OUTDOOR AIR POLLUTION-CARDIOPULMONARY ILL EFFECTS AND CONTROL MEASURES AT COMMUNITY AND SUBJECT LEVEL

Shailesh Agrawal

OVERVIEW

- Disease burden of air pollution
- Important sources of air pollution
- Characteristics of individual air pollutants
- Health effects of air pollution
- Air quality standards
- Measures for prevention and control of air pollution and its health effects

POLLUTION - DEFINITION

Derived from Latin verb *polluere*

The presence in or introduction into the environment

of a substance which has harmful or poisonous effects

Oxford English Dictionary, Second Edition

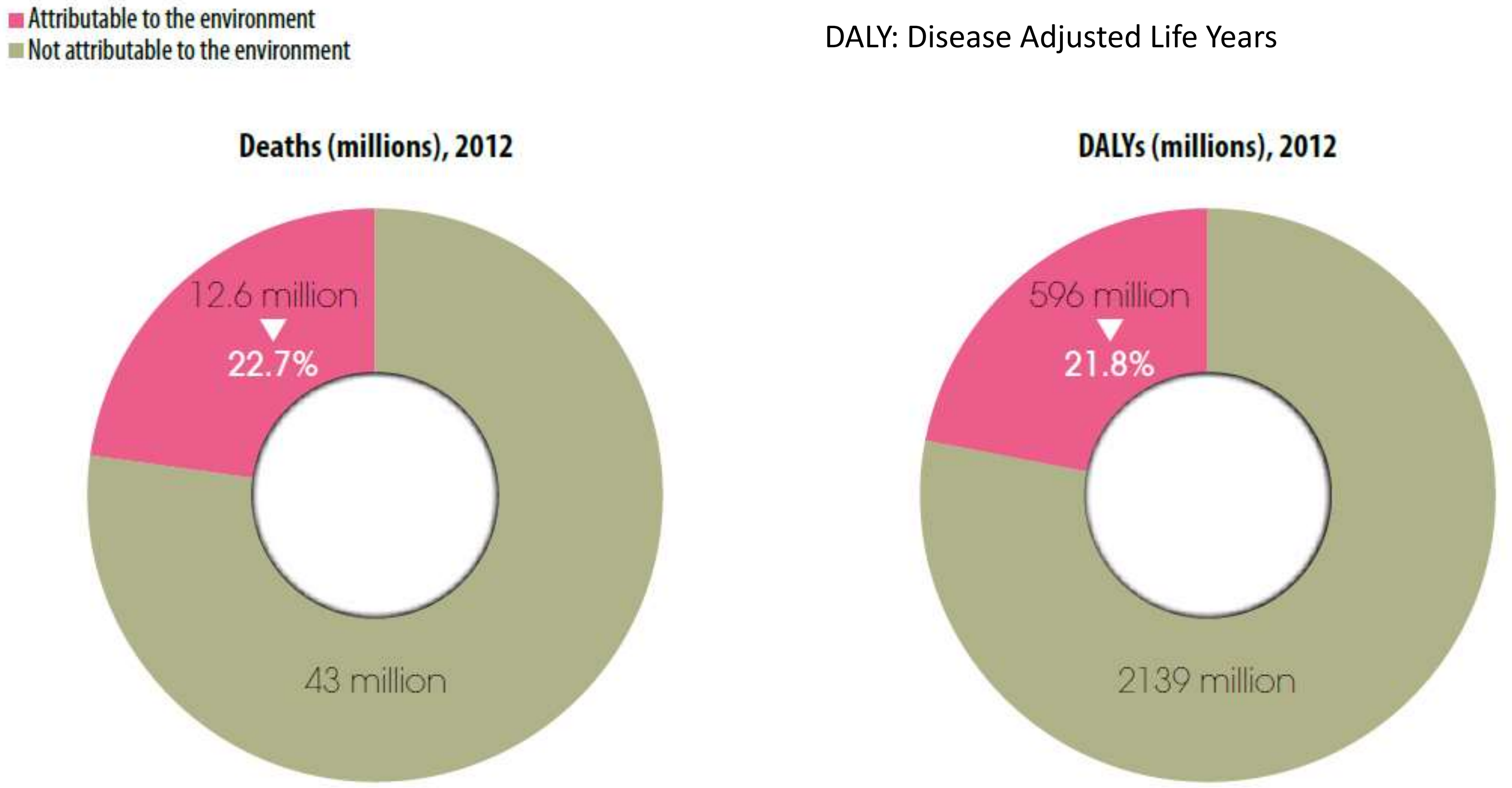
Diseases and key environmental factors

Infectious diseases	
Respiratory infections	Household and ambient air pollution, second-hand tobacco smoke
Noncommunicable diseases	
Cancers	Household and ambient air pollution, second-hand tobacco smoke, ionizing radiation, UV radiation, chemicals
Cataract	UV radiation, household air pollution
Cardiovascular diseases	Household and ambient air pollution, second-hand tobacco smoke, exposure to lead, stressful working conditions, shift work
Chronic obstructive pulmonary disease	Household air pollution, ambient air pollution, exposure to dusts in the workplace
Asthma	Air pollution, second-hand tobacco smoke, indoor exposure to mould and dampness, occupational exposure to allergens

Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks: Annette Prüss-Üstün et al; WHO 2016

Fraction of deaths and DALYs attributable to the environment globally

DALY: Disease Adjusted Life Years



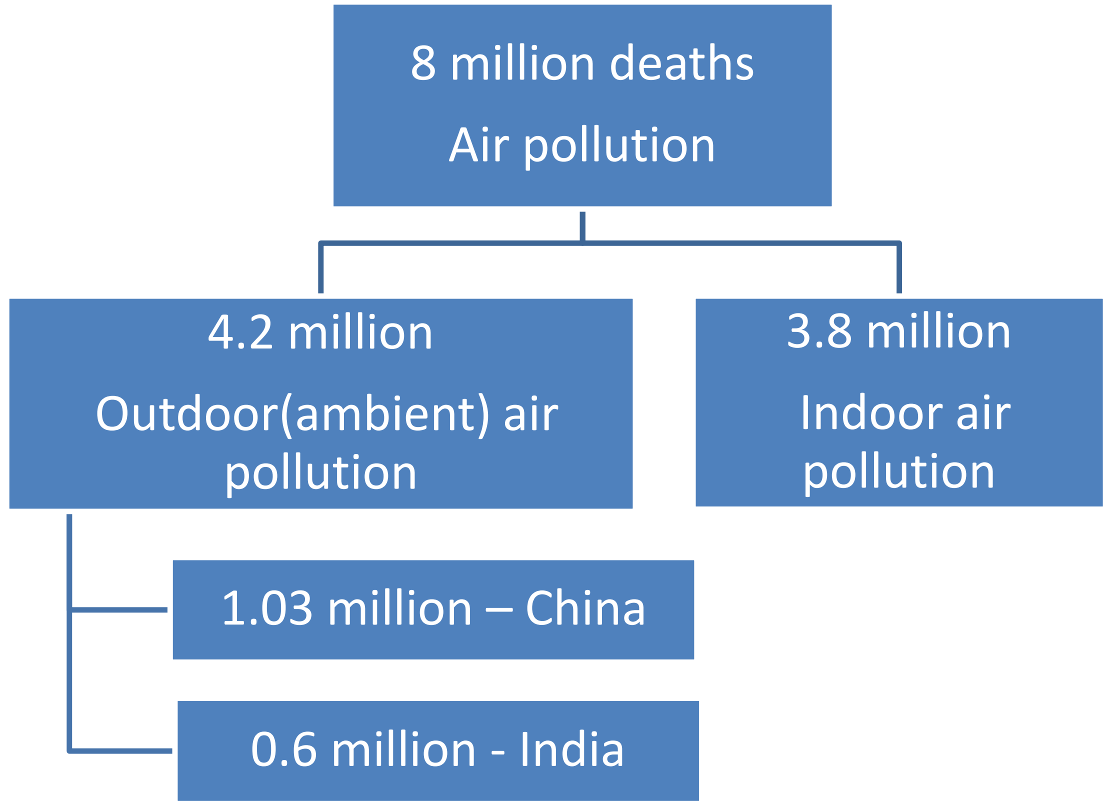
Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks: Annette Prüss-Üstün et al; WHO 2016

Fraction of DALYs attributable to the environment globally

Disease	DALY	% Attributable to environment
LRTI	52 million	35%
Cancers	49 million	20%
Cardiovascular diseases	119 million	31%
Chronic obstructive pulmonary disease	32 million	35%
Asthma	11 million	44%

Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks: Annette Prüss-Üstün et al; WHO 2016

Disease burden of air pollution



http://www.who.int/airpollution/ambient/health-impacts/en/ 2016

Disease burden of air pollution

- Worldwide ambient air pollution accounts for:
  - 25% of all deaths and disease from lung cancer
  - 17% of all deaths and disease from acute lower respiratory infection
  - 16% of all deaths from stroke
  - 15% of all deaths and disease from ischemic heart disease
  - 8% of all deaths and disease from chronic obstructive pulmonary disease
- Nearly 90% of air pollution related deaths occur in low- and middle-income countries, 2/3rd in SEAR and western pacific region.

http://www.who.int/airpollution/ambient/health-impacts/en/2016

- 98% of the cities in the low- and medium income countries (and 56% in high-income countries) with population >0.1 million do not meet WHO air quality guidelines

- More than 3 billion people worldwide rely on polluting technologies and fuels for household cooking, heating and lighting

http://www.who.int/airpollution/ambient/health-impacts/en/ 2016

Countries with the most polluted urban areas

S.no.	Country name	Average PM 2.5 concentration
1	Pakistan	115.7
2	Qatar	92.4
3	Afghanistan	86
4	Bangladesh	83.3
5	Egypt	73
6	UAE	64
7	Mongolia	61.8
8	India	60.6
9	Bahrain	56.1
10	Nepal	50

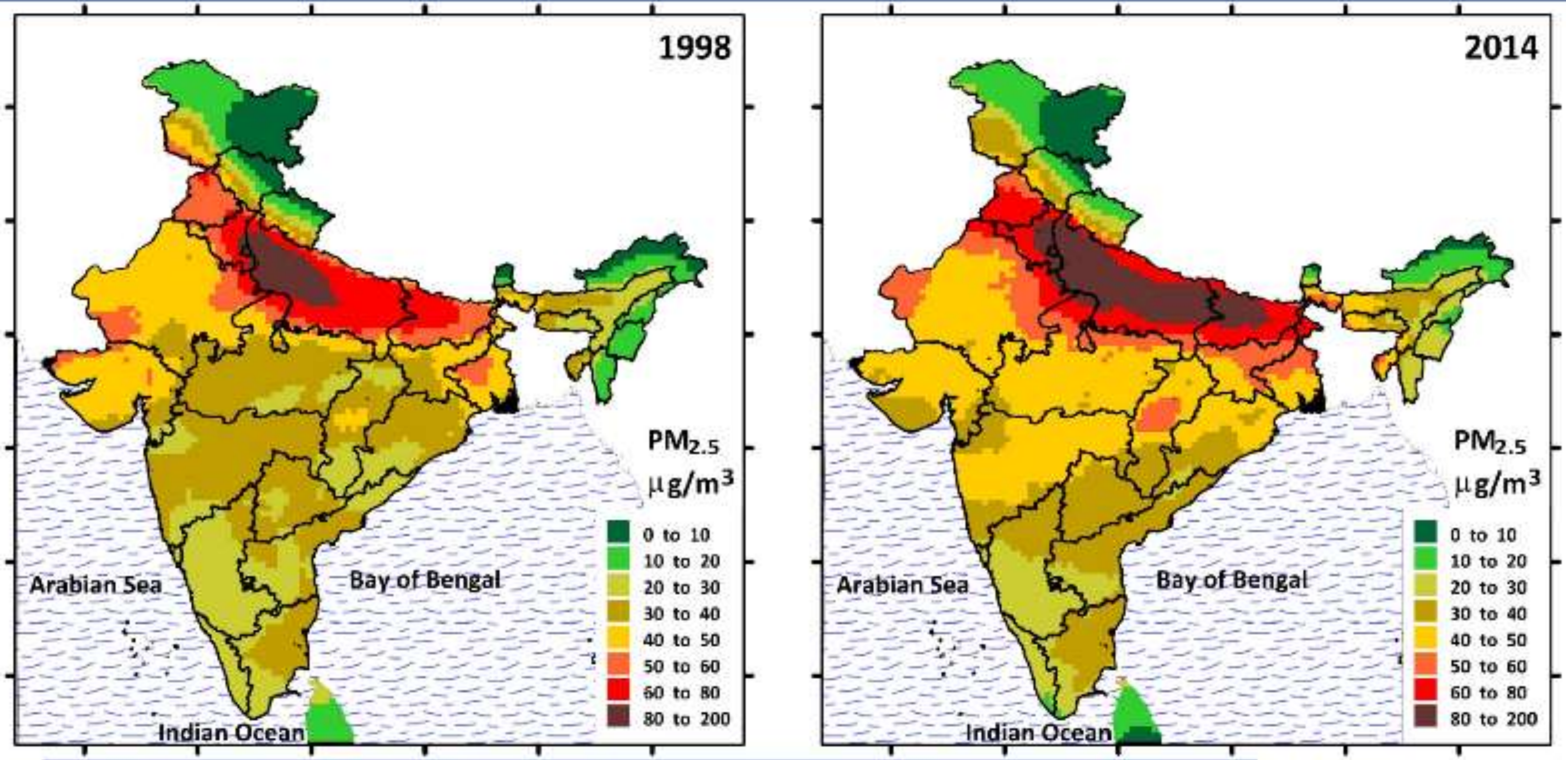
https://www.telegraph.co.uk/travel/maps-and-graphics/most-polluted-countries/

Pollution statement in India

- 14 out of world's 20 most polluted cities in India
- Delhi and Varanasi are among the 14 Indian cities that figured in a list of 20 most polluted cities in the world in terms of PM2.5 levels in 2016

WHO's global urban air pollution database 2016

$PM_{2.5}$ POLLUTION in INDIA 1998 vs. 2014



	#of districts above 10 $\mu g/m^3$	#of districts above 40 $\mu g/m^3$	maximum in $\mu g/m^3$	all district average in $\mu g/m^3$
1998	98%	40%	99.6	41.5
2014	99%	60%	110.8	48.8

Total # of districts 640 (census 2011)

India annual standard 40 $\mu g/m^3$
WHO annual guideline 10 $\mu g/m^3$

Gridded $PM_{2.5}$ data is constructed by combining data from satellite retrievals and a 3D global chemical transport model, and subsequently calibrated with available ground-based observations
(Source: Dalhousie University - http://fizz.phys.dal.ca/~atmos/martin/?page_id=140)

UE info

Air pollution - Sources

- Stationary
  - Factories
  - Waste incinerators
  - Biomass burning
- Mobile
  - Vehicles(road vehicles, trains, ships, aircraft etc)

WHO Air Quality Guidelines, Global Update 2005, updated 2014

Air pollution - Sources

Point sources	Line sources	Area sources
Industries	Vehicles	Domestic heating of coal

- Point source – large stationary; industries, power plants
- Area source – small stationary, mobile source with indefinite routes; cluster of point sources
- Line source – mobile source with definite routes; vehicles travelling along highways, railroads

WHO Air Quality Guidelines, Global Update 2005, updated 2014

Natural Sources of Air Pollution

- Methane
- Dust
- Volcanic eruption

WHO Air Quality Guidelines, Global Update 2005, updated 2014

Natural Sources of Air Pollution

- Methane: emitted by the digestion of food by animals, waste deposition in landfills
  - Highly flammable, may form explosive mixtures with air
  - Also an asphyxiant and may displace oxygen in an enclosed space
- Dust: large areas of land with few or no vegetation
- Volcano: Andaman, Deccan plateau (Western Ghats)
  - contribute to SO2 release, chlorine and ash

WHO Air Quality Guidelines, Global Update 2005, updated 2014

Forest fires

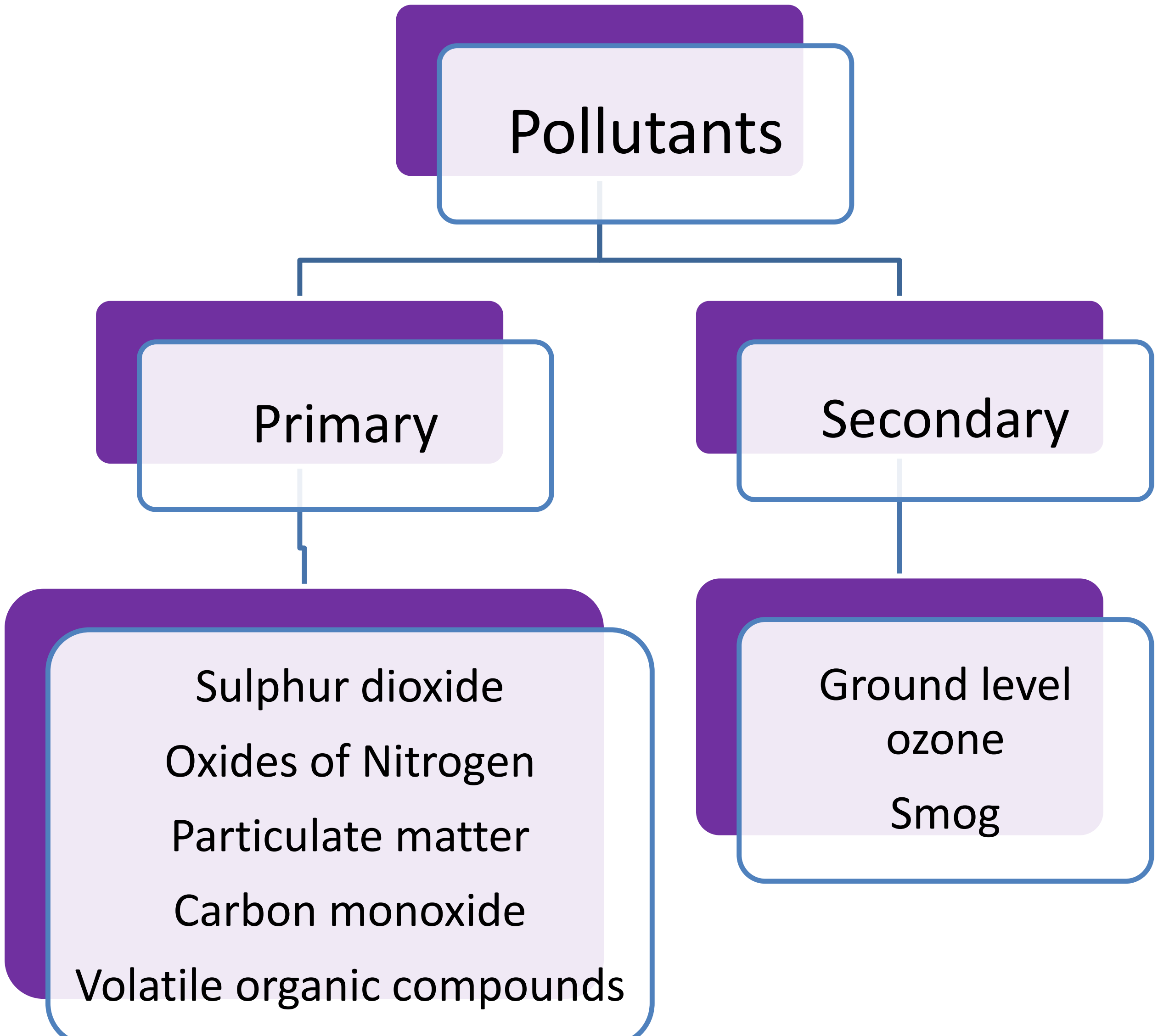
- Natural source of air pollution
- Garhwal Himalayas,

  Uttaranchal and Himachal
- Also leads to loss of forest

  cover

Marlon et al 'Climate and human influences on global biomass burning over the past two millennia' Nature *Geoscience* 2008 **1** (10): 697–702

Air Pollution - Pollutants



Sulphur dioxide

- Sources:
  - Burning fossil fuels: coal, crude oil, diesel – motor vehicles, power plants, industries, domestic heating
  - Smelting metals
  - Volcanoes

WHO Air Quality Guidelines, Global Update 2005; updated in 2014

Sulphur dioxide

- Effects:
  - Acute – respiratory irritant
  - Chronic – aggravates asthma and chronic bronchitis, mortality from cardiac diseases
  - Acid rains

WHO Air Quality Guidelines, Global Update 2005; updated in 2014

Oxides of Nitrogen

- Types: Nitric oxide, nitrogen dioxide, nitrous oxide, nitrate etc.
- Sources:
  - Combustion of coal
  - High temperature combustion (road traffic and electricity generation)

WHO Air Quality Guidelines, Global Update 2005; updated in 2014

Oxides of Nitrogen

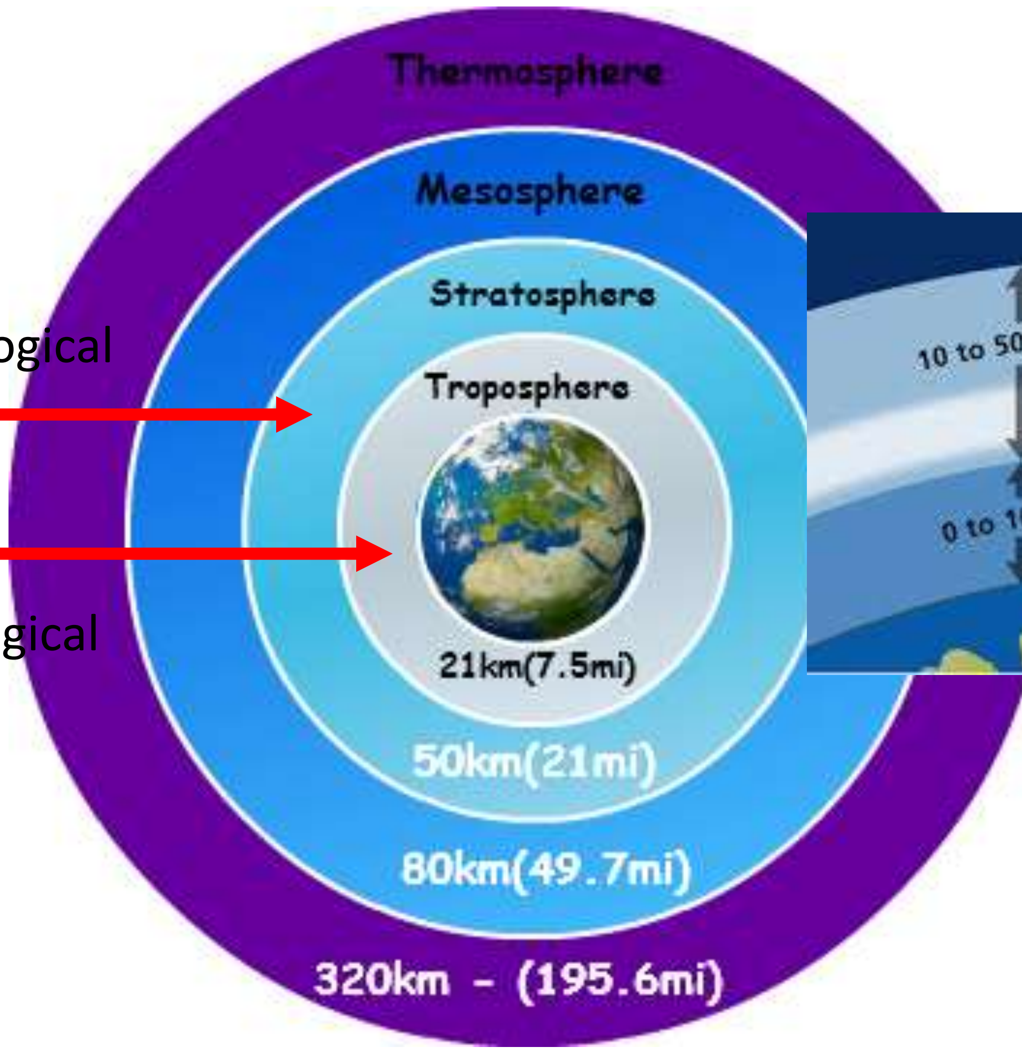
- Effects:
  - Worsening of asthma, irritation of respiratory tract
  - Ozone formation
  - nitrate aerosols - important fraction of $PM_{2.5}$

WHO Air Quality Guidelines, Global Update 2005; updated in 2014

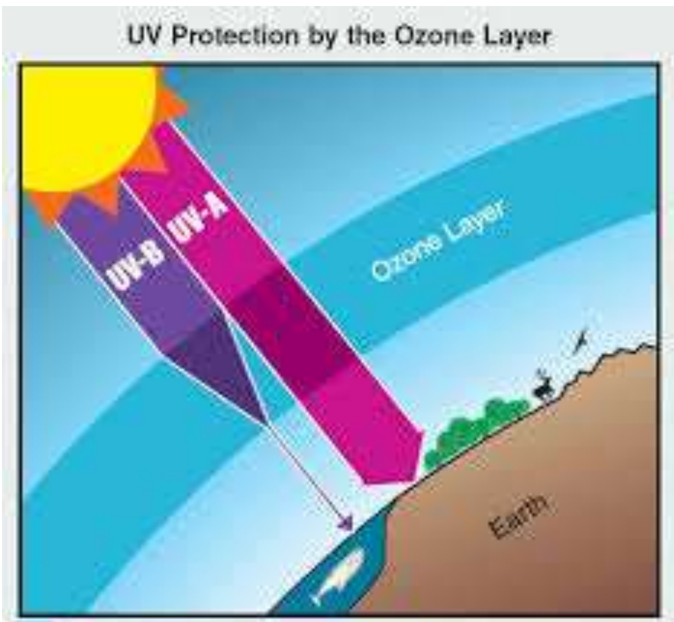
Ozone – layers of atmosphere

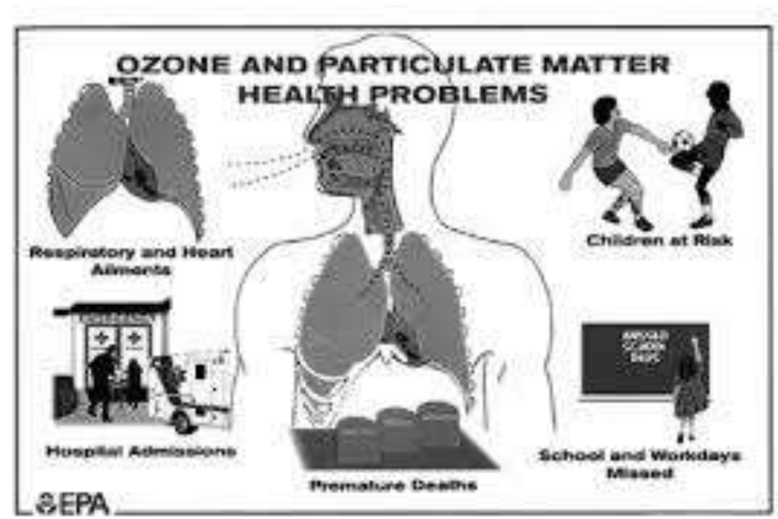
Physiological

Pathological



Ozone

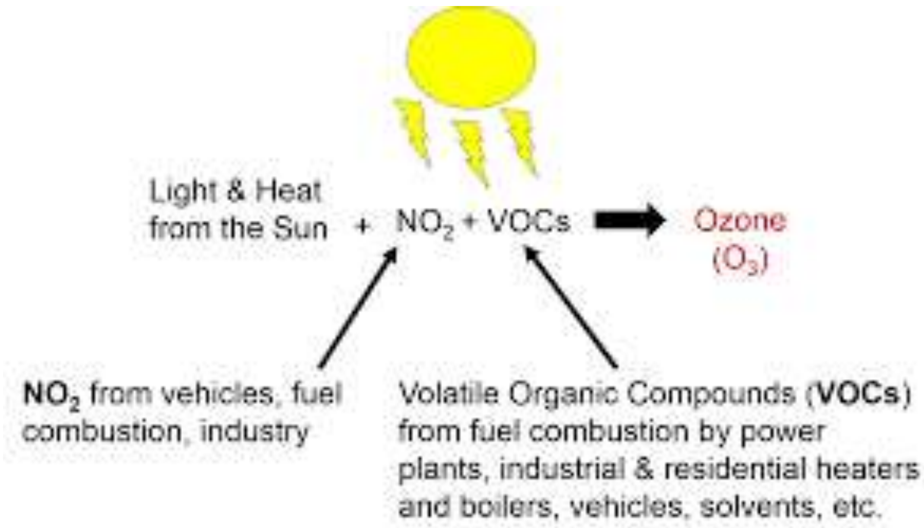




Ozone as a pollutant

Ozone – a double edged sword

Ozone



Ozone formation

Ground level Ozone

- Photochemical reaction between nitrogen oxides and volatile organic compounds
- Component of photochemical smog
- Effects: Respiratory morbidity, accelerates atherosclerosis

WHO Air Quality Guidelines, Global Update 2005; updated in 2014

Particulate matter(PM)

- Complex mixture of solid and liquid particles suspended in air
- Sources of PM: motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, other combustion processes
- 3 fractions:
  - 1) Coarse fraction, PM10(2.5-10um)
  - 2)Fine fraction,PM2.5(0.1-2.5um)
  - 3)Ultrafine nanosize fraction, PM0.1(≤0.1um)

WHO Air Quality Guidelines, Global Update 2005; updated in 2014

Particulate matter(PM)

- **Coarse fraction :** mostly deposited along the large airway due to gravity and is relatively easy to be cleaned by mucociliary clearance
- **Fine fraction :** more potent; small enough to be aspirated into alveoli, absorbed into lung vascular endothelial cells, and transported into the systemic circulation
- **Nanosize particles :** can penetrate through the air-blood tissue barrier into the capillaries after being deposited on the alveolar wall, and thereby translocate to all other organs

Particulate matter(PM)

- Capable of penetrating deep into lung passageways and entering the bloodstream causing cardiovascular, cerebrovascular and respiratory impacts
- Classified as a cause of lung cancer by WHO's International Agency for Research on Cancer, 2013 (IARC)

Organic Compounds

- Carbon monoxide
- Benzene
- Polycyclic aromatic hydrocarbons (PAH)
- Vinyl chloride
- Dichloromethane
- Diesel exhaust particles(DEP)

Carbon monoxide

- Source – incomplete combustion of petrol in road vehicles; smoking especially poorly ventilated areas

Carbon monoxide

- Effects:
  - Acute – hypoxia due to carboxyhemoglobin
  - Chronic - May contribute to cardiovascular mortality
  - Maternal smoking is related to low birth weight
- Guidelines: 100 mg/m^3 (90 ppm) for 15 minutes

1 - *Air quality criteria for carbon monoxide*. Washington, DC, US Environmental Protection Agency, 1991 (Publication EPA-600/B-90/ 045F).
WHO Air Quality Guidelines, Global Update 2005; updated in 2014

Benzene

- Sources:
  - cigarette smoke
  - combustion and evaporation of benzene-containing petrol
  - petrochemical industries
  - combustion processes
- Effects: bone marrow depression, leukemia

Polycyclic aromatic hydrocarbons

- Includes Benzo[*a*]pyrene (BaP), Benzanthracene, Naphthalene etc
- Sources: incomplete combustion of wood, coal; automobile, industries, tobacco
- Effects: carcinogenic

- Pollutants with the strongest evidence for public health concern, include particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2)

- The health risks associated with particulate matter of less than 10 and 2.5 microns in diameter (PM_{10} and $PM_{2.5}$) are especially well documented

http://www.who.int/airpollution/ambient/health-impacts/en/ 2016

Health Effects of Air Pollution

- Vascular
  - Coronary Artery Disease
  - Hypertension
  - Heart failure
  - Cerebrovascular diseases
- Respiratory
  - Exacerbation of COPD
  - Asthma
  - Lung cancer
  - Reduction in FEV1/FVC
  - Upper and lower resp. tract infections
  - ILD exacerbation
- Children
  - Recurrent infections
  - Developmental delay
  - Shortened life span
- Pregnant females
  - Abortion
  - Low Birth Weight

Air Pollution And Pulmonary Effects

Air pollutants exert their detrimental effects on airways and lungs by :

- Attenuating ciliary activity of airway epithelial cells
- Increasing permeability of airway epithelium that leads to inflammatory changes
- Triggering oxidative pathway
- Modulating cell cycle and cell death of respiratory system

Bayram H et al. Clin Exp Allergy. 2002;32:1285-92
Bayram H et al. Toxicol Lett. 2013;218:215-23
Manzo ND et al. Part Fibre Toxicol. 2012;15:9-43

Air Pollution and lung cancer

Carcinogens include:

- Smoking
- Passive smoking
- Diesel exhaust
- Particulate matter
- Outdoor air pollution

1 Alberg AJ et al Epidemiology of lung cancer: Diagnosis and management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. Chest 2013
2 Vermeulen et al Exposure-response estimates for diesel engine exhaust and lung cancer mortality based on data from three occupational cohorts. Environ Health Perspect 2014;122: 172–77
3 Raaschou – Nielsen Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE). Lancet Oncol 2013;14: 813–22
IARC- International Agency for Research on Cancer WHO 2013

Air Pollution and lung cancer

- Type of lung cancer
  - Smoking – squamous and small cell type
  - Particulate matter – Adenocarcinoma
  - Environmental tobacco smoke – Small cell lung cancer

- Each10 g/m^3 increase in concentration of fine particles carries an increased lung cancer risk of 14%

IARC- International Agency for Research on Cancer WHO 2013
Sapkota et al 'indoor air pollution from solid fuels and risk of hypopharyngeal / lung cancers/; a multicentric case control study from India' Intl J Epidemiol 37(2) 321-8

Air Pollution and asthma

- Short-term exacerbations in those who already have respiratory allergies (i.e. asthma and rhinitis)
- Asthma exacerbations (measured as visits to emergency departments) have been frequently reported on days with higher levels of Ozone and other pollutants
- Whether air pollutants play a role in the initiation of new cases of asthma in those previously free from the condition is less clear

Siddique et al 'Effect of air pollution on Incidence of Asthma: A case study in children' Environ We Int J Sci Tech 2010 163-175
Modig et al 'Vehicle exhausts outside the home and onset of asthma among adults' Eur Respir J 2009 33(6):1261
Weisel C et al. Environ Health Perspect. 1995;103(suppl 2):97-102

Air Pollution and asthma

- Few studies have suggested role of air pollution in development of asthma
- In a chinese study environmental tobacco smoke and chemical emissions from new furniture were risk factors for asthma and for wheeze and daytime breathlessness.
- Another study shown male children without allergic predisposition had increased susceptibility to the adverse impact of air pollution on asthma

Dong GH, Chen T, Liu MM, et al. Gender diff erences and eff ect of air pollution on asthma in children with and without allergic predisposition: northeast Chinese children health study. *PLoS One* 2011.
Jiang XQ, Mei XD, Feng D. Air pollution and chronic airway diseases: what should people know and do? *J Thorac Dis 2016;* 8: E31–40

Air Pollution and COPD

- Acute exacerbations of COPD are linked to increased air pollution
- Most studies have focused on the role of air pollution in triggering symptoms and exacerbations, i.e. the short-term (acute or subacute) effects of air pollution
- The role of air pollution in the long-term development of the pathophysiological changes that characterize COPD are far less clear and inconsistent

ATS and HEI review 2008

Air Pollution and Respiratory infections

- Antenatal exposure to air pollution may increase vulnerability of infants to respiratory infections.
- A prospective birth cohort study of 214 children where pregnant mothers exposed to greater levels of outdoor PM2.5 gave birth to children who were 120 g lighter at birth.
- Those in the top tertile subsequently experienced more episodes of recurrent bronchitis and pneumonia with respect to those in the lower tertiles over the 7 year follow-up

Jedrychowski WA et al. Intrauterine exposure to fine parti- culate matter as a risk factor for increased susceptibility to acute broncho- pulmonary infections in early childhood. Int J Hyg Environ Health 2013; 216:395–401

Air Pollution and Respiratory infections

- In a meta-analysis of 10 European birth cohorts from the ESCAPE project in 16,059 children PM10 and traffic exposure were significantly associated with an increased risk of pneumonia

Macintyre EA, Gehring U, Molter A. et al Air pollution and respiratory infec-tions during early childhood: An analysis of 10 european birth cohorts within the escape project. Environ Health Perspect 2013;22:22.

Archives of Environmental & Occupational Health, Vol. 68, No. 4, 2013
Published with license by Taylor & Francis Group, LLC

Respiratory Disease in Relation to Outdoor Air Pollution in Kanpur, India

Hai-Ying Liu, PhD; Alena Bartonova, RNDr; Martin Schindler, PhD; Mukesh Sharma, PhD; Sailesh N. Behera, PhD; Kamlesh Katiyar, PhD; Onkar Dikshit, PhD

Kanpur Study

- Pollution loads/emissions were estimated for SO_2, PM, and nitrogen oxides (NO_x)
- Respiratory diseases were estimated from total number of registered respiratory patients visits to the chest and tuberculosis hospital (Lala Lajpat Rai Hospital).
- The relative number of hospital visits due to respiratory disease/symptoms was compared between the 4 clusters.

Table 4.—Emission of SO_2, PM, and NO_x in Each Emission Cluster

Cluster number	SO_2 (kg/day/grid)	PM (kg/day/grid)	NO_x (kg/day/grid)
1	36.08	44.57	39.00
2	46.57	75.72	104.23
3	62.19	134.76	194.15
4	120.16	259.34	434.97

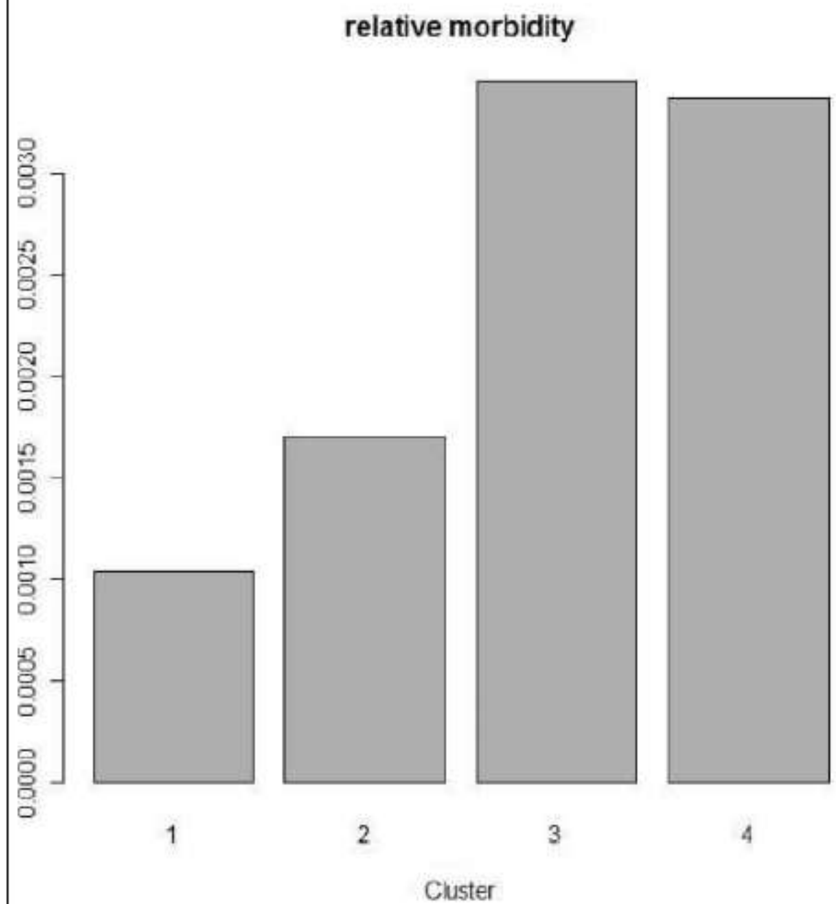


Fig. 8. The ratio of number of inhabitants who visited the LLR Hospital with respiratory symptoms to the total number of inhabitants ("relative morbidity") in the emission clusters (*y*-axis, relative morbidity).

Table 7.—Odds Ratios Quantifying Increased Risk of Visiting the LLR Hospital Between the Emission Clusters

Contrasts between clusters	Estimate	95% CI	Odds ratio	95% CI
2 and 1	0.50	0.36, 0.63	1.64	1.43, 1.89
3 and 1	1.20	1.07, 1.34	3.33	2.91, 3.81
4 and 1	1.18	1.03, 1.33	3.25	2.80, 3.78
3 and 2	0.71	0.61, 0.80	2.03	1.84, 2.24
4 and 2	0.68	0.57, 0.80	1.98	1.76, 2.22
4 and 3	−0.02	−0.14, 0.09	0.98	0.87, 1.09

- The relative number of patients who visited the hospital per number of inhabitants in each cluster was much higher in the highly polluted regions (clusters 3 and 4) than in the less polluted regions (cluster 1)
- A strong correlation was found between visits to a hospital due to respiratory disease and emission strength in the area of residence.

Air Pollution And Pulmonary Effects

- Similarly, in a study carried out in Lucknow, the average levels of PM10 and PM2.5 were above the permissible limits laid by WHO at densely populated and roadside sites.
- Indoor AQI range was alarming with the values of 302 and 209 in some areas.
- 46% of urban people suffered from acute respiratory infections like bronchial asthma, headache, depression and dizziness and these people were mostly from Roadside colonies.

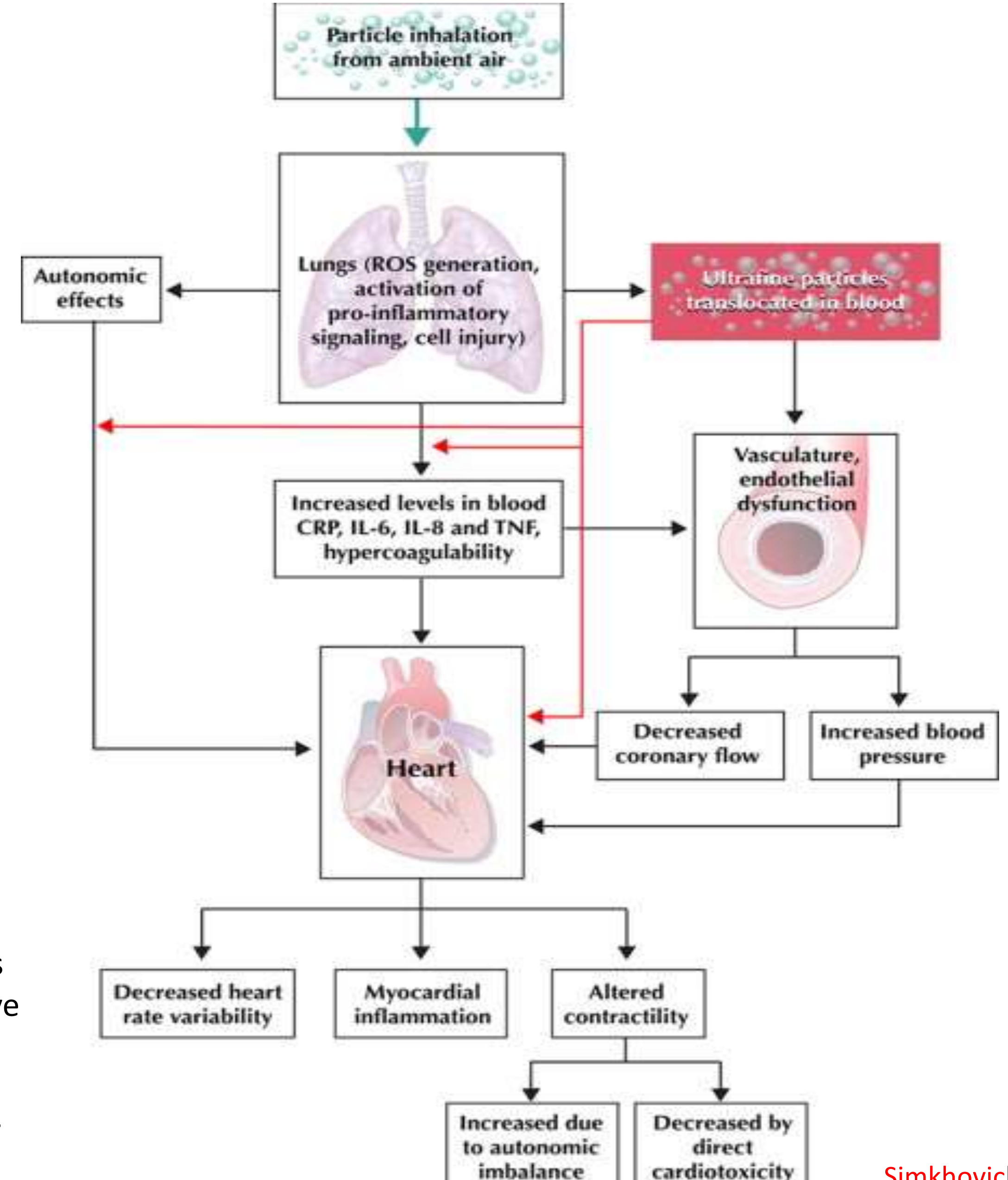
Lawrence A, Urban air pollution & its assessment in Lucknow City--the second largest city of North India. Sci Total Environ. 2014 Aug 1;488-489:447-55.

Air Pollution and Pneumoconiosis

- Reported in Ladakh
- Pneumoconiosis like picture despite absence of industries or mines
- Factors responsible –
  - Dust storms especially in spring
  - Soot exposure – minimum ventilation due to severe cold and use of wood for warmth
- Gujjar lung: anthracotic lung nodules and miliary mottling due to exposure to wood smoke

ICMR Bulletin 2001 ‘ Indoor air pollution in India – A major concern’ Saiyed et al ‘non occupational pneumoconiosis at high altitude villages in central Ladakh’ Br J Industr Med 1991
Hassan et al ‘Gujjar Lung; A disease mimicking Tuberculosis’ Chest 2008 Jan 2(1) 105-108

Air Pollution and Cardiovascular Diseases



ROS – Reactive Oxygen Species
CRP – C Reactive Protein
TNF – Tumor Necrosis Factor
IL - Interleukin

Simkhovich et al *J Am Coll Cardiol*. 2008;52(9):719-726.

Air Pollution and Cardiovascular Diseases

- Long-term exposure to high concentrations of air pollutants has been associated with risk of myocardial infarction and stroke.
- Increased concentrations of PM2·5 and traffic-related air pollution, are associated with progression in coronary calcification, consistent with acceleration of atherosclerosis

Joel D Kaufman : Association between air pollution and coronary artery calcification within six metropolitan areas in the USA (the Multi-Ethnic Study of Atherosclerosis and Air Pollution):a longitudinal cohort study; Lancet 2016
Hoek G, Krishnan RM, Beelen R, et al. Long-term air pollution exposure and cardio- respiratory mortality: a review. Environ Health. 2013; 12:43

Air Pollution and Cardiovascular Diseases

- Many international as well as indian studies suggest causal relationship between air pollution and cardiovascular disorders.
- *Nautiyal et al*(2007) compared cardiac symptoms and ECG findings in a study of 200 people living in industrial Vs rural areas of Delhi and correlated with outdoor air pollutant levels.
  - Significant higher prevalence of anginal symptoms and ECG abnormalities in people living in industrial areas

Air Pollution and Cardiovascular Diseases

Country, year of study and reference	Study type and characteristics	Air pollutant	Air pollutant measurements	Cardiovascular out-comes/biomarkers	Cardiovascular and other measurements	Main results
India	Cross-sectional study	Outdoor PM_{10}	Fixed site monitors	Hypertension	At least 2 blood pressure measures per participant	Elevated PM_{10} a risk factor for hypertension (adj. OR = 2.709, 95%CI: 1.049–6.995)
Banerjee et al. (2012)	1543 volunteer men and 675 volunteer women living in Delhi aged 21–65 years	Outdoor sulfur oxides (SO_x)	Portable indoor monitors	P-selectin expression in non-stimulated, circulating platelets	Hypertension assessed using JNC-7 (2003) criteria (Chobanian et al., 2003) criteria	Higher P-selectin-expressing circulating platelets ($p < 0.05$) in Delhi residents vs. controls (3682 ± 960 vs. 10,268 ± 1232/μL, respectively)
	472 volunteer men and 203 volunteer women living in rural Uttaranchal aged 21–65 years (controls)	Outdoor nitrogen oxides (NO_x)	8 h/day for 3 consecutive days/week for 3 alternative weeks each season	Peripheral blood lymphocytes	Blood samples	Higher CD16 + CD56+ natural killer cells ($p < 0.01$) in subset of Delhi residents vs. controls (243 ± 44 vs. 475 ± 65/μL, respectively)
		Indoor PM_{10} and $PM_{2.5}$				Higher CD19+ B-lymphocyte cells ($p < 0.001$) in subset of Delhi residents vs. controls (465 ± 45 vs. 329 ± 60/μL, respectively) Higher CD8+ T-cytotoxic/suppressor cells ($p < 0.001$) in subset of Delhi residents vs. controls (562 ± 51 vs. 719 ± 68/μL, respectively) Reduced CD4+ T-helper cells ($p < 0.001$) and in subset of Delhi residents vs. controls (939 ± 65 vs. 795 ± 63, respectively)

Air Pollution and Cardiovascular Diseases

Country, year of study and reference	Study type and characteristics	Air pollutant	Air pollutant measurements	Cardiovascular out-comes/biomarkers	Cardiovascular and other measurements	Main results
India	Time series	Outdoor total suspended particulates (TSP)	Fixed site monitors	CVD mortality	Mortality data from New Delhi Municipal Committee	100 µg increase in TSP results in a 4.3% increase in cardiovascular deaths ($p < 0.05$)
1991–1994	1461 residents of one of three regions of National Capital Territory of Delhi	Outdoor sulfur dioxide (SO_2)	Weekday monitoring			
Cropper et al. (1997)		Outdoor nitrogen oxides (NO_x)	Rotation of pollutant measurements between monitors every three days			
Pakistan	Cross-sectional study	Outdoor and indoor ultrafine particulate matter (PM_1)	Portable aerosol mass analyzer	Blood pressure	5 blood pressure measures per participant	Systolic ($p < 0.0001$) blood pressure significantly higher among children living in high pollution area
2009	93 school children aged 8–12 years in a high pollution area in Lahore	Outdoor and indoor $PM_{2.5}$	10 consecutive indoor sampling periods of 20 m each over 21 days		Hypertension assessed using JNC-7 (2003) criteria (Chobanian et al., 2003)	Diastolic ($p < 0.0038$) blood pressure significantly higher among children living in high pollution area
Sughis et al. (2012)	73 school children aged 8–12 years in a low pollution area in Lahore	Outdoor and indoor PM_{10}	24-h outdoor sampling over 21 days Exclusion of PM recorded on days >80% relative humidity			

Lancet. 2013 Sep 21; 382(9897): 1039–1048. PMCID: PMC3809511
doi: 10.1016/S0140-6736(13)60898-3 PMID: 23849322

Global association of air pollution and heart failure: a systematic review and meta-analysis

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Of 1146 identified articles, 195 were reviewed in-depth with 35 satisfying inclusion criteria. Heart failure hospitalisation or death was associated with increases in carbon monoxide (3·52% per 1 part per million; 95% CI 2·52–4·54), sulphur dioxide (2·36% per 10 parts per billion; 1·35–3·38), and nitrogen dioxide (1·70% per 10 parts per billion; 1·25–2·16), but not ozone (0·46% per 10 parts per billion; −0·10 to 1·02) concentrations. Increases in particulate matter concentration were associated with heart failure hospitalisation or death ($PM_{2 \cdot 5}$ 2·12% per 10 μg/m^3, 95% CI 1·42–2·82; PM_{10} 1·63% per 10 μg/m^3, 95% CI 1·20–2·07). Strongest associations were seen on the day of exposure, with more persistent effects for $PM_{2 \cdot 5}$. In the USA, we estimate that a mean reduction in $PM_{2 \cdot 5}$ of 3·9 μg/m^3 would prevent 7978 heart failure hospitalisations and save a third of a billion US dollars a year.

Interpretation

Go to:

Air pollution has a close temporal association with heart failure hospitalisation and heart failure mortality. Although more studies from developing nations are required, air pollution is a pervasive public health issue with major cardiovascular and health economic consequences, and it should remain a key target for global health policy.

Outdoor Air Pollution and Emergency Room Visits at a Hospital in Delhi

J.N. Pande, Narendra Bhatta, Dilip Biswas[1], Ravindra M. Pandey[2], Gautam Ahluwalia, Naveen H. Siddaramaiah and G.C. Khilnani

Departments of Medicine and Biostatistics[2], All India Institute of Medical Sciences, New Delhi and Central Pollution Control Board[1], New Delhi

Observational study on emergency room visits to All India Institute of Medical Sciences Hospital, New Delhi for acute exacerbation of chronic obstructive airways disease, acute severe asthma, and acute coronary event in relation to the levels of ambient air pollution during the period Jan 1 1997 to Dee 31st 1998

Measurement of pollutant levels were made by the Central Pollution Control Board (CPCB)

Table 1. *Mean level of air pollutants (mean of daily averages for the whole year) and the events of interest for the year 1997 and 1998. Mean values of temperature and humidity are also given.*

Parameter	1997	1998	**P** value*
Temp (c)	24.5k5.7	23.3k5.8	0.0040
Humidity (%)	62.2±10	60.7±13	0.0125
TSP*	409±128	426±174	NS
CO#	4810 ±2375	5450±2927	0.0044
NO_x#	67 ±28	63±22	NS
SO_2#	21±13	25±10	0.0000
Events	18±11	26±22	0.0000

*Wilcoxon's rank-sum test; # microgram/cubic meter; CO = Carbon monoxide; SO, = Sulphur dioxide; NO_x = Oxides of nitrogen; TSP = Total suspended particles.

Year	Total No. of patients attending casualty	Total cardio-respiratory events	COAD	Asthma	ACE
1997	50336	6478	1240	2138	3100
1998	52268	9334	1944	3151	4239

Table 2. *Coefficient of correlation as derived by Spearman's rho between events and various parameters.*

	TSP	CO	NO_x	SO_2	Temp	Humidity
Events	0.1809	0.1526	0.1800	0.2265	-0.043"	0.1767
Humidity	-0.0689*	0.1289	0.1861	0.0423*	-0.1177	
Temp	-0.3008	-0.2580	-0.1462	-0.2535		
SO_2	0.4074	0.4170	0.7333			
NO_x	0.3828	0.4539				
CO	0.3527					

- Significant direct correlation was observed amongst all the pollutants. It was strongest between SO2 and NO2.
- They were all negatively correlated with temperature but bore no correlation with humidity.
- Cardiorespiratory events were positively correlated with the levels of all the four pollutants measured(TSP,CO,NO2,SO2) and relative humidity, and negatively correlated with temperature.

Table 4. *Observed and expected daily (mean ± SD) events 1997-98.*

Disease	Observed	Expected*	Extra	%Increase
Asthma	7.23 ± 7.82	5.96 ± 4.55	1.27 ± 4.93	21.30
COAD	4.37 ± 4.97	3.50 ± 2.48	0.87 ± 3.34	24.90
ACE	10.09 ± 7.09	8.11 ± 3.07	1.97 ± 5.70	24.30
Total	21.65 ± 17.65	17.44 ± 9.54	4.20 ± 11.38	24.10

*Calculated by assigning permissible upper level of CO and TSP in the regression model.

- The odds of extra-events calculated from multivariable Poisson regression model.
- Almost one fourth of these events could be attributed to the ambient levels of pollutants exceeding the upper limits recommended for Delhi by the CPCB.
- The risk was the greatest for acute exacerbation of chronic obstructive lung disease, acute coronary events and followed by asthma.

Cardiopulmonary Effects of Air Pollution

- Outdoor air pollution is important cause of cardiovascular morbidity and mortality.
- Diseases like hypertension, ishemic heart disease to emergencies like acute coronary syndrome and stroke.
- Various pulmonary disorders ranging from exacerbation of pre-existing diseases to increased incidence of lung cancer, leading to increased hospital visits and mortality.

Air Quality Standards

WHO Guideline values for levels of pollutants

Air pollutants	Maximum exposure levels
Particulate matters PM2.5 PM10	 10 µg/m^3 annual mean 25 µg/m^3 24-hour mean 20 µg/m^3 annual mean 50 µg/m^3 24-hour mean
Ozone (O_3)	100 µg/m^3 8-hour mean
Nitrogen dioxide (NO_2)	40 µg/m^3 annual mean 200 µg/m^3 1-hour mean
Sulfur dioxide (SO_2)	20 µg/m^3 24-hour mean 500 µg/m^3 10-minute mean

WHO Air Quality Guidelines, Global Update 2005; updated in 2014

Revised National Ambient Air Quality Standards 2009

Maximum exposure limits of individual pollutants (Indian set-up) : based on Revised National Ambient Air Quality Standards 2009

Sl. No	Pollutant	Time Weighted Average	New Standards (Schedule VII, Rule 3 (3B) 16th Nov 2009 — Concentration in ambient air: Industrial Area Residential, Rural & other Areas	Ecologically sensitive area (Notified by Central Govt)	Methods of measurement
1	Sulphur Dioxide(SO2)	Annual Avg*	50.0 µg/m3	20.0 µg/m3	-Improved West and Gaeke method
		24 hours**	80.0 µg/m3	80.0 µg/m3	-Ultraviolet fluorescence
2	Oxides of Nitrogen as NO2	Annual Avg*	40.0 µg/m3	30.0 µg/m3	-Modified Jocob and Hochheise (Sodium Arsenite)
		24 hours**	80.0 µg/m3	80.0 µg/m3	-Chemiluminescence
3	Particulate matter (size less than 10µm)	Annual Avg*	60.0 µg/m3	60.0 µg/m3	-Gravimetric -TOEM -Beta attenuation
		24 hours**	100.0 µg/m3	100.0 µg/m3	
4	Particulate matter (size less than 2.5 µm	Annual Avg*	40.0 µg/m3	40.0 µg/m3	-Gravimetric -TOEM -Beta attenuation
		24 hours**	60.0 µg/m3	60.0 µg/m3	
5	Lead (Pb)	Annual Avg*	0.50 µg/m3	0.50 µg/m3	-AAS/ICP method for sampling on EPM2000 or Equivalent Filter paper -ED-XRF using Teflon filter paper
		24 hours**	1.0 µg/m3	1.0 µg/m3	

Revised National Ambient Air Quality Standards 2009

6	Carbon Monoxide (CO)	8 hours** 1 hour	2.0 mg/m3 4.0 mg/m3	2.0 mg/m3 4.0 mg/m3	-Non Dispersive Infra Red (NDIR) spectroscopy
7	Ozone	8 hours**	100.0 µg/m3	100.0 µg/m3	-Photometric -Chemiluminescence -Chemical method
		1 hour	180.0 µg/m3	180.0 µg/m3	
		24 hours**	60.0 µg/m3	60.0 µg/m3	
8	Ammonia (NH3)	Annual Avg*	100.0 µg/m3	100.0 µg/m3	-Chemiluminescence -Indo-Phenol Blue method
		24 hours**	400.0µg/m3	400.0 µg/m3	
9	Benzene	Annual Avg*	5.0 µg/m3	5.0 µg/m3	-GC based continuous analyzer -Adsorption/desorption followed by GC analysis
10	Benzo(a) pyrene	Annual Avg*	1.0 ng/m3	1.0 ng/m3	-Solvent extraction followed by GC/HPLC extraction
11	Arsenic	Annual Avg*	6.0 ng/m3	6.0 ng/m3	AAS/ICP method for sampling on EPM2000 OR Equivalent Filter paper
12	Nickel		20.0 ng/m3	20.0 ng/m3	-AAS/ICP method for sampling on EPM2000 OR Equivalent Filter paper

Air Quality Index

- Transforms the values of individual air pollution related parameters into a single number or set of numbers
- Includes CO, NO_2 , SO_2 , $PM_{2.5}$, PM_{10}, O_3 , NH_3 and Pb

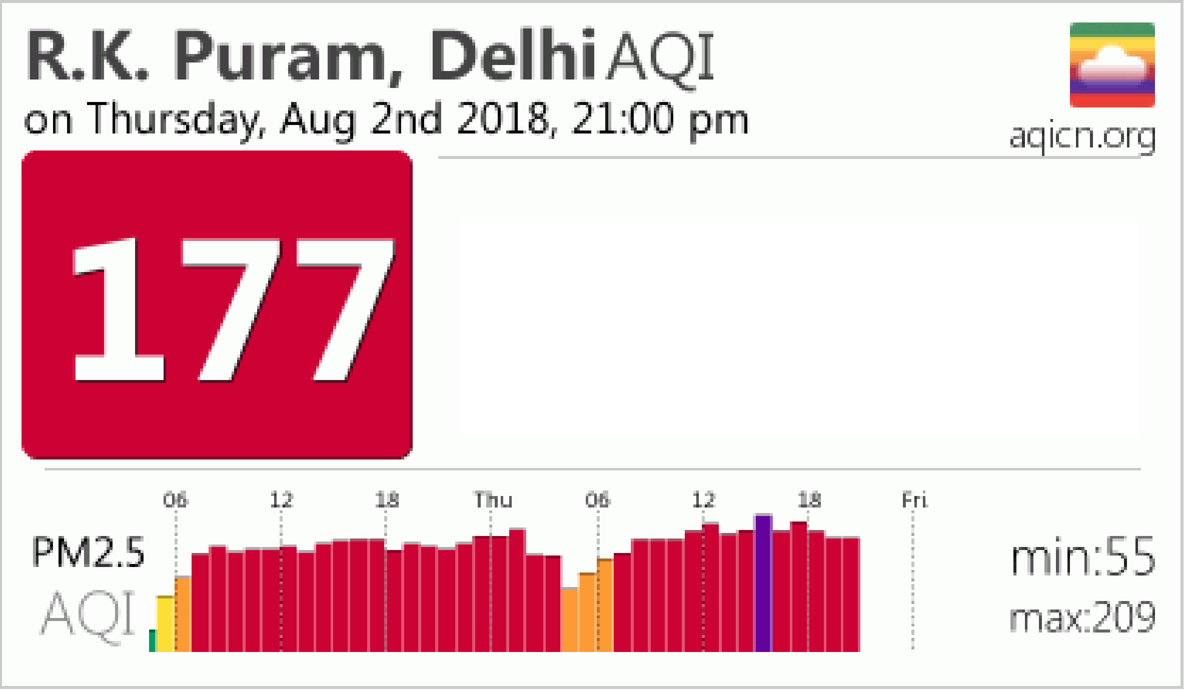
Good (0-50)	Satisfactory (51-100)	Moderately polluted (101-200)	Poor (201-300)	Very poor (301-400)	Severe (> 401)

CO – Carbon Monoxide; NO_2 Nitrogen Dioxide; SO_2 Sulphur Dioxide; $PM_{2.5}$, PM_{10} – Particulate matter; O_3 – Ozone; NH_3 – Ammonia; Pb - Lead

Air Quality Index

AQI	Associated Health Impacts
Good(0–50))	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people
Moderately polluted (101–200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401-500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Air Quality Index



- Current AQI of Chandigarh is 52(Satisfactory)

Air Pollution – Prevention and Control

- Government level:
  - Formation of pollution control commitees and Laws
  - Ban on outdated vehicles
  - Promotion of clean fuels
  - Smoking awareness programmes
  - Reforestration
  - Alternate sources of energy e.g. Solar energy
- Subject level:
  - Carpooling
  - Use of public transport
  - Avoid usage of biomass
  - Use of air filters, face masks and restriction of outdoor activities during hazy days
  - Early medical help in vulnerable groups
  - Supplemental foods

Indian laws on air pollution

- Agencies responsible for air quality standard creation and monitoring:
  - Central Pollution Control Board(CPCB) and several State Pollution Control Boards (SPCBs)
- The CPCB, working in collaboration with the SPCBs, provides technical advice to Ministry of Environment and Forest (MoEF) in order to fulfill the objectives outlined in the Air Act of 1981

Indian laws on air pollution

- Air Act of 1981

The Air Act mandates the CPCB and SPCBs to :

- Establish national ambient air quality standards for criteria pollutants,
- Assist government in planning future environmental prevention and control strategies,
- Carry out research to better understand environmental issues,
- Undertake nationwide air sampling to ascertain the ambient air quality in India and identification of the problem areas,
- Conduct air quality inspections in areas of concern.

Air Pollution – Prevention and Control

- **National Green Tribunal**
  - Enacted in 2010
  - Special tribunal for expeditious disposal of cases pertaining to environmental issues
  - Notable orders
    - Ban on decade old diesel vehicles in Delhi
    - Implementation of BS-IV norms
    - Yamuna conservation zone
    - Restricted the number of vehicles at Rohtang pass (Manali) to 1000 per day

Alternative Sources of Energy

- Solar energy is the ideal source of energy
  - No carbon dioxide emission
  - No need of any dramatic landform changes that could predispose to ecological imbalance

- Other: wind, water, gobar gas

Air Pollution – Prevention and Control

- Use of LPG instead of biomass burning
- Improving ventilation of homes – chimneys / window above cooking stove

Dublin study

ARTICLES

Effect of air-pollution control on death rates in Dublin, Ireland: an intervention study

Luke Clancy, Pat Goodman, Hamish Sinclair, Douglas W Dockery

Background: Particulate air pollution episodes have been associated with increased daily death.
However, there is little direct evidence that diminished particulate air pollution concentrations would lead to reductions in death rates.
Study assessed the effect of air pollution controls—ie, the ban on coal sales—on particulate air pollution and death rates in Dublin

Lancet 2002; 360: 1210–14

Dublin study

- Average black smoke concentrations in Dublin declined by 35·6 g/m3 (70%) after the ban on coal sales
- Adjusted non-trauma death rates decreased by 5·7% (95% CI 4–7, p<0·0001), respiratory deaths by 15·5 (12–19, p<0·0001), and cardiovascular deaths by 10·3% (8–13, p<0·0001)

Lancet 2002; 360: 1210–14

Dublin study

- Respiratory and cardiovascular standardised death rates fell coincident with the ban on coal sales
- 116 fewer respiratory deaths and 243 fewer cardiovascular deaths per year
- Thus, control of particulate air pollution could substantially diminish daily death

Lancet 2002; 360: 1210–14

Measures At Subject Level

Air Filter

- Environmental protection agencies advise members of the public to remain indoors on high air pollution days.
- Infiltration rates vary widely due to differences in building structures, ambient environmental conditions and outdoor-to-indoor air transport.
- Closed windows, with use of air conditioning can reduce air exchange rates by about 50%.

Laumbach R; What can individuals do to reduce personal health risks from air pollution?*J Thorac Dis 2015;7(1):96-107*

Air Filter

- However, staying indoors may potentially increase personal exposures and health risks from indoor air pollutants.
- Air filters reduce concentrations of indoor air pollutants, of either outdoor or indoor origin.
- **Central or portable**
- Efficacy: Reduction in **Indoor/outdoor (I/O)ratio** of pollutants

Laumbach R; What can individuals do to reduce personal health risks from air pollution?*J Thorac Dis 2015;7(1):96-107*

Air Filter

Air Filter	Efficacy
1-inch pleated media filters	32.5%
5-inch pleated media filters	75-80%
Electrostatic air cleaner	94%
HEPA(high efficiency particle air) filter	98%
Portable cleaner with HEPA filter	65%

Laumbach R; What can individuals do to reduce personal health risks from air pollution?*J Thorac Dis 2015;7(1):96-107*
Macintosh DL et al. The benefits of whole-house in-duct air cleaning in reducing exposures to fine particulate matter of outdoor origin: a modeling analysis. J Expo Sci Environ Epidemiol 2010;20:213-24.

Face masks/Respirators

- The ability of a respirator to remove contaminants from inhaled air depends on the contaminant, type of filter or adsorbent material, respirator type, conditions of use and quality of face seal.
- Ideal face mask- ‘**Protection factor’** of 10
  - i.e. reduce the concentration of the air contaminant inside the facepiece to ≤10% of the concentration outside the facepiece.

Face masks/Respirators

- Few commercial face masks (e.g. N95 masks) can effectively filter outdoor PM.
- Limited evidence suggests that the use of negative pressure air-purifying respirators under experimental conditions may reduce cardiovascular risks from exposure to urban PM.

Face masks/Respirators

Reducing Personal Exposure to Particulate Air Pollution Improves Cardiovascular Health in Patients with Coronary Heart Disease

Jeremy P. Langrish,[1,] Xi Li,[2,*] Shengfeng Wang,[2] Matthew M.Y. Lee,[1] Gareth D. Barnes,[1] Mark R. Miller,[1] Flemming R. Cassee,[3] Nicholas A. Boon,[1] Ken Donaldson,[1] Jing Li,[4] Liming Li,[2] Nicholas L. Mills,[1] David E. Newby,[1] and Lixin Jiang[4]*

Background: Air pollution exposure increases cardiovascular morbidity and mortality and is a major global public health concern.

Objectives: We investigated the benefits of reducing personal exposure to urban air pollution in patients with coronary heart disease.

Environ Health Perspect 2012;120:367-72.

Face masks/Respirators

Methods: Open randomized crossover trial.

- 98 patients with coronary heart disease
- Walk on a predefined route in central Beijing, China for 2 hours.
- Once while using a highly efficient face mask(Dust Respirator 8812; 3M, St. Paul, MN, USA) , and once without mask, at least 1 week apart.
- Symptoms, exercise, personal air pollution exposure, blood pressure, heart rate, and 12-lead electrocardiography were monitored.

Environ Health Perspect 2012;120:367-72.

Face masks/Respirators

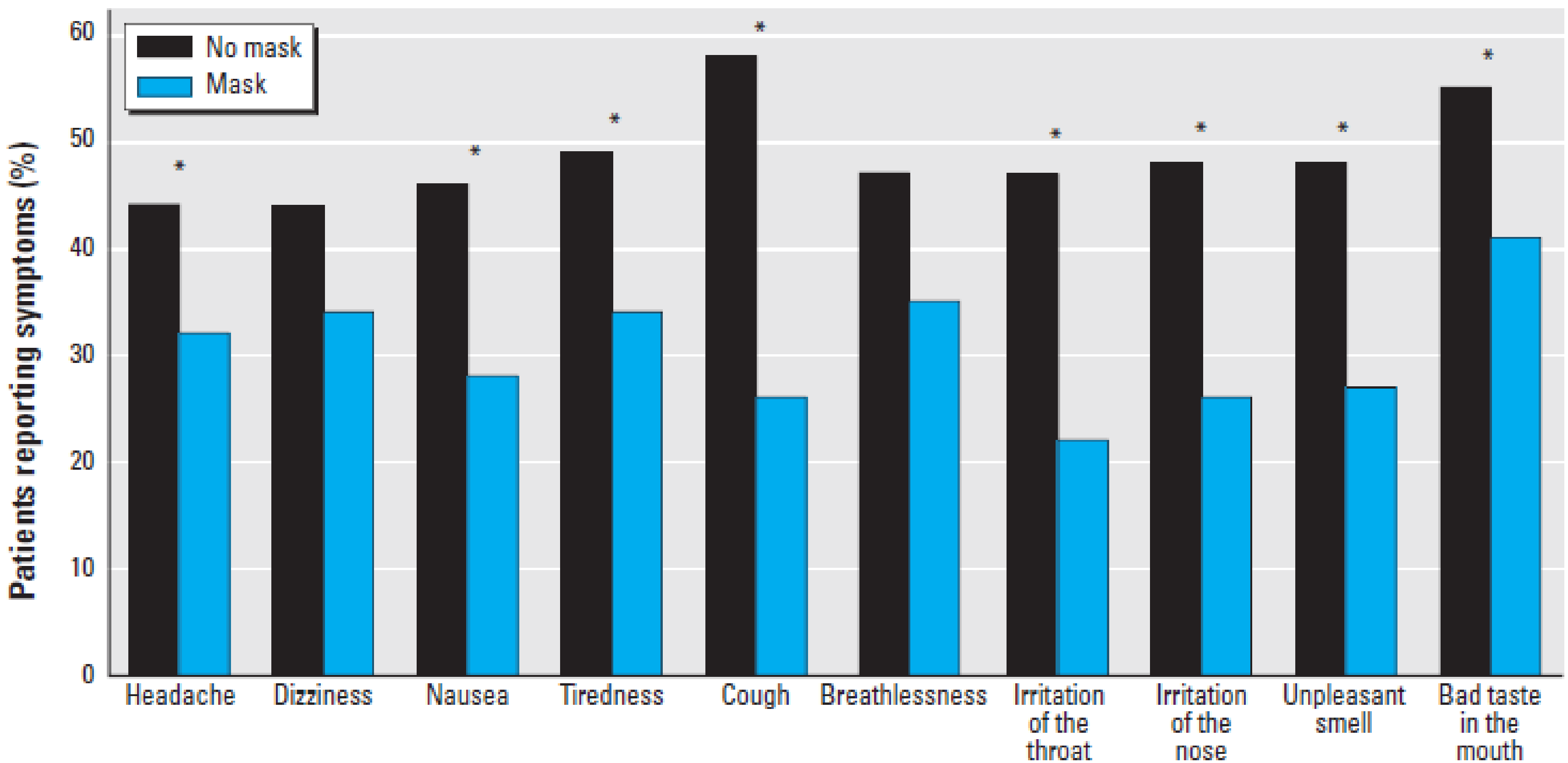


Figure 1. Self-reported symptoms of well-being in the presence or absence of the face mask.
*$p < 0.05$.

Environ Health Perspect 2012;120:367-72.

Face masks/Respirators

Table 2. Personal ambient pollution exposures and background pollution levels on days defined according to mask use.

Parameter	Mask	No mask
Personal $PM_{2.5}$ exposure (μg/m^3)		
Measured	61 (20–88)	89 (25–170)
Estimated	~ 2 (0.6–2.6)	89 (25–170)
Personal particle count (× 10^4 particles/cm^3)		
Measured	4.19 ± 1.29	4.39 ± 1.45
Estimated	~ 0.12 ± 0.04	4.39 ± 1.45
Personal temperature (°C)	17.3 ± 5.2	16.8 ± 5.8
Personal relative humidity (%)	30.4 ± 14.0	34.8 ± 18.2
Personal peaks > 1 ppm (number)		
NO_2	None	None
SO_2	None	None
CO	5 (2–7.5)	4 (2–8)
Background exposure		
PM_{10} (μg/m^3)	92 (70–117)	103 (83–180)
SO_2 (ppb)	38 (29–53)	54 (32–77)
NO_2 (ppb)	36 (29–42)	36 (32–47)

Abbreviations: CO, carbon monoxide; NO_2, nitrogen dioxide; SO_2, sulfur dioxide. Data are mean ± SD or median (interquartile range). Personal monitoring data were collected using portable monitoring equipment during the 2-hr walk. Background data were collected from permanent monitoring stations for the whole 24-hr period. Estimated PM exposure is calculated based on filter efficacy studies where 97% of fresh diesel exhaust PM were removed (Langrish et al. 2009).

Environ Health Perspect 2012;120:367-72.

Face masks/Respirators

Table 3. Ambulatory blood pressure, heart rate variability during the 2-hr city center walk and the 24-hr study period, and myocardial ischemia measured as ischemic burden, in each individual territory and as a composite according to face mask use.

	Walk		24 hr	
Parameter	Mask	No mask	Mask	No mask
Systolic blood pressure (mmHg)	126.9 ± 15.9	128.1 ± 16.5	121.2 ± 11.9	120.8 ± 12.4
Diastolic blood pressure (mmHg)	78.0 ± 9.3	79.5 ± 8.6	73.8 ± 7.2	74.0 ± 7.3
Mean arterial pressure (mmHg)	93.3 ± 9.7*	95.7 ± 10.0	89.8 ± 7.5	90.0 ± 7.9
Heart rate (bpm)	81.5 ± 8.7	81.5 ± 10.1	77.6 ± 11.3	76.7 ± 11.1
LF power (msec^2)	133 (68–97)	136 (52–227)	81 (40–172)	93 (46–208)
HF power (msec^2)	54 (27–108)*	40 (20–69)	27 (11–77)	31 (11–68)
LFn (msec)	58.4 (45.6–69.1)*	62.9 (51.1–75.5)	67.2 (55.5–78.0)	71.1 (59.4–81.1)
HFn (msec)	23.5 (18.0–32.4)*	20.5 (13.5–27.9)	21.4 (15.0–31.6)	20.9 (12.7–30.1)
HF:LF ratio	0.418 (0.258–0.712)	0.328 (0.207–0.573)	0.301 (0.190–0.554)	0.306 (0.161–0.492)
pNN50 (%)	1.2 (0.2–2.8)	0.7 (0.0–2.3)	0.5 (0.0–3.1)	0.6 (0.0–2.6)
RMSSD (msec)	16.7 (13.2–22.5)*	14.8 (10.9–19.6)	15.5 (11.0–22.6)	14.4 (10.3–20.3)
SDNN (msec)	59.8 (46.4–79.1)	60.1 (41.0–79.3)	45.6 (30.8–70.4)	48.2 (30.0–66.3)
Ischemic burden (mV-sec)				
Inferior (II) territory	–66 (–118 to –26)	–52 (–149 to –21)	–641 (–767 to –504)	–615 (–820 to –473)
Anterior (V2) territory	–66 (–142 to –16)	–50 (–124 to –13)	–597 (–859 to –435)	–632 (–905 to –489)
Lateral (V5) territory	–37 (–104 to –8)	–43 (–85 to –18)	–604 (–811 to –429)	–586 (–790 to –412)
Sum (II + V2 + V5)	–189 (–382 to –90)	–188 (–340 to –112)	–1,930 (–2,306 to –1,541)	–1,934 (–2,391 to –1,575)

Abbreviations: LFn, low frequency–normalized; pNN50, percentage of successive RR intervals that differ by > 50 msec; SDNN, standard deviation of RR intervals. Data are mean ± SD, or median (interquartile range). LFn and HFn are normalized units to account for variation in the total power and very low-frequency components. LF and SDNN reflect mainly sympathetic nervous stimulation; HF, pNN50, and RMSSD reflect parasympathetic tone.

*$p < 0.05$ from Wilcoxon matched pairs signed rank test or Student's paired *t*-tests as appropriate, mask versus no mask.

Environ Health Perspect 2012;120:367-72.

Face masks/Respirators

Results: Ambient air $PM^{2.5}$ was at high levels [74 μg/m3.

- The face mask was well tolerated, and its use was associated with decreased self-reported symptoms and reduced maximal ST segment depression (–142 vs. –156 μV, $p = 0.046$) over the 24-hr period.
- When the face mask was used during the prescribed walk, mean arterial pressure was lower (93 ± 10 vs. 96 ± 10 mmHg, $p = 0.025$) and heart rate variability increased (high-frequency power: 54 vs. 40 msec2, $p = 0.005$; high-frequency normalized power: 23.5 vs. 20.5 msec, $p = 0.001$; root mean square successive differences: 16.7 vs. 14.8 msec, $p = 0.007$).

Environ Health Perspect 2012;120:367-72.

Face masks/Respirators

- **Conclusions:** Reducing personal exposure to air pollution using a highly efficient face mask appeared to reduce symptoms and improve a range of cardiovascular health measures in patients with coronary heart disease.

Environ Health Perspect 2012;120:367-72.

Face masks/Respirators- Drawbacks

- Efficacy with gaseous pollutants controversial
- Prolonged wearing (>2 h) can readily lead to breathlessness in healthy individuals.
- Other adverse effects: higher face temperature at rest and exercise, feeling of anxiety and claustrophobia, incomplete fit with dense facial hair as well as social issues with communication

Dietary recommendations

- Some studies have shown role of Vitamin C, E and N-Acetyl Cysteine in reducing nasal inflammation and airway hyper-responsiveness.
- A chinese study has proposed possible role of broccoli via generation of chemopreventive agent, sulforaphane, an inducer of glutathione *S-transferases (GSTs).*
- However, no studies available to suggest definite clinical benefit of these agents in mitigating pollution related health disorders.

Take home message

- Air Pollution is a major health problem
- There are natural as well as manmade sources of pollution
- Myriad effects from infections, noncommunicable diseases including acute coronary syndrome and cancer leading to shortening of life span
- Potential health benefits with pollution control strategies at community as well as individual level
- Need to fight together to control this menace