Health effects of long-term exposure to PM

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In 2021, the World Health Organisation (WHO) published revised recommendations for ambient air quality (WHO 2021). To support this update, WHO published a review paper in 2020 evaluating the best available evidence on the effects of long-term exposure to particulate matter (PM) (Chen & Hoek 2020).

Specifically, the research published updated quantified risk ratios for exposure to PM on premature mortality (people dying earlier than they otherwise would have). They also qualitatively assessed how these risks changed at high and low exposure levels.

Highlights

- There is clear evidence that both $PM_{2.5}$ and PM_{10} are associated with increased mortality from all causes, cardiovascular disease, respiratory disease and lung cancer.
- Associations remained at low exposure levels.
- Associations with $PM_{2.5}$ were more consistent than with PM_{10}.
- There was no evidence of any threshold below which adverse effects did not occur.

(Chen and Hoek 2020)

Key Facts

There is widespread consensus that the relationship between PM and mortality is causal (WHO 2006, WHO 2013, WHO 2021).

For annual $PM_{2.5}$ the certainty of evidence was **high** for mortality due to all-causes, circulatory disease, ischaemic heart disease, stroke, chronic obstructive pulmonary disease, acute lower respiratory infection and lung cancer and moderate for respiratory mortality.

For annual PM_{10} the certainty of evidence was **high** for mortality due to all-causes, respiratory disease and lung cancer, moderate for mortality due to circulatory disease, ischaemic heart disease and chronic obstructive pulmonary disease, and low for stroke mortality. The association was non-significant for annual PM_{10} and acute lower respiratory infection mortality.

Public health protection ideally seeks a threshold concentration below which there is no effect. There is no evidence of a 'safe' threshold for PM.

Research Findings

Following screening and selection, Chen & Hoek systematically reviewed 107 air pollution epidemiology studies. Mean/median annual concentrations of $PM_{2.5}$ ranged from 4.1 – 54 micrograms per cubic metre ($\mu g/m^3$) reported in 70 studies. Mean/median annual concentrations of PM_{10} ranged from 2.2 – 154 $\mu g/m^3$ reported in 34 studies.

The studies were carried out in a wide range of countries however, the majority were conducted in North America (sample size n = 62) and Europe (n = 25). Whilst the number of studies from Asia has increased since 2005 (n = 19), there were no studies from Africa, Central and South America. Widely different populations were studied over wide-ranging time periods.

The size of the populations studied varied from a minimum of 192 (France, idiopathic pulmonary fibrosis patients) to a maximum of over 60 million (USA Medicare study). Of note, Chen and Hoek's review included New Zealand's census-mortality study of 1.4 million people for the period 1996 – 1999 (Hales *et al.*, 2021).

Chen & Hoek developed new risk ratios as presented in the table below, to represent the quantitative risks posed by long-term exposure to PM. The association was non-significant for annual PM_{10} and circulatory mortality, stroke and chronic obstructive pulmonary disease (COPD).

Pollutant Exposure	Mortality type	No. Studies	Risk Ratio	95% Confidence Interval	Certainty of Evidence
Annual $PM_{2.5}$	All-cause	25	1.08	1.06 – 1.09	**High**
	Circulatory	21	1.11	1.09 – 1.14	**High**
	IHD	22	1.16	1.10 – 1.21	**High**
	Stroke	16	1.11	1.04 – 1.18	**High**
	Respiratory	17	1.10	1.03 – 1.18	Moderate
	COPD	11	1.11	1.05 – 1.17	**High**
	ALRI	4	1.16	1.01 – 1.34	**High**
	Lung cancer	15	1.12	1.07 – 1.16	**High**
Annual PM_{10}	All-cause	17	1.04	1.03 – 1.06	**High**
	Circulatory	15	1.04	0.99 – 1.10	Moderate
	IHD	13	1.06	1.01 – 1.10	Moderate
	Stroke	9	1.01	0.83 – 1.21	Low
	Respiratory	13	1.12	1.06 – 1.19	**High**
	COPD	5	1.19	0.95 – 1.49	Moderate
	ALRI	2	–	–	–
	Lung cancer	13	1.08	1.04 – 1.13	**High**

IHD = ischaemic heart disease, COPD – chronic obstructive pulmonary disease, ALRI = acute lower respiratory infection

When viewing this table, it is important to note that the risk ratios for PM_{10} and $PM_{2.5}$ cannot be directly compared because the applied increment of 10 $\mu g/m^3$ in annual $PM_{2.5}$ represents a much larger contrast than for PM_{10}.

The risk ratio can be interpreted as follows:

> **Annual $PM_{2.5}$ risk ratio 1.08** (95% *Confidence Interval*:1.06, 1.09, n = 25)

This means for every 10 µg/m³ increase in annual concentrations of $PM_{2.5}$, deaths in the wider population due to all causes increased by 8%, with 95% of the data being between 6 – 9% in 25 epidemiological studies.[1]

Discussion

The researchers noted the following important observations:

- Virtually the same pooled effect estimates were found for the European Region, Region of the Americas and the Western Pacific Region.
- The review identified **high levels of heterogeneity for most exposure-outcome pairs.** *Heterogeneity* is an indicator of the extent to which variations between study estimates is too great to be explained by chance. However, the authors noted a high level of heterogeneity is to be expected given the wide diversity of study locations, population characteristics, level and composition of PM and methodological differences.
- **Risk ratios tended to be larger in studies with mean $PM_{2.5}$ concentrations below 10 µg/m³**. This has implications for countries with good air quality (like New Zealand), as it suggests that health improvements are still to be found by reducing PM levels below the current WHO guideline of 10 µg/m³. Notably, the combined effects estimate for five studies with a mean $PM_{2.5}$ concentration below 10 µg/m³ was 1.17 (95% CI: 1.12, 1.23). This is double the risk ratio developed in the meta-analysis.
- In general, **associations with $PM_{2.5}$ were more consistent than with PM_{10}, particularly for cardiovascular outcomes**. The less consistent association for PM_{10} may reflect the smaller number of studies compared with $PM_{2.5}$ and the lower risk of long-term exposure to coarse particles (i.e., the $PM_{10\text{-}2.5}$ fraction).
- Application of WHO's risk of bias tool (WHO 2020) showed that **few studies were at a high risk of bias in any domain**. The researchers concluded that, for the entire body of evidence, it was not likely that important confounding had occurred.

Conclusions

Compared to the previous global WHO evaluation (WHO 2006), the evidence base has increased substantially. Chen & Hoek concluded there is clear evidence that long-term exposure to $PM_{2.5}$ and PM_{10} are both associated with increased mortality from all causes, cardiovascular disease, respiratory disease and lung cancer.

There was no evidence of any threshold below which adverse effects did not occur.

[1] For more information on the study methods and interpreting risk ratios please see the separate fact sheet titled "Health Effects of Air Pollutant Factsheets: Supporting Information". (Wickham *et al*. 2022)

WHO Long-Term PM Guidelines

The long-term WHO 2021 air quality guideline levels are defined as the lowest exposure level of an air pollutant above which WHO is confident that there is an increase in adverse health effects (WHO 2021).

In most situations $PM_{2.5}$ is about 50-80% of PM_{10} by weight, therefore the annual PM_{10} guideline is less protective than that $PM_{2.5}$ guideline. In all situations where both $PM_{2.5}$ and PM_{10} measurements are available, preference should be given to the $PM_{2.5}$ guideline level (WHO, 2021).

Pollutant/ Time Average	Guideline (µg/m³)
$PM_{2.5}$	
Annual	5
PM_{10}	
Annual	15

References

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