Health Effects of Air Pollutant Factsheets: Supporting Information

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Air pollution is a major hazard to human health and a leading cause of illness and death. In 2021, the World Health Organisation (WHO) published revised global air quality guidelines to offer quantitative, health-based recommendations for air quality management (WHO 2021). To support this update, WHO published a series of review papers evaluating the best available evidence on the effects of air pollutants on human health (Chen and Hoek 2020; Huangfu and Atkinson 2020; Lee et al. 2020; Orellano et al. 2020, Orellano et al. 2021; Zheng et al. 2021).

This factsheet provides additional technical detail on how the systematic reviews informed the development of WHO's revised global air quality guidelines.

Background

A *systematic review* is a type of literature review that uses systematic methods to collect secondary data, critically appraise research studies and synthesise findings to answer the review question. For example, in Zheng *et al*. 2021, the systematic review question was:

> *"What is the effect of short-term exposure to NO_2 and SO_2 on emergency room visits and hospitalisations due to asthma?"*

Zheng and fellow researchers undertook a *meta-analysis* of current air pollution epidemiology studies for short-term air pollution exposure to NO_2 and SO_2. A meta-analysis is a survey in which the results of the studies included in the review are statistically similar and are combined and analysed as if they were one study. The meta-analysis thus pools together risk ratios from many, similar studies, to establish a new *risk ratio*.

Risk Ratios

A risk ratio *(RR)* is the ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group. For relationships that are known to be causal (such as air pollution and adverse health effects), values of RR can be interpreted as follows:

- RR = 1 means that exposure does not affect the outcome
- RR < 1 means that the risk of the outcome is decreased by the exposure
- RR > 1 means that the risk of the outcome is increased by the exposure

It is important to note that RR are relative (to non-exposure). This means that to understand a RR, the range of exposure needs to be clearly stated. The standard increment in air quality epidemiology (including Zheng *et al*. 2021) is 10 micrograms per cubic metre ($\mu g/m^3$).

Long-term vs short-term effects

The health effects of exposure to air pollution depend on the duration of exposure as well as the concentration of the pollutant. For example, exposure may trigger the occurrence of an acute event (e.g., asthma attack or myocardial infarction) leading to death (short-term effects) and/or increase the underlying frailty of the population due to chronic exposure (long-term effects).

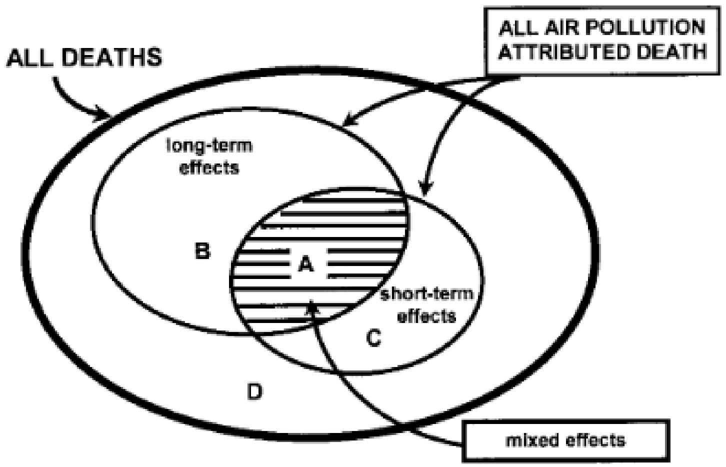

Figure 1: Illustration of deaths due to ambient air pollution in a population, including cases related to both long term and short-term air pollution (Künzli et al. 2001)

To explain the difference between short-term effects and long-term effects, Künzli *et al*. (2001) describes four different categories of mortality effects A, B and C and D. These are illustrated in Figure 1 and categorised as follows.

- For deaths in category A, air pollution may have played a role both in increasing the persons underlying susceptibility or frailty and in triggering the event. For example, patients with chronic bronchitis that has been aggravated by long term air pollution exposure may be hospitalised with an acute, air pollution-related exacerbation of their illness, leading to death shortly afterward.

- For cases in **category B**, the underlying frailty is again related to (among other factors) long term air pollution, but the event or the occurrence of death itself is unrelated to the levels of air pollution shortly before death. For example, suffering from chronic bronchitis may be made worse by long term ambient air pollution exposure but the person may die of acute pneumonia acquired during a clean air period. Therefore, long term cumulative exposure to air pollution contributed to shortening of survival time, whereas air pollution during the final days of life had no further life-shortening effect.

- Among deaths in **category C**, reduced health status or frailty is not related to air pollution, but ambient air pollution experienced before death may trigger the terminal event. For example, a person with diabetes mellitus may be susceptible to heart attacks due to long-standing coronary disease; in such a case, an air pollution episode may trigger the fatal infarction leading to hospital admission, arrhythmia, or death.

- Finally, in **category D**, neither disease history nor the event of death are related to air pollution. In reality (unlike **Figure 1**) category D is much larger than all other categories.

The calculation of air pollution attributable deaths ought to include categories A, B and C.

The policy outcome of this is that air quality guidelines are needed for different exposure periods to protect against different health effects.

Setting WHO 2021 Air Quality Guidelines

The WHO 2021 air quality guidelines (AQG) were developed using the protocol outlined in WHO, 2021, with extensive internal and external review.

Long-term (annual mean, or for ozone, highest six-month average) AQG 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. This confidence is primarily based on there being moderate or high certainty of evidence for an association between a specific pollutant and a specific health outcome.

Short-term AQG levels are typically defined as a high percentile (e.g., 98^{th} or 99^{th}) of concentrations empirically observed in distributions with a mean equal to the long-term AQG level.[1] The reasoning behind this is that for locations in which concentrations are below the long-term AQG, days with such high daily mean concentrations will be rare and a large proportion of days will have concentrations below the long-term AQG level. This means that the health burden related to a few days with higher concentrations corresponds to a very small fraction of total air pollution-related burden. The rationale for choosing a high percentile and not the maximum is that the maximum of daily values for a given year is a less stable statistic than the high percentiles.

It is important to note that the approach to setting guidelines does not identify safe levels and is not based on a defined level of acceptable risk (i.e., the guidelines are not "no adverse effect levels").

[1] For SO_2 there is no long-term AQG so the approach has been to select a high percentile daily value consistent with other pollutants, whereby the estimated excess mortality at days with concentrations at the proposed 24-hour guideline is roughly comparable across all pollutants.

References

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