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VALESOR
Valuation of environmental stressors

Policy Brief

The last decade of air pollution epidemiology and the challenges of quantitative risk assessment

Key messages

- The evolving landscape of air pollution epidemiology underscores the urgency of addressing global challenges through research, advanced modelling, and comprehensive risk assessments.
- Quantitative risk assessment requires robust methodology in choosing the relevant concentration-response functions (CRF) and their application to the population under study.
- We propose a structured and comprehensive framework for assessing the evidence levels associated with each exposure-health outcome pair and to provide an adequate CRF within a health impact assessment context.

Global concern about air pollution has escalated, with most of the world's population exposed to air exceeding the World Health Organization's (WHO) latest air qualitygqualiuidelines [1]. The updated guidelines underscore the pressing need for immediate action to combat the adverse effects of pollutants such as nitrogen dioxide (NO_2), ozone (O_3) and fine particles ($PM_{2.5}$) on public health and the environment [1]. According to the Global Burden of Disease (GBD) study [2], the global mortality attributed to $PM_{2.5}$ ambient air pollution in 2021 was 4.72 million premature deaths. Among all risk factors, particulate matter pollution (indoor plus outdoor exposure) contributed the largest share of total DALYs in 2021 [2]. Modern quantitative risk assessment methods are crucial in transferring fundamental scientific knowledge to policymakers, motivating actions to reduce the burden of air pollution, and evaluating the health benefits resulting from interventions to the costs of measures in a benefit analysis.

The last decade of air pollution epidemiology

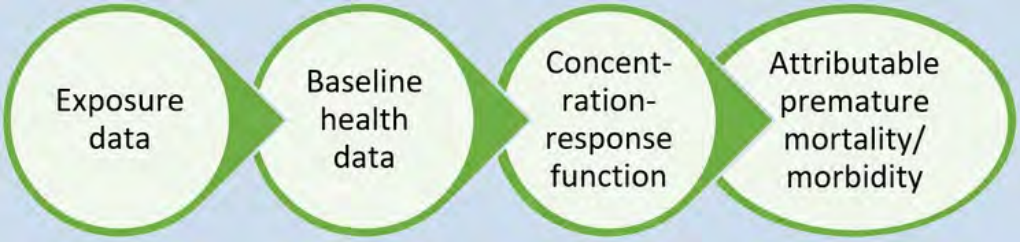
The literature on air pollution and its impact on health has witnessed significant advancements over the past decade that we have been outlined in our recent publication [3]. Firstly, these enhancements have broadened the geographical coverage to encompass both urban and rural areas and offer highly spatially resolved exposure maps, with resolutions down to 0.1 km or less. Secondly, there has been a notable discovery of systemic consequences of air pollution leading to additional adverse health outcomes. While respiratory and cardiovascular conditions have traditionally been linked to air pollution, recent studies suggest potential associations with neurological conditions (such as Alzheimer's disease), diabetes, various forms of cancer, neurobehavioral development disorders in children, mental disorders, and perinatal health [4]. Thirdly, several studies based on “administrative cohorts” have been published. Those cohorts have several advantages over “traditional cohorts” in investigating air pollution risks, namely their size, including millions of people, their representativeness of the general population, including different demographic and socioeconomic groups, enhancing the generalizability of findings, data collected over many years that allow for an extended follow-up.

In recent years, three large-scale studies have been conducted to investigate the health effects of low-level air pollution exposure (below the ambient air quality limit values) in Canada, the United States, and Europe [5-7]. The insights derived from these "low-level studies" have informed the WHO, and played a crucial role in shaping recent regulations in both the USA and Europe. Notably, the US Environmental Protection Agency's decision to lower the National Ambient Air Quality Standards (NAAQS) for fine particulate matter air pollution ($PM_{2.5}$) in urban background areas from 12 to 9 µg/m³ in 2024 [8] and the European Commission's decision to set the annual standard limit of $PM_{2.5}$ from 25 µg/m³ to 10 µg/m³ in 2030 [9] are outcomes directly influenced by the information provided by these studies.

Quantitative risk assessment

Quantitative risk assessment is crucial in formulating air pollution guidelines and regulatory criteria to safeguard human health. Environmental policymakers rely heavily on epidemiological evidence to establish regulatory goals that effectively mitigate the adverse health effects of air pollutants, such as NO_2 and $PM_{2.5}$. Recent initiatives by regulatory bodies like the US Environmental Protection Agency and the European Union have underscored the significance of quantitative risk assessment in shaping appropriate regulatory measures.

Health Impact Assessment (HIA) is a decision-support methodology designed to investigate how a proposed program, project, policy, or intervention plan may impact health and well-being, and inform decision-makers of these potential outcomes before the decision is made [10]. It uses exposure data (either measured or modelled pollutant concentrations), baseline health data (e.g. mortality/morbidity data from registers), and concentration-response functions (CRFs) from epidemiological studies to quantify the health effects in terms of premature deaths and/or morbidity impacts.



The choice of suitable CRFs poses several challenges in relation to three distinct aspects: the degree of causality between the pollutant and the outcome (causal, likely to be causal, suggestive to be causal, inadequate), the presence of systematic reviews that may be considered of good quality, and finally, the confidence in the CRF itself given its characteristics (e.g. extent of the database, precision, heterogenicity of the effect estimates, etc). To address earlier concerns regarding proposing a formal approach to the quantitative handling of the level of evidence regarding each exposure-health outcome pair [11], we have proposed the framework illustrated in Figure 1.

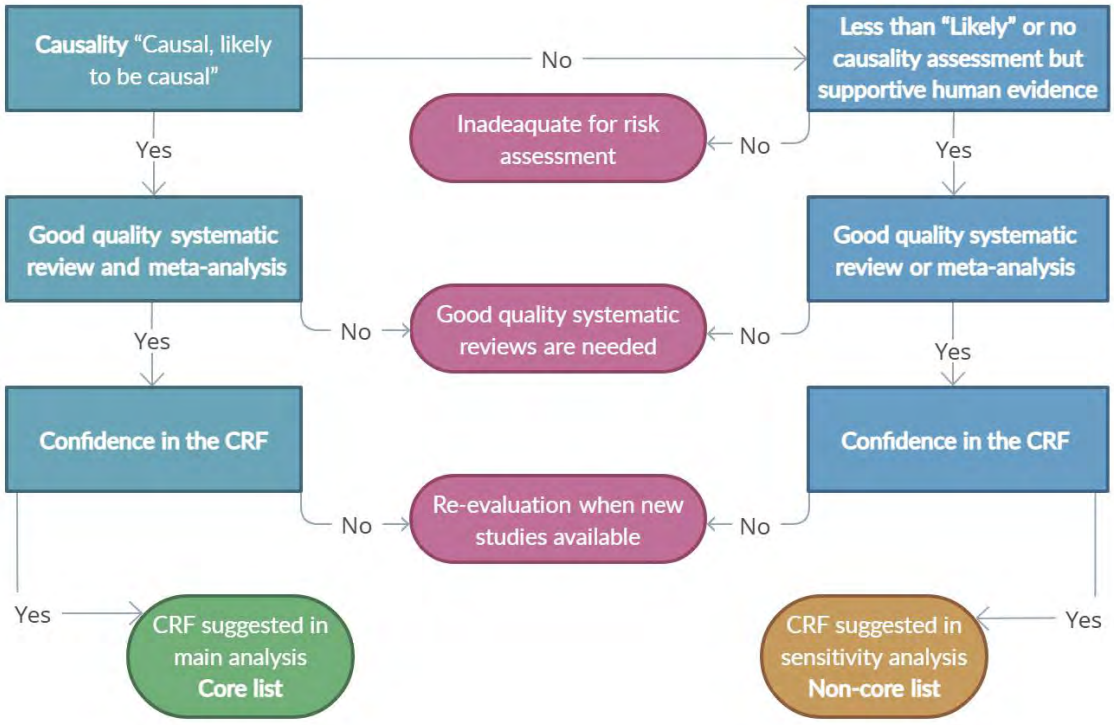


Figure 1. *Steps in choosing the appropriate concentration-response function (CRF).*

This approach has been followed to derive CRFs for morbidity outcomes in relation to $PM_{2.5}$ and NO_2, as briefly indicated in the table below.

Table 1. *Concentration-response functions for the incidence of various diseases and long-term exposure to $PM_{2.5}$ and NO_2. List A is core, and List B+ is non-core for sensitivity analysis only [12].*

Outcome (incidence)	List	RR (95% CI) per 10 µg/m³
Long-term exposure to $PM_{2.5}$		
Asthma in children	A	1.34 (1.10, 1.63)
COPD	A	1.18 (1.13, 1.23)
IHD events	A	1.13 (1.05, 1.22)
Stroke	A	1.16 (1.12, 1.20)
Hypertension	A	1.17 (1.05, 1.30)
Diabetes (type 2)	B+	1.10 (1.03, 1.18)
Dementia	B+	1.46 (1.20, 1.78)
ASD	B+	1.66 (1.23, 2.25)
Lung cancer	A	1.16 (1.10, 1.23)
Long-term exposure to NO_2		
Asthma in children	A	1.10 (1.05, 1.18)
Asthma in adults	A	1.10 (1.01, 1.21)
ALRI in children	A	1.09 (1.03, 1.16)

Additional factors in HIA

Additional factors relevant to the implementation of the HIA have been identified.

- **Global versus regional CRF**

The choice between using a global (based on the ensemble of studies from across the world) or regional/local CRF (based on studies in a particular continent, nation, or location) to estimate the effects of air pollution will depend on several factors, including the nature of the study, the specific context, and the intended application. As the global CRFs are derived from pooled data across multiple regions and populations, they provide a broad understanding of the overall relationship. However, the local CRF could be used in a sensitivity analysis to show the particularities of the impact under specific conditions (e.g. low level of air pollution, a specific population subgroup).

- **Shape of the CRF**

The shape of the CRF should also be carefully considered in potential sensitivity analyses. Usually, the linear exposure-response between $PM_{2.5}$ and natural mortality & morbidity have been applied. However, recent studies have indicated a supralinear relationship with stronger effects per unit mass at lower concentration levels. When applying estimates from the supralinear exposure-response functions, the resulting disease burden in Europe would be greater for $PM_{2.5}$ and for NO_2 [13].

- **Applicability of the CRF**

It is usually assumed that the CRF found in epidemiology studies conducted in a few countries apply globally despite several exposure, particles composition, and population differences. The ranges of concentration levels for the applicability of the CRF should be restricted to the levels that have been observed in the original epidemiological studies providing the CRF.

- **Risk of double counting**

Understanding the interplay between various CRFs and their respective health outcomes is necessary to ensure accurate risk assessments. A typical situation leading to double counting is when different pollutants cause the same health outcome (as in the well-known case of $PM_{2.5}$ and NO_2). In such a case, the results of multipollutant models could be used as indicated in the COMEAP report on the effects of NO_2 on mortality [14]. Potential double counting could occur when one outcome is a risk factor for another outcome (Figure 2).

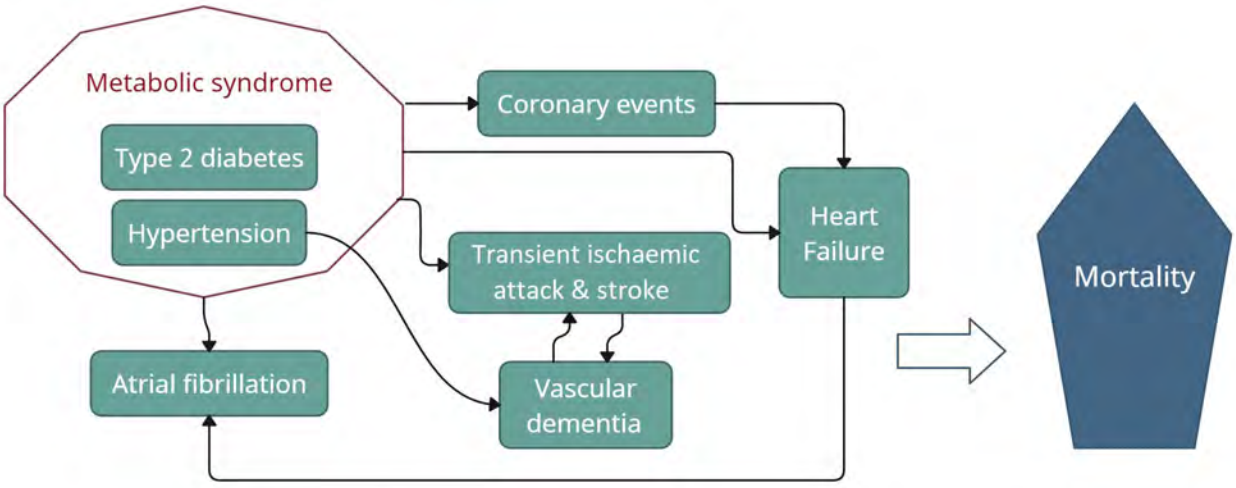


Figure 2. *Schematic representation of the links between various air pollution-related outcomes.*

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