METHODOLOGICAL APPROACH IN AIR POLLUTION HEALTH EFFECTS STUDIES

Morteza A. Khafaie¹,²*, Ajay Ojha³, Sundeep S. Salvi⁴, Chittaranjan S. Yajnik⁵

¹ Environmental Technologies Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
² Department of Public Health, Faculty of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
³ Technogreen Environmental Solutions, Pune, Maharashtra, India
⁴ Chest Research Foundation (CRF), Pune, Maharashtra, India
⁵ King Edward Memorial Hospital Research Center, Pune, Maharashtra, India

ABSTRACT:
Number of scientific studies linking possible effects of air pollution on health are increasing. However, the disparity in the effect estimated from different studies and recognizing important determinants of these diversity are essential. We have explained the types and sources of air pollution, and the common terms in epidemiological studies of air pollution. Then we reviewed the study design and critically evaluated methodological approach to estimate association between air pollution and health with deep insight into dispersion model. The quality of exposure measurement is critical determinant in an environmental epidemiology study. However, the available exposure data and feasible methods for its collection are often the determinant of the design to be used. Beside vast development in this field, epidemiological approaches to find out the risks of exposure to air pollutants is still challenging.

ARTICLE INFORMATION
Article Chronology:
Received 18 June 2016
Revised 2 July 2016
Accepted 21 August 2016
Published 31 August 2016

Keywords:
Air pollution; health effect; exposure assessment; study design

CORRESPONDING AUTHOR:
khafaie-m@ajums.ac.ir
Tel: (+98 61) 33362536
Fax: (+98 61) 33361544

REVIEW

Ambient air pollution, common term

Air pollution
Air pollution is the presence of substances in the atmosphere in concentrations high enough to cause adverse effects on man, animal, vegetation or materials. The substances may be a mixture of solid and liquid particles (Particulate Matter), gases (such as O₃, NOₓ, NO₂, SO₂) and biological aerosols or agents in atmosphere that can disperse, transport, and may transform from time to time in the other forms [1].

Emission inventory
An emissions inventory is assessment of the quantity of pollutants discharged into the atmosphere in a certain geographical area and within a specified time span. Characterizing the emissions inventory usually depends on the activities that cause emissions, the chemical or physical identity of pollutants, topographic area covered, time and methodology are used to estimate the emission. Usually environmental policy makers use emissions inventories to track progress towards emission reduction targets, development control
strategies, and as the inputs in air quality models. The inventory uses two classes of data, point sources (source-specific data) and area sources or category-specific data in the most refined spatial level (for non-point and mobile sources) [2]. Emission inventory needs information on type and location for each emission point, as well as several release features (for example mass emissions, height and diameter of stack, temperature, vertical emission speed) in annual or hourly periods [3]. Mobile sources such as traffic emissions are a subcategory of the area source. Traffic emissions are usually estimated by traffic counts using standard emissions factors for different types of vehicles, speeds, and gradients of the road network [4].

**Human exposure**

Any contact (that is internal or external) to a particular environmental agent is called total exposure. Exposure is defined as the concentration or sum of a particular environmental agent that reaches the target population, organism, organ tissue or cell overtime and space [5]. The quality of exposure measurement is critical in the validity of environmental epidemiology study.

**Dose**

The term is defined as amount of pollution that reaches the target tissue [6]. Most epidemiological studies currently employ exposure methods to find the linkages between adverse health effects and air pollutants. However, this method cannot reflect the mass or concentration of a pollutant that is inhaled by an individual. Dose can also be stated as the total amount of pollutants that was taken, or absorbed by an organism.

**Exposure modeling**

According to the World Health Organization (WHO), exposure modeling is a logical or empirical set up which allows estimation of individual or population exposure parameters from available input data [7].

**Methodological approach in air pollution health effect studies**

**Study design in air pollution health effect studies**

Researches on air pollution and health related issues using all the standard study designs comprise both experimental and nonexperimental studies. When epidemiological experiments do not meet minimal standards of feasibility or is unethical, epidemiologists design observational studies. Here we explain the five main types of nonexperimental epidemiologic studies:

1) Cross-sectional studies are used to study the association between long-term exposure to air pollution and prevalence of chronic symptoms and disease. In a cross-sectional study, exposure to air pollution and health status of population are determined at the same time. However, such studies cannot find out the time-based relationship between exposure and disease.

2) In the case–control study, a particular health issue is recognized in a group of people, then people are classified depending on the exposure of air pollution. A match sample of same population who were free of the disease at the time event is also selected as control. An estimate of the relative risk of event that is associated with exposure to air pollution, odds ratio, can then be calculated.

3) Case–crossover studies, are types of case-control studies and were introduced in the early 1990s [8] to estimate the association between short-term exposure to a particular pollutant and change in a rare acute-onset disease. This design has been commonly applied to air pollution health effect studies. For each person, exposure to air pollution is a period just preceding the time of events (the case period) and other periods during which health event did not occur (control periods). Thus for matched case–control data relative risk can be estimated.

4) Cohort studies used to estimate long-term health effects of exposure of air pollution on mortality and morbidity because of chronic disease. In a cohort study, people who are free of
disease are followed over an extended period of time. Individual are classified according to their exposure of air pollution, often determined based on place of residence. The rates of health events that occur among the exposed and unexposed are compared and, normally presented as a ratio of rates, or relative risk.

5) Ecological studies also called the aggregate level study. Often the exposure are measured in population level and is not collected on individual. This design may be the best or only way to find out the relationship between average rates of disease or death and average exposure of air pollution in the population. Common ecological approaches include investigation of regional disparity through mapping, time-trend change and either variance in time trends across regions over the time. Since relative risk of disease obtained through ecological studies is based on data about population, there is more difficult to interpret in comparison with those from case–control or cohort studies.

There are four research approaches in air pollution studies [9]:

1) Episodes study like 1930 Meuse Valley episode in Belgium [10], Donora 1948 [11] and the London fog of December 1952 [12], and other growing number of studies [13]. This before and after design comparing within community is ideal for examining short time (a few hours to a few weeks or months) affect of air pollution, where migration is not wide-ranging, and when a clear line isolate unexposed from exposed time period.

2) Some studies compare health-related problems in populations with low and high-level exposure to pollutants.

3) Community time series analysis that explores how changes in air pollution levels influence the morbidity. This approach reduces the affect of individual levels confounding since these remain constant over short period of time. Also this approach is useful when the population in the study area is unclear. For example for hospital-based studies in densely populated areas where not all hospitals can be included, counts of admission might be comparative for high versus low-population days.

4) Studies in which individual-level data are integrated with community or individual level exposure. Such studies provide further understanding about mechanism of effect, susceptibility, and more specific indication of the harmful pollution. For example in Wellcome Trust Genetic (WellGen) study of extensive phenotypic database on type 2 diabetic patients allowed us to examine the effect of exposure to ambient air pollutants which are related to chronic respiratory problem [14], glycemic levels [15] and C-reactive protein [16].

**Air pollution exposure assessment methods in epidemiological studies**

Exposure is the contact of pollutants and targets who are either individuals or a population [17]. Human exposure assessments can be considered as a science to define how an individual or a population (who) exposes to a contaminant (what), including quantification of the amount (how much) of exposure across space (where) and time (how long). It is an interdisciplinary science that involves environmental sciences, toxicology, and environmental epidemiology. Exposure assessment links the pollution source and health outcome (see Fig.1).

*Adopted from [18, 19]*

Individual or population exposures of air pollutants, can be estimated either qualitatively (for example questionnaires) or quantitatively (e.g. air pollutants concentration), depending on the purpose of exposure assessment and the availability of relevant data. In exposure studies, measurements of pollutant concentrations are often come with questionnaire surveys. Qualitative exposure assessment is perhaps the simplest method but it is useful only in studies involving many subjects to avoid bias in design (e.g. questionnaire design).

To quantify the individual exposure, we need to know the concentration of a pollutant in the contact boundary of the body [20]. Therefore, we could take personal exposure measurements di-
Chemical or biological contaminant

Depends on the source strength, but also on transport or transformation processes

Depends on concentration but also on duration

Depends on exposure, but also on contact rate and bioavailability

Depends on the dose, but also on host factors such as age, gender, health conditions

Source

Concentration

Exposure

Dose

Health Effects

Fig. 1. Human health effect of air pollution
Table 1. Critical evaluation of important air pollution exposure assessment methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal monitoring</td>
<td>- Direct measurement of exposure during the surveying period</td>
<td>- Expensive and time-consuming for large study populations</td>
</tr>
<tr>
<td></td>
<td>- Measure internal dose of a pollutant in human body</td>
<td>- Hard to different between exposure pathway and chemicals</td>
</tr>
<tr>
<td></td>
<td>- High reliability to confirm result produced from other exposure assessment methods</td>
<td>- The role of biomarker was limited by confounding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- High cost and time-consuming</td>
</tr>
<tr>
<td>Biological</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualitative</td>
<td>- Useful in study large number of human subject</td>
<td>- Accuracy can biased design and subjective responses</td>
</tr>
<tr>
<td></td>
<td>- Can improve the quality of epidemiological analysis</td>
<td></td>
</tr>
<tr>
<td>Urban monitoring network</td>
<td>- Useful for both cross-sectional and cohort study showing community exposure</td>
<td>- Need proper surrogates for exposure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Biased by time activity and other source of exposure such as indoor</td>
</tr>
<tr>
<td>Proximity</td>
<td>-Simple and proper for exposure research for unclear etiology of health outcome</td>
<td>- Exposure misclassification and biased risk estimates</td>
</tr>
<tr>
<td>Interpolation (e.g. Kriging, splines, Inverse Distance Weighting (IDW) and Thiessen triangulation): produce estimates of the concentration of pollutant at sites other than locating monitoring stations</td>
<td>-Use of real pollution measurements in their calculation of exposure estimates</td>
<td>- Do not take terrain or localized patterns into account</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Requires a reasonably dense network of sampling sites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Proper application usually needs experience with geostatistical models</td>
</tr>
<tr>
<td>Land Use Regression (LUR): predict pollution concentrations at a given site based on surrounding land use and traffic characteristics</td>
<td>-Provide within city variability in pollution concentration</td>
<td>-Care must be taken to correctly select the independent variables and buffer radii for the pollutant (e.g. wider for NO₂ and narrower for estimates of diesel)</td>
</tr>
<tr>
<td>Dispersion: use of data on emissions, meteorological conditions, and topography in estimating spatial exposure estimates of air pollution concentrations</td>
<td>-Provide more complete spatial and temporal variation of air pollutant concentration</td>
<td>-Costly input data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Need cross approval with monitoring data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Provide high resolution analysis of patterns in health outcomes and environmental factors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Provide environmental exposure concentration but not internal dose inhaled by individual</td>
</tr>
</tbody>
</table>
through the wind is a complex process. An atmospheric dispersion model is used to mathematically simulate how air pollutants transport, disperse and transform in the atmosphere [25]. The process of air pollution modeling contains four stages (data input, processing, drawing concentrations, and analysis). Models can be set to estimate concentrations of pollutants for either a short-term (3 min) period or for a longer term (years). The most common and easiest mathematical estimate of plume behavior is the Gaussian plume equations [26]. They allow us to combine GIS in dispersion models to analyze a mix of information and form more reasonable scenarios. There are several competing needs for designing an air pollution model. The model must capture the essential physics of the dispersion and provide sound and repeatable estimates of downwind concentrations. This needs detailed knowledge of source features, topography and meteorology, but it is also desirable to keep these requirements to a minimum. Simplicity is an important asset in any model. To test the robustness of a model, we need to evaluate the accuracy of each stage. In other words, the quality of input data will directly affect the quality of the output. Standard statistical techniques have been settled for expressing the doubt and variability of the predicted results when comparing them to measured concentrations [27].

In choosing an air dispersion model, several types of models are available, with gradually increasing levels of mathematical complexity, input data requirements and user ability.

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid: personal or regional exposure plus one of models above</td>
<td>-Provide more accurate exposure -Can use existing methods and do not have to struggle on new methods -Measurement validation</td>
<td>-Assessment cost and results are partly influenced by pollution under study (that is passive NO₂ inexpensive vs. real time particle monitor vs. expensive) and scale affect respectively</td>
</tr>
</tbody>
</table>

CONCLUSIONS

Air pollution exposure assessment and exposure misclassification remain as the most important source of bias in health effect studies. In addition diversity of findings may be related to individual and environmental differences. The evidence for long-term air pollution health effects is mostly based on cross-sectional comparisons.

FINANCIAL SUPPORTS

The study was supported by the Welcome Trust (London, U.K.).

COMPETING INTERESTS

No potential conflicts of interest relevant to this article were reported.

ACKNOWLEDGEMENT

This review is part of PhD thesis report from Interdisciplinary School of Health Sciences, University of Pune. M.A.K. discussed, and edited the manuscript A.O., S.S.S. and C.S.Y edited the manuscript. The authors acknowledge the contributions of K. Kumaran (King Edward Memorial Hospital) and Gayathri Vaidyanathan (Environment and Energy Publishing’s Energywire- Washington DC) in improving the language.

ETHICAL CONSIDERATIONS

“Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission,
redundancy, etc) have been observed by the authors.”

REFERENCES


[26] Bellander T, Berglund N, Gustavsson P, Jonson T, Ny-