Comité Operativo Ampliado

Revisión de la Norma Primaria de Calidad Ambiental para $MP_{2,5}$

SESIÓN N°2
06 de octubre, 2023

Ministerio del Medio Ambiente

Gobierno de Chile

Tabla de sesión

- Efectos en la salud asociados a la exposición del $MP_{2,5}$.

Dr. Andrés Henríquez, Toxicólogo de la Universidad de Carolina del Norte en Chapel Hill, miembro del equipo consultor a cargo del estudio de antecedentes.

- Análisis normativo del $MP_{2,5}$ en Chile.

Dr. Felipe Reyes, Doctor en Química de la Universidad de Santiago de Chile, miembro del equipo consultor a cargo del estudio de antecedentes.

Calendario próximas sesiones

Tabla 1: Planificación tentativa de próximas sesiones.

Sesión	Objetivos	Fecha tentativa
3°	-Escenarios propuestos del estudio -Resultados preliminares de costos y beneficios de escenarios propuestos en el estudio	26 octubre o 3 noviembre
4°	-Borrador de Anteproyecto -AGIES (MMA)	Fines de noviembre
5°	-Programa participación ciudadana	Mediados de diciembre

Expediente electrónico

https://planesynormas.mma.gob.cl/normas/expediente/index.php?tipo=busqueda&id_expediente=939510

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EXPEDIENTES ELECTRÓNICOS

Planes y Normas

Normas de Calidad Normas de Emisión Planes Búsqueda

Normas de Calidad > Revisión Norma de Calidad Primaria de MP2.5, D.S. N°12 de 2011 > Expediente

Según el reglamento de las normas y planes es necesario cumplir con mantener un expediente en el cual se incluya toda la informacion generada en el proceso de elaboración o revisión de normas..

Ficha | Expediente

Nombre: Revisión Norma de Calidad Primaria de MP2.5, D.S. N°12 de 2011

Estado: En elaboración

Documentos Publicados

N°	N° Folio	Documento	Materia	Remitido por	Fecha de Publicación
1	1 - 2	Resolución Inicio Anteproyecto	Resolución N° 1319	Ministerio del Medio Ambiente	22-11-2021
2	3	Rectifica Resolución N°1319	Resolución N° 1382	Ministerio del Medio Ambiente	09-12-2021
3	4-5	Publicación Diario Oficial	Publicación D.O.	Ministerio del Medio Ambiente	24-12-2021
4	6	Publicación Diario Oficial	Publicación D.O.	Ministerio del Medio Ambiente	24-12-2021

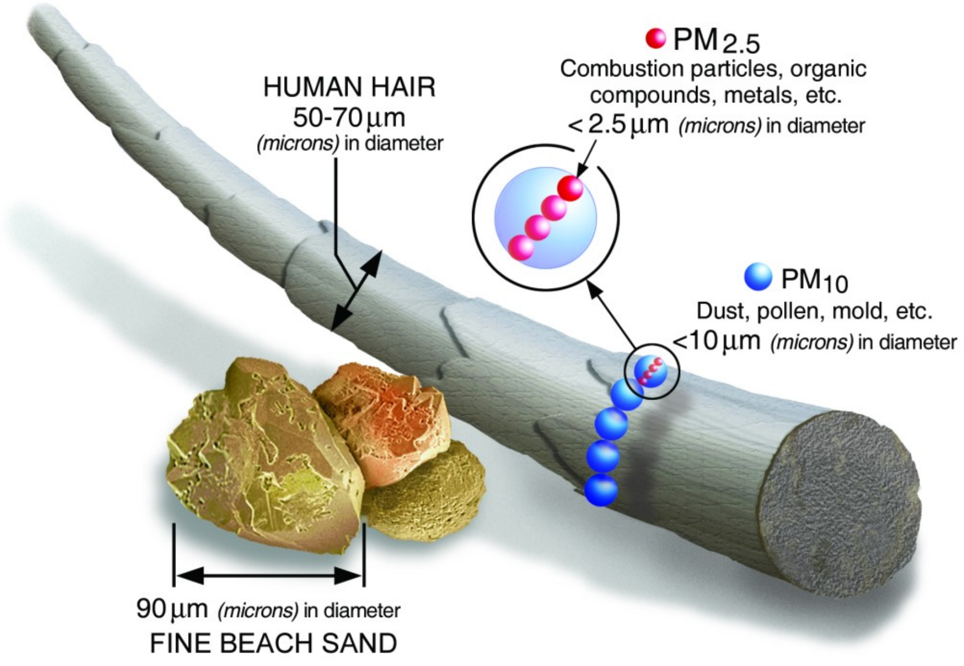
Ministerio del Medio Ambiente

Gobierno de Chile

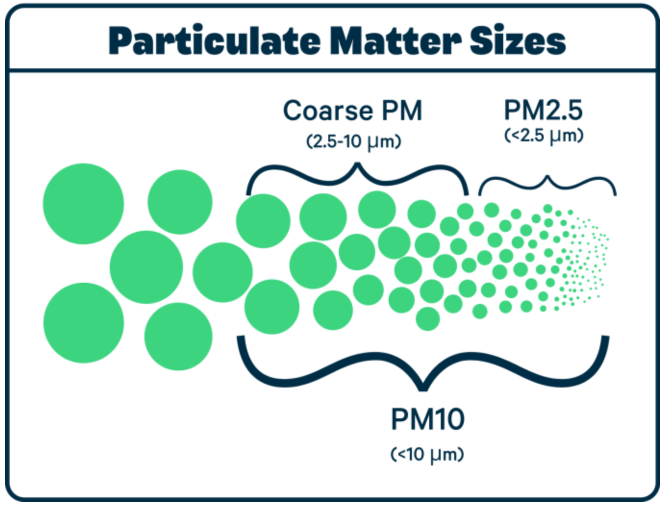
$MP_{2,5}$

Andrés Henríquez, Ph.D.
[redacted]@gmail.com

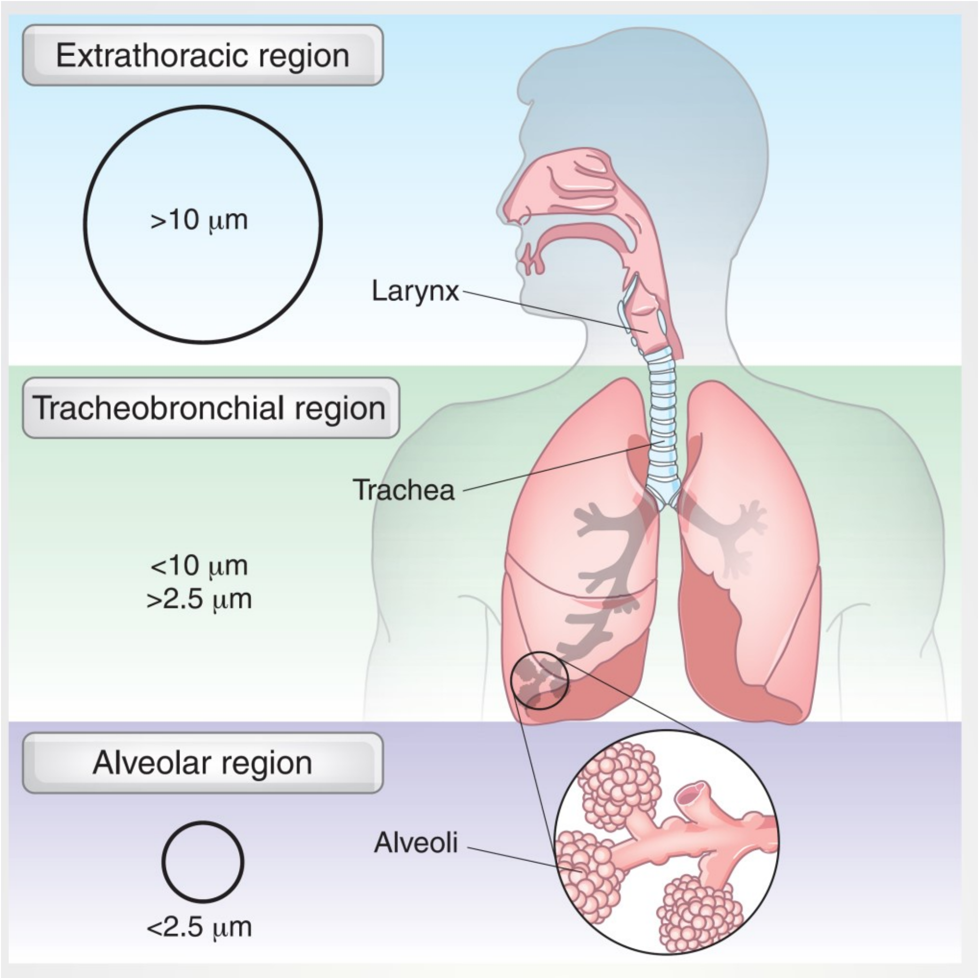
$PM_{2.5}$



https://www.epa.gov/sites/production/files/2016-09/pm2.5_scale_graphic-color_2.jpg



https://learn.kaiterra.com/en/air-academy/particulate-matter-pm



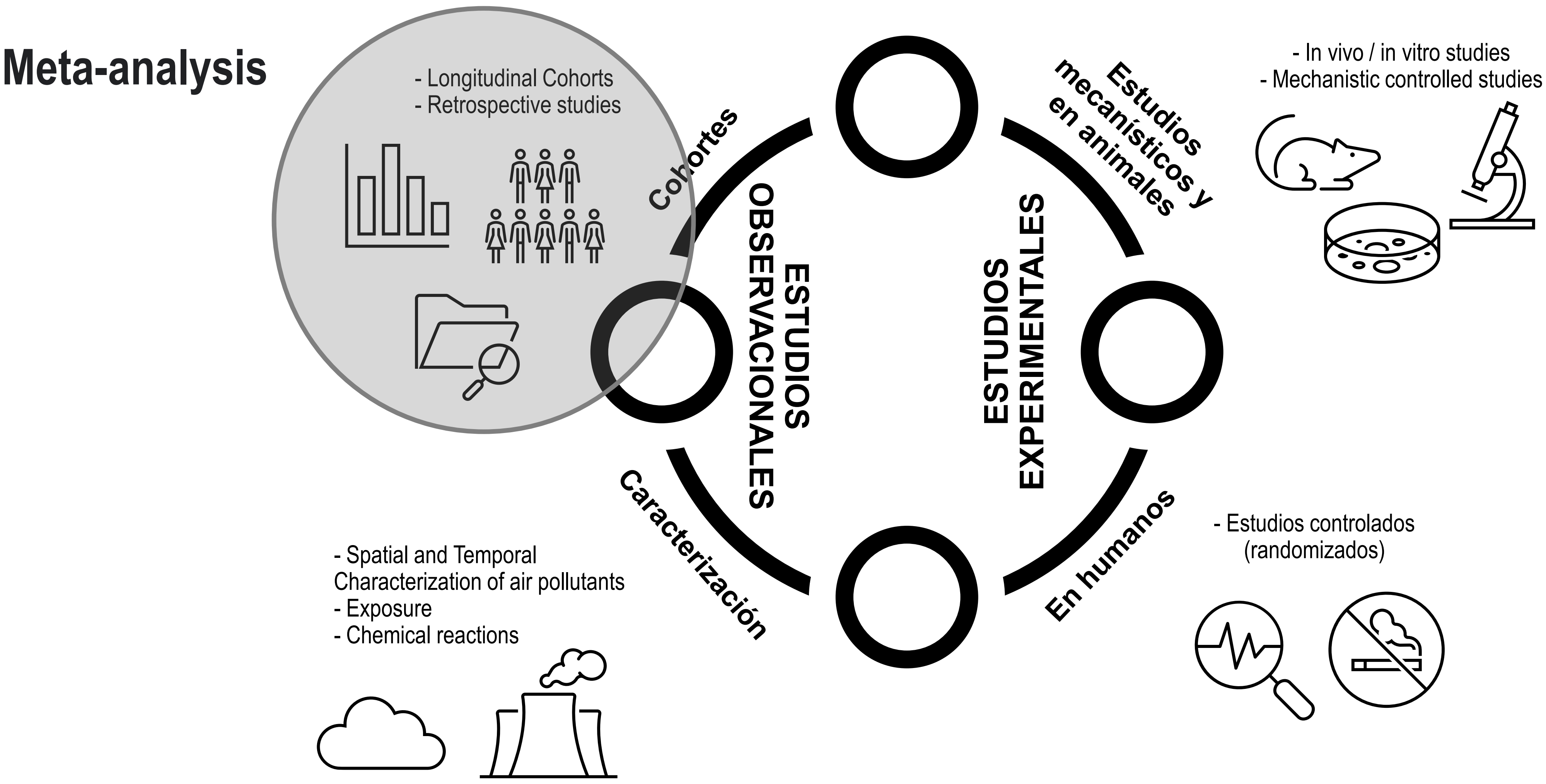
Lippmann 2010

Size → Particle Deposition

PM$_{2.5}$ (and air pollution)-induced Health Effects

000215 VTA

Research



Modified from, Burns et al et al. 2022

$PM_{2.5}$ (and air pollution) **CAUSAL** effects on human health

Bradford Hill criteria in next-generation epidemiology

Bradford Hill criterion	Consideration in next-generation epidemiology
Strength	Size of the estimated effect
Consistency	Consistency of evidence across studies
Specificity	How specific the mechanisms of the effect are
Temporality	Whether the temporal relationship between exposure and outcome is plausible
Biological gradient	Whether there is evidence of a biological gradient (dose–response)
Plausibility	Whether a plausible mechanism between exposure and outcome can be established
Coherence	Whether other types of coherent evidence exist
Experiment	Whether experimental evidence supports the observational data
Analogy	Whether similar exposures are expected to lead to similar outcomes

https://link.springer.com/article/10.1007/s00125-020-05246-w

$PM_{2.5}$ (and air pollution)-induced Health Effects

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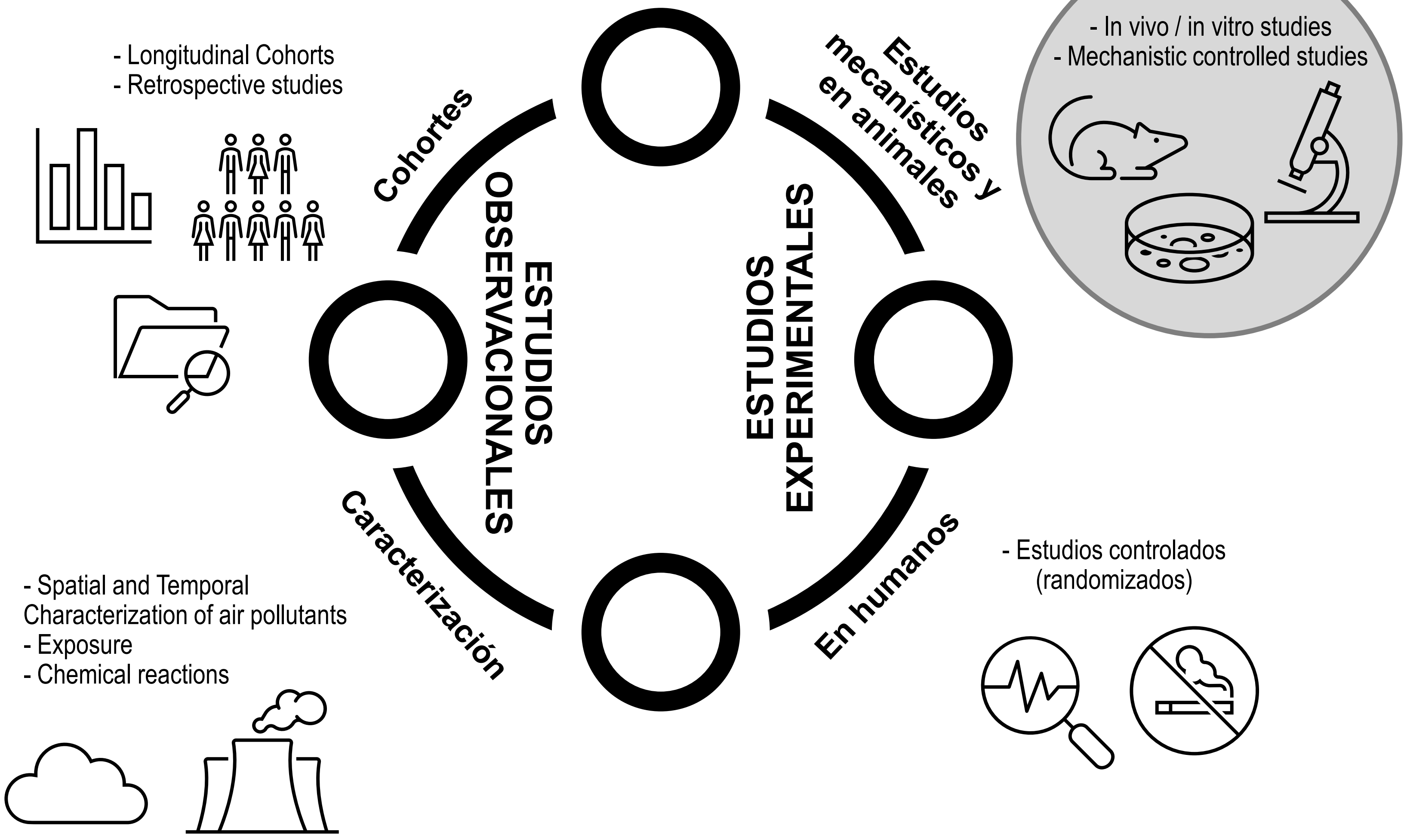
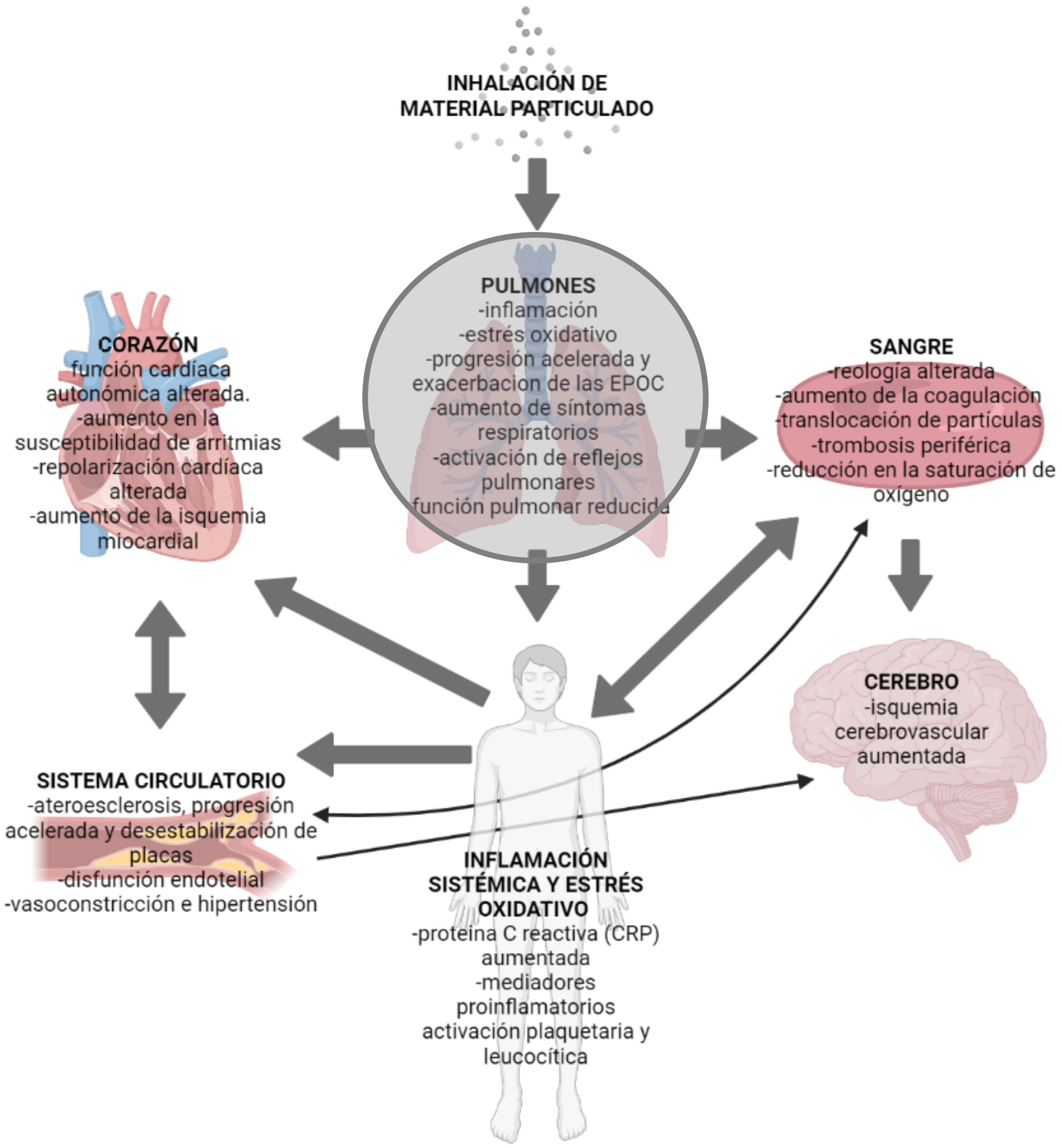
Research

Meta-analysis



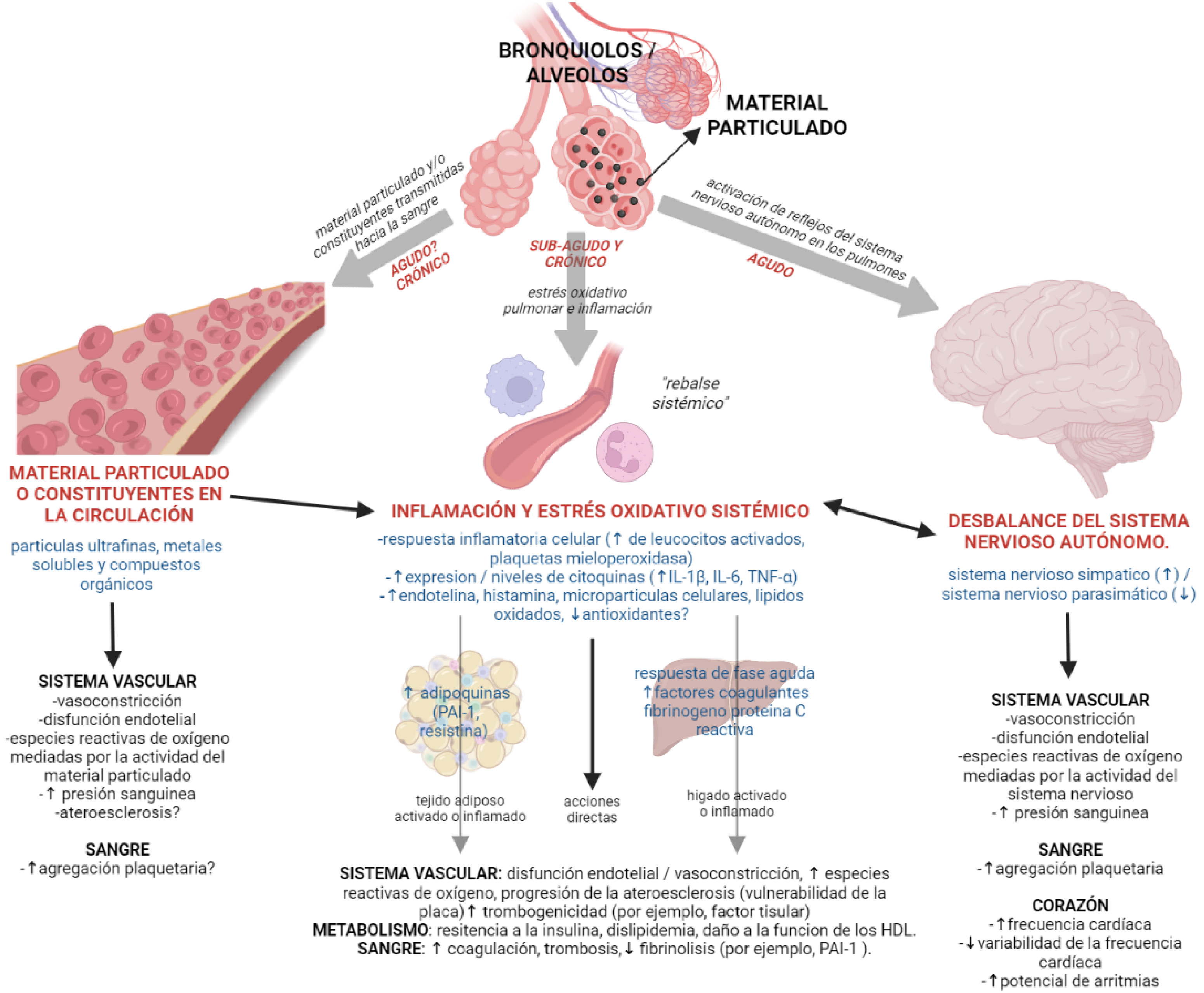
Modified from, Burns et al et al. 2022

$PM_{2.5}$ (and air pollution)-induced Health Effects / Mechanisms



Material particulado y efectos en la salud pulmonares y extrapulmonares.
Figura adaptada y traducida desde (Pope & Dockery, 2006).

$PM_{2.5}$ (and air pollution)-induced Health Effects / Mechanisms 000217 VTA



Pozo sin fondo

Material particulado y efectos en la salud pulmonares y extrapulmonares.
Figura adaptada y traducida desde (Brook et al., 2010b)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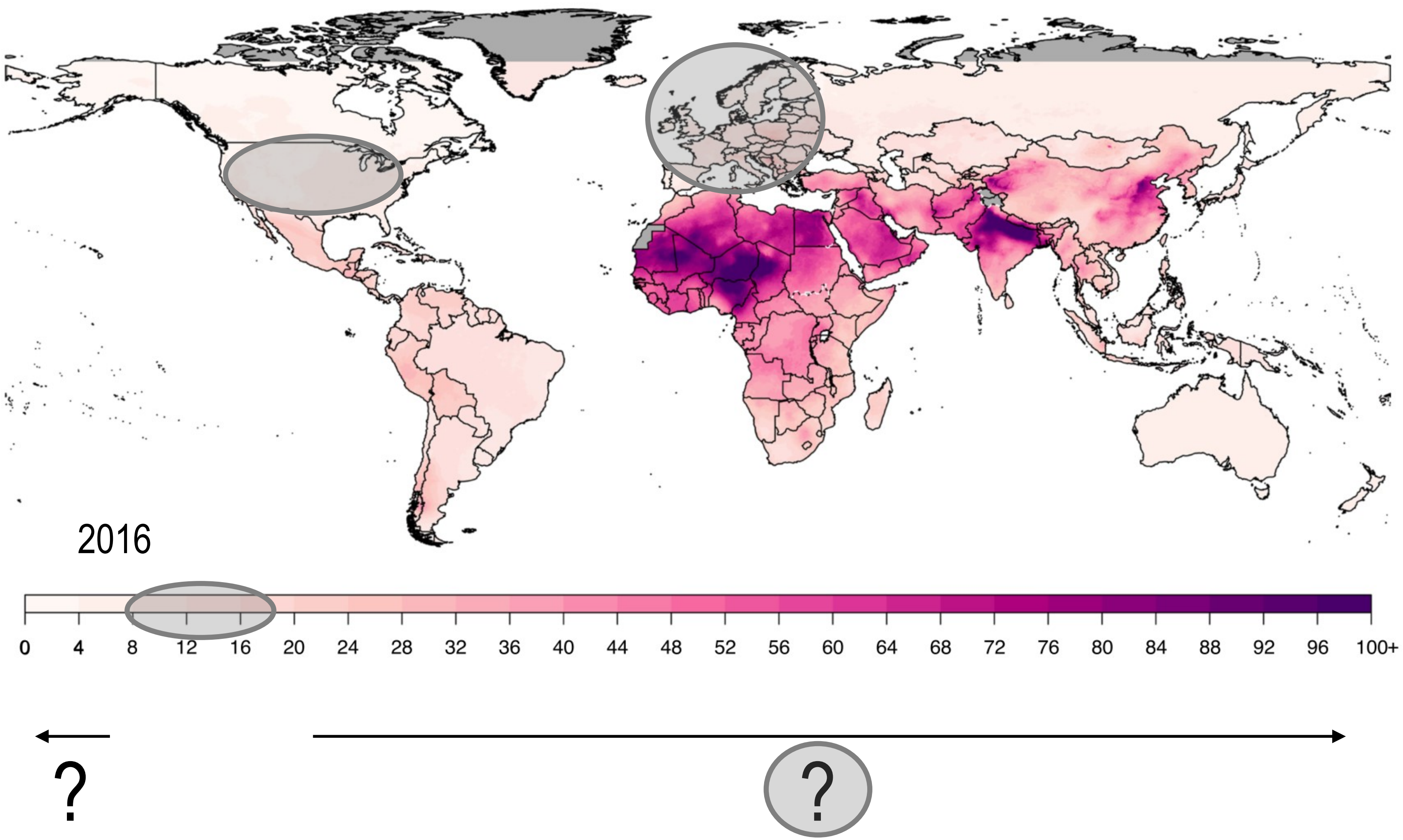
$PM_{2.5}$ levels worldwide

000218 VTA

Annual concentrations (ug/m^3) of $PM_{2.5}$ for 2016



Shaddick et al. 2020

atmosphere

MDPI

Article

Relative Risk Functions for Estimating Excess Mortality Attributable to Outdoor $PM_{2.5}$ Air Pollution: Evolution and State-of-the-Art

Richard Burnett [1,*] and Aaron Cohen [1,2]

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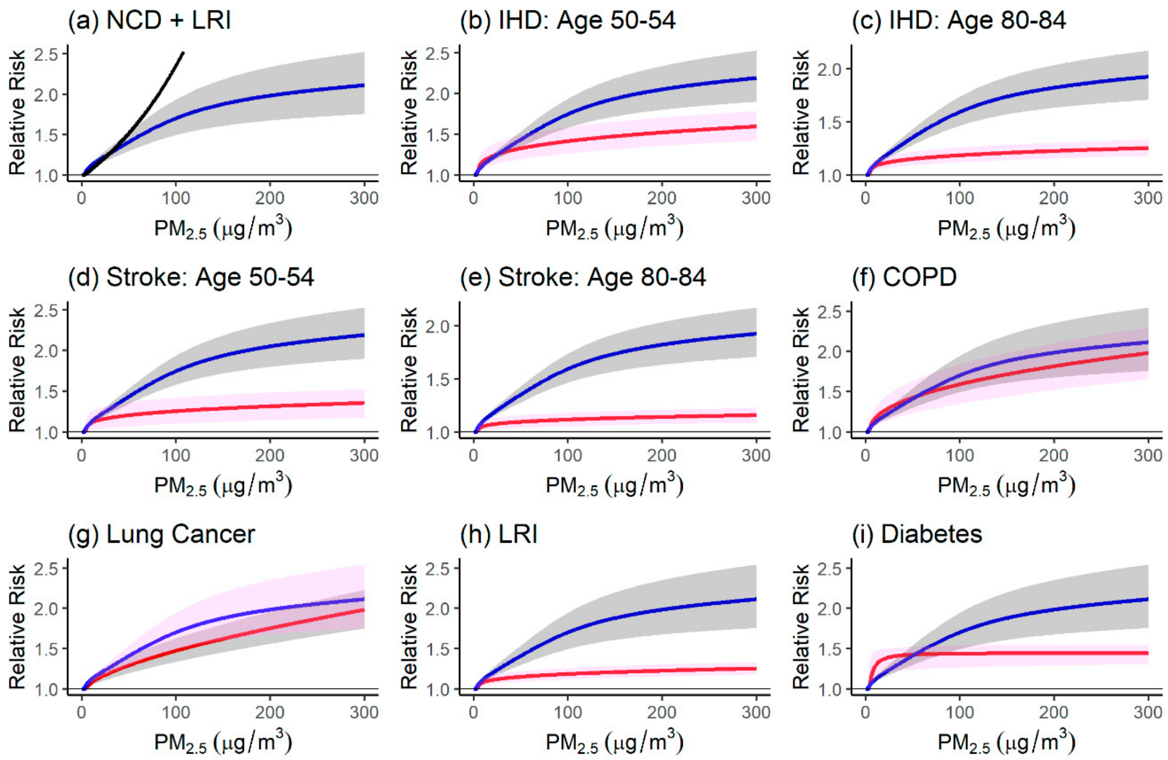


3. Estimators of the PM2.5 Mortality Relative Risk over the Global Concentration Range

3.1. The Integrated Exposure-Response (IER) Relative Risk Model

000219

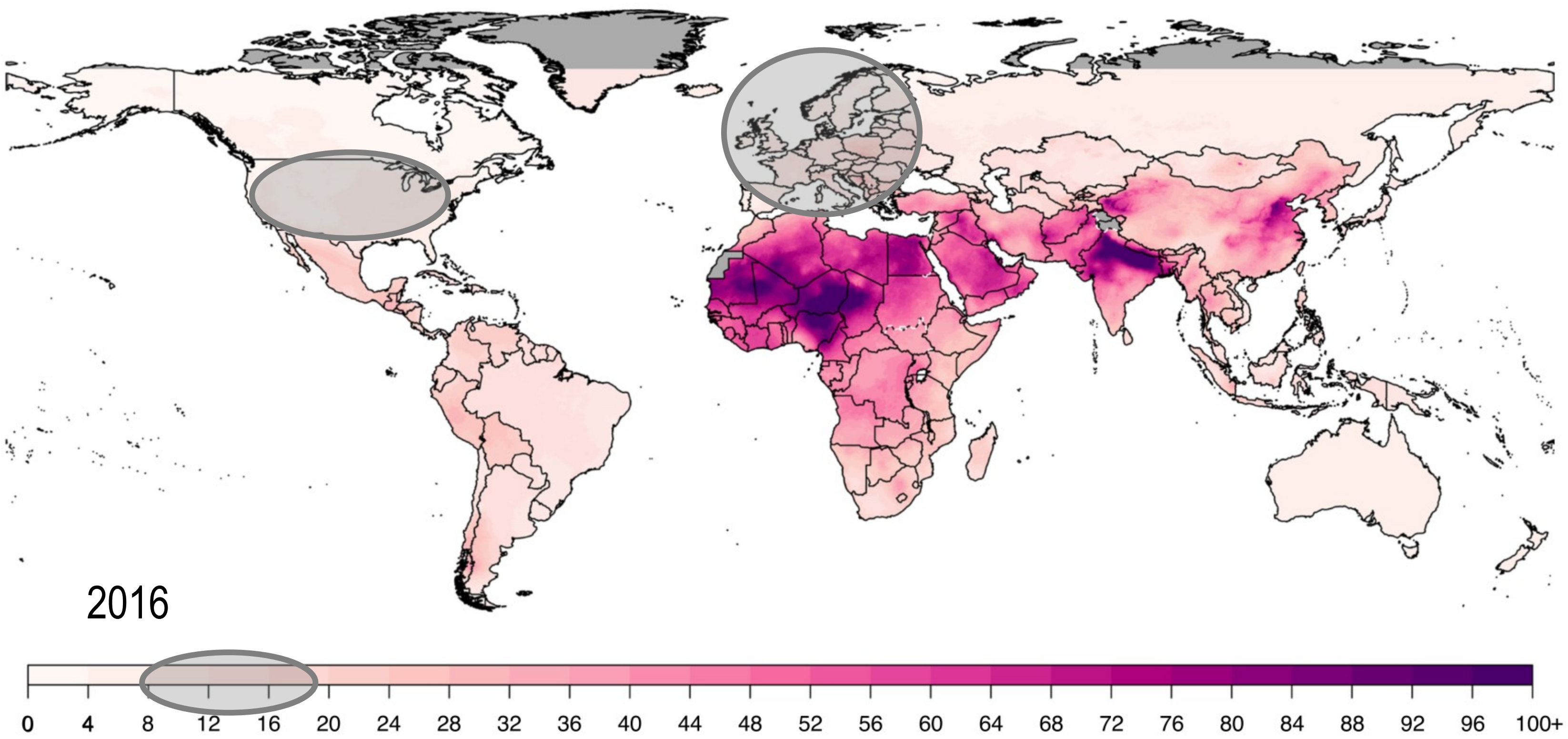
Although the number of outdoor fine particulate air pollution cohort studies increased since 2004, **all of the new studies have been conducted at low levels of exposure in high-income countries;** thus, the GBD still faced the same problem as it planned an updated set of estimates for GBD 2010 [15,18]. In those studies, **the estimated annual-average population-weighted exposure rarely exceeded 50 μg/m3, with most below 30 μg/m3.**

A solution was suggested from an analysis by Pope and colleagues [24,25] which linked relative risks of cardiovascular and lung cancer deaths to other sources of PM2.5, including those from **secondhand and active smoking, which result in much higher PM2.5 exposure than observed outdoors**. They placed outdoor PM2.5 air pollution as well as secondhand and active smoking relative risks on the same dose scale: **total inhaled PM2.5 mass.** Graphically displaying all the relative risks on the total mass scale revealed a **non-linear shape with the change in relative risk decreasing as total mass increased**. However, this non-linear shape was much more pronounced for cardiovascular mortality than for lung cancer [25].

The analysis presented by Pope and colleagues [24,25] paved the way for the GBD to develop the integrated exposure-response (IER) relative risk function. In addition to the three types of PM2.5 exposures considered by Pope and colleagues, the GBD added a **fourth type: household pollution from heating and cooking sources** [17]. This enabled the GBD to estimate attributable mortality from three combustion-derived risk factors, **outdoor fine particulate air pollution, secondhand smoking, and household burning of solid fuels, using a single risk function.**

$PM_{2.5}$ levels worldwide

Annual concentrations (ug/m³) of $PM_{2.5}$ for 2016



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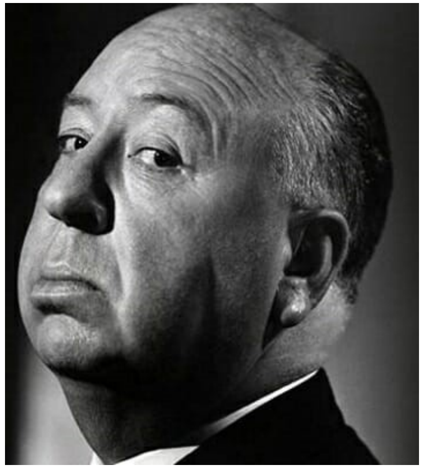

Suspenso

Shaddick et al. 2020


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GUIDELINES

000220 VTA

Foreword

Clean air is fundamental to health. Compared to 15 years ago, when the previous edition of these guidelines was published, there is now a much **stronger body of evidence to show how air pollution affects different aspects of health at even lower concentrations than previously understood**. But here's what hasn't changed: every year, exposure to air pollution is still estimated to cause millions of deaths and the loss of healthy years of life. The burden of disease attributable to **air pollution is now estimated to be on a par with other major global health risks such as unhealthy diets and tobacco smoking**.

In 2015, the World Health Assembly adopted a landmark resolution on air quality and health, recognizing air pollution as a risk factor for noncommunicable diseases such as ischaemic heart disease, stroke, chronic obstructive pulmonary disease, asthma and cancer, and the economic toll they take. The global nature of the challenge calls for an enhanced global response.

These guidelines, taking into account the **latest body of evidence on the health impacts of different air pollutants**, are a key step in that global response. The next step is for policy-makers around the world to use these guidelines to inform evidence-based legislation and policies to improve air quality and reduce the unacceptable health burden that results from air pollution.

We are immensely grateful to all the scientists, colleagues and partners around the world who have contributed time and resources to the development of these guidelines. As with all WHO guidelines, a global group of experts has derived the new recommendations based on a robust and comprehensive review of the scientific literature, while adhering to a rigorously defined methodology. This process was overseen by a steering group hosted and coordinated by the WHO European Centre for Environment and Health.

Although the burden of air pollution is heterogeneous, its impact is ubiquitous. These guidelines come at a time of unprecedented challenges, in the face of the ongoing COVID-19 pandemic and the existential threat of climate change. Addressing air pollution will contribute to, and benefit from, the global fight against climate change, and must be a key part of the global recovery, as prescribed by the WHO Manifesto for a healthy recovery from COVID19.

A guideline is just a tool. What matters is that countries and partners use it to improve air quality and health globally. The health sector must play a key role in monitoring health risks from air pollution, synthesizing the evidence, providing the tools and resources to support decision-making, and raising awareness of the impacts of air pollution on health and the available policy options. But this is not a job for one sector alone; it will take sustained political commitment and bold action and cooperation from many sectors and stakeholders. The payoff is cleaner air and better health for generations to come.

Dr Tedros Adhanom Ghebreyesus
WHO Director-General
Dr Hans Henri P. Kluge
WHO Regional Director for Europe

2021

WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.

ISBN 978-92-4-003422-8 (electronic version) ISBN 978-92-4-003421-1 (print version)

Table 2.5. Eight steps in formulation of long-term AQG levels

Step	Description
Step 1	Assess RR estimates and, when available, CRF for each critical health outcome per pollutant as provided by the systematic review. In its first meeting in 2016, based on an initial survey, the GDG decided that the following health outcomes are critical (depending on air pollutant): (i) all-cause mortality (or all, natural-cause mortality, excluding accidental deaths); (ii) respiratory mortality; (iii) cardiovascular mortality, associated with both long- and short-term exposures; (iv) short-term, day-to-day variations in hospital admissions and emergency room visits related to asthma; and (v) myocardial infarction. The GDG recommends AQG levels for all pollutant–outcome pairs identified in 2016 except for those associations not meeting at least moderate levels of certainty. This includes pairs with different likelihoods of causality, according to authoritative reviews by COMEAP, Health Canada, International Agency for Research on Cancer, US EPA and others
Step 2	Determine the lowest level of exposure measured in the studies included in the systematic review or in the subset of studies in the systematic review that estimate risk at this lowest level. For individual studies that used statistical models to evaluate the shape of the CRF, ensure that the lowest level of exposure is associated with a monotonic increase of the CRF curve
Step 3	Determine the minimal relevant increase in health outcomes
Step 4	Determine the starting point for AQG level determination as the long-term concentration of pollutant from which the minimal relevant amount of the health outcome will result
Step 5	Compare the AQG levels for a specific pollutant across critical health outcomes. Take as the final AQG level the lowest AQG level found for any of the critical health outcomes
Step 6	Assess the certainty of the evidence at low levels of exposure. The adapted GRADE assessment is for the entire body of evidence, not the subset of studies conducted at the lowest exposure levels. The evidence provided by these latter studies needs to be discussed, starting from the RoB assessment that was conducted at individual study level
Step 7	Consider new relevant evidence not included in the systematic reviews in a qualitative or, where possible, quantitative manner
Step 8	Reconsider causality of associations between pollutants and outcomes, taking into account whether or not associations have been classified as causal or likely causal in recent reviews by COMEAP, Health Canada, US EPA, WHO or other authoritative bodies

Assess the literature (RR, CRF). Mortality (total, respiratory, cardiovascular, hospital admissions (asthma) and myocardial infarction.

Lowest level of exposure

Minimal increase in health outcome

Long Term > Short Term

Critical health outcomes

Assess the evidence

Consider new evidence

Reconsider causality

WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Page 61

000221 VTA

Contaminante	Efectos en la salud usados en la guía del año 2005	Efectos en la salud seleccionados y actualizados para la guía del 2021	Determinación de causalidad
		Exposiclón de Largo Plazo	
$PM_{2.5}$ y PM_{10}	Mortalidad total, cardiopulmonar y de cancer al pulmón.	***Mortalidad por todas las causas** ***Mortalidad cardiovascular (total, cerebrovascular, de las arterias coronarias)** ***Mortalidad Respiratoria (cualquiera, enfermedad obstructiva pulmonar crónica [EPOC], Infecciones respiratorias agudas de las vías aereas inferiores)** ***Mortalidad por cáncer pulmonar**	**$PM_{2.5}$** *Causal para mortalidad cardiovascular y respiratoria (US EPA, 2009) *Causal para mortalidad cardiovascular y total (Health Canada, 2013) **PM** *Causal para mortalidad total en relación a PM (Health Canada, 2013) *Grupo 1b para cáncer pulmonar (Straif et al. 2013) *Probablemente causal para mortalidad por cáncer pulmonar (Health Canada, 2013) **Consideraciones adicionales** *PM_{10} --> Efectos en la salud apoyadas por evidencia provenientes del PM2.5 y PM10 **Otras determinaciones causales relevantes** *$PM_{2.5}$ --> Probablemente causal para efectos respiratorios (US EPA, 2009) *$PM_{2.5}$ --> Probablemente causal para efectos respiratorios (Health Canada, 2013)
		Exposición de Corto Plazo	
$PM_{2.5}$ y PM_{10}	Niveles de carboxihemoglobina menor al 2% in la sangre de no-fumadores (WHO Regional Office for Europe, 200a, 2010)	***Mortalidad por todas las causas** ***Mortalidad cardiovascular** ***Mortalidad Respiratoria**	**$PM_{2.5}$** *Causal para mortalidad por todas las causas, cardiovascular y respiratoria (US EPA, 2009) *Causal para mortalidad por todas las causas, cardiovascular y respiratoria (Health Canada, 2013) **PM (Fracción de cualquier tamaño)** *Causal para mortalidad por todas las causas (Health Canada, 2013) **Consideraciones adicionales** *Mortalidad cardiovascular y respiratoria también considerada en la determinación causal de efectos respiratorios y cardiovasculares (US EPA, 2009) *PM_{10}, apoyado por la evidencia del $PM_{2.5}$ **Otras determinaciones causales relevantes** *Probablemente causal para efectos respiratorios (US EPA, 2009) *Causal para efectos cardiovasculares (US EPA, 2009) *Causal para efectos respiratorios (Health Canada, 2013) *Causal para efectos cardiovasculares (Health Canada, 2013)

$PM_{2.5}$ (and air pollution) induced Health Effects

000222

Select, Select, Select !!!!

Table 0.1. Recommended AQG levels and interim targets

Pollutant	Averaging time	Interim target 1	Interim target 2	Interim target 3	Interim target 4	AQG level
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, µg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Long Term

Short Term

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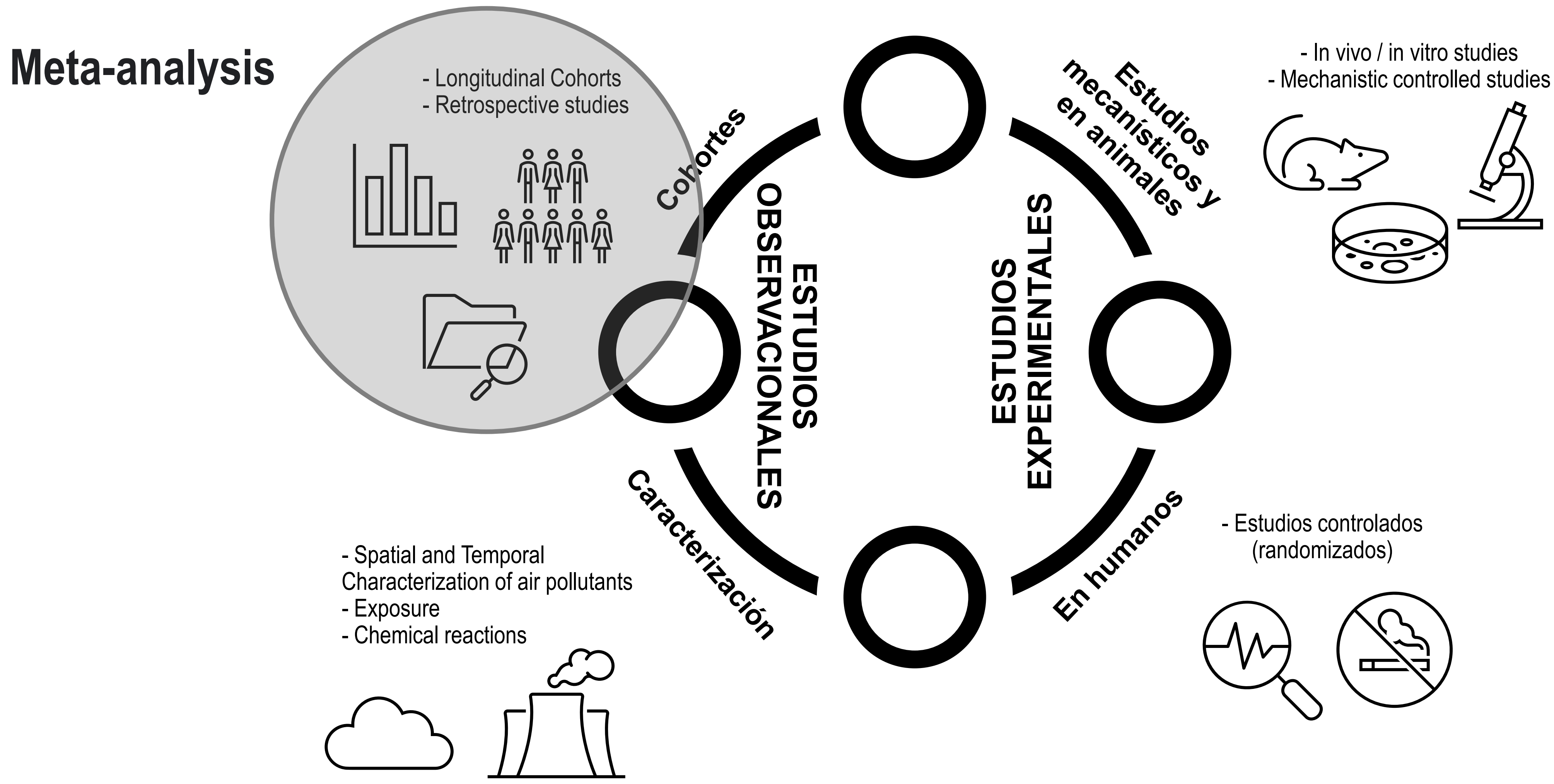
2021

WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.

ISBN 978-92-4-003422-8 (electronic version) ISBN 978-92-4-003421-1 (print version)

PM$_{2.5}$ (and air pollution)-induced Health Effects

Research



Modified from, Burns et al et al. 2022

WHO (Long Term, Annual)

000223

Environment International 143 (2020) 105974

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Review article

Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis

Jie Chen*, Gerard Hoek

Institute for Risk Assessment Sciences, Utrecht University, the Netherlands

Table 2
Pooled effect estimates for all pollutant-outcome combinations.

	PM$_{2.5}$			
	N	pooled RR per 10 μg/m^3	I^2 (%)	Prediction interval
Natural-cause	25	1.08 (1.06, 1.09)	88.9	(1.05, 1.11)
Circulatory	21	1.11 (1.09, 1.14)	72.1	(1.06, 1.17)
IHD	22	1.16 (1.10, 1.21)	77.5	(1.04, 1.29)
Stroke	16	1.11 (1.04, 1.18)	84.7	(0.98, 1.25)
Respiratory	17	1.10 (1.03, 1.18)	83.6	(0.95, 1.29)
COPD	11	1.11 (1.05, 1.17)	49.6	(1.02, 1.21)
ALRI	4	1.16 (1.01, 1.34)	83.0	(0.88, 1.54)
Lung cancer	15	1.12 (1.07, 1.16)	39.4	(1.05, 1.18)

N = number of studies

↑ 10 ug/m^3 → RR: 1.08

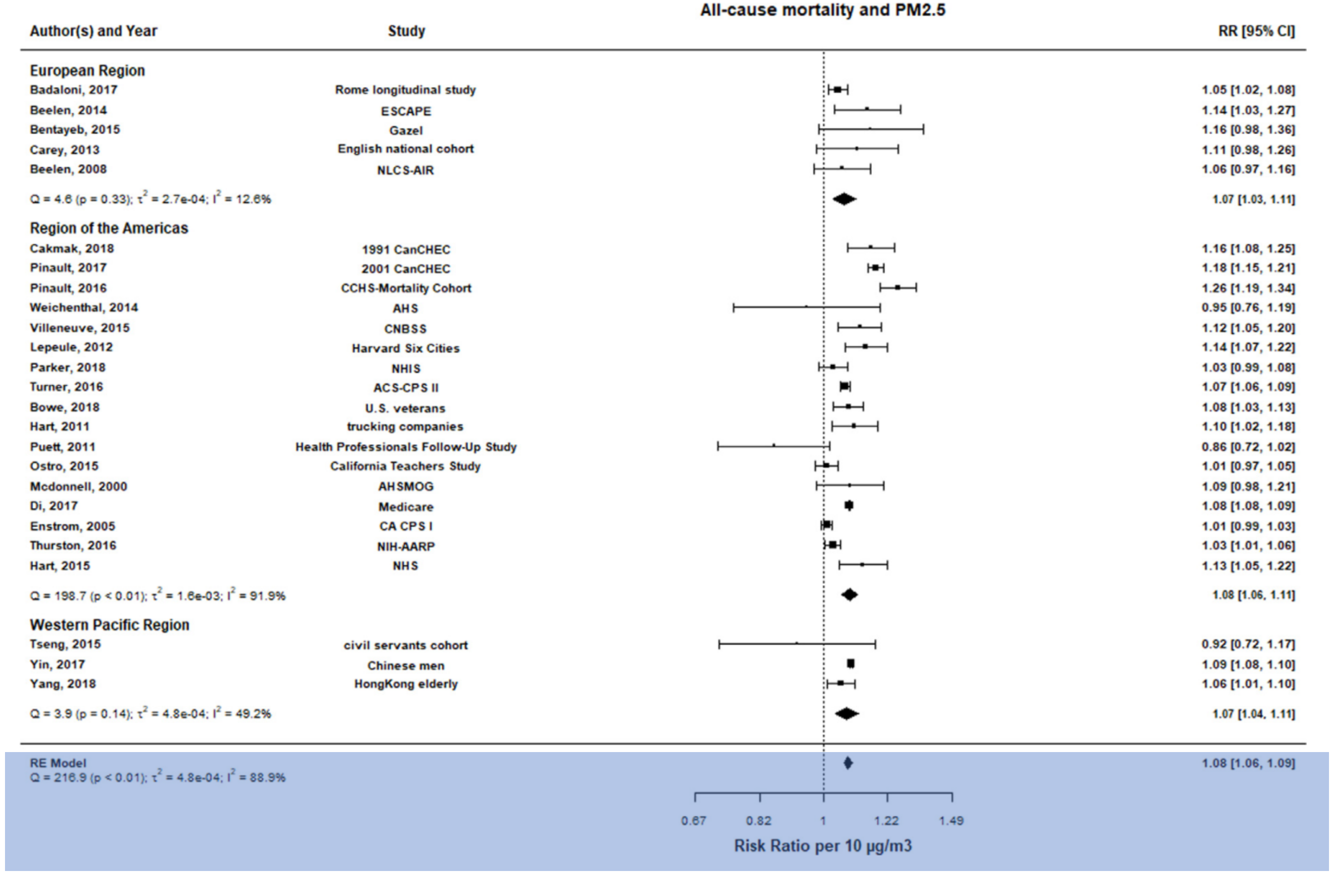


Fig. 6. Meta-analysis of PM$_{2.5}$ and natural-cause mortality: by geographical regions.

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Environment International 142 (2020) 105876

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Review article

Short-term exposure to particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) and all-cause and cause-specific mortality: Systematic review and *meta*-analysis

Pablo Orellano[a,*], Julieta Reynoso[b], Nancy Quaranta[c,d], Ariel Bardach[e], Agustin Ciapponi[e]

[a] Centro de Investigaciones y Transferencia San Nicolás, Universidad Tecnológica Nacional (CONICET), San Nicolás, Argentina
[b] Hospital General "San Felipe", San Nicolás, Argentina
[c] Facultad Regional San Nicolás, Universidad Tecnológica Nacional, San Nicolás, Argentina
[d] Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, La Plata, Argentina
[e] Instituto de Efectividad Clínica y Sanitaria (IECS-CONICET), Buenos Aires, Argentina

WHO (Short Term, 24-h)

000223 VTA

↑ 10 ug/m^3 → RR: 1.007

Table 1
Exposures, outcomes and pooled effect sizes.

Pollutant	Outcome	Number of effect sizes	RR (95% CI)	p-value	PI	Egger's test (p-value)
PM_{10}	All-cause mortality	66	1.0041 (1.0034–1.0049)	< 0.0001	1.0013–1.0070	< 0.001
PM_{10}	Cardiovascular mortality	44	1.0060 (1.0044–1.0077)	< 0.0001	1.0016–1.0105	0.024
PM_{10}	Respiratory mortality	41	1.0091 (1.0063–1.0119)	< 0.0001	1.0017–1.0166	0.209
PM_{10}	Cerebrovascular mortality	20	1.0044 (1.0022–1.0066)	0.0005	1.0001–1.0087	< 0.001
$PM_{2.5}$	All-cause mortality	29	1.0065 (1.0044–1.0086)	< 0.0001	1.0017–1.0114	0.015
$PM_{2.5}$	Cardiovascular mortality	28	1.0092 (1.0061–1.0123)	< 0.0001	1.0026–1.0158	0.803
$PM_{2.5}$	Respiratory mortality	20	1.0073 (1.0029–1.0116)	0.0023	0.9998–1.0148	0.606
$PM_{2.5}$	Cerebrovascular mortality	7	1.0072 (1.0012–1.0132)	0.0257	0.9953–1.0192	N/A
NO_2 (24-hour average)	All-cause mortality	54	1.0072 (1.0059–1.0085)	< 0.0001	1.0031–1.0113	0.048
NO_2 (1-hour max.)	All-cause mortality	10	1.0024 (0.9995–1.0053)	0.0892	0.9985–1.0064	0.154
O_3	All-cause mortality	48	1.0043 (1.0034–1.0052)	< 0.0001	1.0013–1.0073	0.001

RR, pooled relative risks; 95% CI, 95% confidence interval; p-value, significance of the association or statistical tests; PI, 80% prediction interval; N/A, not applicable (< 10 studies).

Select, Select, Select !!!!

WHO AQG ($PM_{2.5}$ Long Term, Annual)

↑ 10 ug/m^3 → RR: 1.08

Step 2. Determine the lowest level of exposure measured

In 18 of the 25 studies included in the meta-analysis, a 5th percentile of the exposure distribution was reported or could be calculated from the reported mean and standard deviation (Table 3.2). As the concentration distributions are often lognormal, this calculation is not straightforward. Therefore, preference was given to actual reports of the relevant numbers obtained from the published papers or upon request from the study authors. This is indicated in Table 3.2, Table 3.3, Table 3.4 and Table 3.5. The five lowest levels reported or estimated in these studies were 3.0 µg/m³ Pinault et al., 2016, 3.2 µg/m³ Cakmak et al., 2018, 3.5 µg/m³ Pinault et al., 2017, 4.8 µg/m³ Villeneuve et al., 2015 and 6.7 µg/m³ Weichenthal et al., 2014. Weichenthal et al. 2014 found no effect. The Villeneuve et al. 2015 study provided no evidence of an effect of PM2.5 on all non-accidental mortality below 8 µg/m³. The study by Di et al. 2017a) has the next lowest 5th percentile (7.1 µg/m³) and the study by Hart et al. 2015 the next lowest (7.8 µg/m³). The average PM2.5 level across these five studies with the lowest exposure measurements in the systematic review is 4.2 µg/m³. A sensitivity analysis disregarding the Villeneuve et al.2015 and Weichenthal et al. 2014 studies produced a mean of 4.9 µg/m³ PM2.5. The sum of weights in the meta-analysis was > 25%, indicating that these studies were influential in the meta-analysis.

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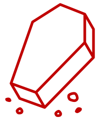
WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Page 76,78

The recommendation is an annual $PM_{2.5}$ AQG level of 5 µg/m³. The GDG recommends maintaining the 2005 interim targets and introducing an interim target 4 at the level of the 2005 air quality guideline, as shown in Table 3.1.

Table 3.1. Recommended annual AQG level and interim targets for $PM_{2.5}$

Recommendation		$PM_{2.5}$ (µg/m³)
Interim target 1	124	35
Interim target 2	116	25
Interim target 3	108	15
Interim target 4	104	10
AQG level	100	**5**



WHO AQG ($PM_{2.5}$ Short Term, 24-h)

000224 VTA

↑ 10 ug/m^3 → RR: 1.007

Step 2. Determine the lowest level of exposure measured

As discussed in the protocol for deriving AQG levels in section 2.5, the lowest concentrations in time-series studies of the effects of daily variations in air pollution concentrations are often very low. Therefore, the 5th percentiles of these daily distributions cannot be used as starting points for AQG level development. In such cases, the protocol suggests identifying the 99th percentile of common distributions of daily air pollution concentrations corresponding to an average long-term concentration equivalent to the annual AQG level. Thus, it is expected that daily means will be higher than the short-term AQG level not more than three to four times per year once air quality complies with the proposed annual mean AQG level. The proposed annual mean AQG level is 5 μg/m³ for PM2.5. Common distributions observed in large numbers of cities around the world (data from Liu et al. 2019) suggest that the 99th percentiles of daily concentrations are about three times higher than the annual mean PM2.5 concentration.

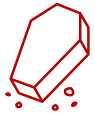
The recommendation is a short-term (24-hour) $PM_{2.5}$ AQG level of 15 μg/m³, defined as the 99th percentile (equivalent to 3–4 exceedance days per year) of the annual distribution of 24-hour average concentrations.

The GDG recommends maintaining the 2005 interim targets and introducing an interim target 4 at the level of the 2005 air quality guideline, as shown in Table 3.6.

Table 3.6. Recommended short-term (24-hour) AQG level and interim targets for $PM_{2.5}$[a]

Recommendation		$PM_{2.5}$ (μg/m³)
Interim target 1	104	75
Interim target 2	102	50
Interim target 3	101	37.5
Interim target 4	101	25
AQG level	100	**15**

[a] Defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).



Select, Select, Select !!!!

WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Page 86, 88

The NEW ENGLAND JOURNAL of MEDICINE
ESTABLISHED IN 1812 JUNE 29, 2017 VOL. 376 NO. 26

Long Term: ↑ 10 ug/m³ → ↑ 7.3%

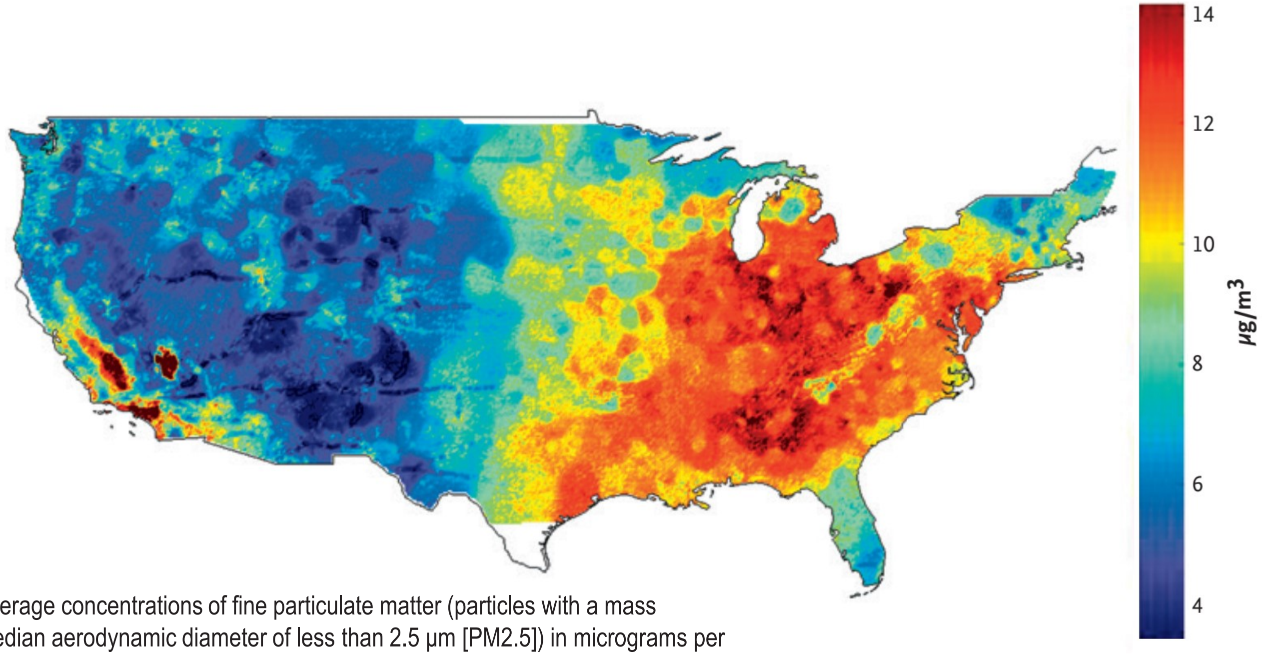
000225

Air Pollution and Mortality in the Medicare Population

Qian Di, M.S., Yan Wang, M.S., Antonella Zanobetti, Ph.D., Yun Wang, Ph.D., Petros Koutrakis, Ph.D., Christine Choirat, Ph.D., Francesca Dominici, Ph.D., and Joel D. Schwartz, Ph.D.

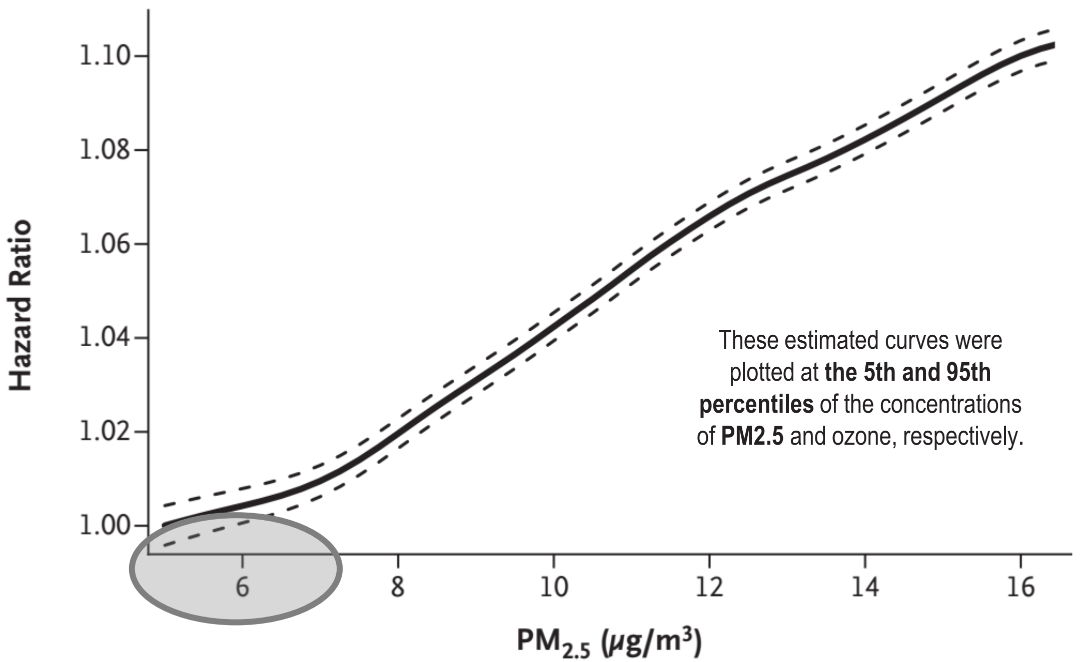
Increases of 10 µg per cubic meter in PM2.5 and of 10 ppb in ozone were associated with increases in all-cause mortality of **7.3%** (95% confidence interval [CI], 7.1 to 7.5) and 1.1% (95% CI, 1.0 to 1.2), respectively.

A Average Concentrations of $PM_{2.5}$



Average concentrations of fine particulate matter (particles with a mass median aerodynamic diameter of less than 2.5 µm [PM2.5]) in micrograms per cubic meter, as estimated on the basis of all daily predictions during the study period.

A Exposure to $PM_{2.5}$



We constructed an open cohort of all Medicare beneficiaries **(60,925,443 persons**) in the continental United States from the years 2000 through 2012, with 460,310,521 person-years of follow-up. **Annual averages of fine particulate matter (particles with a mass median aerodynamic diameter of less than 2.5 µm [PM2.5])** and ozone were estimated according to the **ZIP Code of residence for each enrollee** with the use of previously validated prediction models. **We estimated the risk of death associated with exposure to increases of 10 µg per cubic meter for PM2.5** and 10 parts per billion (ppb) for ozone using a two-pollutant Cox proportional hazards model that controlled for demographic characteristics, Medicaid eligibility, and area-level covariates.

$PM_{2.5}$ levels worldwide

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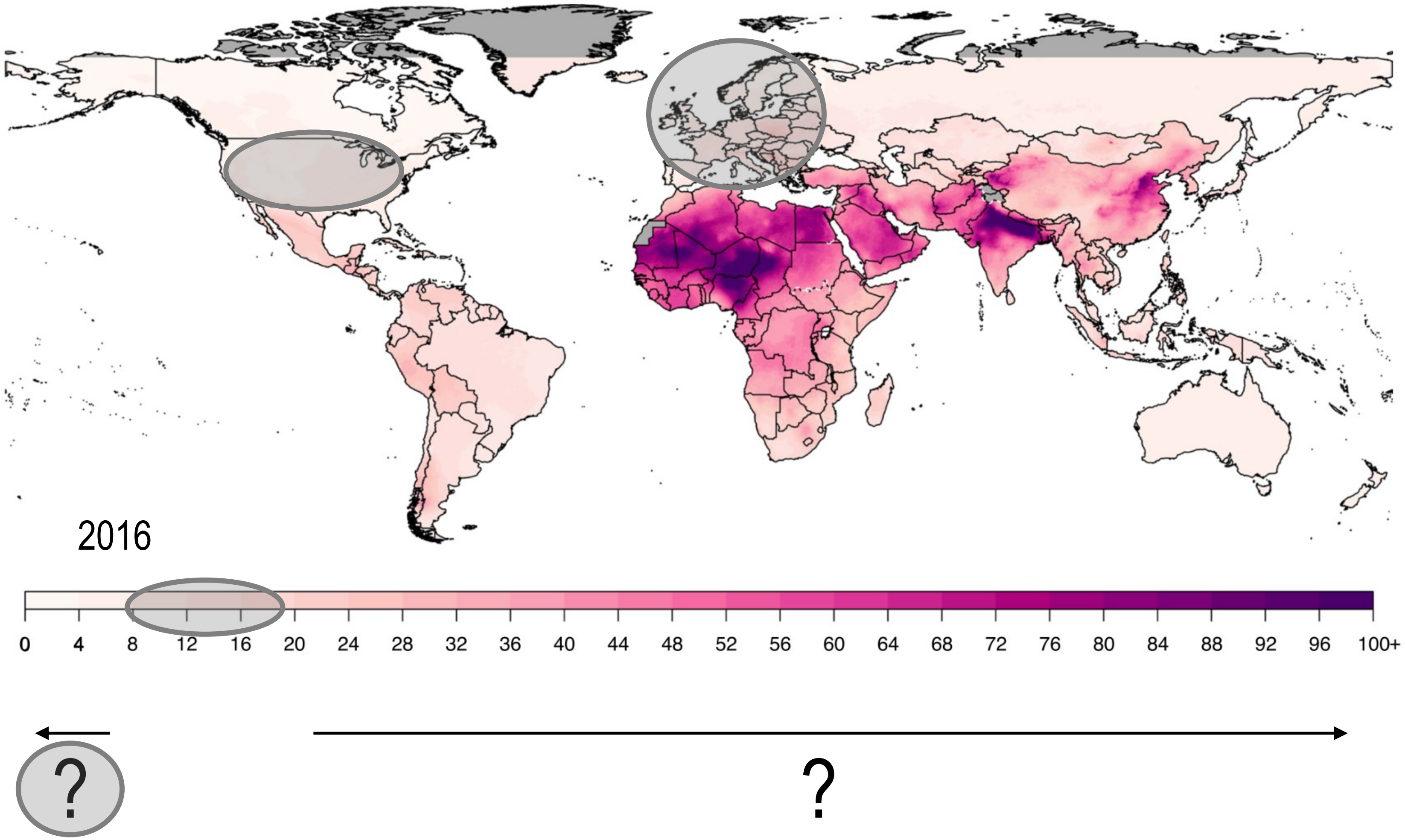
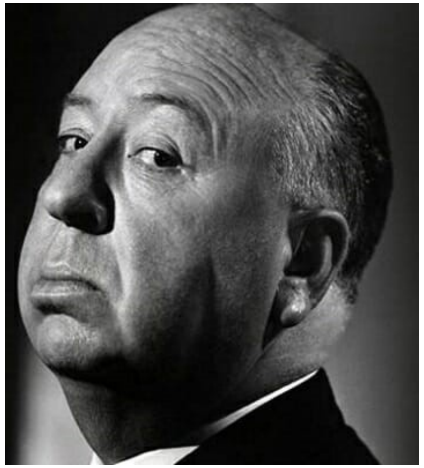
Annual concentrations (ug/m³) of $PM_{2.5}$ for 2016





Suspenso

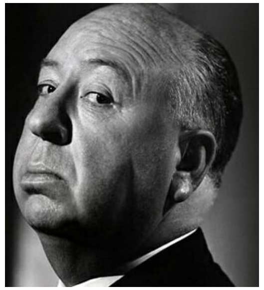
Shaddick et al. 2020

SOCIAL SCIENCES

How low can you go? Air pollution affects mortality at very low levels

Scott Weichenthal[1,2]*†, Lauren Pinault[3]†, Tanya Christidis[3], Richard T. Burnett[4], Jeffrey R. Brook[5], Yen Chu[6], Dan L. Crouse[7], Anders C. Erickson[6], Perry Hystad[8], Chi Li[9], Randall V. Martin[9,10], Jun Meng[10,11], Amanda J. Pappin[2], Michael Tjepkema[3], Aaron van Donkelaar[9,10], Crystal L. Weagle[9], Michael Brauer[4,6]

The World Health Organization (WHO) recently released new guidelines for outdoor fine particulate air pollution (PM2.5) recommending an **annual average concentration of 5 ug/m3**. Yet, our understanding of the concentration response relationship between outdoor PM2.5 and mortality in this range of near-background concentrations **remains incomplete**. To address this uncertainty, we conducted a population-based cohort study of 7.1 million adults in one of the world's lowest exposure environments. **Our findings reveal a supralinear concentration response relationship between outdoor PM2.5 and mortality at very low (<5 ug/m3) concentrations**. Our updated global concentration-response function **incorporating this new information suggests an additional 1.5 million deaths globally attributable to outdoor PM2.5 annually compared to previous estimates**. **The global health benefits of meeting the new WHO guideline for outdoor PM2.5 are greater than previously assumed and indicate a need for continued reductions in outdoor air pollution around the world.**



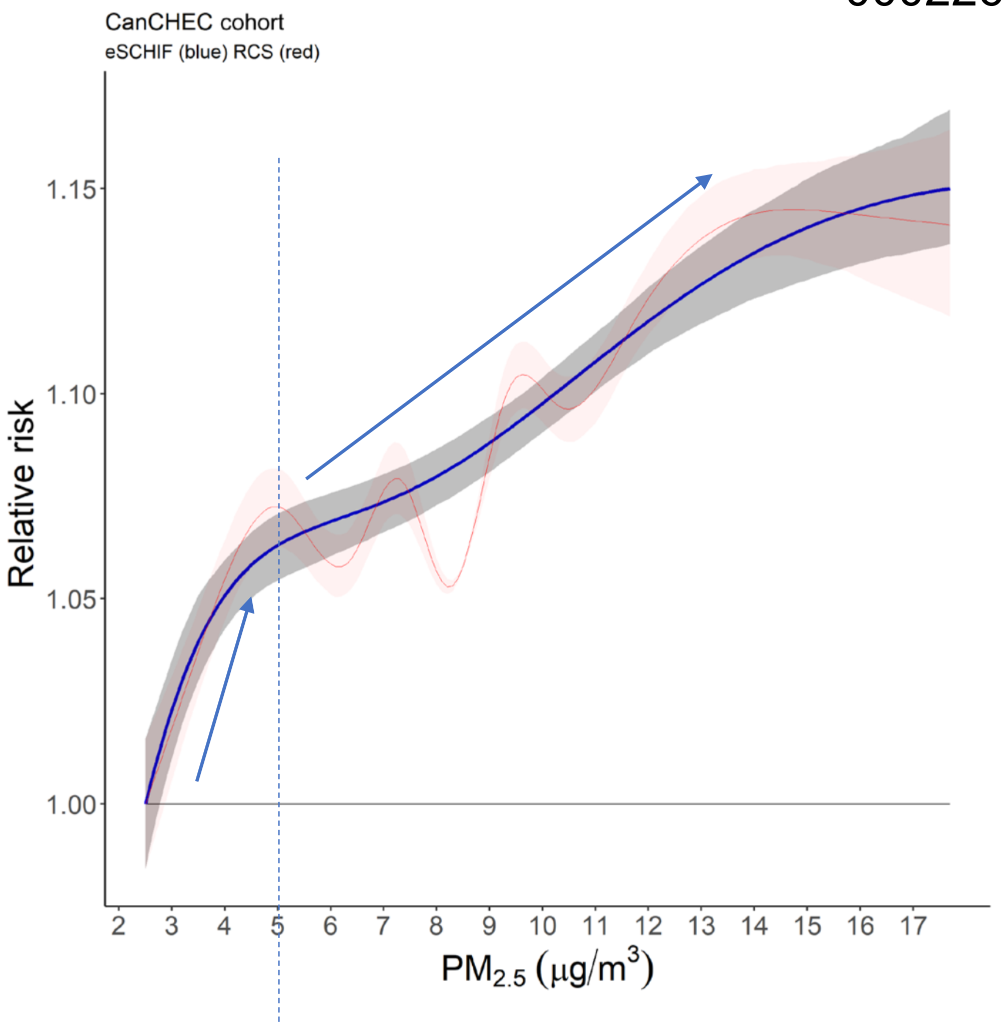


Fig. 1. Fully adjusted restricted cubic spline relative risk predictions for non-accidental mortality over the CanCHEC $PM_{2.5}$ concentration range (red dashed line, mean; red shaded area, 95% CIs) with associated eSCHIF predictions (blue solid line, mean; gray shaded area, 95% CIs). The green *x*-axis tick marks indicate the nine restricted cubic spline (RCS) knot locations that reflect percentiles of $PM_{2.5}$ (2, 14, 26, 50, 62, 74, 86, and 98%) for person-years of during follow-up (13.3% of person-years had PM2.5 values below 5 μg/m^3, which is indicated by the vertical dotted line).

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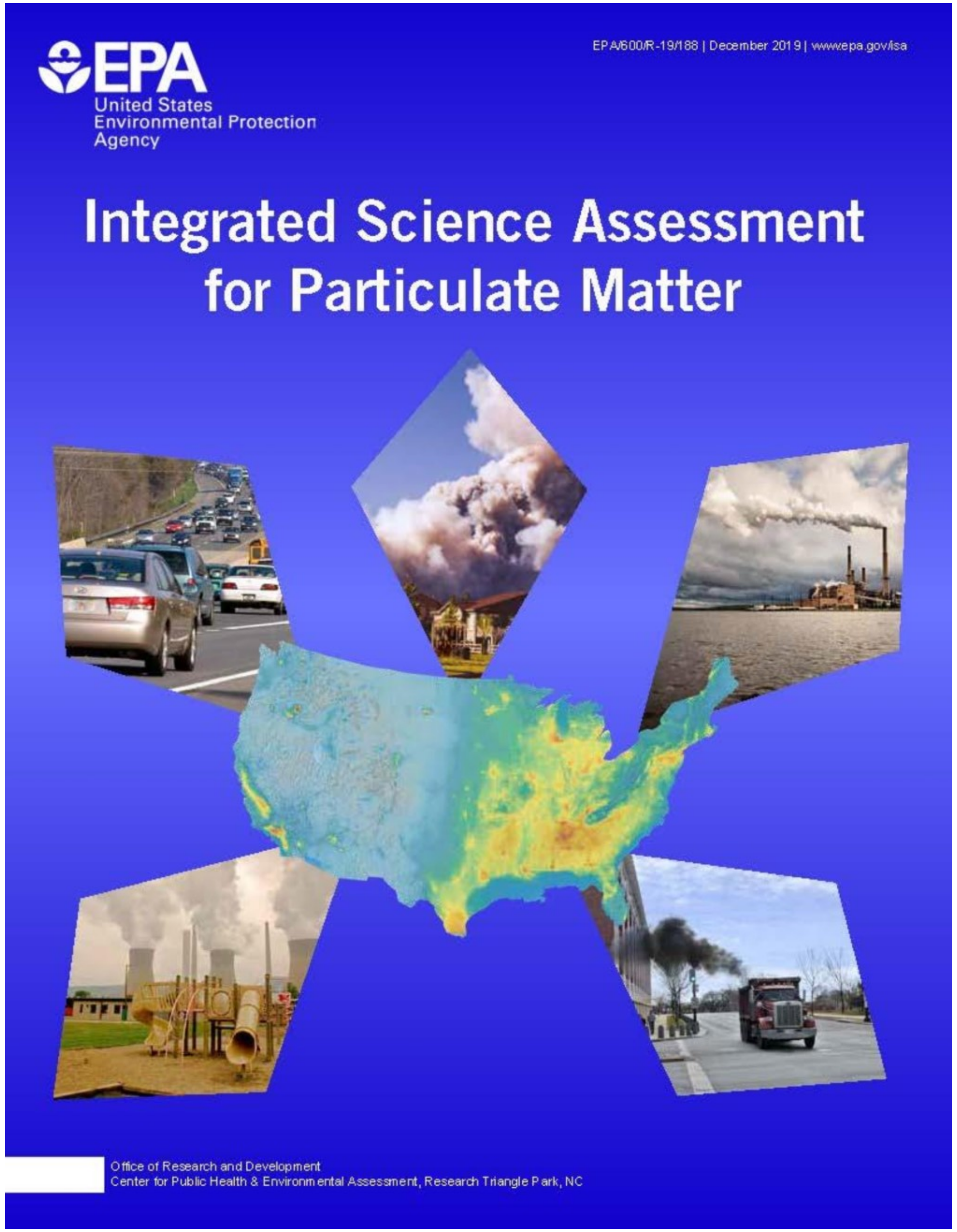
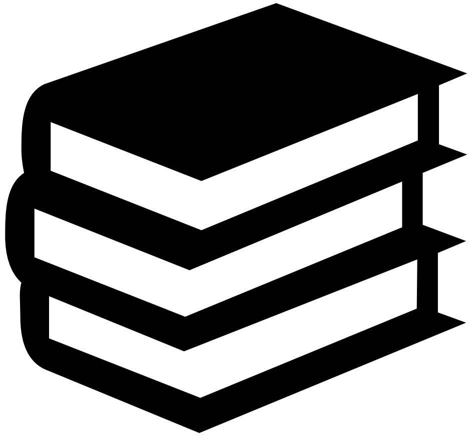


U.S. EPA. (2019). ***Integrated Science Assessment (ISA) for Particulate Matter (Final Report, Dec 2019).*** **Page P-9 https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=347534**

The Integrated Science Assessment (ISA) is a **comprehensive evaluation and synthesis of the policy-relevant science "useful in indicating the kind and extent of identifiable effects on public health or welfare which may be expected from the presence of [a] pollutant in ambient air,"** as described in Section 108 of the Clean Air Act (CAA, 1990a). This ISA communicates critical science judgments of the health and welfare criteria for particulate matter (PM), and serves as the scientific foundation for the review of the current primary (health-based) and secondary (welfare-based) National Ambient Air Quality Standards (NAAQS) for PM.

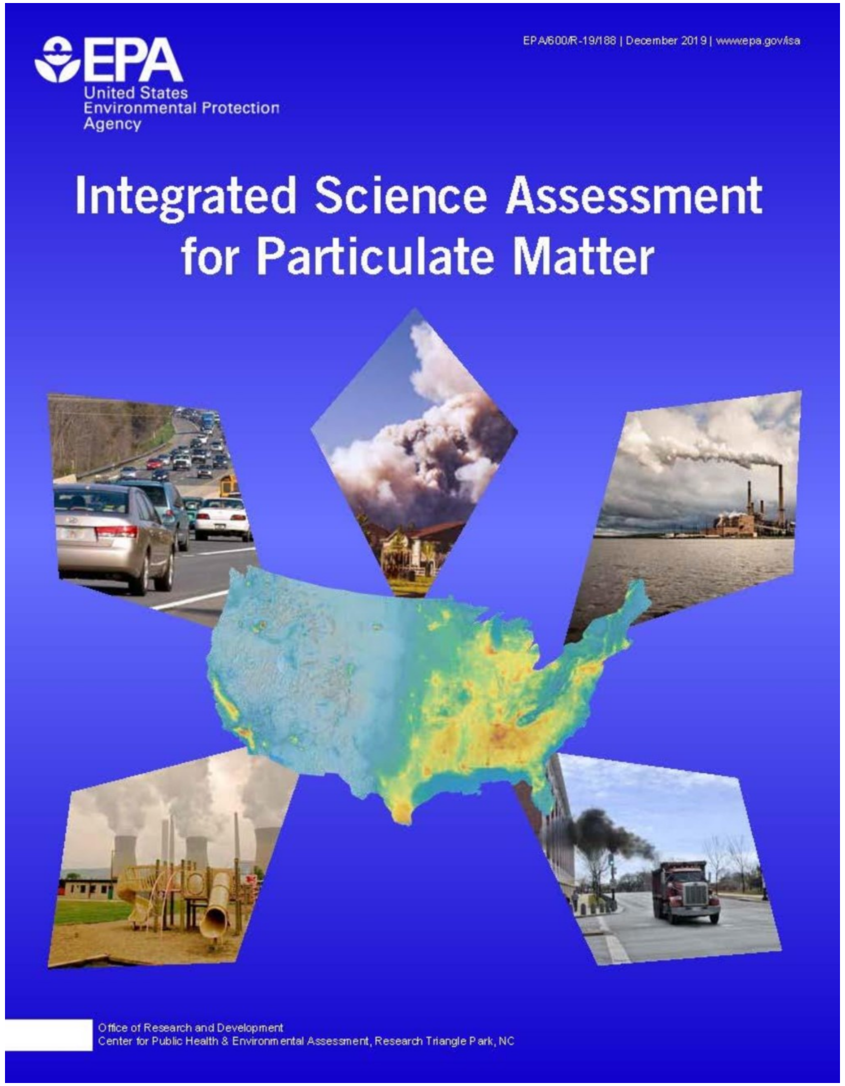


		Fracción	Determinaciones de Causalidad: PM ISA 2009	Determinaciones de Causalidad: PM ISA actual
efectos respiratorios	Exposición de corto plazo	$PM_{2.5}$	probablemente causal	probablemente causal
		$PM_{10-2.5}$	se sugiere,pero no es suficiente para inferirlo	se sugiere,pero no es suficiente para inferirlo
		UFP	se sugiere,pero no es suficiente para inferirlo	se sugiere,pero no es suficiente para inferirlo
	Exposición de largo plazo	$PM_{2.5}$	probablemente causal	probablemente causal
		$PM_{10-2.5}$	inadecuada	inadecuada
		UFP	inadecuada	inadecuada
efectos cardiovasculares	Exposición de corto plazo	$PM_{2.5}$	Causal	Causal
		$PM_{10-2.5}$	se sugiere,pero no es suficiente para inferirlo	se sugiere,pero no es suficiente para inferirlo
		UFP	se sugiere,pero no es suficiente para inferirlo	se sugiere,pero no es suficiente para inferirlo
	Exposición de largo plazo	$PM_{2.5}$	Causal	Causal
		$PM_{10-2.5}$	inadecuada	se sugiere,pero no es suficiente para inferirlo
		UFP	inadecuada	inadecuada
efectos metabólicos	Exposición de corto plazo	$PM_{2.5}$	-	se sugiere,pero no es suficiente para inferirlo
		$PM_{10-2.5}$	-	inadecuada
		UFP	-	inadecuada
	Exposición de largo plazo	$PM_{2.5}$	-	se sugiere,pero no es suficiente para inferirlo
		$PM_{10-2.5}$	-	se sugiere,pero no es suficiente para inferirlo
		UFP	-	inadecuada
efectos al sistema nervioso central	Exposición de corto plazo	$PM_{2.5}$	inadecuada	se sugiere,pero no es suficiente para inferirlo
		$PM_{10-2.5}$	inadecuada	inadecuada
		UFP	inadecuada	se sugiere,pero no es suficiente para inferirlo
	Exposición de largo plazo	$PM_{2.5}$	-	probablemente causal
		$PM_{10-2.5}$	-	se sugiere,pero no es suficiente para inferirlo
		UFP	-	se sugiere,pero no es suficiente para inferirlo
efectos reproductivos y del desarrollo	reproduccion masculina/emenina y fertilidad	$PM_{2.5}$	se sugiere,pero no es suficiente para inferirlo	se sugiere,pero no es suficiente para inferirlo
		$PM_{10-2.5}$	inadecuada	inadecuada
		UFP	inadecuada	inadecuada
	consecuencias en el embarazo y el nacimiento	$PM_{2.5}$	se sugiere,pero no es suficiente para inferirlo	se sugiere,pero no es suficiente para inferirlo
		$PM_{10-2.5}$	inadecuada	inadecuada
		UFP	inadecuada	inadecuada
cancer		$PM_{2.5}$	se sugiere,pero no es suficiente para inferirlo	probablemente causal
		$PM_{10-2.5}$	inadecuada	se sugiere,pero no es suficiente para inferirlo
		UFP	inadecuada	inadecuada
mortalidad	Exposición de corto plazo	$PM_{2.5}$	Causal	Causal
		$PM_{10-2.5}$	se sugiere,pero no es suficiente para inferirlo	se sugiere,pero no es suficiente para inferirlo
		UFP	inadecuada	inadecuada
	Exposición de largo plazo	$PM_{2.5}$	Causal	Causal
		$PM_{10-2.5}$	inadecuada	se sugiere,pero no es suficiente para inferirlo
		UFP	inadecuada	inadecuada

Causal
probablemente causal
se sugiere,pero no es suficiente para inferirlo
inadecuada

Determinaciones de causalidad para diversos efectos de distintas fracciones de material particulado. Tabla adaptada y traducida desde (U.S. EPA., 2019).

Grupos de riesgo

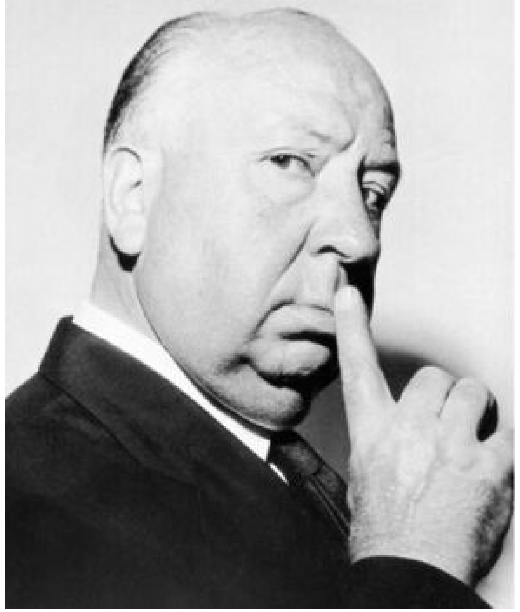


Caracterización de la evidencia para factores que potencialmente aumentan el riesgo de los efectos en la salud del material particulado. Tabla adaptada y traducida desde (U.S. EPA., 2019).

Clasificación	Efectos en la salud
Evidencia adecuada	Existe una evidencia **substancial y consistente** dentro de una disciplina para concluir que el factor resulta en que una población o estado de vida presente un aumento de riesgo a los efectos del contaminante cuando es comparada con alguna población o estado de vida de referencia. Cuando sea aplicable, esta evidencia incluye coherencia con otras disciplinas. La evidencia incluye múltiples estudios de alta calidad
Evidencia sugestiva	La evidencia colectiva **sugiere** que un factor resulta en el aumento de riesgo a los efectos del contaminante en una población o estado de vida relativo a una población/ estado de vida de referencia. La evidencia es limitada debido a algunas inconsistencias dentro de una disciplina o a la falta de coherencia entre disciplinas.
Evidencia inadecuada	La evidencia colectiva es **inadecuada** para sugerir que un factor resulta en el aumento de riesgo a los efectos del contaminante en una población o estado de vida relativo a una población / estado de vida de referencia. Los estudios disponibles son insuficientes en cantidad, calidad o consistencia y / o el poder estadistico es insuficiente para establecer alguna conclusión.
Evidencia de ausencia de efecto	Existe una evidencia **substancial y consistente** dentro de una disciplina para concluir que el factor no resulta en que una población o estado de vida presente un aumento de riesgo a los efectos del contaminante cuando es comparada con alguna población o estado de vida de referencia. Cuando sea aplicable, esta evidencia incluye coherencia con otras disciplinas. La evidencia incluye múltiples estudios de alta calidad

Condiciones / Enfermedades preexistentes	Enfermedades cardiovasculares	Evidencia sugestiva
	Diabetes y síndrome metabólico	Evidencia inadecuada
	Obesidad	Evidencia sugestiva
	Colesterol elevado	Evidencia inadecuada
	Enfermedades respiratorias preexistentes	Evidencia sugestiva
	Factores genéticos	Evidencia sugestiva
Factores sociodemográficos	**Etapa de vida (niños)**	**Evidencia adecuada**
	Etapa de vida (Adultos mayores)	Evidencia inadecuada
	Sexo	Evidencia inadecuada
	Estatus socioeconómico (ESE)	Evidencia sugestiva
	Raza/etnia	**Evidencia adecuada**
	Lugar de residencia	Evidencia inadecuada
Factores conductuales y otros	Tabaquismo (Fumar)	Evidencia sugestiva
	Dieta	Evidencia inadecuada

?



Gracias

Centro Mario Molina
Investigación & desarrollo

ESTUDIO DE ANTECEDENTES PARA LA REVISIÓN DE LA NORMA PRIMARIA DE CALIDAD AMBIENTAL PARA MATERIAL PARTICULADO FINO RESPIRABLE ($MP_{2,5}$)

Diagnóstico de Calidad del Aire a Nivel Nacional
Análisis de las causas, comportamiento y tendencia histórica de la concentración de $MP_{2,5}$ a nivel nacional y regional.

Viernes 06 de octubre de 2023

CONTEXTO

- La norma primaria de $MP_{2,5}$ entró en **vigencia el 1° de enero del año 2012** (D.S.12/MMA)
- **Una década de implementación**. Procede revisión de ella.
- Ya se tenía **interés inclusive desde antes del año 1990** en el marco del Plan de Descontaminación de la RM.
- La **OMS actualizó las Guías de Calidad del Aire** en el año 2021, que reduce significativamente los niveles guías de $MP_{2,5}$ en las referencias diaria y anual.

Estrategia general para reducir $MP_{2,5}$ en Chile - primera década de la norma

- **Dictación de la Norma Primaria $MP_{2,5}$ (2011)** – Entra en vigencia a partir de enero de 2012.
- Implementación de **redes de monitoreo continuo de $MP_{2,5}$** (2012 en adelante)
- Implementación de una **plataforma de acceso a la información en línea** sinca.mma.gob.cl (2012)
- Declaración de **zonas saturadas/latentes por $MP_{2,5}$** (2012 en adelante)
- Elaboración de **Planes de Descontaminación Atmosférica por $MP_{2,5}$** (2012 en adelante)
- Elaboración de **normas de emisión para reducir emisiones de MP y gases precursores**. Estas normas se han enfocado en calidad de combustibles, transporte, industria y calefactores a leña y pellets.
- **Cronograma de Descarbonización**: Compromete el cierre de todas las centrales a carbón al 2040, con 20 unidades cerradas al 2025. (2 unidades cerradas el 2019).
- Publicación de la **Contribución Determinada a Nivel Nacional (NDC)** el año 2020, que incluye metas de reducción de carbono negro para el 2030.
- Publicación de la **Estrategia Climática de Largo Plazo (ECLP)** el 2021. Que establece lineamientos de largo plazo para mitigación y adaptación al cambio climático, las cuales tienen relación con la reducción de contaminantes locales.
- Publicación de la **Ley Marco de Cambio Climático** (Ley 21.455, publicada 13 de junio de 2022) que establece una serie de instrumentos de mitigación de cambio climático, con una meta de carbono neutralidad al 2050.
- Publicación de la **Ley de Eficiencia Energética** (Ley 21.305 – febrero 2021) Que establece diversas exigencias de reducción de consumo energético en ámbitos de la industria, minera, edificaciones y transporte. En febrero de 2022 se publicó el primer estándar obligatorio de eficiencia energética para vehículos livianos nuevos.
- **Ley de Biocombustibles Sólidos** (Ley 21.499 de noviembre de 2022) que entrega atribuciones a la SEC para fiscalización de leña y otros biocombustibles

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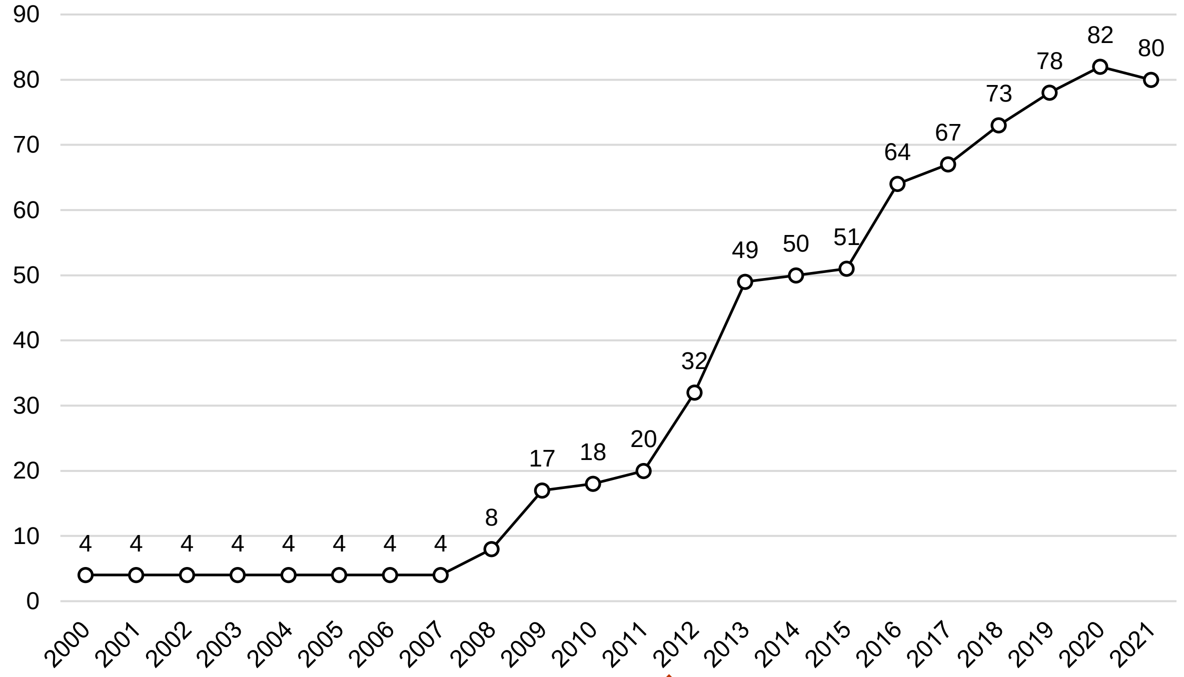
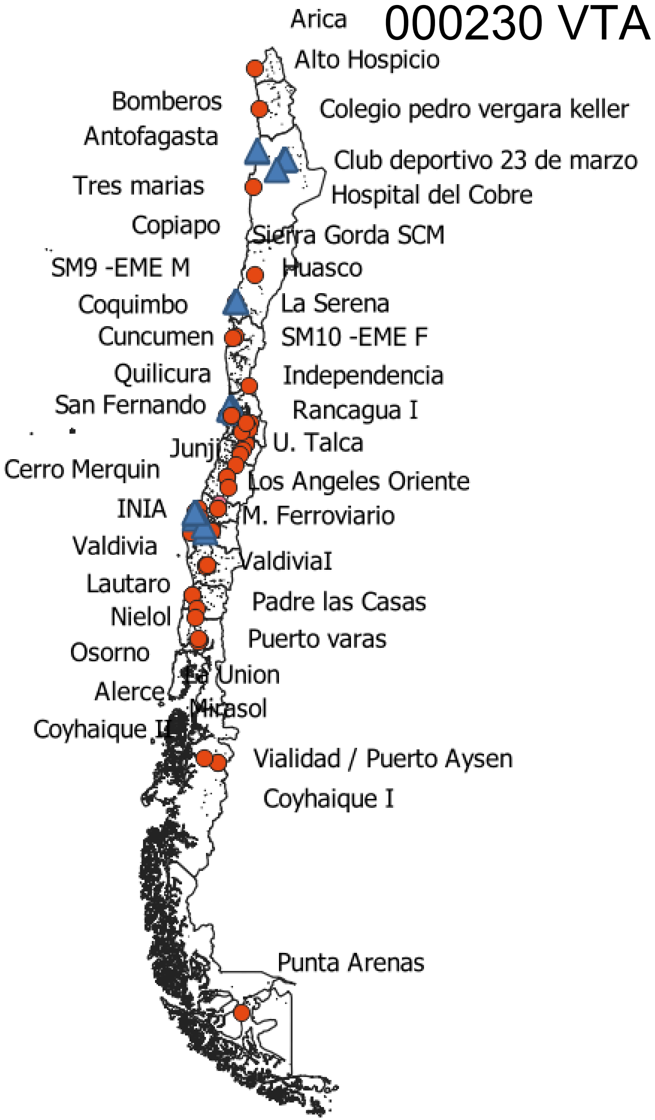
ALCANCE



85 estaciones de calidad del aire
58 son púbicas y 27 son privadas

Norma de $MP_{2,5}$



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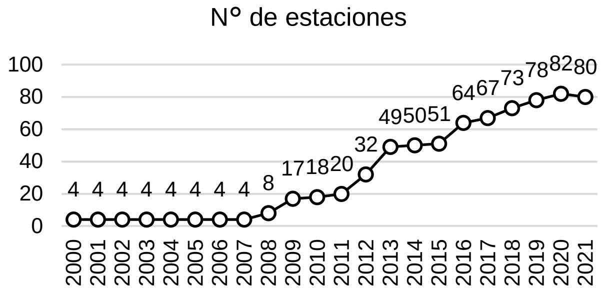
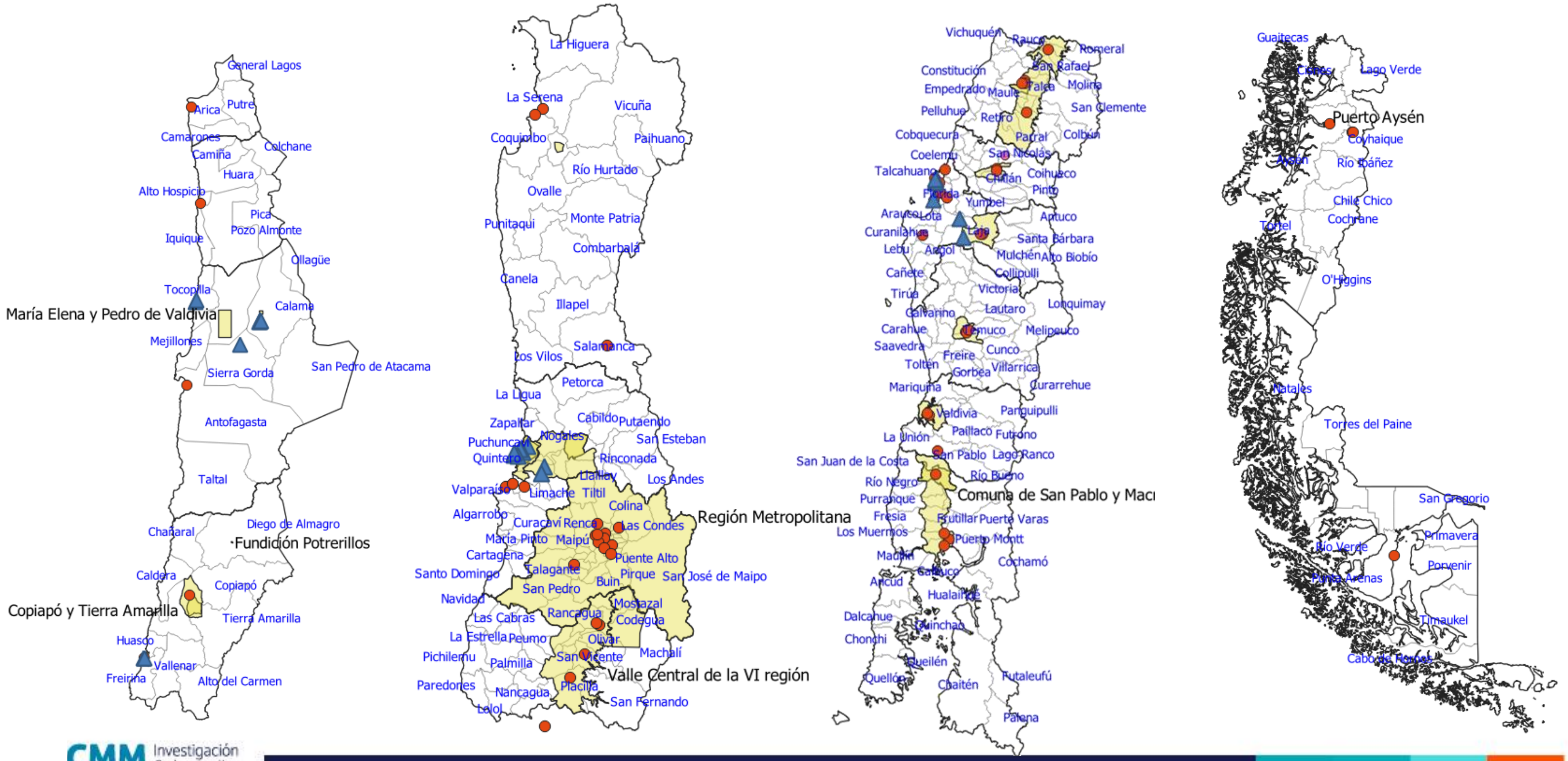
Alcance



Región	Total	Pública	Privada	EMRP $MP_{2,5}$
Arica y Parinacota	1	1	-	-
Tarapacá	1	1	-	-
Antofagasta	8	1	7	-
Atacama	5	2	3	-
Coquimbo	3	3	-	-
Valparaíso	13	4	9	5
Metropolitana	11	11	-	9
O'Higgins	4	4	-	4
Maule	5	5	-	5
Ñuble	2	2	-	1
Bio-Bio	17	9	8	6
Araucanía	4	4	-	3
Los Ríos	3	3	-	1
Los Lagos	4	4	-	4
Aysén	3	3	-	3
Magallanes	1	1	-	-
Total	**85**	**58**	**27**	**41**

Zonas Saturadas/Planes de Descontaminación



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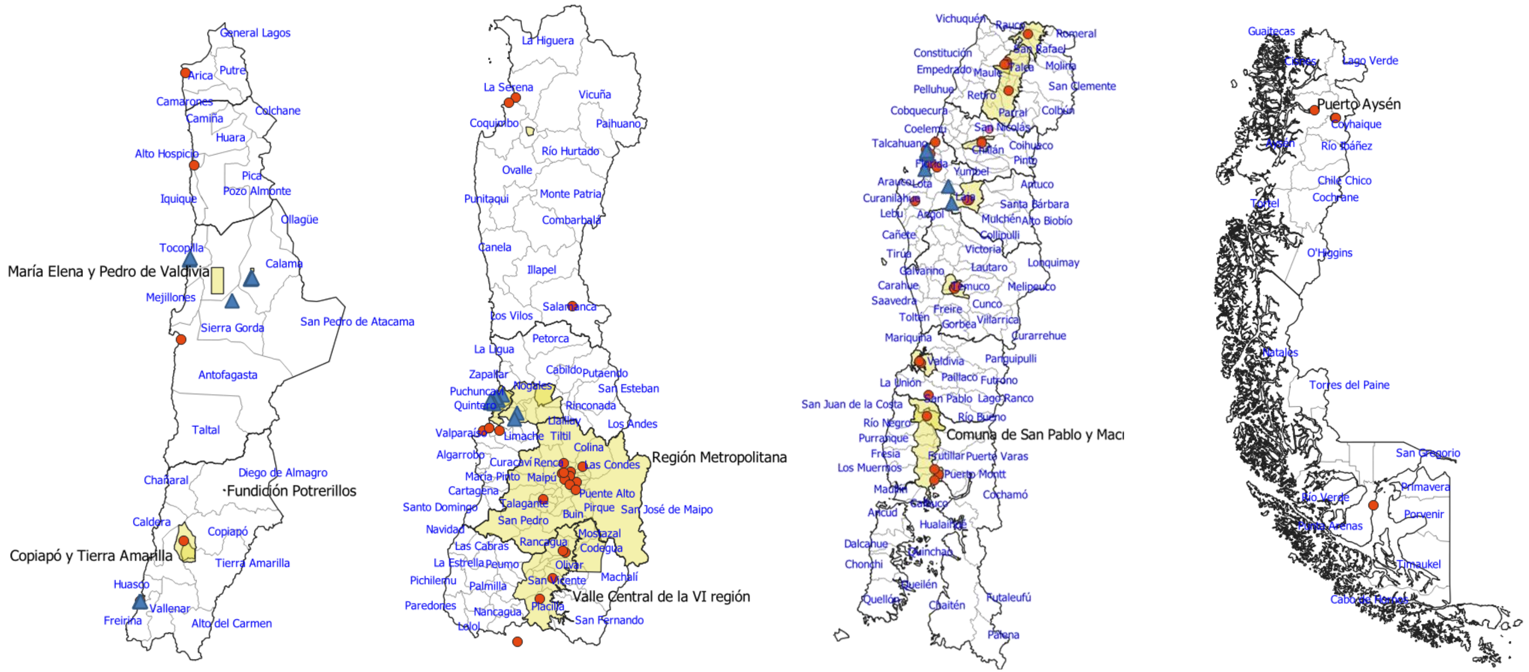


- 27 instrumentos de descontaminación de calidad del aire (zonas saturadas/Latentes, Planes de descontaminación)
- 147 comunas del país (~70% de la población)

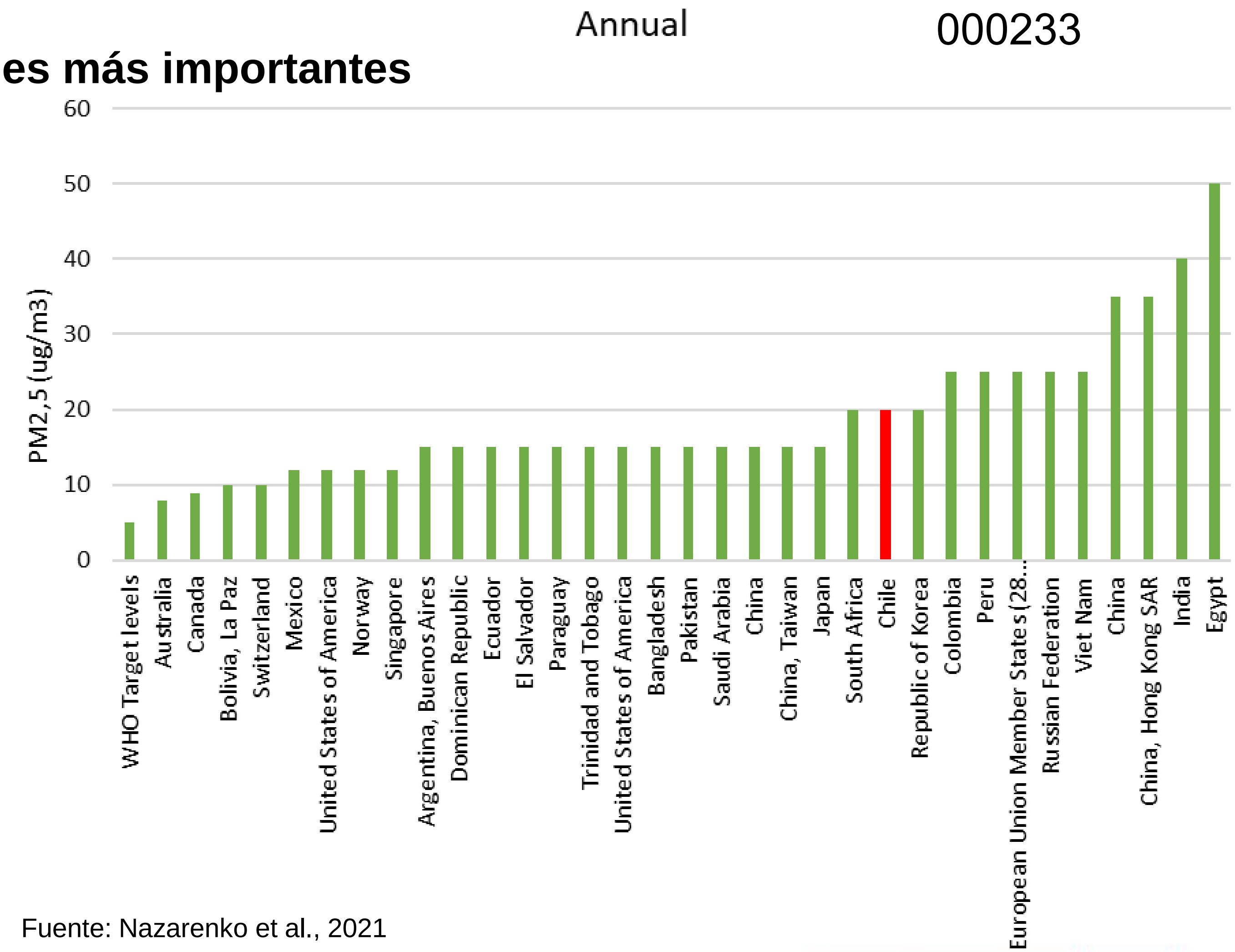
Valle central del sur de Chile se están creando macrozonas que comparten mismos problemas (**Planes de Leña**)

000233

Antecedentes internacionales más importantes

-Valores más frecuentes entre 12 y 15 µg/m³

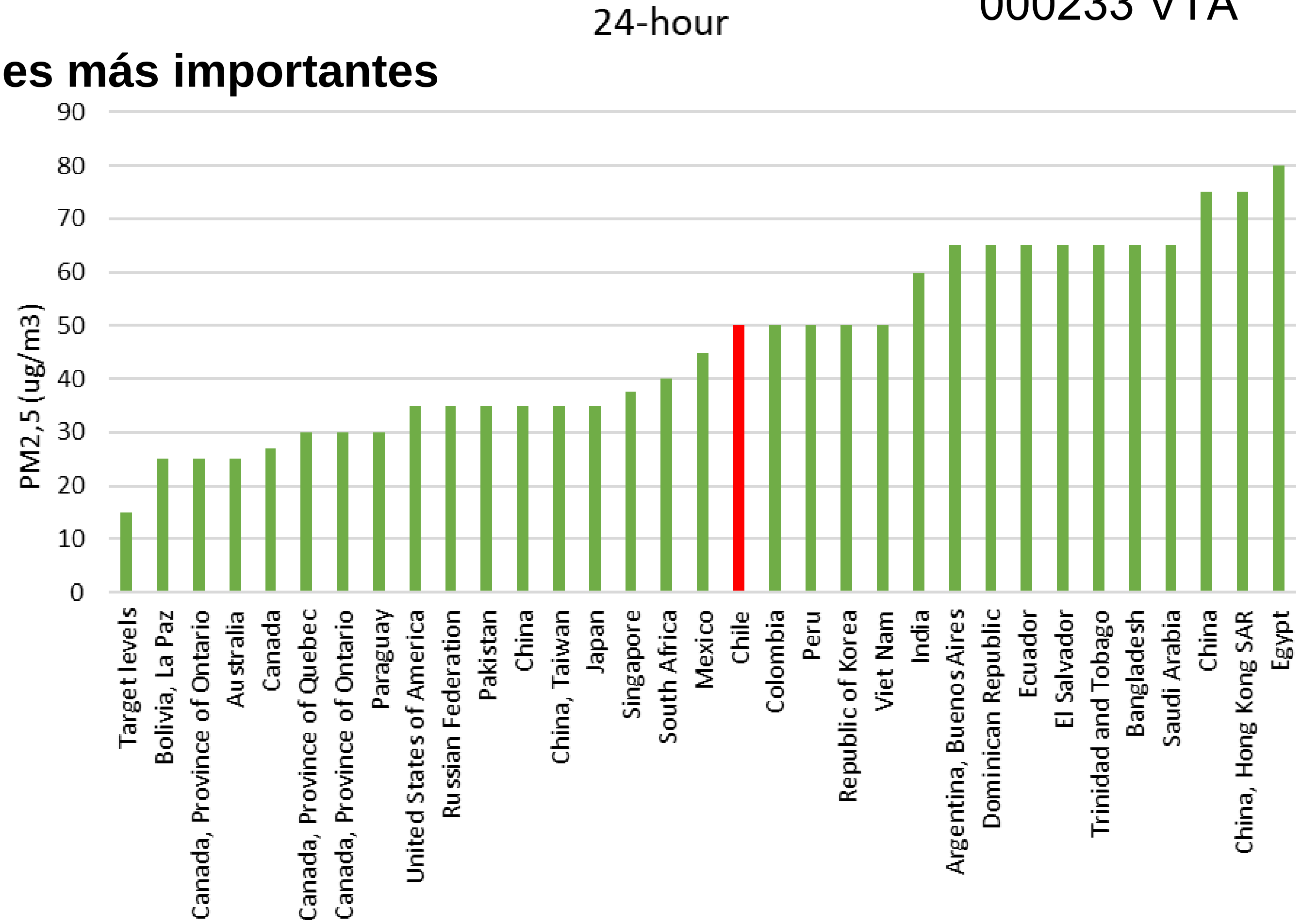
- Promedio aritmético para el estándar anual



Fuente: Nazarenko et al., 2021

Antecedentes internacionales más importantes

-Varían entre 25 y 80 µg/m³
- preferentemente los países suelen utilizar percentil 98 para el estándar de 24 hrs.
-La OMS en su guía del año 2021 también propone un percentil 99 para la norma de 24 hrs.
Un caso relevante es la Unión Europea, en donde no existen estándar para 24 horas de $MP_{2.5}$ (en contraste, si existe para MP_{10}).

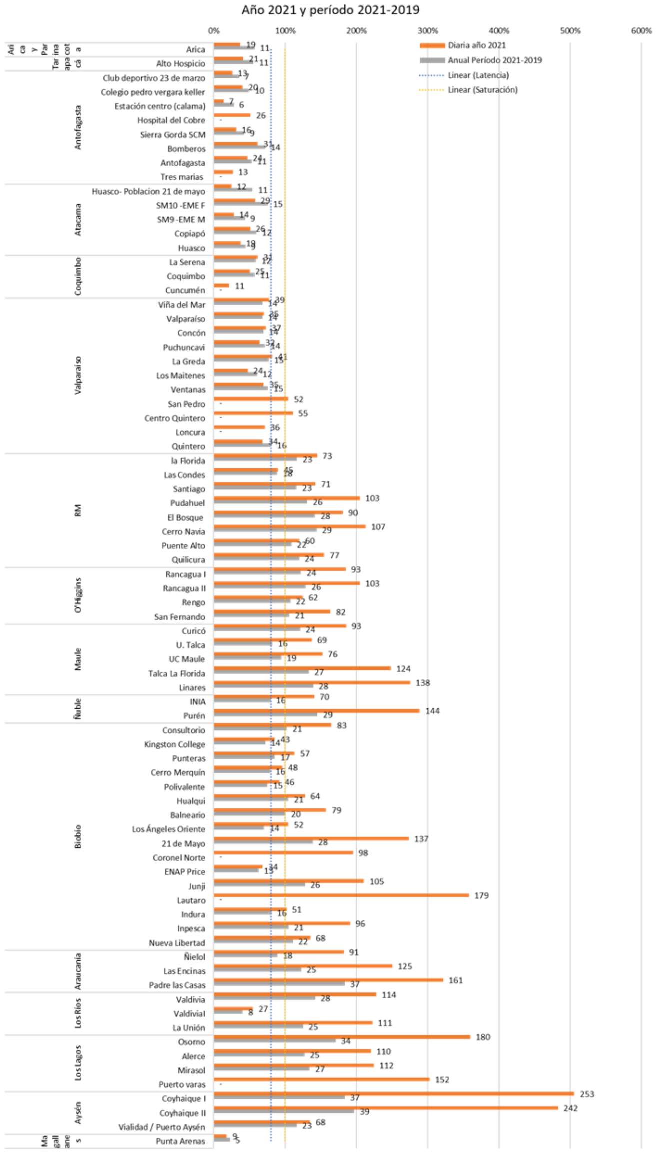


Fuente: Nazarenko et al., 2021

Análisis del Cumplimiento Normativo

000234 VTA

Cumplimiento normativo

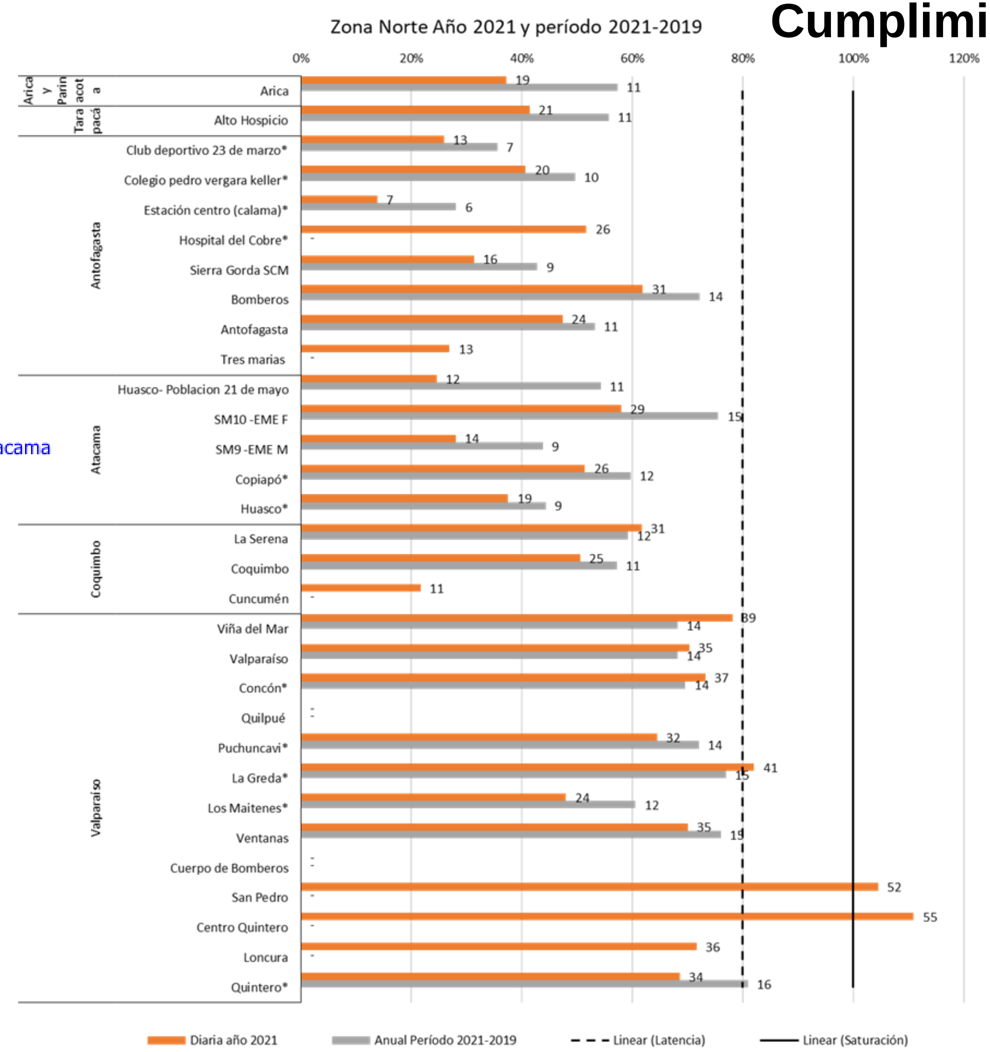


Norma anual: 20 $\mu g/m^3$

Norma diaria: 50 $\mu g/m^3$

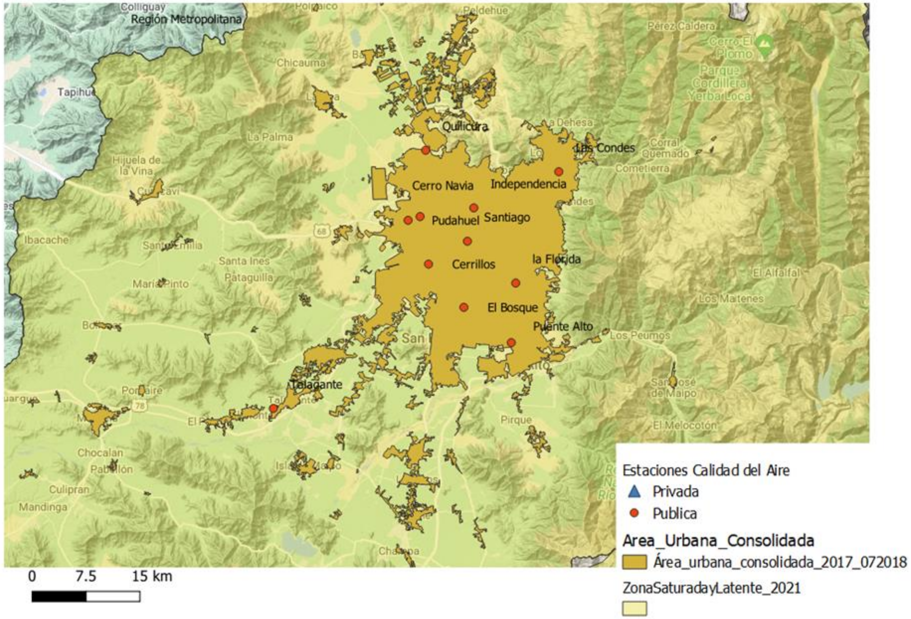
Estaciones con asterisco (*) señalan cuales son EMRP para $MP_{2,5}$.

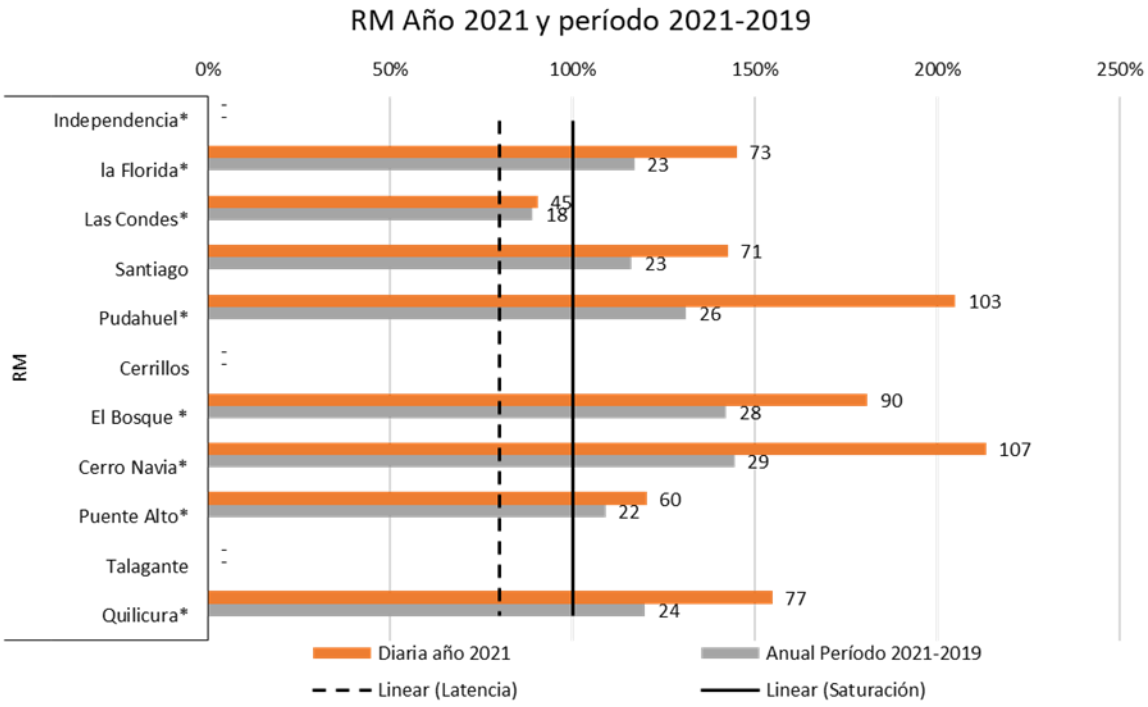
Cumplimiento normativo



Estaciones con asterisco (*) señalan cuales son EMRP para $MP_{2,5}$.

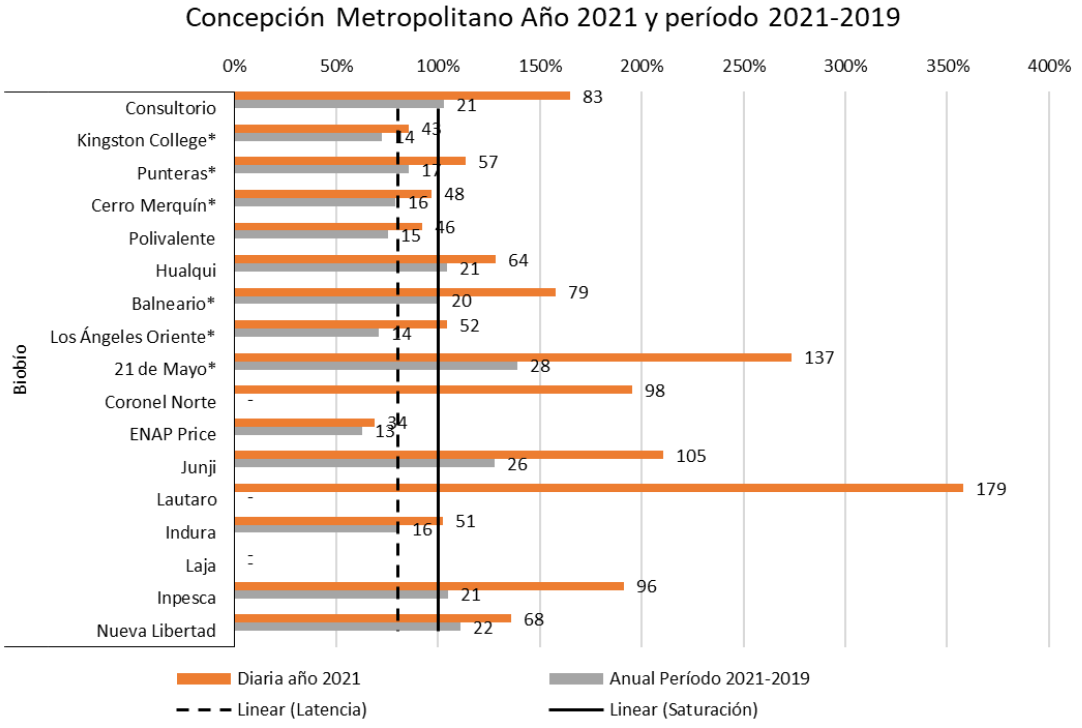
Cumplimiento normativo RM





Estaciones con asterisco (*) señalan cuales son EMRP para $MP_{2,5}$.

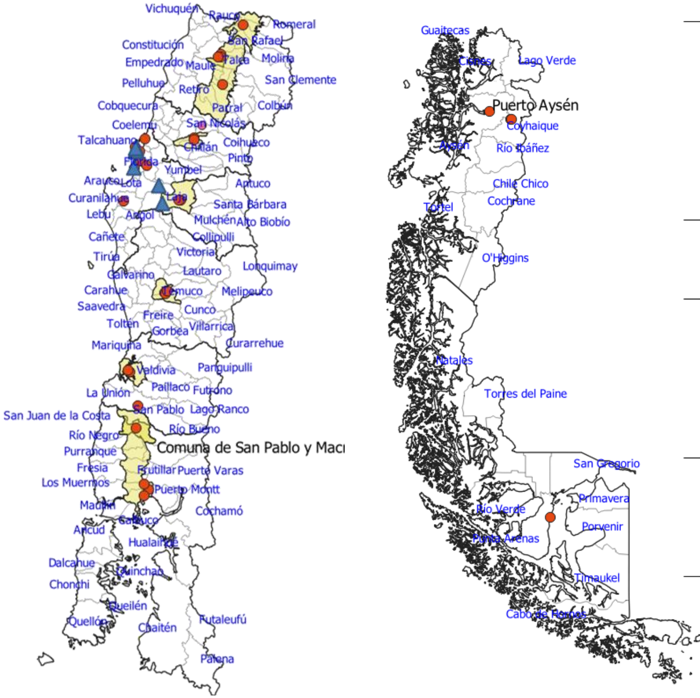
Cumplimiento normativo Biobío

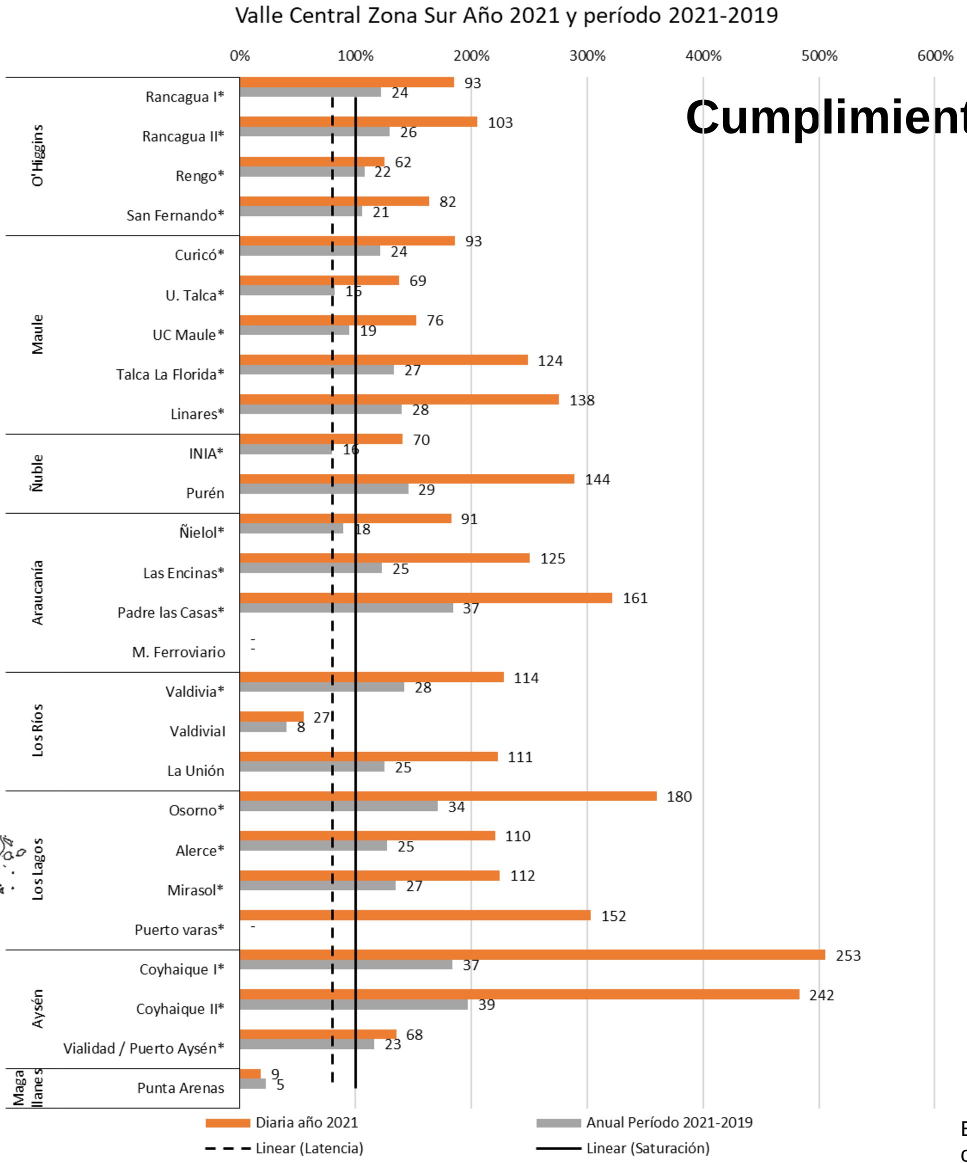


Estaciones con asterisco (*) señalan cuales son EMRP para $MP_{2,5}$.

000236 VTA

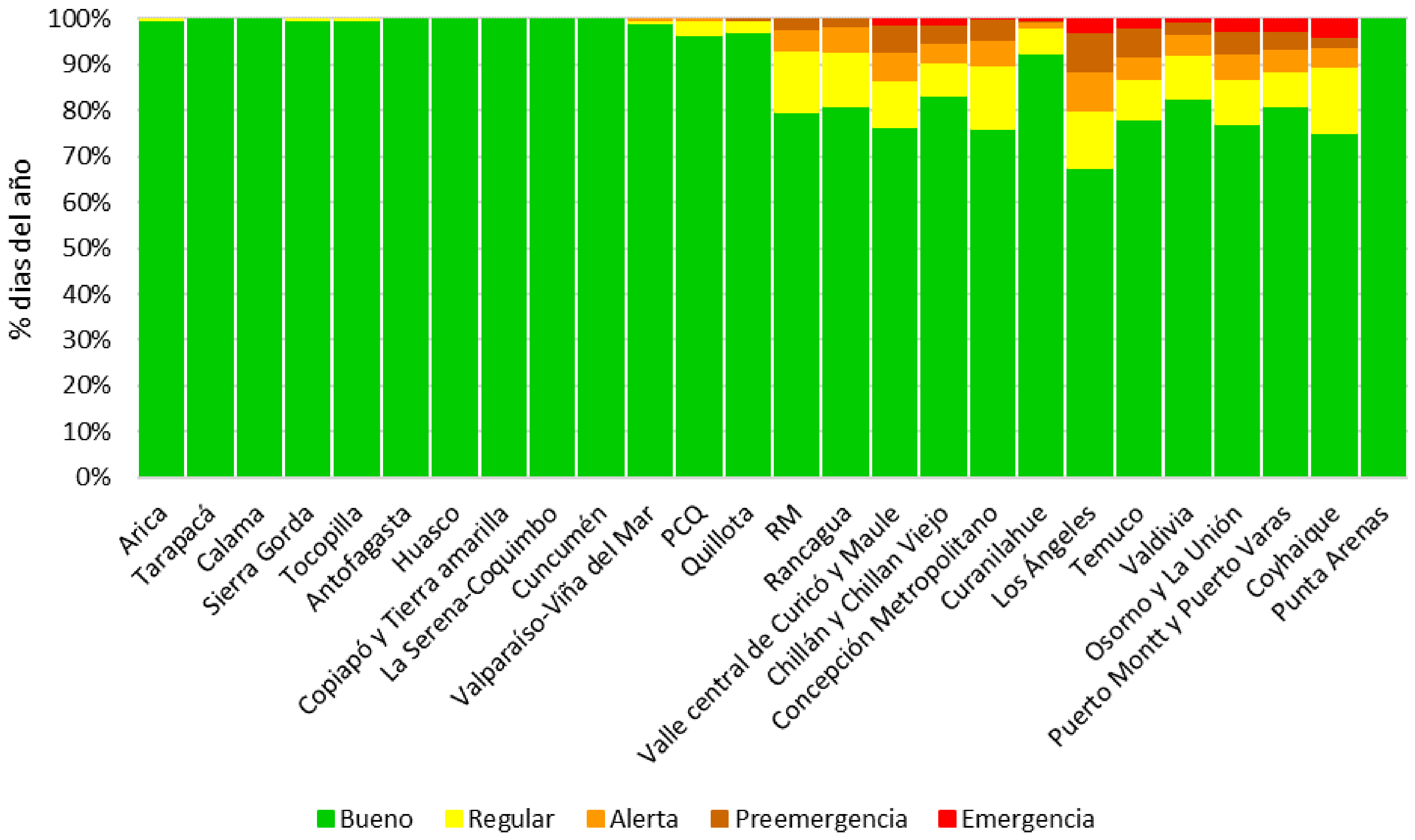
Cumplimiento normativo





Estaciones con asterisco (*) señalan cuales son EMRP para $MP_{2,5}$.

Situación Actual Año 2021



Evolución de la calidad del aire- Tendencias

- Promedio 24 hrs-Promedio Trianual
- Factores de Impacto por Concentración (FIC)

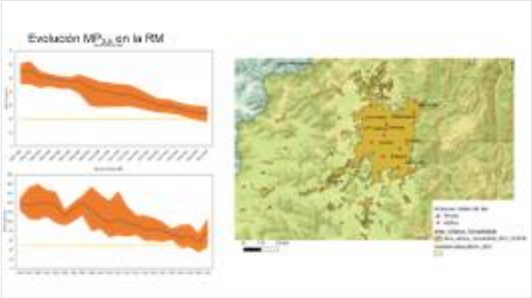
$$\ln(MP) = \alpha + \Sigma\beta_{Aj} * Aj + \Sigma\beta_{Mj} * Mj + \Sigma\beta_{DSi} * DSj + \Sigma\beta_{Tj} * Tj + \Sigma\beta_{HRj} * HRj + \Sigma\beta_{VVj} * VVj \quad (ec. 1)$$

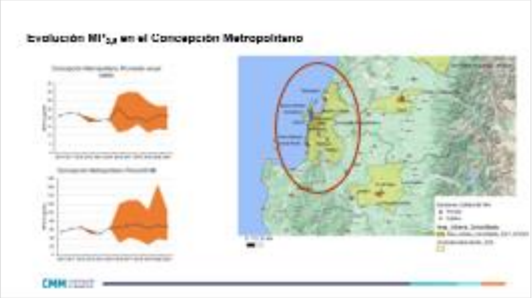
Variables: Año, Mes, Día de la semana y Variables meteorológicas como Humedad Relativa, Temperatura y Magnitud de la Velocidad del Viento

Koutrakis, et al, 2005

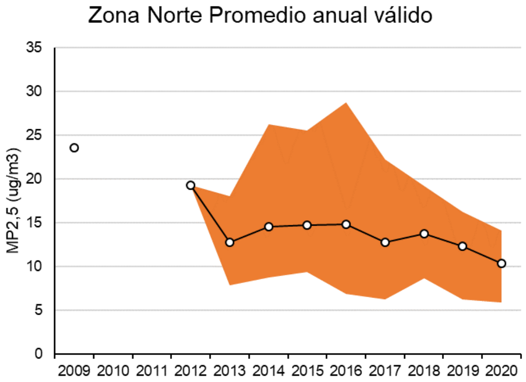
Clasificación

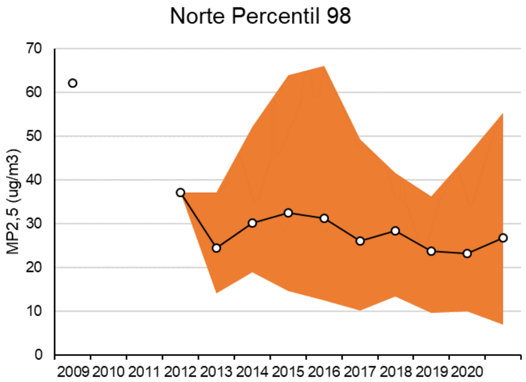
- **Zona norte:** Regiones XV, I, II, III, IV, V.
- **Región Metropolitana:** 52 comunas que componen la Región Metropolitana.
- **Concepción Metropolitano:** 10 comunas que componen la zona Metropolitana de Concepción.
- **Zona sur:** VI, VII, VIII exceptuando Concepción Metropolitano, IX, X, XI y XIV.

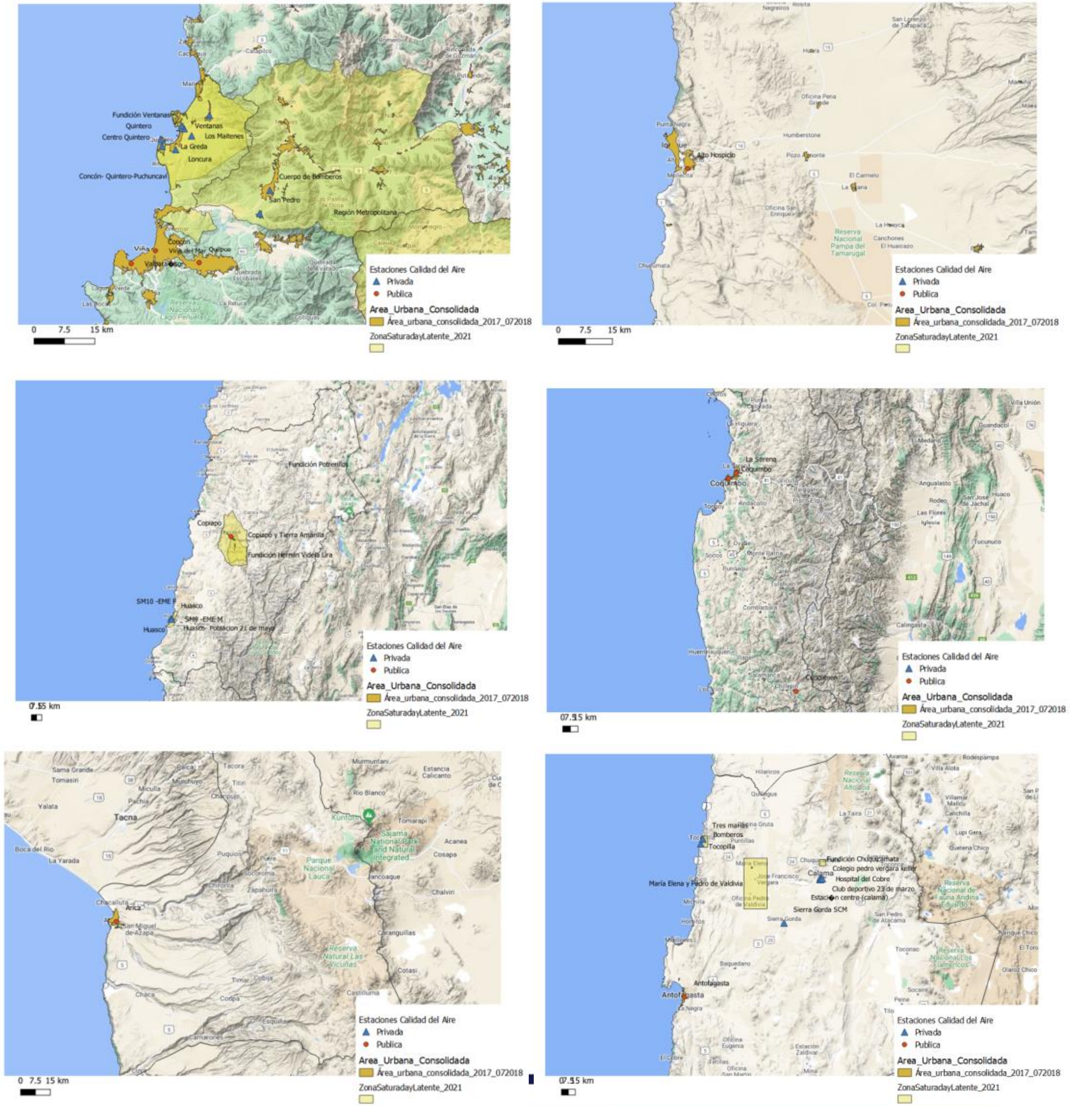




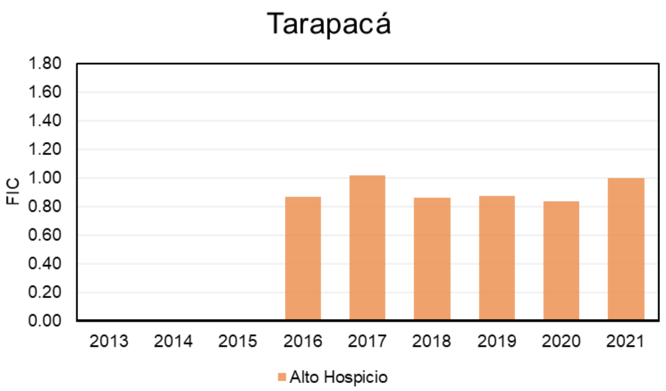
Evolución $MP_{2,5}$ en la Zona Norte (Regiones XV, I, II, III, IV, V)

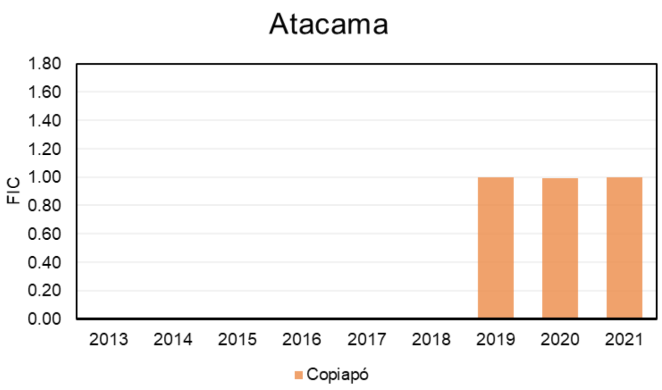


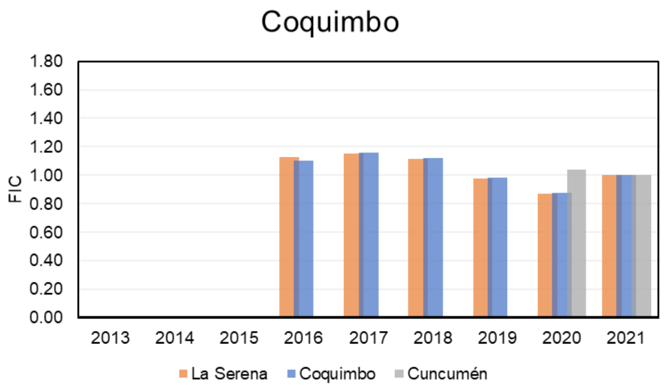


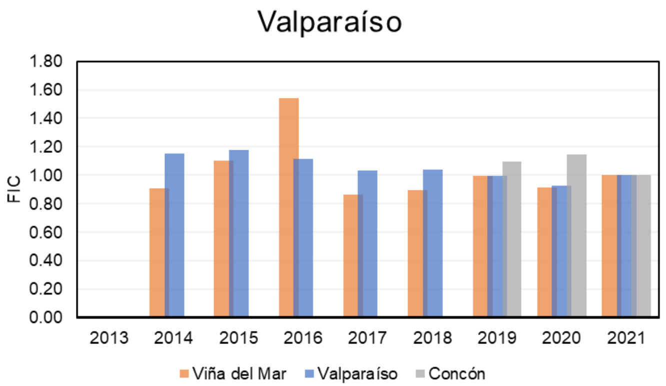


Tendencias-FIC

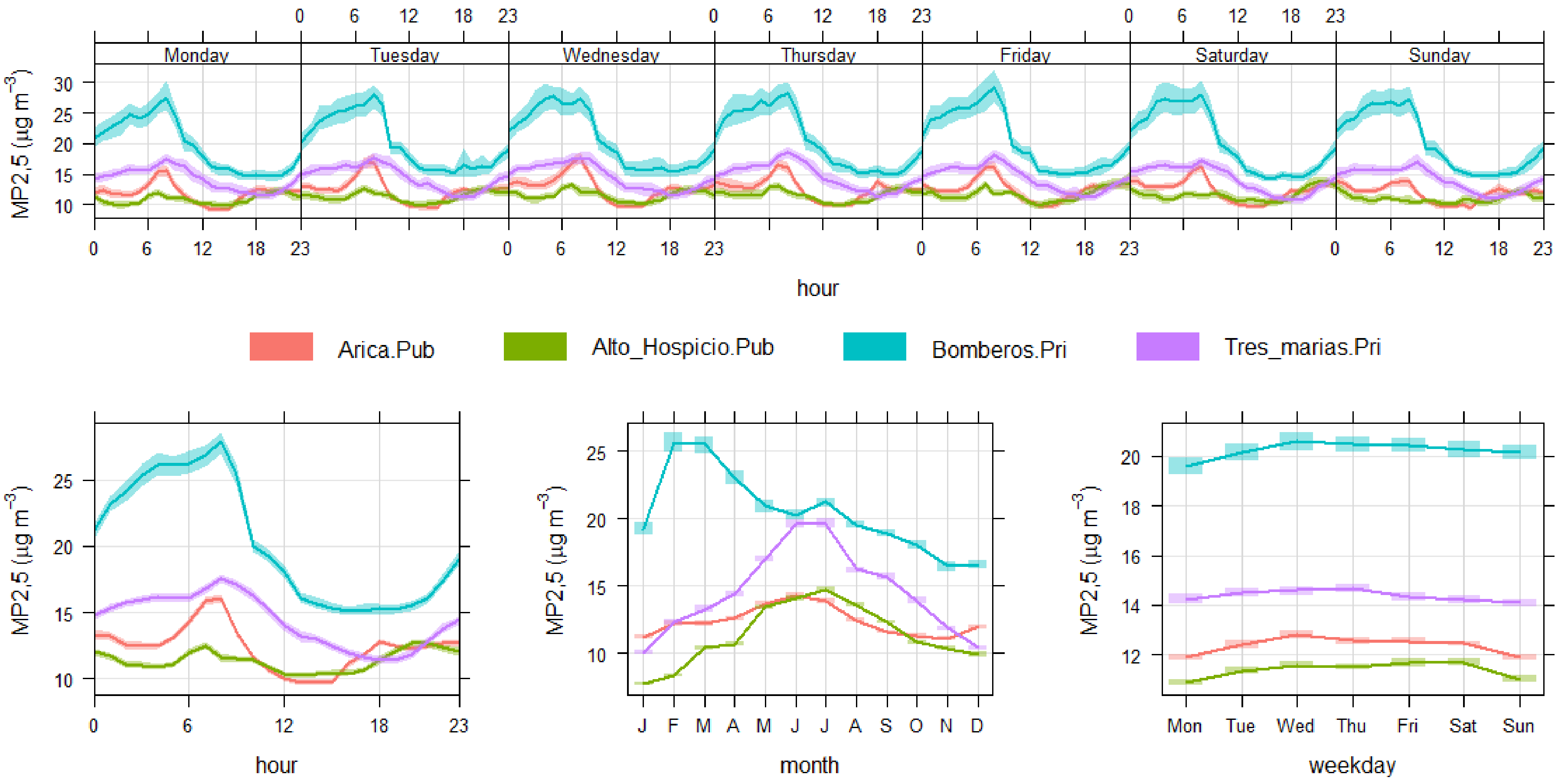






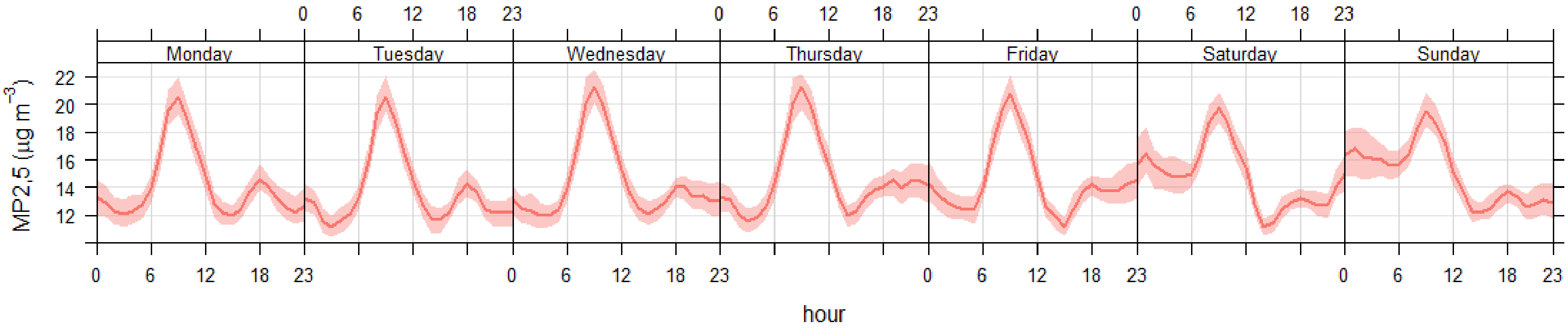


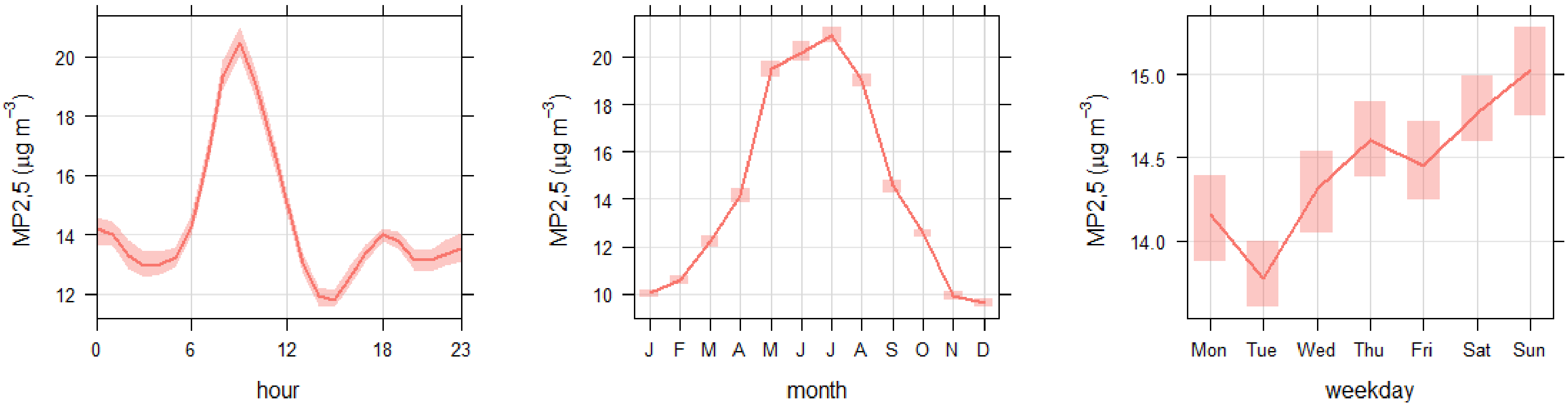
Arica, Tarapacá y Antofagasta (estaciones costeras)



mean and 95% confidence interval in mean

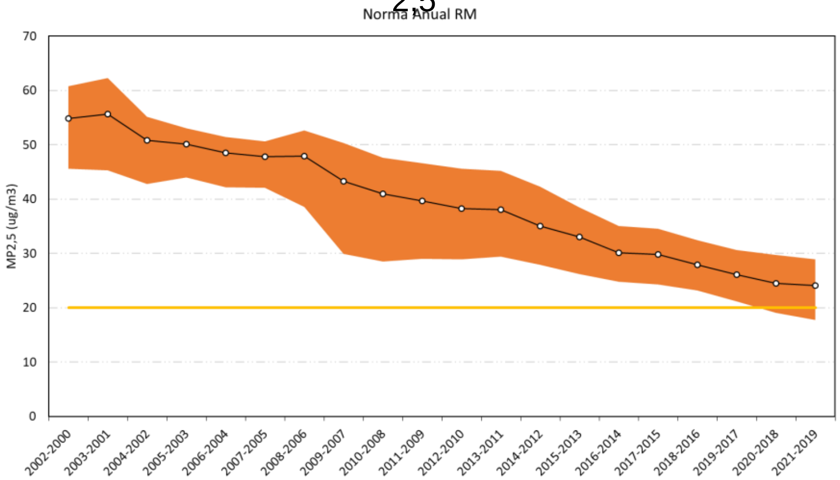
Copiapó Interior

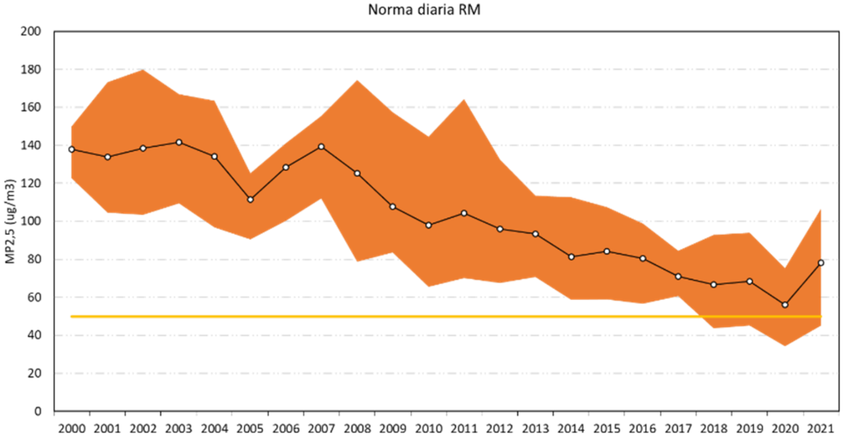


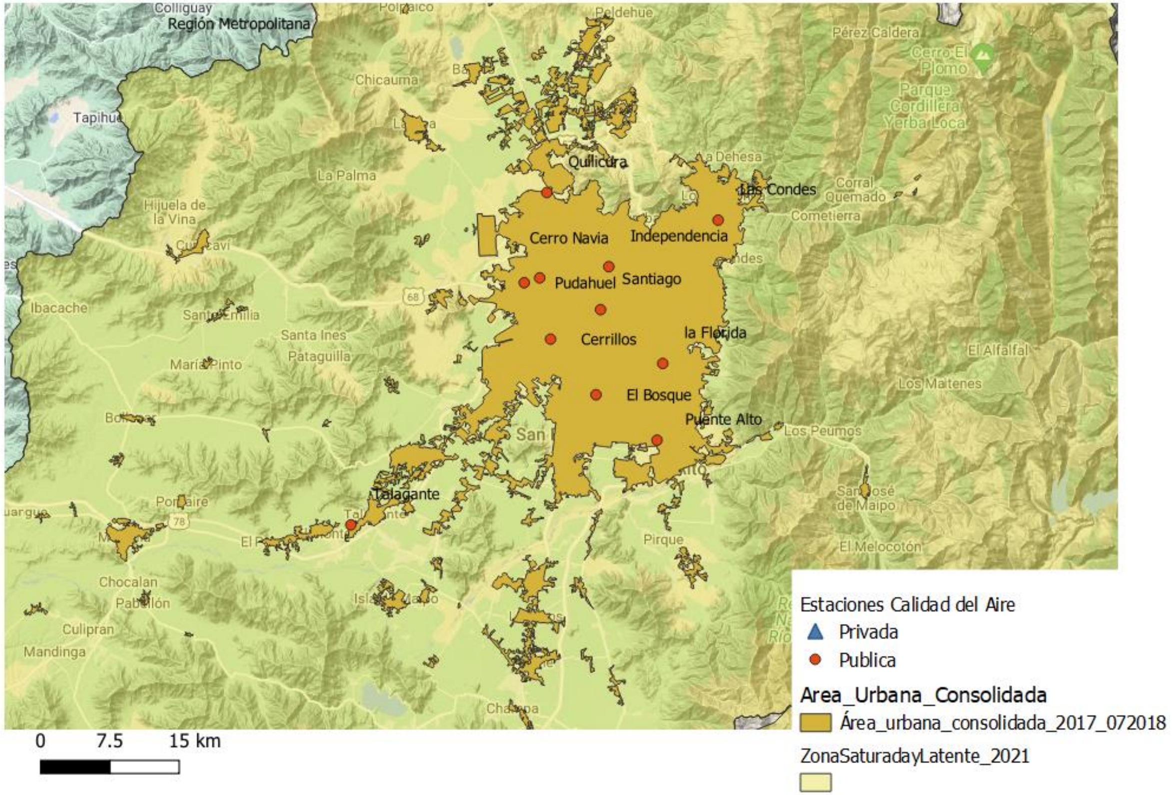


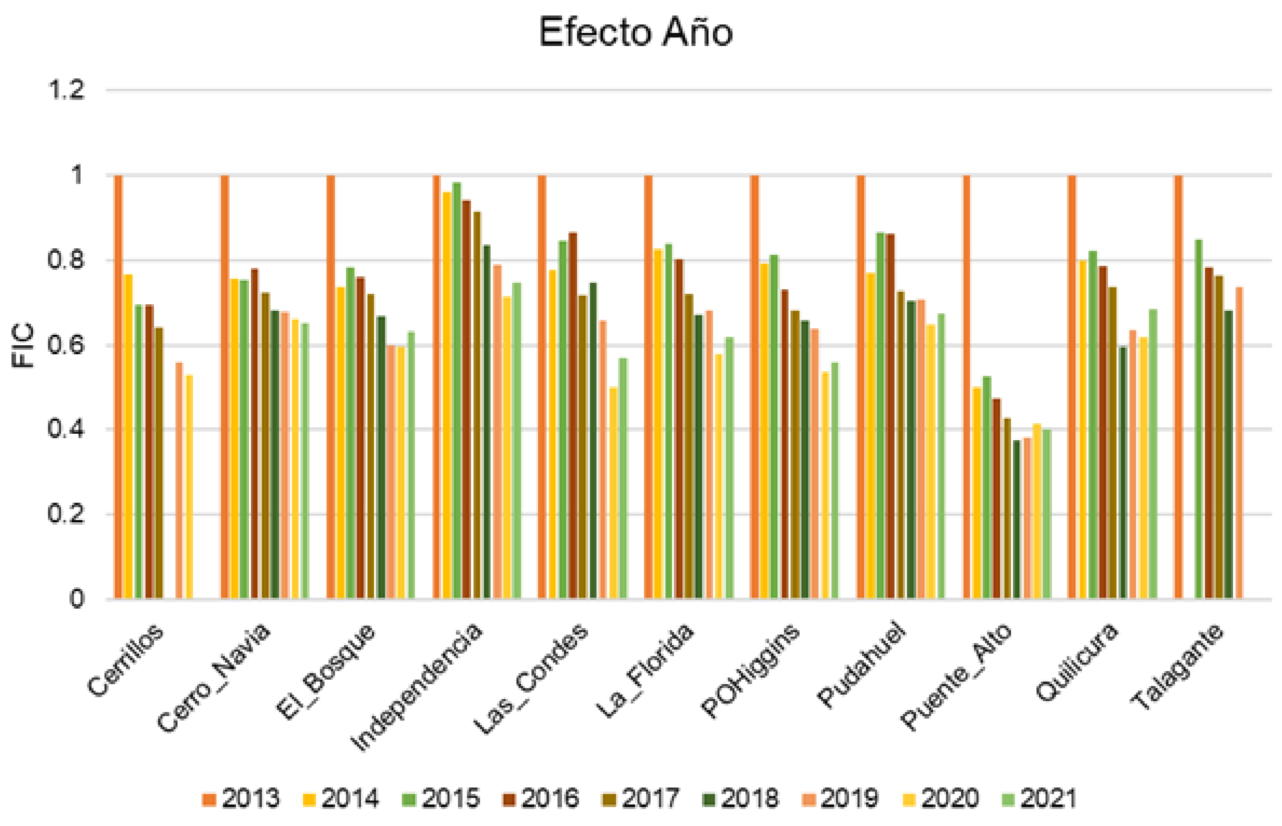
mean and 95% confidence interval in mean

Evolución $MP_{2,5}$ en la RM

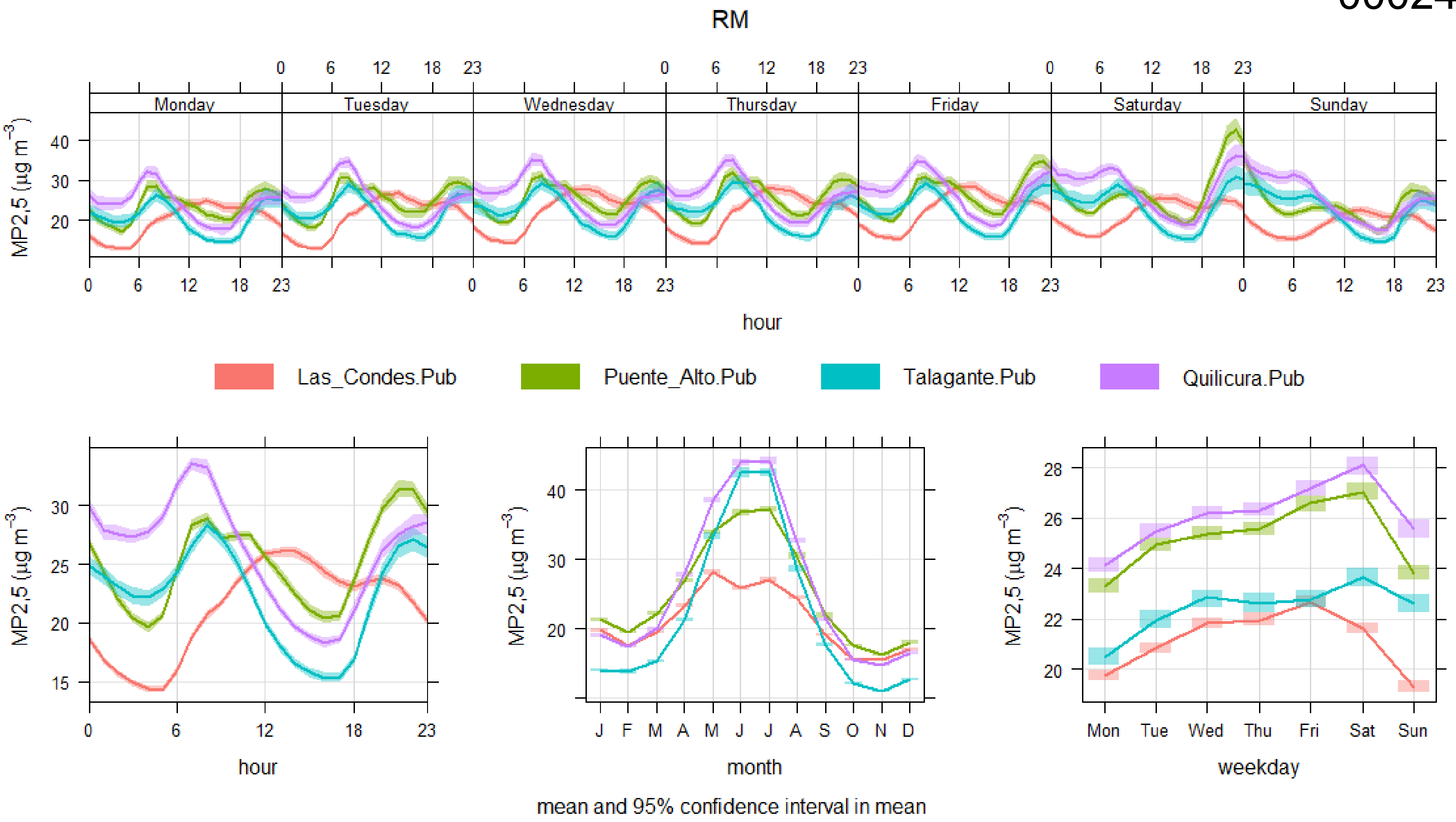




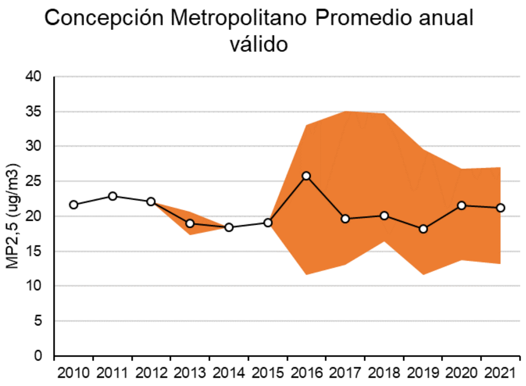


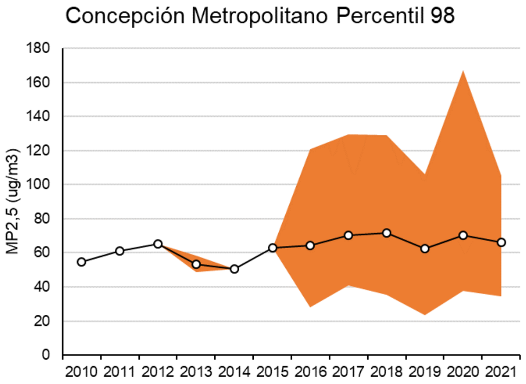


Efecto Año
1.2
1
0.8
0.6
0.4
0.2
0
FIC
Cerrillos
Cerro_Navia
El_Bosque
Independencia
Las_Condes
La_Florida
POHiggins
Pudahuel
Puente_Alto
Quilicura
Talagante
2013
2014
2015
2016
2017
2018
2019
2020
2021

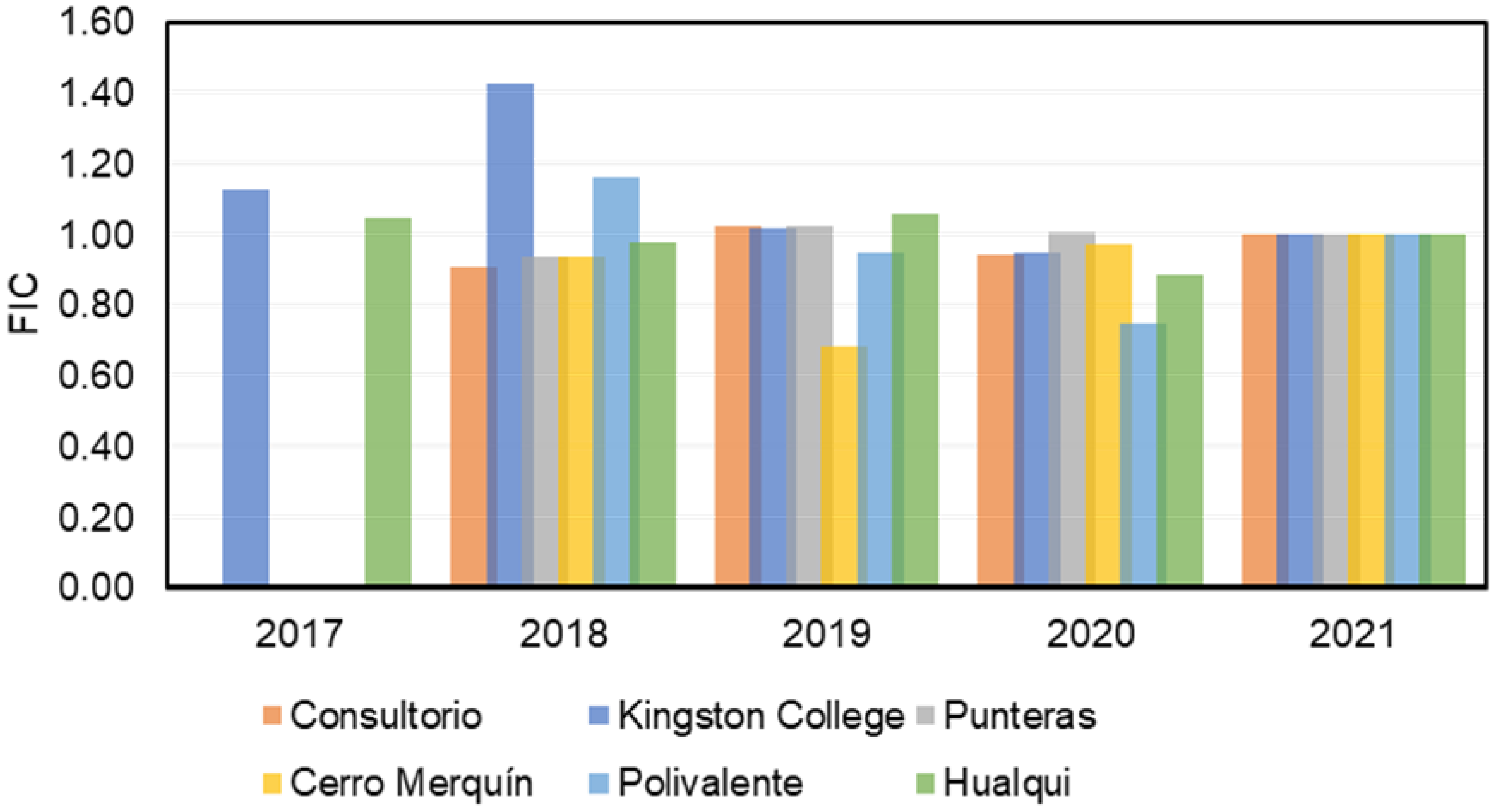

RM
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
MP2,5 (µg m^{-3})
hour
Las_Condes.Pub
Puente_Alto.Pub
Talagante.Pub
Quilicura.Pub
month
weekday
Mon
Tue
Wed
Thu
Fri
Sat
Sun
mean and 95% confidence interval in mean

Evolución $MP_{2,5}$ en el Concepción Metropolitano



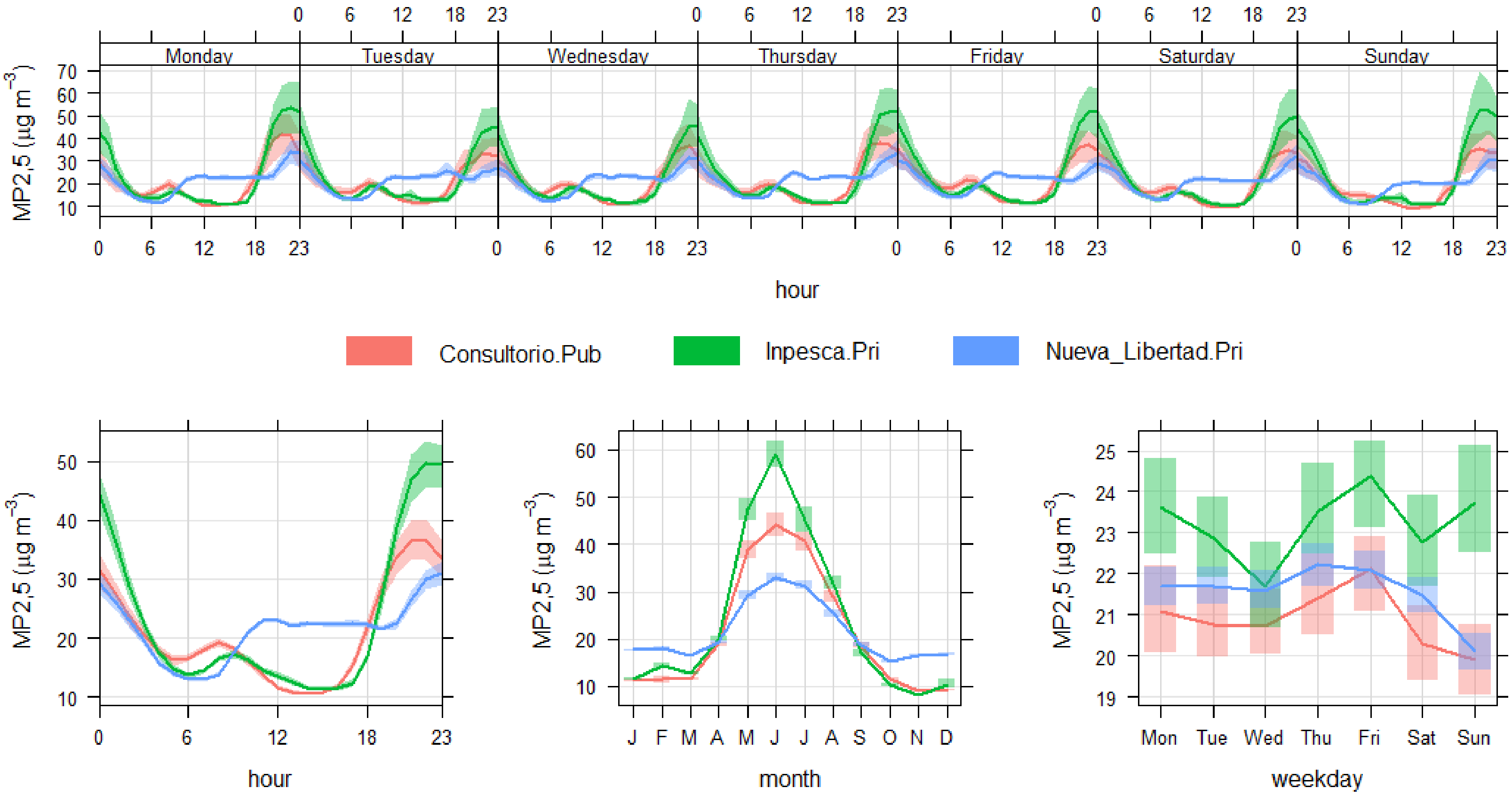


Concepción Metropolitano



CMM Investigación & desarrollo

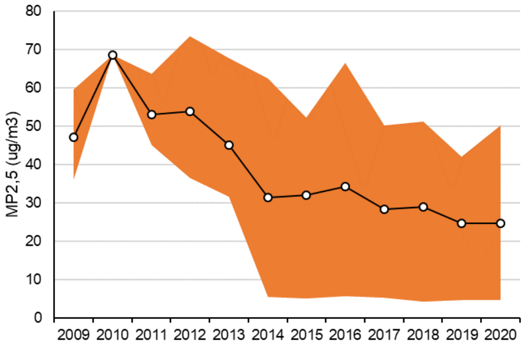
Biobio



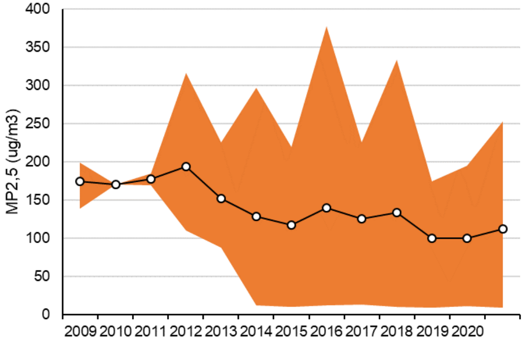
mean and 95% confidence interval in mean

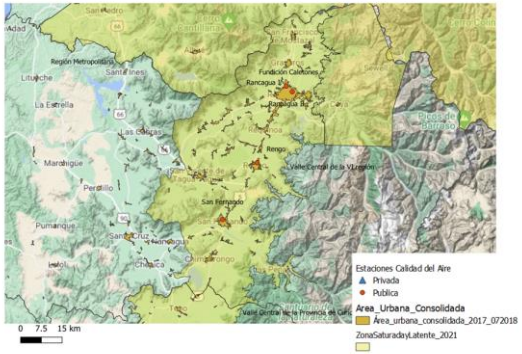
Evolución $MP_{2,5}$ en La Zona Sur

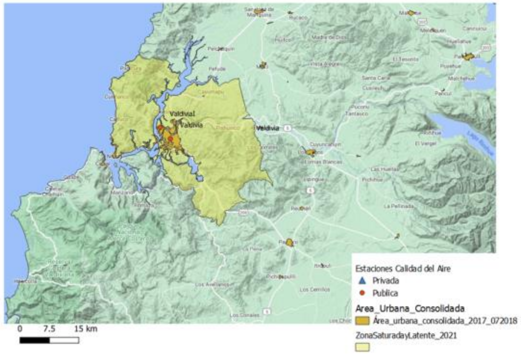
Zona Sur Promedio anual válido

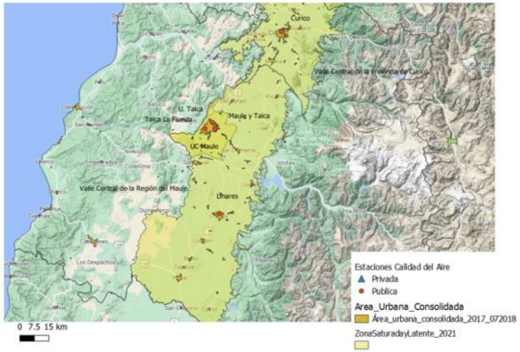


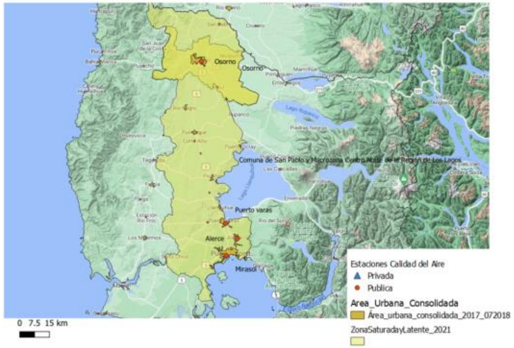
Sur Percentil 98

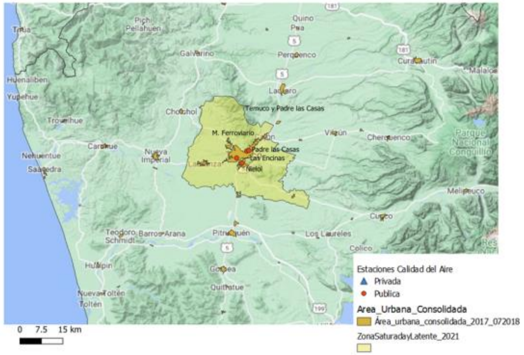


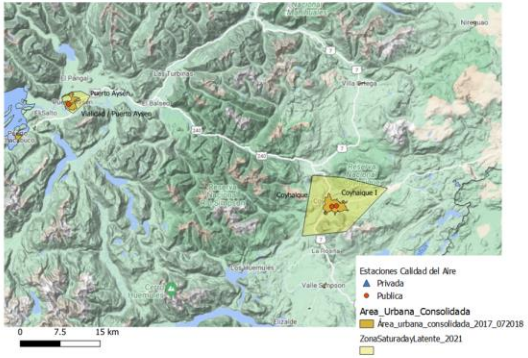




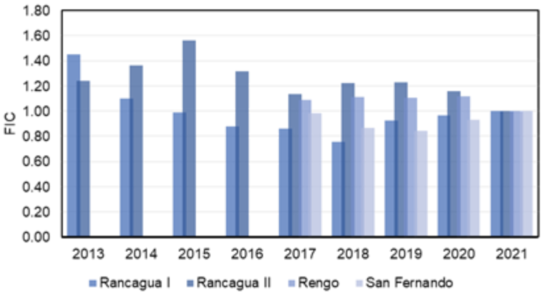




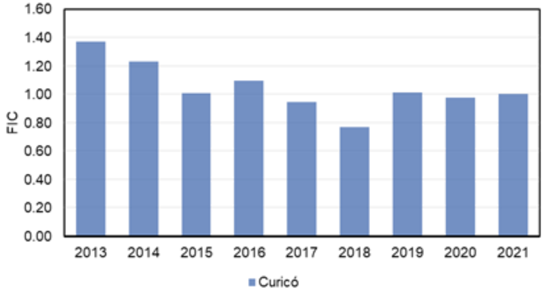




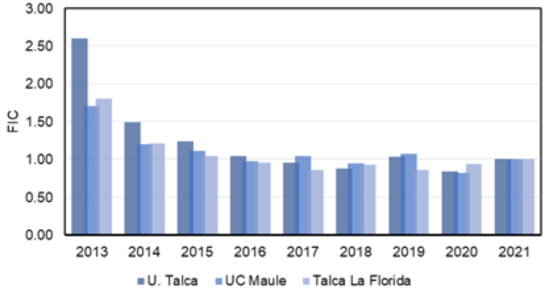
O'Higgins



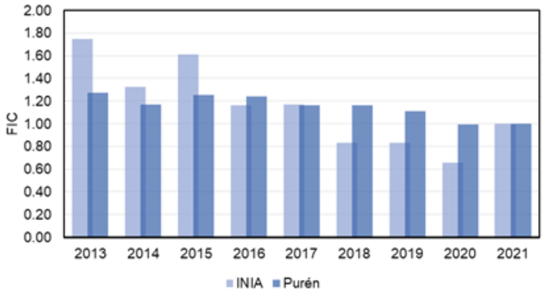
Curicó



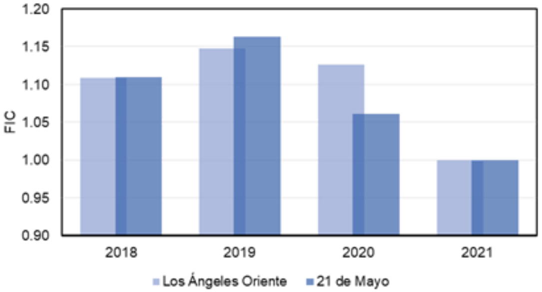
Talca y Maule



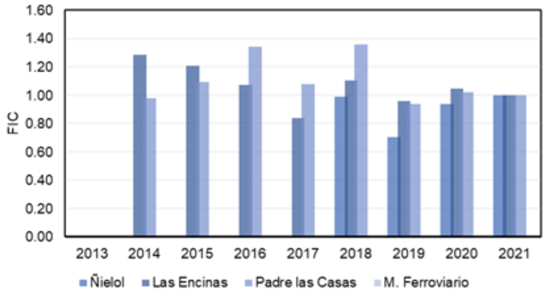
Chillán y Chillán Viejo



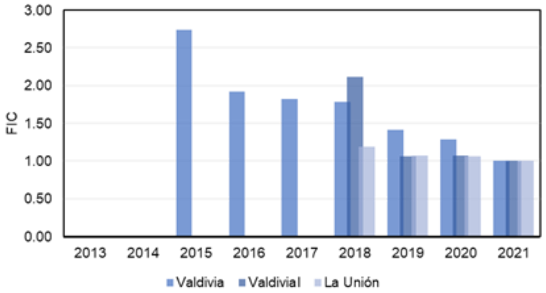
Los Ángeles



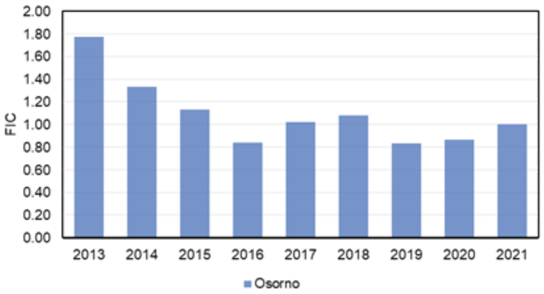
Temuco y Padre Las Casas



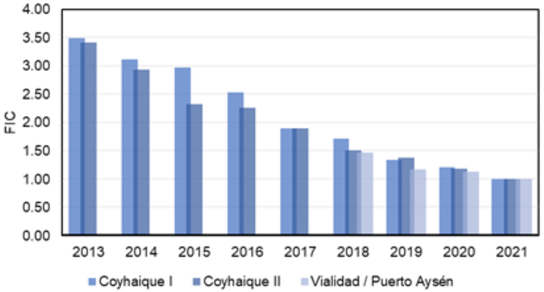
Valdivia

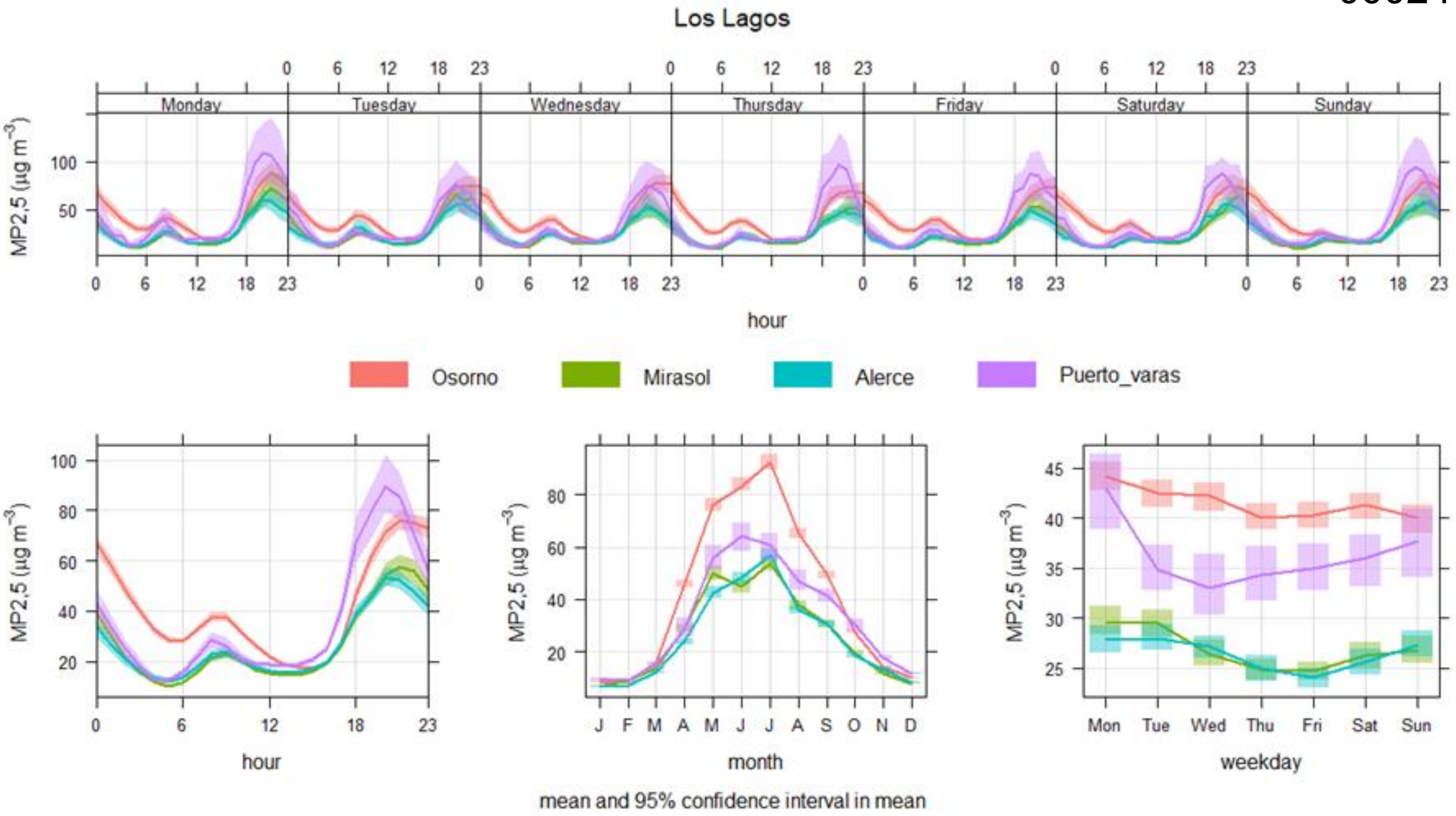


Osorno

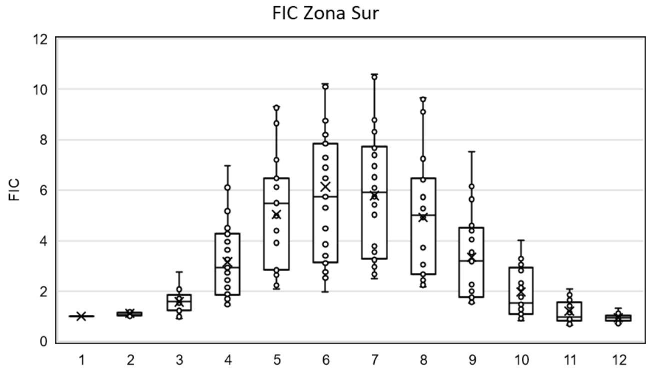


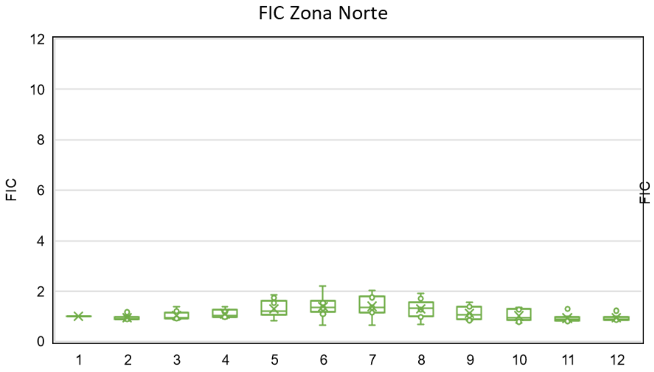
Coyhaique

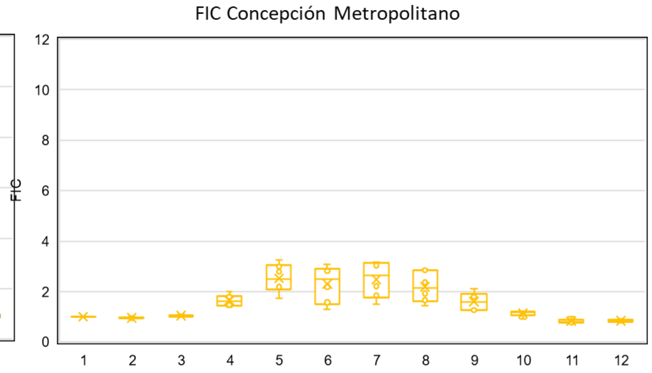


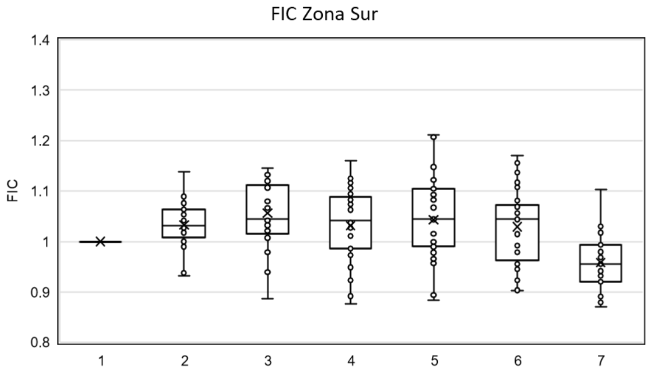

Los Lagos
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
MP2,5 (µg m⁻³)
hour
Osorno
Mirasol
Alerce
Puerto_varas
month
weekday
Mon
Tue
Wed
Thu
Fri
Sat
Sun
mean and 95% confidence interval in mean

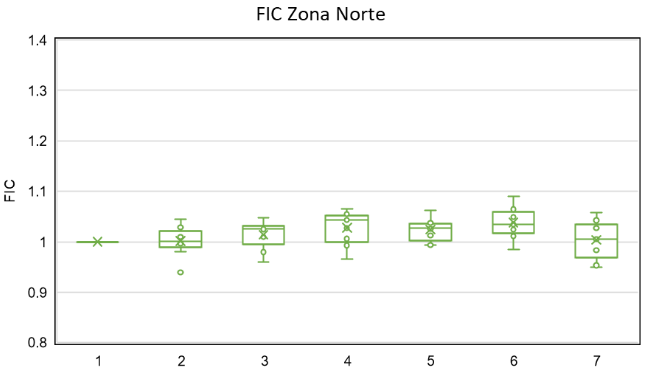
Efecto temporal

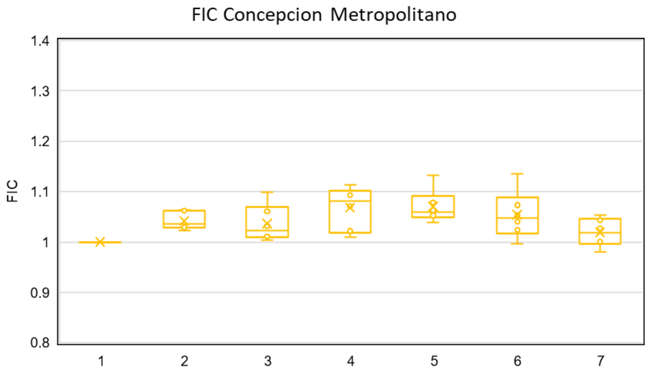






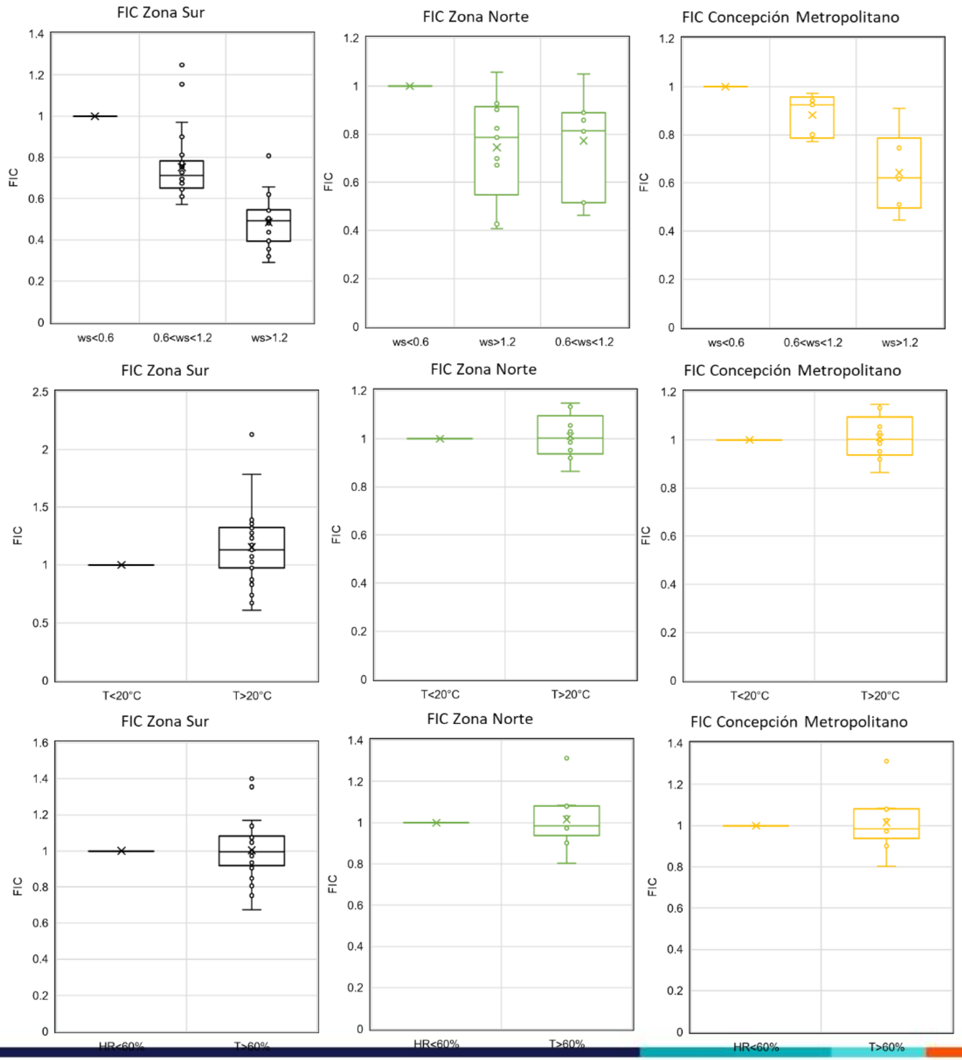






Efecto Meteorológico

La velocidad del viento es la que más influencia el impacto por $MP_{2,5}$



Conclusiones

- Después de una década de implementación, **se ha fortalecido el monitoreo en línea y se han dictado múltiples instrumentos regulatorios** (normas de emisión de alcance nacional y planes de descontaminación).
- Las ciudades con planes de descontaminación **muestran reducción en sus niveles de $MP_{2,5}$** que son atribuibles a las medidas de control implementadas.
- Sin embargo, **aún se observan niveles altos de $MP_{2,5}$ desde la región de Valparaíso hasta Aysén.**
- Las redes de monitoreo entregan información valiosa pero **insuficiente** para caracterizar el $MP_{2,5}$, los impactos en salud, mecanismos de formación y niveles background.
- Las **redes de $MP_{2,5}$ se enfocan en ciudades de mayor tamaño**. Se debe evaluar el uso de monitoreo complementario (screening, p.e. sensores bajo costo) para aumentar la cobertura de monitoreo en ciudades de menor tamaño.

Centro Mario Molina
Investigación & desarrollo

ESTUDIO DE ANTECEDENTES PARA LA REVISIÓN DE LA NORMA PRIMARIA DE CALIDAD AMBIENTAL PARA MATERIAL PARTICULADO FINO RESPIRABLE ($MP_{2,5}$)

Diagnóstico de Calidad del Aire a Nivel Nacional
Análisis de las causas, comportamiento y tendencia histórica de la concentración de $MP_{2,5}$ a nivel nacional y regional.

Viernes 06 de octubre de 2023

[redacted]@cmmolina.cl