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

V. N. Likhvar[1,4], K. Markakis[2], M. Valari[2], A. Colette[3], D. Hauglustaine[4], S. Medina[1], M. Pascal[1], P. Kinney[5]

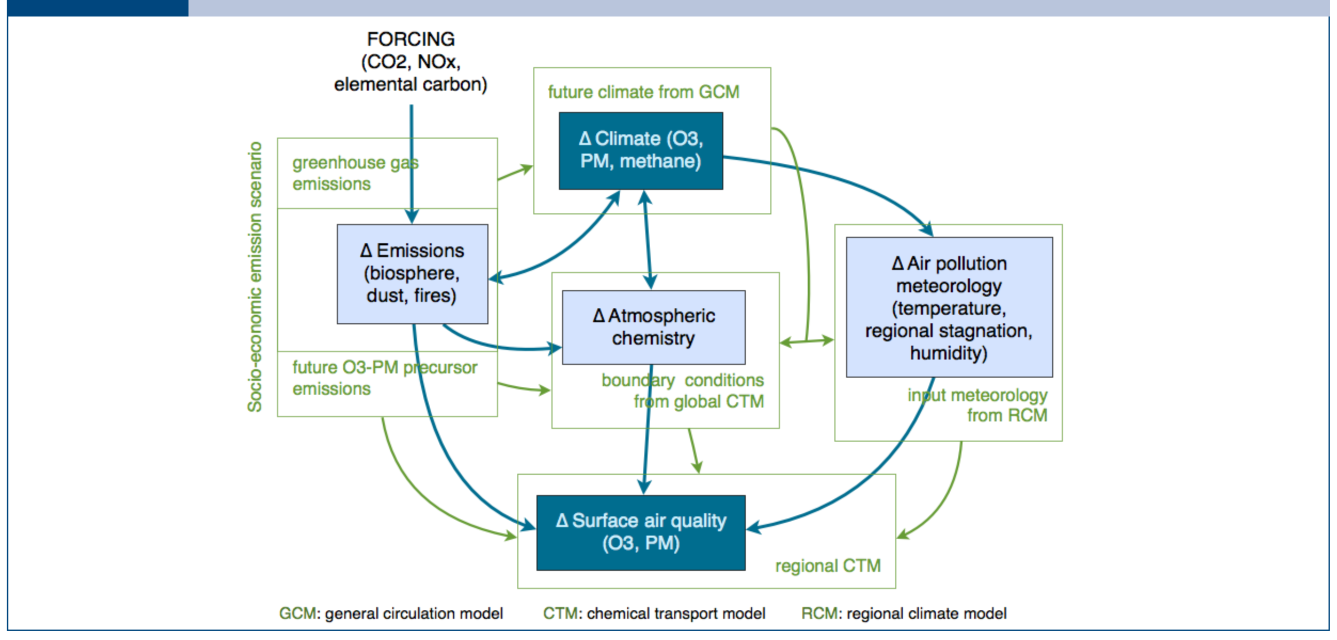
1/ InVS, French Institute of Public Health Surveillance, Saint-Maurice, France – 2/ LMD, Laboratoire de météorologie dynamique, IPSL, École Polytechnique, Palaiseau, France
3/ Ineris, Institut national de l'environnement industriel et des risques, France – 4/ LSCE, Laboratoire des sciences du climat 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.

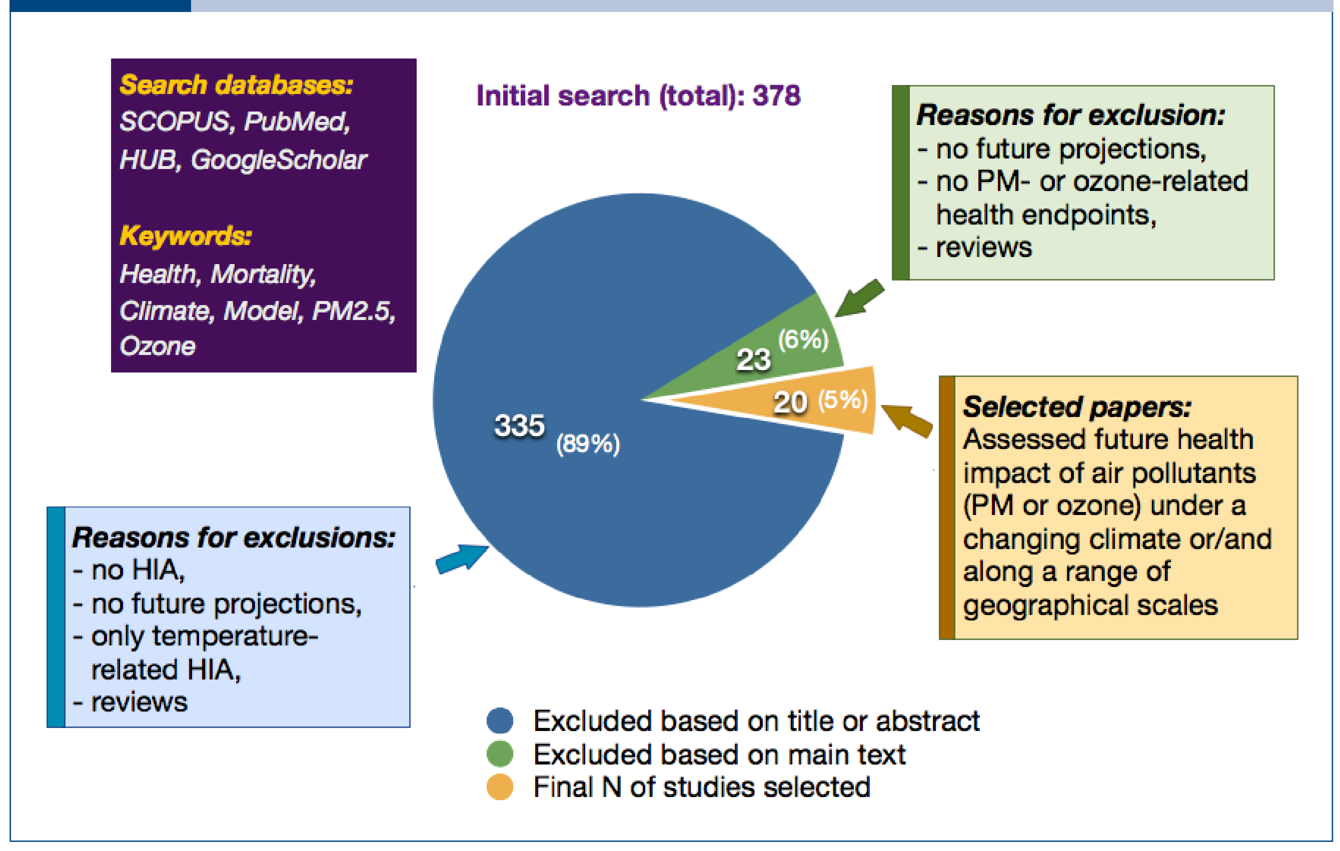
FIGURE 1 Schematization of the links between air pollution and climate change [based on the Jacob & Darrell, 2009]



Method

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

FIGURE 2 Papers included in the review



Results

Three types of papers were distinguished:

a. 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]).

b. 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]).

c. 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	Short-term: CVR
b	West *et al.* 2007	[20]	World	Short-term: Total (non-acc.), CV, Respiratory
b	Anenberg *et al.* 2012	[2]	World	Long-term: Respiratory
c	Selin *et al.* 2009	[13]	World	Short-term: Total, RHA (65+), Respiratory SD, Minor RAD, Asthma “attacks”, BU, LRS in children.
b	Thompson & Selin 2012	[17]	North America	Short-term: BU, Minor RAD
a	Bell *et al.* 2007	[3]	North America	Short-term: Total (non-acc.), CV, Respiratory, COPD (65+), RHA (65+), Asthma (<65)
a	Chang *et al.* 2010	[4]	North America	Short-term: Total (non-acc.)
a	Post *et al.* 2012	[11]	North America	Short-term: Total (non-acc.), RHA, Minor RAD, SDL, Asthma ERV
a	Tagaris *et al.* 2009	[15]	North America	Short-term: Total (all ages), RHA (adults), Asthma ERV (all ages), Days of acute respiratory symptoms (18-64), SDL (5-17)
a	Cheng *et al.* 2008	[5]	North America	Short-term: Total
c	Knowlton *et al.* 2004	[8]	North America	Short-term: All internal causes
c	Sheffield *et al.* 2011	[14]	North America	Short-term: Asthma ERV
c	Tagaris *et al.* 2010	[16]	North America	Short-term: Total
a	Anderson *et al.* 2001	[1]	Europe (EU)	Short-term: Total. RHA
c	Kovats *et al.* 2008	[9]	Europe (EU)	Short-term: Total, RHA
c	Heal *et al.* 2012	[7]	Europe (EU)	Short-term: All-cause, RHA
c	Orru *et al.* 2013	[10]	Europe (EU)	Short-term: RHA
				PM
b	Anenberg *et al.* 2012	[2]	World	Long-term: All-cause, CP, Lung Cancer
b	Saikawa *et al.* 2009	[12]	World	Long-term: Total
a	Tagaris *et al.* 2009	[15]	North America	Short- & long-term: Total (30 and 2-12 months old), Onset of new cases of chronic bronchitis (27), CV HA (18-64 and 65+), Days of aggravation of existing asthma (6-18), Cases of acute bronchitis (8-12), Days with URS (9-11), Days with LRS (7-14)
c	Tagaris *et al.* 2010	[16]	North America	Long-term: Total
a	Dias *et al.* 2012	[6]	EU	Short-term: All internal causes
b	Wang & Mauzerall 2006	[18]	Asia	Long-term: Total

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-PUCCINI^{a} (Shindell *et al.*, 2006)	Global	[4°lat. × 5°lon.]^{1} [2°lat. x 2.5°lon.]^{2}	IPCC SRES (2000): A2, A1B	[$2^{a,2}$;3;8^{1};14; 15^{1};16^{1}]
ECHAM-HAMMOZ^{1}, **ECHAM**4^{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. × 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: HadAM3P^{a}, HadRM3P^{b}	Global^{1} / Regional^{2}	[3.8°lon. × 2.6°lat.]^{1} [50km]^{2}	IPCC SRES (2000): A2, A1B; CLE	[6^{a};9^{b};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}; $16^{1,2}$;$18^{2,3}$]

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^{1}]
Total	All	Thurston & Ito 2001	1.056 (95% CI: 1.032,1.081) per 100 ppb	[8]
Cardio	All	Bell *et al.* 2004	0.64% (95% PI: 0.31%,0.98%)	[19;20]
Cardiovasc. & respirat.	30+	Jerrett *et al.* 2009	1.04 (95% CI: 1.010,1.067)	[2]
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 10 µg/m^{3} 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+	Hiltermann *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 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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FRENCH INSTITUTE FOR PUBLIC HEALTH SURVEILLANCE

Contact : Victoria Likhvar (v.likhvar@invs.sante.fr) - French Institute for Public Health Surveillance - Environmental Health Department - 12, rue du Val d'Osne 94415 Saint-Maurice Cedex - Tél. : +33 (0)1 41 79 69 41 - Fax : +33 (0)1 41 79 67 68