Impact of air pollution on Health

C. Liousse

Air pollution is one of the world's leading risk factors for death

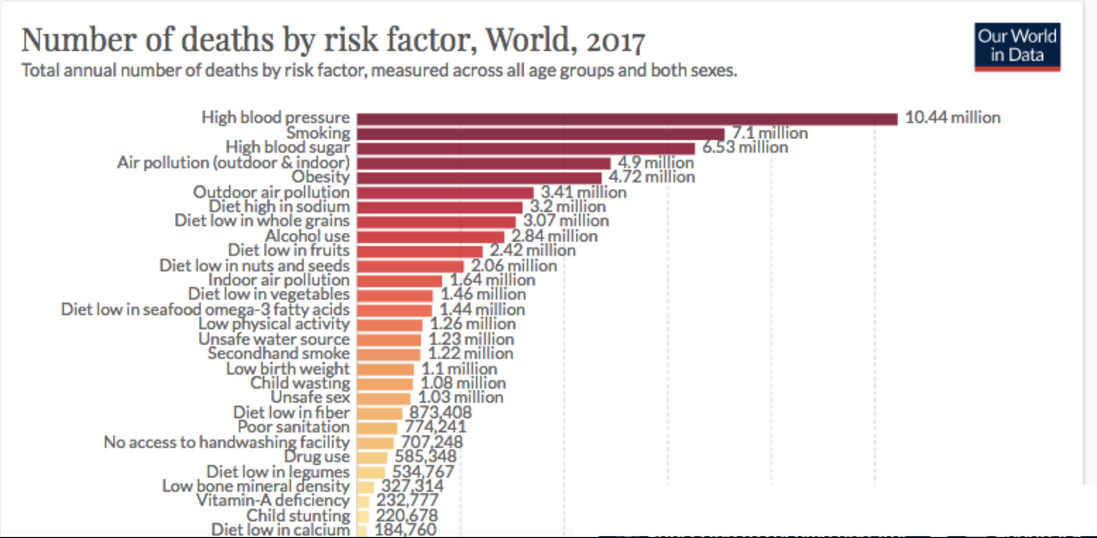
Air pollution is responsible for 5 million deaths each year

Air pollution – the combination of outdoor and indoor particulate matter, and ozone – is a risk factor for many of the leading causes of death including heart disease, stroke, lower respiratory infections, lung cancer, diabetes and chronic obstructive pulmonary disease (COPD).

The Institute for Health Metrics and Evaluation (IHME) in its *Global Burden of Disease* study provide estimates of the number of deaths attributed to the range of risk factors for disease.[1]

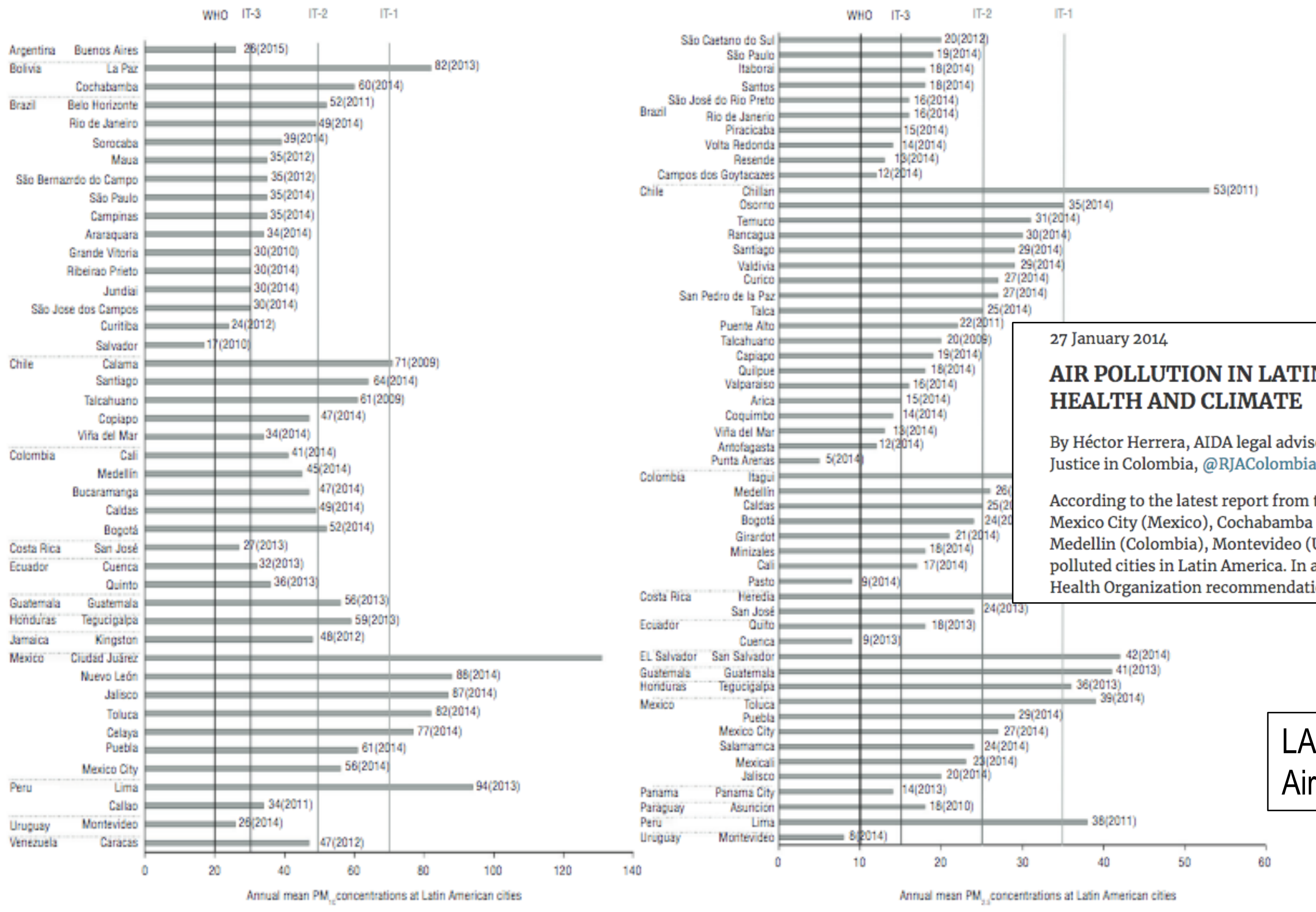
In the visualization we see the number of deaths per year attributed to each risk factor. This chart is shown for the global total, but can be explored for any country or region using the "change country" toggle.

Air pollution is one of the leading risk factors for death. In low-income countries it tops the list. In 2017, it was responsible for an estimated 5 million deaths globally. That means it contributed to 9% – nearly 1-in-10 – deaths.



https://ourworldindata.org/air-pollution

FIGURE 3. Particle matter $(PM)_{10}$ and $PM_{2.5}$ in cities of Latin America and the Caribbean and their situation compared with the World Health Organization–Air Quality Guidelines (WHO-AQG), 2010–2014



27 January 2014

AIR POLLUTION IN LATIN AMERICA AND ITS EFFECT ON OUR HEALTH AND CLIMATE

By Héctor Herrera, AIDA legal advisor and coordinator of the Network for Environmental Justice in Colombia, @RJAColombia

According to the latest report from the Clean Air Institute, Monterrey, Guadalajara and Mexico City (Mexico), Cochabamba (Bolivia), Santiago (Chile), Lima (Peru), Bogota and Medellin (Colombia), Montevideo (Uruguay) and San Salvador (El Salvador) are 10 most polluted cities in Latin America. In all of them, the level of air pollution exceeds World Health Organization recommendations.

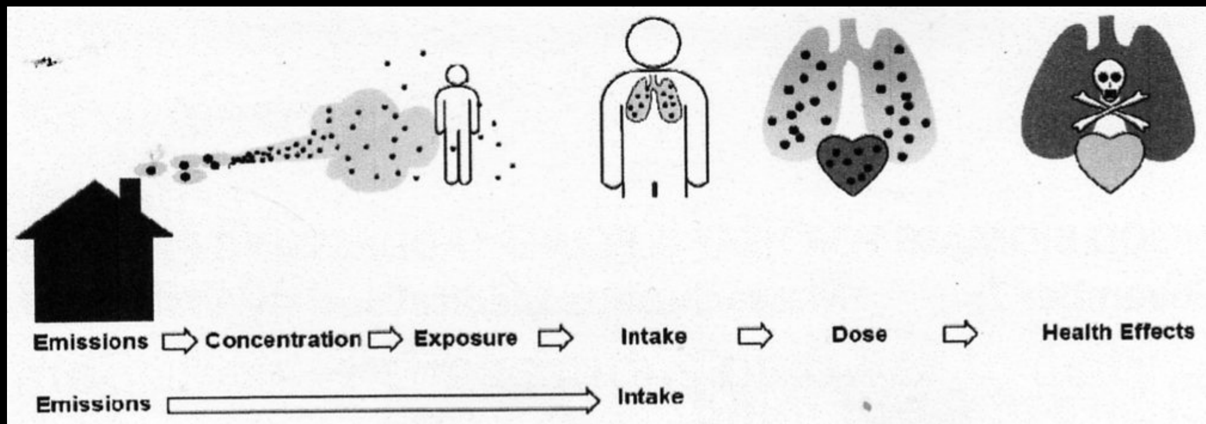
LAC : 26 cities : 86 millions of people
Air quality > WHO norms

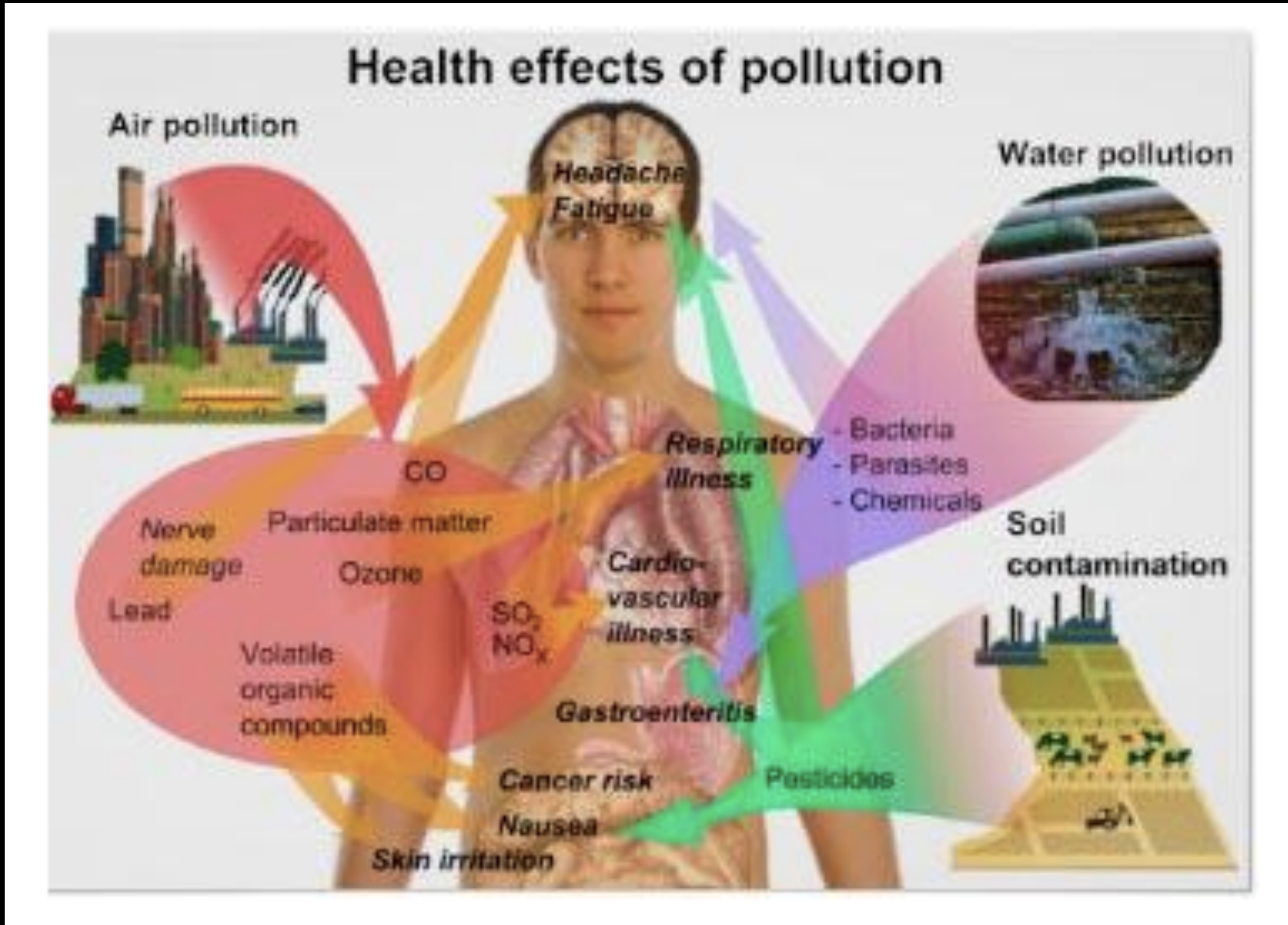
Environmental Science & Technology
Feature
pubs.acs.org/est

"What We Breathe Impacts Our Health: Improving Understanding of the Link between Air Pollution and Health"

J. Jason West,[*,†] Aaron Cohen,[*,‡] Frank Dentener,[*,§] Bert Brunekreef,[‖] Tong Zhu,[*,⊥] Ben Armstrong,[#] Michelle L. Bell,[▽] Michael Brauer,[○] Gregory Carmichael,[◆] Dan L. Costa,[¶] Douglas W. Dockery,[★] Michael Kleeman,[⊗] Michal Krzyzanowski,[⋈] Nino Künzli,[☼,◑] Catherine Liousse,[◊] Shih-Chun Candice Lung,[@] Randall V. Martin,[¢,$] Ulrich Pöschl,[⧳] C. Arden Pope, III,[¥] James M. Roberts,[%] Armistead G. Russell,[€] and Christine Wiedinmyer[Я]

Environ Sci Technol. 2016 May 17;50(10):4895-904.





Health effects of pollution
Air pollution
Water pollution
Headache
Fatigue
Respiratory illness
- Bacteria
- Parasites
- Chemicals
CO
Nerve damage
Particulate matter
Ozone
Lead
SO_2
NO_x
Cardio-vascular illness
Soil contamination
Volatile organic compounds
Gastroenteritis
Cancer risk
Pesticides
Nausea
Skin irritation

Pollution exposure => Health effect

London smog (1952) : 12000 deaths

Since the 1990s …. .. **epidemiological studies**
(Dockery et al., Shwartz et al., Pope et al.…)

Different types of exposure :
-Short term (2 - 40 days) : better known (Daily Concentrations/Daily Mortality)
-Long term (many years) => more severe effect and less wellknown (ex. => long-term exposure/mortality (Pope et al. 2002)), exposure/life expectancy (WHO 2003)

Dose-response functions (RR) : Correlation between polluant concentrations and health response hospital admissions/emergency visits for different types of diseases (morbidity) and premature deaths (mortality) : determination from time series (more frequent, short-term) and cohort studies (expensive, both short and long-term).
Calculated with Poisson regression.

Cohort : More important effect for young children, elder people and sick people

HEALTH ENDPOINT	POLLUTANT	POP SECTOR	FUNCTION	SOURCE
Respiratory hospital admissions - daily exposures	PM10	All persons	1.20×10^{-5}	Ostro 1994 as referenced in World Bank 1998
Respiratory hospital admissions - daily exposures	SO_2	All persons	2.01×10^{-6}	Maddison 1997 as referenced in WB 1998
Respiratory hospital admissions - daily exposures	NO_2	All persons	1.65×10^{-6}	Maddison 1997 as referenced in WB 1998
Cardiovascular hospital admission - daily exposures	PM10	All persons	1.01×10^{-7}	Dockery et al 1989
Daily Mortality - daily exposures	PM10	>=65 years	4.42×10^{-7}	EXMOD - as referenced by Nelson 2000
Daily Mortality - daily exposures	PM10	<65 years	2.35×10^{-8}	EXMOD - as referenced by Nelson 2000
Daily Mortality - daily exposures	SO_2	>=65 years	1.01×10^{-8}	Watkiss and Holland - functions collated for application by the European Commission DG Environment
Daily Mortality - daily exposures	SO_2	<65 years	1.38×10^{-9}	Watkiss and Holland - functions collated for application by the European Commission DG Environment
Chronic Bronchitis - annual exposures	PM10	children (<5 years)	1.61×10^{-3}	Dockery et al 1989
Chronic Bronchitis - annual exposures	PM10	adults (20 years+)	4.90×10^{-5}	Abbey et al 1995
Restricted activity days (RAD) -daily exposures	PM	20-65 years	1.60×10^{-4}	Rowe et al 1994 as referenced in van Horen 1996
Minor restricted activity days (MRAD) - daily exposures	SO_2	20-65 years	9.76×10^{-3}	Watkiss and Holland - functions collated for application by the European Commission DG Environment

Example of dose-response functions (review from Scorgie et al., 2004)

What about dose-response functions in Latin American cities?

2 big reviews :

- Fajersztajn et al., 2017 (https://doi.org/10.1007)

✓ 1628 studies reviewed. Nine elected for the qualitative analysis and seven for the quantitative analyses.

✓ **Each 10 µg/m^3 increments in daily $PM_{2.5}$ concentrations** are significantly associated with increased risk for respiratory and cardiovascular mortality in all-ages (polled RR = 1.02, 95% CI and RR = 1.01, 95% CI).

- Cifuentes et al., 2005 (http://www.iadb.org/sds/env)

Exposure	Type of Endpoint		Endpoint (specific cause)	City/Country providing C-R functions
Long-term	Premature Mortality		All cause	USA
			Cardiopulmonary	USA
			Lung cancer	USA
	Illness or Disease		Chronic Bronchitis	USA
Short-term	Premature Mortality		All cause mortality	Several LA cities / USA
			Respiratory causes	USA
			CVD causes	USA
	Medical Actions	Hospital Admissions	Cardiovascular disease (ICD9 390-429)	USA
			Asthma	USA
			Dysrhytmias (ICD9 427)	USA
			Respiratory Causes (ICD9 460-519)	Sao Paulo/USA
			Pneumonia (ICD9 480-487)	Sao Paulo/USA
		Emergency Room Visits	Asthma (ICD9 493)	Sao Paulo
			Cardiovascular disease	Sao Paulo
			Ischemic Heart Disease	USA
			Respiratory Causes	Santiago
			Pneumonia and Influenza	USA
			Pneumonia (ICD9 480-486)	Santiago
			Lower-RSP	Santiago
			Upper RSP symptoms (ICD9 460, 465, 487)	Santiago
		Medical Visits	Asthma (ICD9 493)	Juarez
	Illness or Disease		Asthma Attacks	USA
			Acute Bronchitis	USA
	Days with Restriction in Activity		Work Loss Days (WLD)	USA
			Restricted Activity Days (RAD)	USA
			Minor Restricted Activity Days (MRAD)	USA
			Shortness of Breath Days	USA

Mortality impacts in LAC : Time series studies

Higher RR(PM10) values for Infants and Elder
Co-pollutant : few studies for Elder only
Risk increased when co-pollutant

Heterogeneous results between the cities
due to different factors (demography, culture,
Socio-economy, mobility, sampling)

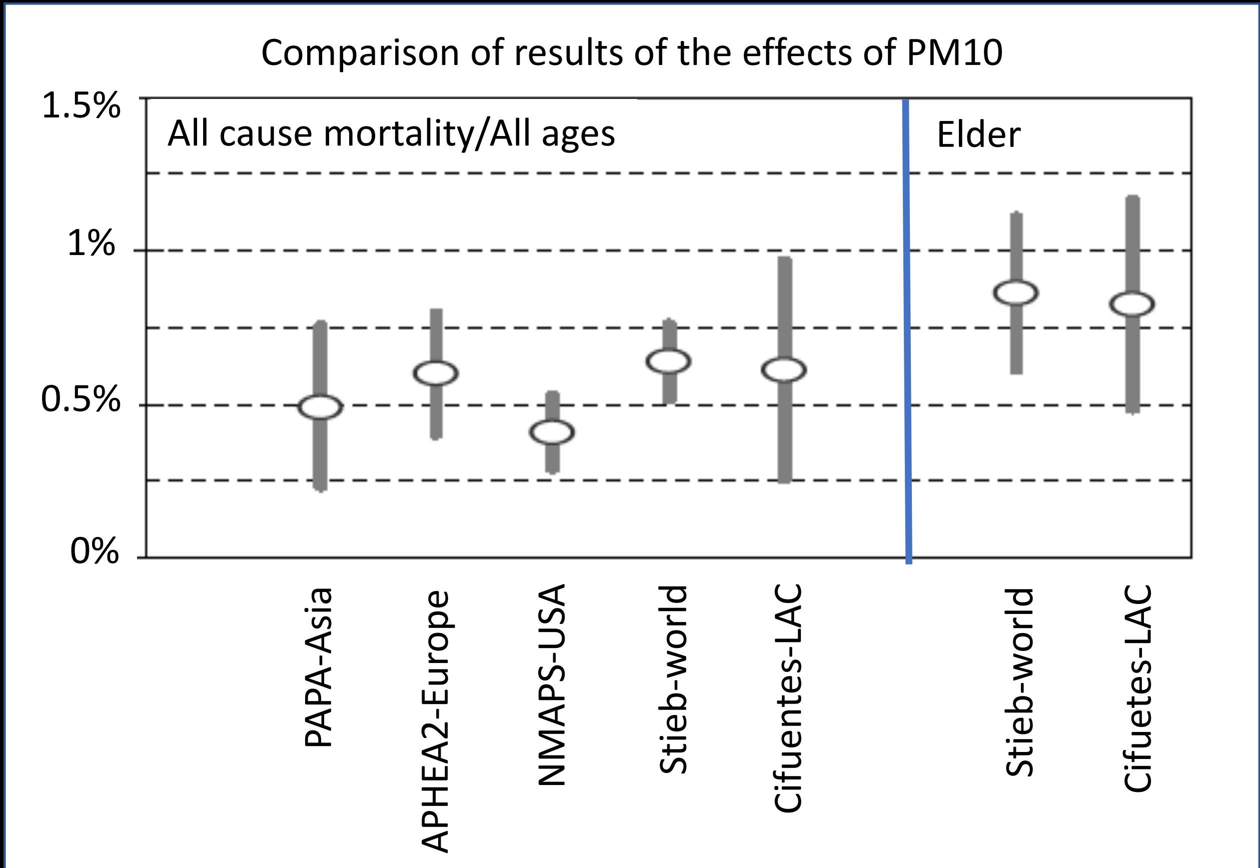
Cifuentes et al., 2005

Table IV-3 Summary estimates from the Meta-analysis of Latin-American studies of the effects of PM_{10} on All Cause Mortality

Age group	City	Co-Pollutant	Number of studies	Metric	% Increase per 10 ug/m3 PM10	(95% CI)	References
All Ages							
	All	**none**	**6**	FE	**0.41%**	(0.32% - 0.51%)	Borja-Aburto 1997, O'Neill 2004, Castillejos 2000, Cifuentes 2000, Ostro 1996, Gouveia 2000b
				RE	**0.61%**	(0.26% - 0.97%)	
		none	**4**	FE	**0.70%**	(0.57% - 0.82%)	Borja-Aburto 1997, Castillejos 2000, Cifuentes 2000, Ostro 1996
				RE	**0.87%**	(0.55% - 1.19%)	
		O3, SO2; O3	**4**	FE	**0.43%**	(0.33% - 0.54%)	Borja-Aburto 1997, Castillejos 2000, Cifuentes 2000, Ostro 1996
				RE	**0.91%**	(0.38% - 1.44%)	
	Mexico City	**none**	**3**	FE	**0.24%**	(0.09% - 0.38%)	Borja-Aburto 1997, O'Neill 2004-b, Castillejos 2000
				RE	**0.89%**	-(0.05% - 1.85%)	
		O3, SO2; O3	**2**	FE	**1.35%**	(0.89% - 1.82%)	Borja-Aburto 1997, Castillejos 2000
				RE	**1.37%**	(0.85% - 1.89%)	
	Santiago	**none**	**2**	FE	**0.63%**	(0.49% - 0.76%)	Cifuentes 2000, Ostro 1996
				RE	**0.64%**	(0.47% - 0.80%)	
		O3	**2**	FE	**0.38%**	(0.27% - 0.49%)	Cifuentes 2000, Ostro 1996
				RE	**0.55%**	(0.03% - 1.07%)	
Elder 65+ yr							
	All	**None**	**5**	FE	**0.66%**	(0.51% - 0.81%)	Castillejos 2000, Ostro 1996, Sanhueza 1998, Gouveia 2000b, Saldiva 1995
				RE	**0.83%**	(0.48% - 1.17%)	
		O3, SO2; O3	**3**	FE	**0.56%**	(0.37% - 0.75%)	Borja-Aburto 1997, Castillejos 2000, Sanhueza 1998
				RE	**1.00%**	(0.24% - 1.77%)	
	México City	**O3, SO2; O3**	**2**	FE	**1.35%**	(0.76% - 1.95%)	Borja-Aburto 1997, Castillejos 2000
				RE	**1.35%**	(0.76% - 1.95%)	
	Santiago	**None**	**2**	FE	**0.61%**	(0.44% - 0.78%)	Ostro 1996, Sanhueza 1998
				RE	**0.69%**	(0.30% - 1.08%)	
	Sao Paulo	**none**	**2**	FE	**0.71%**	(0.37% - 1.06%)	Gouveia 2000b, Saldiva 1995
				RE	**0.81%**	(0.13% - 1.51%)	
Infant < 18yr							
	All	**None**	**3**	FE	**2.73%**	(1.55% - 3.92%)	Loomis 1999, Linn 2000, Nishioka 2004
				RE	**2.94%**	(1.35% - 4.56%)	
	Sao Paulo	**None**	**2**	FE	**2.37%**	(1.05% - 3.72%)	Linn 2000, Nishioka 2004
				RE	**2.59%**	(0.54% - 4.69%)	
		O3, SO2; O3	**2**	FE	**3.20%**	(1.29% - 5.16%)	Loomis 1999, Nishioka 2004
				RE	**3.20%**	(1.29% - 5.16%)	

Note: FE = Fixed effects estimate, RE= Random Effects Estimate. Mid estimates shown in bold, 95% Confidence interval (percentile 2.5 to percentile 97.5 is shown in parenthesis)

Mortality impacts in LAC : Time series studies



PAPA : Asian cities (HEI 2004)
APHEA2 : 29 european cities (Atkinson et al., 2001)
NMAPS : 90 US cities (Samet et la., 2000)
Stieb study : 109 cities worldwide (Stieb et al., 2002)

All ages : results from LAC comparable to European and Stieb studies
Elderly : Stieb slightly bigger than LAC

Cifuentes et al., 2005

Mortality impact in LAC : Time series

ESCALA project (supported by HEI) : 1997-2005
Romieu et al., 2012
Cifuentes et al. : Chili
Gouveia et al. : Brazil
Romieu et al. : Mexico
9 cities/ PM10 and 03

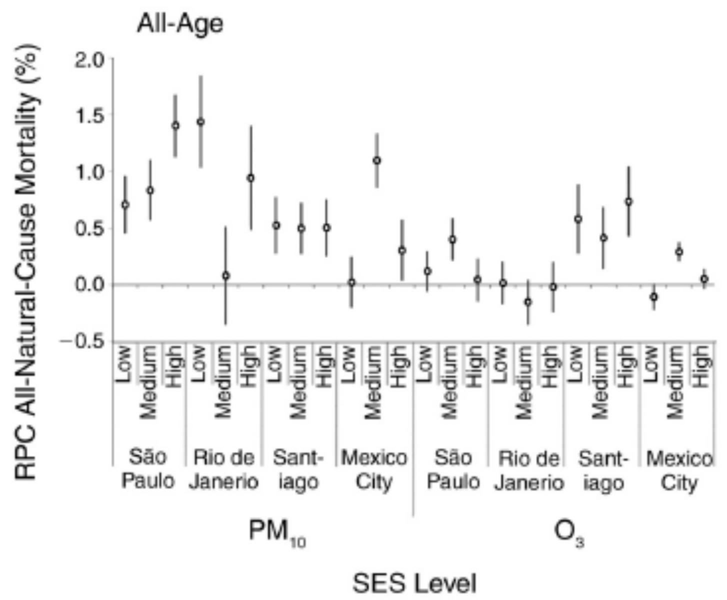


Figure 5. All-natural-cause, all-age mortality. Risk percent changes (95% CI) per 10-µg/m³ increase of PM_{10} and O_3, using DLM 0–3 for low, medium, and high SES levels, in São Paulo and Rio de Janeiro, Brazil; Santiago, Chile; and Mexico City, México (1997–2005). Note: the *y*-axes of Figures 5–10 are scaled differently. Sources: Appendix Tables I.9–I.12, available on the HEI Web site.

Small but significant effect of daily exposure to PM10 and ozone on daily mortality
Link with socioeconomical data

Mortality impact in LAC : no cohort studies in 2005

Table IV-5 Risk estimates reported in the studies of the long-term exposure to particulate matter explain entries – central & confidence interval

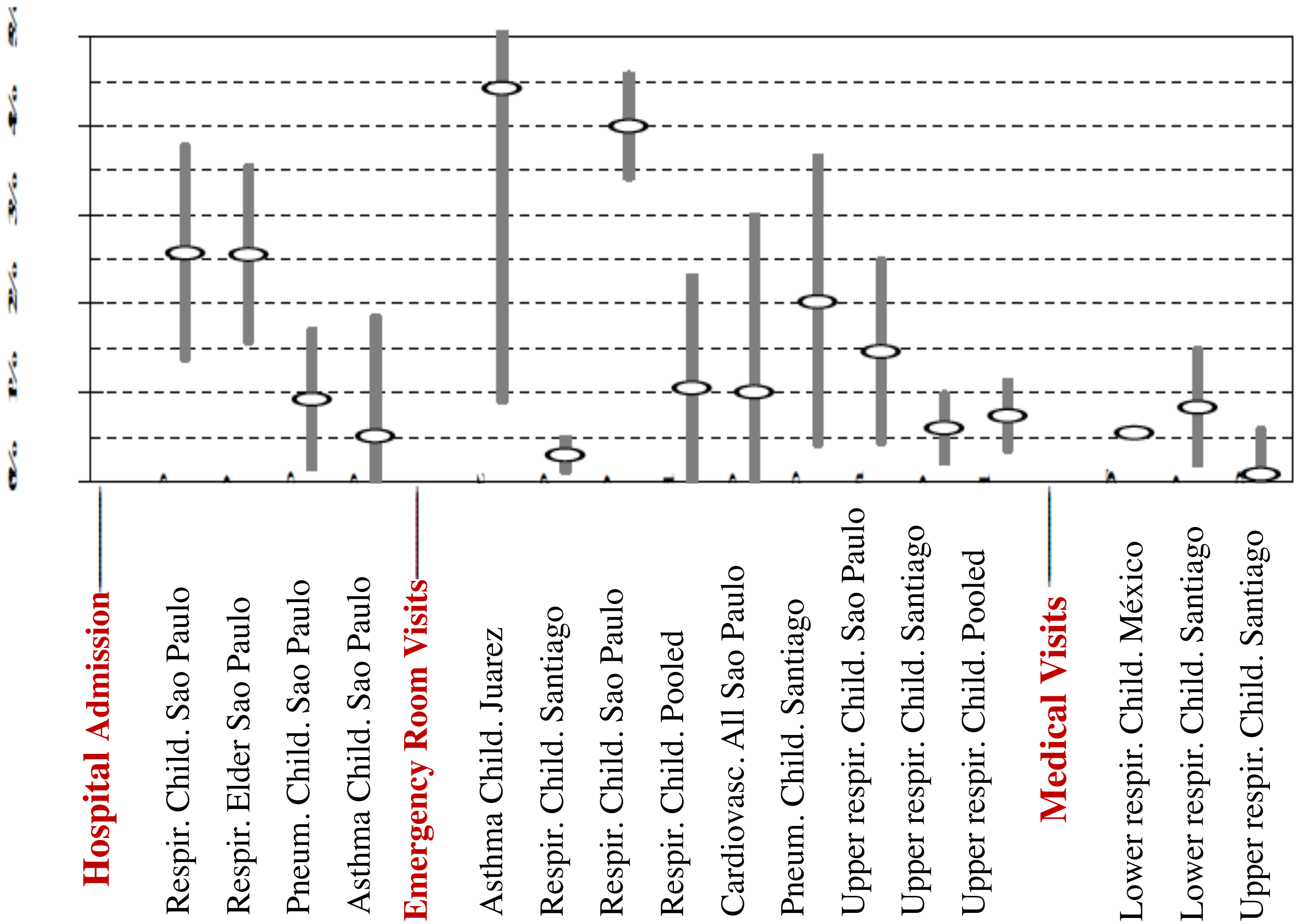
Cause Location	Age Group	Cohort	C-R Specif.	Exposure metric	% change in deaths for given change in PM2.5 (*)	Source
All Cause mortality						
6 US cities	>24	8,192	Linear	Avg $PM_{2.5}$	**13.2%** (4.1% - 23.1%)	Dockery, Pope III et al. 1993
151 US cities (ACS cohort)	>30	552,138 adults	Linear	Median $PM_{2.5}$	**5.7%** (1.5% - 10.0%)	Pope III, Thun et al. 1995
California, USA	>27	6,338 non smoking	Linear	Avg PM_{10}	**0.1%** (0.1% - 0.1%)	Abbey, Nishino et al. 1999
Cardio-pulmonary mortality						
151 US cities (ACS cohort)	> 30	552,138 adults	Linear	Avg. 79-83 $PM_{2.5}$	**5.9%** (1.5% - 10.5%)	Pope III, Burnett et al. 2002
				Avg $PM_{2.5}$	**9.3%** (3.3% - 15.8%)	
			Log-Linear	Avg. 79-83 $PM_{2.5}$	**1.2%** (0.3% - 2.0%)	Cohen, Anderson et al.
				Avg $PM_{2.5}$	**1.6%** (0.6% - 2.5%)	
Lung cancer mortality						
151 US cities (ACS cohort)	> 30	552,138 adults	Linear	Avg. 79-83 $PM_{2.5}$	**8.2%** (1.1% - 15.8%)	Pope III, Burnett et al. 2002
				Avg $PM_{2.5}$	**13.5%** (4.4% - 23.4%)	
			Log-Linear	Avg. 79-83 $PM_{2.5}$	**1.7%** (0.3% - 3.1%)	Cohen, Anderson et al. 2004
				Avg $PM_{2.5}$	**2.3%** (0.9% - 3.8%)	

(*) For linear CR the PM2,5 change considered is 10 ug/m3. For the log-linear CR, the change considered is 10%
For example, if PM2.5 decreases 20%, the % change in lung cancer mortality, based on average PM2.5 (last line), equals -4.6% (2.3 *(-20%/10%))

Cifuentes et al., 2005

Morbidity impacts in LAC : time series study

Figure IV-2. Percentage increase in baseline effects per 10µg/m^3 of PM_{10} for morbidity endpoints in Latin-American studies



Cifuentes et al., 2005

Morbidity impacts in LAC : time series study

Short term effects of AP on respiratory morbidity in Colombia / 2011-2014

NO_2, O_3, SO_2, CO, PM2.5 and PM10

Greater % increase for PM2.5, PM10 and NO_2

Maximum for 5-9 yrs old and >60 yrs old

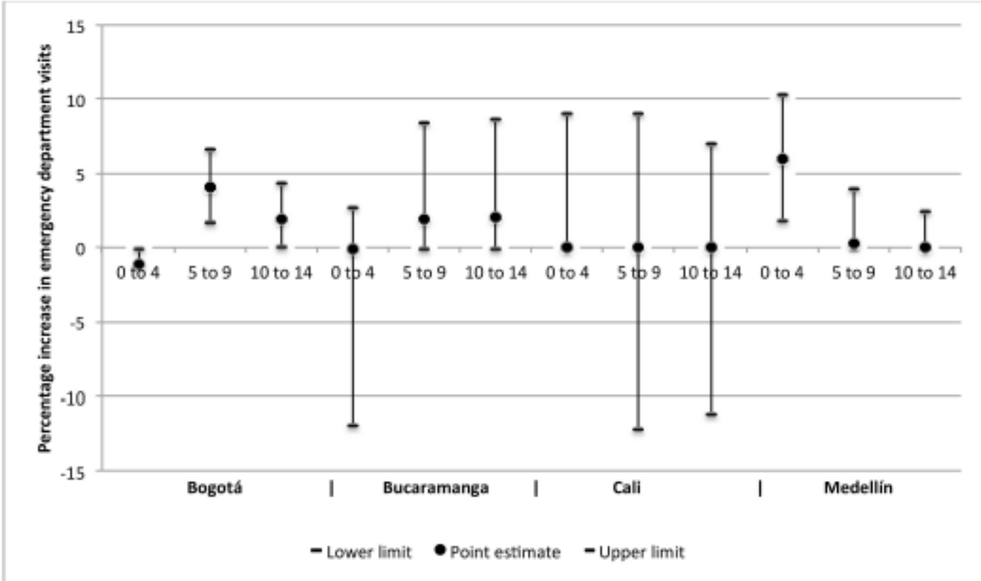


Figure 1. Percentage increases in emergency department visits by children for respiratory diseases associated with $PM_{2.5}$ concentrations, per age group, in the four cities in Colombia, 2011–2014. Point estimates and 95% confidence intervals for age groups of children in years.

Rodriguez-Villamizar Laura et al., 2018

Other morbidity effects (not exhaustive):

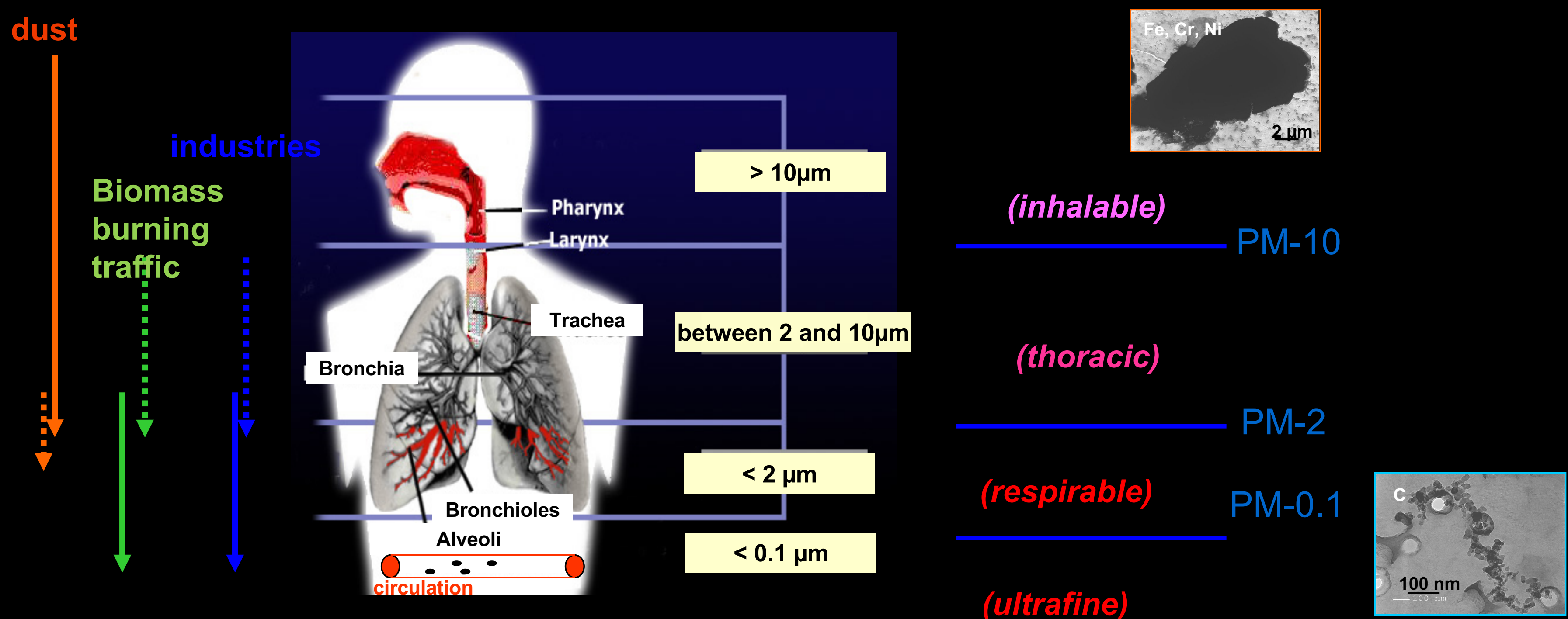
Air pollution effect on **Asthma** morbidity in LAC cities
Forno et al. 2015, Wong et al. 2013
ISAAC study : 46500 children
Impact on lung function
Link with open fire cooking systems and Asthma
Importance of vitamin C and D levels on oxidative stress

Air pollution effect on **Neural** system during neonatal and post-natal period
Gouveia et al., 2018
Medeiros et al., 2009
Calederon-Garciduenas et al. 2015 (Mexico city)
MacIntyre et al. 2014 : 10 european birth cohorts

Air pollution on **Diabetes** : Bowe et al., 2018 (https://doi.org/10.1016/S2542-5196(18)30140-2), The 2016 global and national burden of diabetes mellitus attributable to $PM_{2.5}$ air pollution (from a cohort study with US veterans).

Mechanisms of damage? : Focus on aerosols and biological studies

Respiratory system penetration linked to particle size:
inhalable, thoracic, respirable, ultra-fine

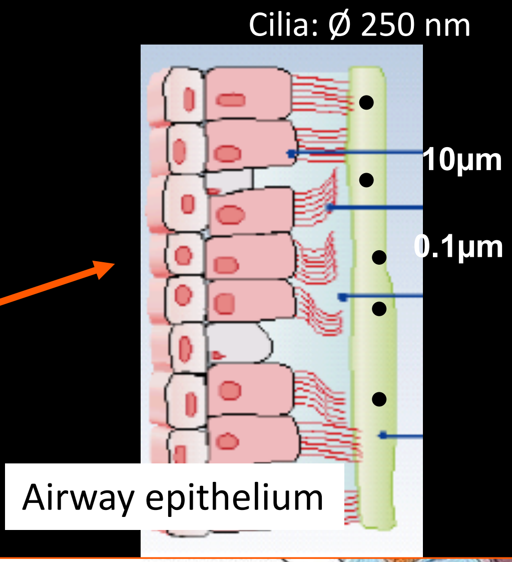


Adapted from H. Cachier, 2009

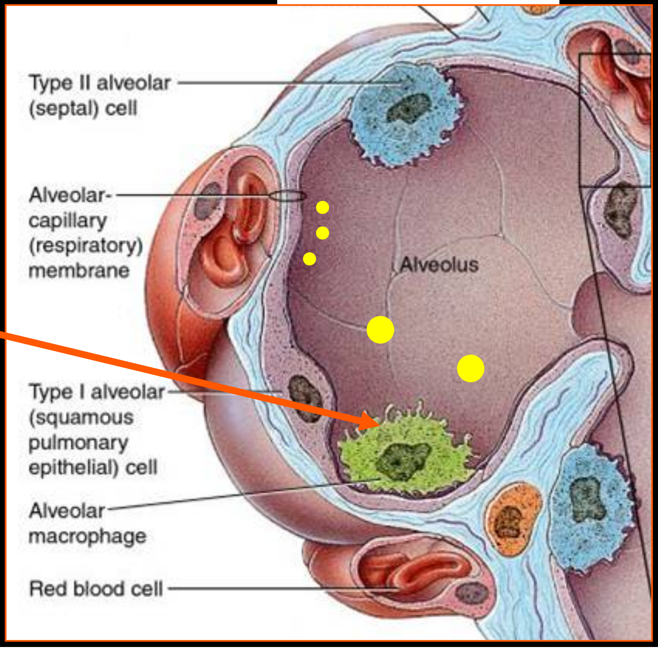
Mechanisms of defense?

Two clearance modes :

Clearance by epithelium cilia (rapid)

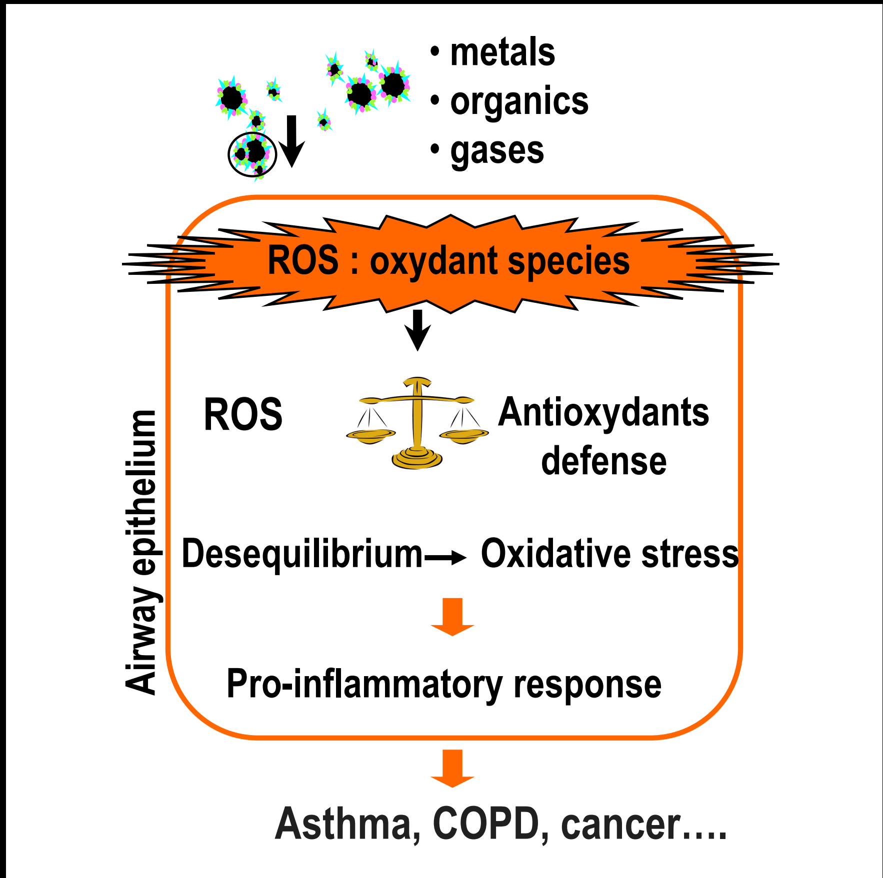


Alveoli clearance by macrophages (slow)



Adapted from A. Baeza, 2009

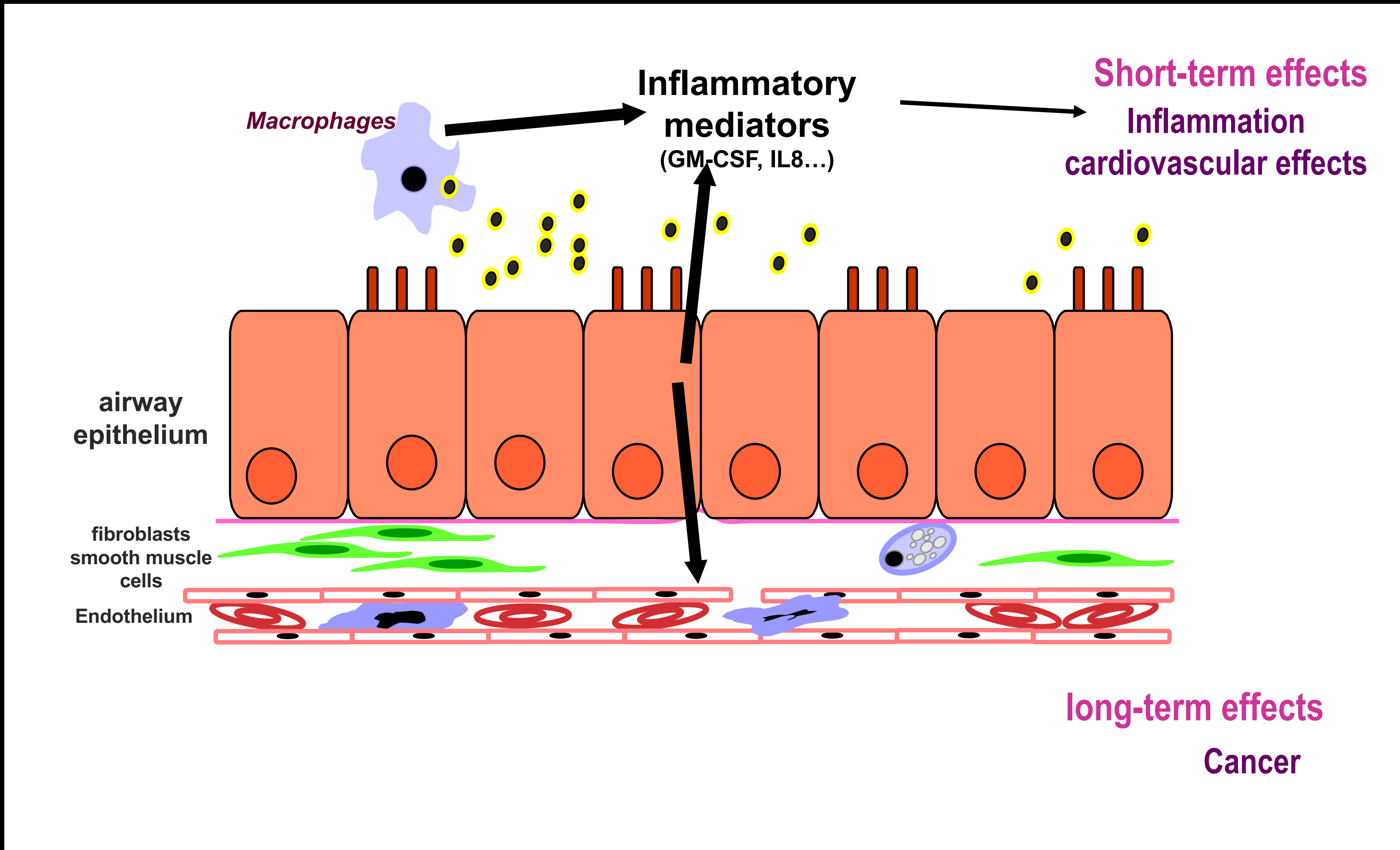
Mechanisms of defense and biological damage



Oxidative stress and inflammation : primary mechanisms to explain the impact of air pollution on health

(Korten et al. 2017)

Biological impact of particles



Adapted from A. Baeza,

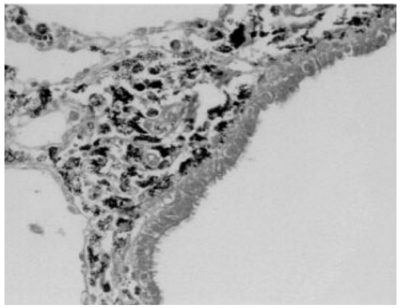
Main important characteristics of particules responsible for biological effects

Size and properties (solubility, hygroscopicity)

- Penetration
- Deposition
- Clearance

Surface reactivity

Rétention *(Churg, 2000)*



Chemical composition

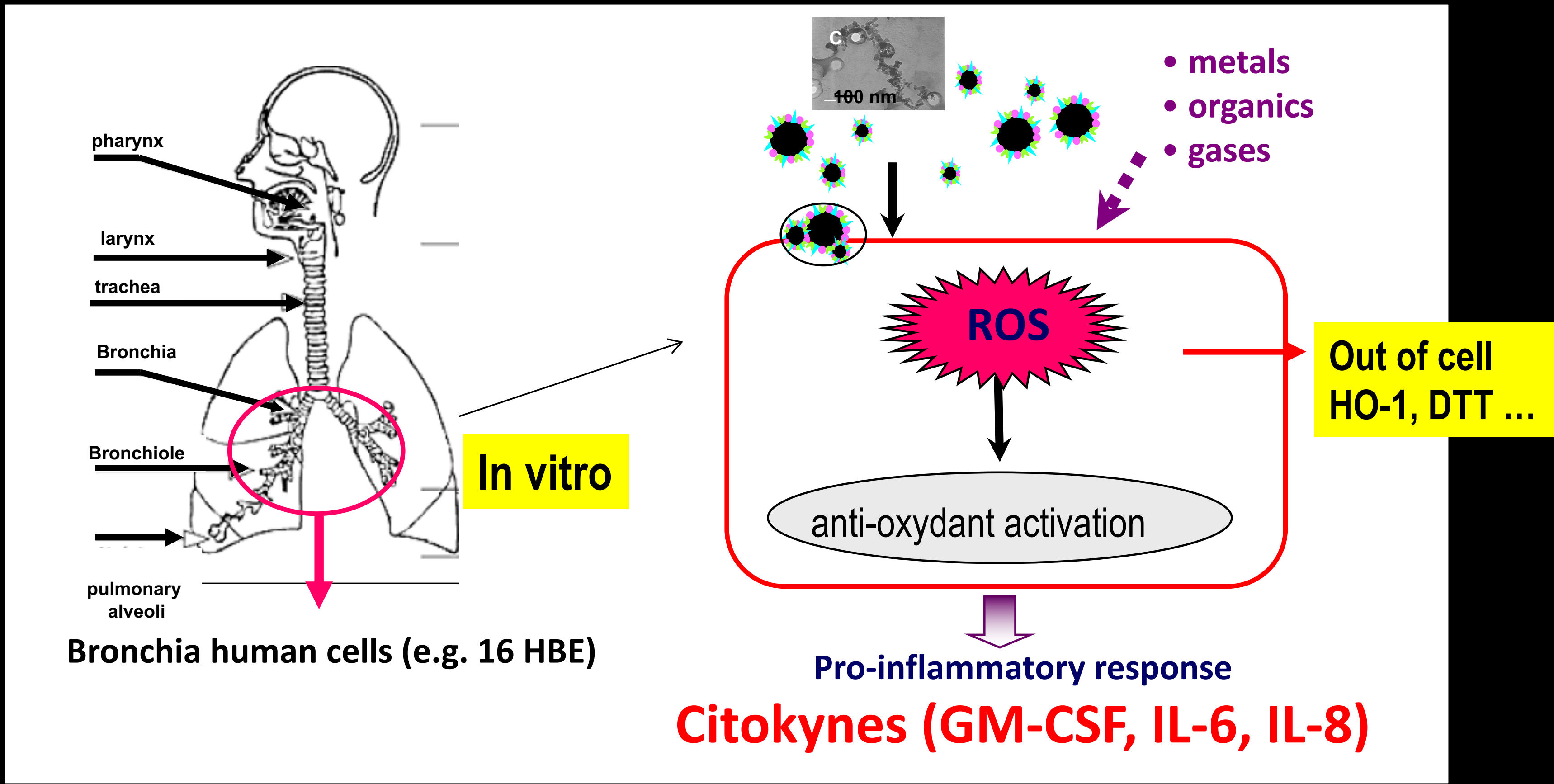
•Metals

•organics

•inorganics

Adapted from A. Baeza,

How to measure : biological measurements



In vivo measures (blood, urines, sputum…)

Adapted from A. Baeza,

Other inflammatory tracers

- Out of cells : particle pro-oxydant capacity (DTT chemical test for PAHs) or Reactive oxygen species measurements (H2O2, fluorometry).
- Urines : see table
- Blood :glutathion tests

Pollutants	PAH	Gazolin	Diesel	NO2	Metals	Oxidative stress
Biological tracer	Urinary 1-hydroxypyre ne	urinary trans, trans-muconic acid	Urinary 8-OHdG	urinary hydroxyproline ratio	Blood test: Ag^{+}, Pb^{2+}, Cd^{2+}	Ratio GSH/GSSH (blood)
Methodology	HPLC ou kit ELISA	HPLC	ELISA Kit	hypronosticon test	ICP-MS	ELISA Kit
Reference	(Llop et al., 2008)	(Ong et al., 1996) (Boogaard et van Sittert, 1995)	(Lee et al., 2010)	(Perdelli et al., 2002)	(Shirali et al., 2004)	(Lee et al., 2010)

Adapted from G. Uzu, 2010

Table 1
Characteristics of identified studies.

Study	Study location	Characteristics of subjects	Sampling technique	Exposure assessment
Bunn et al. (2001)	Leicester, UK	Healthy children (mean age 3 months to 16 years, n = 22)	BAL	Traffic. Distance from home to major road.
Kulkarni et al. (2005)	Gondar, Ethiopia and Leicester, UK	Women (n = 10) and children (n = 10) using biomass fuels for cooking from Ethiopia. Adults (n = 10) and children (n = 10) without exposure to biomass smoke from UK	IS	Biomass smoke. Kitchen and biomass fuels classified into different categories.
Kulkarni et al. (2006)	Leicester, UK	Healthy children (mean age 11.5 years, n = 64) and asthmatic children (mean age 13.6 years, n = 9)	IS	Traffic. Modeled annual mean level of primary PM_{10} at children's residence.
Fullerton et al. (2009)	Blantyre, Malawi	Healthy adults (n = 57)	BAL	Biomass smoke. Fuels for heating and cooking were categorized.
Jacobs et al. (2010)	Leuven, Belgium	Adults with diabetes (n = 137)	IS	Traffic. Recent (2 h) outdoor and indoor PM. Modeled PM_{10} level (1 d, 1 wk, 1 m, 6 m, 1 yr) at subjects' residence.
Jacobs et al. (2011)	Leuven, Belgium	Adults with diabetes (n = 137)	IS	Traffic. Recent (2 h) outdoor and indoor PM. Distance from subjects' residence to major road was calculated.
Kalappanavar et al. (2012)	Davangere, India	Children from industrial area (mean age 13.5 years, n = 300) and children from a "green" zone[a] (mean age 13.6 years, n = 300)	IS	"Ambient air quality monitoring instrument" one week before study: PM_{10} 1403 μg/m^3 (industrial area) vs 315 μg/m^3 ("green" area).
Nwokoro et al. (2012)	London, UK	Adult cyclists (n = 14) and non-cyclists (n = 14)	IS	Traffic. Personal exposure to black carbon monitored by aethalometer on a working day. Background PM_{10} measured by monitoring station.
Brugha et al. (2014)	London, UK	Healthy children (mean age 9.3 years, n = 47), children with mild asthma (mean age 9.4 years, n = 13), children with moderate to severe asthma (mean age 11.6 years, n = 36)	IS	Traffic. Modeled residential $PM_{2.5}$ level and distance between home and main road.

A new biomarker …

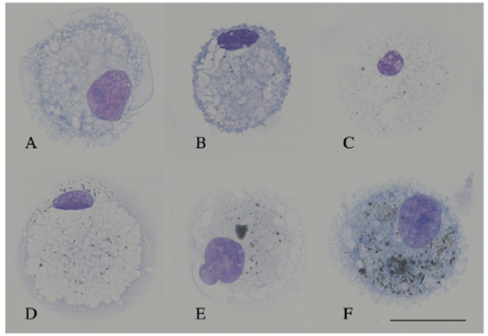


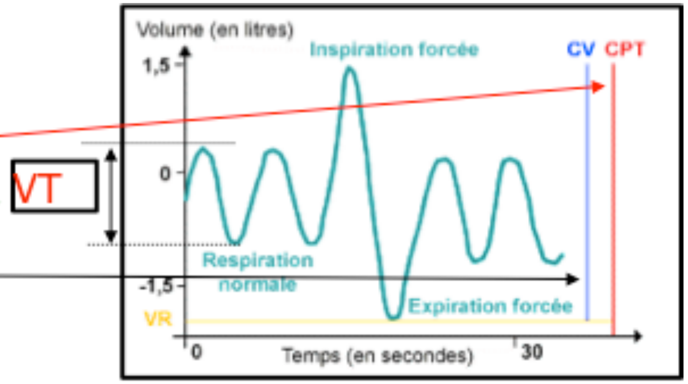
Fig. 1. Representative images of carbon loading in AM. AM were isolated from the sputum samples from one of the authors (YB). Sputum induction and processing were done according to the protocol used in Jacobs et al. (2010) and Pizzichini et al. (1996). AM were viewed under oil immersion (×1000) and digital images of AM were obtained with a light microscope (AxioPlan 2 Imaging; Zeiss, Zaventem, Belgium). Panel A shows an AM without carbon loading. Increasing levels of carbon loading are showed in Panel B through Panel F. Bar = 20 μm.

Bai et al., 2015 : Carbon loading in airway macrophages as a biomarker for an individual exposure to particulate matter => Novel approach to assess personal exposure to combustion-derived particles (9 studies in Europ, adults and children)

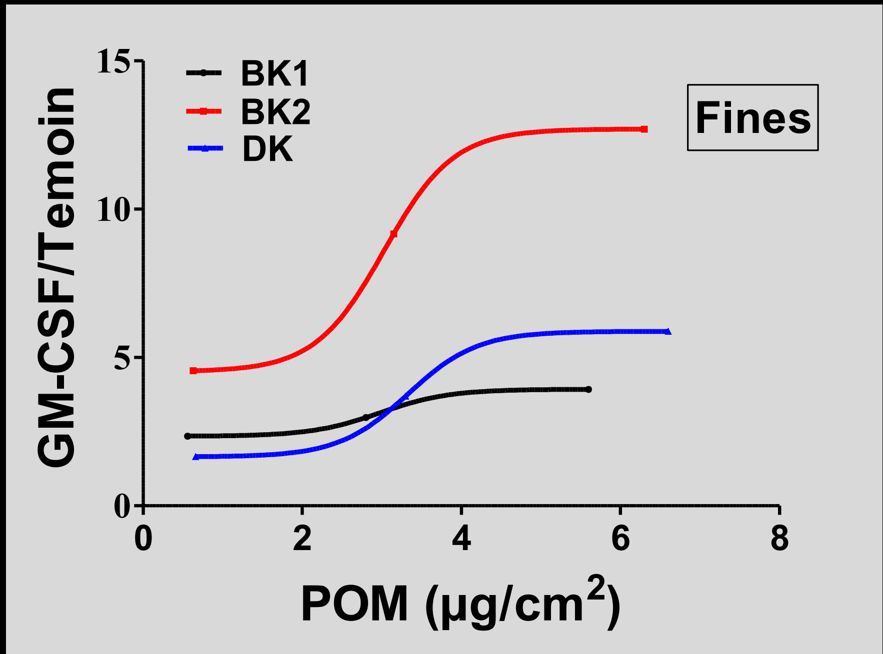
Measure the Inhaled particles phagocytosed by airway macrophages of the epithelial surfaces in the alveoli. Macrophages are collected from BAL : bronchoalveolar lavage (invasive) or IS : induced sputum (non invasive)

In vivo studies : respiratory parameters with spirometry

H : Height
W : Weight
TLC : Total Lung Capacity
FRC : Functional Residual Capacity
VC : Vital Capacity
Q : inspiratory flow rate
VT : Tidal Volume
VR : Ventillation rate



In vitro biological measurements : focus on POM/GM-CSF citokyne dose-response



- Better response for BK2 than for DK => due to POM solubility at Bamako?

	BK2	DK
WSOC/OC	0.8	0.25

- Incomplete sources (two stroke emissions and domestic fires) at Bamako (BK2) with relatively more OC and WSOC => bigger inflammatory responses than diesel sources at Dakar (DK).

Val, S., Liousse, C., Doumbia, T., … and Baeza A.., 2013

Biological measurements in LAC

Table 1 – Levels of carboxyhemoglobin before and after the risk reduction program

	Mean (% COHb)[a]	S.D. (% COHb)[a]	%<2.5[b]	%>2.5[c]	Range (% COHb)
Before	4.9*	4.3	45	55	1.05–13.88
After	1.0	0.14	100	0.0	0.65–1.30

The % of carboxyhemoglobin was measured as stated in Methods.
[a]Values are geometric data.
[b]Percentage of people with levels of carboxyhemoglobin below 2.5%.
[c]Percentage of people with levels of carboxyhemoglobin above 2.5%.
*$p<0.05$ when compared after intervention.

Torres-Dosal, Perez-Maldonado et al., et al., 2008 : Mexico => Wood as energy used by 27M of people
Health risk reductions linked to 3 measures :
soot removal on roofs and walls, floor paving and new wood-stove with a chimney

Biological measurements in LAC

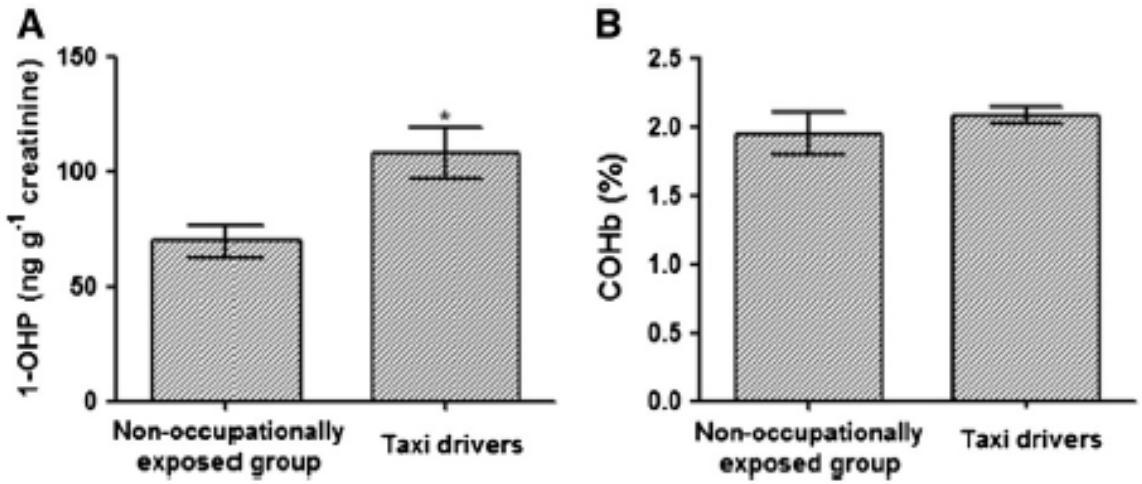


Fig. 2. (A) Urinary 1-hydroxypyrene levels (1-OHP) from non-occupationally exposed group (n = 21) and taxi drivers (n = 39). Data are expressed as mean ± SEM. *p < 0.05. (B) Carboxyhaemoglobin levels (COHb) from non-occupationally exposed group (n = 21) and taxi drivers (n = 39).

Brucker et al., 2013 : Porto Aligre (South of Brazil)
Biomarker of exposure to PAH from traffic on 60 subjects (with urinary and blood tests)

« The » relationship to calculate Excess mortality numbers …. At all scales

Un example: Excess mortalities due to 2005 to 2030 emission change (ΔPM2.5)

=> Use the following relationships (Anenberg et al., 2010, Lelieveld et al., 2013)

$$\Delta death = y0 * (1 - exp - ß \Delta PM2.5) * POP$$

where

y0 is the baseline mortality rate (WH0) for different mortalities

POP is the exposed population (>30yrs)

ß is the concentration response factor

*RR= (exp ß*ΔPM2.5)*

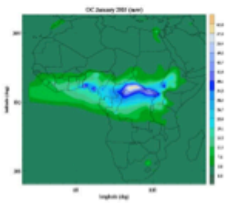
Given by the model

RR is the relative risk for a 10µm/m3 PM2.5 increase

Here : RR (all causes) : 1.06 ; RR (lung cancer) : 1.06; RR (cardiopulmonary : 1.11); RR (respiratory diseases : 1.06) (=> miminim of litterature range)

An example of Aerosol/Health Regional modeling

Spatial distribution
of PM10,PM2.5, BC, OC, WSOC …
with RegCM4 model
for different sources et scenarios



x population

Dose/Response
1- RR-bibliography
2- RR-measured

Estimation of pollution effects
(PM2.5, BC, ..)

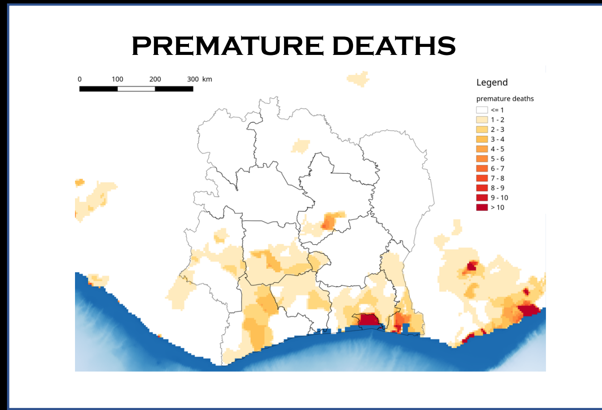
Bronchitis
Asthma
Mortality

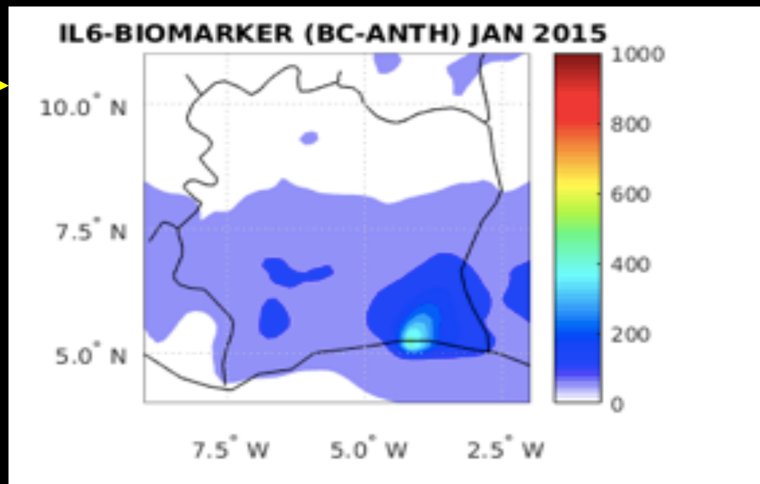
?

x population

Dose/inflammatory biomarkers
(in vitro ..)

Toxicological risk
Spatial distribution





DACCIWA

Liousse et al., 2020

Table 2. Estimated annual mortalities ± 1 SD due to anthropogenic O_3 and $PM_{2.5}$, assuming natural background only or LCTs (33.3 ppb for O_3 and 5.8 μg/m^3 for $PM_{2.5}$) (× 1,000).

	O_3 respiratory		$PM_{2.5}$ cardiopulmonary		$PM_{2.5}$ lung cancer	
	Background	Threshold	Background	Threshold	Background	Threshold
Africa	63 ± 34	45 ± 30	154 ± 44	52 ± 33	3 ± 1	1 ± 1
North America	35 ± 17	25 ± 15	124 ± 37	65 ± 30	17 ± 7	10 ± 5
Europe	41 ± 21	23 ± 17	586 ± 149	383 ± 143	47 ± 17	31 ± 14
Asia	543 ± 253	370 ± 220	2,584 ± 618	1,991 ± 603	152 ± 53	122 ± 47
South America	18 ± 9	8 ± 6	48 ± 15	16 ± 9	2 ± 1	1 ± 1
Oceania	1 ± 1	0 ± 0	2 ± 1	0 ± 0	0 ± 0	0 ± 0
World	700 ± 335	470 ± 288	3,499 ± 864	2,506 ± 816	222 ± 80	164 ± 68

SDs reflect uncertainty in the CRF and simulated present-day concentrations (SD = 25% of simulated concentration).

Anenberg et al., 2010

26 LAC cities (86 M people)
If PM10 = norms : 13500 avoided deaths per year (2-2.6% of death avoided/yr)
If PM10 decrease of 10µg/m^3 : 12-25% of deaths avoided

Cifuentes et al., 2005

Table 1 Excess mortality attributable to ambient air pollution[a]

	Mortality (×10^3/year)	Deaths per 100 000 (year^{-1})	YLL (×10^6/year)	LLE (years)	Avoidable LLE (years)	Avoidable mortality (×10^3/year)	Mortality for disease categories (×10^3/year)					
							LRI	COPD	LC	CEV	IHD	Other NCD
Africa	957	81	40.0	3.1	0.7	230	378	36	7	113	224	199
East Asia	3112	196	67.4	3.9	3.0	2403	204	511	300	738	779	580
South Asia	2809	119	83.6	3.3	1.9	1660	478	509	61	383	981	397
West Asia	544	94	14.6	2.3	1.0	241	50	27	19	76	292	80
Europe	790	133	14.3	2.2	1.7	608	54	49	54	64	313	256
Australia	14	47	0.3	0.8	0.2	3	0.6	0.8	0.9	0.6	4	7
North America	360	74	7.5	1.4	1.1	294	24	40	24	14	112	146
South America	207	42	5.3	1.0	0.5	115	30	14	6	14	63	80
World	8793	120	233	2.9	1.7	5554	1218	1187	472	1403	2768	1745

Avoidable LLE and mortality were calculated by removing anthropogenic emissions in the model. Australia also includes other islands of Oceania. Data for all countries, including 95% uncertainty intervals, are given in the Supplementary material online, *Tables* (overall uncertainty about ±50%).
CEV, cerebrovascular disease; COPD, chronic obstructive pulmonary disease; IHD, ischaemic heart disease; LC, lung cancer; LLE, loss of life expectancy; LRI, lower respiratory infections; NCD, non-communicable diseases; YLL, years of life lost.
[a]Excess mortality expresses the number of deaths over a given period that would not occur in the absence of exposure.

Lelieveld et al., 2013, 2020

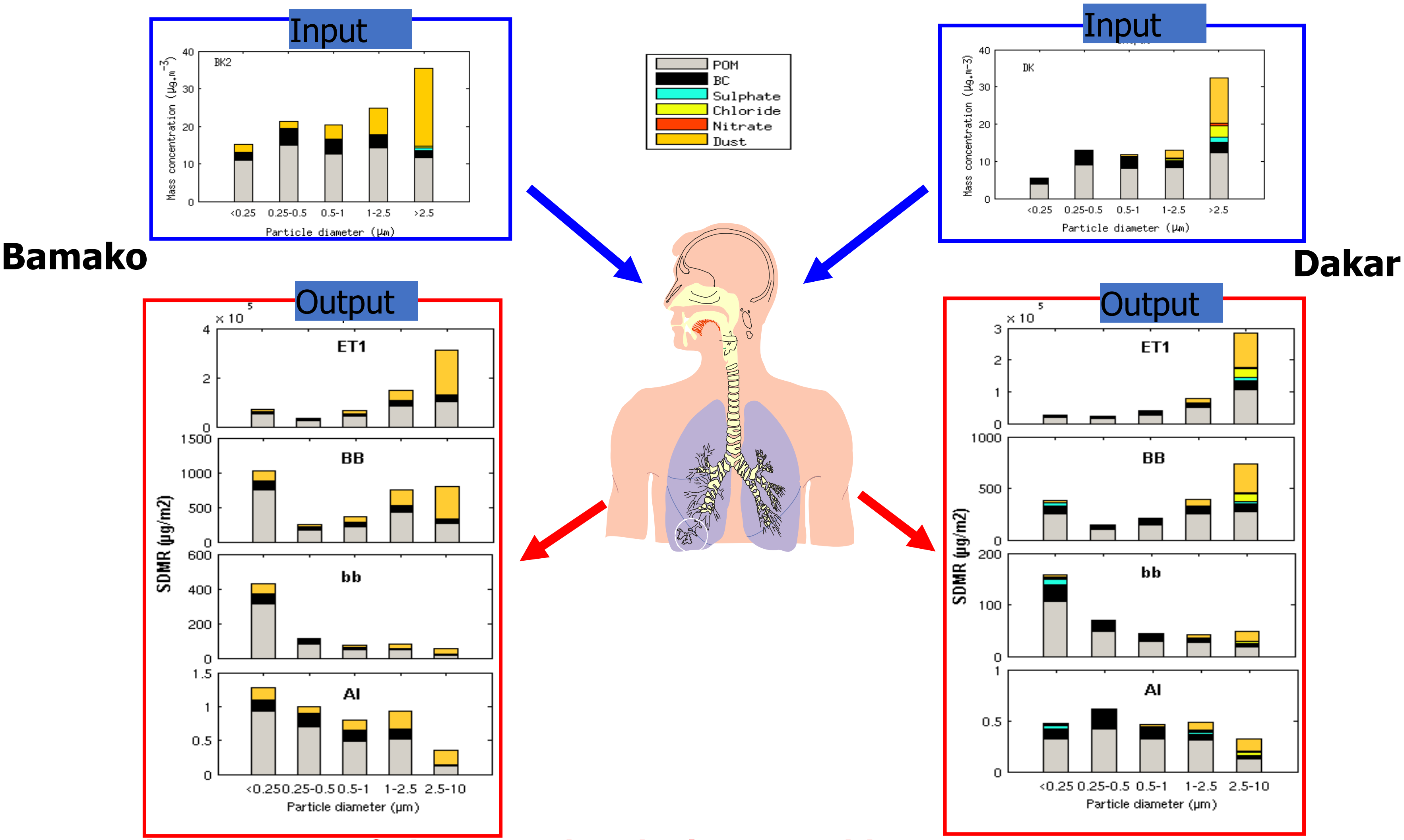
Mexico City; Santiago; and São Paulo.
2000-2020 : 2 scenarios
Modest changes in fossil fuel use
Avoided in the three cities :
156,000 deaths, 4 million asthma attacks,
300,000 children's medical visits,
and almost 48,000 cases of chronic bronchitis

Bell et al., 2005

Take-home messages

- **New proxys for health such as aerosol oxydant capacity are really important for long-term crossed air pollution and health studies**
- **Need to integrate sociological factors within the calculation of dose response functions (people vulnerability to air pollution)**
- **Do not separe urban studies on health and climate (we need win-win results).**
- **Reconciling epidemiological studies with process (biological) studies : need more cohort studies with personal exposure measurements (exposology) : a way to act on source mitigation.**

The inhaled aerosol is not the same than in alveoli



Importance of size and chemical composition

Doumbia T. phD (POLCA program)

Thanks for your attention