

A review of quantitative health impact assessments of ozone and particulate matter under a changing climate

V. N. Likhvar^{1,4}, K. Markakis², M. Valari², A. Colette³, D. Hauglustaine⁴, S. Medina¹, M. Pascal¹, P. Kinney⁵

1/ InVS, French Institute of Public Health Surveillance, Saint-Maurice, France – 2/ LMD, Laboratoire de météorologie dynamique, IPSL, École Polytechnique, Palaiseau, France

3/ Ineris, Institut national de l'environnement industriel et des risques, France – 4/ LSCE, Laboratoire des sciences du climat et de l'environnement, Gif-sur-Yvette, France – 5/ Columbia University in the City of New York, NY, U.S.

Introduction

Health impact assessments (HIA) have been extensively used to assess the burden of present air pollution and promote policies to improve air quality. With the development of air quality and climate models, there has been a growing interest in investigating the future health impacts of air pollution, especially under a changing climate. The interactions between climate change and air quality are complex and involve several modelling steps as summarised in figure 1.

The purpose of this review is to provide an overview of the existing literature on the HIA of future air pollution in a context of climate change.

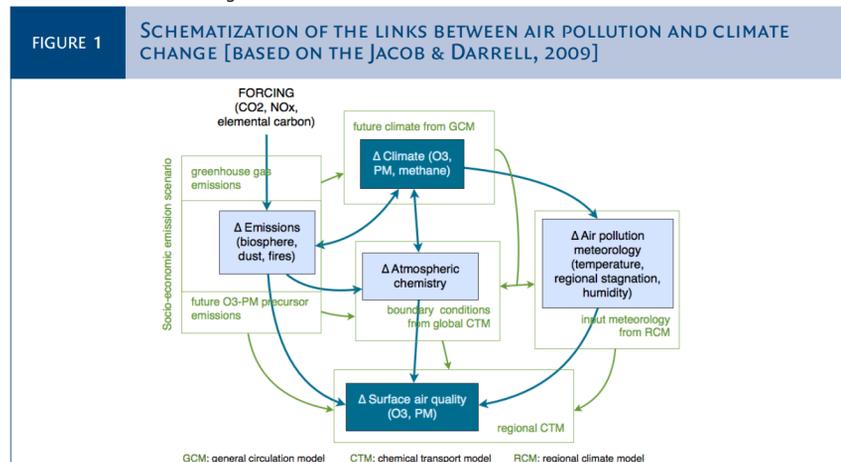
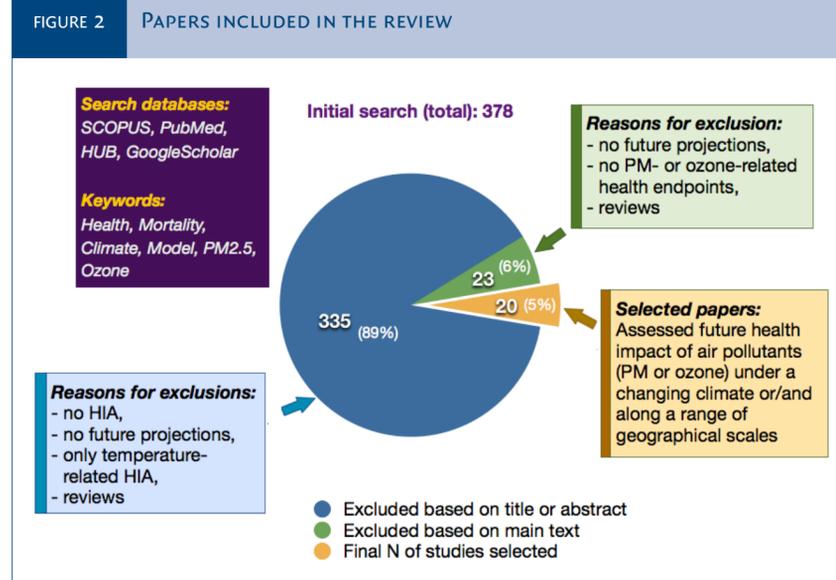


FIGURE 1 SCHEMATIZATION OF THE LINKS BETWEEN AIR POLLUTION AND CLIMATE CHANGE [BASED ON THE JACOB & DARRELL, 2009]

Method

The search for the literature review was conducted in May 2012 through major academic databases (figure 2).



Results

Three types of papers were distinguished:

- Studies examining the potential impact of climate change on air quality and health. The impact of PM or ozone emission mitigation measures are not taken into account (7 papers: [1;3-6;8;11;14-15]).
- Studies examining the potential impact of PM or ozone precursor emission mitigation measures on air quality and health. The impact of climate change is not taken into account (6 papers: [2;12;17-20]).
- Studies examining both, the potential impact of climate change and PM or ozone emission mitigation measures, on air quality and health (7 papers: [7-10;13-14;16]).

17 papers quantified the health impacts of ozone, and 6 of PM. Consistently with the epidemiological literature, short-term mortality was the preferred health outcome for ozone, and long-term mortality was mostly investigated for PM.

Studies are summarized in the following tables (1-3).

TABLE 1		SUMMARY OF THE STUDIES QUANTIFYING THE HEALTH EFFECTS OF PM AND OZONE										
Type	Reference	Ref. N	Area	1960	1990	2000	2020	2030	2050	2060	2080	2100
Ozone												
b	West et al. 2006	[19]	World									
b	West et al. 2007	[20]										
b	Anenberg et al. 2012	[2]										
c	Selin et al. 2009	[13]										
b	Thompson & Selin 2012	[17]	North America									
a	Bell et al. 2007	[3]										
a	Chang et al. 2010	[4]										
a	Post et al. 2012	[11]										
a	Tagaris et al. 2009	[15]										
a	Cheng et al. 2008	[5]										
c	Knowlton et al. 2004	[8]										
c	Sheffield et al. 2011	[14]										
c	Tagaris et al. 2010	[16]										
a	Anderson et al. 2001	[1]	Europe (EU)									
c	Kovats et al. 2008	[9]										
c	Heal et al. 2012	[7]										
c	Orru et al. 2013	[10]										
b	Anenberg et al. 2012	[2]		World								
b	Saikawa et al. 2009	[12]										
a	Tagaris et al. 2009	[15]	North America									
c	Tagaris et al. 2010	[16]										
a	Dias et al. 2012	[6]		EU								
b	Wang & Mauzerall 2006	[18]	Asia									

CV: cardiovascular; CVR: cardiovascular and respiratory; RHA: respiratory hospital admission; SD: symptom day; RAD: restricted activity days; URS: upper respiratory symptoms; LRS: lower respiratory symptoms; SDL: school days loss; ERV: emergency room visits; BU: bronchodilator usage; CP: cardiopulmonary.

TABLE 2		SUMMARY OF THE MODELS AND CLIMATE CHANGE AND EMISSION SCENARIOS USED IN THE STUDIES			
AQ Model	Scale	Resolution	Scenario	Reference	
STOCHEM	Global	5° x 5°	IPCC SRES (2000): A2; IS92a	[1]	
NASA GISS GCM: GISS-PUCCIN ^o (Shindell et al., 2006)	Global	[4°lat. x 5°lon.] ¹ [2°lat. x 2.5°lon.] ²	IPCC SRES (2000): A2, A1B	[2 ^a ;3;8 ¹ ;14;15 ¹ ;16 ¹]	
ECHAM-HAMMOZ ¹ , ECHAM4 ²	Global	2.8° x 2.8°	IPCC SRES (2000): A2, A1B	[2 ¹ ;10 ²]	
NCAR MATCH + RCA3 for downscaling	Global	50km	IPCC SRES (2000): A2, A1B	[10]	
GEOS-CTM	Global	4°lat. x 5°lon.	IPCC SRES (2000): A1B	[13]	
MOZART-2 (Horowitz et al., 2003)	Global	1.9° x 1.9°	IPCC SRES (2000) A2; current legislation (CLE); maximum feasible reduction (MFR)	[12;19]	
LMDz-INCA	Global	3.8°lon. x 2.6°lat.	IPCC SRES (2000) A2	[20]	
HadCM3: HadAM3 ^o , HadRM3 ^o	Global ¹ / Regional ²	[3.8°lon. x 2.6°lat.] ¹ [50km] ²	IPCC SRES (2000): A2, A1B; CLE	[6 ¹ ;9 ¹ ;10]	
EMEP4UK	Regional	50km → 5km	IPCC SRES (2000) A2; CLE + IPCC SRES B2; MFR+ IPCC SRES B2	[7]	
CAMx (www.camx.com)	Regional	36km → (12km, 4km, 2km)	IPCC SRES (2000): A2	[17]	
CHIMERE	Regional / Urban	50km, 10km	IPCC SRES (2000): A2	[6]	
CMAQ + MM5 for downscaling	-	108km ¹ → 36km ² → 12km ³	IPCC SRES (2000): A2, A1B; BAU, BACT, ACGT (based on energy technology improvements)	[3 ² ;8 ¹ ;14 ² ;15 ² ;16 ¹ ;18 ² ;3]	

TABLE 3		SUMMARY OF THE CONCENTRATION RESPONSE FUNCTIONS (CRFs) USED IN THE STUDIES			
O ₃ - Mortality	Age	Ref. of CRFs	RR	Reference	
Total or total non-accidental	All	Bell et al. 2004	0.043 (95% CI: 0.027,0.079)	[3;4;11;15;16;17;20]	
Total	All	Anderson ¹ et al. 2004 Kovats ² et al. 2008	0.3% (95% CI: 0.1,0.43%) ¹ per 10 µg/m ³ ; 0.3% (95%CI: -0.05,0.74) ²	[9 ² ;10 ¹ ;13 ¹ ;17]	
Cardio	All	Thurston & Ito 2001	1.056 (95% CI: 1.032,1.081) per 100 ppb	[8]	
Cardiovasc. & respirat.	30+	Bell et al. 2004 Jerrett et al. 2009	0.64% (95% PI: 0.31%,0.98%) 1.04 (95% CI: 1.010,1.067)	[19;20]	
O ₃ - Morbidity	Age	Ref. of CRFs	RR	Reference	
Respiratory hosp. adm.	All	COMEAP 1998	1.4% per 10 ppb	[7]	
Respiratory hosp. adm.	All	Kovats et al. 2008	0.1% (95%CI: -0.3,0.6)	[9]	
Respiratory hosp. adm.	65+	APHEIS 2002	12.5 (95% CI: -5.0,30.0) per 100,000	[13]	
Respiratory hosp. adm.	[65+] ¹ [15-64] ²	Anderson et al. 2004	1.005 (95%CI: 0.998,1.012) ¹ per 10µg/m ³ 1.001 (95%CI: 0.991,1.012) ² per 10µg/m ³	[9;10]	
Respiratory symptom days		Krupnik et al. 1990	0.033 (95% CI: 0.0057,0.063)	[13]	
Low respiratory symptoms	5-14	Hoek and Brunekreef 1995	0.16 (95% CI: -0.43,0.81) per 10 µg/m ³	[13]	
Asthma ERV	0-17	Tolbert et al. 2007	1.04 (95% CI: 1.008,1.073) per 20 ppb	[14]	
Asthma "attacks"		Whittemore & Korn 1980	0.00429 (95% CI: 0.00033,0.0083)	[13]	
Bronchodilator usage	20+	Hiltemann et al. 1998	730 (95% CI: -255,1570) per 10 µg/m ³ per 1000	[13;17]	
Minor restricted activity days	18-64	Ostro & Rothschild 1989	115 (95% CI: 44,186) per 10 µg/m ³ per 1000	[13;17]	
PM _{2.5} - Mortality	Age	Ref. of CRFs	RR	Reference	
Total	30+	Pope et al. 2002	1.06 (95% CI: 1.02,1.11)	[2;12;15;16;18]	
Cardiopulmonary	30+	Pope et al. 2002	1.09 (95% CI: 1.03,1.16)	[2]	
Lung cancer	30+	Pope et al. 2002	1.14 (95% CI: 1.04,1.23)	[2]	

Discussion

HIA predicting the future impacts of air pollution is a new field with few but increasing number of studies and a large diversity of methods, for climate models, air quality models, and health impact models.

The more common sources of uncertainties in the reviewed studies are: models, geographical resolution, emissions, and CRFs. However, the weight of each source is rarely quantified. The issues of the health data availability and data quality are rarely discussed.

All papers present data modeling on the global or/and regional scales. The coarse resolution, coupled with unrepresentative emission fluxes, limits the capacity to perform HIA in large urban centers where air pollution is a major issue. In this case, a finer resolution should be used.

It is also crucial to fully understand the basis of the emission scenarios, in order to choose the most relevant ones depending on the objectives of the HIA. Close collaboration with climate and air quality modelers is necessary.

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