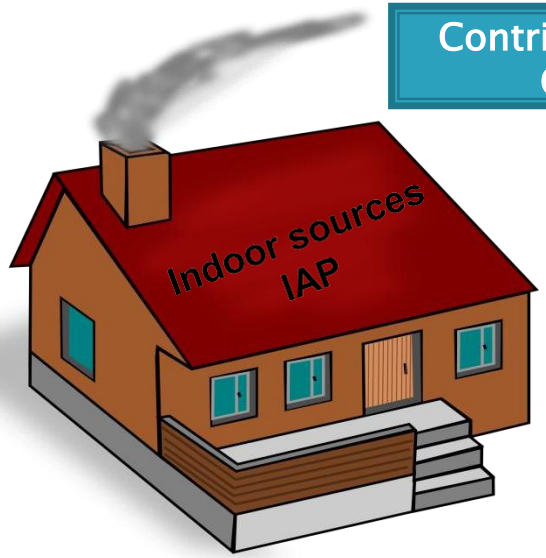
Indoor air quality (IAQ): a major concern

SDGs and linkages with pollution in India

Goal	SDG	Linkage
Goal 1	End poverty in all its forms everywhere	50% $PM_{2.5}$ emissions from biomass based cooking
Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	36% loss of grains due to Ozone pollution
Goal 3	Ensure healthy lives and promote well-being for all at all ages	~million die annually due to IAP
Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all	Coal and biomass based energy
Goal 13	Take urgent action to combat climate change and its impacts	Black carbon, Ozone contributors to warming

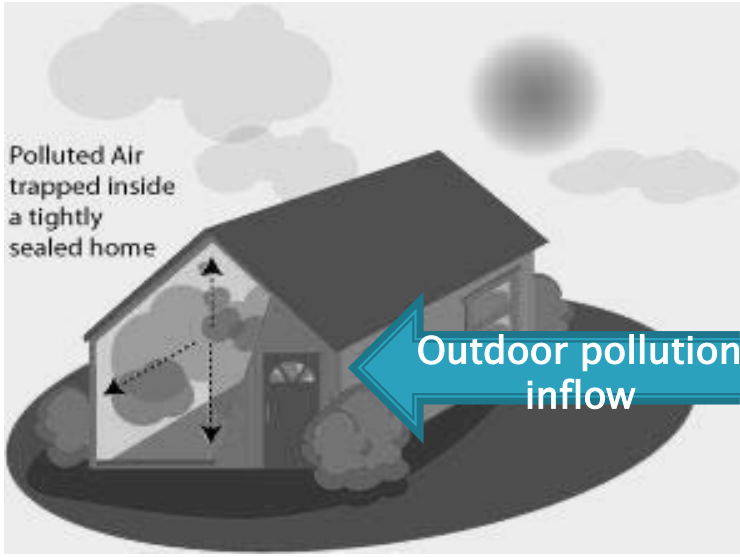
Linkages



Contribution to OAP

Contribution to global pool of warmers

What is IAQ



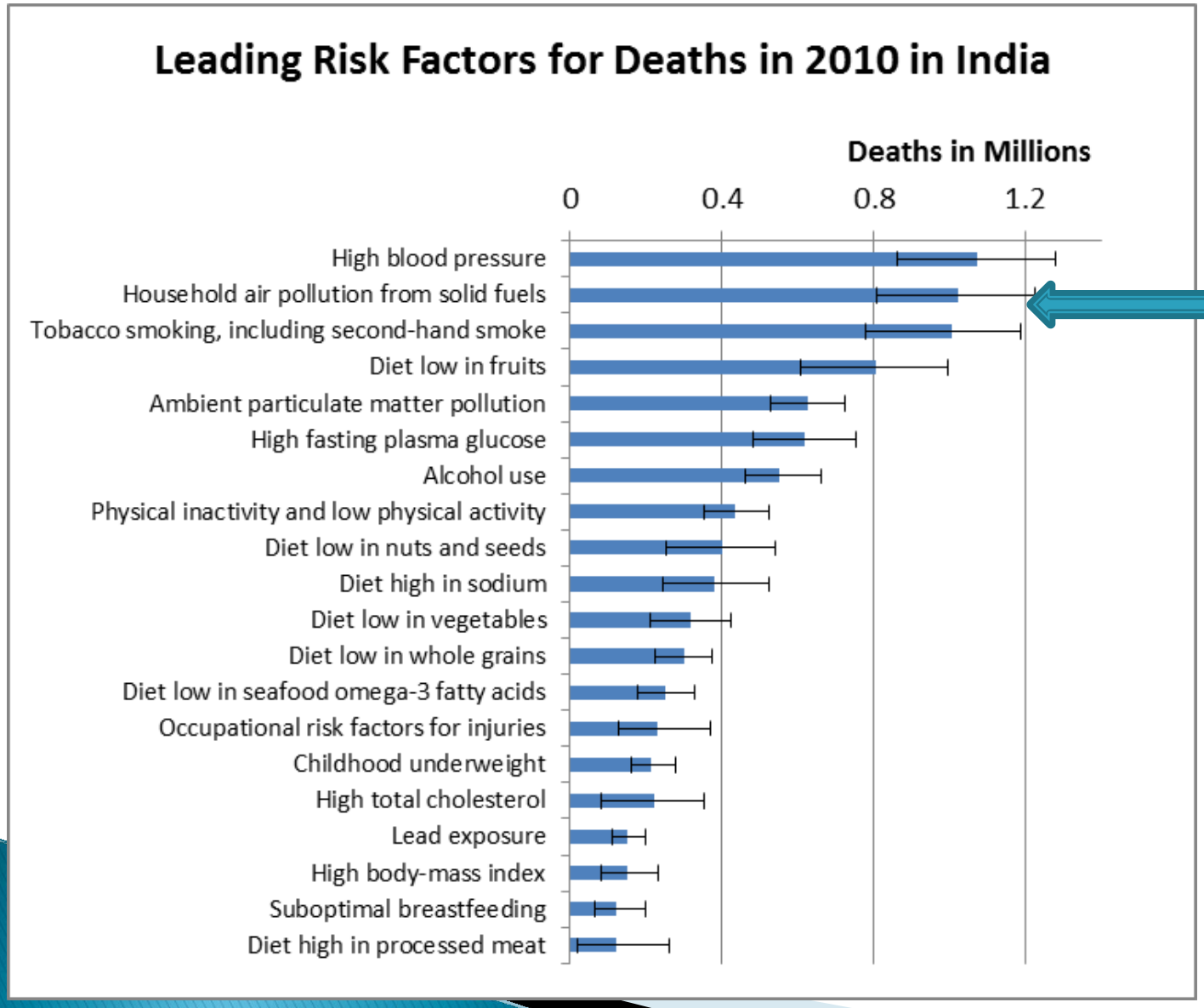
The quality of air inside buildings as represented by concentrations of pollutants and thermal (**Temperature and Relative Humidity**) conditions that affect the **health, comfort, and performance of occupants**

Picture adapted from www.achooallergy.com

IAQ – an area of concern

- While ambient air quality is slowly attracting attention, Indoor air quality is still ignored.
- US EPA: indoor air pollution poses a greater risk than outdoor air pollution – people spend 80-90% of their time indoors (Yu and Browers, 2013)
- IAQ is directly linked to health of the occupants of a building
- IAQ is an important concern – both rural and urban
- VOCs indoors could be 2 to 5 times higher than outdoors
- IAP is a global issue due to adverse effects on human health (Tsakas, Siskos and Siskos, 2011)
- IAP ranked among the top five environmental health risks to the public by EPA.

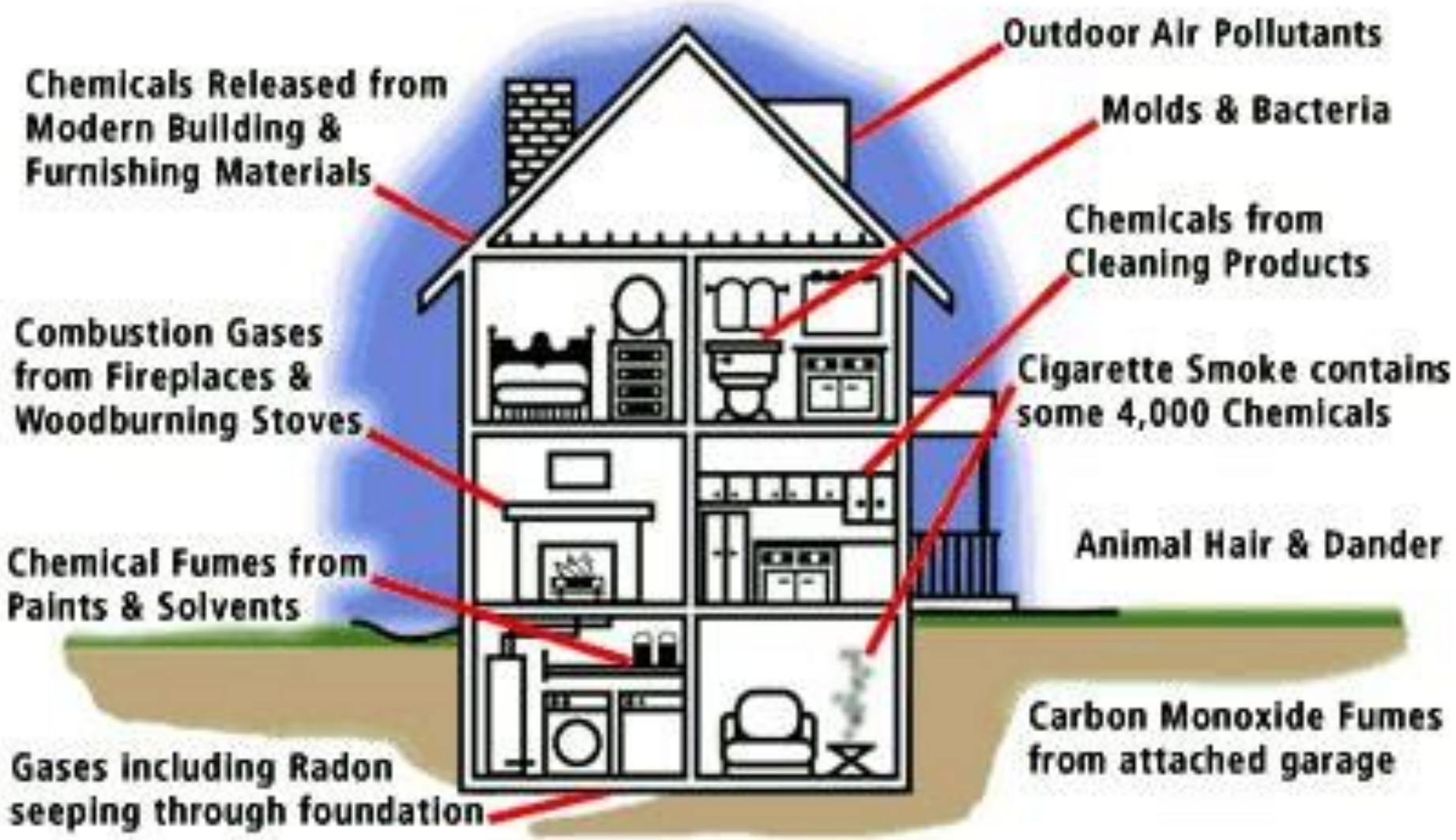
GBD estimates :IAP is 2nd leading risk factor



IAPcaused an estimated ~a million deaths in 2010

GBD-Lancet, 2012

SOURCES OF INDOOR POLLUTANTS



Pollutants & Sources

Location	Sources	Pollutant
Offices, government buildings	HVAC systems, carpets, painting & polishing , household cleaners, aerosols, insecticides, pesticides and personal care products	Primary: PM, VOCs Additional : CO, NOx, SO2
Parking areas	Vehicular movement	Primary : PM, CO, NOx, HC Additional : SO2, PAHs,
Public places such as restaurants, hotels, libraries, shopping malls (misc. sources	HVAC systems, carpets, painting & polishing , insecticides, pesticides, smoking, constriction activities	Primary: PM, VOCs, Nicotine Additional : CO, NOx, SO2
Rural households using biomass	Biomass burning for cooking, heating, waste burning. Kerosene burning for lighting,	Primary: PM, CO, BC Additional : VOCs

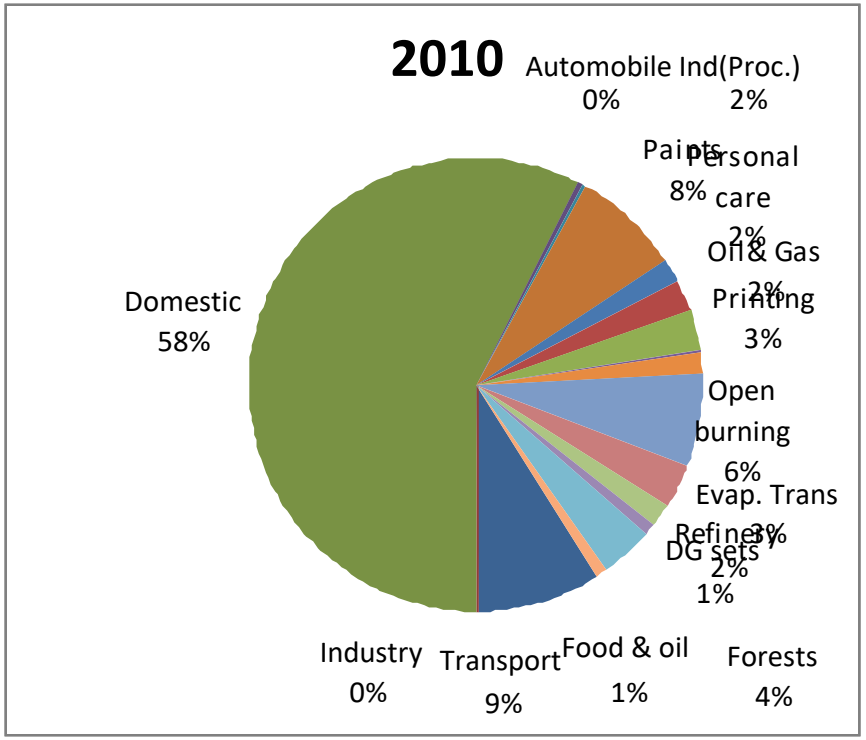
NOx + VOC + Sunlight
= OZONE

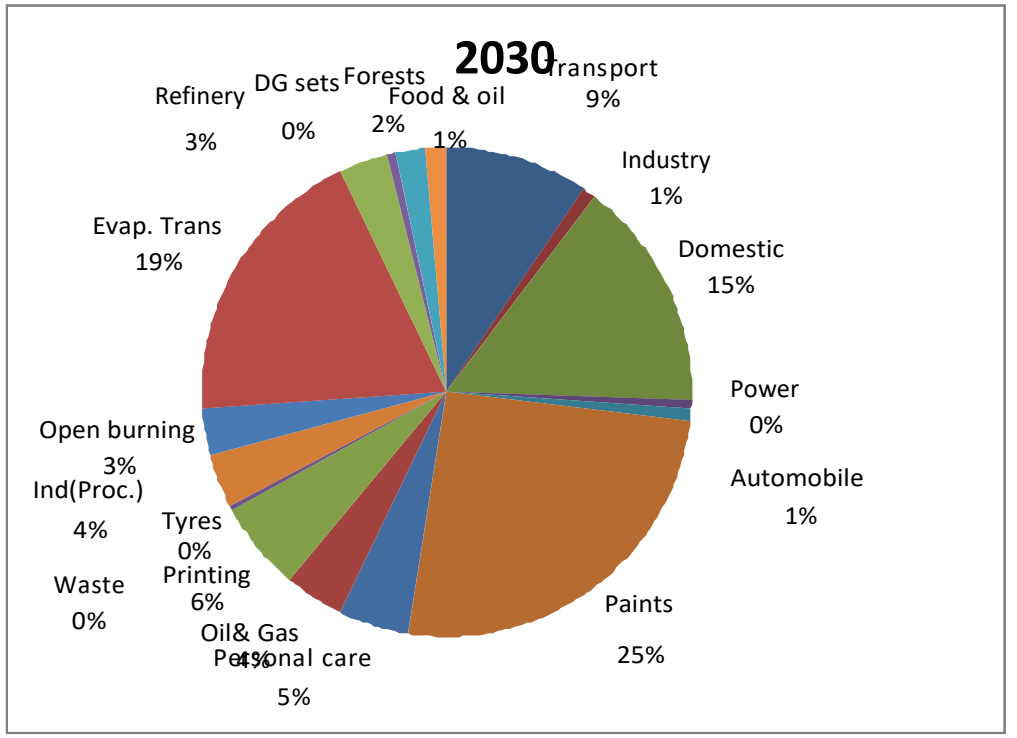
Other problems of IAQ

Enclosed space inhabited by humans produce the following effects

- ⇩Oxygen level or ⇧CO_2 level
- Increase in temperature and humidity
- Increase in bio-aerosol and odor
- Accumulation of air pollutants

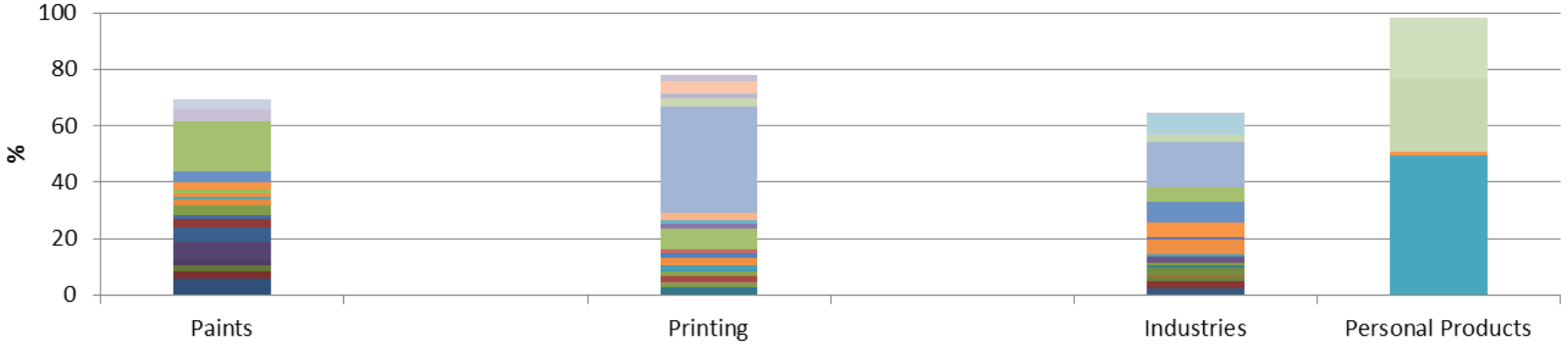
NMVOC emissions in India





- This has implicati

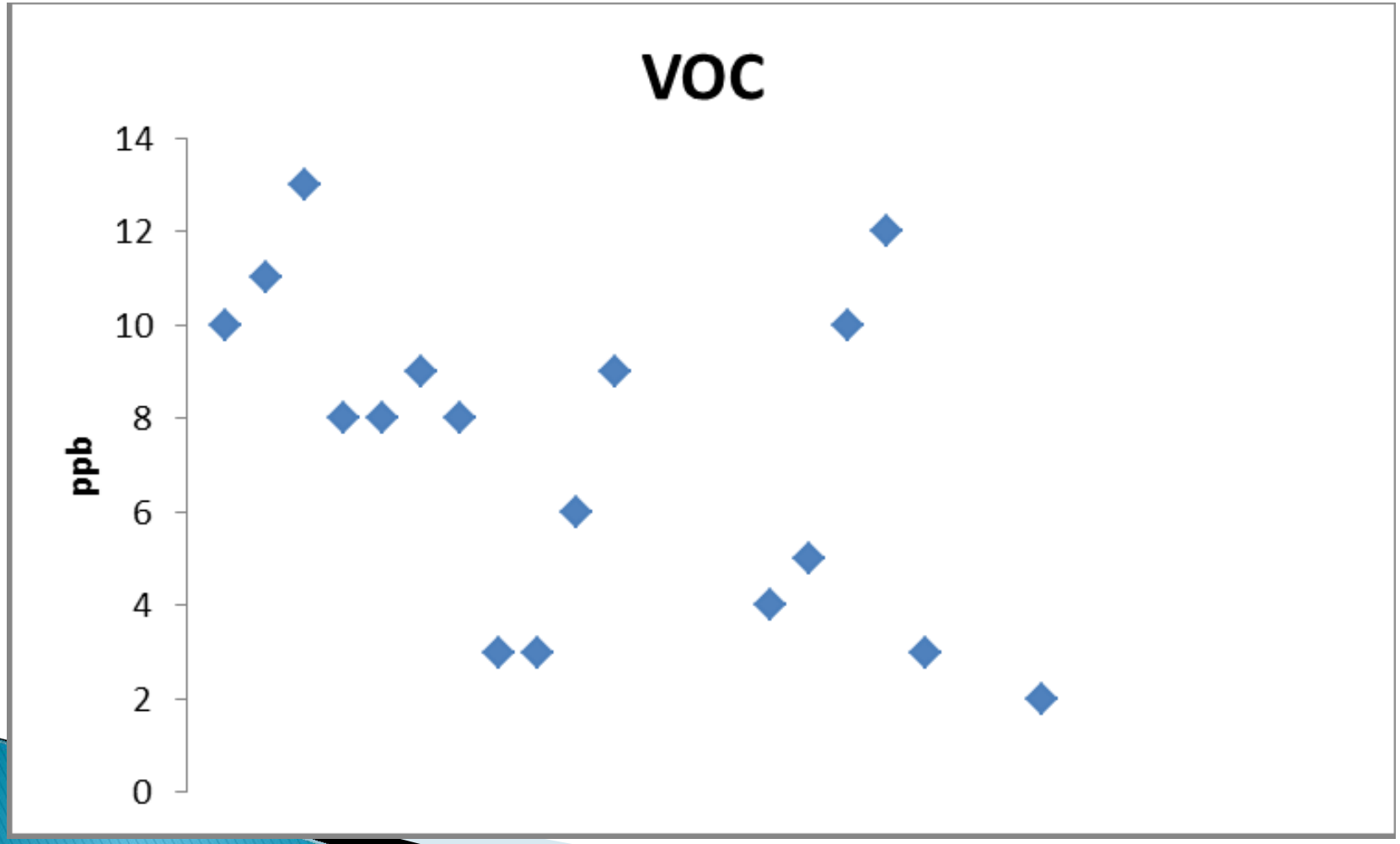
VOCs in products



- C10 Paraffinss (S31)
- C9 Paraffin (S32)
- C7-C16 Paraffins (S36)
- N-decane (N_DEC) [PAMS]
- n-heptane
- Cyclohexane (CYHEXA) [PAMS]
- 2,4-dimethylhexane (HEX24M)
- Methylcyclohexane (MECYHX) [PAMS]
- Ethylene glycol [HAPS]
- Diethylene glycol
- Acenaphthylene (ACNA)
- Phenanthrene (PHEN)
- O-xylene (O_XYL) [HAPS] [PAMS]
- Isomers of xylene [HAPS]
- P-xylene (P_XYL) [HAPS]
- 1,3,5-trimethylbenzene (BZ135M) [PAMS]
- Isomers of diethylbenzene
- Benzene (BENZE) [HAPS] [PAMS]
- 4-ethylsyringol
- 2,2,4-trimethyl-1,3-pentanediol isobutyrate (texanol)
- C-9 Cycloparaffins (S13)
- Paraffins/Olefins (C12-C16) (S30)
- C10 Olefins (S21)
- N-octane (N_OCT) [PAMS]
- C4 Substituted cyclohexane (S25)
- N-hexane (N_HEX) [HAPS] [PAMS]
- Dimethylcyclohexane (S628)
- 2-methylpentane (isohexane) (PENA2M)
- Propylene glycol
- Guaiacol-TMS (guai)
- Naphthalene (NAPHTH) [HAPS]
- UNC Peak CBM Xylene
- M-xylene (M_XYL) [HAPS]
- M & p-xylene (MP_X) [HAPS]
- 1,2,4-trimethylbenzene (1,3,4-trimethylbenzene) (BZ124M) [PAMS]
- Ethylbenzene (ETBZ) [HAPS] [PAMS]
- n-undecane; 1,2-dimethyl-3-ethylbenzene; 1,2,4,5-tetramethylbenzene
- Syringol-TMS , also noted as "syrgol" (syri)
- 4-methyl-syringol-TMS , also noted as "m4syrg" (mesy)
- Sec-butyl alcohol

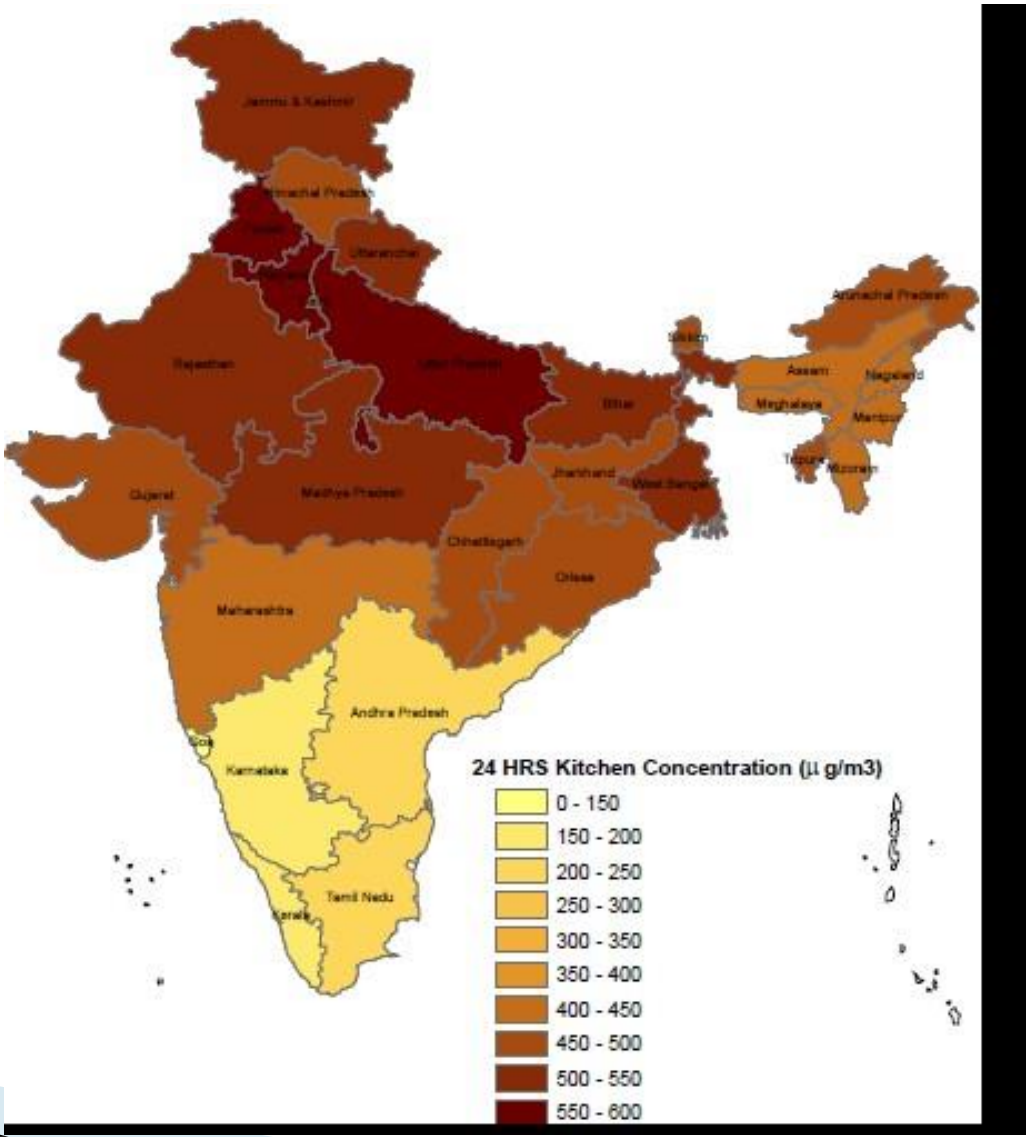
Source p

TERI measurements in office buildings



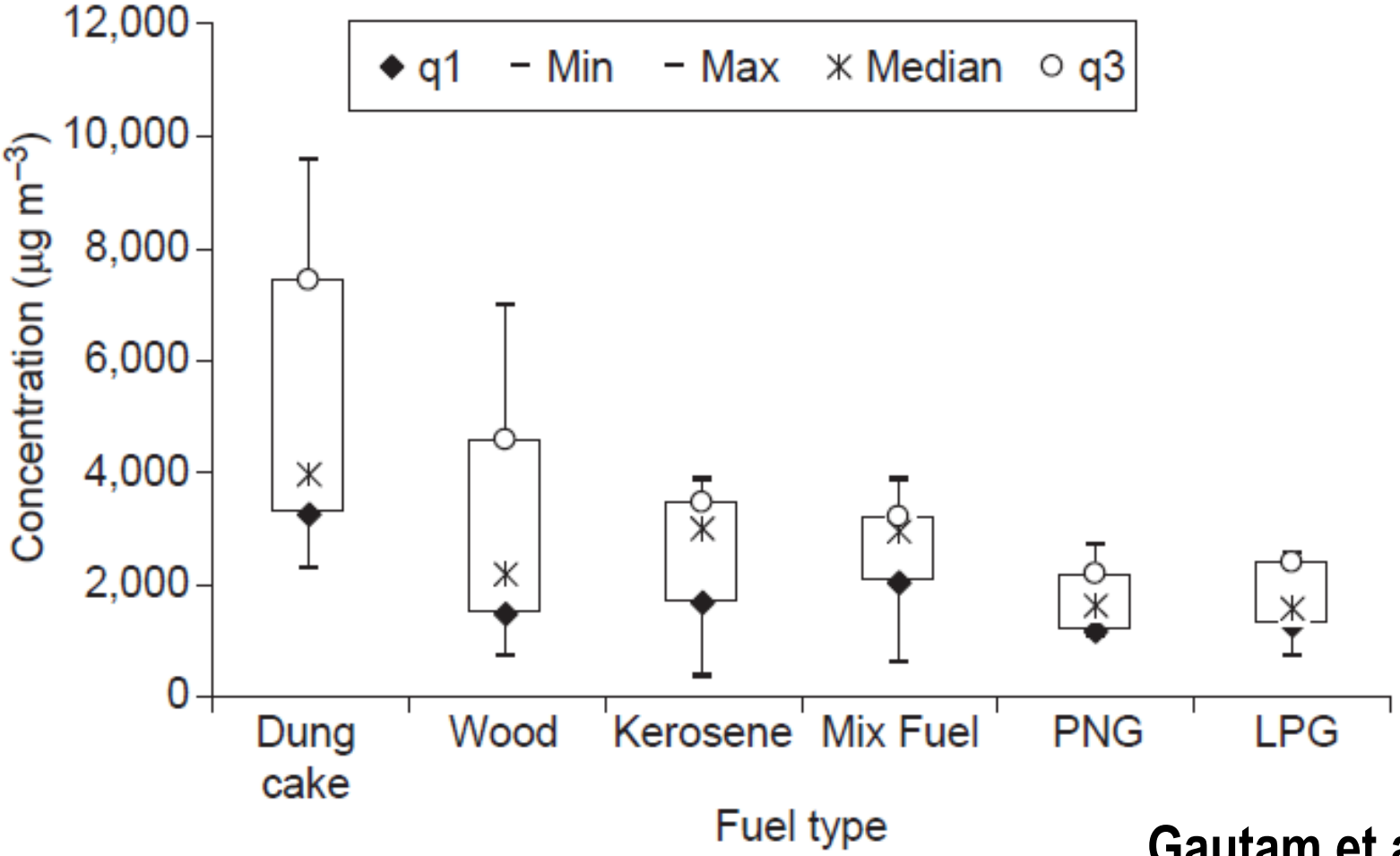
IAQ – Rural measurements

State-wise estimates of 24-h kitchen concentrations of PM2.5 in India



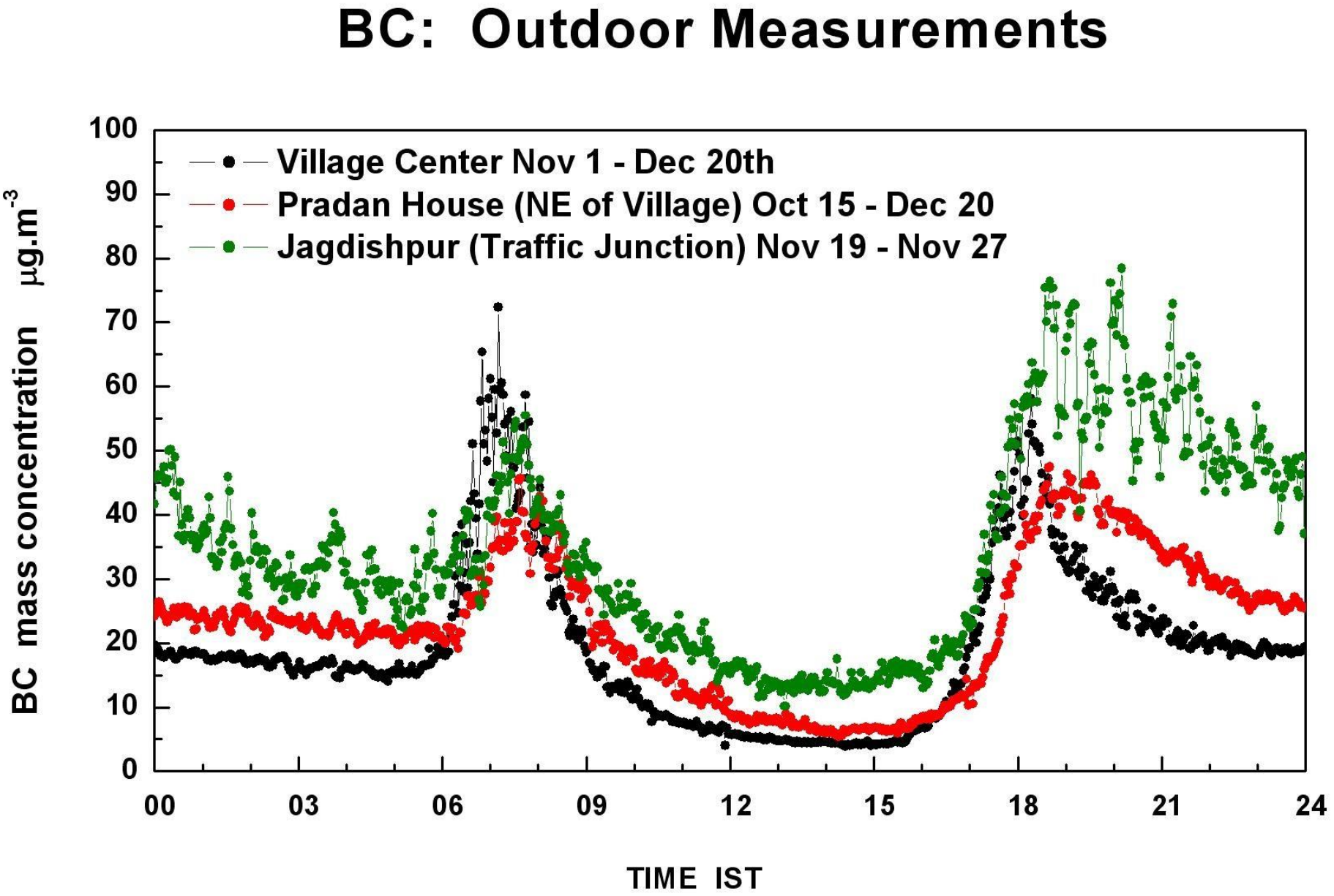
Solid-fuel using households Balakrishnan et al. 2013 (SRU group)

Fuel wise PM2.5 measurement in rural households in Ballabhgarh



Gautam et al, 2012

Indoor cooking affecting outdoor air



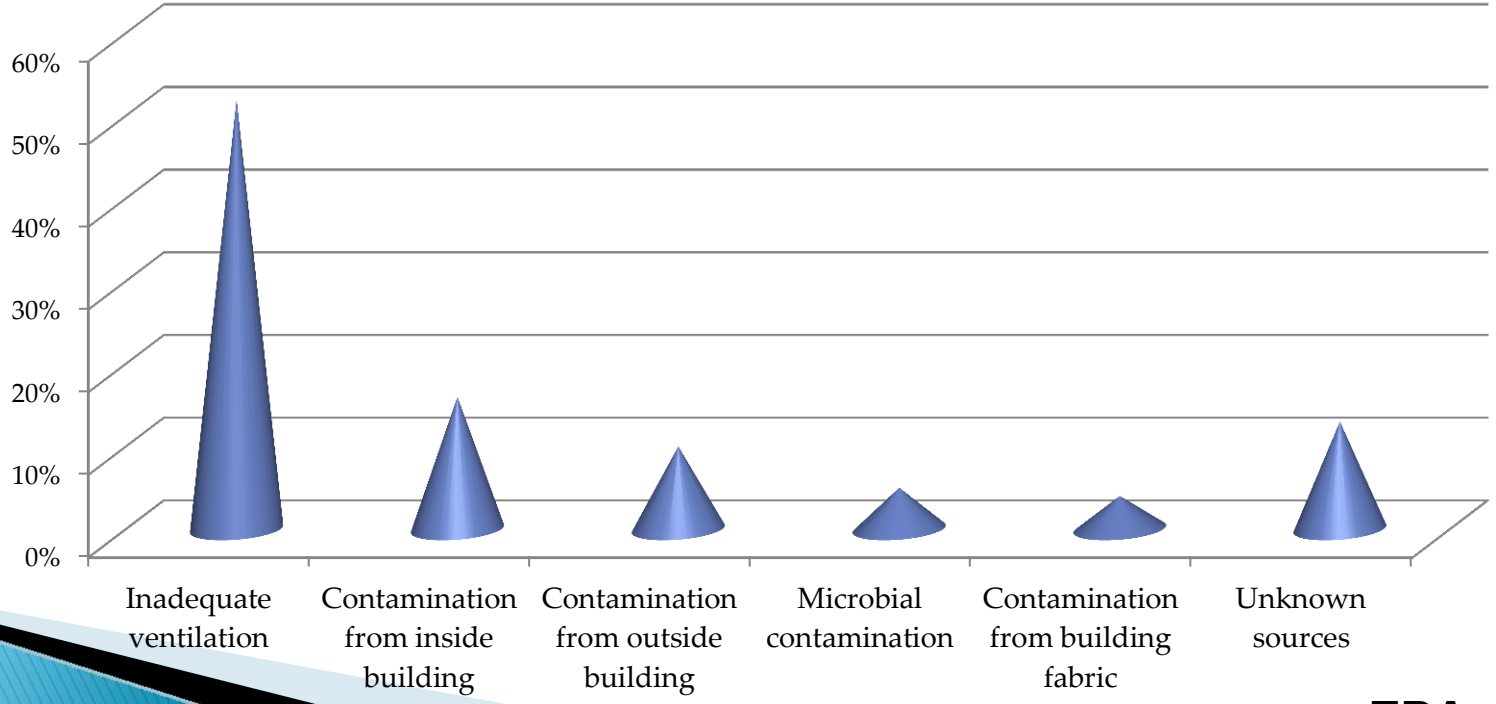
IAP and health

Pollutant	Health effects
NO_2	Type: Immediate: Causes: irritation to the skin, eyes and throat, cough etc
CO	Type: : Immediate; Causes: headache, shortness of breath, higher conc. May cause sudden deaths.
VOCs	Type: : Immediate; Causes: Liver, kidney disorders, irritation to the eyes, nose and throat, skin rashes and respiratory problems.
RSPM	Type: : Cumulative, Causes: Respiratory Illness (upper and lower), Acute (Asthma) and chronic (COPD), Lung cancer,
Pesticides	Type: : Immediate; Causes: Skin diseases
SO_2	Type: : Immediate; Causes: lung disorders and shortness of breath
Asbestos	Type: : Cumulative; Causes: Lung cancer
O_3	Type: : Immediate; Causes: eyes itch, burn, respiratory disorders, lowers our resistance to colds and pneumonia.

Sick building syndrome (SBS)

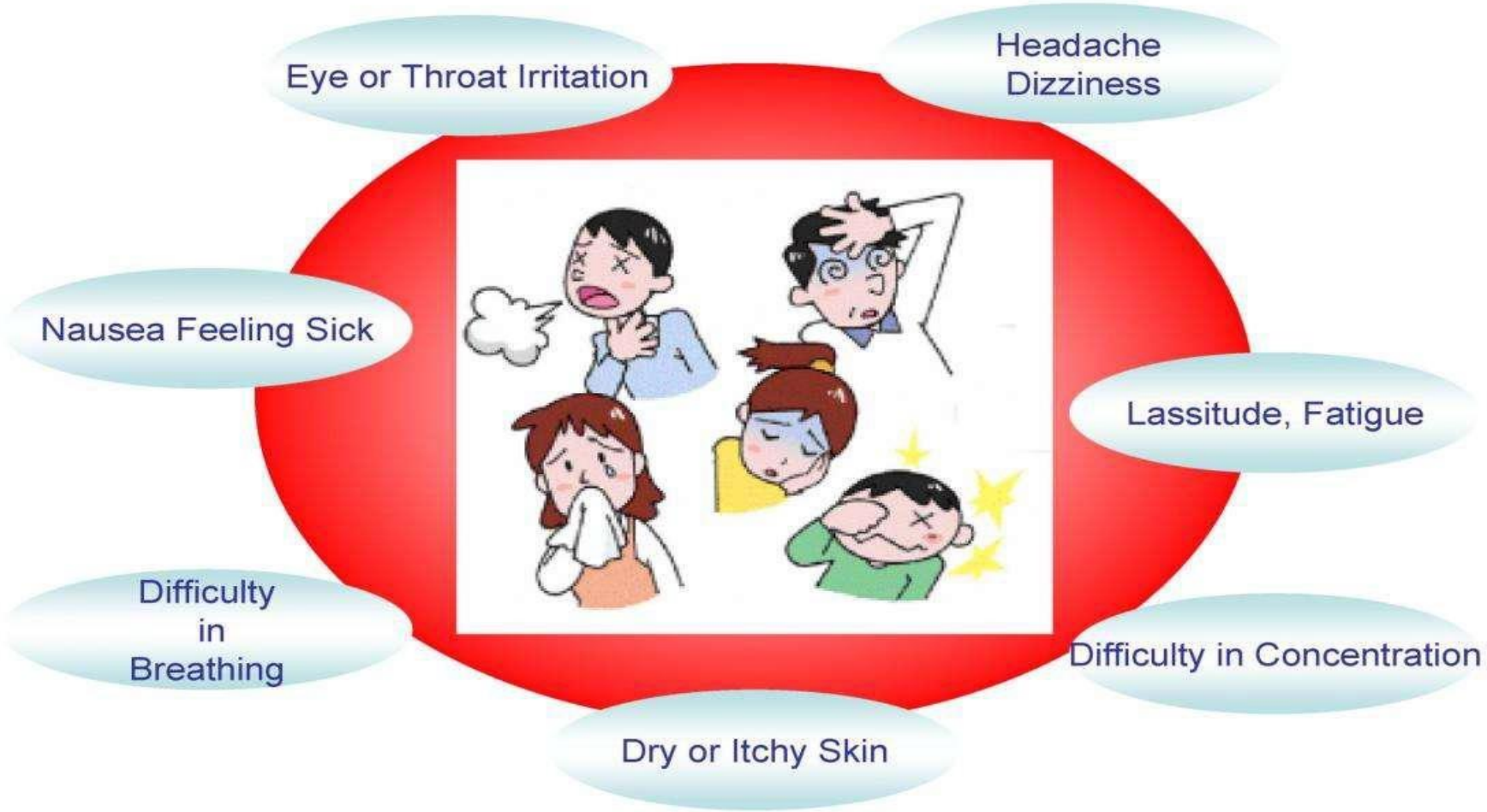
Building occupants experience acute health and comfort effects which is linked to time spent in the building, but no specific illness or cause identified. Not a clinically diagnosable disease.

Causes of SBS



EPA

Symptoms of SBS



Effect of temperature, RH and CO2

Temperature

- direct impact on **perceived comfort** and, **concentration** and **productivity**
- As per **ASHRAE Standard 55**, recommended temperature ranges termed "**comfortable**" are 22.8 to 26.1°C in the summer and 20.0 to 23.6°C in the winter.

Relative humidity

- Too high RH can contribute to the growth and spread of biological contaminants
- RH below 25% – increased discomfort and drying of skin and mucous membrane
- As per **ASHRAE Standard 55**, indoor humidity levels to be maintained between **30 –65 percent** for **optimum comfort**.

CO_2

- **Provides good indication of ventilation rates**
- **Generated in indoor primarily through human metabolism**
- **CO_2 build up in indoor is attributed to in-efficient or non-functioning of ventilation system**
- **As per ASHRAE, above 1000ppm CO_2 – requires adjustment of building's ventilation system**
- **Building shows SBS symptoms if CO_2 concentration > 1000 ppm**

IAQ standards and guidelines

1. Canada
2. Singapore
3. UK
4. Germany
5. USA
6. China
7. India??

Summary of guidelines

Parameter	WHO guideline value*	ASHRAE**	OSHA***	NAAQS/EPA (2000)****
PM_{10}	50µg/m³ (24-hr mean)	--	15mg/m³ (total)	150µg/m³ (24-hr)
$PM_{2.5}$	25µg/m³ (24-hr mean)	--	5mg/m³(resp.)	65µg/m³ (24-hr)
SO_2	20µg/m³ (24-hr mean)	--	5ppm (8-hr)	140ppb (24-hr) 75ppb (1-yr)
NO_2	200µg/m³ (1-hr) 40µg/m³(annual mean)	--	5ppm (8-hr)	53ppb (annual) 100ppb (1-hr)
CO	10ppm (8-hr)	9ppm (8-hr)	50ppm (8-hr)	9ppm (8-hr)
CO_2	--	1000ppm (8-hr)	5000ppm	
Humidity	--	30% - 65%	--	
Temperature	--	68°F - 74.5°F (20-23.6°C)(winter) 73°F - 79F° 22.8-26.1°C)(summer)	--	

*** Occupational Safety and Health Administration Permissible Exposure Limit — this level is a time-weighted average and is an enforceable standard that must not be exceeded during any eight-hour work shift of a 40-hour work week

** ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers Inc.) Standard 55

* WHO air quality guidelines global update 2005 and WHO guideline value for the -classical‖ air pollutants (WHO 1999a

**** The National Ambient Air Quality Standards (NAAQS) were developed by the U.S.

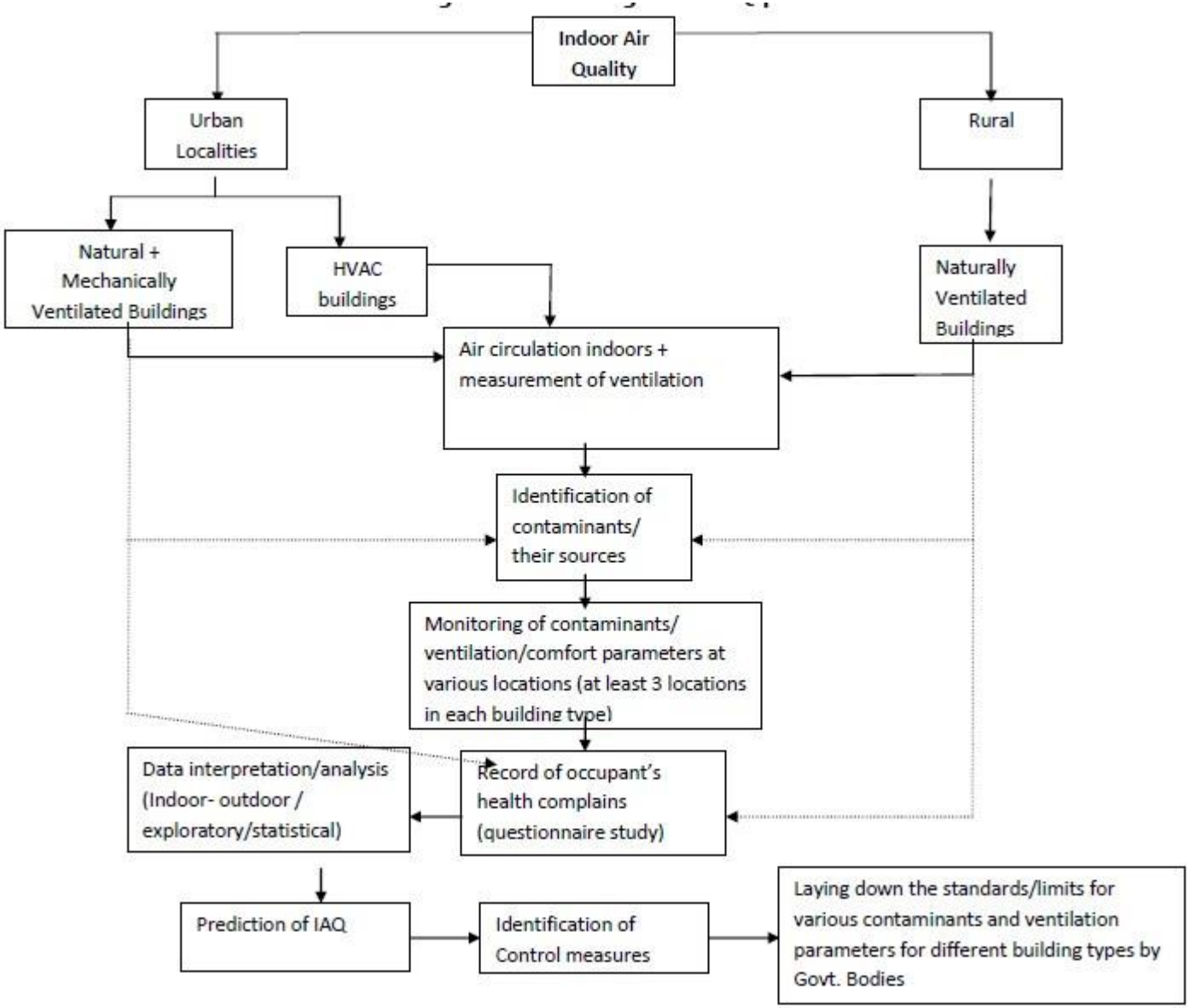
Environmental Protection Agency (EPA) under the Clean Air Act (last amended in 1990). These enforceable standards were developed for outdoor air quality, but they are also applicable for [illegible] air contaminant levels. The concentrations are set conservatively in order to protect the most sensitive individuals, such children, the elderly, and those [illegible] asthma.

Comparison of Regulations & Guidelines Pertinent to Indoor Environments

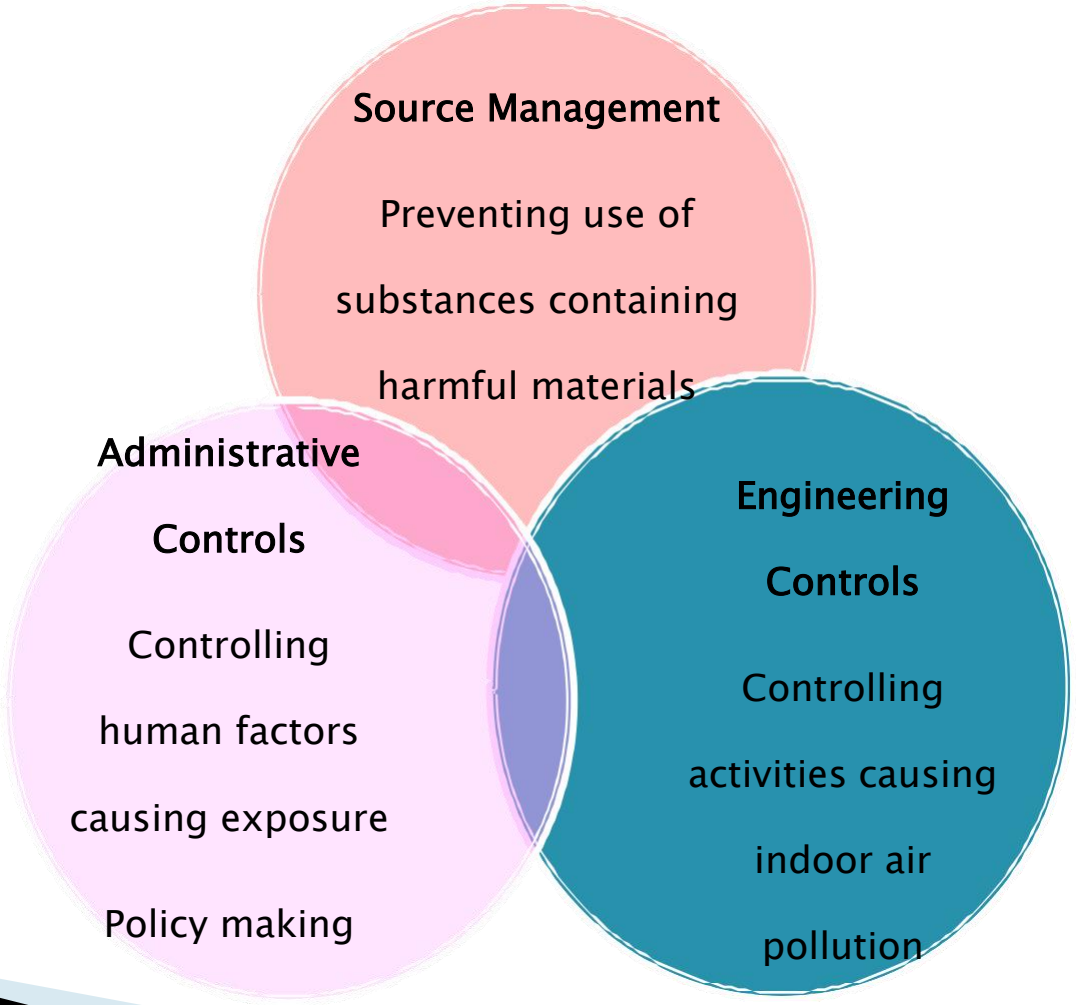
	Enforceable and/or Regulatory Levels			Non-Enforced Guidelines and Reference Levels			
	NAAQS/EPA (Ref. B-4)	OSHA (Ref. B-5)	MAK (Ref. B-2)	Canadian (Ref. B-8)	WHO/Europe (Ref. B-11)	NIOSH (Ref. B-13)	ACGIH (Ref. B-1)
Carbon dioxide		5,000 ppm	5,000 ppm 10,000 ppm [1 h]	3,500 ppm [L]		5,000 ppm 30,000 ppm [15 min]	5,000 ppm 30,000 ppm [15 min]
Carbon monoxide [c]	9 ppm [g] 35 ppm [1 h] [g]	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8 h] 25 ppm [1 h]	90 ppm [15 min] 50 ppm [30 min] 25 ppm [1 h] 10 ppm [8 h]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde[h]		0.75 ppm 2 ppm [15 min]	0.3 ppm 1 ppm[i]	0.1 ppm [L] 0.05 ppm [L] [b]	0.1 mg/m^3 (0.081 ppm) [30 min][p]	0.016 ppm 0.1 ppm [15 min]	0.3 ppm [C]
Lead	1.5 µg/m^3 [3 months]	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30 min]	Minimize exposure	0.5 µg/m^3 [1 yr]	0.1 mg/m^3 [10 h]	0.05 mg/m^3
Nitrogen dioxide	0.05 ppm [1 yr]	5 ppm [C]	5 ppm 10 ppm [5 min]	0.05 ppm 0.25 ppm [1 h]	0.1 ppm[1 h] 0.004 ppm [1 yr]	1 ppm [15 min]	3 ppm 5 ppm [15 min]
Ozone	0.12 ppm [1 h][g] 0.08 ppm	0.1 ppm	j	0.12 ppm [1 h]	0.064 ppm (120 µg/m^3) [8 h]	0.1 ppm [C]	0.05 ppm[k] 0.08 ppm[l] 0.1 ppm[m] 0.2 ppm[n]
Particles[e] <2.5 µm MMAD[d]	15 µg/m^3[1 yr][o] 65 µg/m^3 [24 h][o]	5 mg/m^3	1.5 mg/m^3 for <4 µm	0.1 mg/m^3 [1 h] 0.040 mg/m^3 [L]			3 mg/m^3
Particles[e]<10 µm MMAD[d]	50 µg/m^3[1 yr][o] 150 µg/m^3 [24 h][o]		4 mg/m^3				10 mg/m^3
Radon	See Table B-2[f]				2.7 pCi/L [1yr]		
Sulfur dioxide	0.03 ppm [1 yr] 0.14 ppm [24 h] [g]	5 ppm	0.5 ppm 1 ppm [i]	0.38 ppm [5 min] 0.019 ppm	0.048 ppm [24 h] 0.012 ppm [1 yr]	2 ppm 5 ppm [15 min]	2 ppm 5 ppm [15 min]
Total Particles[e]		15mg/m^3					

***Unless otherwise specified, va given in parts per million (ppm)**
***Where no time is specified, the averagi eight hours.**

IAQ Management



Mitigation strategies



1. Source management

- Lot of indoor air pollutants directly linked to items of daily use
  - Cleaning items (low VOC products)
  - Fuels and cook-stoves (Clean fuels)
  - Building materials and furnishings (low VOC products)

- Building occupants may be the source of pollutants – perfumes or colognes, cigarette smoke (OSHA, 2011)

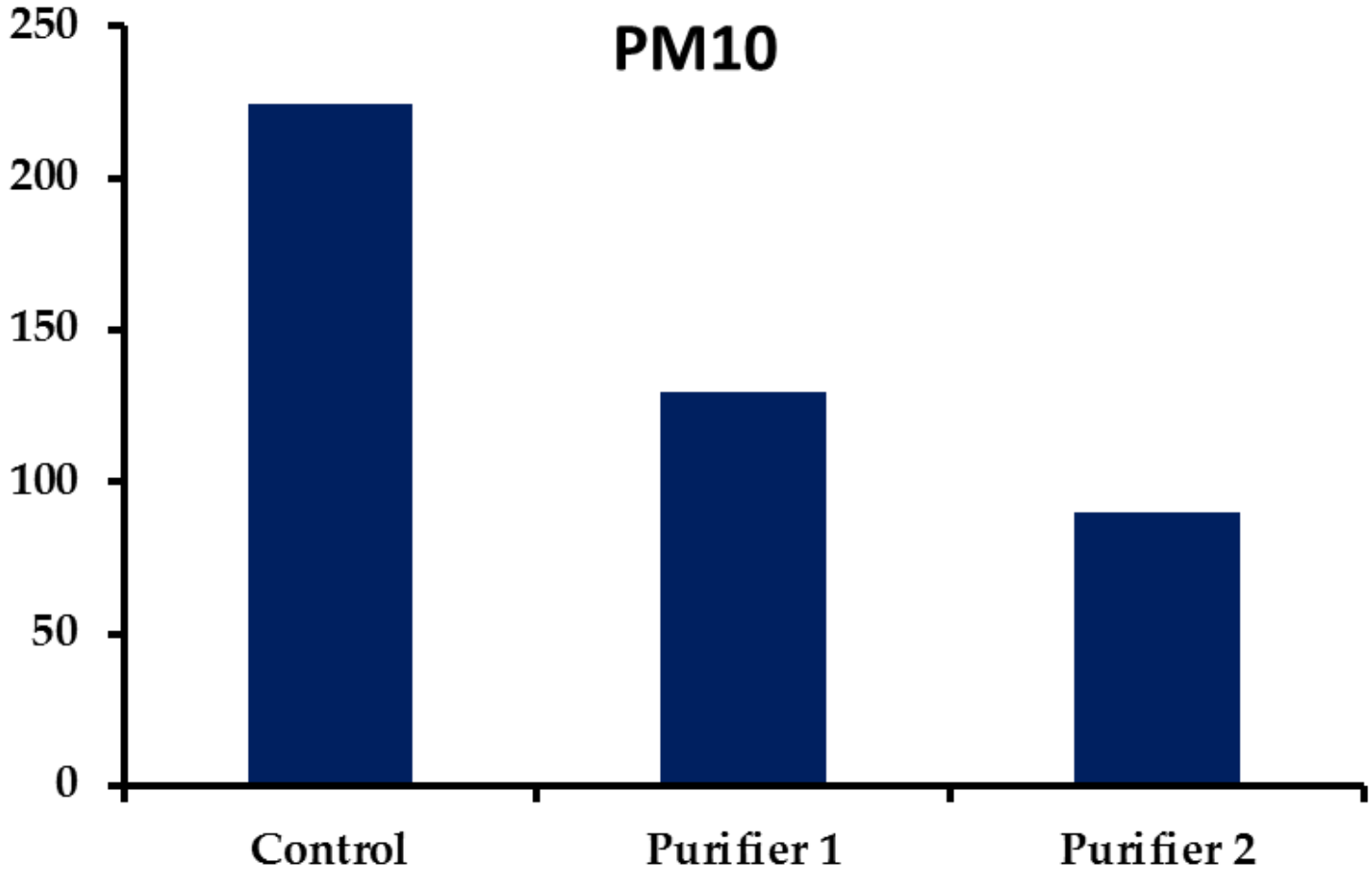
2. Administrative controls

Work schedules	• Eliminate or reduce the amount of time a worker is exposed to a pollutant • Reduce the amount of chemicals being used by or near workers • Control the location of chemical use
Education and Awareness	• Inform about the sources and effects of pollutants • Inform about proper operation of ventilation system • Awareness about clean alternatives, mitigation solutions
Housekeeping	• Prevent dirt from entering the environment • Dispose garbage timely • Store food properly • Choose cleaning products, methods that minimize introduction of pollutants into the building

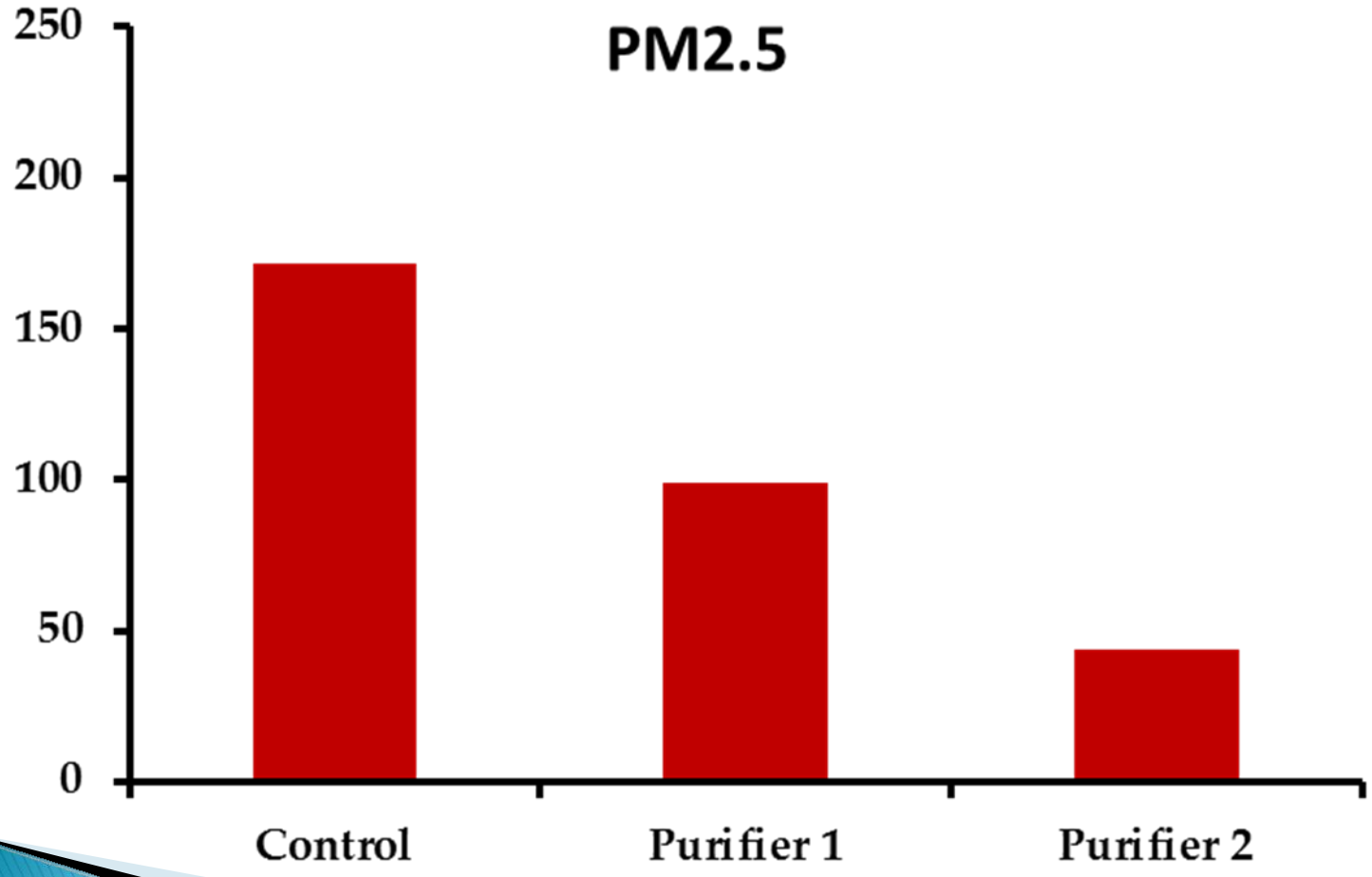
3. Engineering controls

- HVAC (heating, ventilation, and air conditioning systems) control and management
- IAQ improving plants
- Air purifiers

Air purifiers performance



Air purifiers performance



Interventions required

- National standards and/or guidelines on indoor air quality
- Verifying claims of products – certifications
- Evaluation of important existing buildings
- GRIHA Rating evaluation to be included in building projects
- Improving outdoor air quality will help in improving IAQ also and vice versa.

Thank you