An old issue on the front burner: Health and environmental impacts of gas stoves

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THE UNIVERSITY OF BRITISH COLUMBIA

NCCEH Webinar, April 19, 2023


UBC

The issues

- Gas Stoves
  - Exacerbation of respiratory disease (asthma, COPD)
  - Incident asthma
  - Climate impacts
- The role of NO_2
  - Revised WHO Air Quality Guidelines

A US federal agency is considering a ban on gas stoves

By Ramishah Maruf, CNN

Updated 9:02 PM EST, Wed January 11, 2023

Video Ad Feedback

The New York Times

OPINION

FARHAD MANJOO

Your Gas Stove May Be Killing You. How Much Should You Worry?

Jan. 13, 2023

The New York Times

Gas Stoves | Could They Be Banned? | Climate and Health Concerns | How to Lower Your Risk | Alternatives to Gas Stoves

Ban Gas Stoves? Just the Idea Gets Some in Washington Boiling.

The nation's top consumer watchdog agency raised concerns about indoor air pollution from gas stoves. A political firestorm ensued.

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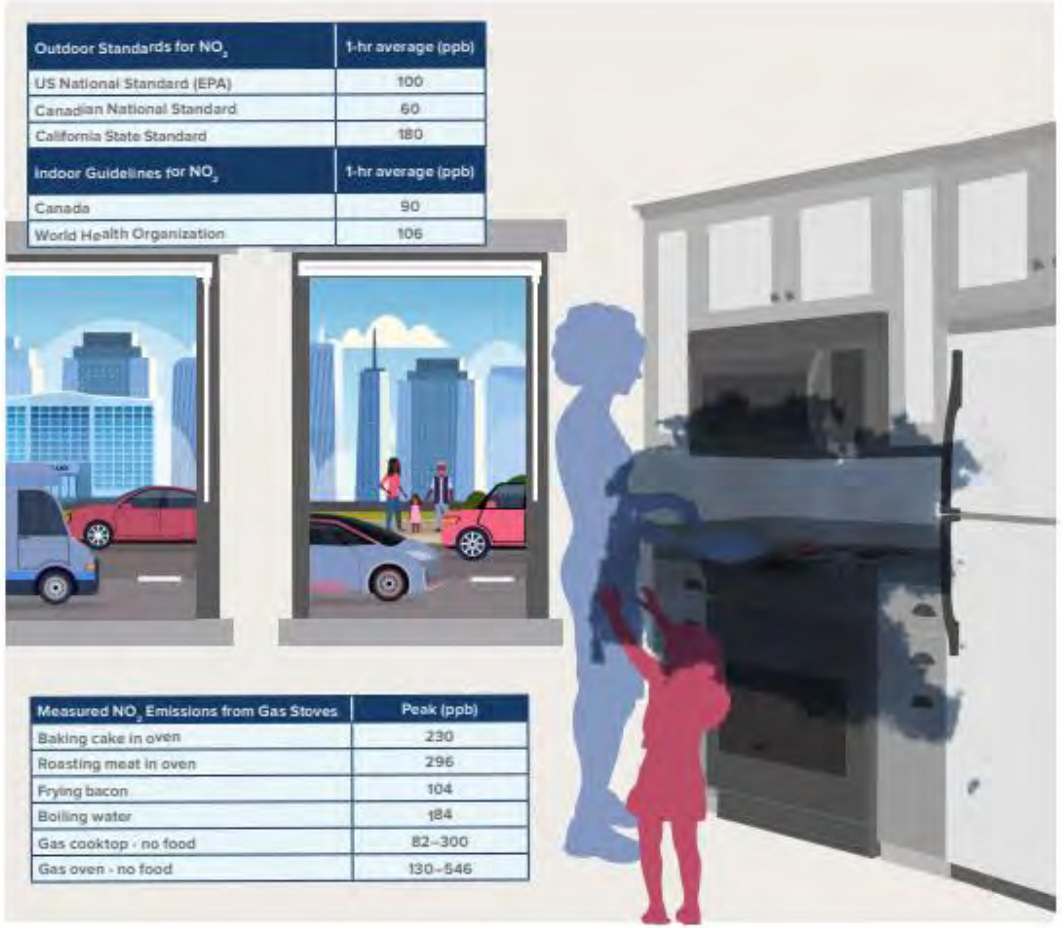
Gas stoves are used in about 35 percent of U.S. households, or about 40 million homes. Sean Gallup/Getty Images

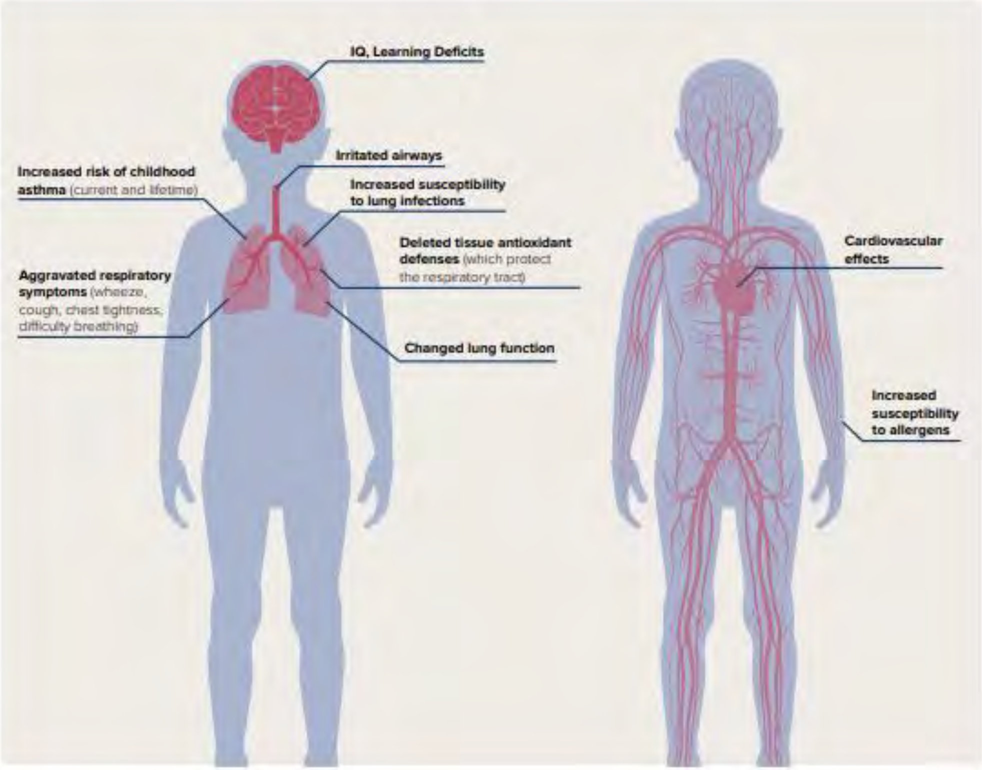


Outdoor Standards for NO_2	1-hr average (ppb)
US National Standard (EPA)	100
Canadian National Standard	60
California State Standard	180

Indoor Guidelines for NO_2	1-hr average (ppb)
Canada	90
World Health Organization	106

Measured NO_2 Emissions from Gas Stoves	Peak (ppb)
Baking cake in oven	230
Roasting meat in oven	296
Frying bacon	104
Boiling water	184
Gas cooktop - no food	82–300
Gas oven - no food	130–546

Low income households



The False Promise of Natural Gas

Philip J. Landrigan, M.D., Howard Frumkin, M.D., Dr.P.H., and Brita E. Lundberg, M.D.

Production of natural gas has grown by nearly 400% in the United States since 1950, and gas is now the country's second-largest energy source. The main driver of this increase has been the wide-scale adoption of hydraulic fracturing ("fracking"). During the fracking process, large volumes of water, sand, and chemicals are injected deep underground at high pressure to fracture shale deposits and sand and coal beds to release trapped gas. The world's largest gas-transmission network — with more than 300,000 miles of interstate and intrastate transmission pipelines, 2.1 million miles of local distribution lines, and more than 1000 compressor stations — brings this gas to the market. The ready availability of gas has reduced dependence on coal and oil, enables the United States to ship gas overseas, and will make the country a net energy exporter by 2020.[1] It has also made gas an important feedstock for the chemical, pesticide, and plastics-manufacturing industries.

Natural gas, composed principally of methane, has been hailed as a clean "transition" fuel — a bridge from the coal and oil of the past to the clean energy sources of the future. This claim is partially true. Gas combustion produces only negligible quantities of sulfur dioxide, mercury, and particulates. It is thus less polluting than combustion of coal or oil, and this benefits health.[2] Gas combustion also generates less carbon dioxide per unit of energy than combustion of coal or oil.

But beneath this rosy narrative lies a more complex story. Gas is associated with health and environmental hazards and reduced social welfare at every stage of its life cycle.[2] Fracking is linked to contamination of ground and surface water, air pollution, noise and light pollution, radiation releases, ecosystem damage, and earthquakes (see table). Transmission and storage of gas result in fires and explosions. The pipeline network is aging, inadequately maintained, and infrequently inspected. One or more pipeline explosions occur every year in the United States. In September 2018, a series of pipeline explosions in the Merrimack Valley in Massachusetts caused more than 80 fires and explosions, damaged 131 homes, forced the evacuation of 30,000 people, injured 25 people, including two firefighters, and killed an 18-year-old boy. Gas compressor stations emit toxic and carcinogenic chemicals such as benzene, 1,3-butadiene, and formaldehyde. Wells, pipelines, and compressor stations are disproportionately located in low-income, minority, and marginalized communities, where they may leak gas, generate noise, endanger health, and contribute to environmental injustice while producing no local benefits. Gas combustion generates oxides of nitrogen that increase asthma risk and aggravate chronic obstructive pulmonary disease.

Compounding these hazards are the grave dangers that gas extraction and use pose to the global climate.[3] Gas is a much more powerful driver of climate change than is generally recognized. As much as 4% of all gas

" Gas combustion generates oxides of nitrogen that increase asthma risk and aggravate chronic obstructive pulmonary disease"

NEJM, 2020

COMMENTARY

Gas stoves and respiratory health

See page 426

Gas appliances for cooking or heating are used by about 30–60% of the population in most European and American countries and are used increasingly elsewhere in the world.[1] Operation of unvented appliances, especially stoves, is associated with increased nitrogen dioxide (NO_2) concentrations in homes. The report from Jarvis and colleagues this week adds to studies supporting a link between the use of gas stoves and adverse effects on respiratory health.

The relation between respiratory health and indoor pollution from these appliances has received considerable attention during the past 25 years; both positive and negative associations have been reported.[2] Most positive studies indicate the effect is relatively small (odds ratios of about 1·2) and therefore difficult to detect, despite high prevalence of exposure.[3] However, although the effect may be subtle, the fact that such large numbers of people are exposed makes this an issue of considerable public health importance.

Jarvis and colleagues show relatively strong positive associations between the use of domestic gas appliances and both lung function decrements and increased respiratory symptoms, especially among young women who cook with gas stoves. This report is important for several reasons. First, it is a carefully conducted observational study of a stratified random population sample. Although subject to the limitations of the cross-sectional observational approach, the design permits generalisation of the results to the population from which the sample was drawn and, probably, to other populations with similar demographic, health, and exposure characteristics.

Second, unlike many previous studies which concentrated on children (believed to be more susceptible to the effects of indoor air pollution), Jarvis et al focused on those likely to be the most exposed—young women who cook with gas stoves. The associations found were stronger than those seen in most previous investigations. This is an important distinction, not only because of potentially higher cumulative exposures of the women relative to children, but also because of higher peak exposures associated with cooking compared with other locations in a home.[4] Most epidemiological studies of NO_2 exposure have used exposure monitors with an averaging period of several days. Over this time frame, kitchen concentrations are higher than those measured elsewhere in the home, but only by about 30%.[5,6] Consequently, the assumption was that children would have similar exposures to their parents who were doing the cooking. However, Harlos[4] showed that peak exposures among those doing the cooking are much higher than among persons elsewhere in the home. This observation may explain the lack of adverse effects observed in men living in the same homes in Jarvis' study, as well as the smaller effects seen previously in studies of children.

Another important feature of Jarvis' paper is the analysis of respiratory effects and their modification by atopy. In a controlled experiment, NO_2 was shown to increase the sensitivity of bronchial response to inhaled dust mite allergen.[7] Jarvis and colleagues are the first to evaluate this interaction in a random population sample. Although the differences in respiratory outcomes were not statistically higher in the atopic group, there was a trend suggesting a possible interaction between gas stove use, and presumably NO_2 exposure, and atopy.

From their results, Jarvis et al compute population-attributable risk fractions for respiratory symptoms in the range 20–40%, suggesting that elimination of this exposure could reduce the prevalence of respiratory symptoms considerably among young women. In interpreting this estimate, we need to recognise (*a*) that these values are specific to the population represented by the study (ie, young women of the region); and (*b*) that for diseases or symptoms with multiple risk factors, some of which are synergistic, population-attributable risk fractions can, and often do, add to more than 100%. Nevertheless, as the researchers suggest, continued investigation of the role of gas appliances and NO_2 in the development and aggravation of respiratory disease is clearly warranted. This study suggests possible avenues along which this research might progress: personal exposure measurements (including peak exposures) of adults cooking with gas appliances, and continued investigation of the interaction between NO_2 exposure and indoor allergens. Although the issue of indoor gas appliances, NO_2, and respiratory health is not new, this remains an extremely common, possibly increasing, exposure throughout the world. The stakes are high.

Michael Brauer, Susan M Kennedy
Occupational Hygiene Program and Department of Medicine, University of British Columbia, Vancouver, BC, Canada

1 Koontz MD, Mehegan LL, Nagda NL. Distribution and use of cooking appliances that can affect indoor air quality. Chicago: Gas Research Institute, 1992 (GRI–93/0013).
2 Samet JM, Utell MJ. The risk of nitrogen dioxide: what have we learned from epidemiological and clinical studies. *Toxicol Ind Health* 1990; **6:** 247–62.
3 Hasselblad V, Eddy DM, Kotchmar DJ. Synthesis of environmental evidence: nitrogen dioxide epidemiology studies. *J Air Waste Manage Assoc* 1992; **42:** 662–71.
4 Harlos DP. Acute exposure to nitrogen dioxide during cooking or commuting. PhD dissertation, Harvard School of Public Health, Boston, 1988.
5 Lambert WE, Samet JM, Hunt WC, Skipper BJ, Schwab M, Spengler JD. Nitrogen dioxide and respiratory illness in infants, part II. Cambridge, MA: Health Effects Institute, report number 58, 1993.
6 Ryan PB, Soczek ML, Spengler JD, Billick IH. The Boston residential NO_2 characterization study: I. Preliminary evaluation of the survey methodology. *J Air Poll Control Assoc* 1988; **38:** 22–27.
7 Tunnicliffe W, Burge P, Ayres J. Effect of domestic concentrations of nitrogen dioxide on airway responses to inhaled allergen in asthmatic patients. *Lancet* 1994; **344:** 1733–36.

Cochlear implantation for children and adults

Cochlear stimulation can be achieved by either single-channel or multiple-channel stimulating electrodes. Weston and colleagues[1] lately showed that multiple-channel devices provide significantly greater benefit and are therefore the method of choice.

The concept of electrical stimulation of the auditory system dates back to Volta, who in 1790 placed metal rods in his ears and connected them to a 50 volt electric source. As well as experiencing "une secousse de tête" (at

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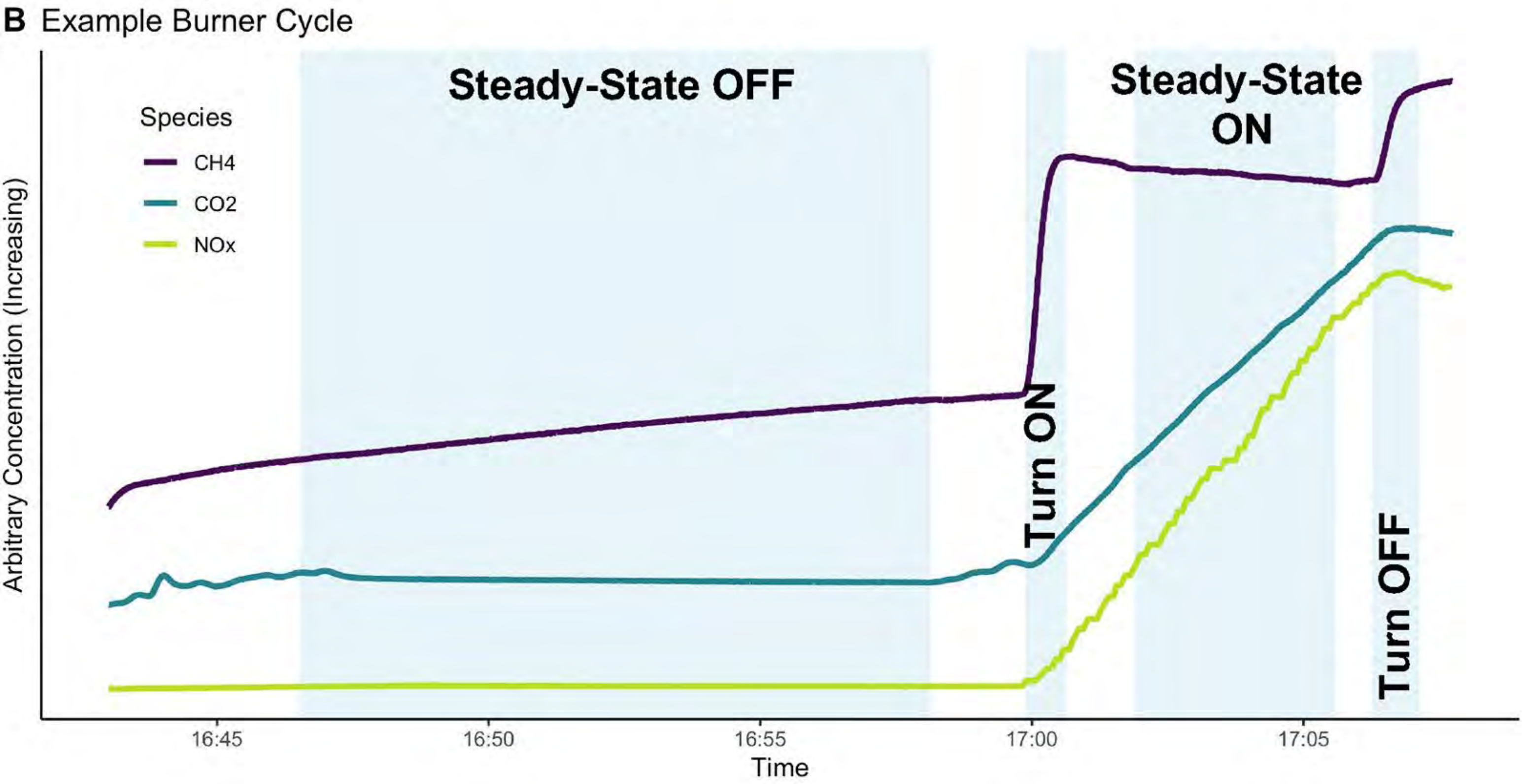
Lancet, 1996

https://doi.org/10.1016/s0140-6736(96)90002-1




Environmental Science & Technology

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Methane and NO_x Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes

Eric D. Lebel,* Colin J. Finnegan, Zutao Ouyang, and Robert B. Jackson

Cite This: *Environ. Sci. Technol.* 2022, 56, 2529–2539 Read Online

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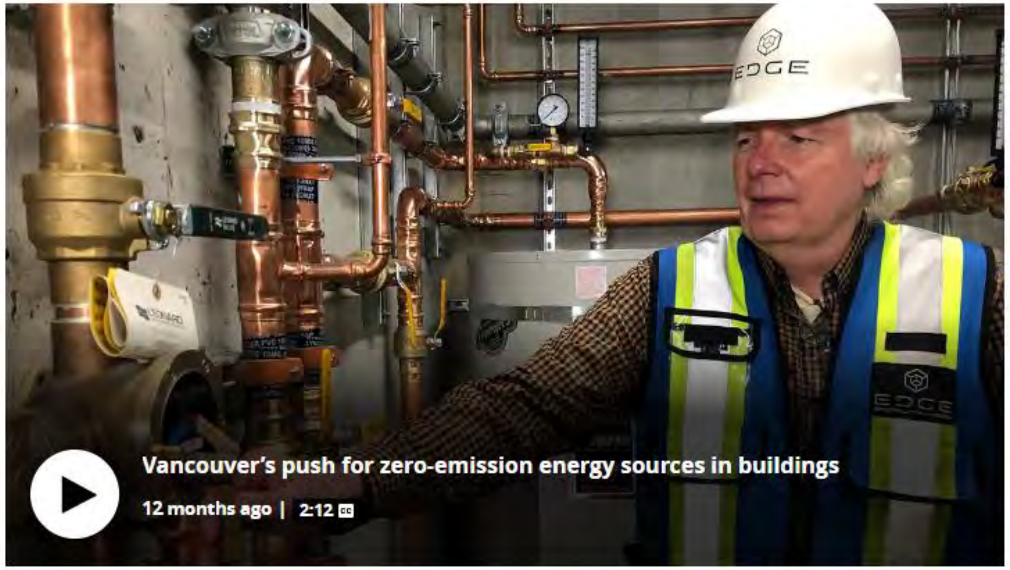
“**More than three**-quarters of methane emissions we measured originated during steady-state-off.”

“Using a 20-year timeframe for methane, annual methane emissions from all gas stoves in U.S. homes have a climate impact comparable to the annual carbon dioxide emissions of 500 000 cars.”

Why oil and gas heating bans for new homes are a growing trend

With growing push toward electric heating, gas industry touts carbon-neutral gas

Emily Chung · CBC News · Posted: Jan 30, 2022 1:00 AM PST | Last Updated: February 1, 2022



The City of Vancouver is joining a North American push to reduce the amount of fossil fuels used to heat buildings by making zero-emission energy sources a policy for new low-rise residential buildings.

Vancouver: Starting Jan. 1, 2022, **equipment for space and hot water heating in new low-rise residential buildings must be zero emissions**. By 2025, all new and replacement heating and hot water systems must be zero emissions.

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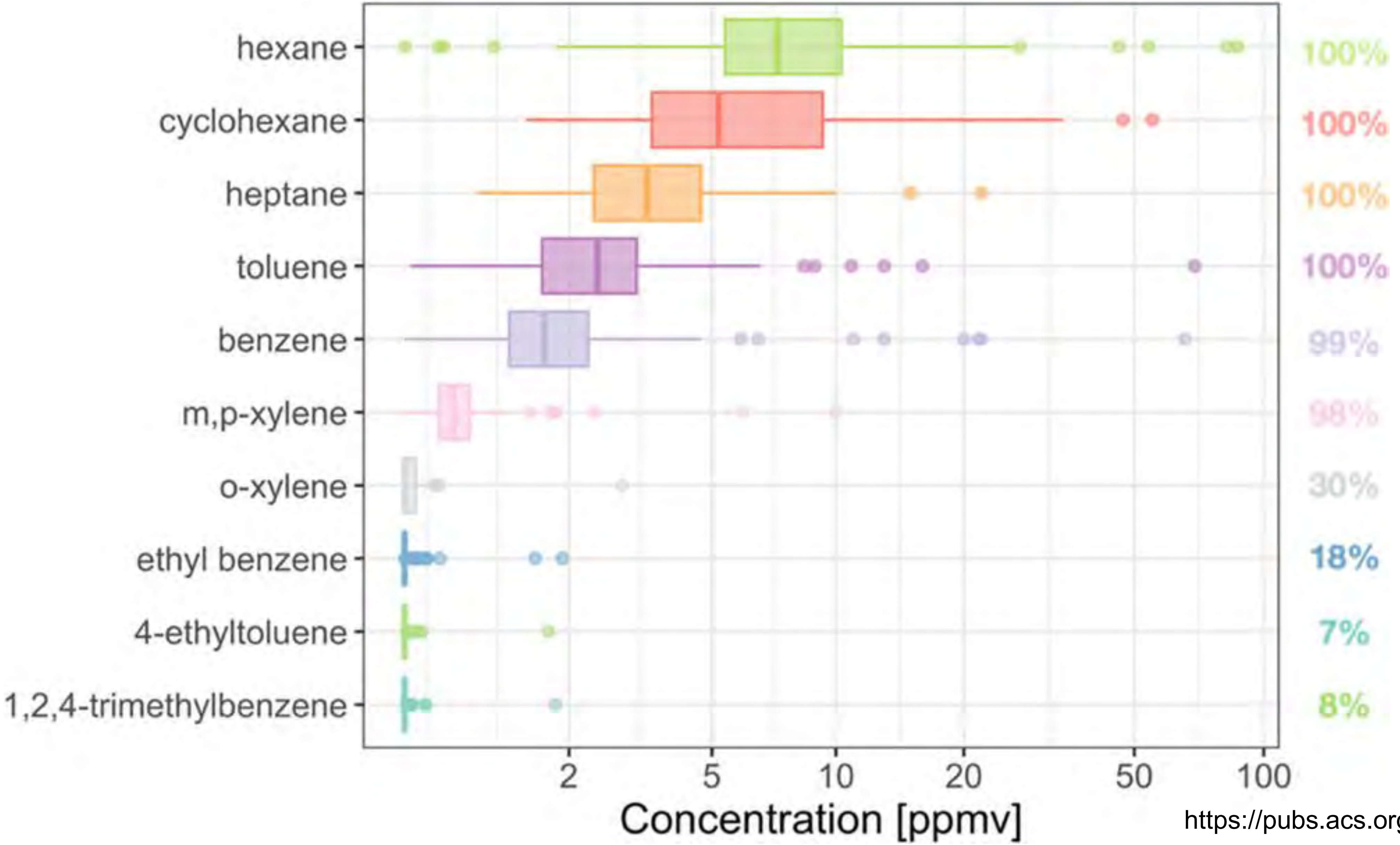
U.S. considers gas stove ban due to 'hidden hazard.' Will Canada follow?

Jan 11, 2023

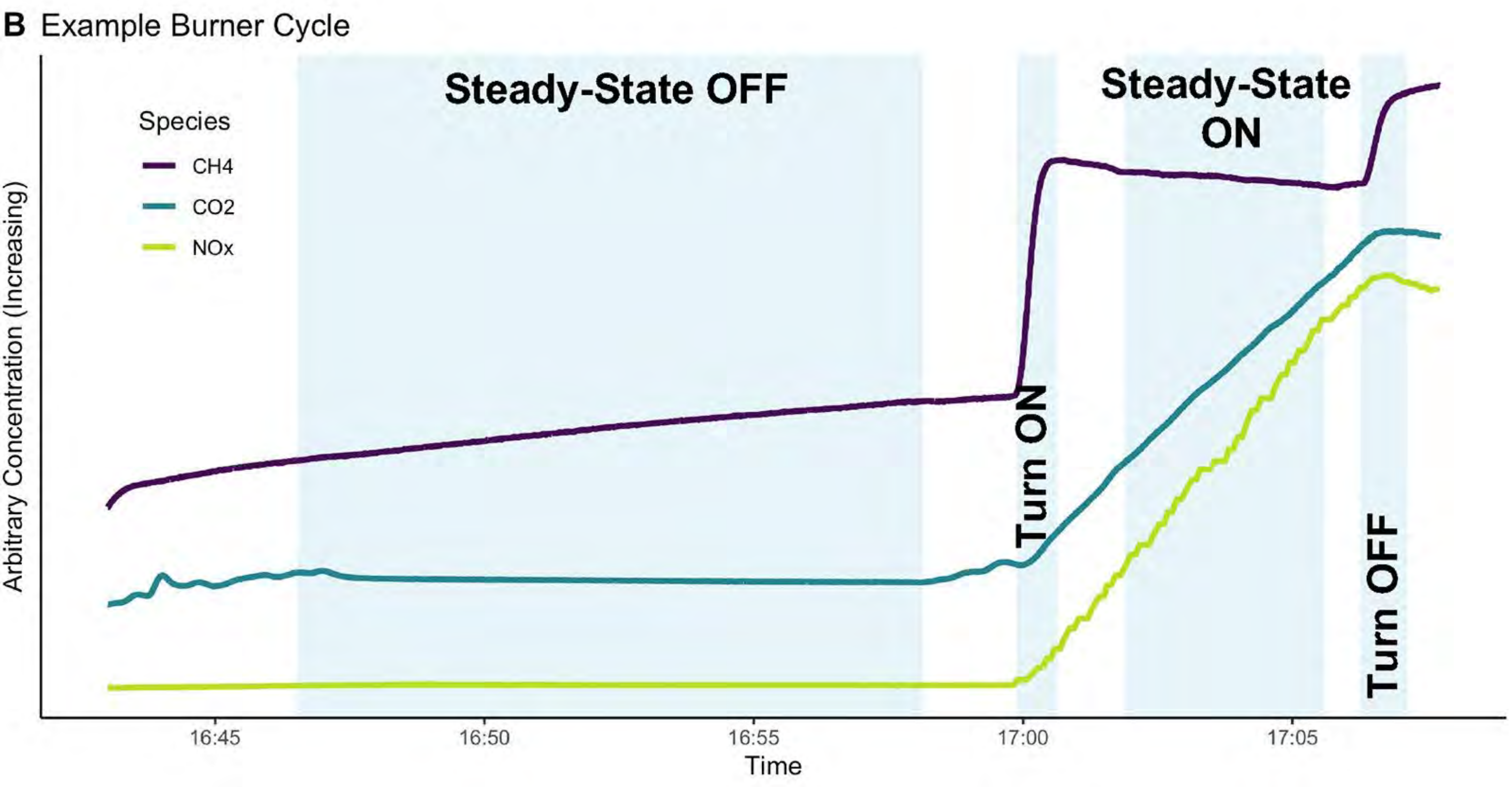
Court throws out Berkeley, California's ban on natural gas

yesterday



https://pubs.acs.org/doi/10.1021/acs.est.2c02581

Unburned NG samples from 159 residential NG stoves across seven geographic regions in California.

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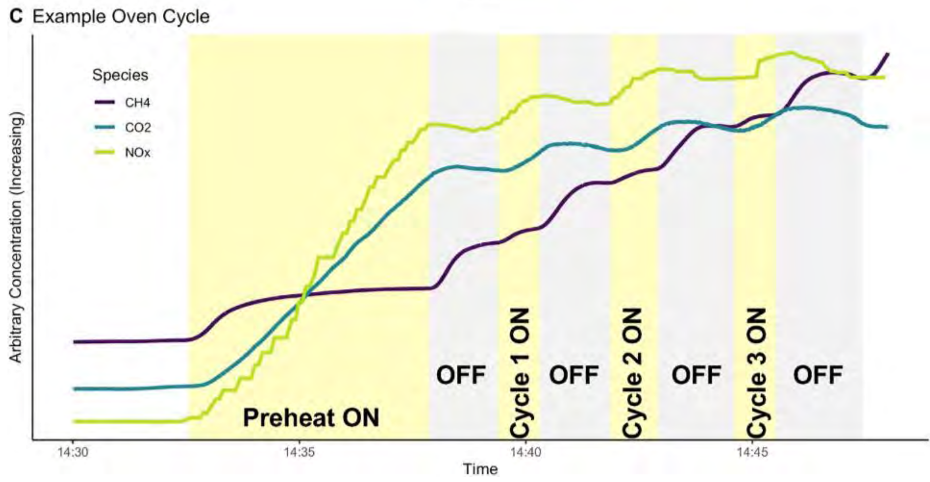


“**More than three**-quarters of methane emissions we measured originated during steady-state-off.”

“Using a 20-year timeframe for methane, annual methane emissions from all gas stoves in U.S. homes have a climate impact comparable to the annual carbon dioxide emissions of 500 000 cars.”

“Our data suggest that families who don’t use their range hoods or who have poor ventilation can surpass the 1-h national standard of NO_2 (100 ppb) within a few minutes of stove usage, particularly in smaller kitchens.”

WHO AQGs …

World Health Organization
REGIONAL OFFICE FOR Europe

Summary of recommended AQG levels and interim targets

Pollutant	Averaging time	IT1	IT2	IT3	IT4	AQG level
$PM_{2.5}$, µg/m³	Annual	35	25	15	*10*	**5**
$PM_{2.5}$, µg/m³	24-hour[a]	75	50	37.5	*25*	**15**
PM_{10}, µg/m³	Annual	70	50	30	*20*	**15**
PM_{10}, µg/m³	24-hour[a]	150	100	75	*50*	**45**
O_3, µg/m³	Peak season[b]	100	70	–	–	**60**
O_3, µg/m³	8-hour[a]	160	120	–	–	**100**
NO_2, µg/m³	Annual	*40*	30	20	–	**10**
NO_2, µg/m³	24-hour[a]	120	50	–	–	**25**
SO_2, µg/m³	24-hour[a]	125	50	–	–	**40**
CO, mg/m³	24-hour[a]	7	–	–	–	**4**

Air quality guideline levels for both long- and short-term exposure in relation to critical health outcomes.

Interim targets to guide reduction efforts for the achievement of the air quality guideline levels.

Good practice statements for management of **Black Carbon, Ultrafine particles, Desert Dust**: types of health-relevant PM (evidence insufficient for quantitative guideline levels

WHO AQGs …

World Health Organization
REGIONAL OFFICE FOR Europe

Summary of recommended AQG levels and interim targets

Pollutant	Averaging	IT1	IT2	IT3	IT4	AQG

Air quality guideline levels

Residential Maximum Exposure Limit for Nitrogen Dioxide

Exposure period	Concentration		Critical Effects
	$\mu g/m^3$	ppb	
Short-term	170	90	Decreased lung function and increased airway responsiveness in asthmatics
Long-term	20	11	Higher frequency of days with respiratory symptoms and/or medication use in asthmatic children

NO_2, µg/m³	Annual	*40*	30	20	–	**10**
NO_2, µg/m³	24-hour[a]	120	50	–	–	**25**
SO_2, µg/m³	24-hour[a]	125	50	–	–	**40**
CO, mg/m³	24-hour[a]	7	–	–	–	**4**

Good practice statements for management of **Black Carbon, Ultrafine particles, Desert Dust**: types of health-relevant PM (evidence insufficient for quantitative guideline levels

CAAQS: ~22 µg/m³ annual: ~79 µg/m³ 1 hr

International Journal of *Environmental Research and Public Health*

MDPI

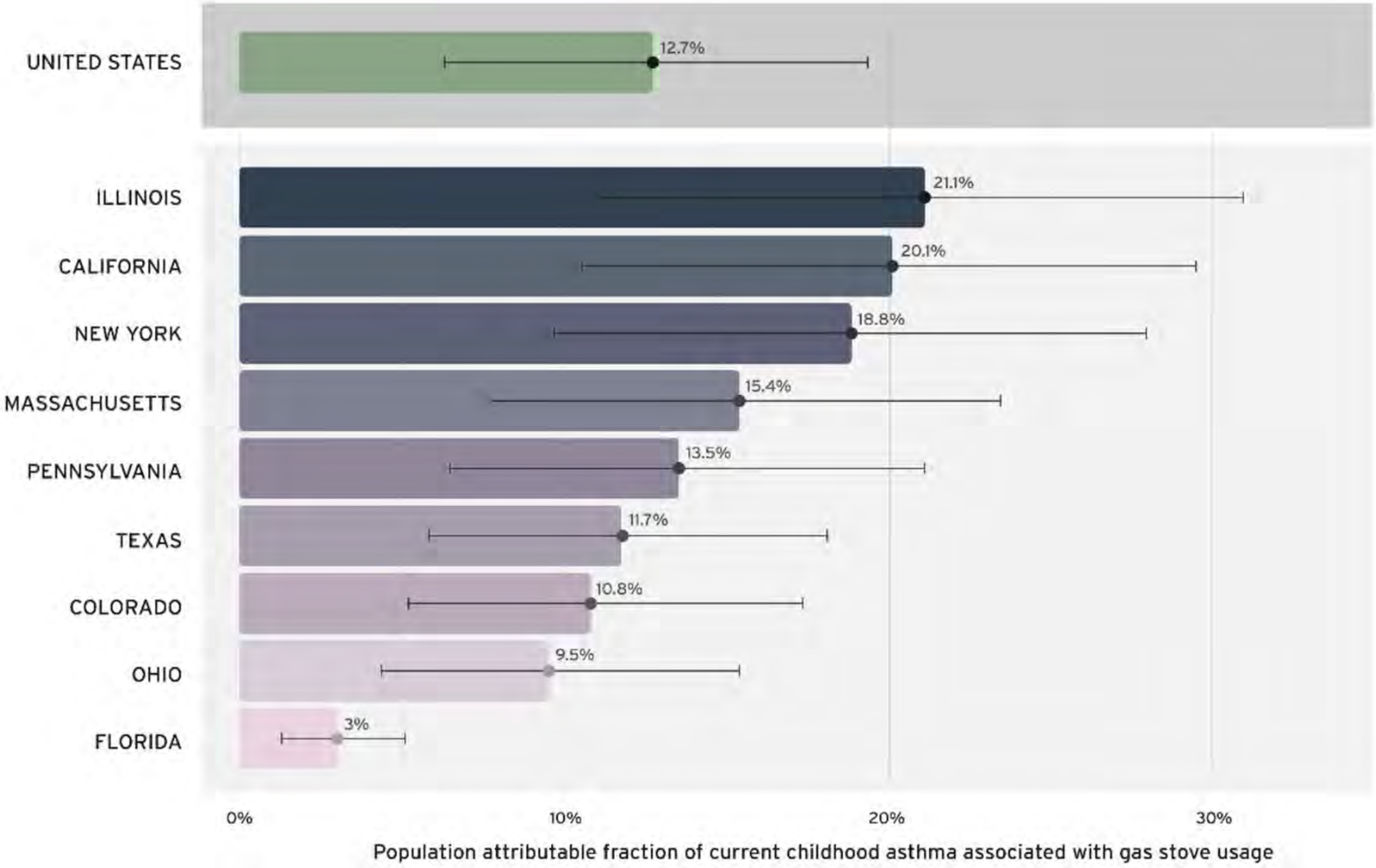
Article

Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States

Talor Gruenwald [1,†], Brady A. Seals [1,*], Luke D. Knibbs [2,3] and H. Dean Hosgood III [4]

- Previously published RRs (Lin et al, 2013)
- Proportion of US households using gas stoves for cooking (surveys from 9 states)

Population attributable fraction of current childhood asthma associated with gas stove use



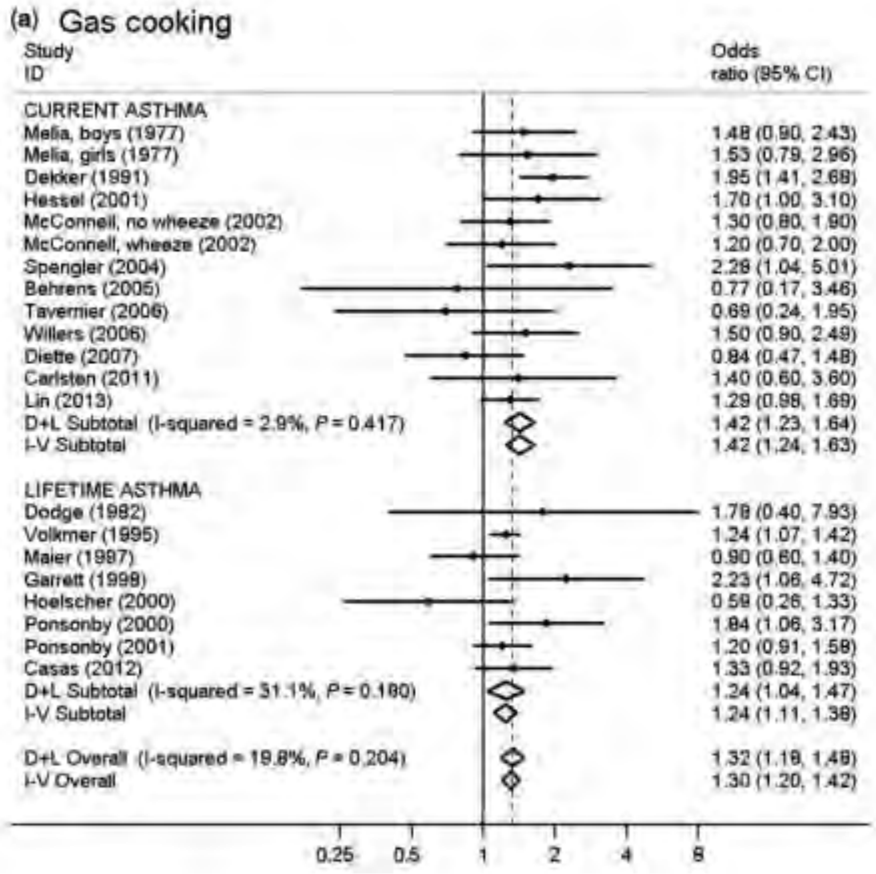
Published by Oxford University Press on behalf of the International Epidemiological Association International Journal of Epidemiology 2013;**42**:1724–1737

Advance Access publication 20 August 2013 doi:10.1093/ije/dyt150

EARLY LIFE

Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children

Weiwei Lin,[1] Bert Brunekreef[1,2] and Ulrike Gehring[1]*

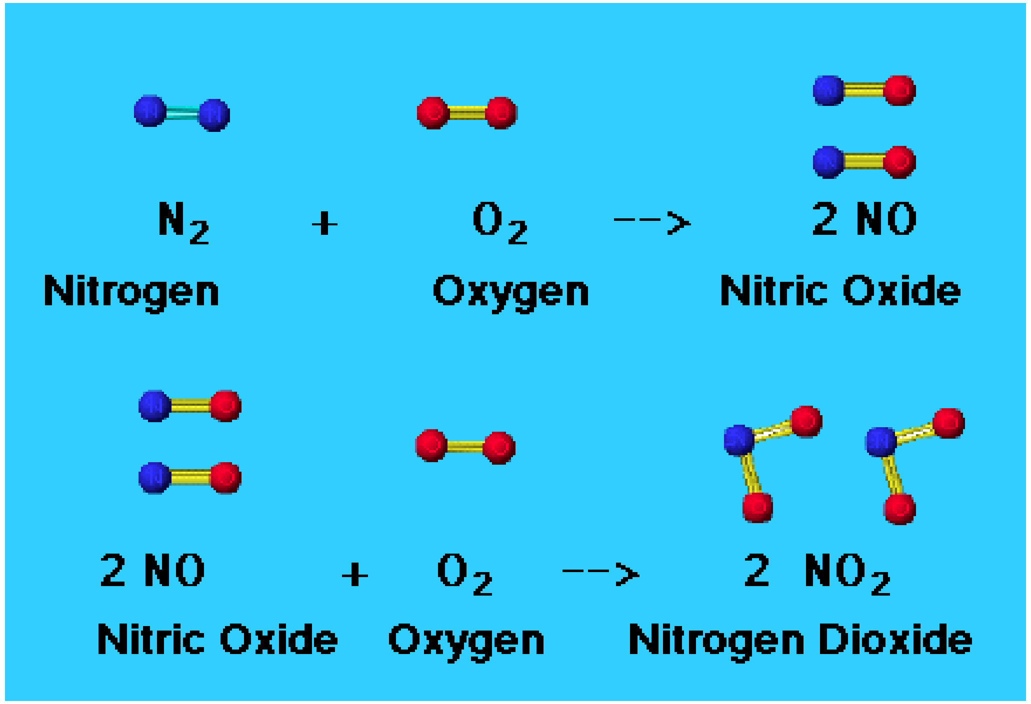


Int J Epidemiol, Volume 42, Issue 6, December 2013, Pages 1724–1737, https://doi.org/10.1093/ije/dyt150

- "…children living in a home with gas cooking have a 42% increased risk of having current asthma…
- per 15 ppb increase in indoor NO2 level, children have a 15% increased risk of having current wheeze..
- …**no increase in the risk of asthma in relation to indoor $\mathbf{NO_2}$ exposure** and **no increase in the risk of wheeze in relation to gas cooking exposure**…"

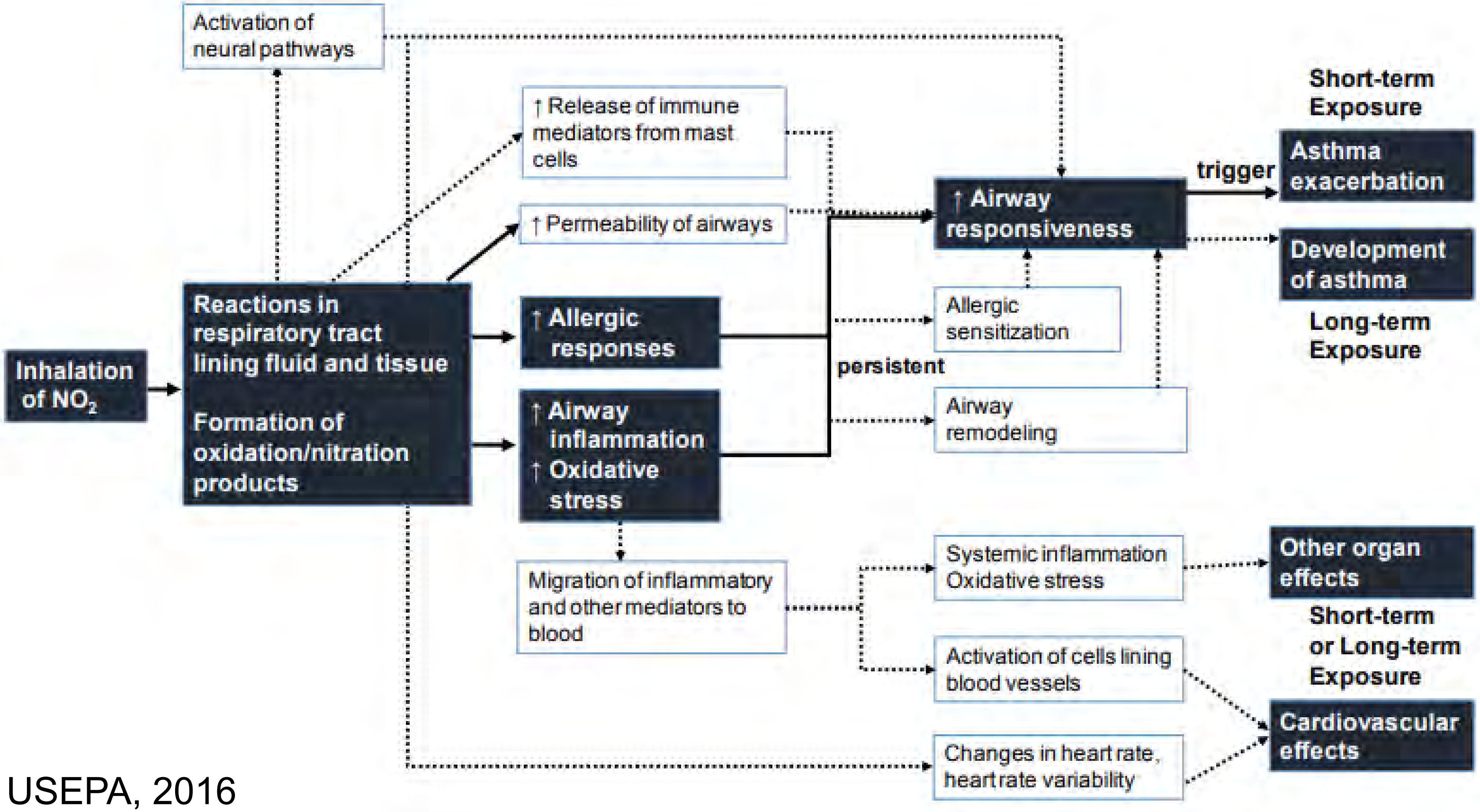
- Gas cooking effects higher
  - Europe/Asia-Pacific vs N America
  - Where gas cooking prevalence <30%
  - Studies published before 2000

Int J Epidemiol, Volume 42, Issue 6, December 2013, Pages 1724–1737, https://doi.org/10.1093/ije/dyt150



- High temperature combustion: oxidation of N_2 in air: $NO \rightarrow NO_2$
- Vehicles, Natural gas (power plants)
- Indoors: Gas stoves, Space heaters, Ice resurfacers

Biological Pathways



USEPA, 2016

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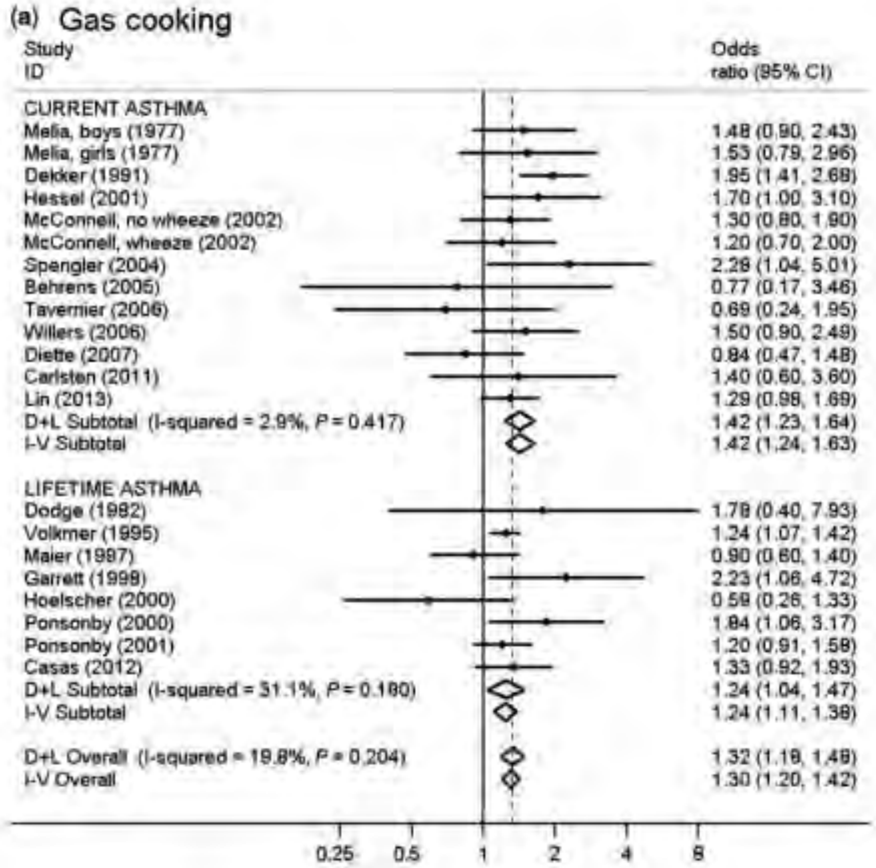
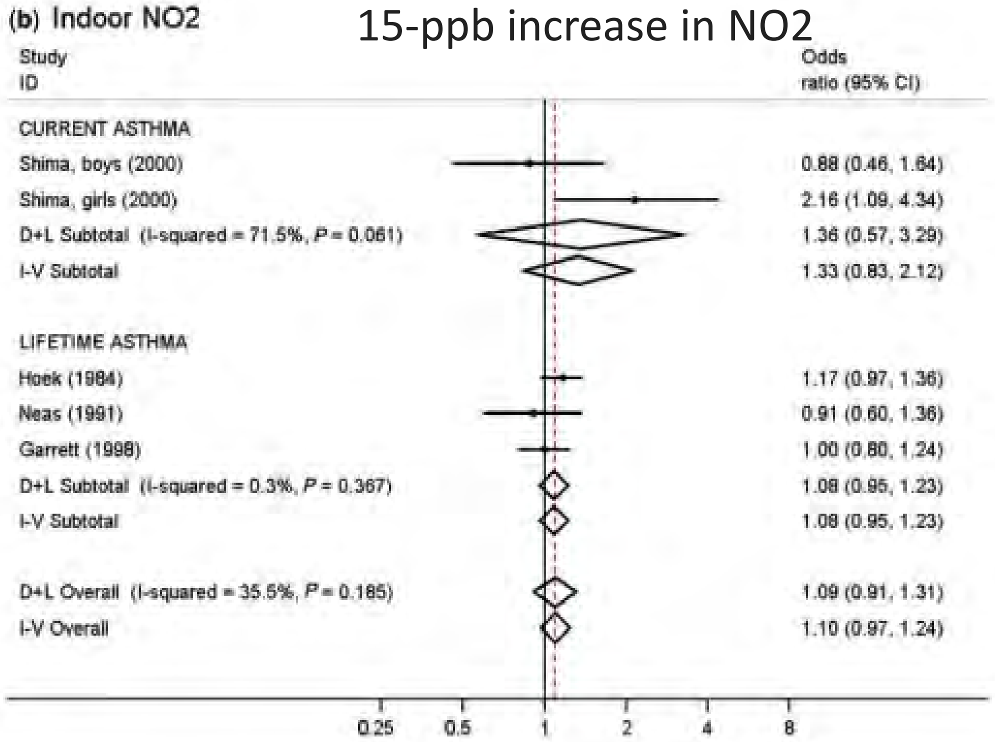


15-ppb increase in NO2



Int J Epidemiol, Volume 42, Issue 6, December 2013, Pages 1724–1737, https://doi.org/10.1093/ije/dyt150

- **Gas cooking produces NO_2 and other pollutants** such as ultrafine particles.
- Our finding of an association between gas cooking and asthma in the absence of an association between measured NO_2 and asthma suggests that **gas cooking may act as a surrogate for causal variables other than air pollutants produced by gas combustion**.
  - Supported by an Australian study, where the association between gas cooking and respiratory symptoms remained significant after adjustment for measured NO_2.

Int J Epidemiol, Volume 42, Issue 6, December 2013, Pages 1724–1737, https://doi.org/10.1093/ije/dyt150

ISAAC

- ~500,000 primary and secondary school children from 108 centres in 47 countries

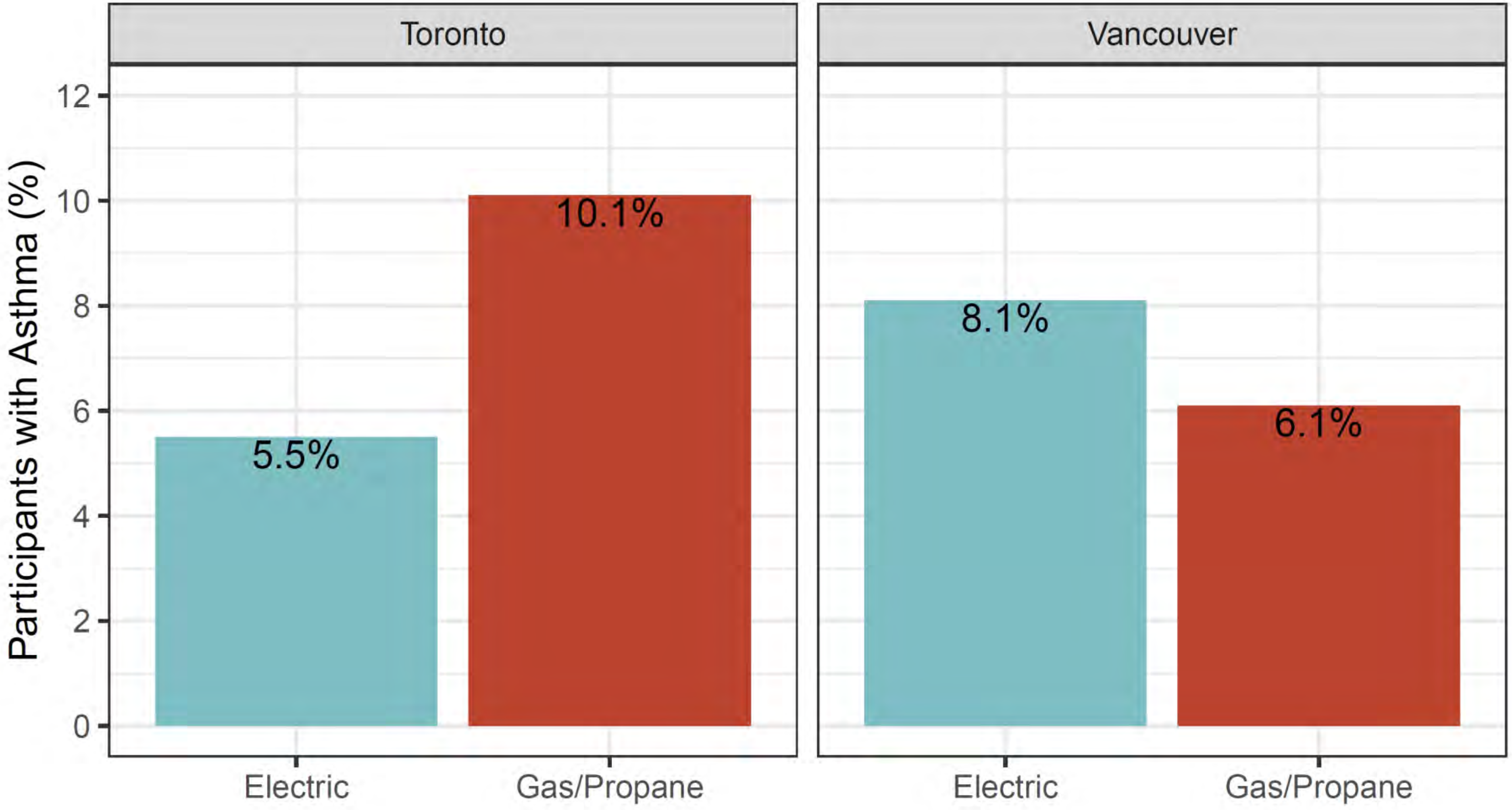
	Adjusted model		Multivariate analysis	
	6–7 years	13–14 years	6–7 years	13–14 years
Current wheeze	0·98 (0·92–1·04)	0·99 (0·94–1·04)	0·96 (0·89–1·03)	0·99 (0·92–1·07)
Current symptoms of severe asthma	1·01 (0·92–1·10)	0·97 (0·91–1·03)	0·97 (0·87–1·09)	0·97 (0·89–1·07)
Asthma ever	0·95 (0·89–1·01)	0·98 (0·93–1·02)	0·94 (0·88–1·02)	0·99 (0·93–1·05)
Current symptoms of rhinoconjunctivitis	1·04 (0·97–1·01)	0·96 (0·91–1·01)	1·00 (0·92–1·09)	0·99 (0·92–1·06)
Hay fever ever	1·02 (0·95– 1·09)	0·96 (0·91–1·01)	1·00 (0·92–1·09)	0·99 (0·92–1·07)
Current symptoms of eczema	0·97 (0·91–1·03)	1·00 (0·94–1·06)	0·94 (0·87–1·02)	1·00 (0·92–1·09)
Eczema ever	0·91 (0·86–0·96)	0·99 (0·93–1·04)	0·93 (0·88–0·99)	1·01 (0·93–1·09)

Data are odds ratio (95% CI), unless otherwise stated. The reference category for these estimates is electricity only used for cooking.

Table 7: **Association between use of gas only for cooking and current symptoms of asthma, rhinoconjunctivitis, and eczema, by age group**

Cooking fuels and prevalence of asthma: a global analysis of phase three of the International Study of Asthma and Allergies in Childhood (ISAAC) *Wong GWK et al. Lancet Respir Med 2013; 1: 386–94*

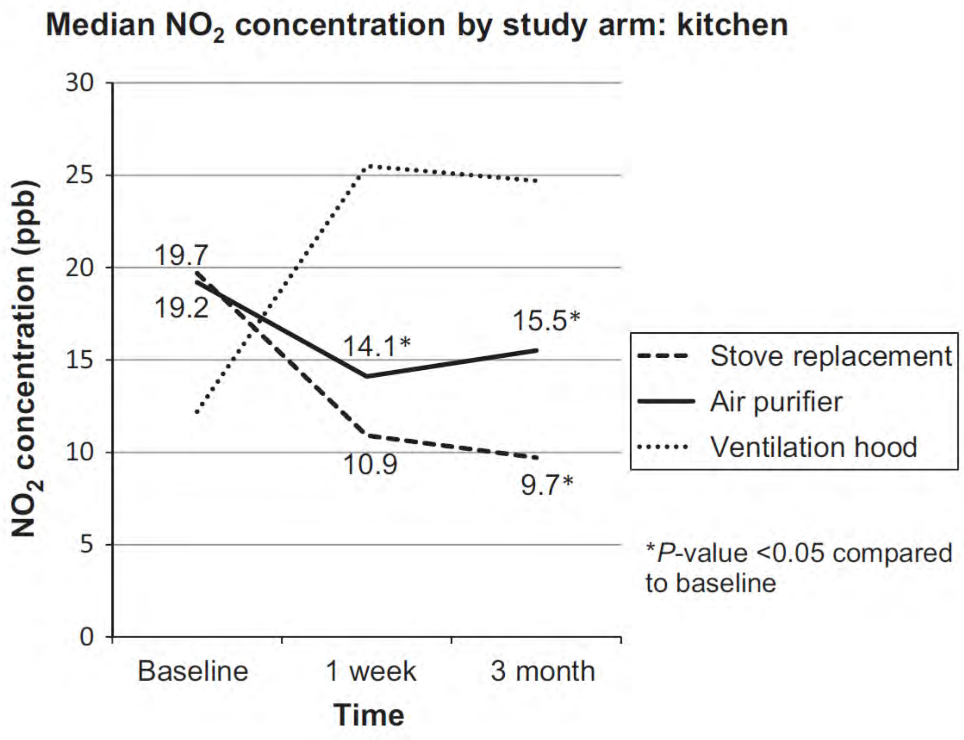
CHILD cohort



Bédard M-A, Reyna ME, et al. Gas Stove use and Asthma Outcomes in the CHILD Study. In press, CJPH 2023

Intervention: Gas stove air cleaning & ventilation

- 100 homes with unvented gas stoves:
  - Electric stove (~$2200)
  - Ventilation hood (~$2000)
  - HEPA (PM) and carbon filters (~$700)
- Electric: 51% (42% in bedroom) reduction in median kitchen NO2 (3 months)
- Filtration: Smaller and less persistent decreases
- Ventilation hoods ineffective



Paulin LM et al. Home interventions are effective at decreasing indoor nitrogen dioxide concentrations. Indoor Air 2014; 24: 416–424

Intervention: Electric heater & gas heater ventilation

- N= 199 children with asthma from 18 primary schools with unvented gas heaters
- Intervention (8 schools) with electric heaters or vented gas for asthma symptoms, lung function and bronchial hyperresponsiveness (no unvented gas appliances at home)
- Reductions in N02 (~32 ppb) and asthma symptoms but not lung function or hyperresponsiveness with intervention

Symptom/activity	Mean rate Intervention (N = 45)	Mean rate Control (N = 69)	RR	95% CI
Wheeze during the day	4.9 (15.2)	5.1 (10.5)	0.95	0.45, 2.01
Wheeze during the night	2.2 (5.6)	2.3 (5.5)	0.94	0.36, 2.50
Difficulty breathing during the day	2.2 (3.7)	5.4 (12.1)	0.41 ($P = 0.045$)	0.07, 0.98
Difficulty breathing during the night	0.8(2.2)	2.6 (6.9)	0.32 ($P = 0.004$)	0.14, 0.69
Chest tightness during the day	2.3 (4.3)	5.1 (9.9)	0.45 ($P = 0.008$)	0.25, 0.81
Chest tightness during the night	1.5 (3.3)	2.5 (6.2)	0.59	0.28, 1.29
Cough during the day	17.5 (21.5)	13.7 (13.7)	1.27	0.81, 2.00
Cough during the night	10.7 (16.6)	11.6 (12.4)	0.92	0.49, 1.73
Difficulty breathing after exercise	3.8 (7.4)	6.4 (13.9)	0.59	0.31, 1.13
Asthma attacks during the day	1.1 (2.3)	2.7 (5.3)	0.39 ($P = 0.034$)	0.17, 0.93
Asthma attacks during the night	0.7 (2.1)	1.8 (3.8)	0.38	0.13, 1.07
Missed school due to asthma	1.6 (2.0)	1.2 (2.8)	1.34	0.68, 2.60
Visit to health care facilities due to asthma	0.5 (0.8)	0.8 (1.2)	0.60	0.35, 1.03
Taking any asthma medication	26.9 (36.7)	34.6 (37.1)	0.77	0.49, 1.21
Taking any reliever	13.8 (23.2)	22.4 (28.8)	0.62	0.31, 1.25
Taking any preventer	26.2 (40.1)	29.9 (42.2)	0.87	0.53, 1.44

Pilotto LS et al. **Randomized controlled trial of unflued gas heater replacement on respiratory health of asthmatic schoolchildren.** *International Journal of Epidemiology* 2003;**33**:208–214

Intervention: Gas stove air cleaning

- 5–11 yr old children (n = 126) with persistent asthma living in homes with gas stoves and NO2 >15 ppb
- 5-week crossover intervention for number of asthma symptom days:
  - (1) NO2 reduction (2) HEPA (PM) filtration
- 4 ppb NO2 reduction, but no reduction in symptom days.
- Small reduction in symptom days for particle filtration

Table 4. Effect of treatment on number of symptom days in final 14 days of treatment shown for intent-to-treat (A) and compliance (B) analyses.

	Treatment arms		Unadjusted			Adjusted[a]		
Analysis	N (Ss)	N (obs)	df	Estimate (SE)	*p*-value[b]	df	Estimate (SE)	*p*-value[b]
A. Intent-to-treat[c]	117	332						
Air Cleaner Configurations			2, 116		.84	2, 106		.77
NO_2-reduction vs Control			116	0.20 (0.45)	.65	106	0.31 (0.45)	.49
Particle-reduction vs Control			116	0.25 (0.44)	.58	106	0.24 (0.44)	.59
B. Compliance[d]	109	270						
Air Cleaner Configurations			2, 108		.86	2, 98		.92
NO_2-reduction vs Control			108	−0.27 (0.50)	.59	98	−0.19 (0.51)	.71
Particle-reduction vs Control			108	−0.20 (0.50)	.69	98	−0.16 (0.51)	.75

Table 6. Effect of treatment including measured NO_2 concentration as a factor on number of symptom days in final 14 days of treatment for adjusted and unadjusted compliance analysis.

	Treatment arms		Unadjusted			Adjusted[a]		
Factors	N (Ss)	N (obs)	df	Estimate (SE)	*p*-value	df	Estimate (SE)	*p*-value
Compliance including NO_2[b]	106	267						
Measured NO_2 (ppb)			1, 105		**.01**	1, 95		**.04**
Treatment arm			2, 105		**.03**	2, 95		**.03**
Measured NO_2 × Treatment			2, 105		**.01**	2, 95		**.009**
Treatment Arm Contrasts								
NO_2-reduction vs Control			105	0.33 (1.03)	.75	95	0.41 (1.05)	.70
Particle-reduction vs Control			105	−1.81 (1.06)	.09	95	−1.80 (1.08)	.10

Childhood asthma and household exposures to nitrogen dioxide and fine particles: a triple- crossover randomized intervention trial. Gent JF et al. Journal of Asthma, 2022. 60:4, 744-753.

Controlled NO_2 exposures (Health Canada, 2016)

- Relationship between exposure to and adverse respiratory effects (lung function; BHR) in asthmatics or COPD subjects, but exposure–response relationship < 1000 ppb NO_2 is unclear
  - Some suggestions of responses to 1 hr exposures of 300 ppb for those with asthma or COPD, whereas for others no impacts until > 1000 ppb

Health Canada, 2016. Human Health Risk Assessment for Ambient Nitrogen Dioxide.
https://publications.gc.ca/collections/collection_2016/sc-hc/H114-31-2016-eng.pdf

Indoor Chemistry

- Exposure-related changes in tear-fluid cytology.
- 10% decrease in specific airway conductance following exercise compared with a 2% decrease in clean air

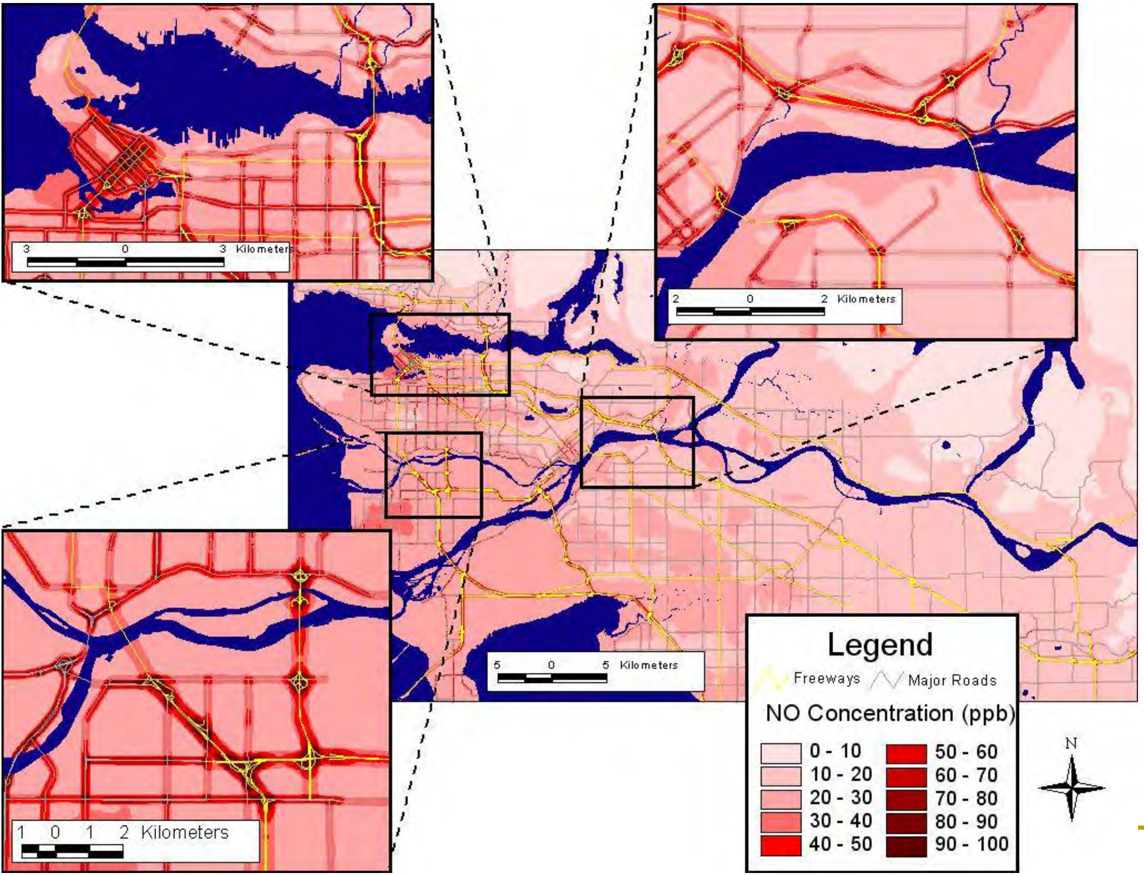
Effects of **nitrous acid** exposure on human mucous membranes. Rasmussen TR, Brauer M, Kjaergaard S. Am J Respir Crit Care Med. 1995. doi: 10.1164/ajrccm.151.5.7735607.

Health Canada NO_2 (2016)

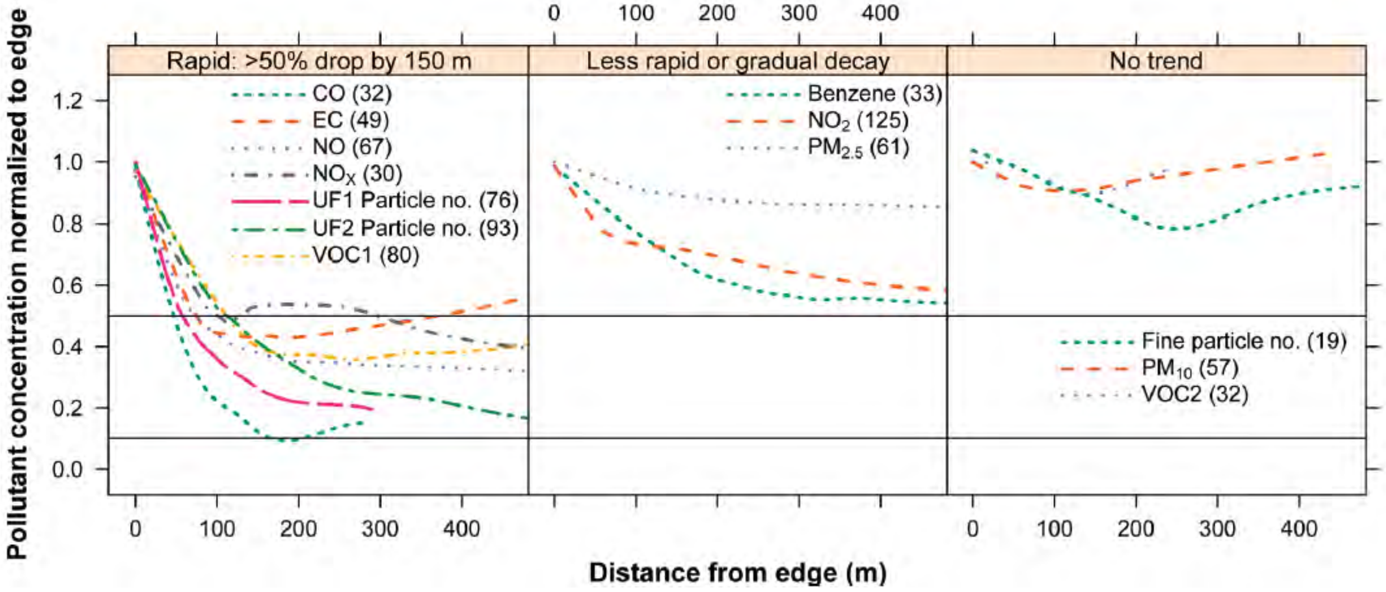
- **Causal:**
  - **Short-term exposure** to ambient NO_2 at current levels and **increased asthma-related morbidity** (airway inflammation and AHR, respiratory symptoms, asthma hospitalizations and ERVs).
- **Likely causal:**
  - **short-term exposure** and total/non-accidental, cardiopulmonary, and to a lesser extent cardiovascular and respiratory **mortality**
  - **long-term exposure** and development of **asthma or allergic-related disease**
- **Suggestive:**
  - **Short-term exposure** and **cardiovascular effects.**

Health Canada, 2016. Human Health Risk Assessment for Ambient Nitrogen Dioxide.
https://publications.gc.ca/collections/collection_2016/sc-hc/H114-31-2016-eng.pdf

In outdoor air pollution studies, NO_2 often is used as a marker of a complex, traffic-related air pollution (TrAP) mixture



Henderson SB et al. Environmental Science and Technology. 2007; 41 (7):2422 -2428



Karner *et al.* (2010) Environ. Sci. Technol. 44, 5334

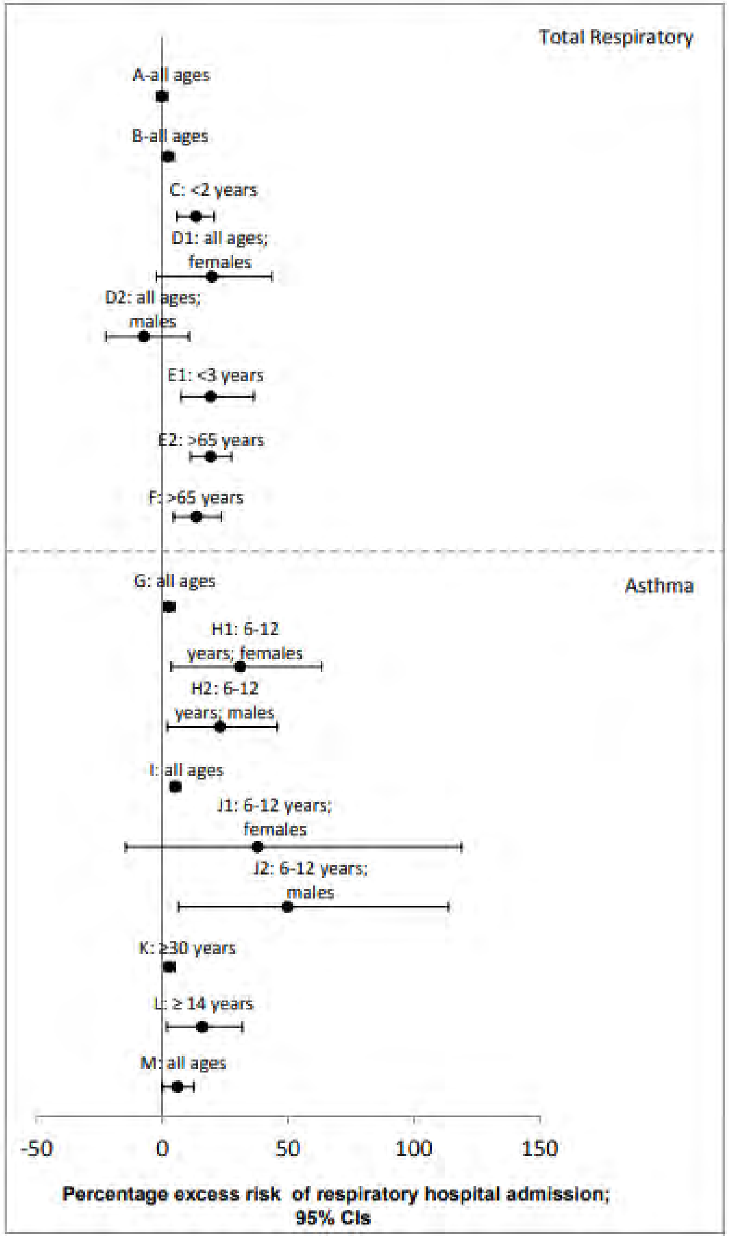
Traffic influence zones (<500m from highway or <100m from major road)

Health Canada NO_2 (2016)

- **Causal:**
  - **Short-term exposure** to ambient NO_2 at current levels and **increased asthma-related morbidity** (airway inflammation and AHR, respiratory symptoms, asthma hospitalizations and ERVs).
- **Likely causal:**
  - **short-term exposure** and total/non-accidental, cardiopulmonary, and to a lesser extent cardiovascular and respiratory **mortality**
  - **long-term exposure** and development of **asthma or allergic-related disease**
- **Suggestive:**
  - **Short-term exposure** and **cardiovascular effects.**

Health Canada, 2016. Human Health Risk Assessment for Ambient Nitrogen Dioxide.
https://publications.gc.ca/collections/collection_2016/sc-hc/H114-31-2016-eng.pdf

Figure 8.2: Percentage excess risk for respiratory hospital admissions and 95% CIs per standardized increment (20 ppb for 24-h avg and 30 ppb for daily 1-h max) in short-term NO_2 ambient concentration from all seasons in single-pollutant models (*unless otherwise noted) in Canadian and US studies



A. 16 Canadian cities; Burnett et al. (1997b); lag 0 d; *three-pollutant model

B. 10 Canadian cities; Cakmak et al. (2006); lag 1–4 d

C. Toronto, ON; Burnett et al. (2001); summer; 2-d avg

D. Windsor, ON; Luginaah et al. (2005); lag 2 d

E. Vancouver, BC; Yang et al. (2003); lag 1 d

F. Vancouver, BC; Fung et al. (2006); 3-d avg

G. Toronto, ON; Burnett et al. (1999); lag 0 d

H. Toronto, ON; Lin et al. (2003); 6-d avg

I. Ontario, Canada; To et al. (2013); lag 0 d; *three-pollutant model

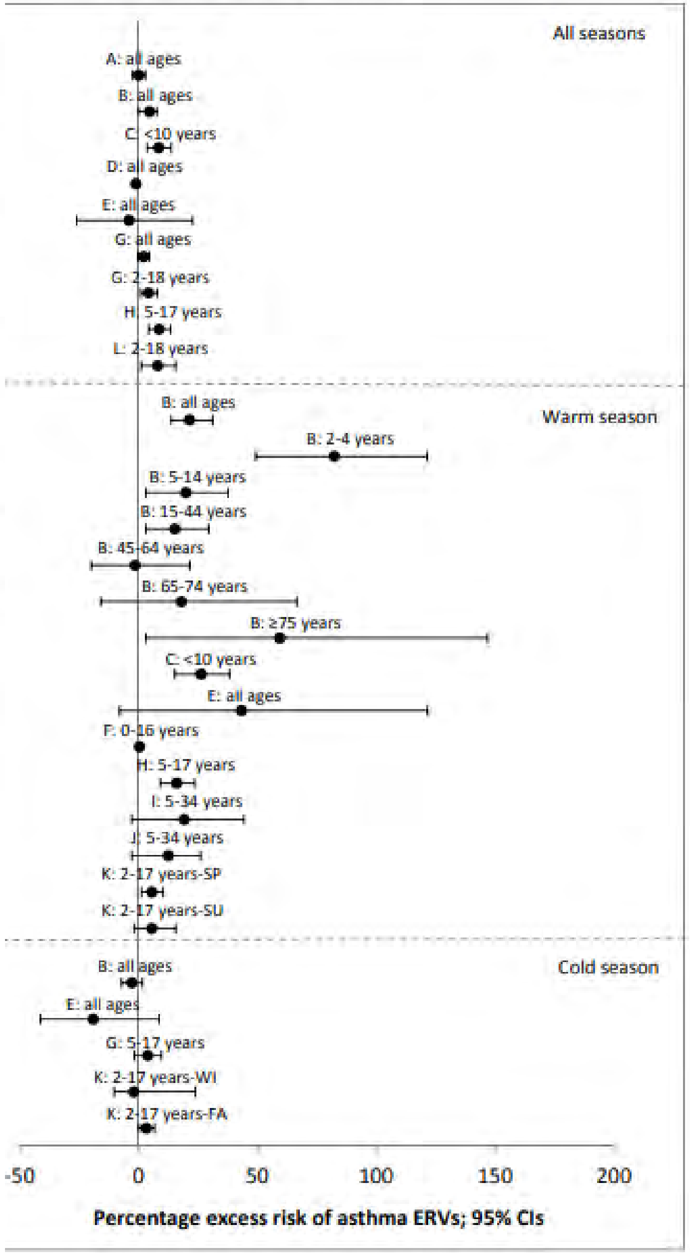
J. Vancouver, BC; Lin et al. (2004); children w/ low SES; 4-d avg

K. Los Angeles, CA; Linn et al. (2000); ≥30 years of age; lag 0 d

L. Oklahoma City, OK; Magas et al. (2007); lag not reported

M. El Paso, TX; Grineski et al, (2011); lag 2 or 3 d

gure 8.3: Percentage excess risk for asthma ERVs and 95% CIs per standardized increment (20 ppb for 24-h avg and 30 ppb for daily 1-h max) in short-term NO_2 ambient concentration in single-pollutant models (*unless otherwise noted) in Canadian and US studies



A. Seven Canadian cities; Stieb et al. (2009); lag 2 d

B. Edmonton, AB; Villeneuve et al. (2007); lag 5-d avg

C. Edmonton, AB; Szyszkowicz et al. (2008a); lag 2 d

D. Ontario, Canada; To et al. (2013); lag 2 d; *three-pollutant model

E. Windsor, ON; Lavigne et al. (2012); lag 1 d

F. Atlanta, GA; Tolbert et al. (2000); lag 1 d**

G. Atlanta, GA; Peel et al. (2005); lag 0–2 d

H. Atlanta, GA; Strickland et al. (2010); lag 0–2d avg

I. Cincinnati, OH; Jaffe et al. (2003); lag 1 d

J. Cleveland, OH; Jaffe et al. (2003); lag 1 d

K. St. Louis, MO; Mohr et al. (2008); lag 1 d; four-pollutant model*

L. Detroit, MI; Li et al. (2011); lag 5 d

Health Canada, 2016.

WHO AQGs …

Summary of recommended AQG levels and interim targets

Pollutant	Averaging time	IT1	IT2	IT3	IT4	AQG level
$PM_{2.5}$, µg/m^3	Annual	35	25	15	*10*	**5**
$PM_{2.5}$, µg/m^3	24-hour[a]	75	50	37.5	*25*	**15**
PM_{10}, µg/m^3	Annual	70	50	30	*20*	**15**
PM_{10}, µg/m^3	24-hour[a]	150	100	75	*50*	**45**
O_3, µg/m^3	Peak season[b]	100	70	–	–	**60**
O_3, µg/m^3	8-hour[a]	160	120	–	–	**100**
NO_2, µg/m^3	Annual	*40*	30	20	–	**10**
NO_2, µg/m^3	24-hour[a]	120	50	–	–	**25**
SO_2, µg/m^3	24-hour[a]	125	50	–	–	**40**
CO, mg/m^3	24-hour[a]	7	–	–	–	**4**

Air quality guideline levels for both long- and short-term exposure in relation to critical health outcomes.

Interim targets to guide reduction efforts for the achievement of the air quality guideline levels.

Good practice statements for management of **Black Carbon, Ultrafine particles, Desert Dust**: types of health-relevant PM (evidence insufficient for quantitative guideline levels

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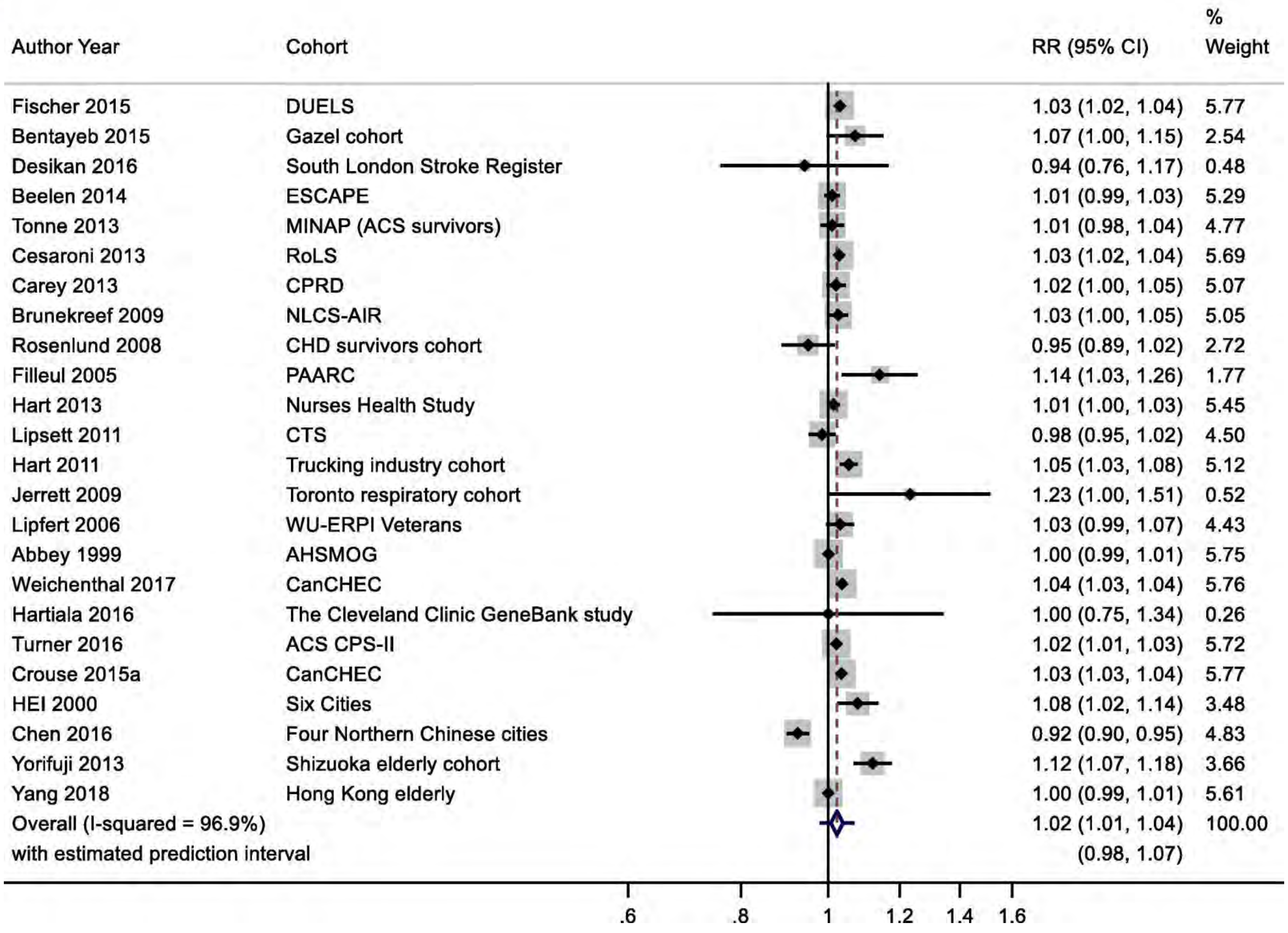
Review article

Long-term exposure to NO_2 and O_3 and all-cause and respiratory mortality: A systematic review and meta-analysis

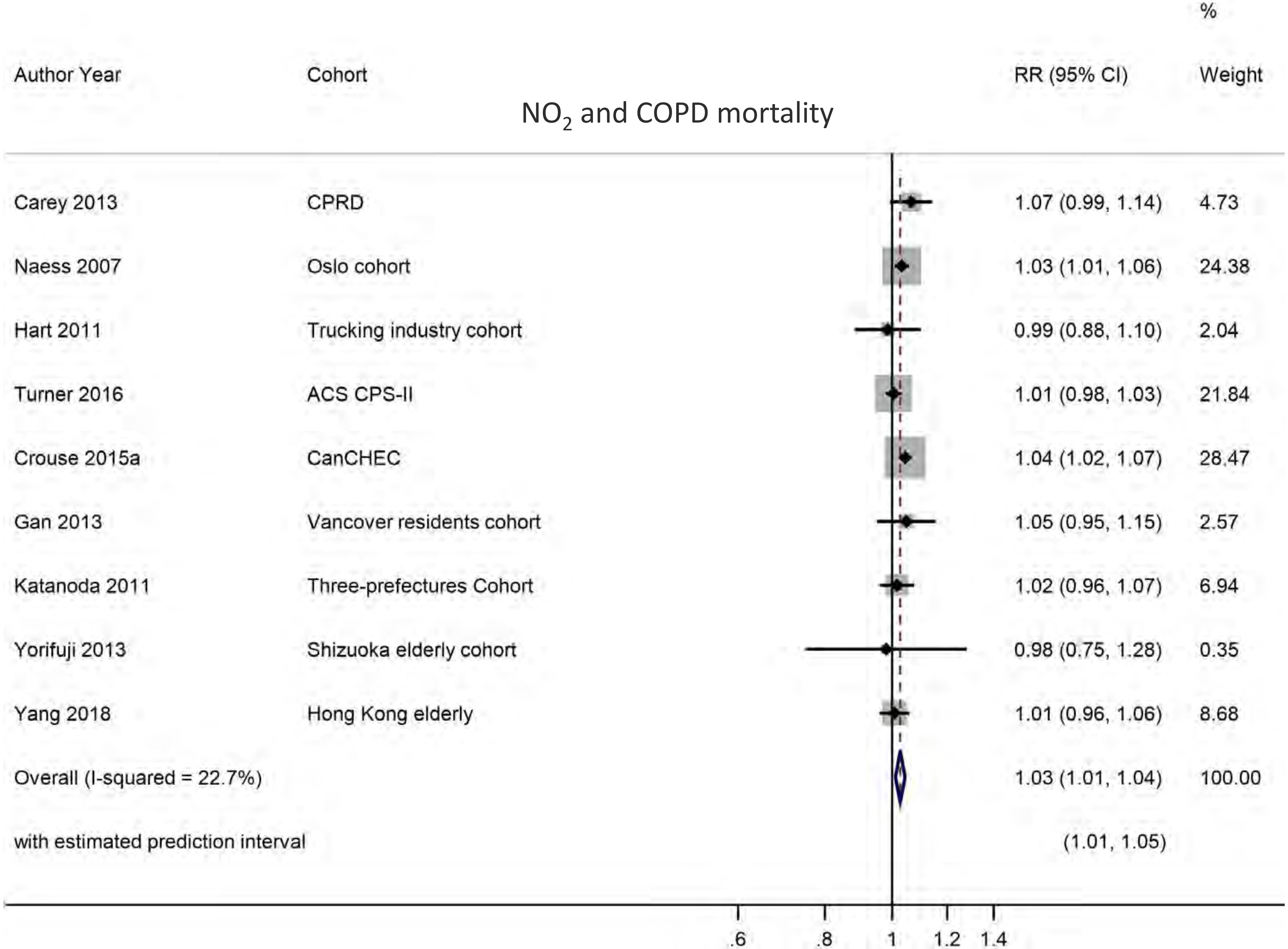
Peijue Huangfu, Richard Atkinson*

Population Health Research Institute, St George's, University of London, UK

NO_2 and all-cause mortality.



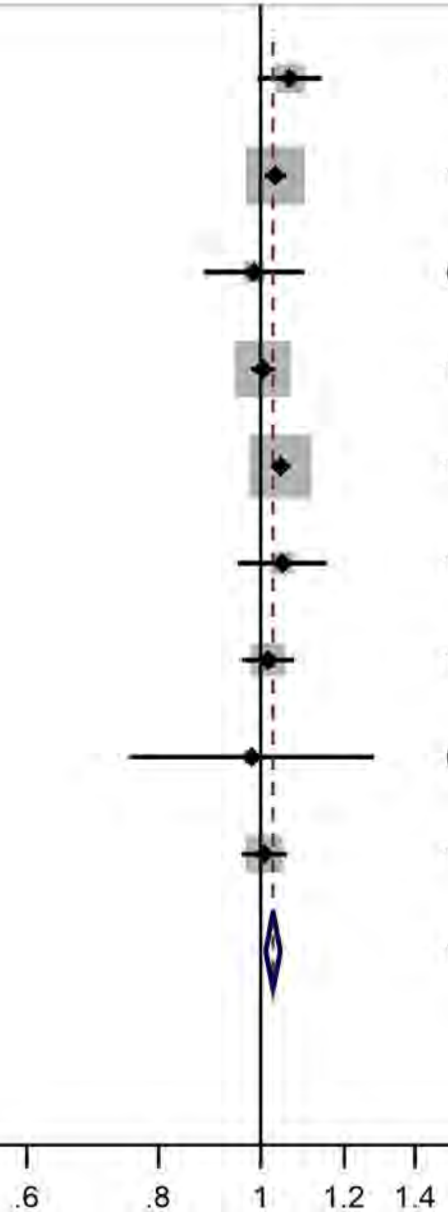
NO_2 and COPD mortality



Health Canada, 2016.

NO_2 and ALRI mortality

Author Year	Cohort	RR (95% CI)	% Weight
Carey 2013	CPRD	1.07 (0.99, 1.14)	4.73
Naess 2007	Oslo cohort	1.03 (1.01, 1.06)	24.38
Hart 2011	Trucking industry cohort	0.99 (0.88, 1.10)	2.04
Turner 2016	ACS CPS-II	1.01 (0.98, 1.03)	21.84
Crouse 2015a	CanCHEC	1.04 (1.02, 1.07)	28.47
Gan 2013	Vancouver residents cohort	1.05 (0.95, 1.15)	2.57
Katanoda 2011	Three-prefectures Cohort	1.02 (0.96, 1.07)	6.94
Yorifuji 2013	Shizuoka elderly cohort	0.98 (0.75, 1.28)	0.35
Yang 2018	Hong Kong elderly	1.01 (0.96, 1.06)	8.68
Overall (I-squared = 22.7%)		1.03 (1.01, 1.04)	100.00
with estimated prediction interval		(1.01, 1.05)	



Health Canada, 2016.

Health Canada (2016)

- **Causal:**
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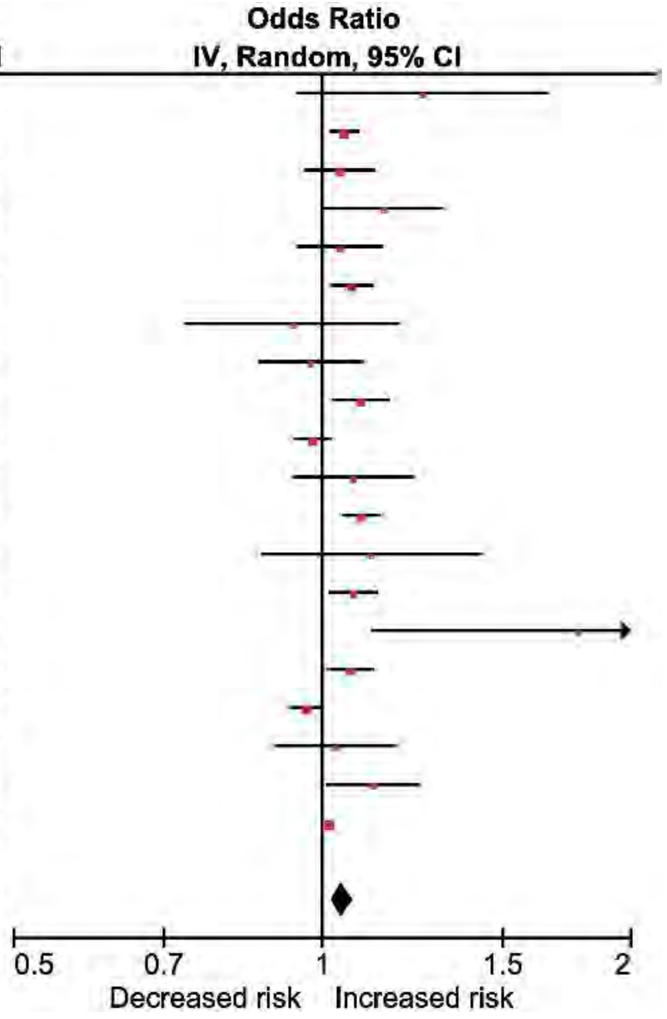
  - **long-term exposure** and development of **asthma or allergic-related disease**
- **Suggestive:**
  - **Short-term exposure** and **cardiovascular effects.**

Health Canada, 2016. Human Health Risk Assessment for Ambient Nitrogen Dioxide.
https://publications.gc.ca/collections/collection_2016/sc-hc/H114-31-2016-eng.pdf

NO_2 and incident asthma

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
Carlsten et al. 2010 - at 7 y.o.	0.2253	0.1448	0.6%	1.25 [0.94, 1.66]
Clark et al. 2010 LUR - at mean age of 4 y.o.	0.0489	0.0171	9.5%	1.05 [1.02, 1.09]
Dell et al. 2014 LUR - 5 to 9 y.o.	0.039	0.04	5.0%	1.04 [0.96, 1.12]
Deng et al. 2016 - 3 to 6 y.o.	0.1374	0.0689	2.4%	1.15 [1.00, 1.31]
Gehring et al. 2015 b - BAMSE birth to 16 y.o.	0.0397	0.0498	3.8%	1.04 [0.94, 1.15]
Gehring et al. 2015 b - PIAMA birth to 14 y.o.	0.0665	0.0246	7.8%	1.07 [1.02, 1.12]
Gehring et al. 2015b - GINI&LISA North birth to 15	-0.0679	0.1235	0.8%	0.93 [0.73, 1.19]
Gehring et al. 2015b - GINI&LISA South birth to 15	-0.0252	0.0602	2.9%	0.98 [0.87, 1.10]
Jerret et al. 2008 - 10 to 18 y.o.	0.0874	0.033	6.1%	1.09 [1.02, 1.16]
Kim et al. 2016 - 6 to 7 y.o.	-0.0214	0.0219	8.4%	0.98 [0.94, 1.02]
Krämer et al. 2009 - 4 to 6 y.o.	0.0698	0.069	2.3%	1.07 [0.94, 1.23]
Liu et al. 2016 - 4 to 6 years old	0.0877	0.0215	8.5%	1.09 [1.05, 1.14]
MacIntyre et al. 2014 - CAPPS&SAGE only birth to 8	0.1111	0.1268	0.8%	1.12 [0.87, 1.43]
McConnell et al. 2010 - 4th to 6th grade	0.0698	0.0281	7.1%	1.07 [1.01, 1.13]
Mölter et al. 2014 b - MAAS only birth to 8 y.o.	0.574	0.2374	0.2%	1.78 [1.11, 2.83]
Nishimura et al. 2013 - 8 to 21 y.o.	0.0632	0.0269	7.3%	1.07 [1.01, 1.12]
Oftedal et al. 2009 - birth to 10 y.o.	-0.0359	0.0196	8.9%	0.96 [0.93, 1.00]
Ranzi et al. 2014 - birth to 7 y.o.	0.0289	0.0701	2.3%	1.03 [0.90, 1.18]
Shima et al. 2002 - 6 to 12 y.o.	0.1136	0.0534	3.5%	1.12 [1.01, 1.24]
Tétreault et al. 2016 - birth to 12 y.o.	0.0153	0.0048	11.6%	1.02 [1.01, 1.03]
Total (95% CI)			**100.0%**	**1.05 [1.02, 1.07]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 54.38$, df = 19 ($P < 0.0001$); $I^2 = 65\%$
Test for overall effect: Z = 3.76 (P = 0.0002)



(per 4 μg/m^3; birth – 21 yrs)

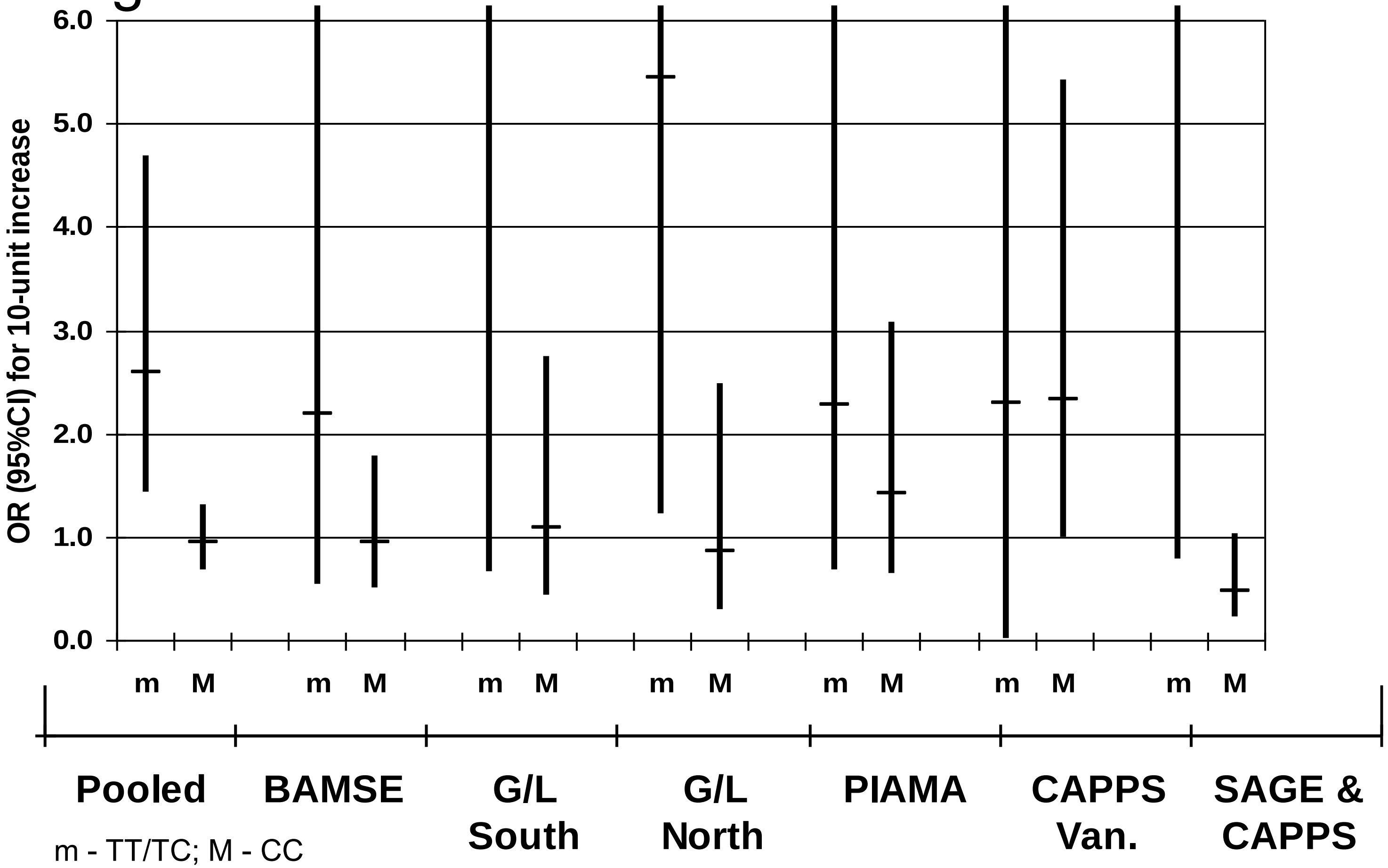
Khreis H, et al. Environ Int. 2017. doi: 10.1016/j.envint.2016.11.012;

Traffic pollution, Asthma Genetics (TAG)

NO_2 - Asthma, by GSTP1 rs1138272

[GSTP1 and TNF Gene variants and associations between air pollution and incident childhood asthma: the traffic, asthma and genetics (TAG) study.] MacIntyre EA, Brauer M, Melén E, Bauer CP, Bauer M, Berdel D, Bergström A, Brunekreef B, Chan-Yeung M, Klümper C, Fuertes E, Gehring U, Gref A, Heinrich J, Herbarth O, Kerkhof M, Koppelman GH, Kozyrskyj AL, Pershagen G, Postma DS, Thiering E, Tiesler CM, Carlsten C; TAG Study Group. Environ Health Perspect. 2014 Apr;122(4):418-24. doi: 10.1289/ehp.1307459.

Significant interaction

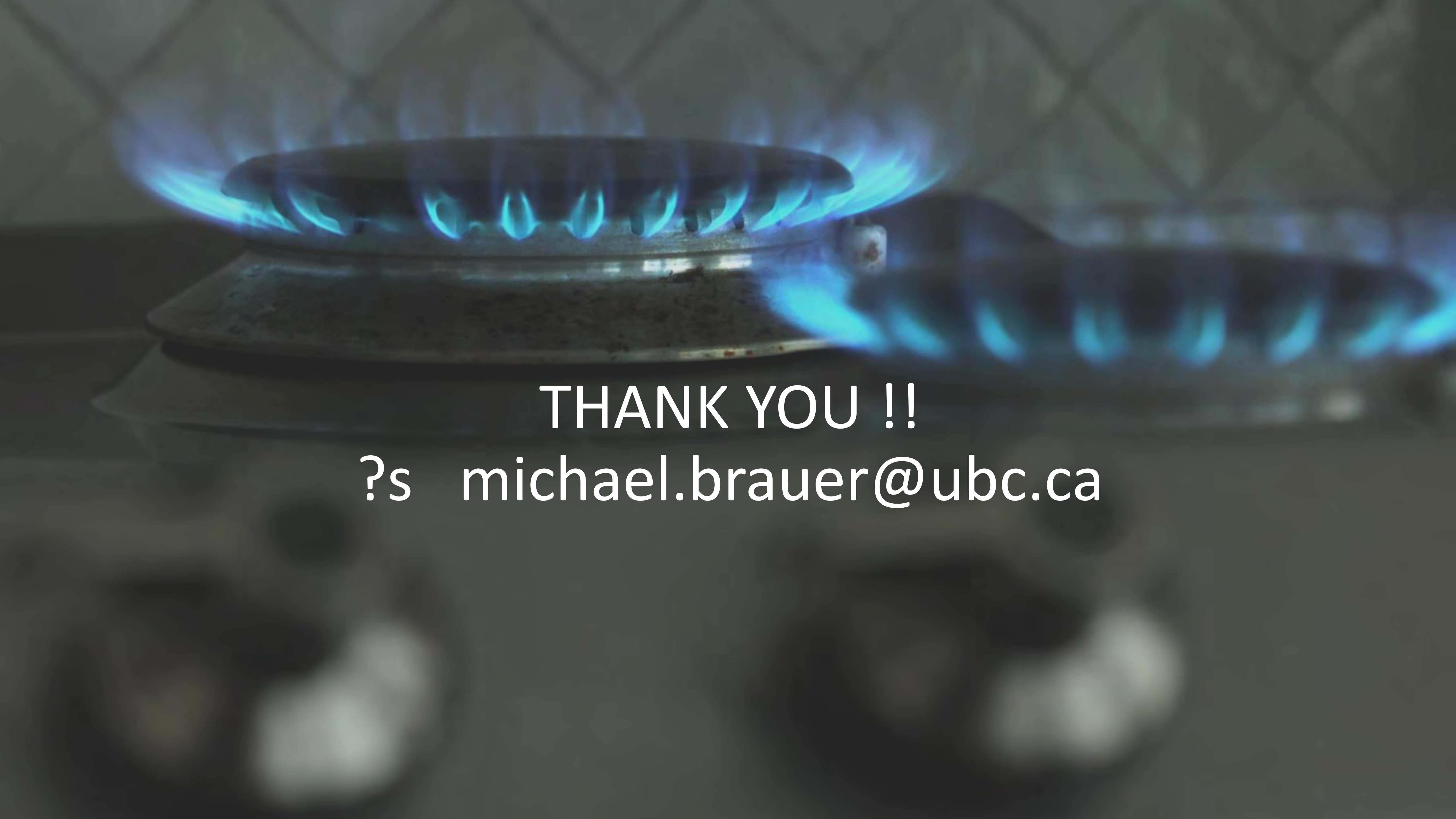


m - TT/TC; M - CC

Adjusted for study, city, intervention, gender, maternal age at birth, maternal smoking during pregnancy, environmental tobacco smoke in the home, birth weight and parental atopy

Conclusions

- (unventilated) Gas stoves
  - No new health info! Small increases in respiratory symptoms and incident childhood asthma (?); unlikely due to NO_2 (or HONO)
    - Climate impacts of methane emissions (leakage)
    - Ventilation (range hoods/open windows) reduces emissions
    - Lower concentrations with ~modern stoves that do not have continuous pilots
- NO_2 in ambient air
  - Short-term exposures and asthma exacerbation
  - Long-term exposures: ~relationship (with substantial heterogeneity) with incident childhood asthma
  - ~NO_2 very likely a marker for TrAP mixture for other outcomes



THANK YOU !!

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