4. **Methods for estimating the environmental burden of disease**

4.1 **General method**

Although the basic approach for estimating the EBD is common to every environmental risk factor, the calculations will vary according to the information available in the country, and the form in which this information is held. Specific information needed for the EBD calculations is laid out in each section, but information on the local epidemiology of disease will also be needed.

An assessment of the EBD requires the following data for each risk factor:

i. the distribution of risk factor exposure within the study population;
ii. the exposure-response relationship for the risk factor;
iii. the DALYs lost to disease for the risk factor of interest (or other epidemiological information, such as mortality rates or disease incidence, if DALYs are not available).

The distribution of the risk factor exposure in the population (i), and the exposure-response information (ii), are combined into an impact fraction, which is applied to the disease estimates (iii). The impact fraction is the percentage of the population risk that can be attributed to hazardous exposures or risky behaviours, multiple levels of exposure, or to incomplete elimination of exposure. When exposure is measured in terms of increasing levels of pollutants, the approach is called an exposure-based approach (Figure 4.1). For example, exposure to outdoor air pollution is commonly reported as continuous or categorical increases in ambient air pollution.

If it is not possible to specify a continuous numerical relationship between the proximal cause of disease and the disease outcomes, for example because of competing relationships between exposures, an alternative approach is to select characteristic exposure scenarios (Figure 4.2). In this way, the study population can be divided into defined exposure scenarios, each of which has a corresponding specific health risk. For example, in the area of water, sanitation and hygiene there are often no direct measurements of drinking-water quality for the entire population of a country. Therefore, exposure scenarios are defined on the basis of more distal causes, such as access to improved water supply and improved sanitation (Prüss-Üstün et al., 2003).
**Figure 4.1** Calculating the EBD using an exposure-based approach

1. Exposure distribution in the population (i)
2. Alternative exposure distribution
3. Exposure-response relationship (ii)
4. Impact fraction
5. Estimation of the attributable burden
6. Disease burden estimates for each disease (iii)

*a* The Roman numerals in parentheses refer to the EBD requirements listed above.

**Figure 4.2** Calculating the EBD using a scenario-based approach

1. Definition of exposure scenarios
2. Categorize the population into exposure scenarios (i)
3. Relative risk per exposure scenario (ii)
4. Impact fraction
5. Estimation of attributable burden
6. Disease burden estimates per disease (iii)

*a* The Roman numerals in parentheses refer to the EBD requirements listed above.
For the exposure assessment (i, above), the following steps are generally followed for each risk factor:

**Step 1** Outline the distal and proximal causes of the disease and their interactions (the causal web) as a framework for assessment.

**Step 2** Choose an indicator to assess exposure. The choice of exposure indicator will be determined by the metric used to assess the exposure-risk relationship.

**Step 3** Define the levels of exposure, and the distribution of the population among the exposure levels, including the unexposed level. Exposure can also be assessed as a continuous variable.

A graphical outline of distal and proximal causes (a causal web) provides a framework for selecting exposure indicators and for displaying the corresponding exposure-risk relationships. An example of the interrelated causes for the transmission of faecal-oral diseases is outlined in Figure 4.3. In this example, the risk of transmission of faecal-oral pathogens in the study population could be assessed by using an indicator that measured access to a water source or sanitation facility. The access, or lack of access, to improved water or sanitation facilities, then define scenarios and the population is distributed into the scenarios. In this way, the exposure distribution is rather simple, and can be summarized as percentages of the population in each scenario. A quantitative example of this approach for calculating the attributable BoD for diarrhoeal disease is outlined in Box 4.1.

The exposure-response relationship (step 2 above) is usually derived from a comprehensive review of the epidemiological literature. If there are good reasons to think that generalized results from other populations cannot be applied directly to the local setting, then local information may be used instead (e.g. if some feature of the local population, such as level of malnutrition, means that the people suffer unusually severe effects from any given level of exposure to the risk factor). Alternatively, schemes exist for combining local studies and global estimates. The type of epidemiological studies that can be used will depend on the parameters needed to assess the EBD of specific risk factors (see the volume in this series on the specific risk factor of interest), and on the quality and size of the study. In any case, an epidemiological study should use an exposure indicator that matches the measure of exposure available for the local population.

Population exposure data (i, above) and exposure-response results (ii, above) are then combined to estimate the population disease burden (iii, above). The calculations can be performed according to one of the methods explained in the following sections. Impact fractions can be applied to NBD estimates to derive the DALYs, or the deaths attributable to the risk factor.
The BoD attributable to a specified change in level of a risk factor can be estimated using the formula for the impact fraction (Last, 2001):

\[
IF = \frac{\sum P_i RR_i - \sum P_i' RR_i}{\sum P_i RR_i}
\]

(Equation 1)

This formula applies to any situation in which a population is distributed into graded levels of exposure. It can be used to estimate the impact of changing the exposure from one distribution to another, for example through a public health intervention. The same formula can also be used to estimate the fraction of the disease burden that is attributable to the risk factor, relative to some alternative or counterfactual level (see below). The counterfactual level could be the minimum disease burden achievable in a given time frame. If the risk factor were to be completely removed, or if exposed populations were to be compared with
unexposed populations, the BoD reduction can be calculated from a simplified form of the above formula:

$$\text{IF} = \frac{\sum P_i \cdot RR_i - 1}{\sum P_i \cdot RR_i} \quad (\text{Equation 2})$$

A generalized potential impact fraction can be calculated for an exposure distributed continuously across the study population (Mathers et al., 2001). However, this approach has not been used to assess environmental risk factors, but rather risks from other areas:

$$\text{IF} = \frac{\int_{x=0}^{m} RR(x)P(x)dx - \int_{x=0}^{m} RR(x)P'(x)dx}{\int_{x=0}^{m} RR(x)P(x)dx} \quad (\text{Equation 3})$$

where:
- $$x$$ = Exposure level.
- $$P(x)$$ = Population distribution of exposure.
- $$P'(x)$$ = Alternative (“counterfactual”) population distribution of exposure.
- $$RR(x)$$ = Relative risk at exposure level $$x$$ compared to the reference level.

To calculate the fraction of disease attributable to a risk factor for any defined population, the total disease burden for the population (in deaths and DALYs) is multiplied by the impact fraction. If there is evidence that the exposure distribution or the relative risks differ between subpopulations (such as by age or gender), then the impact fraction should be calculated separately for each subpopulation:

$$\text{Attributable burden}_{\text{(age, sex)}} = \text{IF} \times \text{total burden}_{\text{(age, sex)}} \quad (\text{Equation 4})$$

If the exposure-response relationships are different for mortality and morbidity, the impact fractions should be calculated separately for YLL and YLD. For example, if the case-fatality rate for diarrhoeal disease caused by exposure to unsafe water, sanitation or hygiene is different from that for the average diarrhoeal disease, then the impact fraction should be different for mortality than for DALYs and incidence. This is due to the fact that the relative risks for diarrhoea incidence and diarrhoea mortality would be different.

An example of how to estimate the disease burden attributable to water, sanitation and hygiene for an entire region (AmrD) is outlined in Box 4.1, and a comparison of this disease burden with other disease burdens is given in Box 4.2.

### 4.2 Alternative or counterfactual exposure

A counterfactual analysis compares current levels of exposure to the exposure that would occur under an alternative, hypothetical scenario. It may be helpful to specify more than one reference scenario. For example, policy-makers may be interested in the health gains that would accrue both from a readily achievable alternative exposure distribution in the population, and from an exposure distribution in the population that would result in the lowest possible disease burden attributable to the risk factor (also called the theoretical minimum exposure).
Box 4.1  Example calculation of the burden of diarrhoeal disease (YLL) attributable to water, sanitation and hygiene\textsuperscript{a}

**Determine the population distribution for the exposure scenarios:**
- Improved water supply and improved sanitation\textsuperscript{b} (Scenario IV\textsuperscript{c}): 68%
- Improved water supply, no improved sanitation (Scenario V\textsuperscript{b}): 7%
- No improved water supply and no basic sanitation (Scenario VI): 25%

In this region, no significant part of the population is in any other scenario.

**Calculate the relative risks associated with the scenarios:**
- The reference group for the risk scenarios is defined as: no transmission of diarrhoeal disease through unsafe water, sanitation and hygiene, but transmission only through other exposures. Also, the relative risks used in this example are global averages (Prüss-Üstün et al., 2003), but they could be made more specific by using region-specific data.
- Scenario IV: RR = 6.9
- Scenario V\textsuperscript{b}: RR = 8.7
- Scenario VI: RR = 11

**Process the data**
Using the formula for the impact fraction, $IF = \frac{\sum P_i RR_i - 1}{\sum P_i RR_i}$ gives:

\[
IF = \frac{(68\% \times 6.9 + 7\% \times 8.7 + 25\% \times 11) - 1}{68\% \times 6.9 + 7\% \times 8.7 + 25\% \times 11} = 87.6\%
\]

**Calculate the disease burden for diarrhoea**
For 2000, the total disease burden of diarrhoea for AmrD was 863 000 DALYs (Mathers et al., 2002). The diarrhoeal disease burden attributable to water, sanitation and hygiene is then 87.6% of this figure, or 756 000 DALYs.

In this particular example, no proportion of the population was unexposed. Had there been an unexposed fraction ($P_i$), this fraction would have been taken into account in the impact fraction formula (with $RR_i = 1$).

\textsuperscript{a} The example is given for the AmrD region which is comprised of Bolivia, Ecuador, Guatemala, Haiti, Nicaragua and Peru.
\textsuperscript{b} Improved water supply and sanitation were defined according to the type of technology (WHO/UNICEF/WSSCC, 2000). Improved water supplies included household connections, public standpipes, boreholes, protected dug wells, and spring or rainwater collection. Improved sanitation included connections to a public sewer or septic system, pour-flush latrines or pit latrines.
\textsuperscript{c} For a definition of the scenarios see Prüss-Üstün et al. (2003).
The counterfactual exposure level may also be an exposure that cannot be avoided, and thus a disease burden that cannot be avoided. For example, although in theory man-made pollution could be reduced, it may never be possible to reduce the natural exposure to pollutants. For exposure to lead, for example, a counterfactual exposure from natural sources could equal the blood lead levels in pre-industrial humans (0.016 μg/dl). In this particular case, such a low exposure probably does not induce a disease burden, but if it did, then the avoidable burden would amount to the total burden caused by lead minus the burden that is unavoidable.

Another way to define the counterfactual exposure is to define it as the level at which no health effects are observed in the population. For example, at blood lead levels as low as 0-1 μg/dl no health effects have yet been shown. Using this definition, the counterfactual exposure is the theoretical minimum exposure.

4.3 Choosing the study population for an EBD assessment

The study population is the population for which the disease burden is calculated. This guide mainly addresses the population of a nation or region of a country. The study population needs to be selected according to the following criteria:

- **Policy relevance.** The study population should be relevant to the policy needs of the country or region. For example, to address the impact of outdoor air pollution on health, the relevant population might be that of a city, or the urban population of a country. For national policy-making, however, the most common choice of population will be that of the entire country.

- **Data availability.** Information about exposures and outcomes may be available only for a subgroup. Outdoor air pollution, for example, may be monitored in some cities, but not in others, and not at all in rural areas. If information is missing, assumptions will need to be made about the exposures if all cities, or the entire national population, are to be included in the assessment. On the other hand, health data may exist for an entire country, but the data may not be subdivided by demographical or geographical

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**Box 4.2** The burden of diarrhoeal disease from poor-quality water, sanitation and hygiene, compared to the burden of other diseases

In 2000, the disease burden in AmrD for diarrhoeal disease associated with poor-quality water, sanitation and hygiene was 756 000 DALYs. For comparison, the burden of several other diseases or risk factors in the region are listed below:

<table>
<thead>
<tr>
<th>Diseases:</th>
<th>DALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIV:</td>
<td>720 000</td>
</tr>
<tr>
<td>All cancers:</td>
<td>883 000</td>
</tr>
<tr>
<td>Nutritional deficiencies:</td>
<td>503 000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk factors:</th>
<th>DALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobacco:</td>
<td>65 000</td>
</tr>
<tr>
<td>Alcohol:</td>
<td>959 000</td>
</tr>
</tbody>
</table>

\* Sources for regional disease burdens: Mathers et al. (2002); WHO (2002a).
variables. In such cases, it may be best to perform an assessment for the whole country only. EBD assessments below national level necessarily assume that a particular disease burden is distributed equally throughout the population. However, this is unlikely to be the case, because exposures are likely to be different throughout the country, for example.

- **Population subgroups.** The impact of a risk factor may be limited to a single population subgroup (e.g. the elderly, children, asthmatics, and those immunosuppressed). Also, data may be available for only one of these groups.

### 4.4 Estimating the EBD when NBD data are available

If a NBD study has already been carried out, the attributable BoD for an environmental risk factor can be obtained simply by multiplying the attributable disease fraction for the risk factor by the total disease burden for the corresponding disease assessed in the NBD study (see Equation 4). NBD studies can be a useful sources of data for EBD assessments, since the former attempt to estimate the disease burden of the major diseases or disease groups at country level (generally, in terms of deaths and DALYs), and the data are sorted by age and gender. However, NBD studies can take months to carry out and involve teams of people with diverse skills. For detailed guidance on how to carry out a NBD study see Mathers et al. (2001). The main result of an NBD consists of a list of the burdens of more than 100 diseases or disease groups, by age group and gender, expressed in deaths and DALYs.

### 4.5 Estimating the EBD from disease-specific national health statistics when NBD data are not available

If a NBD study has not been carried out, it is still possible to estimate the impact fraction for an environmental risk factor. In such cases, national or subnational mortality and morbidity statistics can be used with the method described in Section 4.4. An example of how to calculate the attributable mortality from diarrhoea that is associated with poor water, sanitation and hygiene is outlined in Box 4.3.

---

**Box 4.3**  
**Estimating the mortality in AmrD from diarrhoea attributable to poor water, sanitation and hygiene**

The fraction of diarrhoeal disease attributed to poor water, sanitation and hygiene was estimated to be 87.6% for AmrD (Box 4.1). This fraction can be applied to national or subnational mortality and morbidity statistics, provided that the relative risks are the same for mortality and for morbidity. In 2000, for example, the total mortality from diarrhoea in AmrD was 26 000 deaths. The number of these deaths that can be attributed to poor water, sanitation and hygiene can be estimated by multiplying the total number of deaths from diarrhoea by the attributable fraction for the risk factor (87.6%), which amounts to 22 800 deaths.

*Derived from Mathers et al. (2002). See also Box 4.1.*
Methods for estimating the environmental burden of disease

Such results may certainly be useful for policy-making, as mortality from one risk factor can be directly compared to the number of deaths caused by other risk factors or diseases. However, it is difficult to compare risk factors that induce diseases that are not fatal, but nevertheless cause a high degree of disability. Examples include hearing impairment from exposure to occupational noise, and occupational back pain. In such cases, the risk factors should be expressed in a common unit (such as DALYs lost, or health service dollars spent).

In the absence of a NBD study, an additional problem of internal inconsistency between various figures and health statistics may arise. This could happen for a number of reasons, including the coherence between cases and deaths from the various studies; registers that were not checked; and the total deaths summed for different diseases may not have been checked against the total number of deaths in a country (death certificates, hospital registers etc.). Also, the attributable burden of a specific disease caused by a risk factor should not be unrealistically large, or larger than, the entire “disease envelope” (i.e. the total disease burden of the disease in the study population).

4.6 Estimating the EBD from limited national or local health statistics when NBD data are not available

It is more difficult to carry out accurate EBD assessments if little is known about the health problems related to environmental risk factors. However, it may be possible to develop a preliminary estimate of the proportion of the disease burden attributable to the environment. Surveys could be used to estimate the incidence or prevalence of the disease(s) of interest, or it may be possible to use pre-existing regional estimates of disease burden. Such results may be less accurate than national estimates, but if the country has similar epidemiological, socioeconomic and cultural characteristics to the rest of the region, the results are likely to provide good preliminary estimates of the BoD attributable to environmental factors (Box 4.4).
Methods for estimating the environmental burden of disease

4.7 Estimating the EBD using preliminary NBD estimates from WHO

To develop regional estimates of burden of disease per disease, each year WHO compiles country health statistics and the results of epidemiological studies, and publishes the regional estimates in the statistical annexes of the World Health Report. Mortality estimates are based on analysis of latest available national information on levels of mortality and cause distributions. YLD estimates are based on the GBD 2000 analyses of incidence, prevalence, duration and severity of conditions for the relevant epidemiological subregion, together with national and subnational level information available to WHO (Mathers et al., 2002). The GBD 2000 uses the latest population estimates for WHO Member States prepared by the UN Population Division (UN, 2001).

For each Member State, the data compiled by WHO have been used to develop internally consistent estimates of mortality, incidence, prevalence, duration and DALYs for over 130 major disease causes. The WHO summary tables represent prior estimates of the NBD and are intended to provide a starting point for more in-depth analyses by NBD teams. It is hoped that such national studies will lead, in turn, to improvements in the GBD 2000 estimates at national, regional and global levels. Prior estimates for WHO Member States are now available upon official request to WHO (contact Colin Mathers at

A similar technique can be applied if the NBD is known, but the burden for the city or district is not known. Provided that the country has a relatively homogeneous geographical disease distribution, the subregional disease burden could be estimated.

Box 4.4 Acute lower respiratory infections (ALRI) in children under five years old in India

In India, 81% of children younger than five years old are exposed to indoor smoke from solid fuels. The relative risk for ALRI in exposed children of this age group is 2.3. According to Equation 2, the resulting attributable fraction is 51% (i.e. 51% of ALRI in children younger than five years old in India is attributable to indoor smoke from solid fuels). If the total ALRI burden in India in this age group were not known, a preliminary estimate could be obtained from the per capita rate of ALRI for SearD (which includes India). For example, the total disease burden for ALRI in SearD for children 0-4 years old is 24 007 000 DALYs and 682 000 deaths (Mathers et al., 2002). As 81.6% of the population of SearD is in India, it can be assumed that 81.6% of the disease burden will also occur in India:

\[
81.6\% \times 24\ 007\ 000\ DALYs = 19\ 590\ 000\ DALYs\ of\ ALRI\ in\ children\ 0-4\ years\ old\ in\ India.
\]

\[
81.6\% \times 682\ 000\ deaths = 557\ 000\ deaths\ of\ ALRI\ in\ children\ 0-4\ years\ old\ in\ India.
\]

To calculate the fraction of this ALRI burden that is attributable to indoor smoke from solid fuels, the above figures are multiplied by the attributable fraction for ALRI from indoor smoke, which is 51% in this case. The disease burden from ALRI in children 0-4 years old in India caused by exposure to indoor smoke from solid fuels is thus estimated to be:

\[
51\% \times 19\ 590\ 000\ DALYs = 9\ 991\ 000\ DALYs.
\]

\[
51\% \times 557\ 000\ deaths = 284\ 000\ deaths.
\]

\[a\] Source: Desai, Smith & Mehta (2003).
An example of the type of information available from the WHO prior estimates is provided in Annex 4.1 for the region AmrD (which includes Bolivia, Ecuador, Guatemala, Haiti, Nicaragua and Peru). However, WHO prior estimates cover only one country.

Current WHO prior estimates of the NBD are based on Version 2 results for the GBD 2000 study (Mathers et al., 2002), as published in the World Health Report 2002 (WHO, 2002). Revised prior estimates based on Version 3 results of the GBD 2000 will be available in late 2003. These prior estimates should be interpreted as best estimates, based on the available evidence in mid-2002, rather than as official estimates of Member States. Prior estimates are always open to revision on the basis of additional data.

Documentation and GBD 2000 summary tables are available on the WHO website (www.who.int/evidence/bod), together with software tools and a NBD manual that provides guidelines for conducting an NBD study (Mathers et al., 2002). For further information, contact Colin Mathers at mathersc@who.int, Epidemiology and Burden of Disease unit, Evidence for Health Policy.

4.8 Estimating the EBD for diseases that are caused by one risk factor

Some diseases are caused by one risk factor (although the risk factors themselves may cause more than one disease). Examples include schistosomiasis, hookworm disease and ascariasis, which are defined by the presence of particular microorganisms. Owing to the characteristics of these pathogens, the diseases can be said to be caused entirely by the risk factor “water, sanitation and hygiene”. The health burden of such diseases can then be attributed entirely to the corresponding risk factor, and the attributable fraction need not be determined, since it is defined as 100%. The entire health burden associated with these pathogens can thus be added to other burdens that are attributable to the same risk factor. For example, the schistosomiasis burden can easily be estimated from the disease statistics, and added to the attributable burden of diarrhoeal diseases (see Box 4.5). In other words, the EBD associated with a risk factor is the sum of all attributable disease burdens caused by that risk factor.

<table>
<thead>
<tr>
<th>Disease</th>
<th>DALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schistosomiasis</td>
<td>9 000</td>
</tr>
<tr>
<td>Trachoma</td>
<td>0</td>
</tr>
<tr>
<td>Ascariasis</td>
<td>26 000</td>
</tr>
<tr>
<td>Trichuriasis</td>
<td>46 000</td>
</tr>
<tr>
<td>Hookworm disease</td>
<td>20 000</td>
</tr>
<tr>
<td><strong>Subtotal for above diseases</strong></td>
<td><strong>101 000</strong></td>
</tr>
<tr>
<td><strong>Subtotal for diarrhoeal disease</strong></td>
<td><strong>756 000</strong></td>
</tr>
<tr>
<td><strong>Total, including diarrhoeal disease</strong></td>
<td><strong>857 000</strong></td>
</tr>
</tbody>
</table>
If only the incidence and the mortality are known, the DALYs could be estimated if additional information were available, including the age of onset of disease, its duration and the disability weight of the disease. A DALY calculation template, and list of disability weights used for the yearly estimates of the GBD (WHO, 2002), are available at the WHO web site:

This template should be used in connection with the National Burden of Disease Manual at:
(http://www3.who.int/whosis/menu.cfm?path=whosis,burden&language=english).

4.9 Estimating the EBD for diseases not assessed by national statistics or by WHO

In certain cases, an environmental risk factor may cause a disease that has not been assessed in the country or region of concern, nor has it been compiled as a WHO prior estimate (see Section 4.7). In certain countries, for example, statistics on the occurrence of silicosis, skin lesions from exposure to arsenic, and certain neoplasms associated with environmental exposures may not be available. Neither has WHO assessed these diseases as a specific category. However, for each of these diseases an incidence rate is known for specific exposure levels, and thus the attributable incidence for each disease can be estimated directly:

Attributable incidence = Number of people exposed x Incidence rate \hspace{1cm} (Equation 5)

For certain risk factors and associated diseases, the number of attributable cases, and thus the attributable incidence, is better assessed than the relative risks between exposed and non-exposed populations. This is relatively rare, as the literature often reports relative risks, and there is generally no assessment of the occurrence of disease by cause. There are, however, a few exceptions, one being occupational injuries. A number of countries have a register or reporting system for occupational injuries or occupational fatalities. The data are often listed by type of injury, occupation, or industrial activity sector. By knowing the number of workers, the occupational injury rate can be assessed. In this way, the number of injuries and their fatalities can be directly estimated, and there is no need to estimate an attributable fraction. Countries having no such register, or an incomplete register, could apply injury rates from neighbouring countries, which are likely to have similar working conditions. More information on this approach can be found in the EBD series volume on occupational health.

Once the incidence rate or fatality rate has been estimated by this “direct” method, the number of DALYs could be estimated using the DALY calculation template, provided that the age-specific and gender-specific incidences are known, as well as the duration of disease or injury and its severity weight (see Section 4.8 and Section 3 for further information).
4.10 Estimating uncertainty

The uncertainty around BoD estimates can be influenced by many parameters, including:

- the exposure assessment and associated data sources (e.g. the number of people exposed at each level);
- the exposure-response relationship (i.e. the shape of the function or values associated with each scenario, and whether there are any threshold effects);
- the model combining exposure with exposure-risk information (e.g. the EBD method itself may introduce uncertainty, depending upon the specific approach used to assess the risk factor);
- the total disease burden per disease for the study population;
- the method(s) used to extrapolate data to subpopulations.

For each of these parameters there are a variety of sources that could potentially contribute to uncertainty. For example, uncertainty linked to exposure may arise because the exposure assessment did not use a sample that was representative of the study population as a whole. The sample size, the choice of exposure indicator, or the measurement accuracy can also introduce uncertainty or errors. Similarly, the uncertainty linked to the model can come at numerous steps, such as applying the exposure-risk relationship to the study population, or matching exposure measurements with the measure used in the exposure-risk relationship. While the impact of some sources of uncertainty can be estimated (e.g. those due to small sample size), for others it is very difficult to estimate their effects on the accuracy of the results (e.g. the uncertainty associated with extrapolating the exposure-risk relationship to data-poor population groups).

It can therefore be difficult to provide a reliable interval of uncertainty for EBD estimates. If uncertainties for the main parameters in national or local assessments have been quantified, a Monte Carlo analysis can be used to provide uncertainty estimates for an EBD, but this is rarely the case. As there is no other straightforward mechanism to capture uncertainty around the best estimate, a more approximate approach may be chosen. For example, “low” and “high” estimates can be obtained from the lower and upper confidence intervals for the relative risks used in the method, and from the confidence intervals of exposure estimates obtained through surveys or other empirical techniques. The effects of different combinations of low and high estimates on the final results can then be examined. Such evaluations of uncertainties have no statistical meaning, but they do illustrate the range of health impacts that could be caused by an environmental risk factor. Practical approaches for estimating the low and high values of a disease burden are provided in the series volumes on individual risk factors.