Air Pollution Load – Emission Inventory

For Example

Delhi – Air Pollution Load 2000 T/d

Vehicular Emission – 1400 T/d

Power Generation – 300 T/d

Other Industries – 200 T/d

Miscellaneous – 100 T/d

Decisions

-Control Vehicular Pollution

-What are the constituents (CO, HC, NOx, SO_2 , PM, Pb)

- Priority Pollutant(s)

-Which sources responsible to what extend?

Petrol, Diesel ? 2-W, 3-W, Cars, Trucks ?

To answer these – Pollutants-specific, Source- specific, Area-specific Information and Smart Database with Quick Retrieval System needed

Air Pollution Emission Inventory

"Systematic collection, complication and collation of data concerning air pollution emission in a given industry/area is referred to as Emission Inventory"

Application of Emission Inventory

* Guidance for pollution control
* Assist in AQ Surveillance Programme
* Seasonal and Geographical Distribution of Pollution Loads
* Aiding in Regional Planning and Zoning
* Community Education
* Air Quality Modeling
* For Decision makers/Politicians

How to make Emission Inventory

- Define Boundary of Area (Industry/ IITK, GT Road, Connaught Place, State, Country, Continent)
- Divide the Unit Process-wise

(a) Ammonia (b) Urea (c) Power Generation

(d) Major Traffic Corridors

- Collection of Information

(a) Raw Material and Fuel Quantities

(b) Type of Processes

(c) Efficiency of Pollution Control Devices

Emission Factors – Established Emission Quantity for specific Process and specific Pollutants for unit production.

Emission Rate = [raw mat] x [EF] x[(100 – (% control eff))/100]

Emission Rate = [Production] x [EF] x[(100 – (% control eff))/100]

Emission Rate = [Fuel] x [EF] x[(100 – (% control eff))/100]

EF for Power Plant (US EPA AP-42)
PM (kg/d) = 6.8xA (ash in %)x Coal (in t/d)
SO2 (kg/d) = 19xS (% sulphur)x Coal (in t/d)

Urea
PM (kg/d) = 10xUrea produced (in t)
NH3 (kg/d) = 5x Urea produced (in t)

Emission Inventory

Systematic estimation and collection of data on emissions of…

- **desired pollutants**
- **in a geographic area**
- **for a designated period**

Basic Steps

Identify Geographic area

Pollutants of interest

Locate and Identify sources

Methods

Estimate and Quantify

Identification of Geographic Area

Industry or Establishment

Industrial area or Community

City or District

Regulatory Jurisdiction

Similar Meteorology

Basis

Economy

Interest of the community

Pollutant Type

Criteria Pollutants

- SPM, PM_{10} & $PM_{2.5}$
- SO_2
- NO_X
- CO

Hazardous Pollutants

- Benzene etc.
- Pesticides
- PAH
- Dioxins

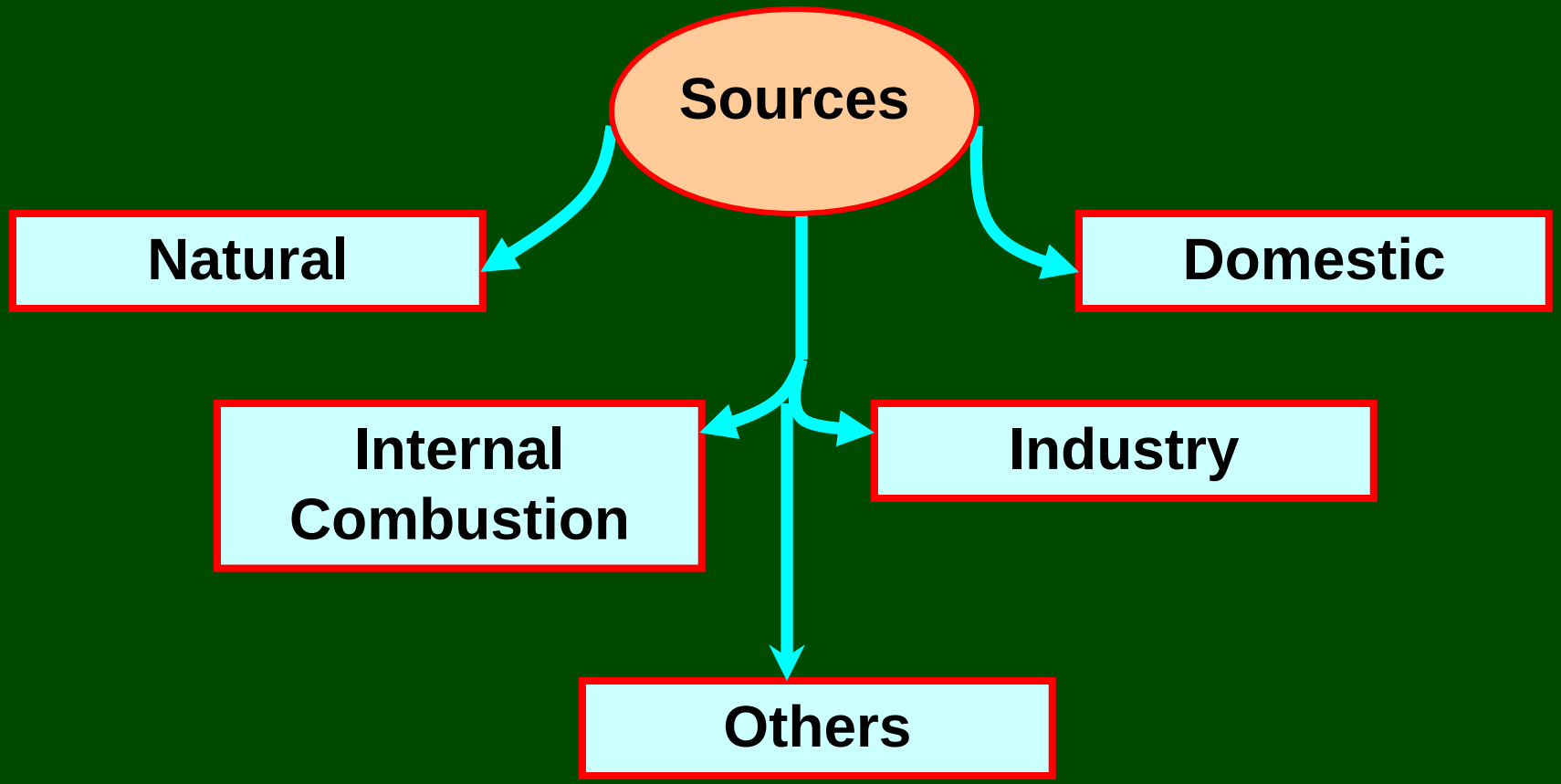
Visibility and photochemical

- Hydrocarbons
- NO_2
- O_3

Greenhouse gas

- CO_2
- CH_4
- N_2O

Locating and Identifying the Sources



Natural Sources

Combustion

Wild fires

Dust Storms

Biological

Fermentation

Anaerobic degradation

Geological

Volcanoes

Wind erosion

Sea salts

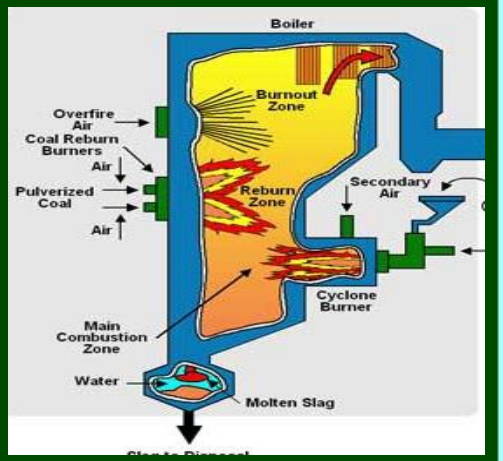
Industry

Process release

Solvent/chemical handling

Mining

Combustion



Internal Combustion

- Public transport
- Registered vehicles
- Fuel loss and evaporation
- Stationary DG sets
- Off road engines

Domestic Sector

- **Fuels**
- **Refrigeration**
- **Portable Gen sets**
- **Chemicals and solvents**

Other Sources

- Mass burning or waste burning
- Wastewater treatment plants
- Agriculture operations
  - Pesticides
  - Biodegradation of crop residue

Source Type

Point source:

- Individual stationary sources of emissions that release pollutants to the atmosphere

Area Sources:

- Individual emissions do not qualify as point sources.
- Represents numerous facilities or activities with small amounts of a given pollutant

General Steps in Inventory Development

- Planning
- Data Collection
- Calculations
- Consolidation
- Documentation

Quality Assurance in Every Step!

Role of Regulatory Agencies

- Identification of sources
- Identification and recommendation of suitable methods
- Preparation of check lists
- Conduct special survey on natural sources
- Data collection and computation
- Preparation of inventories

Responsible Agencies

- Industry
  - Monitoring and data supply
- Institutions
  - District supplies
  - Transport sector
  - Municipal bodies etc.
- Every individual of the community

Emission Factors

An emission factor is a ratio that relates the emission of a pollutant to an activity level at a plant that can be easily measured, such as an amount of material processed, or an amount of fuel used.

EF: Kg/T of fuel fires, Kg/KWhr, Kg/M3 of product

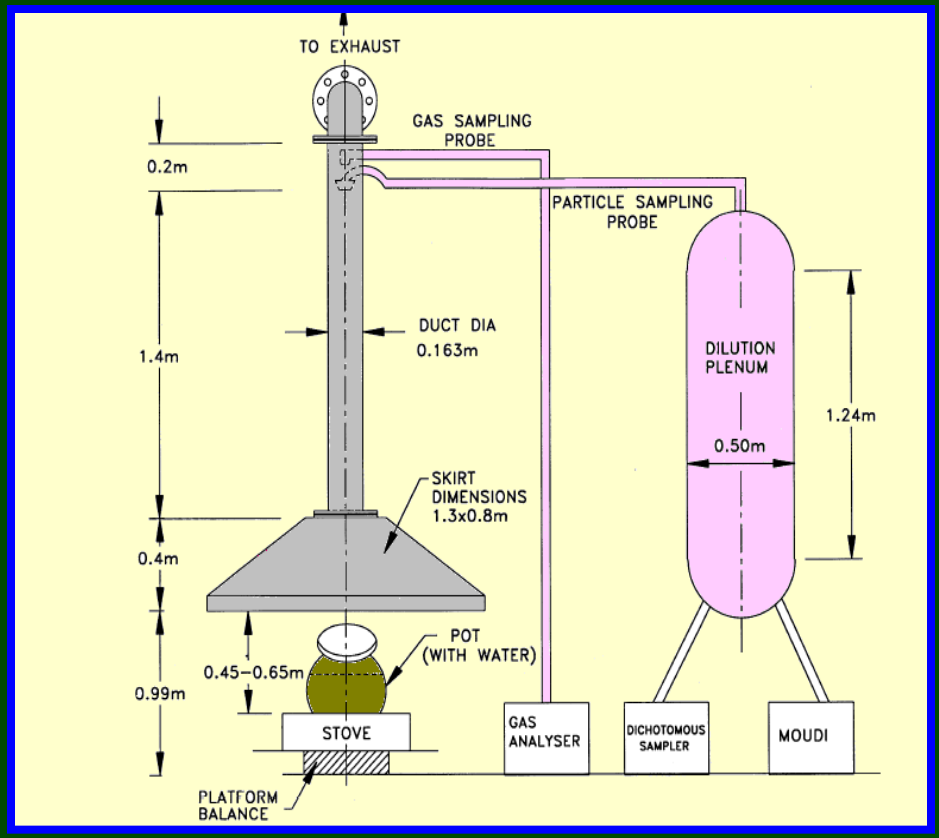
Given an emission factor and a known activity level, a simple multiplication yields an estimate of the emissions.

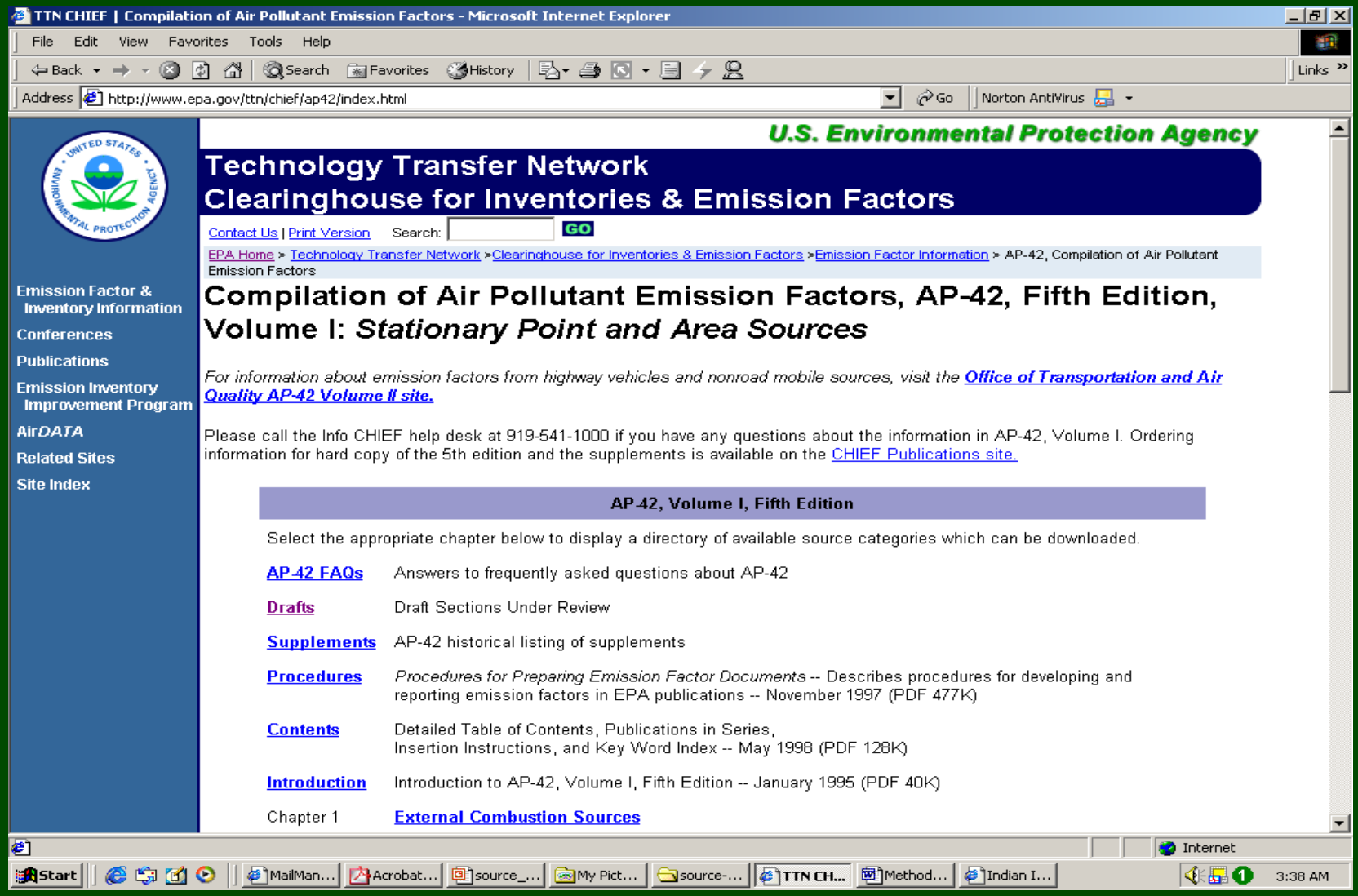
Emission Factors

Emission factors are developed from separate facilities within an industry category,

So they represent typical values for an industry and process

.





Published emission factors are available in numerous sources

Introduction	Introduction to AP-42, Volume I, Fifth Edition -- January 1995 (PDF 40K)
Chapter 1	External Combustion Sources
Chapter 2	Solid Waste Disposal
Chapter 3	Stationary Internal Combustion Sources
Chapter 4	Evaporation Loss Sources
Chapter 5	Petroleum Industry
Chapter 6	Organic Chemical Process Industry
Chapter 7	Liquid Storage Tanks
Chapter 8	Inorganic Chemical Industry
Chapter 9	Food and Agricultural Industries
Chapter 10	Wood Products Industry
Chapter 11	Mineral Products Industry
Chapter 12	Metallurgical Industry
Chapter 13	Miscellaneous Sources
Chapter 14	Greenhouse Gas Biogenic Sources
Appendix A	Miscellaneous Data & Conversion Factors -- S

Technology Transfer Network
Clearinghouse for Inventories & Emission Factors

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EPA Home > Technology Transfer Network >Clearinghouse for Inventories & Emission Factors > Emission Factor Information > AP-42, Compilation of Air Emission Factors > Chapter 1: External Combustion Sources

- Emission Factor & Inventory Information
- Conferences
- Publications
- Emission Inventory Improvement Program
- AirDATA
- Related Sites
- Site Index

AP-42, Fifth Edition, Volume I
Chapter 1: External Combustion Sources

Explanation of File Formats

NOTE: Many AP-42 files contain equation fonts that may not be readable on some computers. If you encounter problems with viewing AP-42 documents, try using our Fax CHIEF system to receive a fax copy or contact the Info CHIEF Help Desk, (919) 541-1000.

1.0 Introduction to External Combustion Sources

1.1 Bituminous and Subbituminous Coal Combustion

- Final Section - Supplement E, September 1998 (PDF 515K)
- Background Document (PDF 8M)
- Related EIIP Documents (PDF 232K)

1.2 Anthracite Coal Combustion

- Final Section - Supplement B, October 1996 (PDF 59K)
- Background Document (PDF 249K)
- Related EIIP Documents (PDF 232K)

1.3 Fuel Oil Combustion

- Final Section - Supplement E , September 1998 (PDF 293K)
- Errata

Emission Factors –Coal Fired Boiler

Table 1.1-3. EMISSION FACTORS FOR SO_x, NO_x, AND CO FROM BITUMINOUS AND SUBBITUMINOUS COAL COMBUSTION[a]

Firing Configuration	SCC	SO_x[b]		NO_x[c]		CO[d,e]	
		Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING	Emission Factor (lb/ton)	EMISSION FACTOR RATING
PC, dry bottom, wall-fired[f], bituminous Pre-NSPS[g]	1-01-002-02 1-02-002-02 1-03-002-06	38S	A	22	A	0.5	A
PC, dry bottom, wall-fired[f], bituminous Pre-NSPS[g] with low-NO_x burner	1-01-002-02 1-02-002-02 1-03-002-06	38S	A	11	A	0.5	A
PC, dry bottom, wall-fired[f], bituminous NSPS[g]	1-01-002-02 1-02-002-02 1-03-002-06	38S	A	12	A	0.5	A
PC, dry bottom, wall-fired[f], sub-bituminous Pre-NSPS[g]	1-01-002-22 1-02-002-22 1-03-002-22	35S	A	12	C	0.5	A
PC, dry bottom, wall fired[f], sub-bituminous NSPS[g]	1-01-002-22 1-02-002-22 1-03-002-22	35S	A	7.4	A	0.5	A
PC, dry bottom, cell burner[h] fired, bituminous	1-01-002-15	38S	A	31	A	0.5	A
PC, dry bottom, cell burner fired, sub-bituminous	1-01-002-35	35S	A	14	E	0.5	A

Typical Example

(Emission Inventory for Automobile Sources)

Assessment and Interpretation of Air Pollution load In the Campus of Indian Institute of Technology, Kanpur

Emission Inventory

Objectives of the Study

Identification and Quantification of various sources of Air Pollutants in IITK campus

- Mobile and stationary sources
- Fugitive (non point sources) – Focus on road dust emissions

Interpretation of Emission loads

- Type of pollutants
- Type of sources
- Campus emission profile

Emission Inventory (IITK vis-à-vis Kanpur City)

Methodology

- Designate air shed (boundaries of the study area – IITK)
- Combustion related sources
  - –Stationary sources: Domestic fuels, Cooking in hostels, activities at commercial areas, generator sets
  - –Mobile sources: On road vehicles
  - –Mass burning: Leaves, garbage etc.
- Non-combustion related sources
  - –Road dust, construction activities. evaporative losses

Identification and classification of sources

Source	Fuel firing	Non-Fuel	Point/mobile	Area
Automobiles emissions	✓		✓	
Cooking				
1.Residential	✓		✓	
2.Restaurants	✓		✓	
3.Hostels	✓		✓	
Diesel Generators	✓		✓	
Aircraft	✓		✓	
Fumigation of insecticides		✓		✓
Road dust Emissions		✓		✓

General information of IITK campus

- Total area of the campus = 1055 acres
- Total residential houses = 1685
- The Population of students = 2100
- Population of staff = 1550
- Total population (approximately) = 15000

Estimation of Emissions from Cooking Fuels

Residential

Type-1 and 1a, 2, 3, 4 and 5

Servant quarters

SBRA

Hostels

Hall - I, II, III, IV, V, VI, VII, GH and VH

Canteens

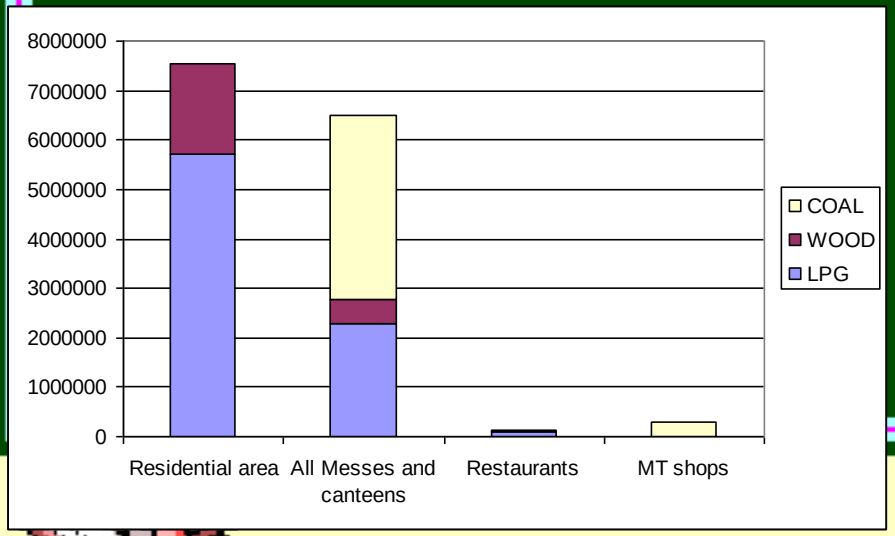
Commercial

Restaurants, SIS mess, MT shops

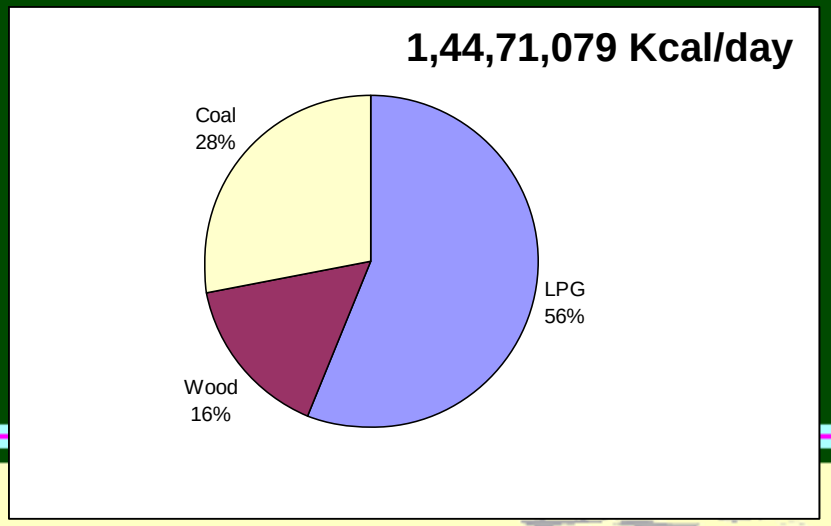
Major Cooking fuels in the Campus

	LPG (Kg/day)	Wood (Kg/day)	Coal (Kg/day)
Residential area	543.3	652.0	-
All Messes and canteens	218.65	174.75	825.9
Restaurants	9.8	2.93	7.9
MT shops	-	-	65.0

Energy Consumption (Kcal/day)



Energy Supply by Fuel Type (Kcal/day)



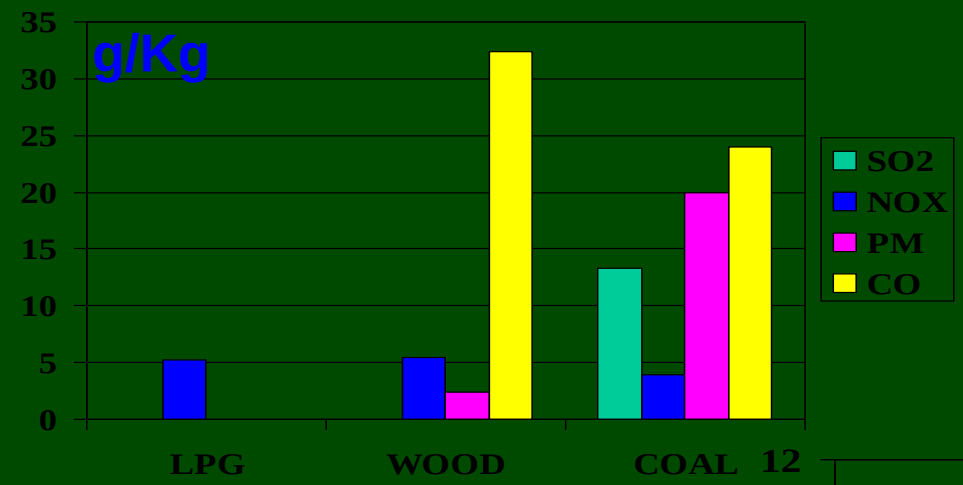
	IITK	Kanpur	India
Per Capita Domestic Energy Consumption (Kcal/day/Person)	964	803[1]	134[2]

20% more than that of Kanpur

1 Shukla (2002), CPCB, Kanpur

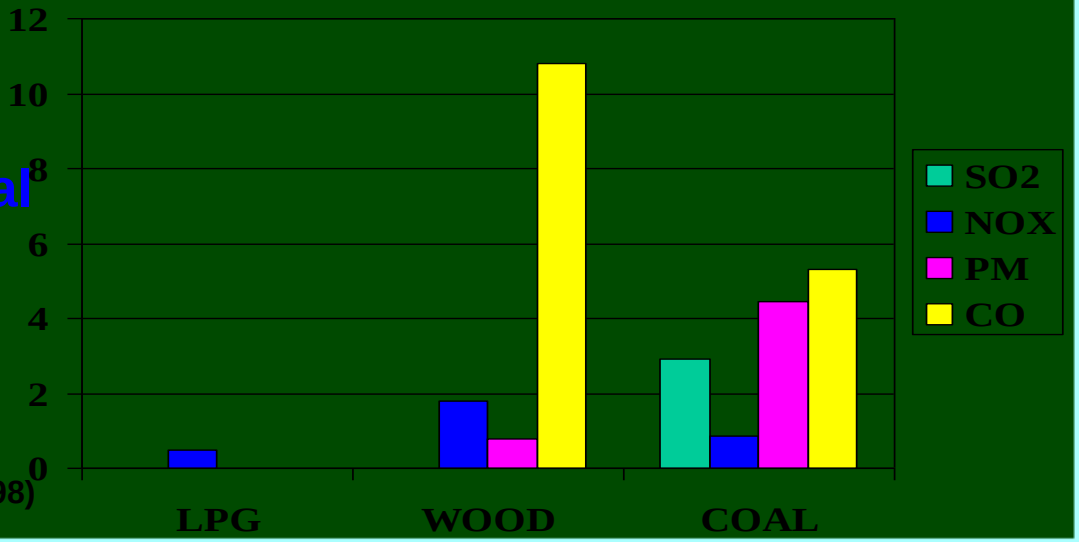
2 *Chandra Venkat Raman, (2000), Aerosol Research Lab, IITB*

Emission Factors for Fuel Combustion



Coal – Highly polluting fuel

LPG - Clean fuel



More health hazards due to Particulates

Source: Tata Energy Research Institute, Delhi (1998)

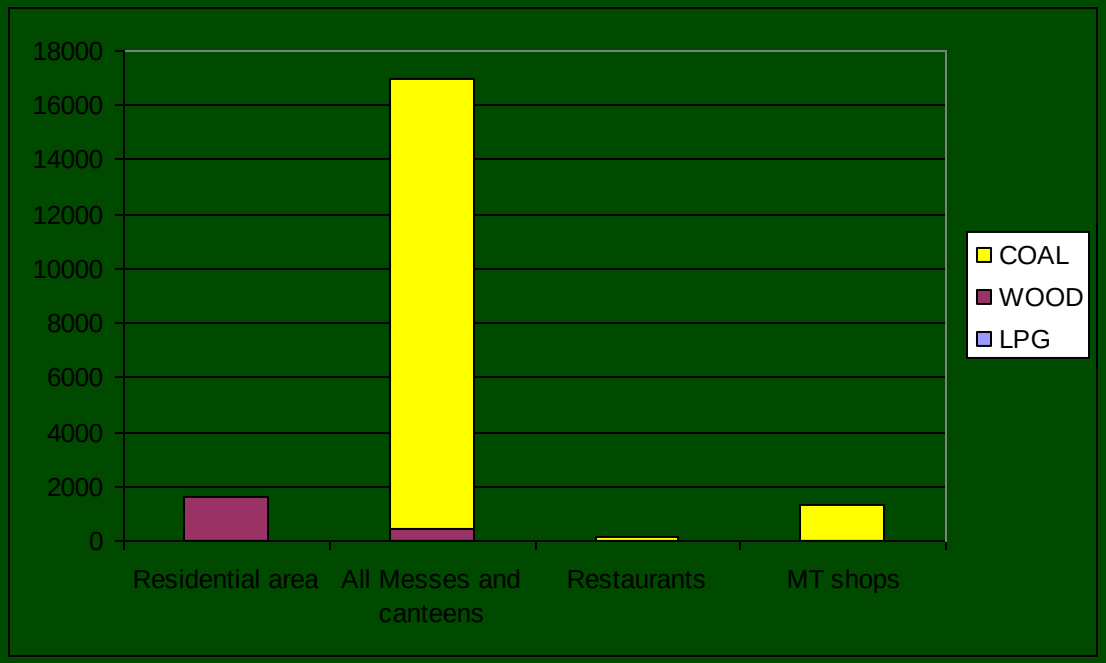
NO_X Emissions- Domestic Fuels

	g/day
Residential	6,424
Hostels etc.	5,399
Restaurants	99
MT Shops	259

SO_2 Emissions- Domestic Fuels

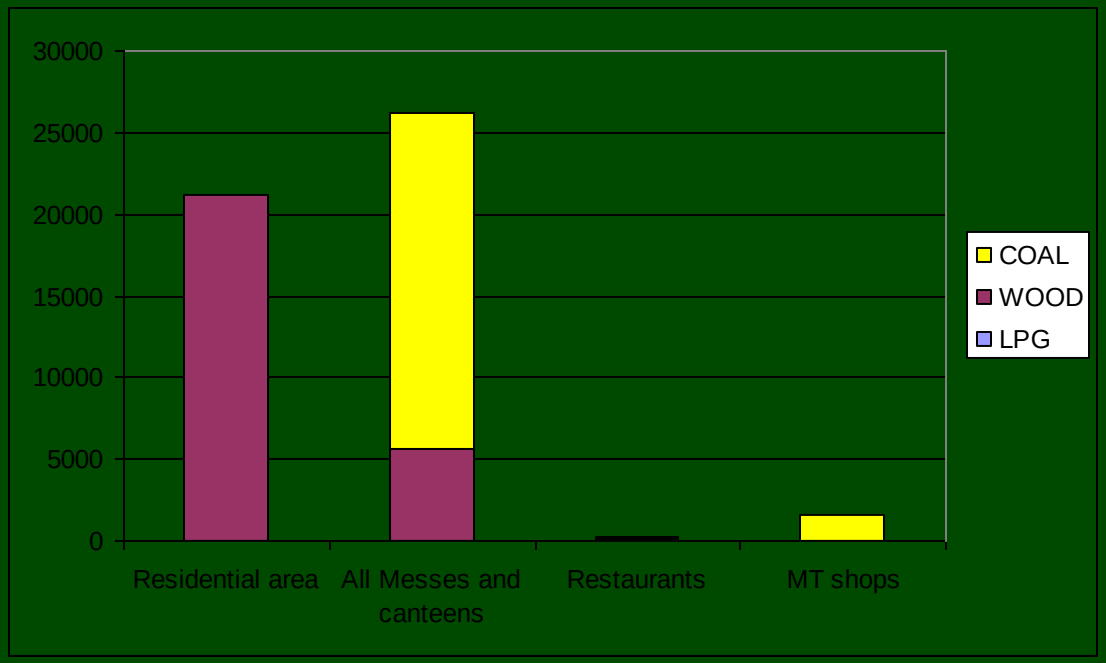
	g/day
Residential	0.0
Hostels etc.	10556
Restaurants	104
MT Shops	864

“PM” Emissions- Domestic Fuels



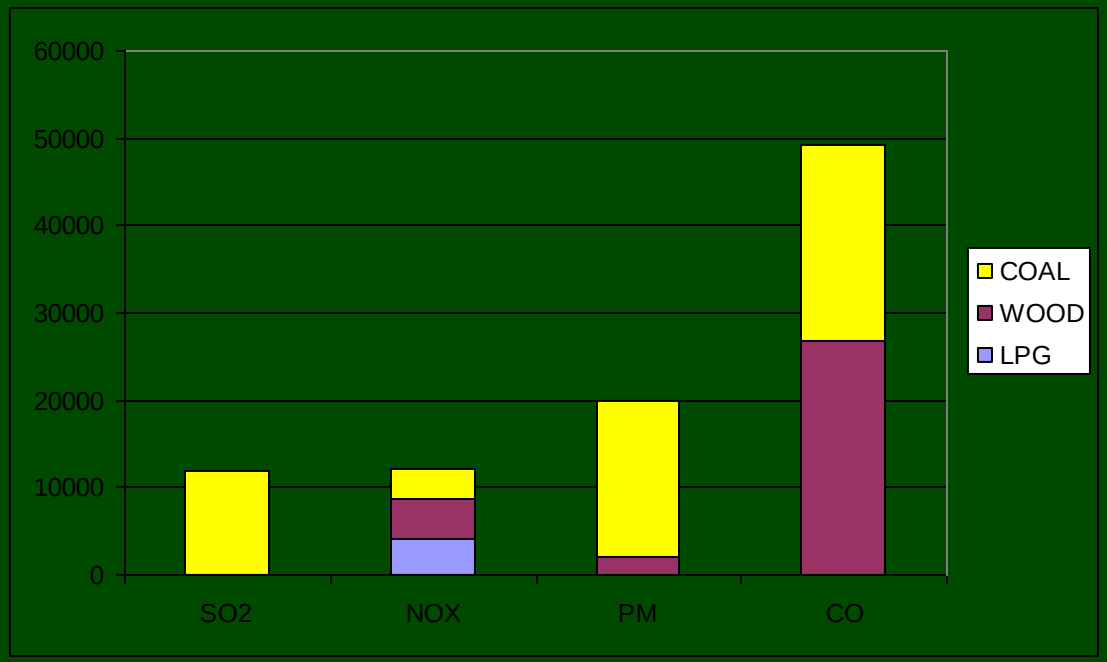
	g/day
Residential	1597
Hostels etc.	16306
Restaurants	190
MT Shops	1300

“CO” Emissions- Domestic Fuels



	g/day
Residential	21134
Hostels etc.	25321
Restaurants	499
MT Shops	1619

Total Emission Rate - Domestic Fuels



g/Day

SO_2	12007
NO_X	11879
PM	20113
CO	48030

Per Capita Emission Rate - Domestic Fuels (g/day/person)

	IITK	Kanpur
SO_2	0.8	0.3
NO_X	0.8	0.19
PM	1.3	0.27
CO	3.3	1.07

Coal and wood - major fuels contributing maximum pollution load at IITK

Alternative – Solar Power for cooking in hostels

Estimation of emission from Automobiles

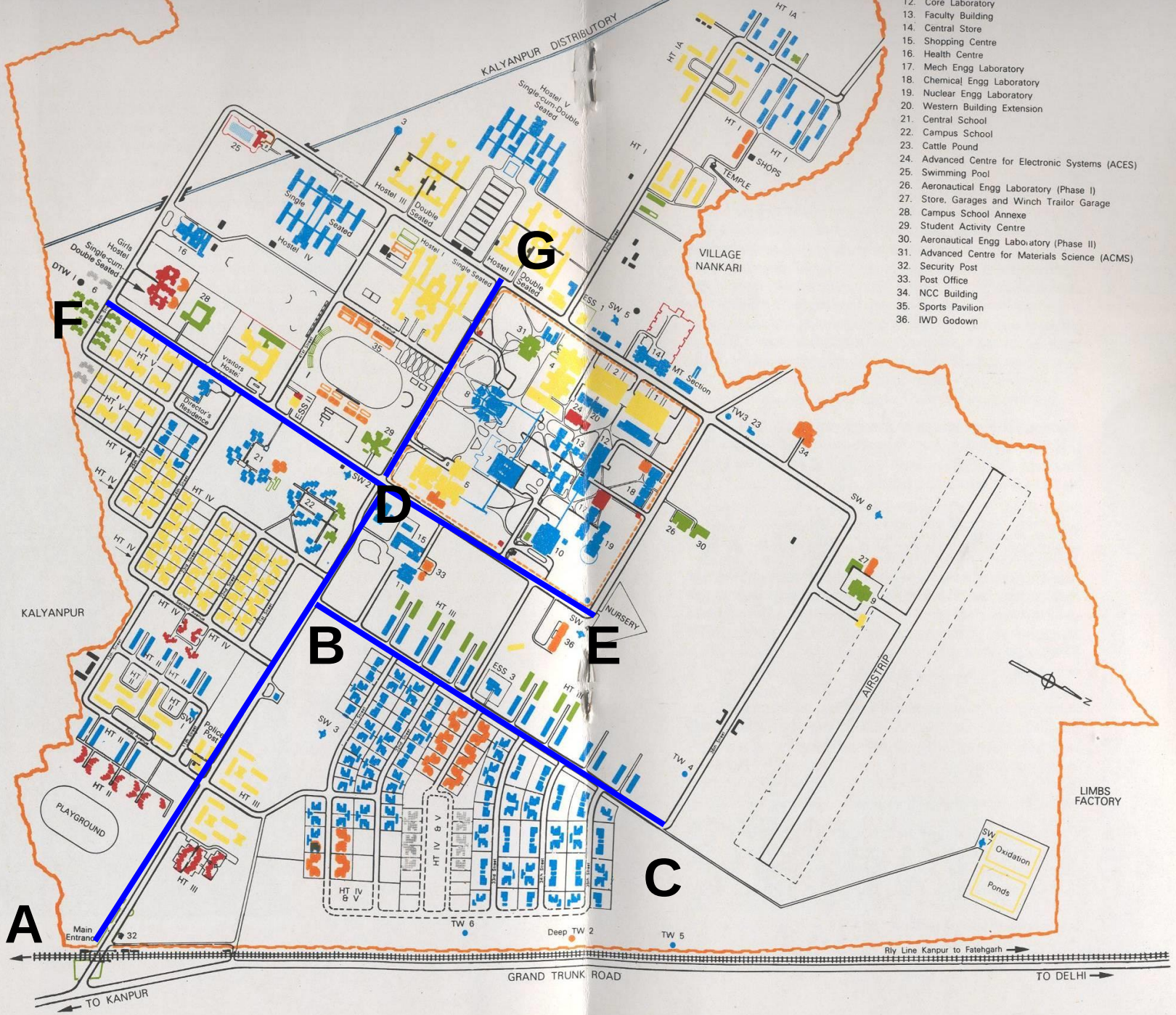
Automobiles

Diesel-driven

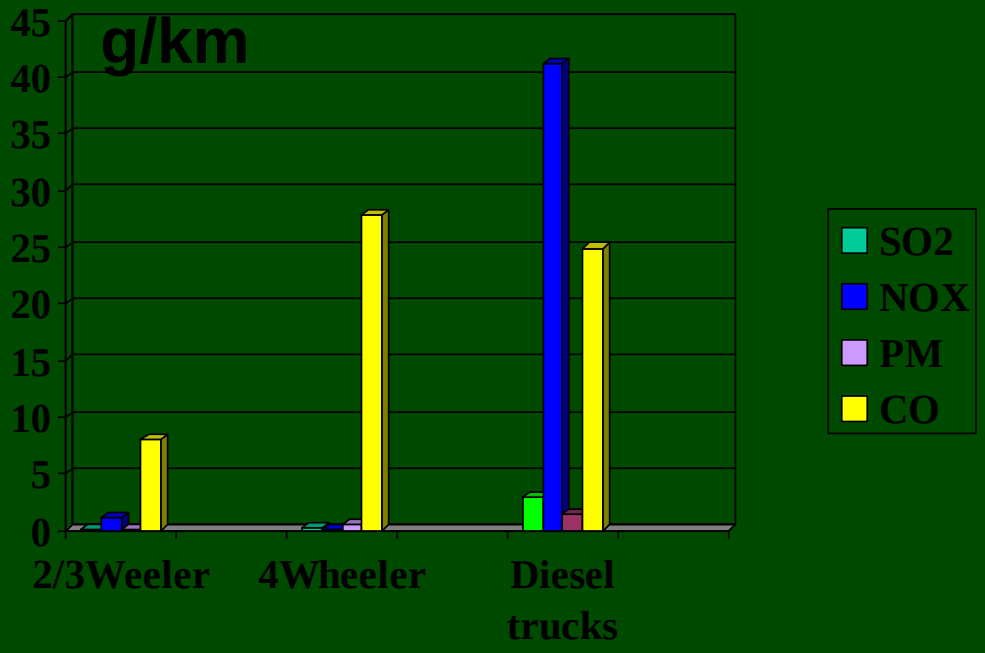
- Two-wheelers
- Three-wheelers
- Cars

Petrol-driven

- Buses
- Trucks
- Tractors


KALYANPUR DISTRIBUTORY
VILLAGE NANKARI
KALYANPUR
PLAYGROUND
AIRSTRIP
LIMBS FACTORY
NURSERY
Oxidation Ponds
Main Entrance
GRAND TRUNK ROAD
TO KANPUR
TO DELHI
Rly Line Kanpur to Fatehgarh
A
B
C
D
E
F
G
12. Core Laboratory
13. Faculty Building
14. Central Store
15. Shopping Centre
16. Health Centre
17. Mech Engg Laboratory
18. Chemical Engg Laboratory
19. Nuclear Engg Laboratory
20. Western Building Extension
21. Central School
22. Campus School
23. Cattle Pound
24. Advanced Centre for Electronic Systems (ACES)
25. Swimming Pool
26. Aeronautical Engg Laboratory (Phase I)
27. Store, Garages and Winch Trailor Garage
28. Campus School Annexe
29. Student Activity Centre
30. Aeronautical Engg Laboratory (Phase II)
31. Advanced Centre for Materials Science (ACMS)
32. Security Post
33. Post Office
34. NCC Building
35. Sports Pavilion
36. IWD Godown

Emission Factors for Vehicular Emissions

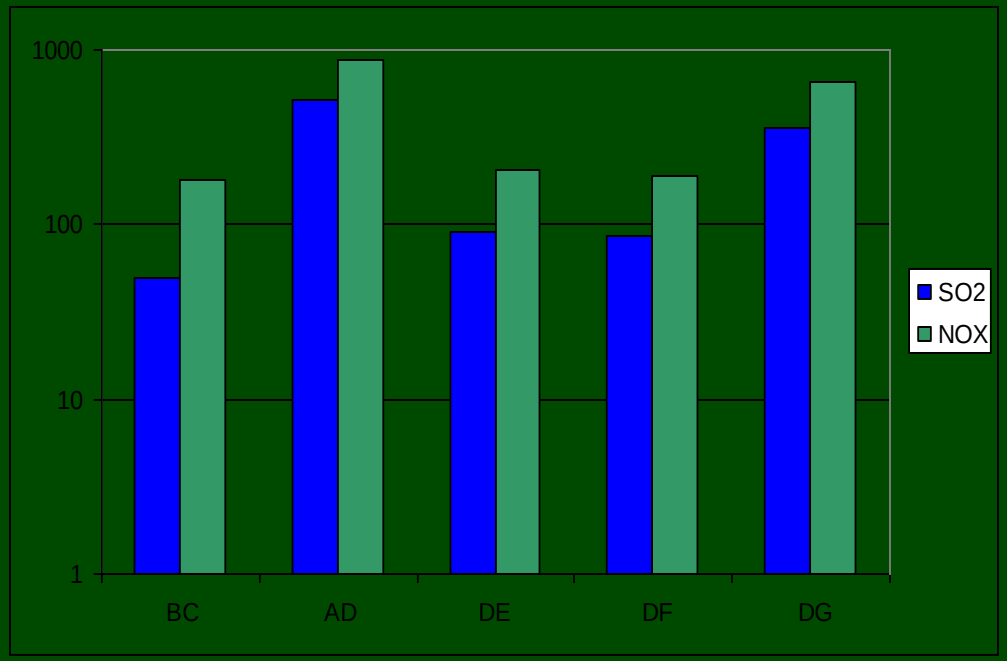


Diesel-driven vehicles – major sources of NO_x

Source: Tata Energy Research Institute, Delhi (1998)

Air pollution load due to automobiles

Locations	Pollution (g/day)				
	SO_2	PM	NO_x	CO	Total
Road BC	49.95	610.15	179.42	10394	11233.4
Road AD	512.30	10279	871.33	43978.6	55641.3
Road DE	90.13	1942.9	206.57	10881.4	13121
Road DF	85.5	1773.5	189.17	9831.6	11879.8
Road DG	356.7	7820.7	660.78	34372.5	43210.6
Total (g/day)	**1094.5**	**22426**	**2529.7**	**109205.3**	**135086.1**

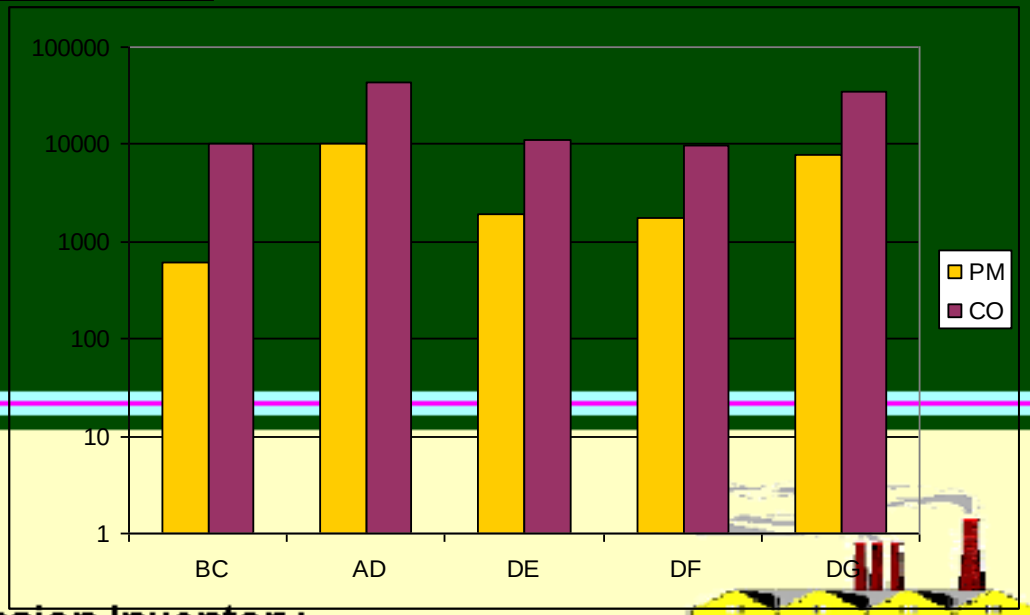


SO_2 g/day

NO_x g/day

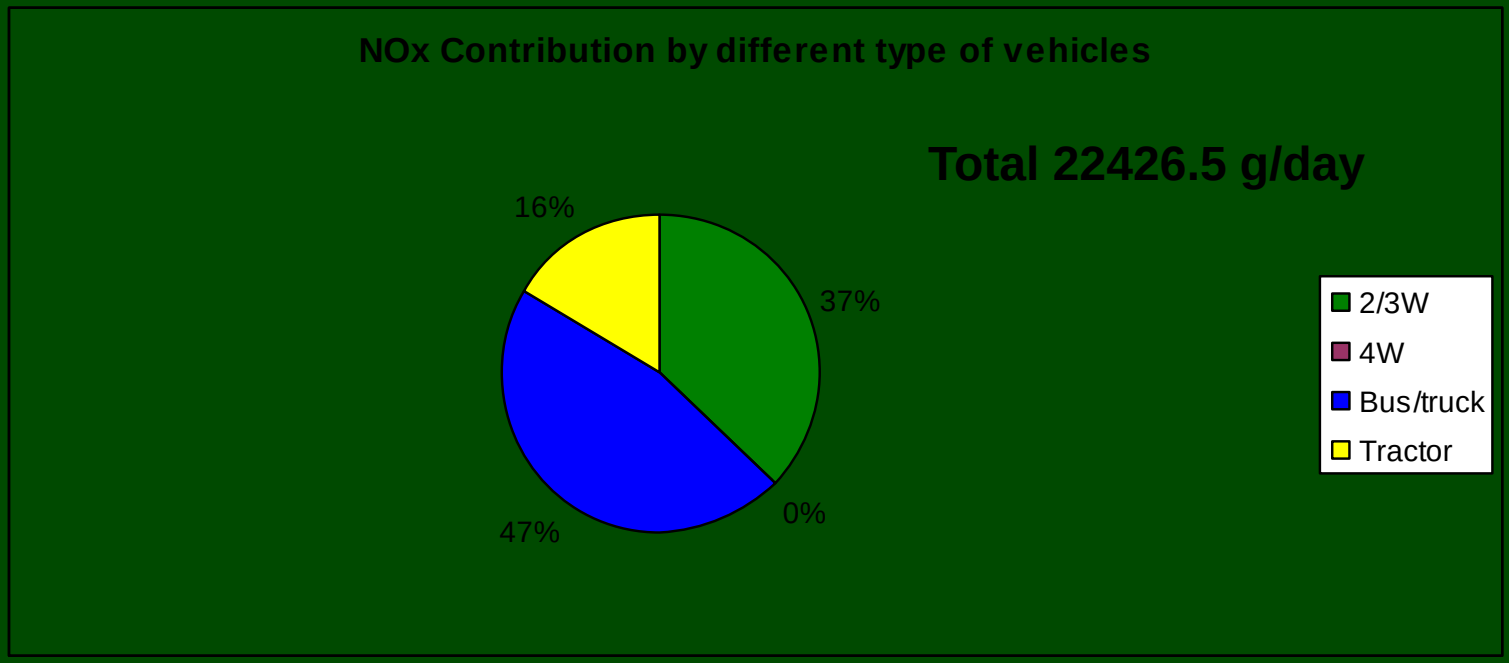
PM g/day

CO g/day

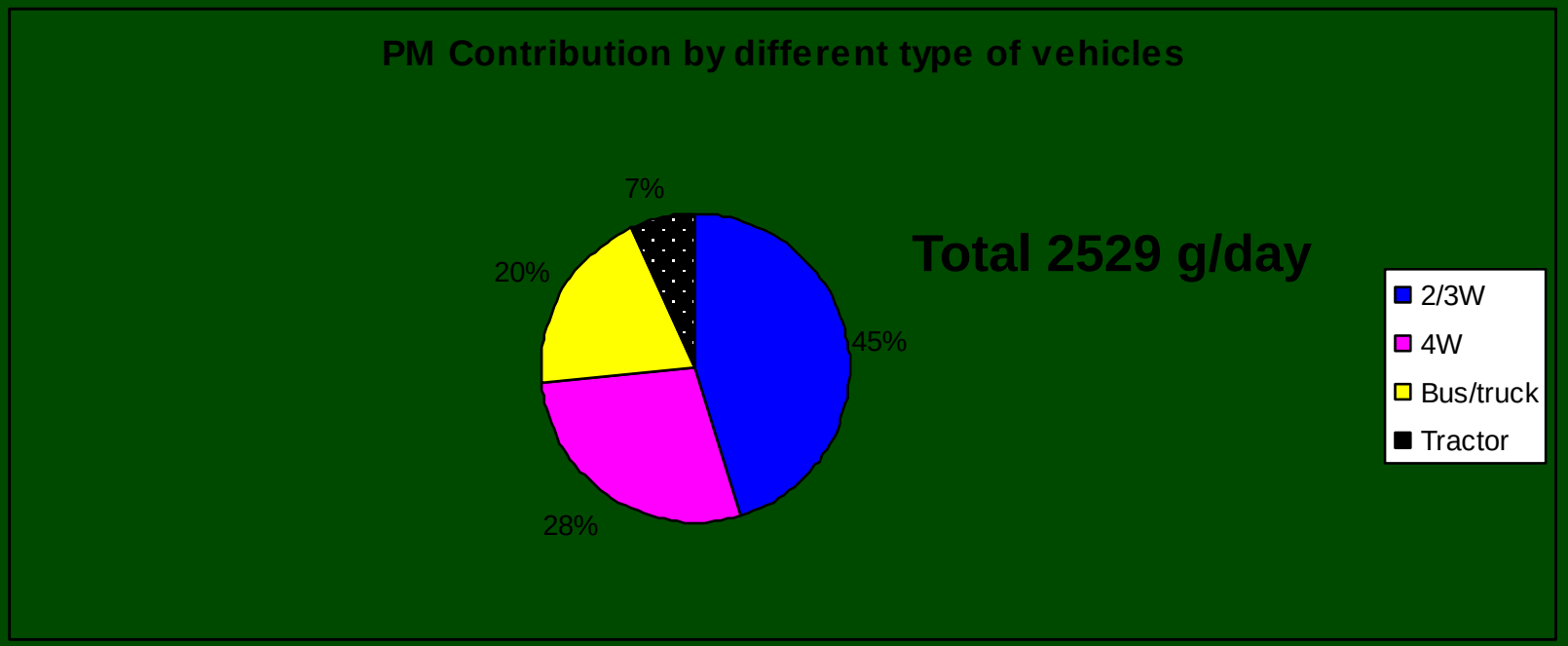


Emission Inventory

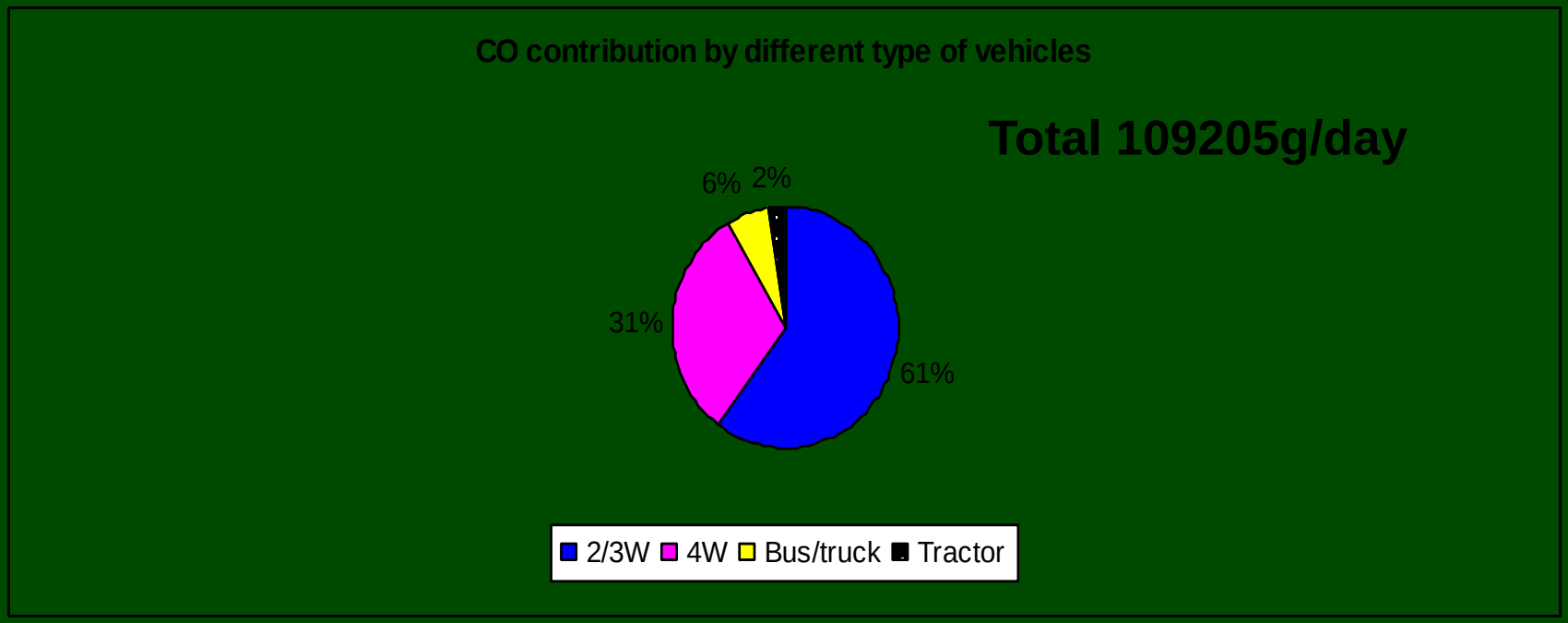
NO_X Emissions- Automobiles



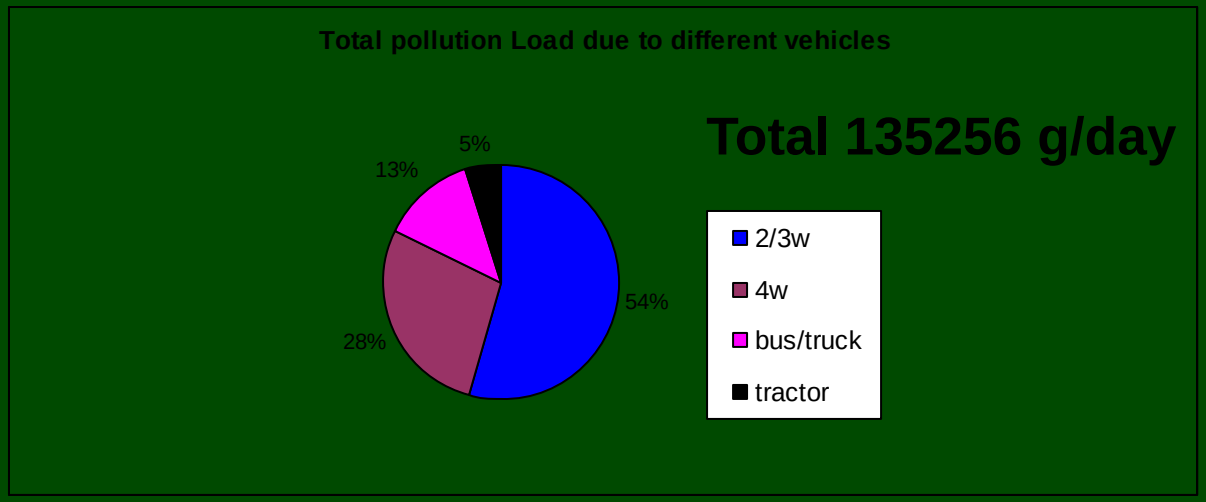
PM Emissions- Automobiles

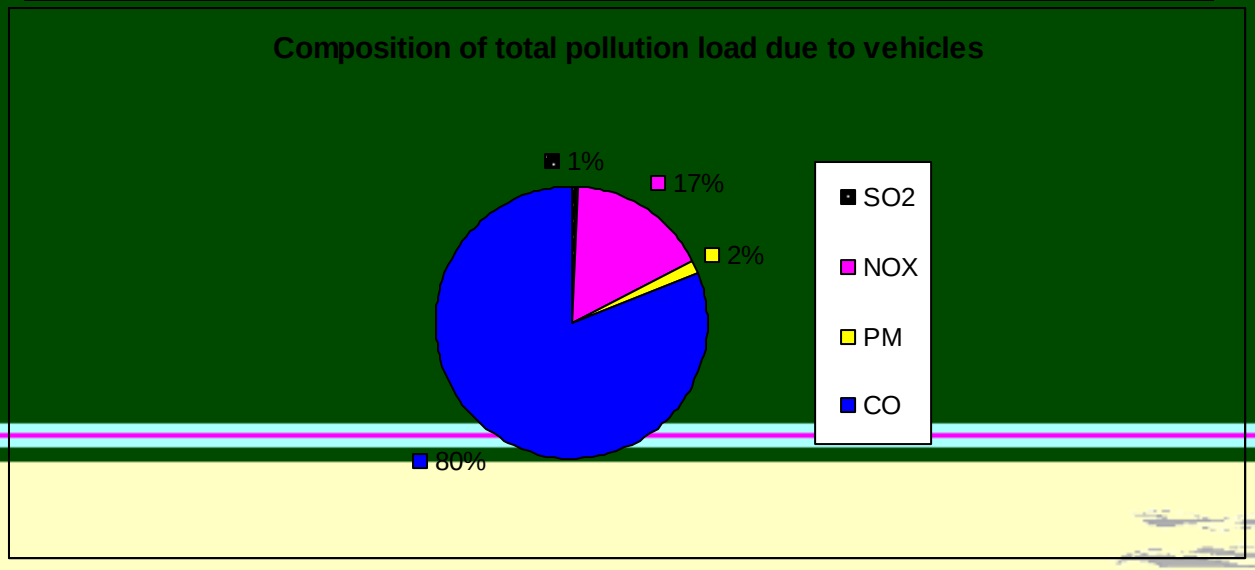


“CO” Emissions- Automobiles



Contribution & composition of various pollutants by different vehicles





Per Capita Emission Rate - Automobiles (g/day/person)

	IITK	Kanpur
SO_2	0.07	0.18
NO_X	1.49	2.17
PM	0.17	0.22
CO	7.28	12.30

Vehicle transportation in Kanpur City includes vehicles for industrial goods and product transportation

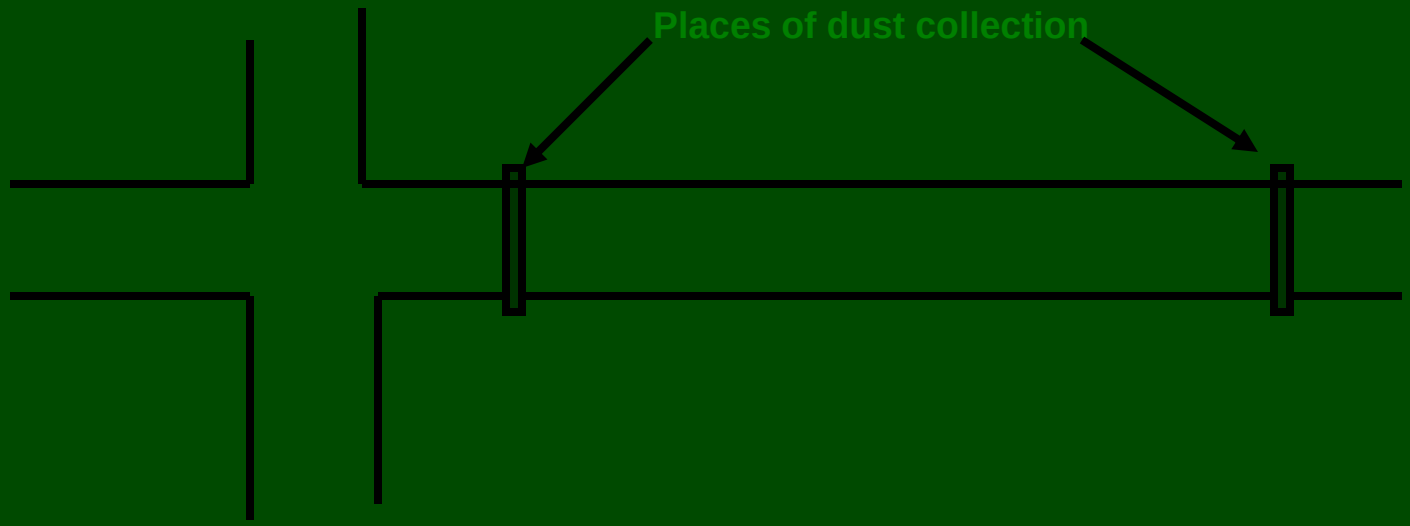
Fugitive dust sources

Pollutants generated from open sources exposed to air and are discharged in to atmosphere without confined flow stream

- USEPA, 1978

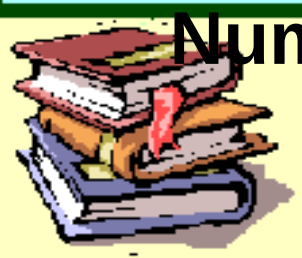
Road dust is the main source of Fugitive dust in the campus

Procedure of dust collection



Total roads covered = 5

Number of samples at each location = 2



Two samples have been collected from each place and These samples have been analyzed for silt content, moisture Content.

On the basis of concept given by USEPA, the emission factor for each Road has been calculated

Formula used for calculation of Emission factor

$$E = k\left(sL/2\right)^{0.65}\left(W/3\right)^{1.5}$$

E	Emission rate of specific particle size (g/VKT)
K	Particle multiplication factor (function of particle size)
SL	Silt loading factor (g/m^2)
W	Mean fleet weight (tons)

VKT -- vehicle kilometer traveled

USEPA, Emission Factor Documentation For AP-42, Roads, Final Report, Midwest Research Institute, Kansas City, MO, September 1998.

Validity of formula

Emissions from Roads depends on

- Silt content and silt loading
- Moisture content
- Vehicle weight (mean fleet average weight)
- Vehicle mean speed

The equation is *not* intended to be used to calculate a separate emission factor for each vehicle weight class.

Particle Multiplication Factor “k”

Particle Size	K (g/VKT)
PM2.5	1.1
PM10	4.6
PM15	5.5
PM30	24

VKT Vehicle Kilometer Travel

Silt Loading "sL"

Silt content – Particles passing through 200 mesh (75 micron size)

Silt Loading - Mass of silt (grams) per unit area of the road

$$sL = \left(\text{Mass of Total dust collected on the road (g/m2)}\right) \times \left(\text{Fraction of silt content in the dust}\right)$$

Flowchart for Estimation of EF

Dust collection across the road

↓

Estimation of silt content

↓

Estimation of Silt loading

↓

Hourly vehicular population

↓

Mean VKT and Weight

↓

EF for specific PM Size

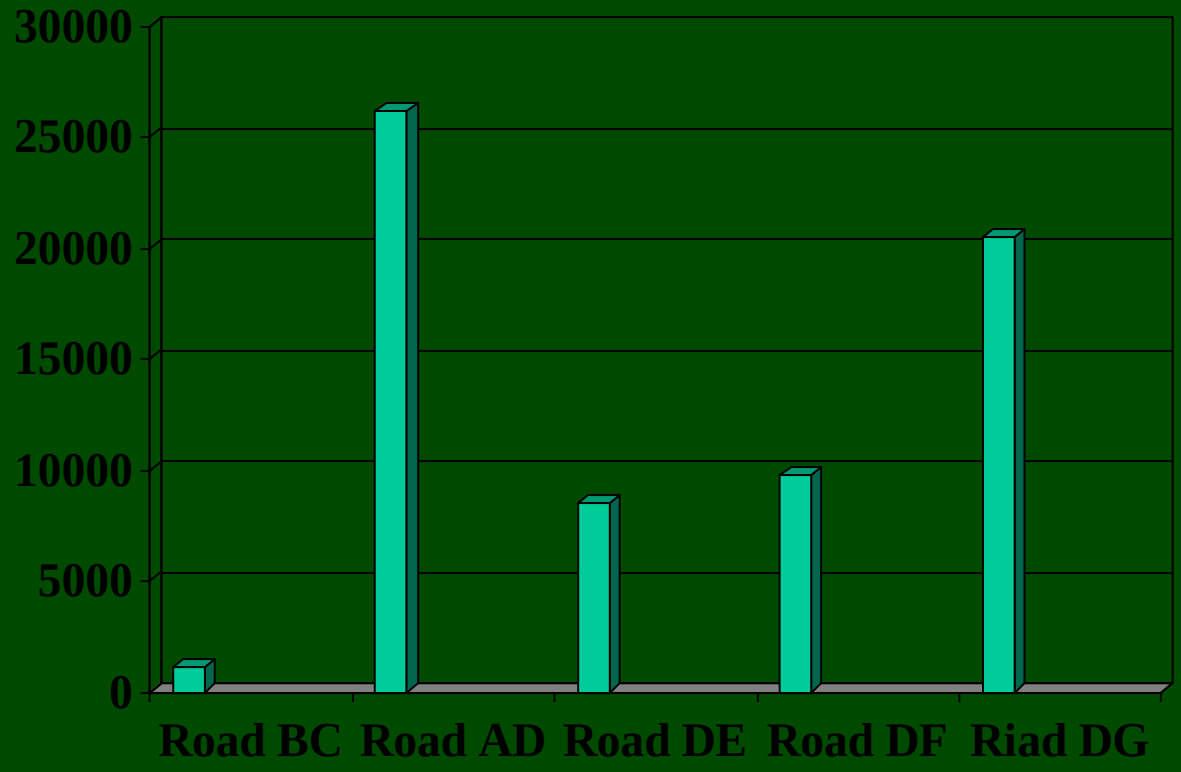
Dust collection across the road

Table4.5 Fugitive dust emission

Emission factors and total PM loading

Location	LENGTH (km)	MEAN FLEET WEIGHT (t)	SILT LOAD (g/m2)	E F FOR PM 10 (g/vkt)	E F FOR PM 2.5 (g/vkt)	LOAD PM10 (g/day)	LOAD PM2.5 (g/day)
ROAD BC	1.05	0.33	60.3	1.57	0.375	1131.88	270.66
ROAD AD	1.65	1.02	47.5	7.21	1.72	26150.67	6253.4
ROAD DE	0.5	0.93	96.8	9.98	2.38	8523.09	2038.13
ROAD DF	0.65	1.73	35	12.96	3.1	9786.3	2340.2
ROAD DG	1.1	0.905	61.3	7.05	1.68	20497.37	4901.5
TOTAL						66089.3	15803.96

Particulates loading on roads



Fumigation of malathion

Malathion is a trademark used for the organic compound, $C_{10}H_{19}O_6PS_2$, used as an insecticide.

A mixture of high speed diesel (95%) and malathion (5%) by weight burn (at about 400 C) to produce smoke to kill insects and Mosquitoes.

The emission from malathion fumigation could be due to combustion of diesel in the hot chamber and direct vaporization of malathion.

Assumptions

- Diesel produces only SO_2 and CO_2
- One kg of diesel produces 0.01 kg SO_2
- One kg of diesel produces 3.1 kg of CO_2
- Malathion is coming out as a vapor

Pollution load due to malathion fumigation

Pollutants	(g/day)	SO2 (g/day)
Malathion	4005.6	
Diesel	19063.6	190.63

Although the amount of SO2 produced by combustion process is very-very low as compared to SO2 contributed by other sources.

But the malathion as a whole is coming out, which is a toxic pollutants.

Estimation of emission from Diesel generator houses

Diesel Generator Houses

DG House-1	DG House-3	DG House-4
Two of 320 and one of 81.25 KVA	One of 81.25 and other of 60 KVA	Three, each of 320KVA

Average duration of operation = 10 hr/month

Emission factors for DG sets

Pollutants	Emission factor (g/kw-h)
NOx	18.8
CO	4.06
SO2	1.25
PM	1.54
NOx	18.8

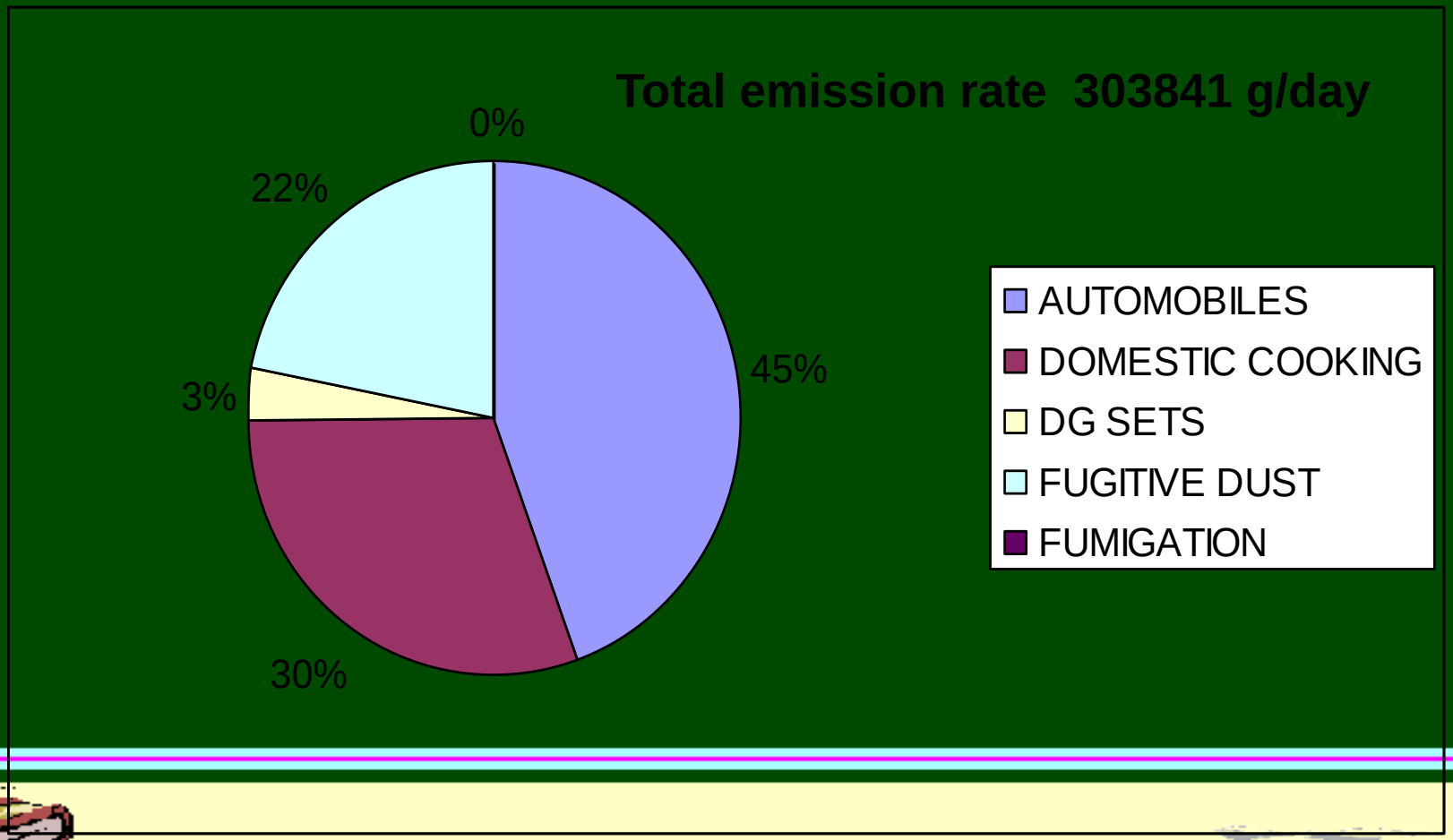
Source: USEPA, (2000)

Pollution load due to DG Houses

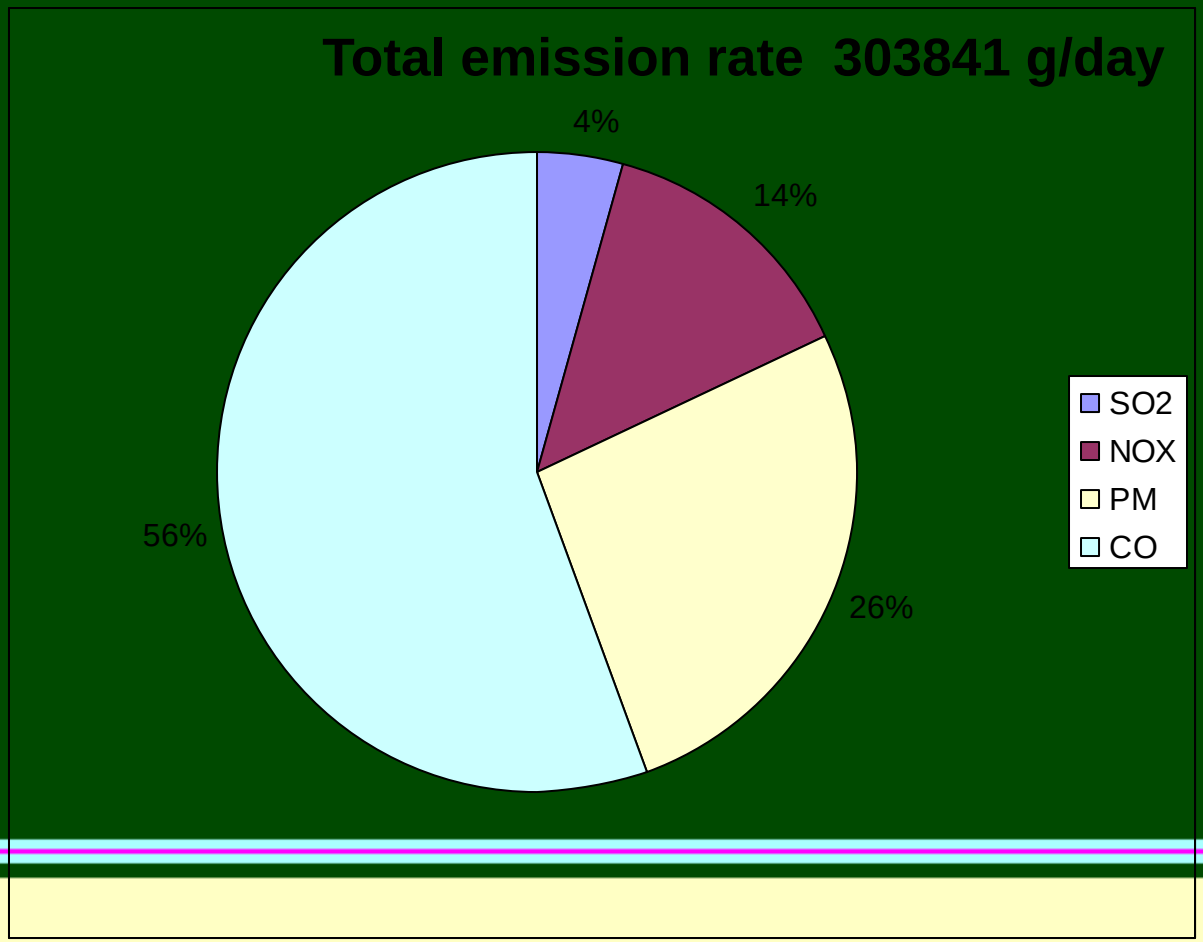
Pollutants	Emission Factor	DG House-1	DG House-3	DG House-4	Total (g/day)
NOx	18.8	2011.6	708.1333	4812.8	7532.533
CO	4.06	434.42	152.9267	1039.36	1626.707
SO2	1.25	133.75	47.08333	320	500.8333
PM	1.54	164.78	58.00667	394.24	617.0267
Total(g/day)		2744.15	966.15	6566.96	40277.13

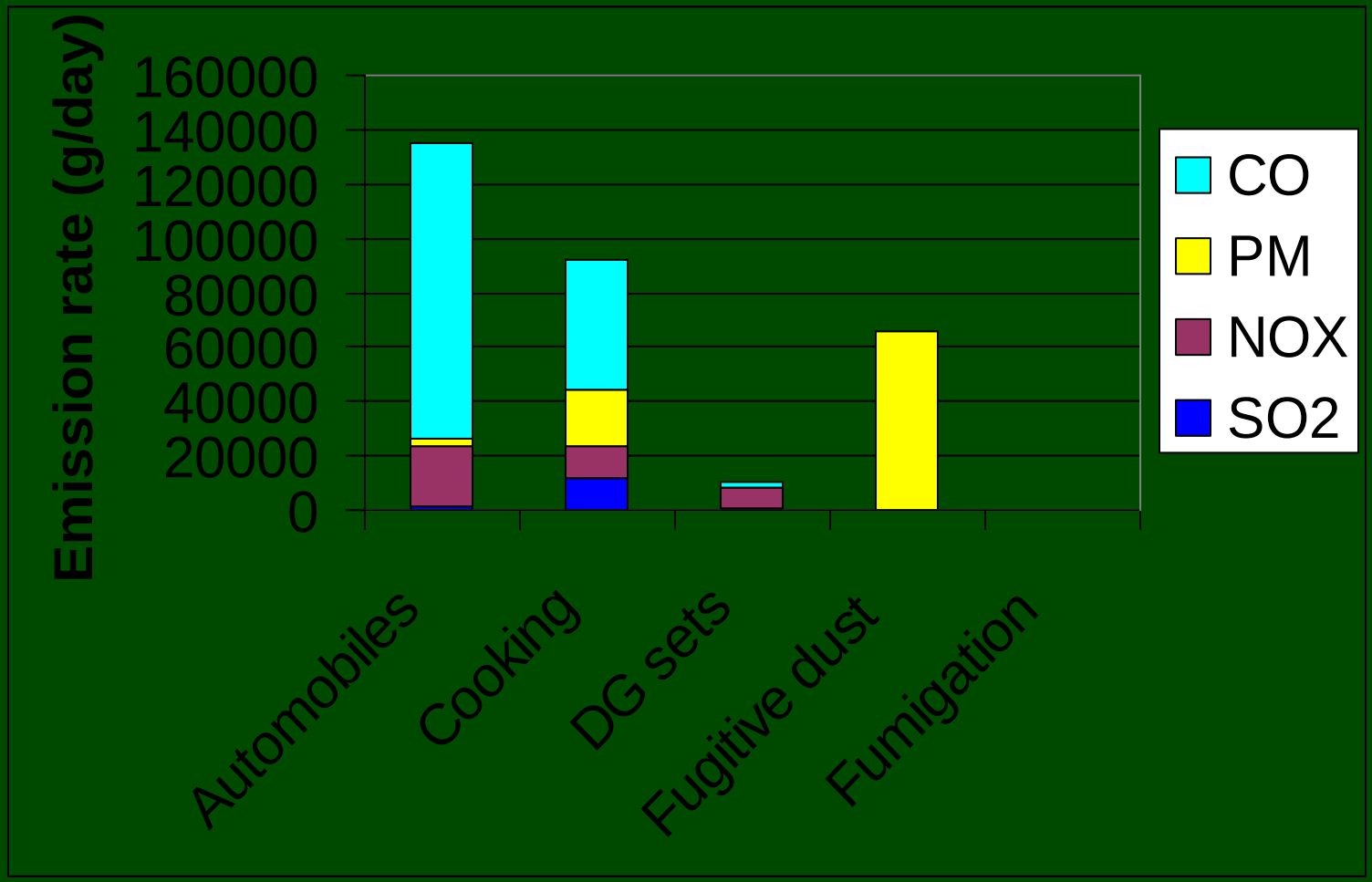
Pollution load scenario at IIT Kanpur

Air pollution contribution by different source



Composition of air pollution in the campus

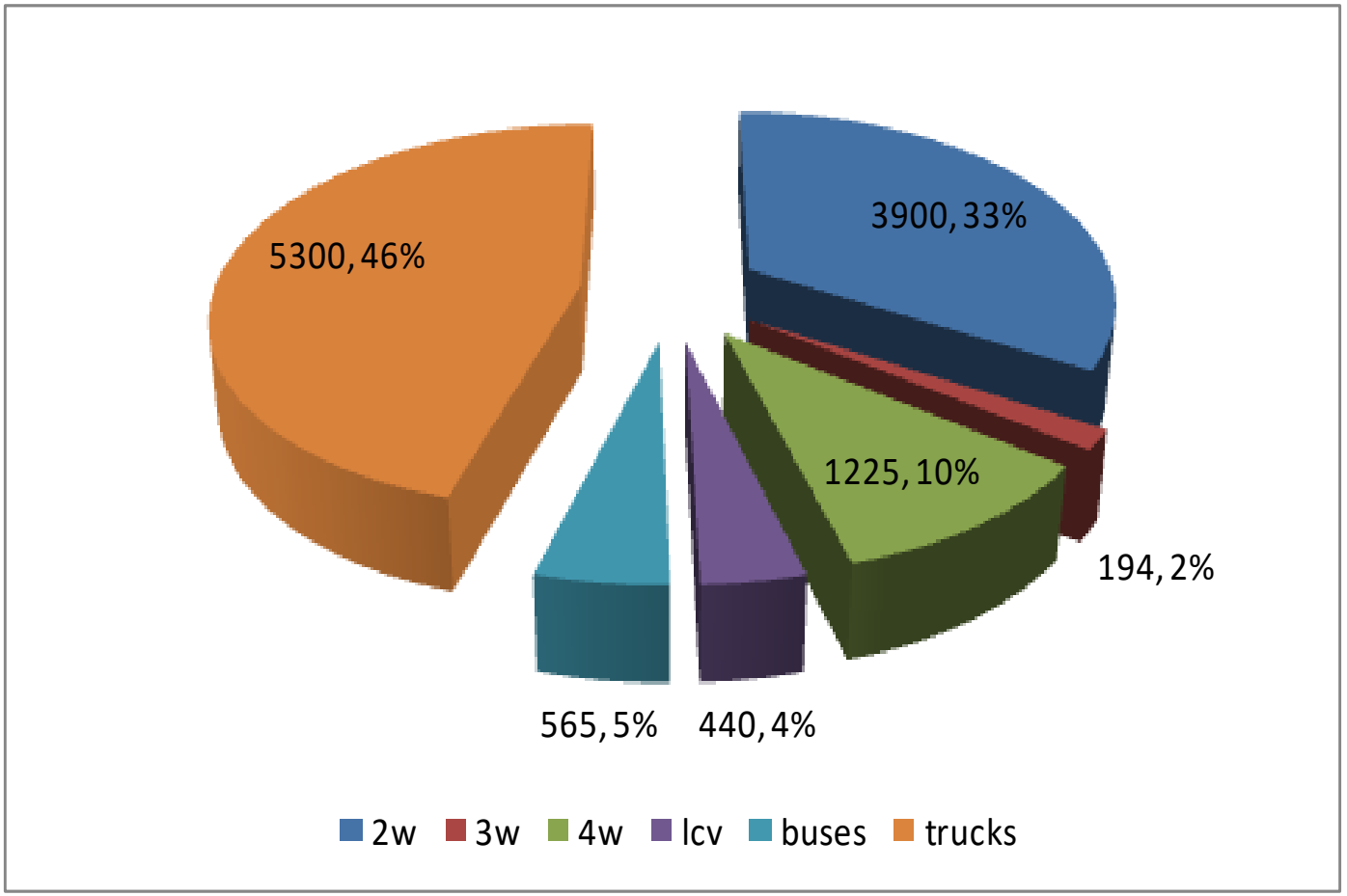




Fugitive dust – main source of particulates

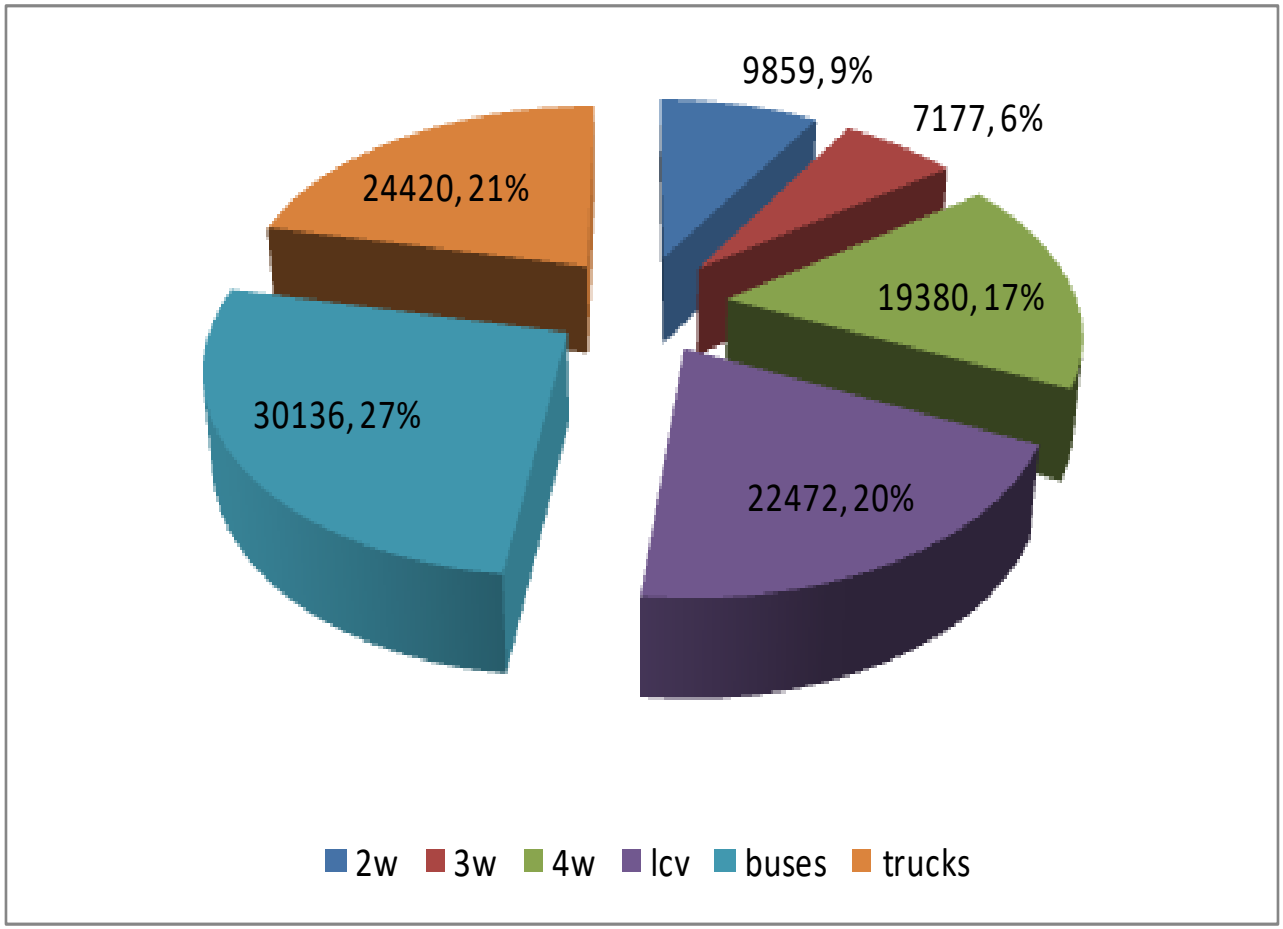
Automobiles– main source of carbon monoxide

$PM_{2.5}$ Emission Load from Vehicles (kg/day, %)



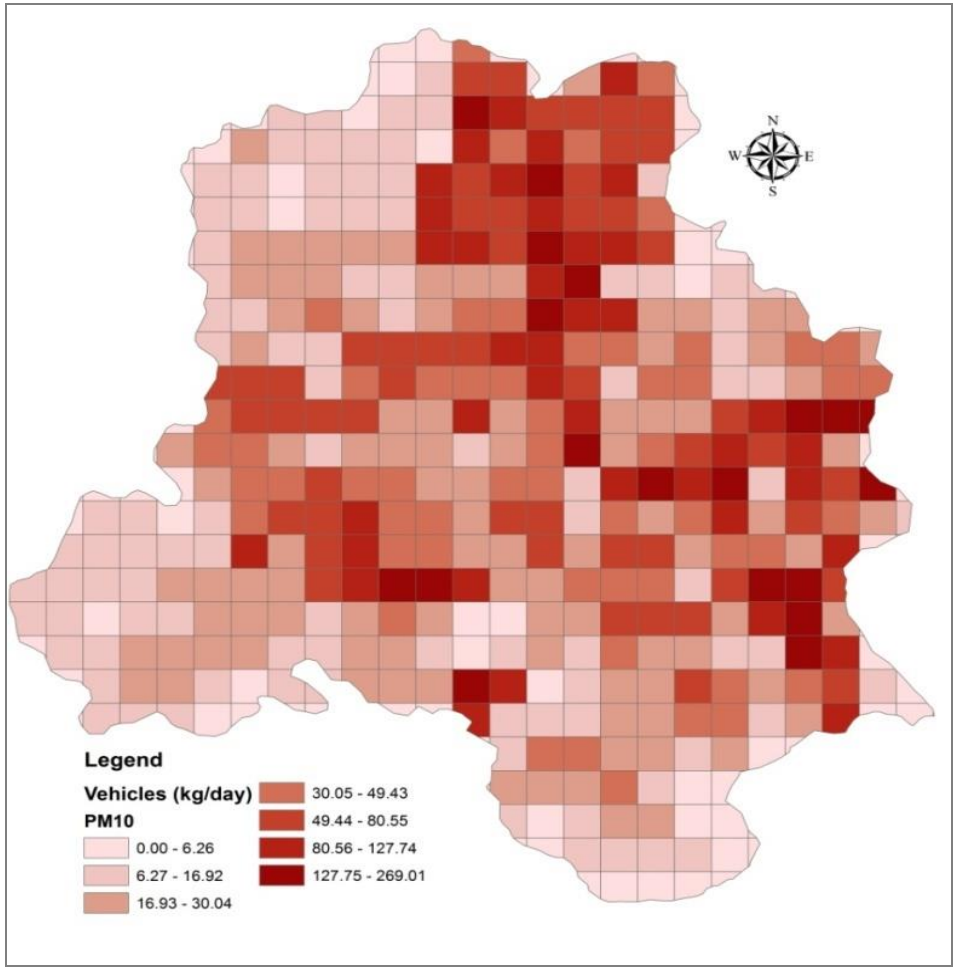
- **Major Contributor : Trucks – 46% , 2W – 33%, 4W – 10%**

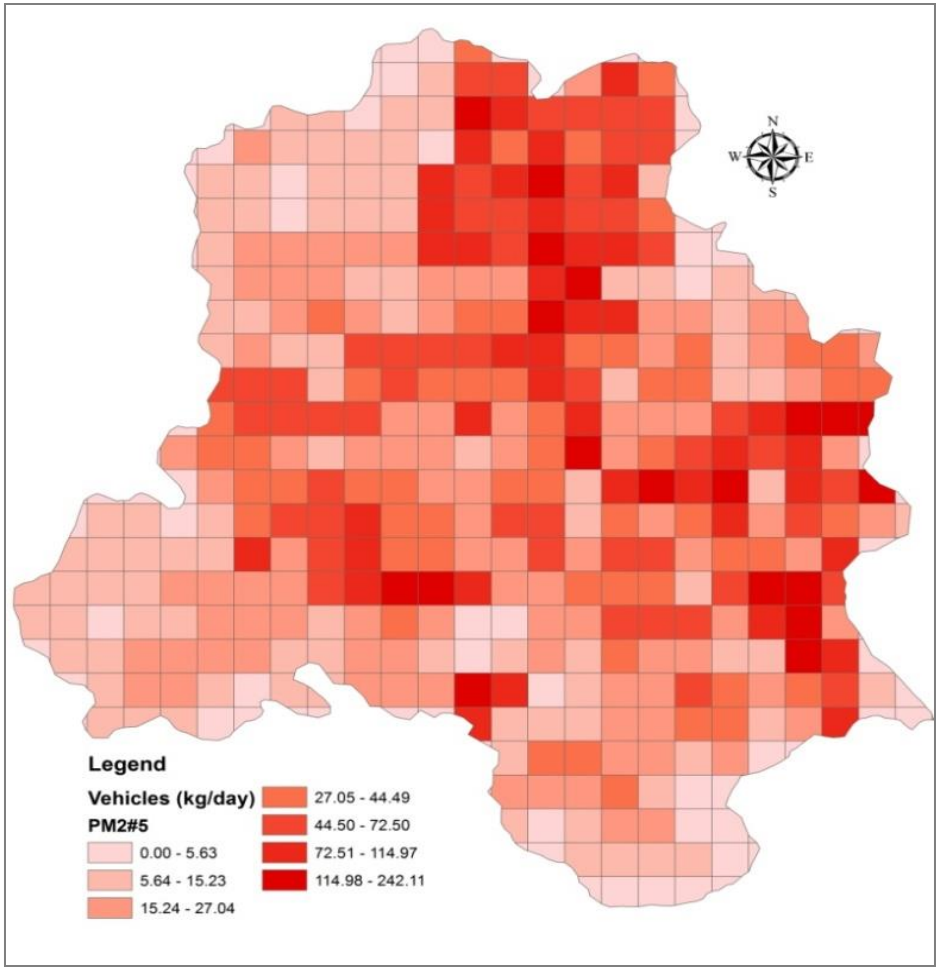
NO_X Emission Load from Vehicles (kg/day, %)



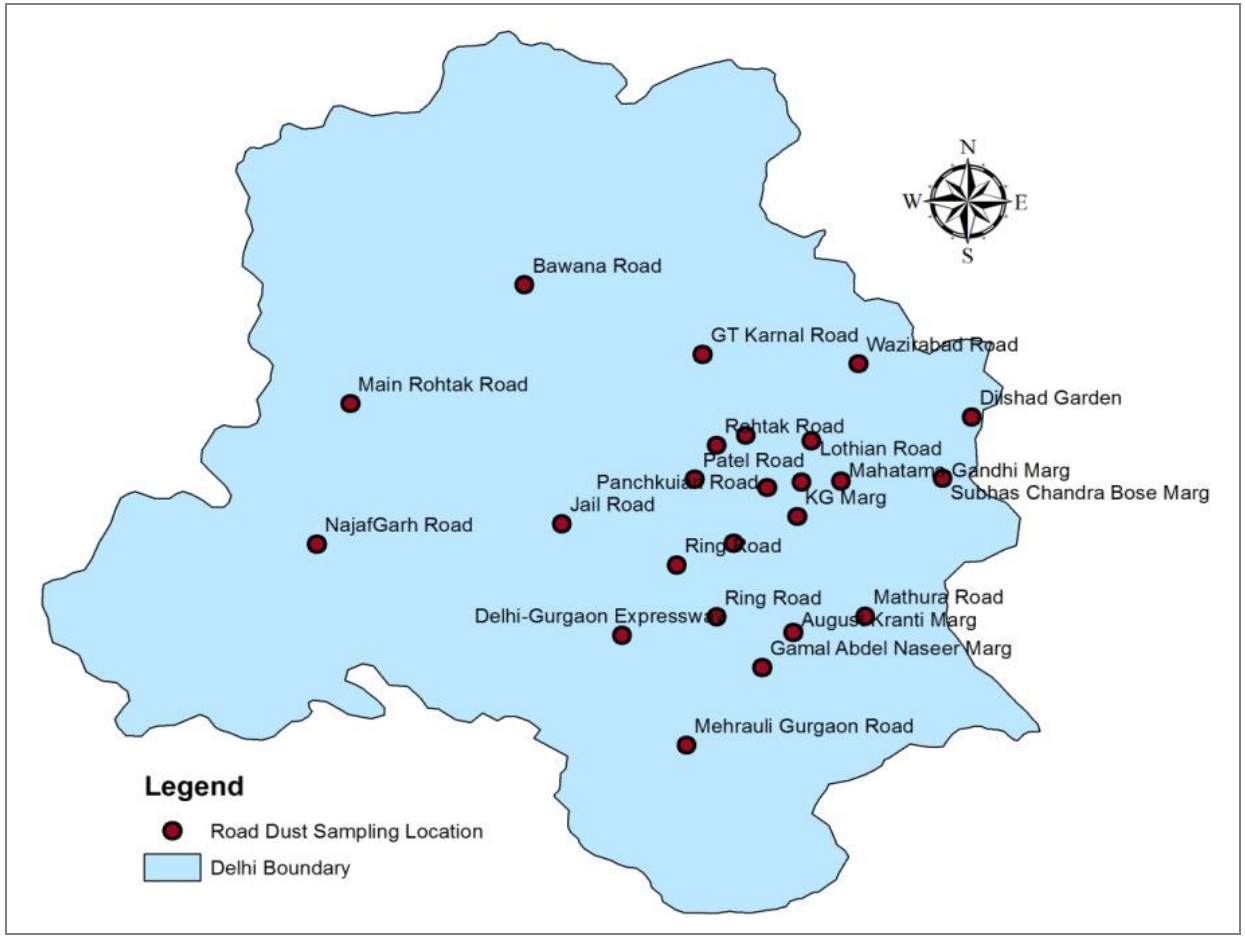
- **Major Contributor : Buses- 27%, Trucks – 21%, LCV – 20%, 4W – 17%**

Spatial Distribution of PM_{10} and $PM_{2.5}$ Emissions from Vehicles



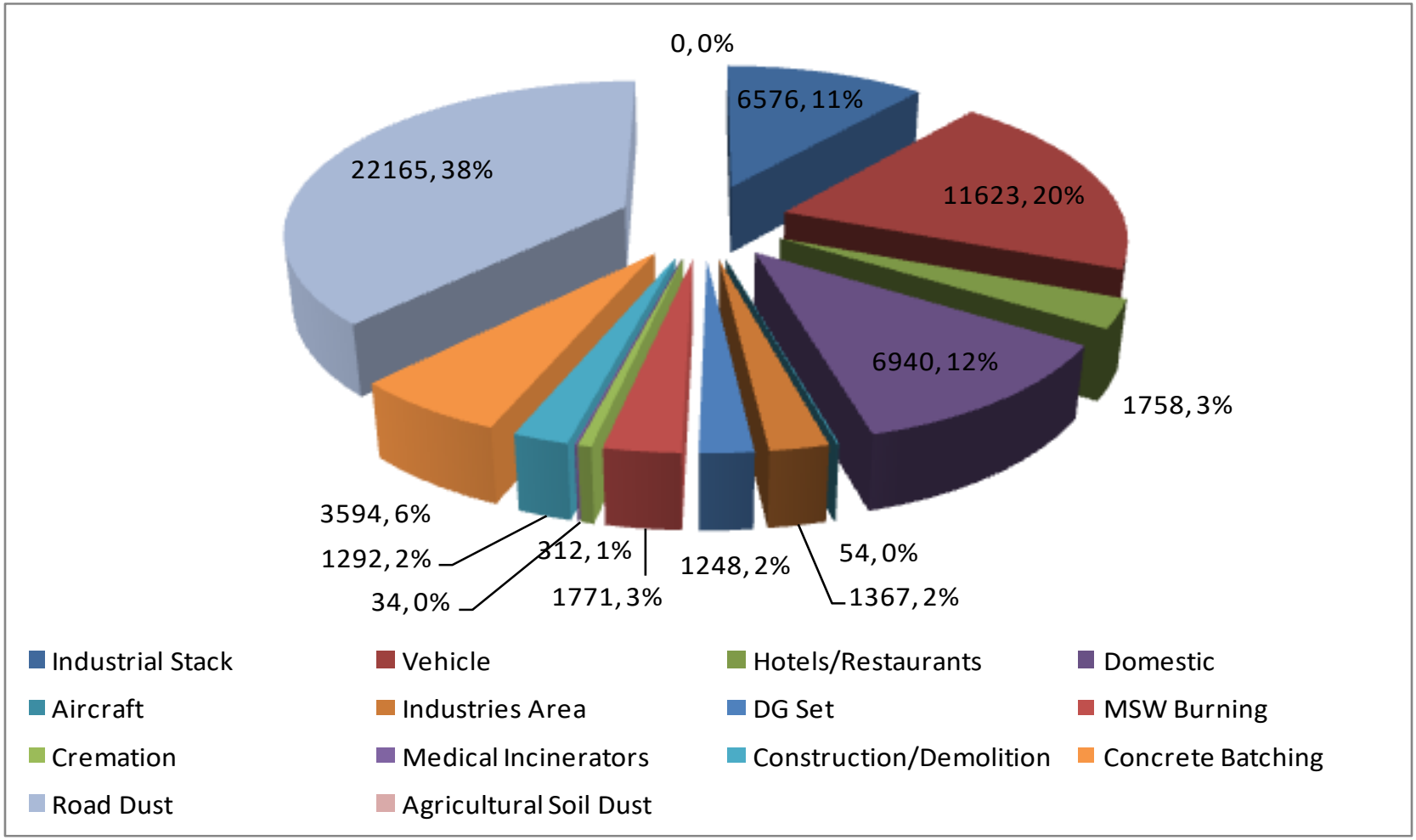


Road Dust Sampling Locations



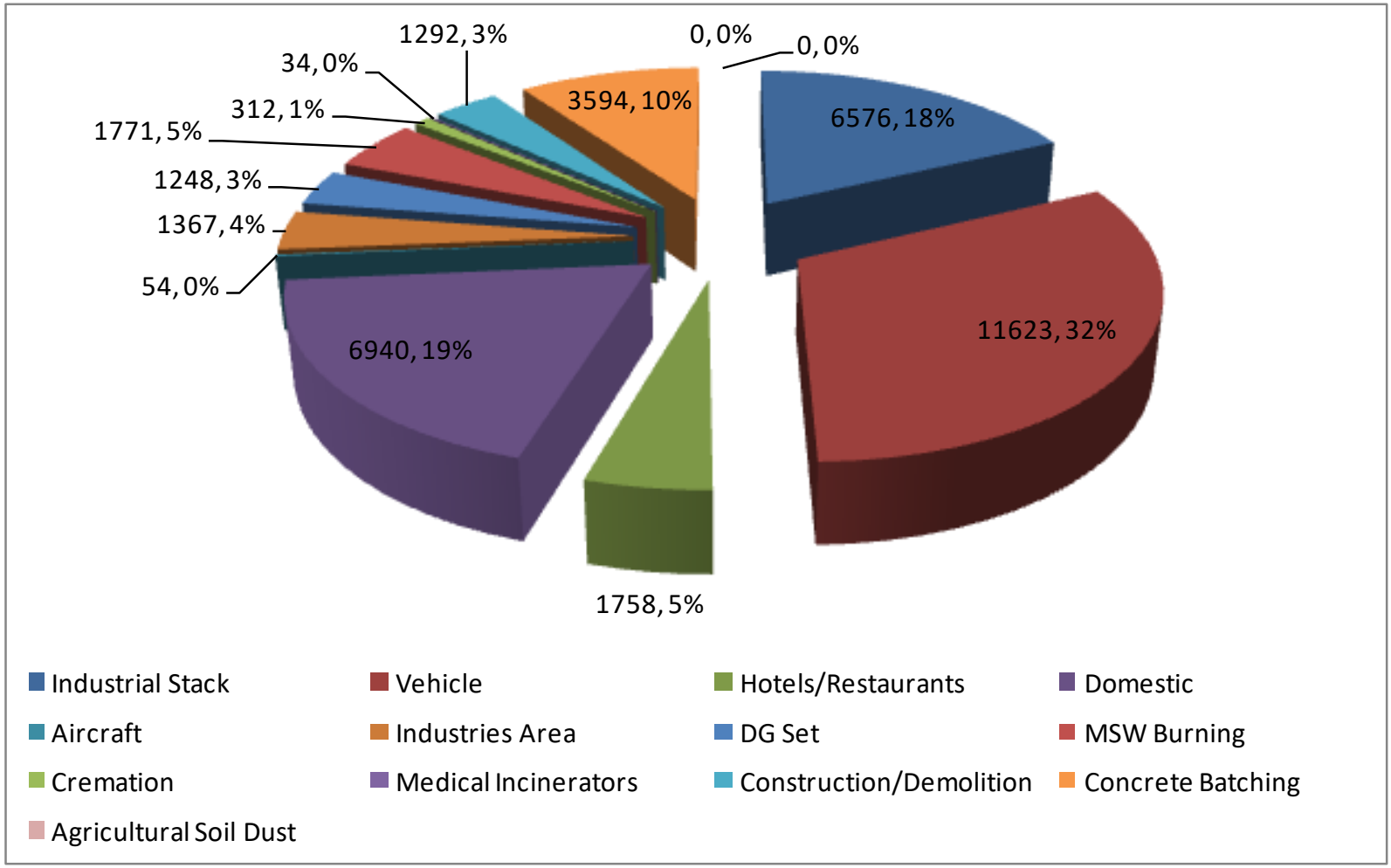
- PM_{10} emission from road dust: 79626 kg/day
- $PM_{2.5}$ emission from road dust: 22165 kg/day

$PM_{2.5}$ Emission Load of Different Sources



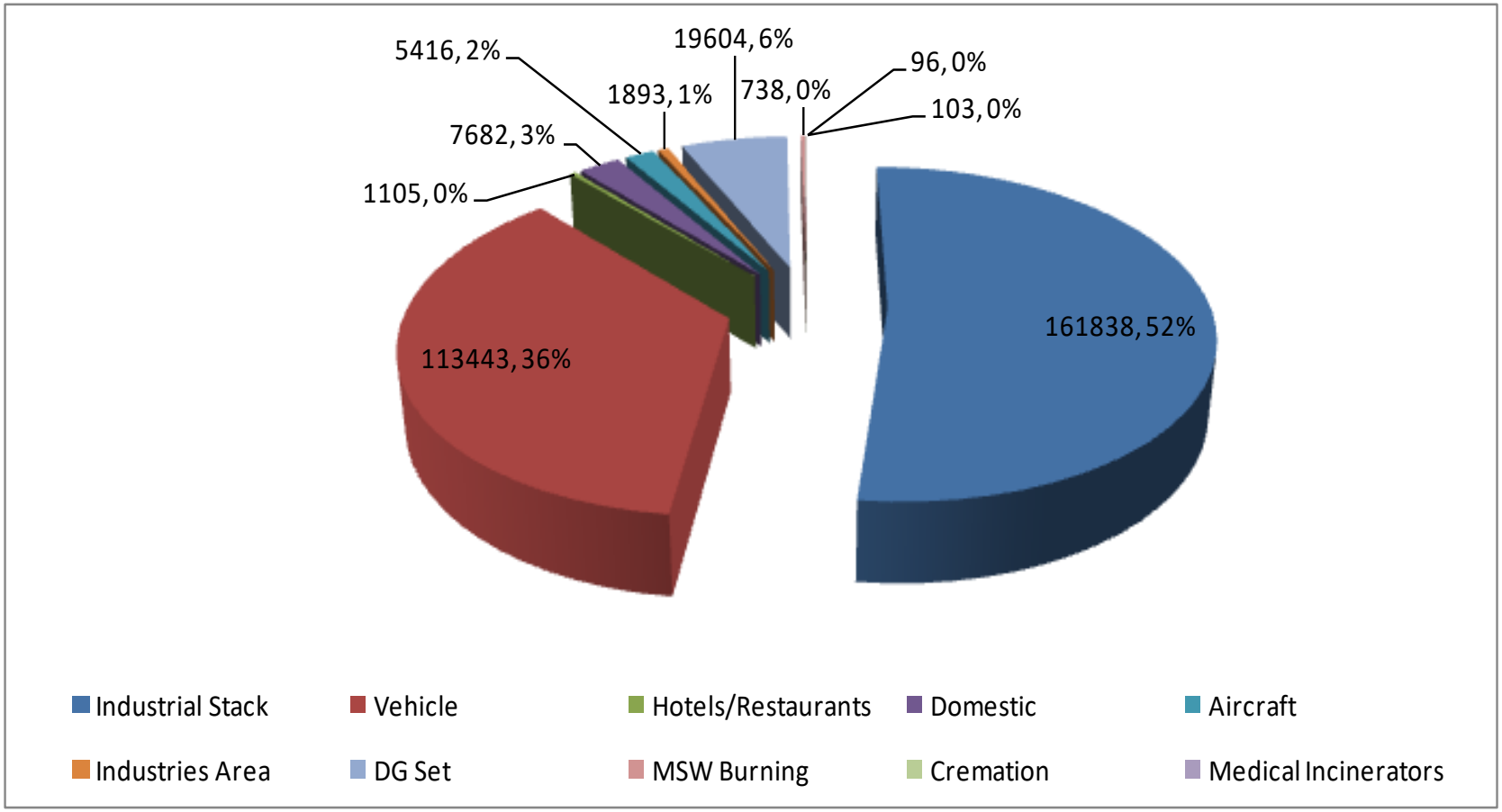
- $PM_{2.5}$ emission load: 59 t/d.
- Road dust (38 %), vehicles (20 %), domestic (12 %) and industrial point sources (11%).
- PM_{10} emission load: 143 t/d.
- Road dust (56%), concrete batching (10%), industrial point sources (10%) and vehicles (9%).

$PM_{2.5}$ Emission Load excluding Road dust



- Major Contributors: vehicles (32 %), domestic fuel burning (19 %), industrial point sources (18%), concrete batching (10%)

NO_x Emission Load of Different Sources



- NOx emission load: 312 t/d.
- Nearly 52 % emissions from industrial point source (largely from power plants).
- Major Contributors: Industrial (52 %), vehicles (36%), DG set (6%), Domestic (3%)