ETHANOL AND AIR POLLUTANTS

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PhD

SUSTAINABLE MOBILITY: ETHANOL TALKS

INDIA

ETHANOL AND AIR POLLUTANTS

- Health & Environment (WHO, TWB, IHME - GBD)
- Evidences
- Overview and MASP experience
- Main results
- Conclusions

HEALTH & ENVIRONMENT

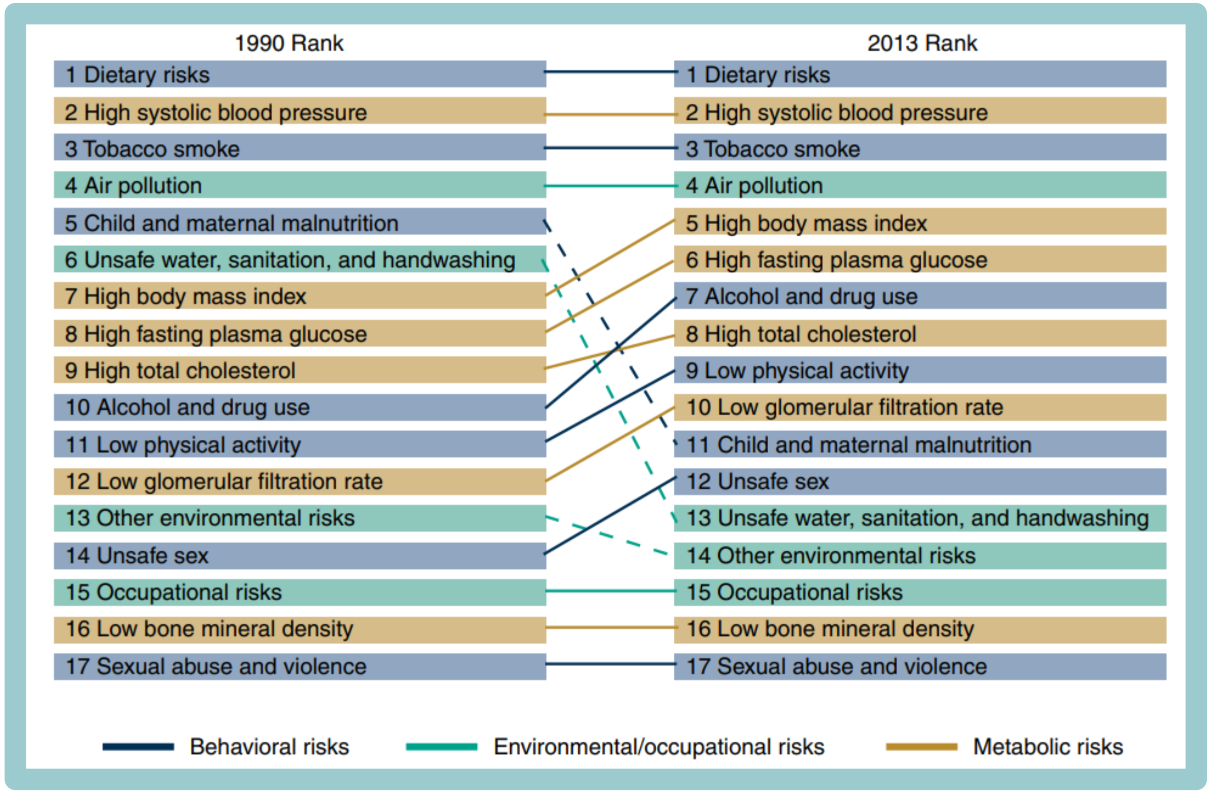
Leading Modifiable Risks by Number of Deaths: **Globally, 1990 and 2013**

Estimated deaths – 2016

Ambient $PM_{2.5}$

- **7 millions (11,6%) premature deaths (600,000 children)**
- **3 x (AIDS+Tuberculosis+Malaria)**

(WHO, 2018)



Source: IHME – GBD 2013 (World Bank, 2016)

HEALTH & ENVIRONMENT

Health-related air pollution economic impact (Blumberg, 15,jan.2020)

Air Pollution from fossil fuel burn (fine particulate matter) economic impact

- US $8 billion / day (worldwide)
- US $150 billion / year (India)

HEALTH & ENVIRONMENT

Health-related air pollutants, according World Health Organization (WHO)

PM_{10} – respirable particulate matter

- complex mixture of solid and liquid particle suspended in the air, with different physical and chemical characteristics
- Particles less than 10 µm
- Annual mean limit = 20 µg/m^3

$PM_{2.5}$ – fine particulate matter

- Particles less than 2.5 µm
- Annual mean limit = 10 µg/m^3

UF – Ultra fine particles

- Particles less than 100 nm

NP – Nano particles

- Particles less than 50 nm

HEALTH & ENVIRONMENT

Health-related air pollutants, according World Health Organization (WHO)

O_3 – Ozone: a secondary pollutant

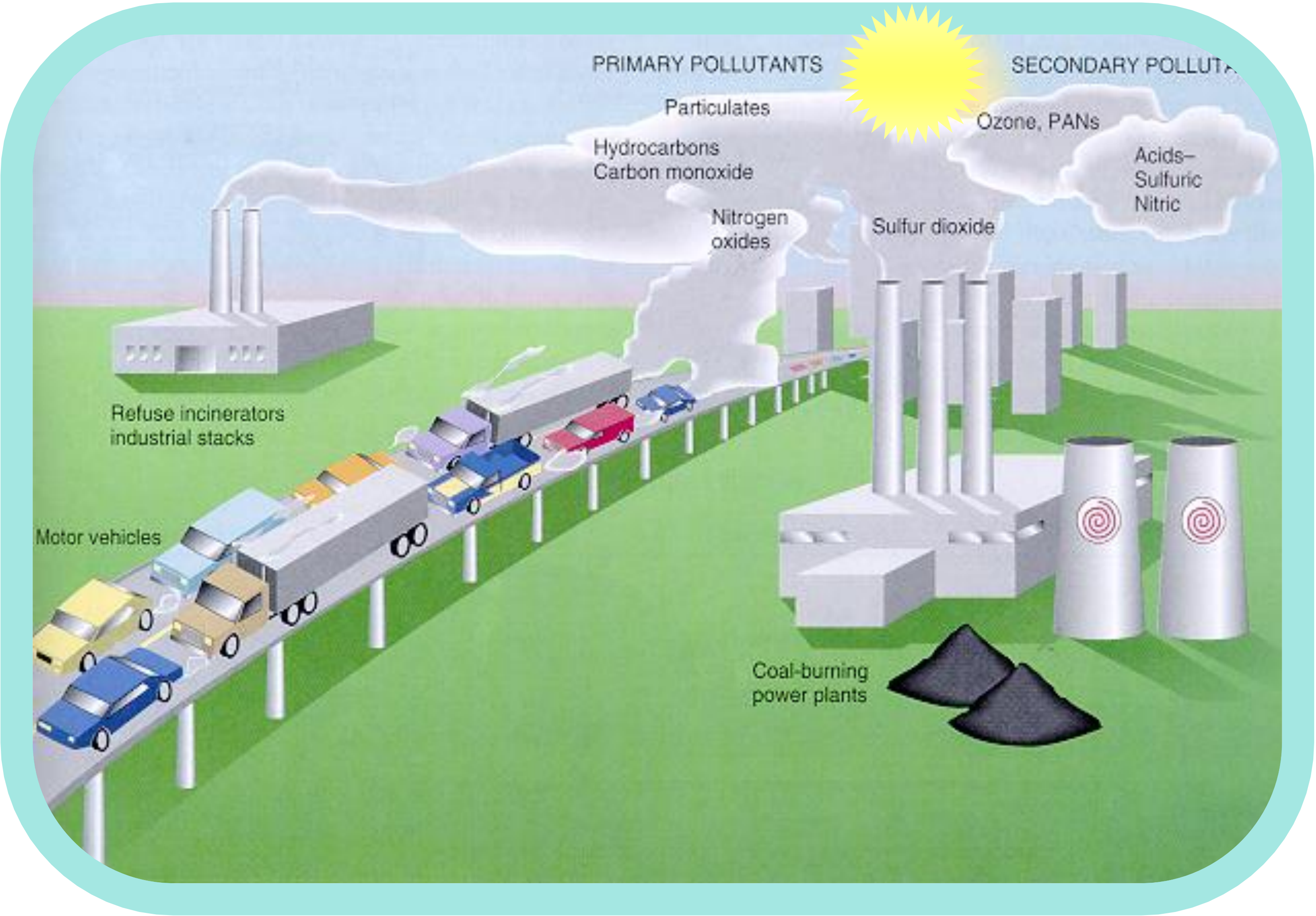
- photochemically produced
- Precursors: NO_2, NMVOC, methane
- Strongly dependent on meteorological availability of data + dispersion + photochemical modelling
- Daily 8h mean limit = 100 µg/m^3

SO_2 - Sulfur dioxide

- Main sources: burning of fossil fuel
- Annual mean limit = 20 µg/m^3

NO_2 - Nitrogen dioxide

- Main sources: burning of fossil fuel
- Annual mean limit = 40 µg/m^3



SOURCE

EMISSION

CONCENTRATION

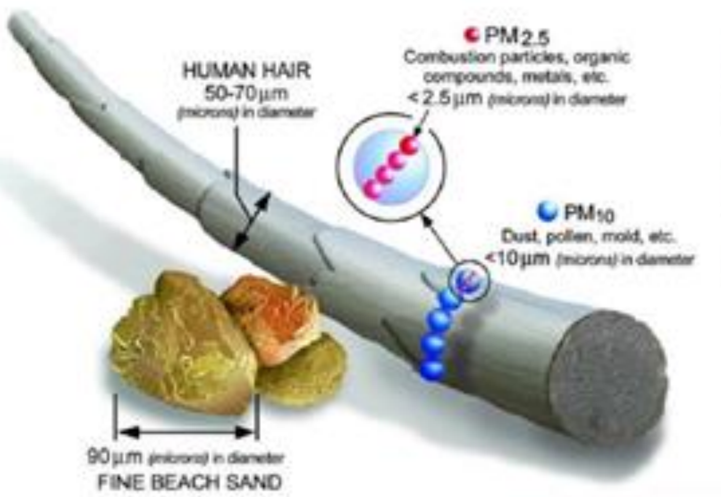
EXPOSURE

DOSE

HEALTH EFFECT

HEALTH & ENVIRONMENT

Particulate Matter (PM) by size



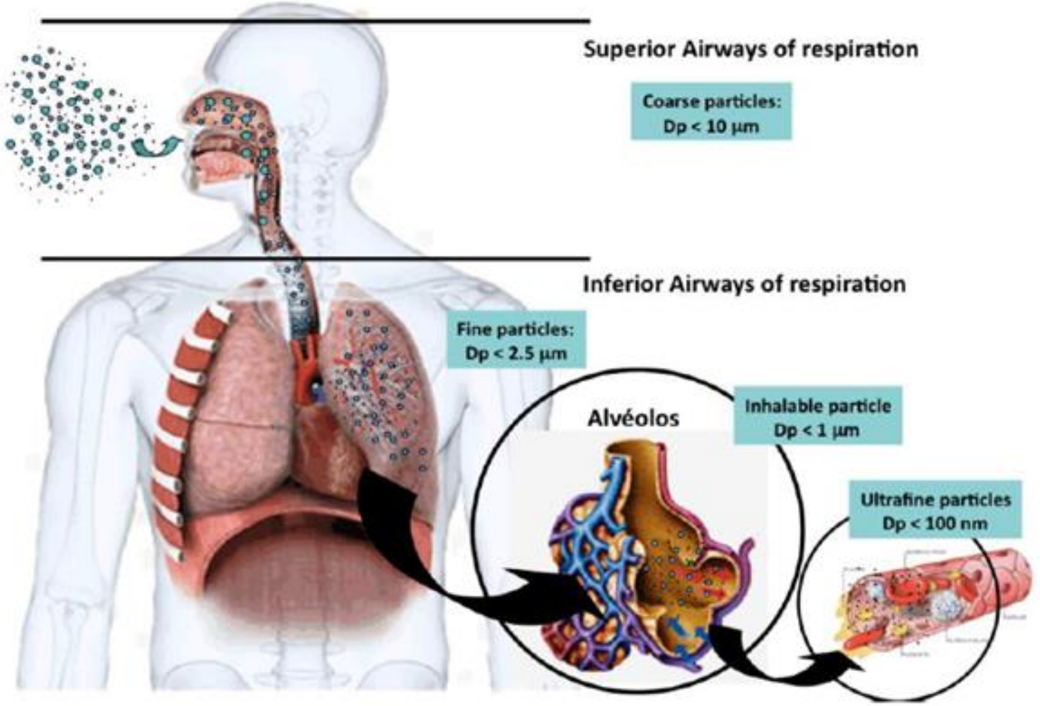
Credit: US EPA

Not all particles are created equal. Toxicity varies with:

- Particle number, size, surface area
- Chemical composition
- Pollution mixture (O_3, metals, organics, endotoxins)
- Mechanism of action (oxidative stress, inflammation, lung function)

HEALTH & ENVIRONMENT

Particulate Matter (PM) in human body



Credit: Guariero et al. (2013), InTech, doi:10.5772/52513

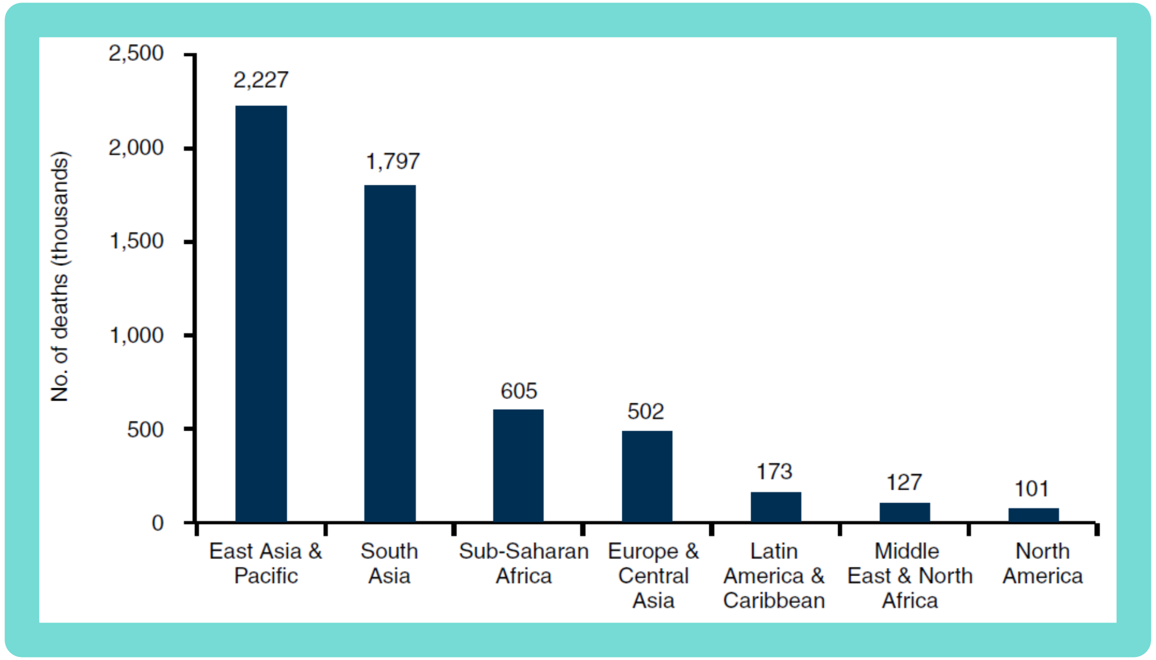
HEALTH & ENVIRONMENT

Total Deaths from Ambient $PM_{2.5}$ Pollution by Region

Main factors – upward trend

- PM2.5 increases in large populations
- Population growth
- Population aging
- Changes in the prevalence of diseases afected by air pollution

(TWB, 2016)



Sources: World Bank and IHME, using data from IHME, GBD 2013 (World Bank, 2016)

HEALTH & ENVIRONMENT

Urban regions - outdoor
(+ severe in fasten-growing cities)

Main sources of $PM_{2.5}$

- More people and vehicles
- More constructions
- Energy from dirty fuels
- Improper management of wastes

Most affected countries

- South Asia
- East Asia & Pacific

(TWB, 2016)

Cooking & heating - indoor
(Urban and rural areas)

Burn solid fuels

- **Wood, charcoal, coal, dung**

Most affected countries

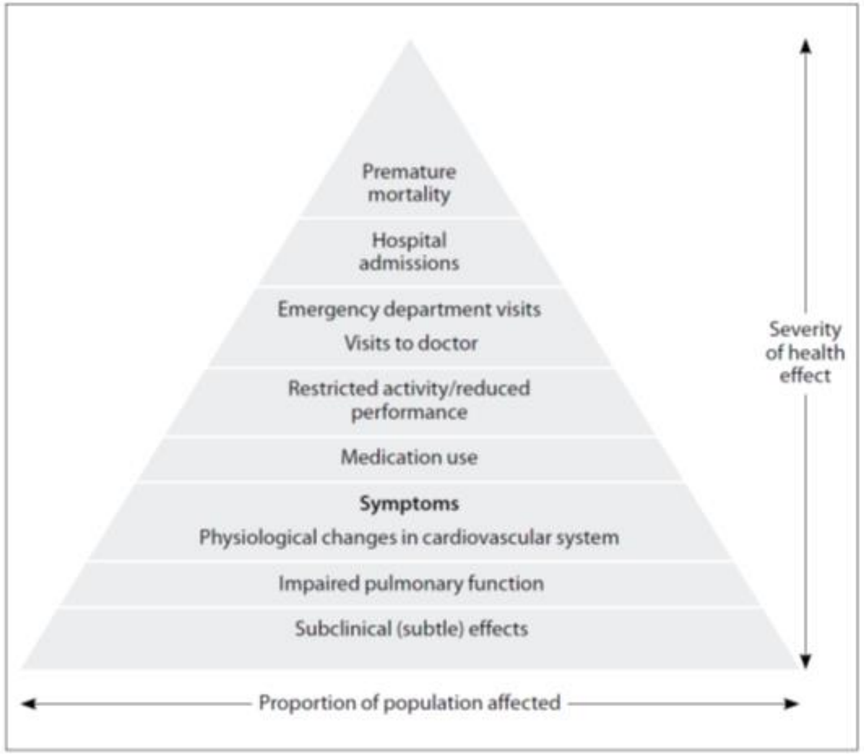
- Poor people
- Poor rural areas with lack of modern forms of energy

(TWB, 2016)

HEALTH & ENVIRONMENT

Health Effect severity x Proportion of population affected

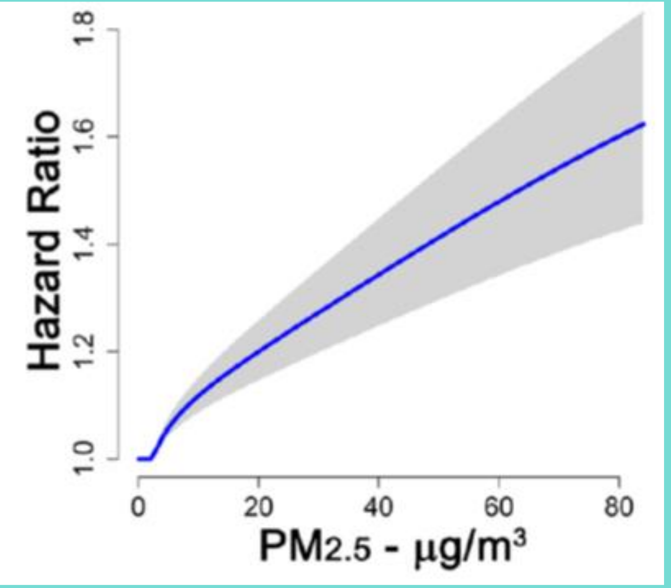
- Most severe effect => less frequent
- Less severe effect => more frequent
- The severity of each health effect depends on the dose of pollutant exposure, and it´s associated hazard ratio



Source: American Thoracic Society (in WHO, 2006)

HEALTH & ENVIRONMENT

Hazard ratio – nonaccidental premature death for $PM_{2.5}$



WHO Air Pollution Guidelines targets (global update 2005):

- **Annual mean:** 10 µg/m^3
- **24-h mean: 25** µg/m^3
- **A** 10 µg/m^3 **reduction in $PM_{2.5}$ reduces total mortality risk by 6%**

Source: Burnett et al, 2018

HEALTH & ENVIRONMENT

Hazard ratio – nonaccidental premature death for Ozone

Increases in daily mortality, per 10 µg/m³ (8 hours average) of Ozone variation:

- **0.3-0.5% by WHO (2005)**
- **0,256% by** Saldiva and others (2010)
- **0,18% by Vicedo-Cabrera and others (2020)**

Remarks:

- **Refers to short term ozone-mortality**
- **Highly reactive and meteorological-dependant**
- **Heterogeneous behavior across the day, locations and seasons**

IMPACT EVIDENCES

Toxicological studies with animal exposition

In exposition chambers with diluted gasoline and ethanol emissions

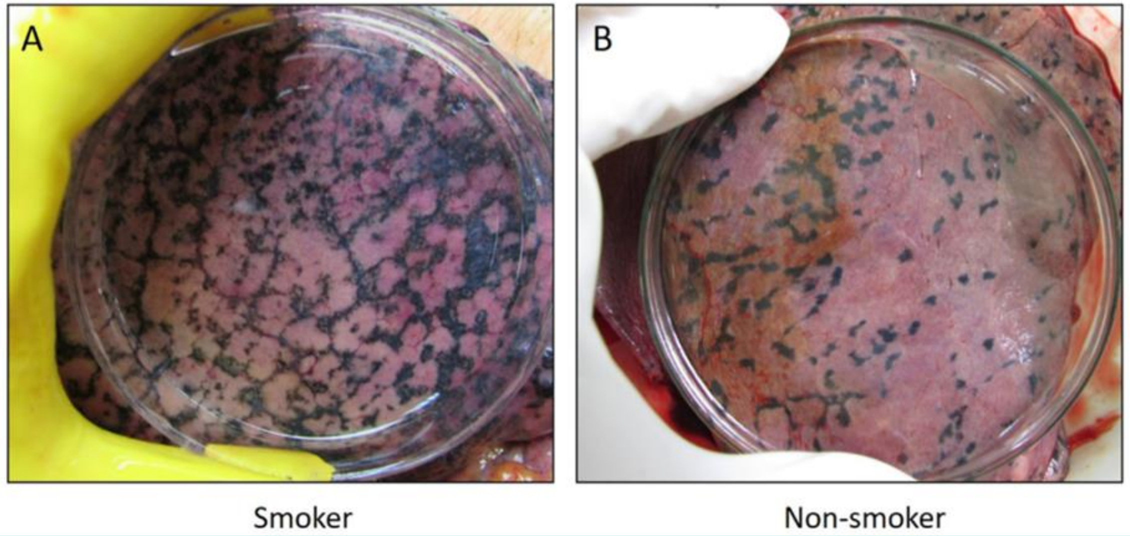
- Accute impact: lower for ethanol engine emissions
- Chronic impact: lower for ethanol engine emissions

In Open Top Chambers and Harvard concentrator of atmospheric particles (CAP) comparing real world emissions x filtered air

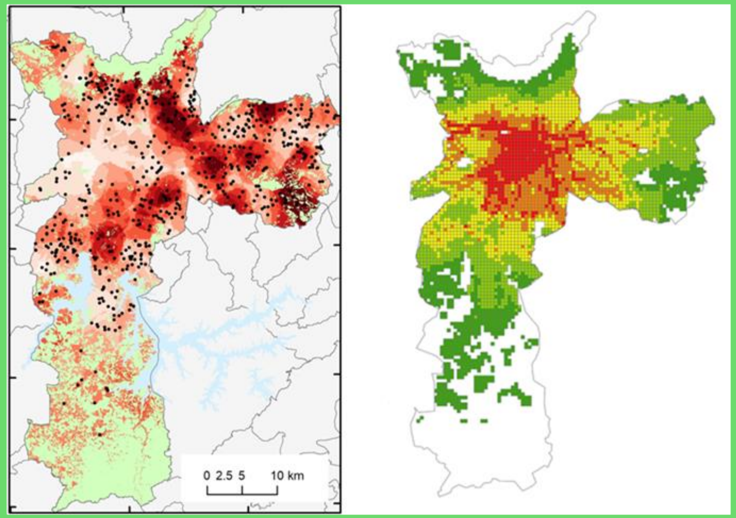
- Respiratory and cardiovascular impact
- Reproductive impact

IMPACT EVIDENCES

Autopsy-based studies (Antracosys)

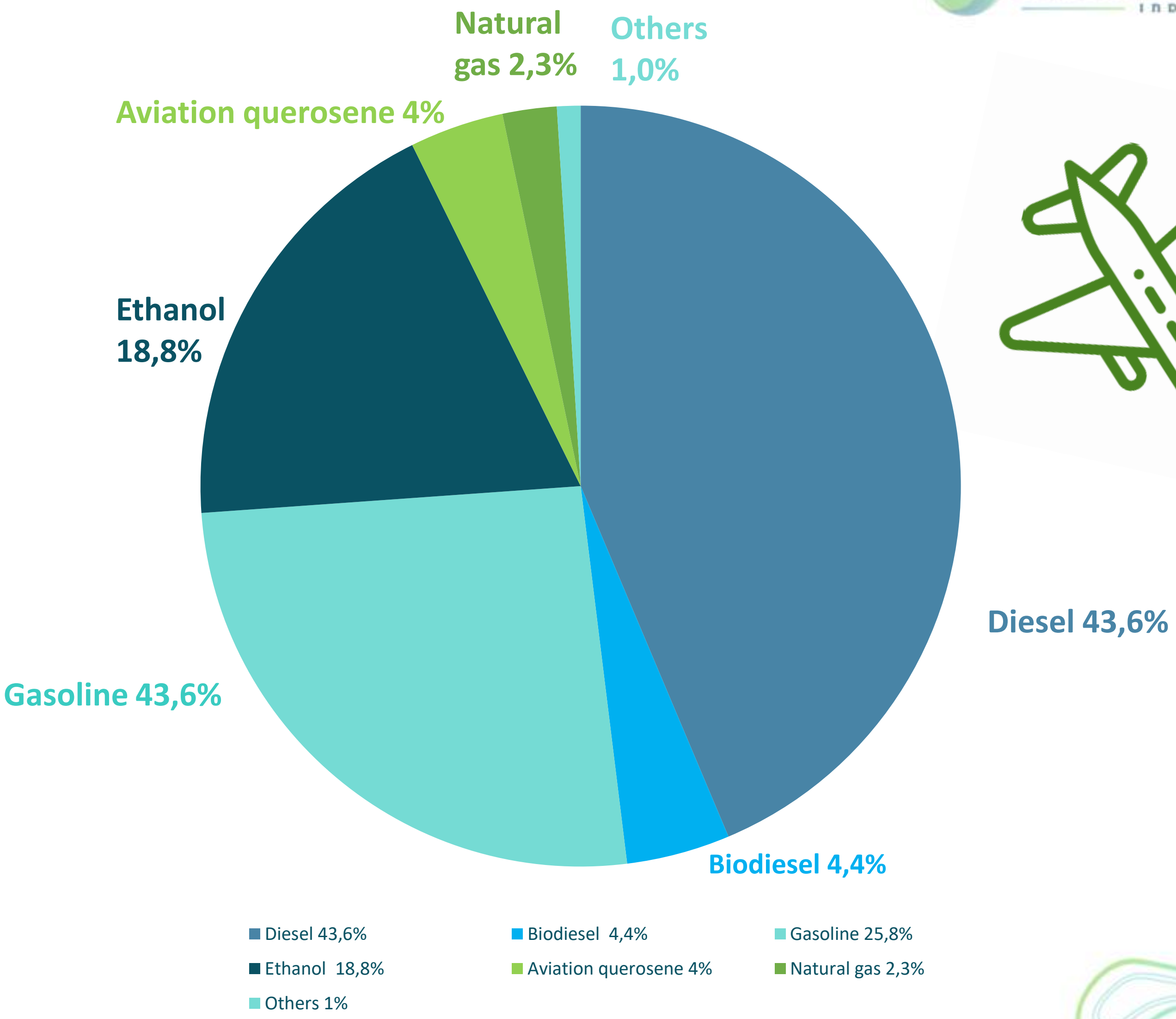


Lung



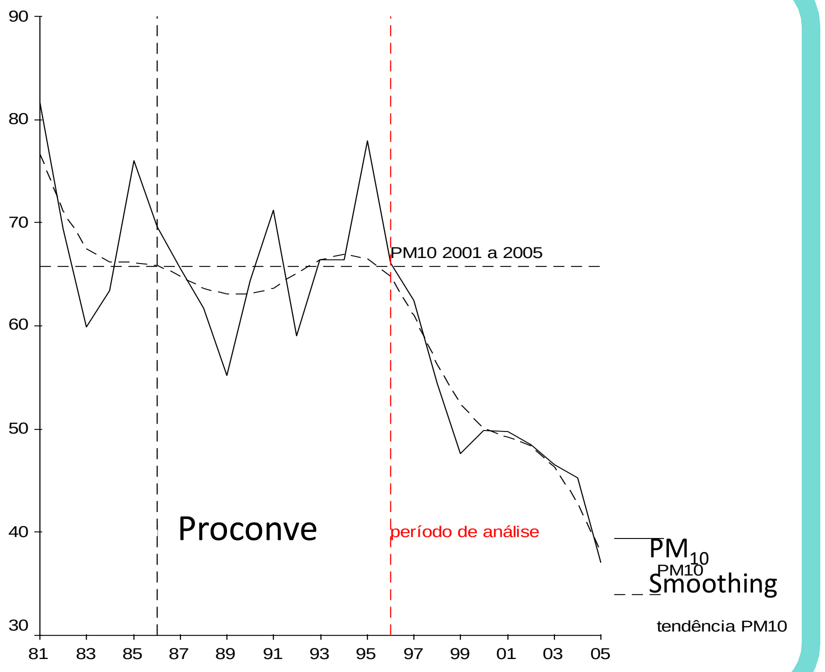
ENERGY USES

FUEL FOR TRANSPORT USE



ETANOL AND AIR POLLUTANTS - MAIN RESULTS

Metropolitan Area of São Paulo (MASP) – yearly concentration of PM_{10}



PROALCOOL = started in 1975

PROCONVE = Started on 1986

$PM_{2.5}$ variation from 1996~2005 = 18 µg/m^3

- Annual deaths ~ 80,278 (2005)
- Mortality risk @ 18 µg/m^3 ~ 10.8%
- Avoided annual deaths (2005) ~ 8.640
- Costs (DALY) ~ US $1.5 billion

ETANOL AND AIR POLLUTANTS - MASP EXPERIENCE

Tailpipe emissions

Muñoz et al. 2016

- Gasoline Direct Injection Flex-fuel vehicle
- 2 Test cycles: WLTC & SSC
- Fuels: Gasoline (E0), ethanol (E10, E85)
- PN: Nano particle (number/m^3)
- NO_2: concentration below 1.8 ppm

WLCT=Wolrdwide harmonized test cycle / SSC=Steady-state cycle

POLUTANTS	ETHANOL E10 - E85	REDUCTION	GASOLINE E0
PM (PN)	↓	96%	↑
CO	↓	81%	↑
CO_2	↓	13%	↑
NO_2	●	very low	
PAH	↓	67~96%	↑
Genotoxicity Potential	↓	72~83%	↑

↑ Higher

↓ Lower

PAH = Polycyclic Aromatic Hidrocarbon

ETANOL AND AIR POLLUTANTS - MASP EXPERIENCE

Tailpipe emissions

Tibaquirá et al. 2018

- Tested carburated and fuel-injected vehicles with E20
- Every 10,000 Km until 100,000 Km
- Evaluated: power, torque, emission CO_2, CO, NO_X, unburned HC, VOC´s
- **Vehycle performance remains unchanged**
- **Ethanol reduced 20-40% VOC** (ethane, formaldehyde, ethylene, etanol) emissions
- Implied an average **reduction of 17% in the ozone formation potential**

ETANOL AND AIR POLLUTANTS - MASP EXPERIENCE

Ultrafine particle level in MASP

Salvo et al. 2017

- Analyze aerossol, meteorological, traffic, pollutants monitoring data, consumer behaviour (gasoline-etanol mix)
- UF particles concentrations fall 1/3 when ethanol low price induce higher use

POLUTANTS	ETHANOL	REDUCTION	GASOLINE
PM (PN)	↓	33%	↑

↑ Higher

↓ Lower

ETANOL AND AIR POLLUTANTS - MASP EXPERIENCE

Aldehydes emissions from ethanol use

Toxicity of acetaldehyde and formaldehyde on health come from the occupational area, and even supposing their exposition throughout life, the risk to cancer or tumor is pretty much little: less than 2 cases per 100.000 inhabitants (Saldiva, 2010)

Although the fleet increase advances in the MASP, vehicle emissions control prevented any significant increase in the atmospheric concentrations of aldehydes, but only an increase in the formaldehyde/acetaldehyde ratio (Nogueira, 2014)

ETANOL AND AIR POLLUTANTS - MASP EXPERIENCE

Aromatics emission from Ethanol x Gasoline

- Stackelberg et al. 2013 estimated a public health impact from exposure to $PM_{2,5}$ (SOA) originating from aromatics in gasoline of 3,800 premature mortalities
- A report from NRL (2016) details the aromatics content of ethanol blended fuels:
  - Aromatics reduction of 9.3% for E25/30, and 17.3% for E83
- UIC/Energy Resources Center (2019) project the mortality reduction in all above ethanol blended fuel with aromatics reduction:
  - E25/30: reduction in mortalities of 2,403 deaths ~ US $22 billion
  - E83: reduction in mortalities of 4,469 deaths ~ US $40 billion

ETANOL AND AIR POLLUTANTS - MASP EXPERIENCE

Ozone levels in MASP

Martins et al. 2008, and Suck et al. 2019

- **Ozone formation is:**
  - **Primary limited by VOC**
  - **Inhibited by NO_x**
- Fossil fuels highly contribute to ozone formation
- Reduction on fossil fuels use is a good strategy to control Ozone

Suck et al. 2019 (two decades study)

- **Ozone presents a significant correlation with fuel sales of gasohol and diesel**
- Ethanol sales does not explain the ozone anual variability

ETANOL AND AIR POLLUTANTS – MAIN RESULTS

Increase on the share of ethanol over gasoline and diesel (Saldiva, 2010)

#1: 15% replacement of diesel by ethanol

- ✓ Deaths avoided: 112 per year
- ✓ Hospitalar admission: 675 per year
- ✓ Mortality valuation: US $20.1 million/year
- ✓ Morbidity valuation: US $1.9 million/year
- ✓ Total valuation: US $22 million/year

#1: 100% replacement of gasool by ethanol

- ✓ **Deaths avoided: 130 per year**
- ✓ **Hospitalar admission: 8,002 per year**
- ✓ **Mortality valuation: US $23.3 million/year**
- ✓ **Morbidity valuation: US $19.8 million/year**
- ✓ **Total valuation: US $43.1 million/year**

ETANOL AND AIR POLLUTANTS – MAIN RESULTS

Adding more 13% of biofuel on diesel – 2015-2025 (Vormittag, 2018)

#1: Metropolitan Area of São Paulo - MASP

- ✓ **Deaths avoided: 7,319**
- ✓ **Hospital admission: 22,003**
- ✓ **Mortality valuation: US $612 million**
- ✓ **Morbidity valuation: US $22.9 million(*)**
- ✓ **Total valuation: US $634.9 million**

(*) only public hospital admissions

#2: Metropolitan Area of Rio de Janeiro - MARJ

- ✓ **Deaths avoided: 5,712**
- ✓ **Hospital admission: 6,167**
- ✓ **Mortality valuation: US $311.7 million**
- ✓ **Morbidity valuation: US $5,0 million(*)**
- ✓ **Total valuation: US $316.7 million**

(*) only public hospital admissions

ETANOL AND AIR POLLUTANTS

CONCLUSIONS

- Accute and chronic toxicity of ethanol is lower than gasoline
- Tailpipe emissions from ethanol blended fuels are lower than gasoline
- UF particles have more significant toxicity than the attributable to $PM_{2,5}$
- Ethanol blended fuels emit a much lower UF particles than gasoline
- In MASP despite the fleet increase and extensive use of ethanol and advanced engine technologies, the concentration of aldehydes did not show any growth

ETANOL AND AIR POLLUTANTS

CONCLUSIONS

- Photochemical modeling for MASP concluded that ethanol use does not explain ozone behavior
- Among several scenarios the use of biofuels replacing fossil fuels always relay on positive and significative impact on public health and economic
- The more time we take to act, the more people will die

SUSTAINABLE MOBILITY: ETHANOL TALKS
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