ETHANOL AND AIR POLLUTANTS

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PhD

SUSTAINABLE MOBILITY: ETHANOL TALKS PAKISTAN

ETHANOL AND AIR POLLUTANTS

- Health & Environment (WHO, TWB, IHME - GBD)
- Tailpipe emissions
- Evidences and real world evaluation
- Conclusions

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

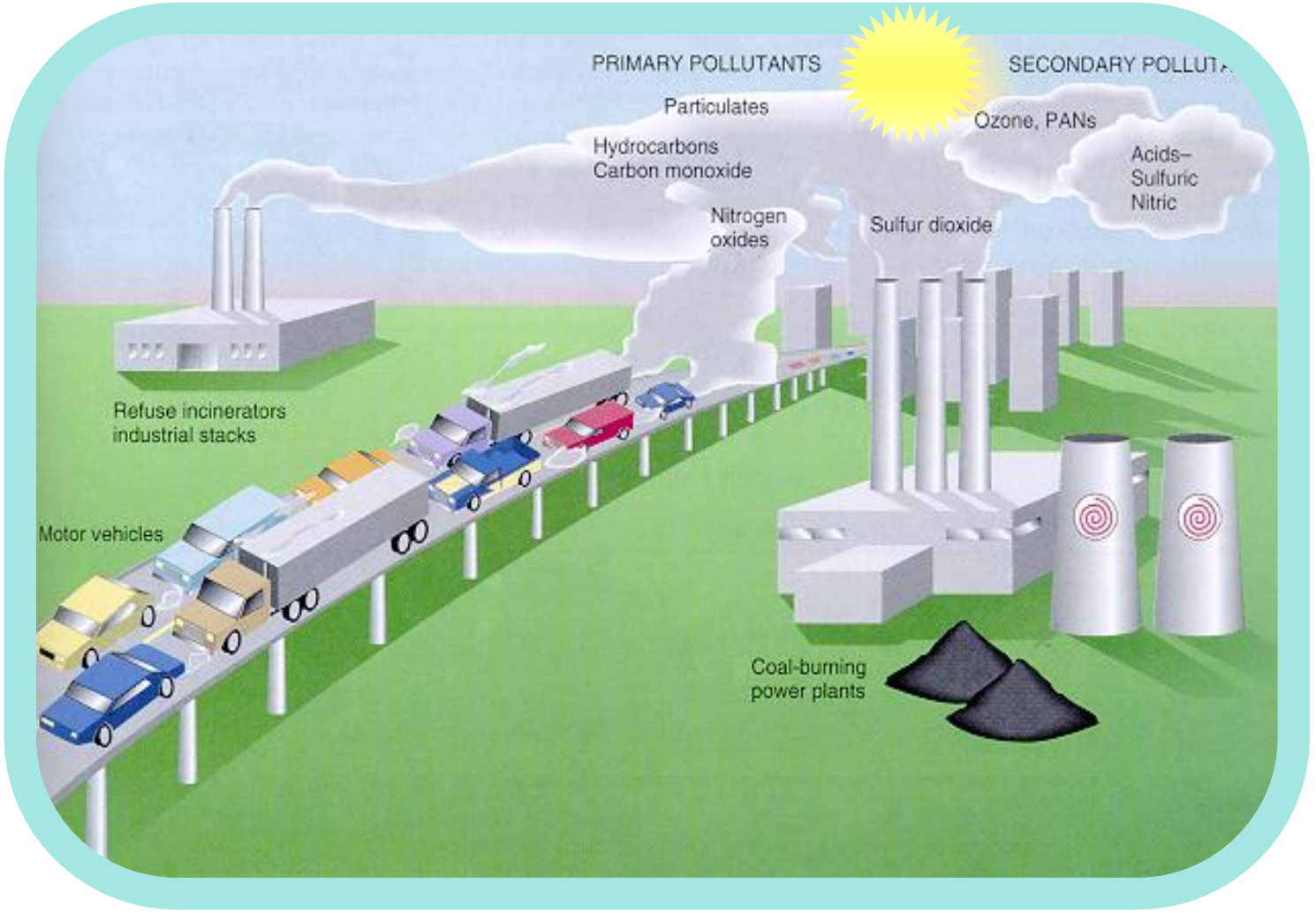
- Particles less than 100 nm

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



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)

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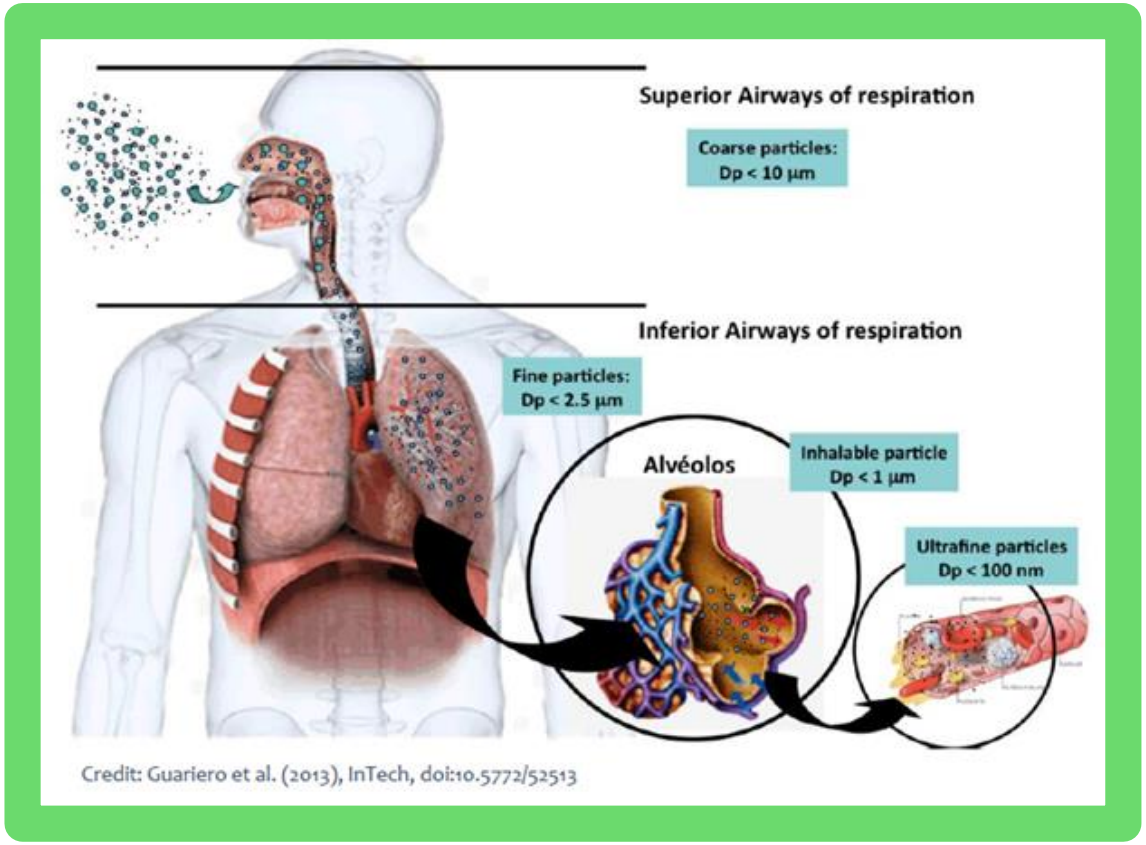
Particulate Matter (PM) in human body



HEALTH & ENVIRONMENT

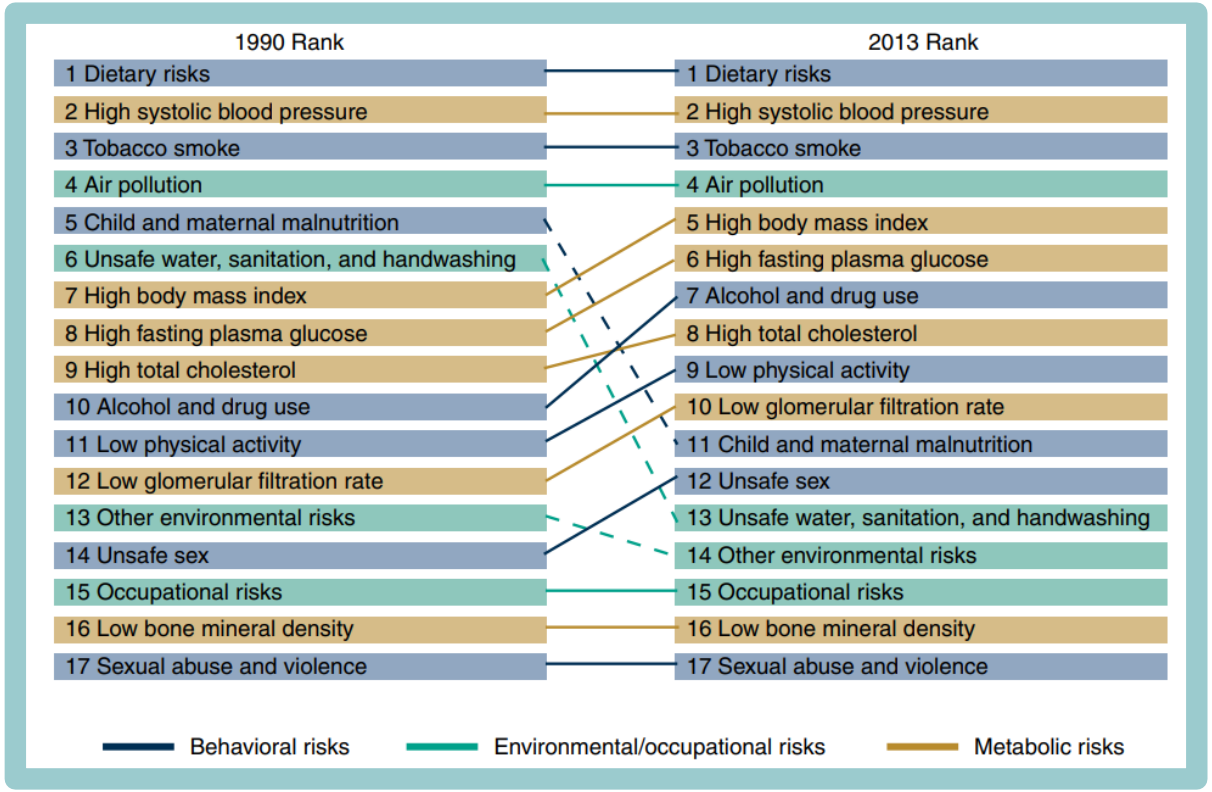
Leading Modifiable Risks by Number of Deaths: **Globally, 1990 and 2013**

Estimated deaths – 2016

Ambient $PM_{2.5}$

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

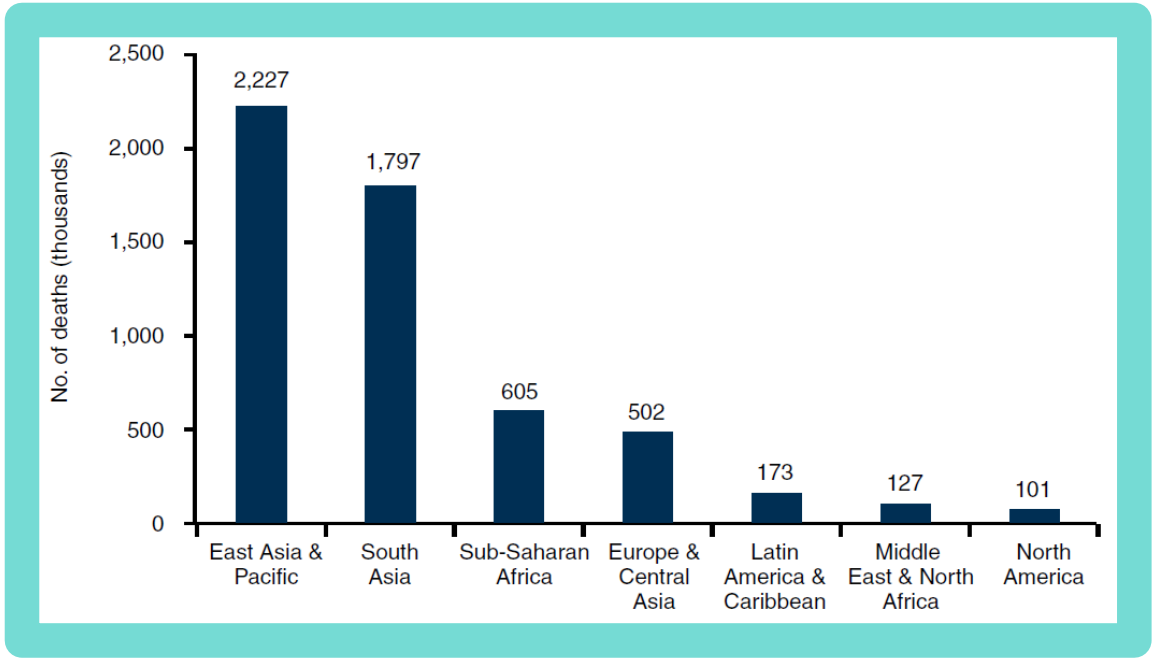
(WHO, 2018)



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

HEALTH & ENVIRONMENT

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



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

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)

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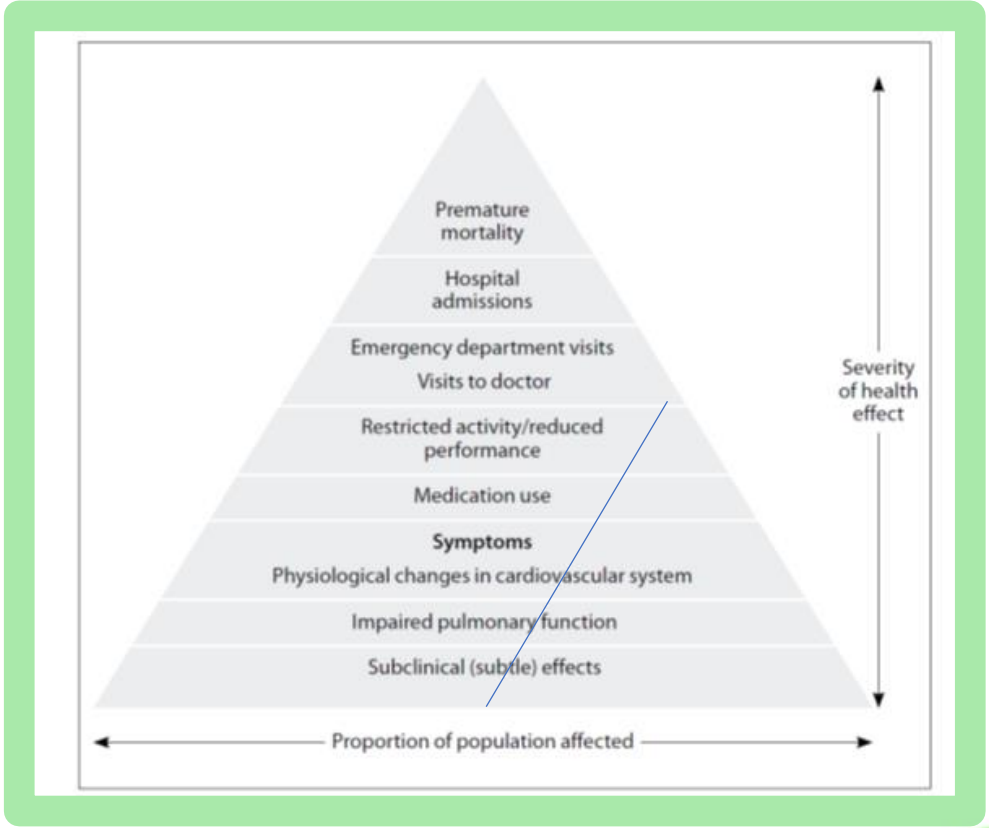
Health Effect severity x Proportion of population affected

- 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)

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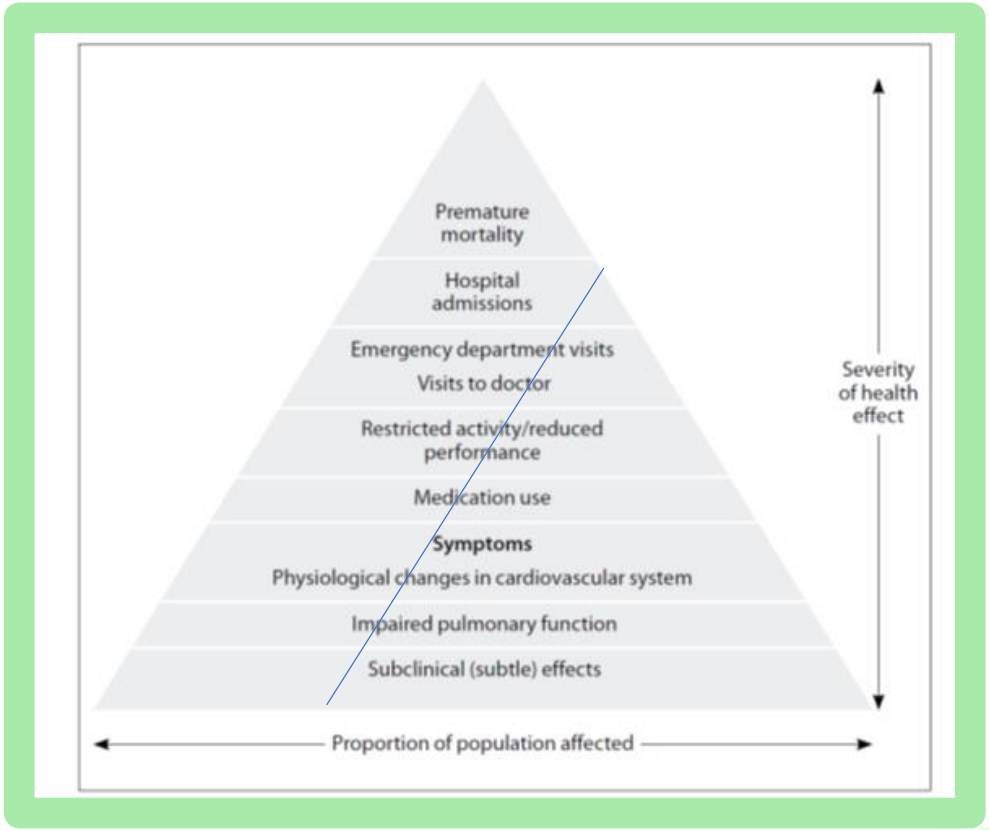
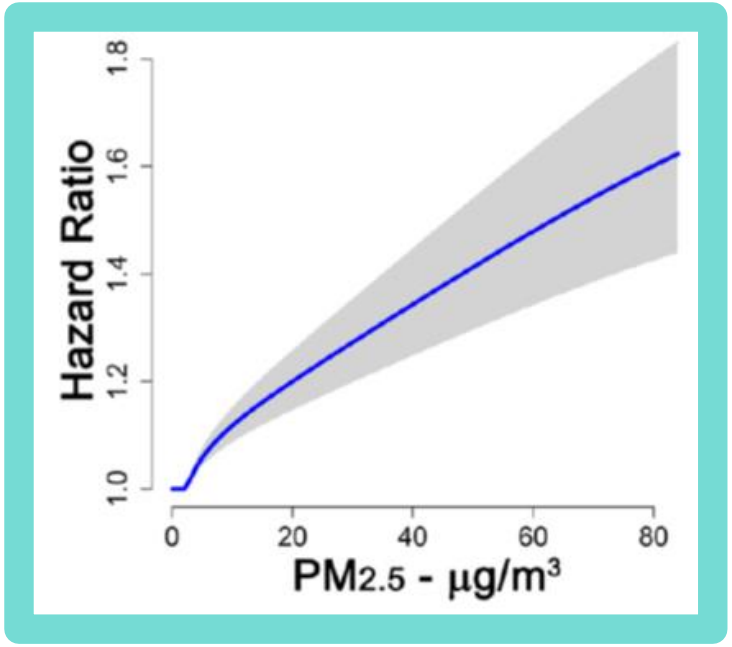


Source: American Thoracic Society (in WHO, 2006)

HEALTH & ENVIRONMENT

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



WHO Air Pollution Guidelines targets (global update 2005):

- **Annual mean:** 10 µg/m³
- **24-h mean: 25** µg/m³
- **A** 10 µg/m³ **reduction in $PM_{2.5}$ reduces total mortality risk by 6%**

Source: Burnett et al, 2018

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Tailpipe emissions

	MUÑOZ (2017) E0 / E10 / E85						TIBAQUIRA (2018) (*) E0 / E20		UIC (2019) E0 / E25-30, E83
	PM (PN)	CO	CO_2	NO_2	PAH	Genotox. Potential	Performance	VOC	AROMATICS
GASOL	↑	↑	↑		↑	↑		↑	↑
ETHANOL	↓	↓	↓	●	↓	↓	●	↓	↓
REDUCTION	96%	81%	13%	very low	67~96 %	72~83 %	=	20-40 %	9.3~17.3 %

(*) Carburated vehicles
PAH = Polycyclic Aromatic Hidrocarbon

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Tailpipe emissions

	ETHANOL	GASOLINE
ACETALDEHYDE	⇧	⇩
FORMALDEHYDE	⇩	⇧
TOXICITY RATIO (ACET : FORM)	1 : 6	
FINAL TOXICITY	⇩	⇧

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Toxicological studies with animal exposition

HARDWARE	ENDPOINT	ETHANOL	GASOLINE
EXPOSITION CHAMBER	ACCUTE	↓	↑
	CHRONIC	↓	↑

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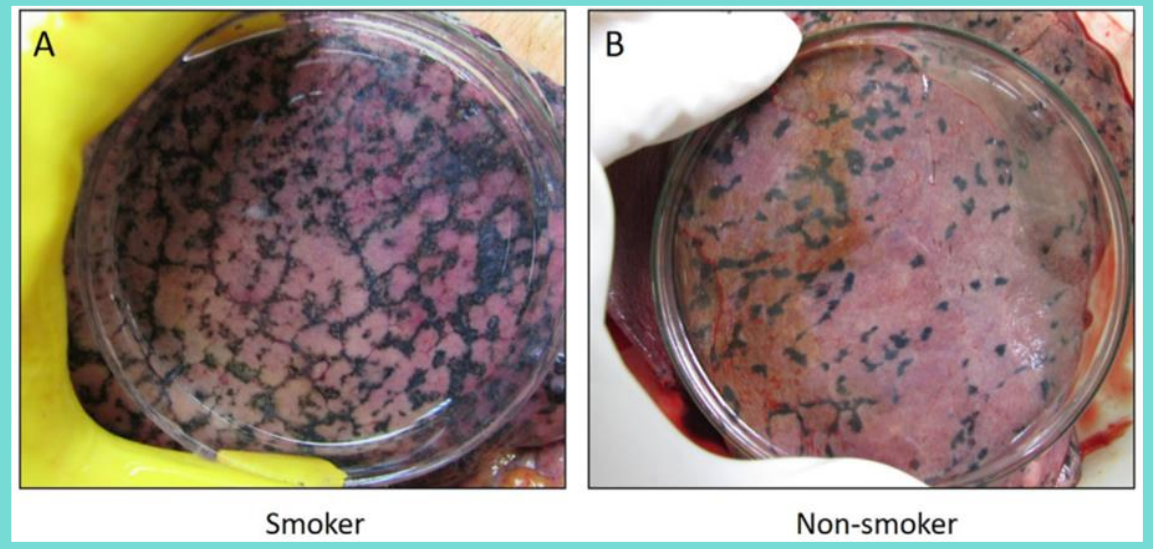
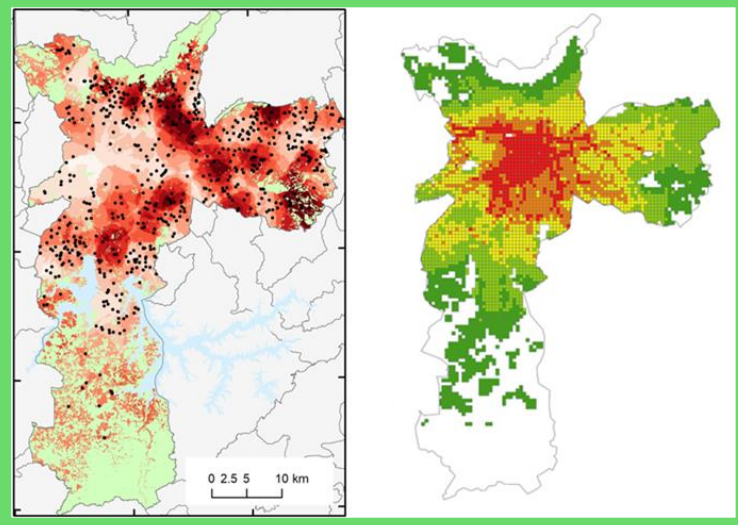
Autopsy-based studies (Antracosys)



Lung



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UF - ultrafine particle and Ozone formation

POLUTANTS	ETHANOL	REDUCTION	GASOLINE
PM (PN) SALVO, 2017	↓	33%	↑
OZONE FORMATION TIBAQUIRA, 2018	↓	17%	↑

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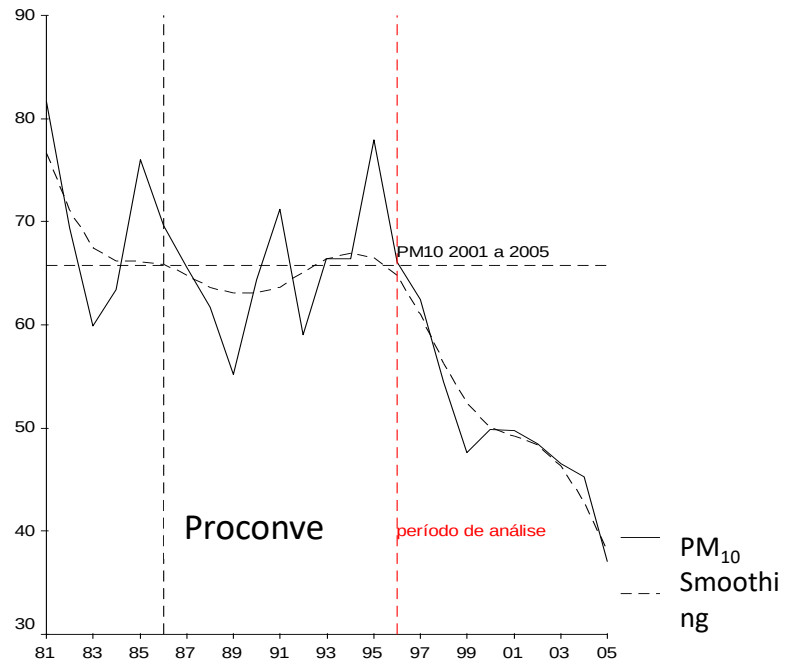
Metropolitan Area of São Paulo (MASP) – yearly concentration of PM_{10}



PROALCOOL = started in 1975

PROCONVE = Started on 1986

$PM_{2.5}$ variation from 1996~2005 = 18 µg/m³

- Annual deaths ~ 80,278 (2005)
- Mortality risk @ 18 µg/m³ ~ 10.8%
- Avoided annual deaths (2005) ~ 8.640
- Costs (DALY) ~ US $1.5 billion

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		PROCONVE (2005)	SALDIVA (2010)		UIC (2019)		VORMITTAG (2018)		PINICHKA (2017)
		MASP	10% D => E	100% G => E	100% E0 => E25/30	100% E0 => E83	MASP D => 18% biof	MARJ D => 18% biof	20% $PM_{2.5}$ reduction
NUMBER OF CASES	MORTALITY	8,640	112/y	130/y	2,403	4,469	7,319	5,712	160 ~ 5,982
	MORBIDITY	-	675/y	8,002/y	-	-	22,003	6,167	-
US $	MORTALITY	1.5 b	20.1 m/y	23.3 m/y	22 b	40 b	612 m	311.7 m	-
	MORBIDITY	-	1.9 m/y	19.8 m/y	-	-	22.9 m	5 m	-
	TOTAL	1.5 b	22 m/y	42.1 m/y	22 b	40 b	634.9 m	316.7 m	-

m=million; b=billion

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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

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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

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REALIZATION:

PSMA

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Sugarcane Bioenergy Solution

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