	0.008	0.045
Pb2203	0.122	0.105	-0.023	0.029
Se1960	0.022	-0.061	0.048	0.062
V_3093	0.013	0.006	-0.003	0.006
Zn2138	0.083	0.143	0.204	0.039
Cl-	0.049	0.362	0.825	-0.176
NO3-	0.124	4.210	12.500	2.170
SO4=	10.600	1.760	5.030	-2.290

Mathematical models were used to conduct source apportionment (UNMIX and PCA).

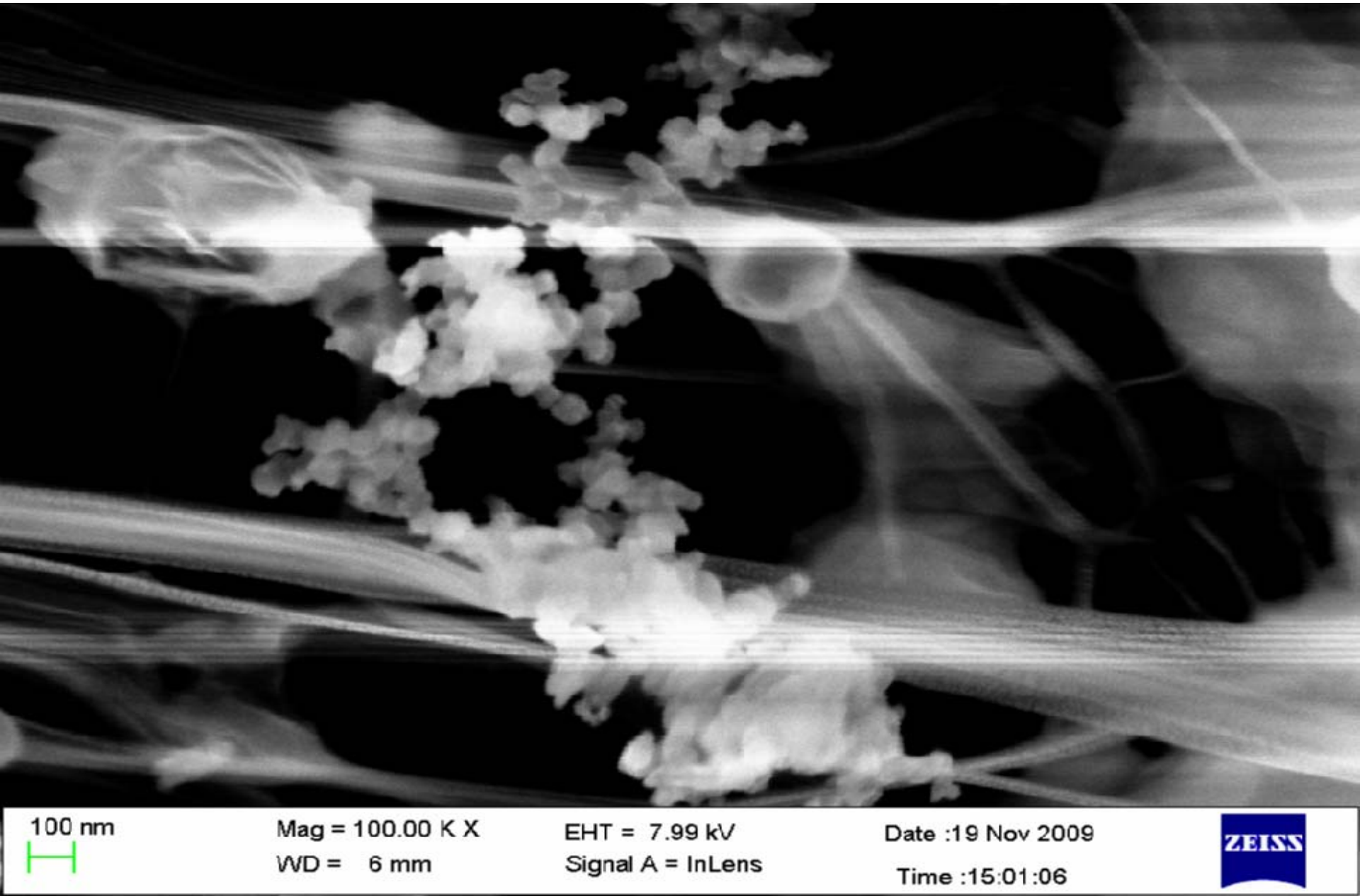
Source Apportionment



Source Apportionment (PM_{10} Vs PM_1)

Sources	PM_{10} Industrial (Auto Fuel Policy Study)	PM_1 IIT Kanpur (Current Study)
Vehicular Exhaust	32	24
Resuspended Dust	24	14
Secondary Aerosol	12	39
Others	32	23

How well do we know PM?



Thank You!

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Source distribution of PM10 (RSPM) in various areas of Kanpur

Sources	Percentage of PM_{10} (RSPM) contributed in various areas			
	Industrial	Commercial	Residential	Kerb side
Auto exhaust	-	-	-	16
Auto exhaust and Diesel generating sets	32	22	39	-
Resuspended dust	24	30	20	31
Secondary aerosol formation	12	8	-	10
Earth crust	-	-	6	14
Small scale industries	8	16	12	-
Other sources	24	24	23	29

Source: Auto Fuel Policy Study