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Occupational airborne particulates

Assessing the environmental burden of disease at national and local levels

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Preface

The disease burden of a population, and how that burden is distributed across different subpopulations (e.g. infants, women), are important pieces of information for defining strategies to improve population health. For policy-makers, disease burden estimates provide an indication of the health gains that could be achieved by targeted action against specific risk factors. The measures also allow policy-makers to prioritize actions and direct them to the population groups at highest risk. To provide a reliable source of information for policy-makers, WHO recently analysed 26 risk factors worldwide, including occupational airborne particulates, in the *World Health Report* (WHO, 2002).

The Environmental Burden of Disease (EBD) series continues this effort to generate reliable information, by presenting methods for assessing at national level the burden of disease from occupational exposure to airborne particulates. The methods in the series use the general framework for global assessments described in the *World Health Report* (WHO, 2002). The introductory volume in the series outlines the general method (Prüss-Üstün et al., 2003), while subsequent guides address specific environmental risk factors. The guides on specific risk factors are organized similarly, first outlining the evidence linking the risk factor to health, and then describing a method for estimating the health impact of that risk factor on the population. All the guides take a practical, step-by-step approach and use numerical examples. The methods described in the guides can be adapted both to local and national levels, and can be tailored to suit data availability. The EBD series of guides aims to provide reliable information for designing protective measures to reduce workplace risks.

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Abbreviations

AF	Attributable fraction (equivalent to the impact fraction)
COPD	Chronic obstructive pulmonary disease
DALYs	Disability-adjusted life years
FEV_1	Forced expiratory volume
FVC	Forced vital capacity
IF	Impact fraction
ILO	International Labour Organization
USA	United States of America
WHO	World Health Organization

Summary

This guide provides practical information for assessing the burden of nonmalignant respiratory diseases that arise from occupational exposures to airborne particulates (mainly dusts). The respiratory diseases are asthma, chronic obstructive pulmonary disease (COPD), and the three main pneumoconioses: asbestosis, silicosis and coal workers' pneumoconiosis. The focus is on assessing the current burden of disease that results from past and current occupational exposures to airborne particulates. Exposure is estimated from country workforce data, including exposure data for different occupations or industries based on European data.

In the approach proposed for asthma and COPD, the relative risks for exposed populations versus nonexposed populations are obtained from the literature. These data are then combined with the exposure data to calculate a population Attributable Fraction (AF) for each country (i.e. the fraction of deaths or disability from asthma or COPD in a country that is attributable to occupational exposure to airborne particulates). The burden of asthma and COPD in a country can then be estimated by multiplying the AF by the number of deaths in the country. The disability associated with the diseases can also be estimated by multiplying the AF by disease-specific estimates of disability-adjusted life years (DALYs).

For the pneumoconioses, the proposed approach is simpler, because all cases are attributed to work (that is, the population AF is 100%). Therefore, the annual mortality burden can be estimated simply by counting the number of deaths from pneumoconioses per year in a given country. The disability associated with the pneumoconioses (in DALYs) is obtained from WHO published data.

1. Introduction

1.1 Overview

This guide provides practical information for assessing the burden of nonmalignant respiratory diseases that arise from occupational exposures to airborne particulates (mainly dusts). The respiratory diseases are asthma, chronic obstructive pulmonary disease (COPD), and the three main pneumoconioses: asbestosis, silicosis and coal workers' pneumoconiosis. The focus is on assessing the current burden of disease that results from past and current occupational exposures to airborne particulates.

1.2 Identification of the risk factors

Nonmalignant respiratory diseases in workers can result from exposures to airborne agents during the course of their work. These agents are mainly in the form of particulates or dusts[1] and the primary route of exposure is inhalation. The agents gain access to the respiratory system and are either deposited (in the case of dusts) or enter the circulatory system. For some agents, there is a clear connection between exposure to the agent and the disease (e.g. silicosis is only caused by exposure to silica). Some agents cause more than one type of disease and more than one type of respiratory disease. For example, asbestos can result in malignant conditions of the lung and the pleura (the inside lining of the chest), malignant conditions of the peritoneum (the inside lining of the abdomen), and nonmalignant conditions of the lungs (asbestosis and COPD). Other agents have not been well characterized, but the condition they cause is clear (such as some forms of occupational asthma).

1.2.1 Causative agents of asthma

Asthma is a narrowing of the upper respiratory passages that results in difficulty in breathing, and wheezing. Asthma has both occupational and nonoccupational causes, and hundreds of occupational agents, including dusts of biological and nonbiological origins, have been associated with occupational asthma (Chan-Yeung & Malo, 1994; Venables & Chan-Yeung, 1997; Balmes et al., 2003). Biological agents include grains, flours, plants, gums and woods; fur, feathers and other parts from animals, insects and fungi; and drugs and enzymes. Chemical agents include chlorofluorocarbons, alcohols, metals and their salts, and welding fumes (CCOHS, 1997). These agents are found in various workplaces, including facilities for processing food and natural products, animal handling facilities, and manufacturing and construction sites. As it is not possible to conduct exposure assessments, nor obtain relative risk data for all the factors contributing to this important occupational disease, occupation can be used as a proxy for exposure to agents that are associated with occupational asthma.

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1 Dusts are technically defined as dry particle aerosols produced by mechanical processes such as breaking, grinding, and pulverizing (Johnson & Swift, 1997). Particle sizes range from less than 1 μm to over 100 μm in diameter. The smaller particles present a greater hazard, as they remain airborne for longer periods and are more likely to gain access to the respiratory tract. Dusts may be of biological (e.g. grain dust) or nonbiological (e.g. silica, asbestos, coal dust) origin.

1.2.2 Causative agents of COPD

The causative agents of COPD are nonspecific dusts and fumes, with dusts showing a more consistent relationship than fumes. Because there are no worldwide data on the prevalence of occupational exposures to dusts, work in specific industrial sectors can be used as a surrogate for dust exposure.

1.2.3 Causative agents of pneumoconioses

The most important causative agents of pneumoconioses are silica, asbestos and coal dust. Silica refers to several naturally occurring minerals made primarily of silicon dioxide. Commonly occurring forms are quartz, cristobalite, and tridymite. Since these materials make up a large proportion of the earth's crust, silica exposure is common in mining, quarrying and tunneling. Exposure also occurs during processes that involve sand, such as sandblasting, foundry work, cement work, brickwork, pottery-making and glassmaking, and during paint and chemical manufacturing.

Asbestos is a general term applied to six naturally occurring minerals that contain magnesium silicate. The most common forms are chrysotile, crocidolite, and amosite. From the beginning of the industrial revolution until the latter part of the twentieth century, these compounds were incorporated into thousands of products because of their resistance to heat, abrasion and acids. Historically, exposures have occurred in mining, manufacturing and construction, but in developed countries current exposures are related mainly to the removal of asbestos from buildings and structures.

Coal dust exposure occurs primarily as the result of coal mining and processing, although it is not limited to these activities.

1.3 The burden of occupational respiratory diseases

1.3.1 Asthma

Occupational asthma is characterized by limited airflow or bronchial hyper-responsiveness related to workplace exposures. However, the precise definition of occupational asthma has been widely debated. The most controversial issue is whether only immunologically-mediated asthma should be considered to be occupational asthma, or whether asthma arising from workplace exposure to irritants, and pre-existing asthma that is exacerbated by workplace irritants, should also be considered in the definition (Wagner & Wegman, 1998; Lombardo & Balmes, 2000; Malo & Chan-Yeung, 2001). Recently, consensus seems to have been reached in favour of a broad definition (Balmes et al., 2003). A broader approach has been supported by others (Milton et al., 1998; Blanc & Toren, 1999; Kogevinas et al., 1999; Toren et al., 1999; Karjalainen et al., 2001), and recent studies of occupational asthma have tended to use a more inclusive approach (Milton et al., 1998; Karjalainen et al., 2001, 2002).

Occupational asthma is probably the most common work-related respiratory disorder in industrialized countries (Kogevinas et al., 1999), and its incidence is either stable

(Singh & Davis, 2002) or increasing (Sears, 1997). Although hundreds of occupational agents, including dusts of biological and nonbiological origins, have been associated with the disease (Chan-Yeung & Malo, 1994; Venables & Chan-Yeung, 1997; Balmes et al., 2003), until recently there was only limited information about the total risk of developing asthma from workplace exposures.

The results of a study in the USA indicated that about 5% of the mortality associated with nonmalignant, work-related, respiratory disease was due to asthma (Steenland et al., 2003). Studies of substance-specific risks have helped to identify or implicate particular substances as causative agents (e.g. Monso et al., 1998), but the studies generally focused on a limited number of agents thought to be sensitizers, and are therefore not useful for determining the true extent of asthma from work-related exposures. Several population-based studies have partially rectified this problem (Ng et al., 1994; Toren, 1996; Kogevinas et al., 1996, 1999; Toren et al., 1999; Karjalainen et al., 2001, 2002). These studies focused on occupation-specific risks, rather than on substance-specific risks, because many substances potentially cause asthma and it is difficult to characterize all the substance-specific exposures. These studies provided measures of relative risk and/or population AFs. In a recent study in Finland, the overall population AF for occupational asthma was estimated to be 18% (Nurminen & Karjalainen, 2001), with corresponding values of 17% and 29% for women and men, respectively (Karjalainen et al., 2002). An earlier comprehensive review found a median value of 9% for the population AF, and a median value of 15% for the highest-quality studies (Blanc & Toren, 1999). In a recent review of studies largely carried out in developed countries, the American Thoracic Society estimated that approximately 15% of asthma was attributable to occupational exposure (Balmes et al., 2003).

1.3.2 Chronic obstructive pulmonary disease

COPD is defined as "a disease state characterized by progressive development of airflow limitation that is not fully reversible. The airflow limitation is usually both progressive and associated with an abnormal inflammatory response by the lungs to noxious particles or gases" (WHO, 2000). COPD overlaps with emphysema and chronic bronchitis, although some view the condition as a continuum of a single pathological process (Kirkhorn & Garry, 2000). Similarly, COPD is a different disease than the pneumoconioses, although clearly there is overlap between some of their pathological and clinical features (Becklake, 1994).

By 2020, COPD is expected to be the fifth-highest cause of disability in the world (Murray & Lopez, 1996). Tobacco smoking is clearly the most important risk factor, but many work-related exposures have been demonstrated to cause COPD (Hendrick, 1996). A recent study in the USA used a figure of 14% for the population AF for COPD due to occupational dust exposure (based on a community study of severe COPD (Korn et al., 1987)). This figure represented 87% of all fatal, work-related, nonmalignant, respiratory disease (Steenland et al., 2003), although some of the other types of respiratory disease may have been underestimated. A review of Finnish data also used a population AF of 14% for men (5% for women) (Nurminen &

Karjalainen, 2001), and a similar figure (15%) was used in a recent review by the American Thoracic Society (Balmes et al., 2003).

As noted for asthma, difficulties arise from the array of definite, probable and possible causes of work-related COPD. The role of smoking, particularly in causing confounding effects, makes the interpretation of study results difficult. Apparently significant differences in individual susceptibility, and uncertainty about pathological mechanisms, also cause problems. The area has been the subject of several reviews, some covering all exposures and some concentrating on mineral dusts (Becklake, 1989, 1994; Oxman et al., 1993; NIOSH, 1995; Hendrick, 1996; Attfield & Wagner, 1998; Balmes et al., 2003).

1.3.3 Pneumoconioses

Globally, three dusts – silica, asbestos and coal dusts – are mainly responsible for occupational lung diseases due to airborne particulates. The three pneumoconiotic conditions caused by these dusts are included in this analysis. Other pneumoconioses relevant to specific industries and occupations are reviewed in Merchant et al. (1986), but their prevalence is low. They are not included in this approach because there are not enough data.

Human and animal studies in many countries have demonstrated that silica causes a specific pneumoconiosis known as silicosis, a fibrotic condition of the lung (IARC, 1987, 1997). The disease can progress, even after cessation of exposure.

It has been recognized since the 1920s that asbestos causes a specific fibrotic lung disease known as asbestosis. Asbestos as a cause of asbestosis has also been studied extensively in animal and cellular experiments (IARC, 1977; IPCS, 1998). Asbestosis risk is influenced by cumulative exposure, exposure intensity, fiber type (crocidolite and amosite are more fibrogenic than chrysotile), age, work process, and possibly smoking. The disease can progress, even after cessation of exposure. However, many exposed workers do not develop the disease, even after high-intensity exposures (Becklake, 1991).

Since about 1940, coal workers' pneumoconiosis has been recognized as distinct from silicosis. It results from the lungs' "…reaction to the deposited dust resulting in coal macules, coal nodules, and progressive massive fibrosis'' (Attfield & Wagner, 1998). Although dust levels are now controlled in Australia, Britain, Europe, and the USA, coal workers' pneumoconiosis still remains an important occupational lung disease in many parts of the developing world.

2. Summary of the method

The method for asthma and COPD follows that used in the occupational airborne particulates section of the WHO Global Burden of Disease project (Ezzati et al., 2002; Concha-Barrientos et al., 2004). The first step is to determine the proportion of the working population in industrial sectors and/or occupations with exposure to airborne particulates (primarily dusts). Second, the relative risks of asthma and COPD for exposed populations versus nonexposed populations are obtained from the literature. Third, the information on the fraction of the population exposed to occupational particulates is combined with the relative risks to determine the population AF (otherwise known as the impact fraction (IF)). The global population AF is described in terms of the fractions of the deaths and disability from asthma and COPD that are caused by the risk factor. Finally, to estimate the annual burden in terms of deaths (or DALYs), the AF is multiplied by the number of deaths (or DALYs) from asthma or COPD each year.

DALYs are "disability-adjusted life years", a weighted estimate of the number of years lived with disability. The weighting refers to the severity of the disability. DALYs require an estimate of the age at which a disease occurs, an estimate of the duration of the disease, and often an estimate of the life expectancy of the person who is ill. The calculation of DALYs also requires a severity weighting that is based on expert judgement of the relative importance of the disability. In the case of "premature" death due to the disease, the weighting is 1.0 and DALYs are in effect an estimate of the years of life lost due to premature death. DALYs can be calculated for all diseases, regardless of cause, provided that certain parameters such as the severity weighting, duration of illness and age of onset are known. A table of DALYs by disease is shown for the different WHO subregions (Table 6), and more information is available from WHO (www.who.int/evidence/bod)[1]. Additional information on sources of health statistics and on how to estimate DALYs can be found in the introductory chapter to this series (Prüss-Üstün et al., 2003).

For the pneumoconioses, the approach is simpler, because all cases are attributed to work (that is, the population AF is 100%). Therefore the annual mortality burden can be estimated simply by counting the number of deaths from pneumoconioses per year in a given country. The pneumoconioses have been assigned their own specific codes for causes of death (ICD 9 and, since 1999, ICD 10)[2].

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1 Select: "Global burden of disease estimates", "GBD 2001 estimates", "Estimates by subregion", and then "DALY".

2 ICD-9 codes: 500 = coal worker's pneumoconiosis; 501 = asbestosis; 502 = silicosis.
ICD-10 codes: J60 = coal worker's pneumoconiosis; J61 = asbestosis; J62 = silicosis.

3. Choice of health outcomes

There are a number of respiratory conditions that can arise directly, or indirectly, from work. However, it is not possible to estimate exposures, risks and attributable proportions for many of these conditions on a national (or international) scale because there are no data. Therefore, only the more important of the work-related respiratory conditions, in terms of the total number of cases or the risks arising from exposure, are included here. Infectious respiratory conditions related to work are not included, and malignant respiratory disease is described in a separate document.

The most important criteria used in the Global Burden of Disease study to assess whether there was a causal connection between exposures and outcomes of interest were: the consistency of the relationship between the risk factor and the outcome in different settings; and the strength of the evidence of the relationship. The data sources used in this guide were critically evaluated to assess the strength of the evidence that linked exposure to an agent, and the development of specific nonmalignant respiratory diseases (Table 1).

Table 1 Literature sources used to assess the strength of evidence for causality, selected occupational particulates

Risk factor	Health outcome	Sources
Asthmagens	Occupational asthma	Chan-Yeung & Malo, 1994; Kogevinas et al., 1996, 1999; Venables & Chan-Yeung, 1997; Karjalainen et al., 2001, 2002; Balmes et al., 2003.
Dusts and gases	Occupational COPD[a]	Becklake, 1989, 1994; Oxman et al., 1993; NIOSH, 1995; Hendrick, 1996; Attfield & Wagner, 1998; Balmes et al., 2003.
Coal, asbestos and silica	Pneumoconioses	IARC, 1977, 1987, 1997; Becklake, 1991; Attfield & Wagner, 1998; IPCS, 1998.

[a] COPD = chronic obstructive pulmonary disease.

4. Relative risk estimates from the literature

We reviewed the evidence for a quantitative link between occupational airborne particulates and health outcomes for several risk factors, using the framework of the Global Burden of Disease assessment (for occupational airborne particulates, see Concha-Barrientos et al., 2004). For the analysis presented here, relative risks were determined for asthma and COPD. The health burden of pneumoconiosis arising from exposure to silica, asbestos or coal was based on the assumption that all cases of the pneumoconioses were due to occupational exposures. That is, the AF was assumed to be 100% for the pneumoconioses, and relative risks were not required.

4.1 Asthma

Only one of the previously-mentioned occupational asthma studies provided useable risk information for the whole workforce (Karjalainen et al., 2001, 2002). Another provided useful information for the agriculture sector (Kogevinas et al., 1999). The Karjalainen et al. study was a longitudinal study of the entire Finnish population over a period of 13 years, and it provided relative risks for a number of broad occupational categories. Asthma in the study was defined as clinically diagnosed asthma during the follow-up period (N = 49 575). Presumably, only a minority of individuals in these categories were actually exposed to occupational asthmagens, and they were responsible for the increased risk of the entire occupational category. The data were obtained from national medical records linked to census data on an individual's occupation. The study population was composed of all currently employed individuals 25−59 years old at baseline who did not have a prior history of asthma. Relative risks were calculated by comparing the occupation-specific incidence of asthma to the incidence of occupational asthma in administrative, managerial and clerical workers, whose risk was assumed to be similar to the background population risk. The relative risks were adjusted for age, and separate risks were available for males and females, although these were very close to each other and within the limits of random variation. The Kogevinas et al. (1999) study was a cross-sectional study of asthma involving 15 000 people in 12 European countries. The relative risks of asthma morbidity in both the Kogevinas et al. study and the Karjalainen et al. study were assumed to apply to asthma mortality. The available information did not allow reliable confidence intervals to be estimated.

4.2 Chronic obstructive pulmonary disease

As a result of the difficulties in characterizing all the likely causative occupational exposures, few published papers provide information that comprehensively describes the risk of developing COPD as a result of work. The study by Korn et al. (1987) is the only source of relative risks used in this analysis, as it provided relative risk information covering all workplace exposures. The study used methods described earlier (Ferris et al., 1979), and was based on a random sample of white adults 25−74 years old from six USA cities and their surrounding areas (8515 subjects were included in the final sample). COPD was defined as occurring when the ratio of the forced expiratory volume divided by the forced vital capacity (FEV_1/FVC) was less than 0.6, representing reasonably severe disease. The odds ratios for various respiratory conditions were determined by logistical regression analyses, controlling for age, gender, current and lifetime smoking history, and city of residence. The odds ratios for COPD morbidity reported by Korn et al. (1987) were assumed to apply to COPD mortality. The available information did not allow reliable confidence intervals to be estimated.

5. Estimation of exposure

The approach presented here for asthma and COPD follows the approach used in the WHO Global Burden of Disease assessment for major health risks arising from occupational airborne particulates (Ezzati et al., 2002; Concha-Barrientos et al., 2004).

For asthma, because relative risks were primarily available for entire occupations rather than for specific occupational agents, we propose using occupation as a proxy for exposure. The basic approach is to use routine employment data to estimate the proportion of the population working in occupations associated with an increased incidence of asthma, and then to correct for the participation of the total population in the work force. A similar approach is proposed for COPD, except that industrial sector is used as the proxy exposure. To provide estimates of the AF, this information should be combined with relative risk estimates from the literature for each occupation (for asthma) or industrial sector (for COPD).

To determine the proportion of workers exposed, the following information is required:

- the proportion of the workforce employed in each occupation and industrial sector;
- the proportion of the population in the workforce.

The method for the pneumoconioses is simpler, and requires only knowledge of the number of deaths due to each of asbestosis, silicosis and coal workers' pneumoconiosis in the country, together with other information taken from the WHO Global Burden of Disease project. This method is described in Section 7.3.

As far as available, the above information should come from data assessed in the country or study area. As information is often not available at country level, we propose values on the basis of the literature used in the WHO Global Burden of Disease analysis (Concha-Barrientos et al., 2004).

A worked example is shown in Section 9, using data for WHO subregion Africa D (AFR D), but the same approach can be used incorporating data from individual countries.

5.1 The proportion of the workforce employed in each occupation or sector

The approach requires information on the employment distribution of workers in the country. This information is required in the same groupings as were used in the literature from which the relative risk estimates were taken.

For asthma, the relative risks can be based on occupation. To match standard occupation groups to those used in the study that supplies most of the relative risk estimates (Karjalainen et al., 2002), cross-classified information on occupation and sector is required. The International Labour Organization (ILO) standard occupation groups, for example, provide a good match to those used in the Karjalainen et al. study, with the main exceptions being mining and transportation workers. For the purpose of this analysis, countries would need to compare the occupational groups used in their national statistics with those used in the Karjalainen et al. study. Mining occupations are defined as those performed by production workers employed in the mining industry. Similarly, transportation occupations can be defined as those performed by production workers employed in the transportation industry. Table 2 outlines an example of how to match and adapt a classification (in this case, the International Standard Classification Codes for occupations) to the categories used in the Finnish study by Karjalainen et al. (2001, 2002).

Table 2 Comparison of occupational categories

Code	Finnish classification[a]	1968 ISIC[b]	Comments
1	Administrative, managerial and clerical work.	Administrative and managerial workers. Clerical and related workers.	Combine categories 2 and 3 (ISIC) for all industrial subsectors.
0	Technical, physical science, social science, humanistic and artistic work.	Professional, technical and related workers.	Use category 0/1 (ISIC) for all industrial subsectors.
2	Sales work.	Sales workers.	Use category 4 (ISIC) for all industrial subsectors.
3	Agriculture, forestry, commercial fishing.	Agricultural, animal husbandry and forestry workers; fishermen and hunters.	Use category 6 (ISIC) for all industrial subsectors.
4	Mining and quarrying work.		Use category 7/8/9 for the mining industrial subsector.
5	Transportation and communications work.		Use categories 7/8/9 in ISIC in the transportation industrial subsector. Does not include communications workers.
6/7	Manufacturing and related work.	Production and related workers, transport equipment operators and labourers. Specific transportation equipment operators: motor vehicle drivers; bus, truck, and tram drivers.	Use categories 7/8/9 in all industrial subsectors except mining and transportation.
8	Service work.	Service workers.	Use category 5 (ISIC) for all industrial subsectors.

[a] Source: Karjalainen et al. (2001).
[b] Source: 1968 International Standard Industry Classification Codes for occupations (UN, 2000).

For COPD, the relative risks can be based on industry (sector). To match the exposure groups used in the study that supplies the relative risk estimates (Korn et al., 1987), the workforce information needs to be classified by industry. The industries are combined into three groups, based on exposure level (Table 3).

Table 3 Allocation of industries to levels of exposure to dusts and fumes associated with COPD[a]

Exposure level	Industries
Background	Trade, finance, services.
Low	Agriculture, electricity, transportation.
Medium/high	Mining, manufacturing, construction.

[a] Source: Korn et al., 1987. COPD = chronic obstructive pulmonary disease.

5.2 The likely turnover of workers

In contrast to occupational injury, in which the worker is only at risk during exposure to potentially unsafe conditions, nonmalignant respiratory conditions can have long latency periods. Once the disease process has begun, the worker continues to be at risk, even after exposure ceases. In addition, once these conditions have developed, they are usually chronic, so people remain at risk of dying from the disease. This means that people who were exposed in the past must be considered as currently at risk, even if they are currently working in jobs that no longer expose them to the risk, or are retired. Thus, at any one time, the total number of people who have *ever* been exposed will be greater than the number of people *currently* exposed. Occupational turnover refers to the annual replacement of workers in jobs, and it accounts for exposed workers who leave their jobs. Occupational turnover increases the number of people exposed to an occupational risk.

The current exposure prevalence usually needs to be adjusted to allow for people at risk, but no longer exposed. However, for asthma, individuals currently employed in occupations at increased risk for asthma, as indicated in the Finnish population study by Karjalainen et al. (2001), are assumed to approximate the number ever-exposed in these occupations, since the occupations with some increased risk included the majority of the population. Similarly, in the absence of more precise information, it is assumed that the number of people currently employed in industries with an increased risk of dust-induced COPD (as defined by Korn et al., 1987) is approximately equal to the number of people ever-exposed to dusts occupationally (Korn et al., 1987).

5.3 The proportion of the population in the workforce

Information is required on the proportion of the total population in the workforce (i.e. the Economically Active Population). This information should be available from employment surveys or other employment information collected by the government (e.g. by a ministry of labour or equivalent). This information will be different for each country.

6. Average relative risks for asthma and chronic obstructive pulmonary disease used in this analysis

Relative risks adjusted for age were obtained from the literature. These were assumed to be the same for all countries, except for the low-exposure risks for COPD. Separate risks were available for males and females. The approach is described in detail elsewhere (Concha-Barrientos et al., 2004) and is summarized here.

6.1 Asthma

The relative risk of developing asthma is based on the work of Karjalainen et al. (2001, 2002), which focuses on Finland. In addition, the work by Kogevinas et al. (1999) is used to obtain the relative risk of asthma due to occupational exposure in agriculture. While the Finnish study was large, prospective, and covered all occupations, there is concern that exposures within Finnish occupations might not be typical of the rest of the world. Finnish agriculture, in particular, might involve more indoor work where the relative risk for asthma is comparatively high. The Kogevinas et al. (1999) results are therefore used for agriculture, as it is believed that the data can be generalized to agriculture in the rest of the world, and especially to agriculture in the developing world.

The relative risks of asthma morbidity due to employment in occupational categories can be assumed to be approximately equal to the relative risks of asthma mortality. Nonworking people and individuals employed in administration can be considered to be in the nonexposed reference category (relative risk = 1.0). The calculations should be performed separately for men and women. It is assumed that the relative risks apply across all age categories. The relative risks, by occupation, are shown in Table 4.

Table 4 Relative risks for asthma in males and females, by occupation[a]

	Male		Female	
Occupation	**RR[b]**	**95% CI[c]**	**RR**	**95% CI**
Background	1.00		1.00	
Administration	1.00		1.00	
Technical	1.05	0.98–1.12	1.06	1.03–1.10
Sales	1.14	1.05–1.23	1.13	1.08–1.18
Agricultural	1.41	0.98–2.02	1.41	0.98–2.02
Mining	1.95	1.58–2.40	1.00	0.25–4.02
Transportation	1.31	1.22–1.40	1.22	1.13–1.31
Manufacturing	1.56	1.47–1.65	1.33	1.27–1.39
Services	1.53	1.42–1.66	1.41	1.35–1.46

[a] Sources: Karjalainen et al. (2001, 2002); Kogevinas et al. (1999).
[b] RR = relative risk.
[c] CI = confidence interval.

6.2 Chronic obstructive pulmonary disease

We use the Korn et al. (1987) relative risks for COPD, since the study defined COPD, provided relative risks for both men and women, and used a large number of participants. The relative risk for COPD prevalence is used as an approximation of the relative risk for COPD mortality.

For men and women with a history of exposure to dusts, Korn et al. (1987) found COPD relative risks of 1.62 and 1.24, respectively. The relative risks are partitioned into high-exposure and low-exposure categories, and slightly different relative risks are used for low exposure in developed and developing countries. In developing countries, the majority of employment with low exposure is in agriculture, where much of the dust is nonrespirable. In developed countries, much of the exposure in the low category is in industries other than agriculture, where a higher percentage of dust exposure may be respirable and toxic. It is assumed that the relative risks apply across all age categories. Uncertainty ranges for the estimates are not provided. The estimated relative risks are shown in Table 5.

Table 5 Annual relative risks of COPD[a] mortality for males and females, by WHO subregion[b]

	Relative risk			
	Developing subregions[c]		Developed subregions[d]	
Exposure level	**Males**	**Females**	**Males**	**Females**
Unexposed	1.0	1.0	1.0	1.0
Low	1.2	1.1	1.4	1.2
High	1.8	1.4	1.8	1.4

[a] COPD = chronic obstructive pulmonary disease.
[b] Source: Korn et al. (1987).
[c] Developing subregions: all subregions except AMR A, EUR A and WPR A. See Annex 1 for a list of countries in the WHO subregions.
[d] Developed subregions: AMR A, EUR A, WPR A.

7. Estimating the disease burden

The approach presented here for asthma and COPD follows that used in the WHO Global Burden of Disease project (Ezzati et al., 2002; WHO, 2002) for diseases arising from occupational airborne particulates (Concha-Barrientos et al., 2004). This approach combines information on exposure with relative risk information from the literature, to obtain estimates of the AF. Although the estimates in this guide are based on WHO subregions (WHO, 2002), the method we use nevertheless allows countries to produce their own estimates from national employment data.

To estimate the burden of disease caused by exposure to occupational airborne particulates, the following information is required:

- the proportion of people exposed (see Section 5);
- the relative risk of developing the outcome of interest (asthma or COPD) in exposed people (see Section 6);
- the total number of deaths and/or DALYs due to asthma or COPD in the country or subregion (for the use of health statistics see Prüss-Üstün et al., 2003, Chapter 4).

For the second requirement, we propose using relative risks from the literature (see Section 6). Although several options are available for obtaining health statistics (the third requirement), national sources are preferable. Some information is also available from WHO.

The method for the pneumoconioses is much simpler, and requires only knowledge of the number of deaths due to pneumoconioses in the country. This method is described in Section 7.3.

7.1 Estimating the attributable fraction

The AF is calculated using Equation 1 (Prüss-Üstün et al., 2003):

$$IF = \frac{\Sigma\, P_i\, RR_i - 1}{\Sigma\, P_i\, RR_i} \qquad \textit{(Equation 1)}$$

where:

IF = impact fraction (equivalent to the AF);

P_i = proportion of the population at exposure category “i” (this includes the unexposed population, for which $P_i\ RR_i = P_{background} \times RR_{background}$);

RR_i = relative risk at exposure category “i” compared to the reference level.

7.2 Estimating the number of deaths and DALYs

Since males and females have different employment characteristics, it is sensible to present the resulting AFs separately for males and females.

The number of deaths due to occupational asthma or COPD can be estimated by multiplying the total number of asthma (or COPD) deaths in the country (obtained from routine deaths statistics) by the AF for that country (obtained using Equation 1). This can be done separately for males and females, with the sum of these two providing an estimate of the total number of deaths due to occupational asthma (or COPD).

Several methods could be used to estimate the number of DALYs attributable to exposure to occupational airborne particulates, depending on the type of data available in the country. If a national burden of disease study has been carried out (see Chapter 3, Prüss-Üstün et al., 2003), or if the number of DALYs caused by asthma or COPD have been estimated directly, the attributable number of DALYs is estimated as for deaths: the AF is multiplied by the number of DALYs for the disease. Preferably, this calculation should be performed separately for males and females and for different age groups, provided such data are available. If no DALYs for asthma or COPD are available at country level, the following data could be used instead:

- WHO prior estimates for the country, available upon request from WHO (see Chapter 4, Prüss-Üstün et al., 2003).
- The number of DALYs for each country can be estimated by multiplying WHO subregional estimates of DALYs by the ratio of the country population to the subregional population. This should only be done as a preliminary estimate, however, as it assumes that the disease rates are similar in all countries of the WHO subregion. Subregional DALY estimates are available from the site www.who.int/evidence[1]. Annex Tables 2 and 3 of the World Health Report also contain a summary of these information tables, but without distribution into gender and age groups at the subregional level (WHO, 2002). As indicative values, the number of DALYs estimated for asthma or COPD in the global analysis are shown in Table 6.

Further information on health statistics can be found in Prüss-Üstün et al., 2003.

[1] Select: "Global burden of disease estimates," "GBD 2001 estimates", "Estimates by subregion", and “DALY”.

Table 6 DALYs[a] due to occupational asthma and COPD[a] for all WHO subregions, by sex, 2000

	Asthma			COPD[a]		
WHO subregion[b]	Male	Female	Percentage of total (%)[c]	Male	Female	Percentage of total (%)[c]
AFR D	62 858	26 796	10	43 099	10 178	11
AFR E	84 187	56 484	11	57 029	12 444	11
AMR A	36 873	14 567	7	147 058	21 274	11
AMR B	97 961	26 797	8	115 480	16 936	10
AMR D	15 685	3 743	7	5 534	459	7
EMR B	17 818	3 486	7	19 570	923	12
EMR D	73 621	26 768	10	74 511	12 539	11
EUR A	40 622	14 028	8	175 739	29 097	12
EUR B	30 010	13 084	12	74 930	18 895	13
EUR C	31 969	9 110	14	135 478	33 752	14
SEAR B	44 473	25 752	13	90 306	21 092	12
SEAR D	309 661	166 076	13	552 475	149 015	11
WPR A	23 298	9 269	9	44 240	8 527	14
WPR B	240 808	115 210	12	1 484 773	377 699	14
Totals	1 109 844	511 170	11	3 020 222	712 830	12

[a] Abbreviations: DALYs = disability-adjusted life years; COPD = chronic obstructive pulmonary disease.
[b] See Annex 1 for a list of countries in each WHO subregion.
[c] The sum of the male and female DALYs as a proportion of the total asthma (or COPD) DALYs within the WHO subregion.

7.3 Asbestosis, silicosis and coal workers' pneumoconiosis

As described earlier, asbestosis, silicosis and coal workers' pneumoconiosis are essentially only caused by work-related exposures. Therefore, it is assumed that the AF for these diseases is 100%.

The number of deaths due to asbestosis, silicosis and coal worker's pneumoconiosis can be estimated simply by counting the total number of asbestosis, silicosis and coal worker's pneumoconiosis deaths in the country (obtained from routine deaths data). This can be done separately for males and females, with the sum of these two providing an estimate of the total number of deaths due to work-related pneumoconiosis.

It is more complex to estimate the number of DALYs due to pneumoconioses arising from occupational exposures, and this will not be discussed here. As indicative values, the number of DALYs estimated in the global analysis (WHO, 2002), which applied estimated risks to estimates of subregional exposures, are shown in Table 7.

Table 7 DALYs[a] due to asbestosis, silicosis and coal worker's pneumoconiosis for all WHO subregions[b], by sex[c]

WHO subregion	Asbestosis		Silicosis		Coal workers' pneumoconiosis	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**
AFR D	4 805	4 049	5 861	2 215	27	-
AFR E	6 056	6 372	7 392	2 998	2 724	-
AMR A	1 658	898	4 360	1 223	11 519	-
AMR B	7 219	3 643	16 081	4 155	819	-
AMR D	907	288	2 342	331	8	-
EMR B	4 411	755	10 477	828	80	-
EMR D	8 743	4 787	14 456	3 201	201	-
EUR A	2 834	1 703	7 949	2 853	48 371	-
EUR B	6 837	4 014	14 337	4 025	24 290	-
EUR C	10 607	11 269	25 896	21 159	75 278	-
SEAR B	4 573	3 060	7 456	2 715	862	-
SEAR D	41 117	36 522	52 138	25 484	26 741	-
WPR A	93 658	858	95 713	1 750	3 190	-
WPR B	66 360	37 920	107 370	41 178	171 758	-

[a] DALYs = disability-adjusted life years.
[b] See Annex 1 for a list of countries in each WHO subregion
[c] Source: WHO (2002).

8. Uncertainty

8.1 Calculation of relative risk

When the relative risk values used in this analysis are based on disease incidence studies, the incidence rate ratio is assumed to be comparable to the corresponding mortality risk ratio. Although the number (and rate) of deaths from these diseases is not likely to be the same as the number and rate of incident cases, the relative rate is likely to still be the same in many situations. There are insufficient data to confirm or refute this assumption for the outcomes of interest in this study.

The relative risks used here are not related to any absolute measure of cumulative exposure, because the necessary exposure–risk data are not available. The studies used are based on cohorts of people exposed for different periods of time, followed up for varying periods of time, with varying periods of time between exposure cessation and follow-up. The average duration of exposure of all the relevant populations on which the relative risks are based is not certain, and the average duration in the populations to which the relative risks are to be applied is also not known. It is important to remember that the relative risks are *not* based on duration. They are simply calculated for exposed versus nonexposed populations, without consideration of duration.

For asthma and COPD, the best available studies are used as the basis for the risk estimates. Risks for these conditions are difficult to estimate accurately because many of the causative exposures are not known, and there are few studies that cover the whole of the workforce. Nevertheless, the final subregional AF estimates obtained using these values (determined in the Global Burden of Disease project (Concha-Barrientos et al., 2004)), are consistent with those available from the literature.

8.2 Age

The method presented here does not take account of differences in exposure or risk with age. This is because relative risk data are rarely available for separate age groups, and only occasionally available by years employed. Older people can be expected to have a higher level of absolute risk of disease, because cumulative exposure would usually be higher and the risk of disease usually increases with cumulative exposure. However, the advantage of using relative risks is that in younger ages, when there are fewer nonmalignant respiratory disease deaths than in the general population, the same AF (which is based on relative risk) will give less mortality than in older ages. This is because exposure accumulation for various particulates, as well as latency effects, cause more people of older age to die of nonmalignant respiratory diseases in general. Such an approach, of reporting a single relative risk for different ages, has been used elsewhere (Peto et al., 1992). The biological effect of a given exposure is likely to be similar in young and middle-aged adults. The effect in older people is not as easy to predict, since the body's susceptibility to the effects of exposure may change with age. However, for the exposures considered in this report, it is unlikely that there would be major changes to the relative risk with age, provided exposure–disease latencies are taken into account.

8.3 Smoking

Smoking is the main potential confounder of most studies of respiratory diseases. In this analysis, studies are used that produced risk estimates after controlling for smoking, or that showed that smoking had little or no effect on the risk estimates. However, there were no data available to allow subregion-specific smoking rates or levels to be taken into account when developing the final risk estimates. This should not matter significantly, since the relative risk estimates were developed taking the effect of smoking into account.

8.4 Nutrition

No attempt has been made to account for the effects of nutrition on the exposure–risk estimates. Populations with poor nutrition may have an increased risk of developing the diseases in question, compared to a population with the same exposure but good nutrition. However, there are not enough data to adjust the risk estimates for poor nutrition. To the extent that poor nutrition does increase risk at a given exposure level, the risks will be underestimated for countries and subregions that have relatively poor nutrition.

8.5 Latency

All of the conditions considered in this analysis usually have a medium-to-long latency between exposure and development of recognizable disease. Therefore, most of the cases included result from past exposures, and lower risks could be expected from current exposures (which are generally lower than past exposures). The data presented here describe the current burden arising from relevant workplace exposures, both past and present. Therefore, for conditions with prolonged latency, and to the extent that current exposures are less than those present 10, 20 or 30 years ago, the population AFs based on this analysis will be overestimates of the attributable burden that will arise from current exposures.

8.6 Omitted exposures

Some occupational exposures that potentially cause nonmalignant respiratory disease are excluded from this analysis, including exposures to infective agents and to some of the dusts causing rarer pneumoconioses. This is because of one or more of the following reasons: workplace exposure levels are very low; there is limited evidence that exposure causes the conditions of interest; or there are no data. This will lead to some underestimation of the total burden of nonmalignant respiratory disease arising from workplace exposure, but it is unlikely that these omissions will produce significant underestimates because of the low prevalence of occupational exposure to these agents.

8.7 Omitted conditions

Some nonmalignant respiratory diseases (such as respiratory tract infections and some of the rarer pneumoconioses) have been excluded because there is no information regarding either conditions or risks. The omitted exposures will lead to some underestimation of the total burden of nonmalignant respiratory diseases arising from workplace exposure, but the error is unlikely to be significant because few cases arise from the excluded occupational exposures.

8.8 Quantification of best estimate ranges

Estimates of uncertainty for the relative risks proposed here for occupational asthma are available from the literature. They can be included in calculations in the same manner as the point estimates, to produce upper and lower bounds for the estimated AF. These bounds can also be used for the estimated deaths and DALYs. Uncertainty estimates are not provided for the COPD relative risk estimates because the relative risks were developed by partitioning the risks provided (Korn et al., 1987). Estimating uncertainty around the exposure information is also not straightforward, but if countries are able to make such estimates, these can also be used to produce upper and lower bounds for the estimated AF, deaths and DALYs.

8.9 Problems with diagnosis

Diagnosis of asbestosis, silicosis and coal workers' pneumoconiosis can be difficult and requires expertise. In areas with limited access to this expertise, as may be the case in many developing nations, there are likely to be considerable underestimates in the number of cases of these three pneumoconioses. Therefore, estimates made using the approach proposed here, based on a country's official deaths data, can be expected to lead to an underestimate of the true burden of ill-health arising from pneumoconiosis.

9. Worked example: occupational nonmalignant respiratory disease in Africa D

The following worked example for AFR D[1], one of the subregions in the global analysis, is a step-by-step guide on how to estimate the burden of disease for asthma, COPD and the main pneumoconioses. Using males as an example, detailed information is presented separately for asthma and COPD. The same approach is also used to estimate the corresponding disease burden for females, and for males and females combined, but the detailed calculations are not shown. Information on the pneumoconioses is also provided, but in less detail than for asthma and COPD. All calculations and results are highlighted in grey.

9.1 Occupational asthma

9.1.1 Proportion of the workforce in each occupation–industry group

The proportion of male workers in each occupation-industry group for AFR D can be obtained from ILO sources (the data are reproduced in Table 8). For individual countries, the information should be available from government departments and the ILO.

Table 8 Proportion of the male workforce employed in each occupation–industry group, for AFR D[a]

	Occupation							
Industry	**0/1 Profess-ional**	**2 Adminis-tration**	**3 Clerical**	**4 Sales**	**5 Services**	**6 Agriculture**	**7 Produc-tion**	**Total**
Agriculture	0.000	0.000	0.000	0.000	0.000	0.539	0.011	0.550
Mining	0.000	0.000	0.000	0.000	0.001	0.000	**0.010**	0.011
Manufacturing	0.004	0.003	0.006	0.002	0.003	0.001	0.077	0.094
Electrical	0.001	0.000	0.001	0.000	0.000	0.000	0.007	0.009
Construction	0.003	0.001	0.001	0.000	0.000	0.000	0.031	0.036
Trade	0.001	0.001	0.002	0.050	0.002	0.00	0.003	0.059
Transportation	0.001	0.000	0.002	0.000	0.000	0.00	**0.034**	0.038
Finance	0.005	0.002	0.011	0.006	0.003	0.00	0.002	0.029
Services	0.053	0.002	0.028	0.002	0.051	0.003	0.026	0.164
Totals	**0.066**	**0.009**	**0.050**	**0.060**	**0.060**	**0.544**	**0.202**	**0.991**[b]

[a] (Source: ILO, 2000). The figures in bold font indicate data used to adapt the ILO occupation groups to those used to calculate relative risks.
[b] The total does not equal 1.000 because of rounding.

[1] See Annex 1 for a list of countries in AFR D.

The ILO workforce proportions in Table 8 need to be adapted to the groups used for the relative risks. This is done by labeling professional workers as technical workers; combining the administrative and clerical occupation groups as administration workers; and defining the production workers in the mining industry as miners, production workers in the transportation industry as transportation workers, and the remaining production workers as manufacturing workers. The data used in this adaptation are shown in bold font in Table 8, and the resulting workforce proportions are shown in Table 9. These are used in the subsequent calculations.

Table 9 Proportion of the male workforce employed in each occupation group[a], AFR D

Technical	Administration	Sales	Services	Agriculture	Mining	Transportation	Manufacturing	Total[b]
0.066	0.059	0.060	0.060	0.544	0.010	0.034	0.158	0.991

[a] Occupation groups are described in Karjalainen et al. (2001, 2002).
[b] The total does not equal 1.000 because of rounding.

9.1.2 Proportion of the population in the workforce

The Economically Active Population[1] for males in AFR D was obtained from ILO sources. For individual countries, the information should be available from relevant government departments and the ILO.

Economically Active Population for males (15 years of age and older) in AFR D

= **0.85**

9.1.3 Proportion of the male population in each occupation group

The proportion of the total male population (15 years of age and older) in each occupation group is estimated by multiplying the proportion of the male workforce in each group (Table 9) by the proportion of the total male population in the workforce (i.e. the Economically Active Population). Those males who are not in any of the exposure groups are considered to have "background" exposure. In the current example they comprise 15% of the total male workforce.

proportion of the total male population in an occupation group =

proportion of the male workforce in the occupation group × proportion of the total male population in the workforce

Thus, the data in Table 9 are multiplied by 0.85 (the Economically Active Population) to obtain the data shown in Table 10.

[1] The Economically Active Population is all the employed and unemployed people in a population (i.e. all people in the population who are working or seeking work).

Table 10 Proportion of the male population (15 years of age and older) in each occupation group[a], for AFR D

Back-ground	Techni-cal	Adminis-tration	Sales	Services	Agricul-ture	Mining	Transpor-tation	Manufac-turing	Total[b]
0.15	0.056	0.05	0.051	0.051	0.462	0.008	0.029	0.134	0.992

[a] Occupation groups are described in Karjalainen et al. (2001, 2002).
[b] Total does not equal 1.000 because of rounding.

9.1.4 Relative risk of dying from occupational asthma

The relative risks of dying from occupational asthma are obtained from Table 4 (Section 6.1), and are reproduced in Table 11 for the different occupation groups, and for males and females. The same risks are used for all WHO subregions.

Table 11 Relative risks for occupational asthma, by sex[a]

	Relative risk	
Occupation	**Males**	**Females**
Background	1.00	1.00
Administration	1.00	1.00
Technical	1.05	1.06
Sales	1.14	1.13
Agricultural	1.41	1.41
Mining	1.95	1.00
Transportation	1.31	1.22
Manufacturing	1.56	1.33
Services	1.53	1.41

[a] Data are for all WHO subregions

9.1.5 Estimating the attributable fraction for asthma

The AF for asthma in males that arises from occupational exposure is calculated with Equation 1 (Section 7.1), using the proportions of the male population in each occupation group (Table 10) and the relevant relative risks (Table 11). The step-by-step calculations can be programmed into a Microsoft Excel spreadsheet. An example output is shown in the following spreadsheet.

$$AF = IF = \frac{\Sigma P_i RR_i - 1}{\Sigma P_i RR_i}$$

	Back-ground	Tech-nical	Adminis-tration	Sales	Services	Agricul-ture	Mining	Transpor-tation	Manufac-turing	∑
P_i	0.150	0.0560	0.050	0.0510	0.0510	0.4620	0.0080	0.0290	0.1340	
RR_i	1.000	1.0500	1.000	1.1400	1.5300	1.4100	1.9500	1.3100	1.5600	
P_iRR	0.150	0.0591	0.050	0.0585	0.0781	0.6515	0.0158	0.0379	0.2098	1.311
AF										**0.237**

Therefore, for males in AFR D, the AF (IF) for asthma arising from occupational exposures is **0.237**, or 23.7%.

Using the same approach, but incorporating the lower and upper 95% confidence limits for each of the relative risk estimates, the 95% confidence interval for the AF is estimated to be 0.074–0.385, or 7.4%–38.5%.

Using the same approach for females produces the following results:

	Back-ground	Tech-nical	Adminis-tration	Sales	Services	Agricul-ture	Mining	Transpor-tation	Manufac-turing	∑
Pi	0.470	0.030	0.0250	0.0320	0.0290	0.3550	0.0010	0.0150	0.0480	
RR	1.000	1.060	1.0000	1.1300	1.4100	1.4100	1.0000	1.2200	1.3300	
P_iRR	0.470	0.032	0.0249	0.0366	0.0406	0.5007	0.0012	0.0177	0.0642	1.188
AF										**0.158**

Therefore, for females in AFR D, the AF (IF) for asthma arising from occupational exposures is **0.158**, or 15.8% (the 95% confidence interval is 2.5%–29.4%).

9.1.6 Estimating deaths due to occupational asthma

National statistics should be used to estimate the number of occupational asthma deaths at national level. For the example of AFR D, the total number of deaths from asthma in the year 2001 was about 8400 in the population 15 years or older – 3700 males and 4700 females (www.who.int/evidence/bod[1], or Annex Table 2 of the World Health Report (WHO, 2002)). The number of male deaths attributable to occupational exposures is estimated by multiplying the total number of asthma deaths for males (3700) by the AF for occupation-related asthma in males (23.7%, Section 9.1.5).

male deaths from asthma due to occupational exposures =

total deaths in males 15 years or older × AF for asthma in males from occupational exposures

= 3700 × 0.237

= 877

1 Select: "Global burden of disease estimates", "GBD 2001 estimates", "Estimates by subregion", and "Mortality".

Therefore, for 2001, it is estimated that there were approximately 877 deaths of males 15 years or older in the AFR D subregion due to asthma caused by occupational exposures.

Using the same approach, the corresponding figure for females is estimated to be 743 (4700 × 0.158).

Therefore, for the year 2001, it is estimated there were 1620 deaths of males and females in the AFR D subregion due to asthma caused by occupational exposures.

9.1.7 Estimating DALYs due to occupational asthma

The total number of DALYs for asthma in AFR D was 447 000 for the population 15 years or older in the year 2001 (www.who.int/evidence/bod)[1]. The numbers of DALYs lost were 269 000 for males and 178 000 for females. The proportion of these that is due to occupational exposures is estimated by multiplying the total DALYs lost by the AF for asthma from occupational exposures (Section 9.1.5).

DALYs from asthma in males in AFR D due to occupational exposures =

total DALYs from asthma in males 15 years or older × AF for asthma in males from

occupational exposures

= 269 000 × 0.237

= **63 750**

Therefore, for 2001, it is estimated there were **63 750** DALYs due to asthma caused by occupational exposures in males 15 years or older in the AFR D subregion.

Using the same approach, corresponding figure for females is estimated to be **28 120** (178 000 × 0.158).

Therefore, for the year 2001, it is estimated there were **91 870** DALYs lost in the AFR D subregion due to asthma in males and females caused by occupational exposures.

9.2 Occupational COPD

The steps outlined in this section closely follow the example for occupational asthma (Section 9.1).

9.2.1 Proportion of the workforce in each industry group

The proportion of male workers in each industry group for AFR D can be obtained from ILO sources. For individual countries, the information should be available from

[1] Select: “Global burden of disease estimates”, “GBD 2001 estimates”, “Estimates by subregion”, and “DALY”.

relevant government departments and the ILO. The data used in the example for AFR D are shown in Table 12.

Table 12 Proportion of the male workforce employed in each industry, for AFR D[a]

Agricul-ture	Mining	Manufac-turing	Electrical	Construc-tion	Trade	Transpor-tation	Finance	Services	Total[b]
0.550	0.011	0.093	0.009	0.036	0.058	0.039	0.029	0.164	0.990

a Source: ILO (2000).
b Total does not equal 1.000 because of rounding.

9.2.2 Proportion of the workforce in different exposure groups

The industry information (Table 12) needs to be categorized into the exposure groups used for the relative risks. The results are shown in Table 13.

Table 13 Proportion of the male workforce employed in each exposure group[a], AFR D

Exposure group	Industries	Proportion
Background	Trade, finance, services	0.251
Low	Agriculture, electricity, transportation	0.598
Medium / High	Mining, manufacturing, construction	0.141
Total	All industries	0.990[b]

a The exposure groups are based on Korn et al. (1987).
b Total does not equal 1.000 because of rounding.

9.2.3 Proportion of the population in the workforce

The Economically Active Population for males in AFR D is obtained from ILO sources. For individual countries, the information should be available from relevant government departments and the ILO.

Economically Active Population for males 15 years or older in AFR D = 0.85

9.2.4 Proportion of the total male population in each exposure group

The proportion of the total male population (15 years and older) in each exposure group is estimated by multiplying the proportion of the male workforce in each group by the proportion of the total male population in the workforce (i.e. the Economically Active Population). The proportion of the population not in the workforce (0.15 in this case) is considered to have “background” exposure.

proportion of the total male population in an exposure group =

proportion of the male workforce in the exposure group × proportion of the total male population in workforce

The results are shown in Table 14.

Table 14 Proportion of the male workforce employed in each exposure group[a], AFR D

Exposure group	Industries	Proportion
Background	Not in workforce, trade, finance, services	0.372
Low	Agriculture, electricity, transportation	0.508
Medium / High	Mining, manufacturing, construction	0.119
Total	All industries	0.999[b]

[a] The exposure groups are based on Korn et al. (1987).
[b] Total does not equal 1.000 because of rounding.

9.2.5 Relative risk of dying from occupational COPD

The relative risks for dying from occupationally-related COPD are obtained from Table 5 (Section 6.2) and are reproduced in Table 15. Separate relative risks are used for different exposure groups, and for males and females. In the low-exposure categories, the relative risks used for WHO “A” subregions are slightly different from those used for WHO subregions B, C, D and E.

Table 15 Annual relative risks of COPD[a] mortality for males and females, by WHO subregion[b]

	Relative risk			
	Developing subregions[c]		Developed subregions[d]	
Exposure group	Males	Females	Males	Females
Unexposed	1.0	1.0	1.0	1.0
Low	1.2	1.1	1.4	1.2
High	1.8	1.4	1.8	1.4

[a] COPD = chronic obstructive pulmonary disease.
[b] Source: Korn et al. (1987). See Annex 1 in this guide for a list of countries in the WHO subregions.
[c] Developing subregions: all subregions except AMR A, EUR A and WPR A.
[d] Developed subregions: AMR A, EUR A, WPR A.

9.2.6 Estimating the attributable fraction for occupational COPD

The AF for COPD in males that arises from occupational exposure is calculated from Equation 1 (Section 7.1), using the exposure proportions (Table 14) and relative risks

(Table 15). The step-by-step calculations can easily be programmed into a Microsoft Excel spreadsheet. An example output is shown in the following boxed spreadsheet output:

$$AF = IF = \frac{\Sigma P_i RR_i - 1}{\Sigma P_i RR_i}$$

	Background	Low	High	∑
Workers exposed	0.251	0.598	0.141	
Population exposed (Pi)	0.364	0.508	0.119	
RR_i	1.000	1.200	1.800	
P_i RR_i	0.364	0.610	0.215	1.189
AF				**0.159**

Therefore, for males in AFR D, the AF for COPD arising from occupational exposures is **0.159**, or 15.9%.
Using the same approach for females produces the following results:

	Background	Low	High	∑
Workers exposed	0.239	0.714	0.057	
Population exposed (Pi)	0.597	0.378	0.030	
RRi	1.000	1.100	1.400	
Pi x RRi	0.597	0.416	0.043	1.055
AF				**0.052**

Therefore, for females in AFR D, the AF for COPD arising from occupational exposures is **0.052**, or 5.2%.

9.2.7 Estimating deaths due to occupational COPD

National statistics should be used to estimate the number of occupational COPD deaths at national level. For the example of AFR D, the total number of deaths in the year 2001 from COPD was about 52 700 in the population 15 years or older – 27 300 males and 25 400 females (www.who.int/evidence/bod[1]; or Annex Table 2 of the *World Health Report* (WHO, 2002)). The number of these male deaths attributable to occupational exposures is estimated by multiplying the total number of COPD deaths for males (27 300) by the AF for occupation-related COPD in males (15.9%, Section 9.2.6).

[1] Select: "Global burden of disease estimates", "GBD 2001 estimates", "Estimates by subregion", and "Mortality".

male deaths from COPD due to occupational exposures =

total deaths from COPD in males 15 years or older × AF for COPD in males from occupational exposures

= 27 300 × 0.159

= **4340**

Therefore, for 2001, it is estimated there were approximately **4340** deaths of males 15 years or older in the AFR D subregion due to COPD caused by occupational exposures.

Using the same approach, the corresponding figure for females is estimated to be **1320** (25 400 × 0.052).

Therefore, for 2001, it is estimated there were **5660** deaths of males and females in the AFR D subregion due to COPD caused by occupational exposures.

9.2.8 Estimating DALYs due to occupational COPD

The total number of DALYs for COPD in AFR D was 488 000 in the population 15 years or older in the year 2001 (www.who.int/evidence/bod)[1]. The numbers of DALYs lost were 269 000 for males and 219 000 for females. The proportion of these due to occupational exposures is estimated by multiplying the total DALYs lost by the AF for COPD from occupational exposures (15.9%, Section 9.2.6).

DALYs from COPD in males in AFR D due to occupational exposures =

total DALYs from COPD in males 15 years or older × AF of COPD in males from occupational exposures

= 269 000 × 0.159

= **42 770**

Therefore, for 2001, it is estimated there were **42 770** DALYs due COPD caused by occupational exposures in males 15 years or older in the AFR D subregion.

Using the same approach, the corresponding figure for females is estimated to be **11 390** (219 000 × 0.052).

Therefore, in 2001, it is estimated there were **54 160** DALYs lost in the AFR D subregion due to COPD caused by occupational exposures.

1 Select: “Global burden of disease estimates”, “GBD 2001 estimates”, “Estimates by subregion”, and “DALY”.

9.3 Pneumoconioses

9.3.1 Estimating deaths due to pneumoconioses

Estimates of the number of deaths due to pneumoconioses come directly from the deaths data, since we assume that all deaths due to pneumoconioses are due to work-related exposures. Information on the number of deaths from pneumoconioses is not easily available for AFR D, so a calculation with numbers is not presented here.

number of male deaths due to pneumoconioses =
number of male deaths from pneumoconioses due to occupational exposures

number of female deaths due to pneumoconioses =
number of female deaths from pneumoconioses due to occupational exposures

9.3.2 Estimating DALYs due to pneumoconioses

Estimates of the number of DALYs due to occupational pneumoconioses also come directly from DALY estimates for pneumoconioses, with all cases assumed to have been due to work-related exposures. Since there are no data for AFR D no calculation is presented here.

10. Policy actions to reduce the burden of disease

Assessments of the burden of disease can be important guides for policy-makers. They allow the effects of different risk factors to be compared, and can therefore help in prioritizing health issues. Various options are available to reduce the burden of occupation-related asthma, COPD and pneumoconiosis. The primary approach is to stop or minimize exposure to causative substances. Ideally, this involves eliminating the substance from work tasks, either by modifying the work task, or by substituting the causative substance with a less hazardous one. In extreme cases, substances can be banned or restricted by government statute. However, such elimination or substitution may be practically difficult, and engineering solutions are often required. These include isolating the process from the worker, enclosing the process, decreasing dust levels through wet-work methods, and using ventilation to decrease the concentration of the substance in the breathing zone.

These approaches should be used first, but if they do not result in suitable levels of exposure, then personal protective equipment, such as respirators, may be required. Such equipment should not be used as the sole means of exposure control, because the equipment is often hard to use for extended periods, and can be hard to maintain. Therefore, personal protective equipment cannot be relied upon to decrease exposures to the levels that might be expected if the equipment were used exactly as intended during all periods of potential exposure.

Administrative approaches can also be used to minimize the effects of exposure, including: regular exposure monitoring, either environmental or personal; restricting the number of workers who conduct tasks that involve hazardous or potentially hazardous exposures; and limiting the length of time that workers are exposed. For occupational asthma and COPD, such approaches are not straightforward, because most of the causative agents have not been identified. Nevertheless, minimizing exposures to substances known to be harmful should control the main causal exposures for these conditions. For pneumoconiosis, the traditional approach outlined above should be appropriate.

As an example of global action, ILO and WHO have created the Global Campaign for the Elimination of Silicosis. It is designed to assist countries eliminate silicosis as an occupational health problem. Aspects of implementing such a programme at national level are discussed in Box 1.

Box 1 Implementation of a national programme to eliminate silicosis

Evidence from several countries, including Australia, Belgium, Canada, Finland, France, Germany, Japan, Switzerland, Sweden, United Kingdom, and USA, has demonstrated that well-organized prevention programmes can significantly reduce the incidence rate of silicosis. The success in preventing silicosis evidently derives from a range of preventive measures.

At the national level, the necessary elements of a sound infrastructure to combat silicosis are: effective laws and regulations, and their enforcement; the adoption of occupational exposure limits and relevant technical standards; governmental advisory services; effective inspection and reporting systems; and a national action programme involving government institutions, industry and trade unions.

At the enterprise level, it is imperative to: use technologies that do not generate silica-containing dust; use engineering methods of dust control; comply with prescribed exposure limits and technical standards; assess the effectiveness of preventive measures in the workplace; conduct surveillance of workers' health to detect the development of silicosis early; use personal protective equipment (as a temporary measure); and provide health education and training for the workers. Cooperation between employers and workers is critical for success.

Technical knowledge and professional expertise are important elements in the fight against silicosis. Qualified personnel should be trained in using appropriate technologies and methods of dust control, and given access to relevant information. To assess the efficiency of prevention measures, and to be able to recommend effective prevention measures, the technologies used to control silica dusts should also be evaluated.

With due attention to local conditions, a national programme to eliminate silicosis should comprise the following main elements:

– the socioeconomic context of silicosis in the country;
– economic incentives for preventing silicosis;
– the identification of groups of workers at risk;
– a definition of the prevention strategy;
– the involvement of principal partners in the implementation of the programme;
– tripartite consultation and cooperation;
– an institutional framework for programme implementation;
– a mechanism for monitoring and evaluation;
– national standards and a link with international standards;
– the protection of the general environment.

A more detailed national action plan to eliminate silicosis can accompany the national programme, and be a compilation of actions necessary to achieve targets set up by the national programme. The action plan should indicate how to mobilize resources; make contributions in kind; exchange technical information and expertise; set up an institutional framework for cooperation; and establish partnerships to implement the programme.

Positive experiences by many countries show that it is possible to reduce significantly the incidence rate of silicosis by using appropriate technologies and methods of dust control. The use of these technologies and methods has proved to be effective and economical.

11. References

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Annex 1 Country groupings for the WHO Global Burden of Disease study, by WHO subregion[a]

Subregion[b]		WHO Member States
AFR	D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo.
AFR	E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.
AMR	A	Canada, Cuba, United States of America.
AMR	B	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela.
AMR	D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru.
EMR	B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates.
EMR	D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen.
EUR	A	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom.
EUR	B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia.
EUR	C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine.
SEAR	B	Indonesia, Sri Lanka, Thailand.
SEAR	D	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal, Timor Leste.
WPR	A	Australia, Brunei Darussalam, Japan, New Zealand, Singapore.
WPR	B	Cambodia, China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

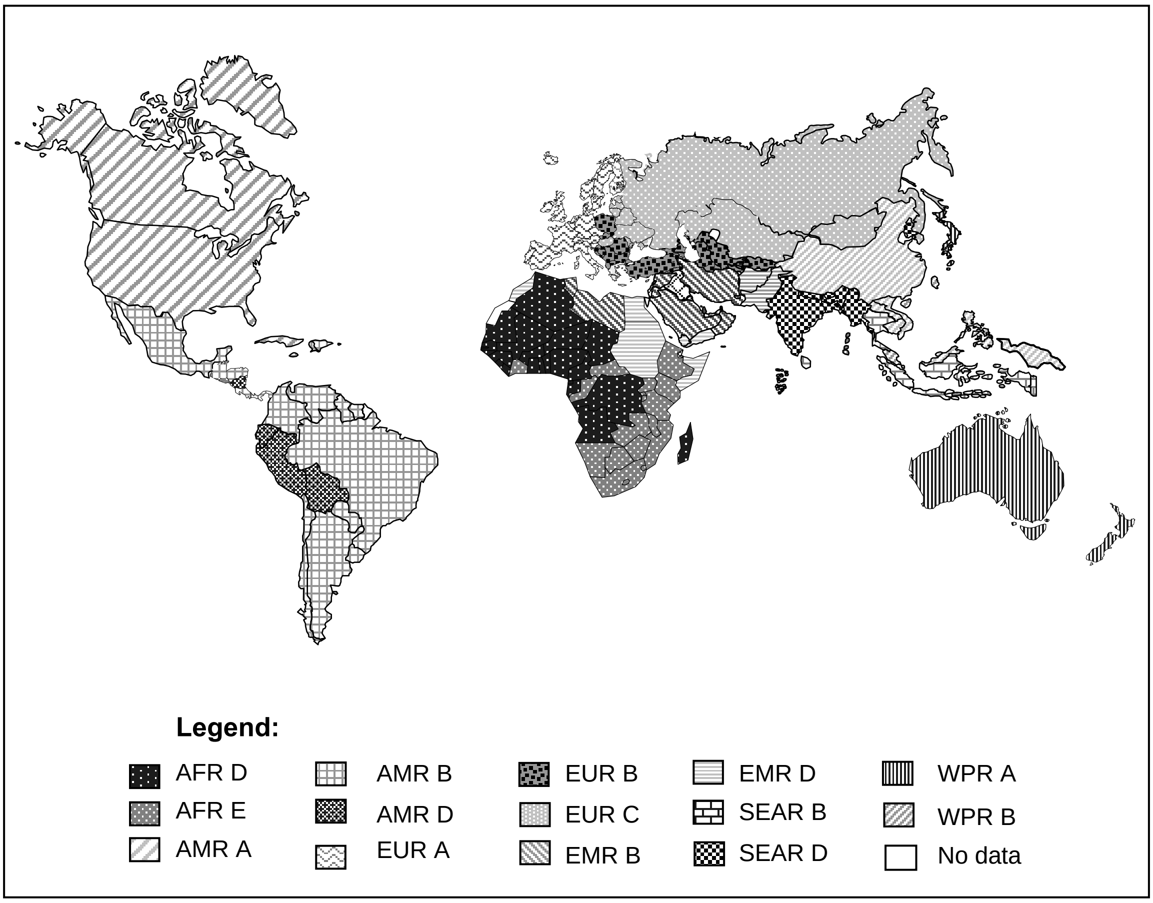
[a] Source: WHO (2002).

[b] Subregions: AFR = Africa; AMR = Americas; EMR = Eastern Mediterranean; EUR = Europe; SEAR = South-East Asia; WPR = Western Pacific; A: Very low child, very low adult mortality; B: Low child, low adult mortality; C: Low child, high adult mortality; D: High child, high adult mortality; E: High child, very high adult mortality.

Annex 2 Summary results of the global assessment of the disease burden from occupational airborne particulates

The approach described in this guide was also used in a global analysis of the disease burden caused by occupational exposures to risk factors (WHO, 2002; Concha-Barrientos et al., 2004). One of the risk factors examined was occupational airborne particulates. The analysis was performed for the year 2000 for each of the 14 WHO subregions of the world (Figure A1, and Annex 1), and the results were reported both for age and sex groups.

Figure A2.1 Subregional country groupings for the global disease burden



This is only a schematic representation. The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Many respiratory conditions can arise directly, or indirectly, from work. However, it was not possible to estimate exposures, risks or attributable proportions for many of the conditions at international or national levels because there were no data. Therefore, only the more important of the work-related respiratory conditions, in terms of the total number of cases or the risks arising from exposure, are included here. Malignant respiratory diseases are described in a separate guide in this series, on occupational carcinogens.

Two different approaches were used to estimate the proportion of the population in each subregion exposed to agents related to asthma and to COPD. Exposure to agents associated with asthma was based on the distribution of the Economically Active Population[1] into occupational categories, which have varying relative risks for asthma. Exposure to agents associated with COPD was based on the distribution of the Economically Active Population into nine industrial subsectors[2], each of which was rated as having background, low or high exposure. The primary data sources used to estimate exposures included: World Bank (2001); ILO (1995, 2001, 2002); published literature on the prevalence and level of exposure to occupational airborne particulates; and published literature on the epidemiology of health outcomes linked to occupational airborne particulates.

The data of Karjalainen et al. (2001, 2002) were used to estimate the relative risks of asthma for occupational categories. This was done by adapting the occupational categories in the study to globally available statistics. Those not working and those employed in administration were considered to be in the nonexposed reference category (relative risk = 1.0). The calculations were done separately for men and women in each WHO subregion. The relative risks for each occupational category were applied to all ages above 15 years. Table A2.1 summarizes the proportions of the labour force in each occupational category. The relative risks applied to these categories are the same as those presented in this guide (Section 6.1, Table 4).

[1] Includes people in paid employment, the self-employed, and people who work to produce goods and services for their own household consumption

[2] Industrial subsectors comprise agriculture, mining, manufacturing, utilities, construction, trade, transport, finance and services.

Table A2.1 Distribution of the labour force population into occupational categories, by subregion and sex[a]

		Occupation									
Sub-region	**Sex**	**Background**	**Admini-stration**	**Technical**	**Sales**	**Agricultural**	**Mining**	**Transpor-tation**	**Manufac-Turing**	**Services**	**Totals**
AFR D	Male	0.1595	0.0498	0.0562	0.0513	0.4612	0.0081	0.0289	0.1342	0.0510	1.0
	Female	0.4645	0.0249	0.0303	0.0324	0.3551	0.0012	0.0145	0.0482	0.0288	1.0
AFR E	Male	0.1510	0.0524	0.0618	0.0447	0.4662	0.0082	0.0219	0.1377	0.0563	1.0
	Female	0.3498	0.0360	0.0497	0.0328	0.4171	0.0010	0.0114	0.0547	0.0475	1.0
AMR A	Male	0.2746	0.1971	0.1080	0.0875	0.0327	0.0035	0.0196	0.1940	0.0830	1.0
	Female	0.4079	0.1772	0.1223	0.0789	0.0134	0.0005	0.0080	0.0928	0.0991	1.0
AMR B	Male	0.1896	0.1124	0.0794	0.0665	0.1592	0.0077	0.0310	0.2225	0.1317	1.0
	Female	0.5823	0.0662	0.0671	0.0410	0.0531	0.0013	0.0032	0.0878	0.0979	1.0
AMR D	Male	0.1785	0.1894	0.0346	0.0912	0.0521	0.0020	0.0386	0.3115	0.1021	1.0
	Female	0.6110	0.1033	0.0198	0.0466	0.0119	0.0001	0.0026	0.1328	0.0719	1.0
EMR B	Male	0.2134	0.1042	0.1499	0.0854	0.1194	0.0046	0.0409	0.2072	0.0749	1.0
	Female	0.6903	0.0523	0.0866	0.0443	0.0293	0.0001	0.0101	0.0463	0.0407	1.0
EMR D	Male	0.1805	0.0419	0.0490	0.1742	0.3584	0.0014	0.0000	0.1465	0.0480	1.0
	Female	0.6303	0.0110	0.0105	0.0509	0.2427	0.0002	0.0000	0.0401	0.0142	1.0
EUR A	Male	0.3227	0.1176	0.2145	0.0252	0.0420	0.0040	0.0000	0.1934	0.0807	1.0
	Female	0.5296	0.0942	0.1889	0.0131	0.0254	0.0008	0.0033	0.0733	0.0713	1.0
EUR B	Male	0.2593	0.0747	0.0680	0.0400	0.2133	0.0136	0.0226	0.2490	0.0595	1.0
	Female	0.4624	0.0453	0.0552	0.0131	0.2352	0.0020	0.0041	0.1379	0.0449	1.0
EUR C	Male	0.2700	0.0946	0.0532	0.0317	0.1536	0.0212	0.1097	0.2239	0.0421	1.0
	Female	0.4269	0.0818	0.0542	0.0512	0.0919	0.0138	0.1041	0.1239	0.0522	1.0
SEAR B	Male	0.1756	0.0599	0.0482	0.0729	0.3664	0.0051	0.0336	0.1930	0.0452	1.0
	Female	0.4240	0.0397	0.0368	0.0812	0.2487	0.0013	0.0032	0.1244	0.0407	1.0
SEAR D	Male	0.1502	0.0645	0.0550	0.0150	0.4634	0.0149	0.0392	0.1535	0.0444	1.0
	Female	0.5298	0.0134	0.0125	0.0028	0.3781	0.0026	0.0000	0.0509	0.0098	1.0
WPR A	Male	0.2447	0.2058	0.1023	0.0787	0.0336	0.0014	0.0340	0.2270	0.0723	1.0
	Female	0.4795	0.1410	0.0832	0.0755	0.0281	0.0002	0.0094	0.1118	0.0713	1.0
WPR B	Male	0.1600	0.1023	0.0655	0.0454	0.3659	0.0194	0.0370	0.1399	0.0645	1.0
	Female	0.2901	0.0928	0.0588	0.0753	0.2812	0.0066	0.0290	0.0925	0.0738	1.0

[a] Each occupational category has a different relative risk for asthma

To estimate the proportion of workers exposed to airborne particulates that cause COPD, the workforce data of Korn et al. (1987) were distributed into the nine industrial subsectors, and into levels of exposure. In the Korn et al. study, self-reported exposures to dust (current and past exposures) were linked to some categories of industrial subsectors among the currently employed. Low-exposure was assigned to workers in finance; medium-exposure to those involved in the manufacture of nondurable goods, transportation, utilities, and the wholesale and retail trades; and high-exposure to those involved in the manufacture of durable goods, agriculture, mining or construction. Exposure was to “dusts” and to “gases”, terms not further defined in the study.

For the global analysis, nonexposed individuals were defined as those not in the workforce or those in utilities, trade, finance and services. Workers in agriculture, manufacturing, and transportation were defined as having low exposure, while those in mining and construction were defined as having high exposure. The results are shown in Table A2.2.

Table A2.2 Proportion of the population exposed to agents that cause COPD, by subregion, sex and level of exposure

		Proportion ever exposed	
Subregion	**Exposure level**	**Male**	**Female**
AFR D	Background	0.3722	0.5920
	Low	0.5086	0.3776
	High	0.1192	0.0305
AFR E	Background	0.3744	0.5386
	Low	0.5051	0.4365
	High	0.1204	0.0249
AMR A	Background	0.6879	0.9056
	Low	0.0879	0.0314
	High	0.2242	0.0630
AMR B	Background	0.5653	0.8908
	Low	0.2336	0.0553
	High	0.2011	0.0539
AMR D	Background	0.6465	0.9337
	Low	0.1253	0.0169
	High	0.2281	0.0494
EMR B	Background	0.5829	0.9256
	Low	0.2007	0.0441
	High	0.2164	0.0303
EMR D	Background	0.5818	0.7780
	Low	0.2204	0.1776
	High	0.1978	0.0444
EUR A	Background	0.6819	0.8965
	Low	0.0565	0.0253
	High	0.2616	0.0781
EUR B	Background	0.5096	0.6598
	Low	0.2636	0.2469
	High	0.2268	0.0933
EUR C	Background	0.4312	0.6463
	Low	0.3273	0.2409
	High	0.2415	0.1128
SEAR B	Background	0.4190	0.6694
	Low	0.4112	0.2384
	High	0.1698	0.0922
SEAR D	Background	0.3965	0.5723
	Low	0.4822	0.3869
	High	0.1213	0.0408
WPR A	Background	0.5994	0.8387
	Low	0.1200	0.0531
	High	0.2806	0.1082
WPR B	Background	0.3700	0.5244
	Low	0.4474	0.3807
	High	0.1826	0.0949

The relative risks for COPD for each of these exposure categories were the same as those given earlier (Section 6.2, Table 5).

The resulting disease burdens from occupational airborne particulates for the 14 WHO subregions are summarized in Tables A2.3 to A2.6. A breakdown of the data by disease, age group and sex is given in Tables A2.7 and A2.8.

The analysis suggested that COPD from exposure to occupational airborne particulates accounted for 12% of the total COPD mortality, amounting to 318 000 deaths, and 13% of all COPD DALYs. Asthmagens were estimated to cause 17% of the total asthma mortality, amounting to 38 000 deaths, and 11% of all asthma DALYs. Globally, asthma and COPD from occupational airborne particulates account for 0.6% for all deaths and 0.4% of DALYs. Most of this burden (ca. 77%) occurs in males. Occupational asthmagens disproportionally affect the young, with 55% of the burden borne by the 15–29 years age group.

Table A2.3 Attributable fractions for mortality from asthma and COPD caused by workplace exposure[a]

	Asthma			COPD		
Subregion	**Males**	**Females**	**Total**	**Males**	**Females**	**Total**
AFR D	21	15	18	16	5	11
AFR E	23	18	20	16	5	11
AMR A	15	9	11	18	3	11
AMR B	20	8	13	17	3	11
AMR D	19	7	13	15	2	9
EMR B	18	5	12	17	2	11
EMR D	20	10	16	17	3	11
EUR A	16	7	11	19	4	13
EUR B	22	14	18	19	6	14
EUR C	21	12	18	21	6	16
SEAR B	23	14	18	18	6	13
SEAR D	23	14	18	16	5	11
WPR A	17	9	13	21	5	16
WPR B	22	16	19	19	7	12
World	21	13	17	18	6	12

[a] Source: Concha-Barrientos et al. (2004). Attributable fractions are shown as percentages.

Table A2.4 Attributable fractions for the burden of disease (DALYs) for asthma and COPD caused by workplace exposure[a]

Subregion	Asthma			COPD		
	Males	Females	Total	Males	Females	Totals
AFR D	11	7	10	16	5	11
AFR E	13	9	11	16	5	12
AMR A	9	4	7	18	3	11
AMR B	12	4	8	17	3	10
AMR D	11	3	7	13	1	7
EMR B	11	2	7	17	2	12
EMR D	14	6	10	17	3	11
EUR A	11	4	8	19	4	12
EUR B	15	8	12	19	6	13
EUR C	18	8	14	21	6	14
SEAR B	16	9	13	18	6	13
SEAR D	17	10	13	16	5	11
WPR A	12	5	9	21	5	14
WPR B	15	9	12	19	7	14
World	14	7	11	18	6	13

[a] Source: Concha-Barrientos et al. (2004). Attributable fractions are shown as percentages.

Table A2.5 Numbers of deaths from asthma and COPD caused by workplace exposure[a]

Subregion	Asthma			COPD			% of total
	Males	Females	Total	Males	Females	Total	deaths
AFR D	1	1	2	4	1	6	0.2
AFR E	2	1	3	5	1	7	0.2
AMR A	0	0	1	12	2	14	0.5
AMR B	1	0	1	8	1	9	0.4
AMR D	0	0	0	0	0	0	0.0
EMR B	0	0	0	1	0	1	0.1
EMR D	2	1	2	7	1	8	0.3
EUR A	1	1	1	16	2	18	0.5
EUR B	1	1	2	5	1	7	0.5
EUR C	2	1	3	12	2	15	0.5
SEAR B	2	2	4	8	1	9	0.6
SEAR D	7	5	12	47	13	60	0.6
WPR A	1	0	1	3	0	4	0.4
WPR B	3	3	6	109	52	161	1.6
World	23	15	38	240	78	318	0.6

[a] Source: Concha-Barrientos et al. (2004). The numbers of deaths are given in thousands.

Table A2.6 DALYs from asthma and COPD caused by workplace exposure[a]

Subregion	Asthma Males	Asthma Females	Asthma Total	COPD Males	COPD Females	COPD Total	% of total DALYs
AFR D	63	27	90	43	10	53	0.1
AFR E	84	56	141	57	12	69	0.1
AMR A	37	15	51	147	21	168	0.5
AMR B	98	27	125	115	17	132	0.3
AMR D	16	4	19	6	0	6	0.1
EMR B	18	3	21	20	1	20	0.2
EMR D	74	27	100	75	13	87	0.2
EUR A	41	14	55	176	29	205	0.5
EUR B	30	13	43	75	19	94	0.3
EUR C	32	9	41	135	34	169	0.4
SEAR B	44	26	70	90	21	111	0.3
SEAR D	310	166	476	552	149	701	0.3
WPR A	23	9	33	44	9	53	0.5
WPR B	241	115	356	1485	378	1862	0.9
World	1110	511	1621	3020	713	3733	0.4

[a] Adapted from Concha-Barrientos et al. (2004). The numbers of DALYs are given in thousands.

Table A2.7 Age-specific mortality attributable fractions, deaths and DALYs for asthma and COPD, males

	Age group (years) 15–29	30–44	45–59	60–69	70–79	80–89	Totals for males of all ages
Attributable fractions (%)							
Asthma	23	23	23	22	22	21	21
COPD	17	18	18	18	18	19	18
Deaths (000s)							
Asthma	3	4	6	4	4	2	23
COPD	0	3	29	56	91	62	240
DALYs (000s)							
Asthma	670	228	144	43	20	5	1110
COPD	88	564	992	710	517	149	3020

[a] Source: Concha-Barrientos et al. (2004).

Table A2.8 Age-specific mortality attributable fractions, deaths and DALYs for asthma and COPD, females[a]

	Age group (years)						Totals for females of all ages
	15–29	**30–44**	**45–59**	**60–69**	**70–79**	**80–89**	
Attributable fractions (%)							
Asthma	13	14	14	13	13	12	13
COPD	6	5	5	6	6	6	6
Deaths (000s)							
Asthma	2	3	4	2	2	2	15
COPD	0	1	6	13	28	30	78
DALYs (000s)							
Asthma	228	95	81	28	15	5	511
COPD	45	133	149	152	166	69	713

[a] Source: Concha-Barrientos et al. (2004).