Quantifying the health impacts of outdoor air pollution: useful estimations for public health action

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According to WHO,1 health impact assessment (HIA) is

A combination of procedures, methods and tools used to evaluate the potential health effects of a policy, programme or project. Using qualitative, quantitative and participatory techniques, HIA aims to produce recommendations that will help decision makers and other stakeholders make choices about alternatives and improvements to prevent disease/injury, and to actively promote health.

The typical procedural steps in HIA include screening, scoping, assessment of health effects, recommending alternatives and mitigations, reporting and monitoring.2 Each step helps predict or foresee potential effects of policy decisions on a population's health. In specific, quantitative risk assessment, an essential component of HIA, provides estimations of the potential health risks or impacts associated with a variety of hazards.3,5

Since the beginning of HIA development, environmental risk factors have been one of the targeted groups of health determinants—besides the social ones. In this commentary, we would like to discuss some methodological aspects and potential uses of the quantitative estimation of the health impact of outdoor air pollution.

In recent years, this hazard has been one of the environmental factors most frequently quantified using HIA because the toxicological and epidemiological evidence supports a strong causal relationship between exposure and health effects.3 Since the individual risk from air pollution is relatively low while the whole population is exposed, HIA provides a clearer view of its impact on public health.5

The classical HIA method, derived from the WHO-HIA general method,9 quantifies the impact on health of short-term and long-term exposures to air pollution using four successive steps: (1) selecting concentration-response functions (ie, relative risks, (RRs)) from epidemiological studies; (2) estimating the distribution of exposure levels in the population studied; (3) collecting data on the prevalence or incidence of selected health indicators and, finally, (4) calculating the number of attributable cases.

In the following, we discuss the different ways of formulating these HIAs and their implications for health and economic valuation. We then briefly review the uncertainties in HIA calculations and discuss the usefulness for different groups of quantitative estimations from HIAs. Lastly, we address recent advances and future use of the quantitative component of HIAs. In boxes, we illustrate how HIA quantification was performed in two projects on air pollution and health in Europe.

TWO WAYS OF FORMULATING THE QUANTITATIVE COMPONENT OF HIAS

There are two different ways of formulating the quantification of health impacts by HIAs.4 The predictive approach assesses the future consequences for health of public policies implemented today or in a given time frame. It requires making assumptions about the future trends in demographics and health status, about the time required to achieve the decrease in pollutant levels and about the lag between the change in pollutant levels and the potential impact on health (positive or negative effects on health).10

This was the approach used in the Clean Air for Europe cost–benefit analysis11 and in the first part of the Committee on the Medical Effects of Air Pollutants (COMEAP) report on the mortality effects of long-term exposure to particulate air pollution in the UK.12

This predictive approach is related to, but different from, the counterfactual approach.13 The latter compares the current health status of the population studied with what might have been if pollution levels had been reduced and the time required for the onset of health effects had elapsed.

This counterfactual approach estimates the actual burden of air pollution on health and derives the potential health benefits of a hypothetical improvement in air quality, assuming that public policies implemented to improve air quality can reduce this burden. This approach builds on the epidemiological concept of an attributable fraction defined at the population level as the proportion of disease cases that can be attributed to a given exposure level and is closely related with the concept of burden of disease used by WHO.14

This was the approach used by the Apheis project,15-17 by the Aphekom project,18 in the second part of the COMEAP report on the impact of particulate matter on mortality in the UK,12 in Italy,19 as well as in emerging countries like China.20

The counterfactual approach is particularly useful to provide a picture of the health burden of air pollution and to encourage the planning of actions to reduce air pollution levels. In addition, stakeholders are likely to be interested in the benefits associated with specific concrete policies that they plan to develop, in which case the predictive approach could be advantageously used.

Although less used, assessments of broader policies, such as qualitative and quantitative analysis of the risks and benefits associated with alternative modes of transportation, are also valued by the stakeholders.

ECONOMIC VALUATION

By allowing the expression of multidimensional health impacts in a single dimension (money), economic valuation makes comparisons across public policies easier. For mortality effects, the standard valuation procedure generally consists in using monetary values derived from stated preference surveys, in which people express trade-offs between risk of death and money. These are what economists call the Value of a Statistical Life (for the number of postponed deaths) and the Value of a Life Year (for gains in life expectancy).

For morbidity effects, market-derived values are generally used for direct effects (using the cost of illness method) and indirect effects (using the loss of productivity work). Intangible effects are sometimes accounted for, and this is done through preference-derived values.

Both the predictive and the counterfactual approaches can be used for economic valuation. However, interpretation of the economic findings varies depending on...
the approach used and the nature of the health effects that are taken into account. Economic valuation should take into account the time lag between the implementation of a policy and the resulting changes in air pollution and in associated health benefits. This lag is not a concern for short-term health impacts, which occur a few days after exposure. However, when assessing long-term health effects, occurring after several years of exposure, the time lag before the achievement of full health benefits and the additional impact of discounting future monetary benefits—which are partial until full achievement—are not taken into account in the counterfactual approach. This results in an overestimation of benefits that may exceed two orders of magnitude.21

The predictive approach is, therefore, more appropriate for cost–benefit analysis when considering long-term health effects: the flow of discounted future benefits can be properly compared with the costs of the policy that generates these benefits. Within its limits, the counterfactual approach may, however, provide clear, simple and informative enough results to give an idea of the current magnitude of the public health problem.

The Aphekom project (see box 1) has applied these economic approaches to a traditional HIA quantification by using the best recommended values, including country-specific values for morbidity effects.20 In addition, a non-standard valuation was applied to an innovative quantitative HIA approach that assessed the long-term impact of air pollution exposure on the development of chronic diseases. Based on a review of 150 studies, it computed an average annual disease cost that is a mixture of various costs depending on age, severity of the disease and the probability of occurrence of each disease-related health expenditure.22

**UNCERTAINTIES IN CALCULATIONS**

It is worth remembering that, like other research methods, calculations for risk assessment in HIAs suffer from inherent uncertainties. These relate to the choice of concentration-response functions, to the way exposure is assessed, to the health data available, to the health impact methods used, to the economic values of health outcomes and the discount rate chosen, and to the way findings are interpreted.1 9 15 23 Some of the uncertainties can be quantified,6 24 and sensitivity analysis can be used to explore them.

Uncertainties in HIA quantification are not extensively discussed here, as much literature exists on this topic.6 25 26 We would rather like to underline three important points. First, it is important to acknowledge the uncertainties; state clearly the hypotheses and limits that underlie our research choices; and propose a range of possible scenarios, indicators and outcomes that provide a broad picture of the possible impacts. Second, it should be made clear to stakeholders which uncertainties could be reduced with concrete actions. These actions could include improving the monitoring of air quality in cities (pollutants monitored, locations of the stations, measurement techniques) or encouraging epidemiological studies that produce more specific concentration–response functions. Third, not doing a quantitative HIA because of its uncertainties would give the impression of an absence of impact. That impression would be worse than the uncertain estimates produced by HIA calculations.

**USEFULNESS OF QUANTITATIVE ESTIMATIONS FROM HIAS**

Quantitative estimations of the health effects of air pollution are valuable to non-epidemiologists, as they give an eloquent picture of the public health burden of air pollution. Indeed, epidemiological findings of the health effect estimates of air pollution, such as RRs or ORs, are difficult to interpret by non-specialists, especially because the risks are low compared with other risks and the effects are not easily identifiable in a multicausal setting.

Quantitative information from HIAs is valuable to stakeholders, as it provides a global picture of the collective burden of the risks associated with air pollution, knowing that the results are based on solid scientific grounds and robust methods. HIA quantification has another advantage for policy making: it helps frame the question of air pollution by using time frames and geographical units relevant to local policy making. And by using concentration–response functions from epidemiological studies often conducted in a small number of cities and sometimes in other countries. For instance, in France, the epidemiological analysis of the short-term impacts of air pollution was restricted to nine cities, but quantitative estimations from HIAs were used to provide information on the impacts of air pollution in 45 cities.

Quantification of HIAs also provides information to evaluate the effectiveness of different scenarios for reducing air pollution levels at the European level, where legislation on air quality is set. Indeed, risk assessment in HIAs using a common protocol provides comparable findings across Europe, as illustrated in box 2. Comparable assessments are also valuable in providing citizens with similar and relevant levels of information.

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**Box 1 Aphekom: enriching health impact assessment findings**

Using standard quantitative methods of HIA, Aphekom (Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe) has showed that a decrease to WHO’s annual air quality guideline on PM2.5 particles (10 μg/m3) in 25 large European cities could add up to 22 months of life expectancy for persons 30 years of age, depending on the city and its average level of PM2.5. In addition, the monetary health benefits from complying with WHO guidelines would total some €31.5 billion annually, including savings on health expenditures, absenteeism and intangible costs such as wellbeing, life expectancy and quality of life.

Using the same HIA methods, Aphekom’s analysis of the effects of European Union (EU) legislation to reduce the sulfur content of fuels has showed not only a marked, sustained reduction in ambient SO2 levels in 20 cities but also the resulting prevention of some 2200 premature deaths valued at €192 million.

By applying innovative HIA methods, Aphekom has separately determined that the additional long-term impacts on the development of chronic diseases from living near busy roads substantially increase the burden of disease attributable to air pollution in Europe. Specifically, in 10 European cities, Aphekom has estimated that living near busy roads could be responsible for 15% of asthma in children and possibly for similar or higher percentages of other common chronic diseases in adults 65 years and over, such as coronary heart disease and chronic obstructive pulmonary disease. In the cities studied, for children and adults 65 years and over, the economic burden likely totals some €300 million every year.

Aphekom’s work is particularly relevant now when various EU member states have exceeded mandated limit values on particles since 2005 and when EU and national agendas are being prepared for implementing existing regulations on air pollution and for revising current EU legislation in 2013.31
Quantitative estimations from HIAs are a powerful means of illustrating the health impacts of air pollution. Together with other information from HIAs, they inform not only policy makers but also health professionals, NGOs and the public on the role of air pollution in the development of chronic pathologies and acute exacerbations, and how they interact. Providing the public with informative messages is key, since reducing air pollution is not achievable without significant changes, including active participation by the public, for instance, in changing transportation modes. Also, specific information on the health risks for vulnerable people with underlying health conditions is valuable to promote appropriate behaviours during peaks of air pollution. NGOs can use HIA findings to ask for better protection of specific populations or neighbourhoods. For instance, HIA findings could help them question the location of schools near major traffic roads. And health professionals can use HIA findings to inform their patients on the risks related to air pollution and how to reduce their exposure.

HIA quantification can also be used to ensure that actions taken to reduce the health impacts of air pollution at one place do not increase the impacts at another location.

HIA quantification would also be highly valuable to move air pollution up the political agenda, especially in developing countries. This quantification poses several problems due to the lack of air pollution data needed to characterise exposure and the lack of local concentration-response functions. However, these problems are not unsolvable as shown by the recent WHO Global Burden of Disease Study 2010 reporting 1 850 428 (1 614 010–2 082 474) deaths and 46 732 (41 393–52 602) disability-adjusted life-years (1000s) attributable in 2010 to ambient particulate matter pollution worldwide.27

In addition, there is a duty for HIA practitioners and researchers from developed countries to share their methods and quantify the health burden created by the displacement of pollution sources to developing countries. HIA computations can be easily performed with tools freely available on the Internet. Therefore, the spreading use of HIAs, including risk assessment in public health, holds great promise. However, potential misuse of the information provided by HIAs needs to be reduced through adequate training of public health professionals in HIA quantification.

**RECENT ADVANCES AND FUTURE OF THE QUANTITATIVE COMPONENT OF HIAS**

Various projects have recently aimed at enriching the quantification methods for HIAs. Some projects have developed online tools for integrated assessments,6 whereas others have assessed the benefits of cycling on health and the environment by increasing exercise and reducing air pollution and CO2 emissions.28

Coupling climate and air quality model outcomes with HIA has been used to assess the benefits to air quality of policies intended to mitigate climate change. Here, quantifying the effects of air pollution illustrates the short-term and medium-term local benefits associated with the longer-term and more global benefits of tackling climate change.29

The Aphekom project aimed at making HIAs more informative to those who need to know at both the city and European levels. It did so by first providing a global picture of the potential benefits of improving air quality in 25 European cities. It then used the epidemiological evidence on the role of air pollution in the development of chronic diseases10 to assess the health impacts of living close to traffic. Lastly, it evaluated the health and economic benefits of European Union regulations implemented in the 1990s to reduce sulfur content in fuel. For these purposes, as illustrated in box 1, Aphekom used the counterfactual approach and expressed findings in terms of gain in life expectancy, number of postponed deaths and economic benefits.31

To make the quantification of HIAs more useful for stakeholders, HIAs can be enriched by providing a spatial vision of the burden of air pollution, with infarct contrasts of exposure. Doing so can help take into account parameters describing the social and health inequalities that can increase the burden of air pollution on the most vulnerable populations.

Vulnerability depends on individual sensitivity to air pollution (eg, age, underlying health conditions), on the exposure to air pollution (eg, proximity to traffic), on the ability to reduce exposure (eg, using a bicycle or public transportation) and/or the adverse effects of this pollution (eg, through access to healthcare).

It is possible to take into account gradients of exposure within cities (epidemiological findings suggest that intraurban exposure gradients may be associated with larger health effects than reported in interurban studies24). But more localised epidemiological data are needed to provide RRs for different characteristics of a specific population. For instance, the American Cohort Study found different RRs of long-term mortality for different educational levels. However, the validity of transposing such risks to other countries is disputable.

Other authors33 suggest using an equity index to provide a quantitative measure of inequality in the distribution of the health burden of air pollution. Their methods are based on assumptions on inequalities and social concerns and should be developed in close collaboration with social scientists.

We thus believe it is now time for HIAs to better address the issue of susceptibility and vulnerability and help achieve environmental justice and health equity.34 35 Such information would help policy makers take into account ethics and social justice in their decisions.

**CONCLUSION**

In the broad context of HIAs, the quantification of the health impacts of air pollution has proven to be a useful decision-support tool by providing objective estimates of these impacts. It has also helped facilitate...
preventive action by integrating different risk factors and sources. HIA has become an essential component of risk governance now that important methodological advances in qualitative and quantitative techniques are being made. As such, HIA can help cross the last mile to protecting public health more effectively.

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