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Solar ultraviolet radiation

Assessing the environmental burden of disease
at national and local levels

Robyn Lucas



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Editors

Annette Prüss-Ustün and Emilie Perkins van Deventer

A Microsoft Excel spreadsheet for calculating the estimates described in this document can be obtained from WHO/PHE. E-mail contact: EBDassessment@who.int



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Preface

Exposure to ultraviolet radiation (UVR) from the sun is a well-known risk factor for human disease. Indeed, in many countries, skin cancers are the most common types of cancer and account for a large economic burden to health-care systems. The health risks associated with exposure to UVR are distributed unevenly across the world, depending on the match between skin type and ambient levels of UVR. However, public health policies promoting appropriate sun protection at both personal and population levels may contribute to the reduction of health risks from UVR exposure. Indeed, many countries have developed comprehensive sun protection programmes.

Quantitative assessment of the size and distribution of UVR-associated health risks can be an important tool in comparing the associated disease burden with that due to other risk factors to guide public health spending and the focus of sun protection programmes. Such assessments will also provide a means for countries to assess the relative risks and benefits of UVR exposure with regard to their specific population and location. This guide provides a method by which countries can estimate their current disease burden (in terms of incidence, mortality and a combined measure of mortality and morbidity, called disability-adjusted life years) from UVR exposure—and thus the burden that could be avoided by use of selected protective measures.

This guide is based on the methods developed in the framework of the global assessment of burden of disease from UVR (Lucas et al., 2006). Certain methodological aspects are only summarized in the present guide but can be found in more detail in the global assessment.

This guide is part of a series providing guidance on quantifying the disease burden from various environmental risks. It is complemented by an introductory volume on methods for estimating the environmental burden of disease (Prüss-Üstün et al., 2003).

Affiliations and acknowledgement

This document is based on previous work on the global assessment of the burden of disease due to solar UVR (Lucas et al., 2006). Dr Robyn Lucas is a researcher at the National Centre for Epidemiology and Population Health, Canberra, Australia. The other authors of the global assessment include Professor Anthony McMichael, National Centre for Epidemiology and Population Health, Canberra, Australia; Professor Bruce Armstrong, School of Public Health, University of Sydney, Sydney, Australia; and Professor Wayne Smith, Centre for Clinical Epidemiology and Biostatistics, University of Newcastle, Newcastle, Australia.

The global assessment was carried out in the framework of the INTERSUN programme, a global project that is engaged in protecting the public from health hazards associated with UVR exposure. Editorial and scientific support at the World Health Organization was provided by Drs Colin Mathers, Emilie Perkins van Deventer, Annette Prüss-Üstün, Michael Repacholi and Hajo Zeeb.

Acronyms

BCC	basal cell carcinoma of the skin
CMM	cutaneous malignant melanoma
DALY	disability-adjusted life year
DNA	deoxyribonucleic acid
HIV	human immunodeficiency virus
ICD-10	International Classification of Diseases 10
NMSC	non-melanoma skin cancers
PAF	population attributable fraction
SCC	squamous cell carcinoma
SCCC	squamous cell carcinoma of the cornea and conjunctiva
SPF	sun protection factor
UV	ultraviolet
UVA	ultraviolet radiation A
UVB	ultraviolet radiation B
UVC	ultraviolet radiation C
UVR	ultraviolet radiation
WHO	World Health Organization

Summary

This guide aims at assisting countries or regions in estimating their disease burden caused by solar ultraviolet radiation (UVR). Several approaches with different degrees of precision are proposed, depending on the availability and precision of input data, such as incidence and mortality rates. The methods were derived from the previous global assessment of the burden of disease from solar UVR (Lucas et al., 2006). In that assessment, an estimated 56 000 deaths per year worldwide were caused by solar UVR.

The disease outcomes addressed in the estimations include melanoma, squamous cell and basal cell carcinoma of the skin, squamous cell carcinoma of the cornea and conjunctiva, solar keratosis, pterygium, cortical cataract, sunburn and reactivation of herpes labialis. Owing to the limited evidence, only adverse effects from inappropriate overexposure are addressed by the proposed methods. It is, however, acknowledged that UVR also has beneficial health effects, and it is essential to determine conditions associated with these benefits while minimizing the risk of adverse effects.

The proposed methods range from rough and succinct to more sophisticated, work-intensive and precise, according to the specific requirements and available data. First rough estimates are provided by country and by disease, which can be refined if additional data and/or local evidence (e.g. on skin pigmentation or personal sun exposure habits) are available.

1. Introduction to the risk factor

Sunlight is central to life on earth—without the warmth (infrared wavelengths of solar radiation) and light (visible light wavelengths) provided by the sun, humankind could not survive. Ultraviolet radiation (UVR) is another part of the spectrum of electromagnetic radiation emitted by the sun, with wavelengths shorter than those of visible light. It can be divided into three bands of biological effect, based on wavelength: UVA (315–400 nm), UVB (280–315 nm) and UVC (<280 nm) (Roy et al., 1998). Earth's atmosphere absorbs all UVC and over 90% of incoming solar UVB. UVA passes through the atmosphere relatively unchanged.

UVA penetrates human skin more deeply than UVB, but has been considered less damaging than UVB and primarily responsible for skin changes typical of photoageing (wrinkling and sunspots on the skin). UVB causes particular deoxyribonucleic acid (DNA) damage (“signature mutations”) that is a key factor in the initiation of skin cancer (IPCS, 1994; Horneck, 1995). Notably, stratospheric ozone blocks UVR in the UVB wavelengths from reaching Earth's surface; the health risks from stratospheric ozone depletion arise from this consequent greater contribution of DNA-damaging UVB to ambient UVR. Very recently, however, the relative importance of UVA and UVB wavelengths, particularly for the development of cutaneous malignant melanoma (CMM), has been challenged, with growing evidence for an important role for UVA. Therefore, the International Agency for Research on Cancer (IARC) has now classified the whole ultraviolet radiation spectrum (UVA, UVB and UVC) as carcinogenic to humans (El Ghissassi et al., 2009).

The amount of UVR reaching Earth's surface (ambient UVR) depends on the following parameters:

- the angle at which the sun's rays pass through the atmosphere (more intense solar irradiation at lower latitudes nearer to the equator, at midday and in summer);
- the air mass through which the solar radiation must pass (more intense UVR at higher altitudes);
- the presence of clouds and pollution in the lower atmosphere (Diffey, 2002).

The highest UVR levels thus occur in countries close to the equator with clear skies, particularly during the middle hours of the day in summer. The personal UVR dose depends on the intensity of the ambient UVR, the duration of exposure, the body surface exposed and, for the skin, the level of (protective) skin pigmentation.

There is a tendency to see UVR overexposure as a risk factor for disease only in countries of warmer climates, and to a certain degree this is true. However, with increasing affluence and global mobility, many persons entirely unsuited to environments of high ambient UVR (fair-skinned, blue-eyed, red-haired persons) are now enjoying them, including for brief intense exposure during holidays. In the opposite case, persons naturally unsuited to environments of low ambient UVR (e.g. dark-skinned persons wearing clothing that limits skin surface exposure) may show the effects of UVR underexposure, in particular vitamin D deficiency.

It is now clear that it is UVR exposure that is inappropriate for skin type (high exposure in fair-skinned persons, low exposure in dark-skinned persons) that causes disease, rather than “underexposure” or “overexposure” per se. For each country, the relative importance of underexposure and overexposure as a cause of disease will differ, depending on the genetic skin type of the population, typical sun exposure patterns, the age distribution and the ambient UVR. The methods for disease burden estimation outlined in this guide refer to UVR exposure that is not optimal for the individual (compared with the counterfactual exposure, which is the “optimal exposure for the individual”). These disease burdens would comprise those resulting from underexposure or overexposure to UVR. In practice, however, the evidence and data on the disease burden due to current levels of underexposure are not sufficiently defined to allow quantitative estimates to be completed.

In this work, the exposure variable is *erythemally weighted UVR*. That is, the wavelengths of ambient UVR are weighted to the erythema action spectrum¹ (taking account of the higher erythema potential of UVB, but the greater proportion of ambient UVR that is UVA).

¹ The erythema action spectrum is defined by the Commission Internationale d’Eclairage and weights UVR wavelengths according to their biological effectiveness (CIE, 1998). Biologically effective UVR as used here is expressed as joules per square metre (J/m^2).

2. Evidence of health impacts from UVR

The evidence base for the relationship between exposure to UVR and various health outcomes has recently been reviewed (Lucas et al., 2006) and constitutes the basis for the current guide.

Adverse health outcomes fall into two major groups:

1. outcomes associated with higher levels of UVR exposure than are appropriate for skin type;
2. outcomes associated with insufficient UVR exposure to maintain adequate vitamin D levels.

The health outcomes associated with UVR exposure are listed in Table 1. Of those with strong evidence of causality, some outcomes have been excluded from the analysis, including those of sporadic occurrence with lack of suitable incidence or prevalence data (acute photokeratitis and photoconjunctivitis [snow blindness] and acute solar retinopathy [eclipse blindness]) and those representing an idiosyncratic reaction to sunlight (photodermatoses). The remaining nine diseases, primarily affecting the skin and eyes, are considered here for burden of disease assessment based on a comparative risk assessment methodology (WHO, 2002a; Ezzati et al., 2004).

Over time, with new evidence accruing, some of those diseases currently only “associated with UVR” (i.e. only in the left column of Table 1) may be reclassified as having “strong evidence of causality” with UVR and could also be included in burden of disease assessments.

This section, which is based on a previous comprehensive review of the literature (Lucas et al., 2006), summarizes the evidence suggesting that UVR exposure is a causal risk factor for each of the nine selected disease outcomes. It further provides a basis for the proposed approach for estimating the disease burden due to UVR exposure at national, regional or local levels.

Diseases that result from excess UVR exposure are primarily diseases affecting older age groups. Cumulative damage from ongoing UVR exposure and possibly a long time lag between exposure and disease generally account for this. In contrast, UVR underexposure in the very young may lead, in certain cases, to the most important disease burden, if measured in disability-adjusted life years (DALYs), since diseases such as rickets affect young children and may cause ongoing disability for the remaining years of life.

Table 1 Candidate and selected health outcomes to be assessed for the disease burden due to UVR

Outcomes associated with UVR	Outcomes with strong evidence of causality	Outcomes with proposed methods for burden of disease assessment
Immune effects		
Acute		
Suppression of cell-mediated immunity		
Increased susceptibility to infection		
Impairment of prophylactic immunization		
Reactivation of latent viral infection - herpes labialis	Reactivation of latent viral infection - herpes labialis	Reactivation of latent viral infection - herpes labialis
Chronic		
Reactivation of latent viral infection - human papillomavirus		
Rheumatoid arthritis ^a		
Type 1 diabetes mellitus ^a		
Multiple sclerosis ^a		
Effects on the eyes		
Acute		
Acute photokeratitis and photoconjunctivitis	Acute photokeratitis and photoconjunctivitis	
Acute solar retinopathy	Acute solar retinopathy	
Chronic		
Climatic droplet keratopathy		
Pterygium	Pterygium	Pterygium
Pinguecula		
Squamous cell carcinoma of the cornea	Squamous cell carcinoma of the cornea	Squamous cell carcinoma of the cornea
Squamous cell carcinoma of the conjunctiva	Squamous cell carcinoma of the conjunctiva	Squamous cell carcinoma of the conjunctiva
Cataract	Cortical cataract	Cortical cataract
- cortical cataract		
- sub-capsular cataract		
- nuclear cataract		
Ocular melanoma		
Macular degeneration		
Effects on the skin		
Acute		
Sunburn	Sunburn	Sunburn
Photodermatoses	Photodermatoses	
Chronic		
Cutaneous malignant melanoma	Cutaneous malignant melanoma	Cutaneous malignant melanoma
Cancer of the lip		
Basal cell carcinoma of the skin	Basal cell carcinoma of the skin	Basal cell carcinoma of the skin
Squamous cell carcinoma of the skin	Squamous cell carcinoma of the skin	Squamous cell carcinoma of the skin
Chronic sun damage	Photoageing/solar keratoses	Photoageing/solar keratoses
- photoageing		
- solar keratoses		
Other direct effects		
Acute		
Medication reactions		
Chronic		
Vitamin D production ^a	Vitamin D production	Vitamin D production
- rickets, osteomalacia, osteoporosis	- rickets, osteomalacia, osteoporosis	- rickets, osteomalacia, osteoporosis
- tuberculosis		

Outcomes associated with UVR	Outcomes with strong evidence of causality	Outcomes with proposed methods for burden of disease assessment
Non-Hodgkin lymphoma ^a		
Other cancers ^a		
- prostate		
- breast		
- colon		
Hypertension ^a		
Psychiatric disorders ^a		
- seasonal affective disorder		
- schizophrenia		
- general well-being		
Indirect effects		
Effect on climate, food supply, disease vectors, atmospheric chemistry		

^a Possible beneficial effects of adequate UVR exposure (Lucas et al., 2006; see section 2.9).

2.1 Cutaneous malignant melanoma

CMM arises from pigment cells (melanocytes) in the dermis and epidermis of the skin. It affects all ages from mid-teens to the elderly and is responsible for most deaths from skin cancer (International Classification of Diseases 10 [ICD-10] code C43; WHO, 2007). A large body of literature supports the causation of CMM by UVR exposure (reviewed in Lucas et al., 2006) (see Box 1 for supporting evidence).

Box 1: Evidence supporting UVR as causative of CMM

- Positive association between melanoma incidence and residence at lower latitudes
- Decreased risk of melanoma in those who migrated in childhood from an area of low ambient UVR to an area of high ambient UVR (compared with those born in the area of high ambient UVR and still resident there)
- Body site distribution that mirrors those areas of the body usually exposed to sunlight
- Correlation with freckling and development of non-melanocytic naevi
- Low incidence of melanoma in people with deeply pigmented skin
- Increased risk of melanoma with a history of intermittent heavy sun exposure and sunburn

The population attributable fraction (PAF)—the proportion of the total burden of disease that is due to exposure to an environmental risk factor—for UVR as a causative factor for CMM has been estimated as >0.9 from ecological studies, but approximately 0.2 in individual-level case-control studies (probably due to difficulties in defining past exposure accurately). In the global assessment of disease burden due to UVR (Lucas et al., 2006), a synthesis of the evidence resulted in a PAF range of 0.5–0.9 to account for these different estimates.

Many countries maintain disease registers of the incidence of and mortality from CMM (as well as other cancers). These figures are collated by the International Agency for Research on Cancer and are readily available.¹

2.2 Non-melanoma skin cancers

The UVR-related non-melanoma skin cancers (NMSC) consist of squamous cell carcinoma of the skin (SCC) and basal cell carcinoma of the skin (BCC) (ICD-10 code C44 for “other malignant neoplasms of skin”; WHO, 2007). Few countries maintain comprehensive disease registers for NMSC. However, many epidemiological studies have estimated the incidence of and/or mortality from these diseases in a small area. We used these data and measures of ambient UVR (from satellite monitoring, available from the International Research Institute for Climate and Society),² to derive population-level dose–response relationships. In the framework of the global assessment (Lucas et al., 2006), NMSC incidence and mortality were estimated on the basis of these dose–response relationships.

(a) Squamous cell carcinoma of the skin

SCC is a malignant tumour arising from the squamous cells of the epithelium (ICD-10 code C44; WHO, 2007). The epidemiological and biological evidence supporting a causal link between UVR exposure and SCC is convincing (reviewed in Lucas et al., 2006; see Box 2).

Box 2: Evidence supporting UVR as causative of SCC

- Increased risk in persons with light complexion and increased sensitivity of the skin to sunburn
- Increased incidence in patients with xeroderma pigmentosum (a hereditary disease in which there is defective repair of sun-damaged DNA), particularly on sun-exposed areas
- High incidence in African albinos
- Site distribution corresponds to the areas of greatest sun exposure
- Increased risk related to total lifetime sun exposure, but particularly occupational exposure
- Regular use of broad-spectrum sunscreen can decrease the incidence of SCC
- Association with solar or actinic keratoses, freckling and loss of skin elasticity, caused by UVR exposure
- Evidence of mutation in *TP53* gene (tumour suppressive) and DNA damage following UVR exposure
- Development of SCC in neonatal foreskins (grafted onto mice) following chronic exposure to UVR

In the global assessment for UVR as a risk factor for SCC (Lucas et al., 2006), the PAF range was estimated as 0.5–0.7 in lightly pigmented populations, based on a synthesis of published epidemiological studies. Where incidence and mortality data are available, the summarized PAF estimates of the global assessment (i.e. 0.5–0.7) can be directly applied to these to estimate the attributable disease burden.

¹ <http://www.iarc.fr>

² <http://iridl.ldeo.columbia.edu/SOURCES/NASA/GSFC/TOMS/EPTOMS>

SCC is less common in more deeply pigmented populations, and UVR exposure may be less important as a cause of SCC in these populations. However, few studies quantify this variation. Most published epidemiological studies reviewed for the global assessment were undertaken in predominantly lightly pigmented populations. Incidence rates for intermediately and deeply pigmented populations were calculated by applying a multiplier to the rates for lightly pigmented populations, based on studies that compared rates in different population groups (Weinstock et al., 1991; Hoy, 1996). That is, for populations with skin pigmentations intermediate between light and deep pigmentations, a multiplier of 0.1 was used to derive incidence estimates; for deeply pigmented populations, a multiplier of 0.018 was used.

These factors are used in the method described in section 3 for estimating incidence and mortality rates and in the proposed calculation tool (see section 3).

(b) Basal cell carcinoma of the skin

BCCs arise from the basal cell layer of the skin (ICD-10 code C44; WHO, 2007). They are the most common type of skin cancer, but the least likely to cause death. Epidemiological studies confirm excessive UVR exposure as a risk factor for the development of BCC (reviewed in Lucas et al., 2006; see Box 3).

Box 3: Evidence supporting UVR as causative of BCC

- Higher risk of BCC in people born in an area of high solar irradiance (who do not migrate) compared with those migrating from an area of low solar irradiance to an area of high solar irradiance (i.e. importance of early-life UV exposure)
- Higher risk of BCC in subjects with a history of sunburn or other evidence of skin damage (e.g. loss of skin elasticity, freckling or solar keratoses)
- More common lesions on body sites that are exposed intermittently to the sun, rather than sites, such as the back of the hand, that are constantly exposed
- Mutations in *TP53* found in BCCs, and risk of BCCs significantly associated with the prevalence of these mutations
- Sun protection associated with decreased risk of BCC

The PAF for UVR exposure causing BCC as estimated from the epidemiological literature and used in the global assessment (Lucas et al., 2006) was a range of 0.5–0.9. These PAFs are proposed as the basis for estimating the disease burden from UVR due to BCC. Derivation of incidence and mortality estimates and adjustment for skin pigmentation were undertaken as for SCC. They are built into the formulae in the calculation tool (see section 3).

2.3 Photoageing/solar keratoses

Photoageing is the premature ageing of the skin, including gradual deterioration of the skin structure and function, as a result of excessive exposure to UVR. Characteristics of photoageing include dryness of the skin, loss of elasticity, wrinkling, discoloration, changes in texture and the development of solar/senile/actinic keratoses. The latter are very common with increasing age.

Photoageing is distinguishable from chronological ageing of the skin and is solely attributable to UVR exposure (i.e. PAF = 1.0). There is no disease burden due to photoageing per se, but solar keratoses may incur a disease burden both because of their (low) premalignant potential and because their removal may create disfigurement and suffering.

Incidence estimates for solar keratoses are derived as for the NMSC above, using models based on epidemiological studies and measures of ambient UVR. Note, however, that these estimates are derived from relatively few studies, generally in lightly pigmented populations living under high ambient UVR conditions, and are thus highly uncertain when generalized globally.

2.4 Sunburn

Sunburn (ICD-10 code L55; WHO, 2007) is a burn to the skin produced by overexposure to UVR. The spectrum of outcomes ranges from mild reddening of the skin (erythema) to more severe erythema with swelling or blistering, sometimes accompanied by systemic symptoms, such as fatigue or dizziness, and requiring hospitalization.

Sunburn is extremely common and fully attributable to UVR exposure (i.e. PAF = 1.0). It is uncommon in young children, although if it does occur, it may be severe and even life threatening. The incidence rises through childhood and reaches a peak in adolescence and early adulthood because of increasing sun-seeking behaviour and/or less use of sun protection strategies. Sunburn is common even at high latitudes, either during sunny seasons or during winter on holidays in sunny locations.

Estimates suggest that approximately 33% of all recorded sunburns are painful (Reynolds et al., 1996; Morris et al., 1998; Hall et al., 2001) and approximately 3% are severe, blistering burns (Reynolds et al., 1996; Morris et al., 1998). We consider disability arising from both painful and blistering sunburns.

Deeply pigmented persons also suffer sunburns, but less commonly (Hall & Rogers, 1999). We propose a multiplier of 0.5 to obtain the incidence (from models of incidence under various levels of ambient UVR) in persons with intermediate pigmentation and a multiplier of 0.1 for deeply pigmented persons, based on the available evidence.

Data on the incidence of sunburn are scarce in all regions. The proposed method and calculation tool for estimating disease burden from UVR use sunburn incidence rates derived for the global assessment of disease burden from UVR (see section 3). However, these estimates carry a relatively high uncertainty.

2.5 Cortical cataract

Senile cataracts are opacities that develop in the lens of the eye and may impair vision (ICD-10 code H25; WHO, 2007). There are three pure cataract types—cortical cataract, posterior sub-capsular cataract and nuclear cataract—but most cataracts are of mixed type. While there is some evidence of a causal role for UVR exposure in each

cataract type, the strongest is for cortical cataract, affecting the cortex of the lens. This is the only cataract type included in the global assessment of UVR (Lucas et al., 2006) and covered here.

Cataract disease burden arises primarily from vision loss. In most studies, cortical cataracts are more likely to cause mild vision loss and less likely to cause moderate or severe vision loss compared with the other forms of cataract. PAF estimates calculated from case-control studies suggest that UVR exposure causes approximately 25% of the disease burden due to cataracts, through vision loss caused by cortical cataracts.

Cataract incidence rates may be available from national statistics and are also available from the World Health Organization (WHO), by country and age/sex group.¹ Although several epidemiological studies suggest that there is an increased risk of mortality in those with severe cataracts, mortality due to cataract is not included in the estimates.

The proposed method and calculation tool for estimating disease burden from UVR includes a section for estimating the burden of cortical cataract attributable to UVR exposure (see section 3).

2.6 Pterygium

Pterygium (ICD-10 code H11; WHO, 2007) is a wing-shaped fleshy growth, usually occurring on the nasal conjunctiva and cornea and growing towards the centre of the cornea. Impingement on the cornea eventually causes visual impairment. Several factors may be associated with the development of pterygia, including UVR exposure, low humidity, wind and exposure to particulate matter (e.g. dust). The disability associated with pterygium arises from surgical removal of pterygia and recurrent pterygia or from severe untreated pterygia with associated loss of vision.

Although earlier studies were inconclusive about the importance of UVR exposure to the development of pterygia (IPCS, 1994), more recent studies suggest a PAF for sunlight exposure of 0.42–0.74 (Threlfall & English, 1999; McCarty et al., 2000).

The regional prevalence data estimated in the framework of the global assessment of disease burden from UVR (Lucas et al., 2006) represent a summary of epidemiological data and form the basis of the calculation tools for the estimation of national or local disease burden presented here (see section 3). However, pterygium prevalence may vary widely within a small region (McCarty et al., 2000). As most of the available data come from surveys of small areas, the estimated prevalence carries relatively high uncertainty.

2.7 Squamous cell carcinoma of the cornea and conjunctiva

Squamous cell carcinomas of the cornea and conjunctiva (SCCCs) are relatively rare malignant neoplasms (ICD-10 codes C69.0 and C69.1; WHO, 2007), particularly in white populations. The ecological and individual epidemiological evidence supports an association with excessive exposure of the eye to UVR. The incidence of SCCC has increased in recent years in association with human immunodeficiency virus (HIV)

¹ Available upon request from whosis@who.int.

infection. Although SCCC is predominantly a rare disease of the elderly, this tumour also affects young to middle-aged adults in association with HIV.

The PAF for UVR as a causative factor for SCCC was estimated to be in the same range as that for SCC, 0.5–0.7. The section addressing SCCC in the calculation tool (see section 3) for estimating disease burden from UVR is based on disease models developed from epidemiological studies under different levels of ambient UVR.

2.8 Reactivation of herpes labialis

Herpes labialis is a common infection, caused by herpes simplex virus (ICD-10 code B00.1; WHO, 2007) and manifesting as small, painful blisters on the skin of the lips, mouth or gums. After the first infection (commonly occurring before 20 years of age), the virus becomes latent. Recurrence may be triggered by menstruation, sun exposure, intercurrent illness, psychological stress, trauma or other unknown causes.

Reactivated herpes labialis generally causes only minor discomfort for up to a week, but it may be more severe and occasionally requires hospitalization. It is generally a self-limiting illness, which can be minimized with early use of antiviral therapy.

In animal models and in humans, there is strong circumstantial evidence for the reactivation of herpes virus (resulting in herpes labialis) by excessive exposure to sunlight. However, there are few quantitative data to allow accurate calculation of the risk attributable to UVR exposure. Estimates from cross-sectional studies suggest that UVR exposure is a cause of 25–50% of reactivations of herpes labialis. The section addressing herpes labialis in the calculation tool (see section 3) for estimating disease burden from UVR is based on disease models developed from epidemiological studies under different levels of ambient UVR.

2.9 The disease burden due to insufficient UVR exposure

The current burden of disease due to insufficient exposure to UVR is unclear. Diseases of UVR deficiency (due to frank vitamin D deficiency) are relatively uncommon, but recent research suggests that there may be a high burden of disease due to other diseases, such as multiple sclerosis and type 1 diabetes, that are, at least in part, associated with inadequate UVR exposure. Further research is required to better understand these diseases. For any country, the burden of disease caused by inappropriate UVR exposure will depend on the extent of the mismatch between sun exposure and skin type.

The adverse effects associated with insufficient UVR exposure are not considered further here. Assessment of the disease burden associated with insufficient UVR exposure at a national level would require better data on local dietary intake of vitamin D and the local prevalence of frank vitamin D deficiency.

3. Methods for estimating disease burden from UVR

As described in the previous section, the global assessment of disease burden from UVR exposure (Lucas et al., 2006) synthesized evidence to estimate the UVR PAF for the nine diseases with strong causal evidence for UVR exposure (Table 2). Although the detailed analysis of the literature in the framework of the global assessment has shown differences with latitude, these were not significant. Based on available evidence, the PAF for SCC is lower with higher levels of skin pigmentation. The disease-specific PAFs shown here can be directly applied to estimates of mortality, incidence or disease burden in DALYs to derive the UVR-attributable disease burden for each region.

Table 2 Population attributable fraction for health outcomes caused by UVR exposure

Health outcome	Upper PAF estimate	Lower PAF estimate
Cutaneous malignant melanoma	0.9	0.5
Squamous cell carcinoma of the skin ^a	0.7	0.5
Basal cell carcinoma of the skin	0.9	0.5
Photoageing/solar keratoses	1.0	1.0
Sunburn	1.0	1.0
Cortical cataract	0.25	0.25
Pterygium	0.74	0.42
Squamous cell carcinoma of the cornea and conjunctiva	0.7	0.5
Reactivation of herpes labialis	0.5	0.25

^a The PAF provided here is for light-skinned populations; based on limited epidemiological data, the PAF assumed for intermediately pigmented populations is one fifth of this (i.e. 0.10–0.14), and for deeply pigmented populations, one fifth of that (i.e. 0.02–0.03).

The global assessment of the disease burden from UVR exposure (Lucas et al., 2006) also provides an estimate of regional mortality and disease burden (in DALYs) data (Tables A1.1 and A1.2 in Appendix 1) for each disease, by WHO subregion (see Table A1.3 for country grouping). Worldwide, about 56 000 deaths per year can be attributed to UVR (estimate for the year 2000). This estimate represents the mid-point between the lower and upper estimates (41 000 and 71 000 deaths per year, respectively).

To estimate the disease burden at the country level, different approaches with different levels of precision are proposed in this guide, depending on the level of detail available for input data (e.g. incidence and mortality rates). Preliminary estimates are provided, but they can be improved if the country has more precise incidence, mortality or other epidemiological data, which can be used in the proposed calculation tool.

The burden of adverse health outcomes, estimated on the basis of this guide, assumes an average pattern of current UVR exposure in the studied population that is similar to that experienced over the preceding 20 years (as data were derived from epidemiological studies undertaken over the past 20 years).

The disability weights used in the global disease burden assessment were derived, where available, from the Murray & Lopez (1996) Global Burden of Disease study. Where disability weights were not available from this work, we used disability weights from the Australian burden of disease study (Mathers et al., 1999) or from the Dutch study (Stouthard et al., 1997). For diseases without available disability weights, we

imputed a weight based on diseases or illnesses that were considered to have a similar level of disability, in the opinion of the UVR working group (Lucas et al., 2006). Further work may improve the quantification of the relative disability from these diseases and further develop consideration of these outcomes in terms of disease burden.

3.1 Preliminary method

Preliminary estimates of the national UVR-associated disease burden can be made, using the methods described below.

For certain diseases addressed in this guide (e.g. melanoma and cataract), incidence and mortality rates, as well as disease burden, may be available at the national level or from WHO.¹ The UVR-attributable disease burden (in terms of incident cases, deaths or DALYs) can be estimated by applying the listed PAFs (see Table 2) directly to these data.

For other diseases for which incidence and mortality data are not generally available at the national level, incidence/prevalence rates (by three levels of skin pigmentation) can be estimated based on a synthesis of available epidemiological evidence and the resulting models used for the global assessment (Lucas et al., 2006). These rates are then combined with population data (divided into three pigmentation groups), country-specific population-weighted average daily ambient UVR level (Table A1.4) and disease-specific parameters (see Figures A2.1–A2.6 in Appendix 2) to calculate the national disease burden in deaths and DALYs. Again, the UVR-attributable disease burden in deaths and DALYs can be estimated by applying the listed PAFs to these data.

Approximate estimates of country disease burden caused by UVR exposure have been calculated and are presented in Table A1.5. The calculation tool for these estimates is available from WHO.² Parameters (such as specific incidence and mortality rates) used in these calculations are detailed in the spreadsheets (under the “Disease_details” worksheets).

¹ http://www.who.int/healthinfo/global_burden_disease/en/index.html; currently under “Disease and injury – country”; more detailed data by age and sex group can be requested from whosis@who.int.

² Available upon request from EBDassessment@who.int.

3.2 More detailed assessment

A more refined assessment can be developed by using additional input data that may be available at the national, regional or local level. A calculation tool (spreadsheet) has been developed to assist in such calculations.¹ This tool uses predictive models based on epidemiological studies to estimate disease-specific incidence and mortality rates (by age group and sex). Available data (e.g. incidence and mortality rates, population by pigmentation group, disease model parameters at national, regional or local levels) can be entered to replace the estimates used in the original model. The calculation tool assists in estimating the disease burden due to UVR exposure and displays these estimates on its “Front_sheet” worksheet.

To calculate the disease burden in deaths and DALYs:

1. Request the UVR burden of disease spreadsheets.²
2. Select the population-weighted average daily ambient UVR level (years 1999–2003) for the country from Table A1.4.
3. Input the population-weighted average daily ambient UVR level for your country into the “Summary” worksheet of the UVR spreadsheet, cell B2 (highlighted green) (note that steps 2 and 3 are not required if the estimates are being derived for the country entered in cell A1 on the “Summary” worksheet).
4. If more precise population data are available, input these; data may be inserted by sex, skin type (three broad levels: light, medium and dark) and 5-year age groups (0–4, 5–9, 10–14, 15–19, 20–24 years, etc.) into the yellow cells on the “Summary” worksheet.
5. Each disease has a worksheet “Disease_details” containing formulae for calculating incidence rates (based on the population-weighted average daily ambient UVR level) and mortality rates (where relevant). If country-specific incidence or mortality rates are available, they may be entered here, but they must be entered in exactly the same places and formats as the calculated incidence rates and in the same age groups as currently in the worksheet.
6. For cataract and CMM, incident cases, deaths and DALYs (also available from WHO,³ in the absence of more precise national data) may be inserted into the appropriate “Disease_details” worksheets over the current data.
7. The pale yellow cells on each “Disease_details” worksheet provide the calculation tool with the parameters from the disease models in Figures A2.1–A2.6. The latter relate to the proportion, duration and disability weight for different disease stages and are set up based on whether countries fall into the ABC or DE WHO classifications (see Table A.3). If country-specific estimates of these disease parameters are available, they should be entered under the “Disease parameters” heading, in the same format, according to the disease models in Figures A2.1–A2.6.
8. The total and attributable deaths and DALYs will be automatically calculated and displayed in the “Summary” and the “Front_sheet” worksheets.

¹ Available upon request from EBDassessment@who.int.

² Available upon request from EBDassessment@who.int.

³ http://www.who.int/healthinfo/global_burden_disease/en/index.html; currently under “Disease and injury – country”.

9. Estimates of disease-specific incidence, mortality and disease burden in DALYs, by sex and age group, will be displayed on the “Disease_details” worksheets.

For subnational estimates, the average daily ambient UVR level for the country (Table A1.4) may be a reasonable approximation (for countries spanning only a small latitude range). Alternatively, an average daily ambient UVR level for the geographic position (in latitude and longitude) can be calculated from data available at the Total Ozone Mapping Spectrometer (National Aeronautics and Space Administration Goddard Space Flight Center), from the International Research Institute for Climate and Society.¹ Inputting a different average daily ambient UVR level will automatically change the incidence and mortality data according to the underlying models and recalculate the applicable disease burden due to UVR exposure.

The UVR spreadsheet addresses diseases with sufficient evidence currently available to infer a causal association with UVR exposure (and thus assessed in the global assessment of disease burden caused by UVR; Lucas et al., 2006). The estimates derived from this work were adjusted for skin pigmentation, but were based on assumptions that the sun exposure behaviour of a population was similar to that of the study sample from which the estimates were made. In populations with specific intent to cover the face, arms and legs for reasons other than cold or UVR protection, the estimates here will likely overestimate the adverse effects of UVR overexposure (skin cancers, cataracts, immune suppression).

¹ <http://iridl.ldeo.columbia.edu/SOURCES/.NASA/.GSFC/.TOMS/.EPTOMS>

4. Effects of risk-taking behaviour on the disease burden due to excessive UVR exposure

Risk-taking behaviour with respect to excessive UVR exposure may be linked to the following:

- the amount of time spent in the sun, in particular around midday;
- personal protection from the sun, including protective clothing/sunscreen;
- protection of children.

In most populations, the distribution in personal sun exposure is wide, given a certain level of ambient UVR. Studies indicate that most people in a population receive 5–15% (with the average somewhat less than 10%) of the total ambient UVR, with a range from one tenth of the average to 10 times the average. Table 3 shows the average annual ambient UVR over the years 1997–2003 for 10-degree-latitude bands and how the received dose varies as the proportion received changes.

Table 3 Average daily erythemal UVR (1997–2003) over 10-degree-latitude bands

Latitude (degrees)	Daily average UVR (J/m ²)	Daily average UVR received as personal dose (J/m ²)				
		5%	10%	20%	30%	50%
0–10	5419	271	542	1084	1626	2710
10–20	5251	263	525	1050	1575	2626
20–30	4403	220	440	881	1321	2201
30–40	3191	160	319	638	957	1595
40–50	2041	102	204	408	612	1021
50–60	1262	63	126	253	379	631
60–65 ^a	928	46	93	186	278	464

^a Note that the last latitude band spans only 5 degrees, as satellite-derived ambient UVR data at very high latitude are unavailable for large parts of the year.

Different personal exposures at similar latitudes may simulate living at different latitude bands—and most UVR-associated disease rates vary greatly with latitude. Suppose a population group has twice as much exposure (20% of ambient UVR) as the usual average (assumed here as 10%); then their exposure level is equivalent to moving up approximately two 10-degree-latitude bands. The incidence rates for this new latitude band will apply to the group of people having this excessive exposure over their lifetime. For many of the UVR-related diseases, the association between incidence and ambient UVR (and therefore latitude) is exponential—so that risk-taking behaviour confers a greatly increased risk of these diseases associated with UVR overexposure.

The following example illustrates the importance of sun exposure behaviour to risk of UVR-associated diseases. For a population living at 30–40 degrees latitude, increasing the average personal exposure from 10% of ambient UVR (319 J/m²) to 20% of ambient UVR (638 J/m²) is equivalent to moving to a latitude of less than 10 degrees from the equator (with average exposure of 10%). This means that the average incidence rate of SCC for these latitudes (based on models for the global burden of disease due to UVR exposure; Lucas et al., 2006) will increase from 192 to 362 cases

per 100 000 people (i.e. the risk almost doubles). In contrast, if this population halves its UVR exposure (160 J/m^2), the incidence of SCC will become equivalent to that of a population living at around 50–60 degrees latitude. This would result in an incidence of only 21 cases of SCC per 100 000 people. This means that the risk of SCC decreases by a factor of 9. A population living at 60–65 degrees latitude, but having very high UVR exposure (50% of ambient UVR), would have the risk of UVR-induced disease of a population with average exposure (10% of ambient UVR) living at 20–30 degrees latitude.

One should, however, also keep in mind the risks related to underexposure to UVR, and a total avoidance of sun exposure should not be advocated. Rather, the level of sun exposure that is optimal for health depends on the ambient UVR level and skin pigmentation. There are few data available with which to calculate this optimal exposure. Calculations that have been done (Samanek et al., 2006) are based on small studies or experimental work using vitamin D precursors in solution. However, to the best of our current knowledge, “optimal” sun exposure will consist of short, repeated exposures well below a level at which sunburning could occur. Excessive exposure, sufficient to cause sunburn, should certainly be avoided.

5. Available interventions to reduce the disease burden related to UVR

Measures that have been used to reduce population risk due to overexposure to UVR include mainly education on the health risks associated with UVR exposure and personal protection (WHO, 1995). Education can take the form of national education campaigns that may be directed at various population groups, such as the workforce, and may be implemented at the level of specific settings, such as schools (WHO, 2002b). Personal protection may include reducing the duration of exposure to the sun, depending on the intensity of radiation and skin pigmentation. It also includes measures such as clothing (hats, shirts, sunglasses, etc.) and sunscreens. Interventions to increase the protection of a population from UVR may include tools aimed at raising awareness about the health risks associated with UVR exposure or providing information to assist individuals to understand when personal sun protection is required, such as the Global Solar UV [Ultraviolet] Index (WHO et al., 2002). Such indices may be broadcast over television or radio or be part of the weather forecast in daily newspapers.

A few sun safety measures could prevent skin cancers and other UVR-related health outcomes (WHO, 2005):

- Limit time in the midday sun.
- Use shade wisely: seek shade when UV rays are most intense.
- Know the UV index: when the UV index predicts radiation levels of 3 (moderate) or above, sun safety practices should be implemented.
- Wear protective clothing, including hats and sunglasses.
- Use a broad-spectrum sunscreen with a sun protection factor (SPF) of 15 or higher.
- Avoid sunlamps and tanning parlours; WHO recommends that persons under the age of 18 do not use them at all.
- Be particularly mindful of appropriate sun exposure in children, particularly avoiding overexposure.

Appendix 1: Disease burden and basic parameters

Tables A1.1 and A1.2 are summaries of UVR-attributable disease burden for nine health outcomes, by WHO subregion (Lucas et al., 2006).

Table A1.1 UVR-attributable disease burden in deaths in 2000 by WHO subregion^a

Disease	Afr D	Afr E	Amr A	Amr B	Amr D	Emr B	Emr D	Eur A	Eur B	Eur C	Sear B	Sear D	Wpr A	Wpr B	Total
Population (000)	294 099	354 533	325 186	430 951	71 235	139 071	342 584	411 910	218 473	243 192	293 821	1 241 813	154 358	1 532 946	6 054 172
CMM	2 773	3 791	8 889	3 338	347	508	847	10 564	2 843	5 963	761	1 461	1 943	1 581	45 613
SCC	125	131	707	871	122	268	317	757	235	218	514	1 454	436	1 967	8 120
BCC	4	5	229	230	24	104	78	293	97	101	73	177	162	691	2 272
Photoageing/ solar keratoses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sunburn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cortical cataract	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterygium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SCCC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RHL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2 902	3 927	9 824	4 439	493	879	1 242	11 614	3 176	6 281	1 347	3 092	2 541	4 238	56 005

Afr: Africa; Amr: Americas; Emr: Eastern Mediterranean; Eur: Europe; Sear: South-East Asia; Wpr: Western Pacific

BCC: basal cell carcinoma of the skin; CMM: cutaneous malignant melanoma; RHL: reactivation of herpes labialis; SCC: squamous cell carcinoma of the skin; SCCC: squamous cell carcinoma of the cornea and conjunctiva

^a Country grouping of WHO subregions is shown in Table A1.3. Estimates represent the midpoint of the lower and upper estimates of the global assessment (Lucas et al., 2006).

Table A1.2 UVR-attributable disease burden in DALYs in 2000 by WHO subregion^a

Disease	Afr D	Afr E	Amr A	Amr B	Amr D	Emr B	Emr D	Eur A	Eur B	Eur C	Sear B	Sear D	Wpr A	Wpr B	Total
<i>Population (000)</i>	294 099	354 533	325 186	430 951	71 235	139 071	342 584	411 910	218 473	243 192	293 821	1 241 813	154 358	1 532 946	6 054 172
CMM	24 753	41 829	93 272	37 630	3 494	6 789	13 042	102 284	30 063	64 424	7 667	20 467	18 700	18 758	483 176
SCC	208	886	6 279	9 057	1 314	3 408	5 159	6 714	2 607	2 212	2 298	4 264	4 156	22 369	70 930
BCC	90	114	3 241	4 623	557	2 169	1 911	4 102	1 670	1 628	1 676	3 807	2 341	12 654	40 588
Photoageing/ solar keratoses	0	0	799	547	0	345	1	1 108	478	438	30	0	721	3 844	8 311
Sunburn	3 857	3 545	16 072	23 134	2 946	12 772	14 965	21 569	13 753	13 175	11 970	48 978	8 962	97 850	293 557
Cortical cataract	59 515	55 718	2 233	18 152	7 026	10 597	44 272	1 035	5 027	13 949	37 984	189 405	1 058	83 269	529 242
Pterygium	2 610	2 868	419	795	791	133	2 646	360	158	112	354	14 041	316	1 876	27 136
SCCC	63	280	44	100	26	23	73	36	17	11	95	385	38	296	1 490
RHL	3 228	4 023	3 087	3 593	487	1 719	2 022	3 924	2 050	2 163	1 747	5 944	1 798	15 440	51 224
Total	94 323	109 263	125 445	97 631	16 640	37 954	84 091	141 131	55 822	98 111	63 820	287 290	38 090	256 354	1 505 653

Afr: Africa; Amr: Americas; Emr: Eastern Mediterranean; Eur: Europe; Sear: South-East Asia; Wpr: Western Pacific

BCC: basal cell carcinoma of the skin; CMM: cutaneous malignant melanoma; RHL: reactivation of herpes labialis; SCC: squamous cell carcinoma of the skin; SCCC: squamous cell carcinoma of the cornea and conjunctiva

^a Country grouping of WHO subregions is shown in Table A1.3. Estimates represent the midpoint of the lower and upper estimates of the global assessment (Lucas et al., 2006).

Table A1.3 Countries in WHO subregional groups (year 2000)

Subregion^a	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 (Bolivarian Republic of)
Amr D	Bolivia (Plurinational State of), 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, Cyprus, 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 of Great Britain and Northern Ireland
Eur B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Montenegro, Poland, Romania, Serbia, Slovakia, Tajikistan, The former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan
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

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

^a Grouped according to WHO region and mortality strata, year 2000 (to match the regional estimate developed for the year 2000; WHO, 2001).

Table A1.4 Population-weighted average daily ambient UVR level (1997–2003) for selected countries

Country	WHO subregion	UVR (J/m ²)	Country	WHO subregion	UVR (J/m ²)
Afghanistan	Emr D	4 132	Democratic People's Republic of Korea	Sear D	2 335
Albania	Eur B	2 542	Democratic Republic of the Congo	Afr E	5 100
Algeria	Afr D	3 253	Denmark	Eur A	1 691
Andorra	Eur A	2 469	Djibouti	Emr D	5 461
Angola	Afr D	5 287	Dominica	Amr B	5 464
Antigua and Barbuda	Amr B	5 148	Dominican Republic	Amr B	4 880
Argentina	Amr B	3 476	Ecuador	Amr D	4 929
Armenia	Eur B	2 899	Egypt	Emr D	4 202
Australia	Wpr A	3 206	El Salvador	Amr B	5 364
Austria	Eur A	1 888	Equatorial Guinea	Afr D	4 635
Azerbaijan	Eur B	2 702	Eritrea	Afr E	5 914
Bahamas	Amr B	4 119	Estonia	Eur C	1 781
Bahrain	Emr B	4 419	Ethiopia	Afr E	5 929
Bangladesh	Sear D	4 029	Fiji	Wpr B	4 431
Barbados	Amr B	5 787	Finland	Eur A	1 494
Belarus	Eur C	1 795	France	Eur A	1 907
Belgium	Eur A	1 645	Gabon	Afr D	4 654
Belize	Amr B	4 639	Gambia	Afr D	5 358
Benin	Afr D	5 168	Georgia	Eur B	2 489
Bhutan	Sear D	4 180	Germany	Eur A	1 812
Bolivia (Plurinational State of)	Amr D	5 344	Ghana	Afr D	5 166
Bosnia and Herzegovina	Eur B	2 205	Greece	Eur A	2 753
Botswana	Afr E	4 868	Grenada	Amr B	4 875
Brazil	Amr B	4 552	Guatemala	Amr D	5 141
Brunei Darussalam	Wpr A	5 148	Guinea	Afr D	5 391
Bulgaria	Eur B	2 331	Guinea-Bissau	Afr D	5 319
Burkina Faso	Afr D	5 567	Guyana	Amr B	5 203
Burundi	Afr E	5 111	Haiti	Amr D	5 016
Cambodia	Wpr B	5 152	Honduras	Amr B	4 924
Cameroon	Afr D	5 185	Hungary	Eur C	1 932
Canada	Amr A	1 887	Iceland	Eur A	957
Cape Verde	Afr D	5 372	India	Sear D	4 514
Central African Republic	Afr E	5 498	Indonesia	Sear B	5 220
Chad	Afr D	5 669	Iran (Islamic Republic of)	Emr B	4 038
Chile	Amr B	3 982	Iraq	Emr D	3 825
China	Wpr B	2 908	Ireland	Eur A	1 509
Colombia	Amr B	5 385	Israel	Eur A	3 682
Comoros	Afr D	5 524	Italy	Eur A	2 444
Congo	Afr E	4 943	Jamaica	Amr B	4 942
Cook Islands	Wpr B	4 708	Japan	Wpr A	2 521
Costa Rica	Amr B	4 884	Jordan	Emr B	4 026
Côte d'Ivoire	Afr E	4 931	Kazakhstan	Eur C	2 257
Croatia	Eur A	1 976	Kenya	Afr E	5 803
Cuba	Amr A	4 401	Kiribati	Wpr B	6 229
Cyprus	Eur A	3 439	Kuwait	Emr B	4 214
Czech Republic	Eur A	1 707	Kyrgyzstan	Eur B	3 094

Table A1.4 Population-weighted average daily ambient UVR level (1997–2003) for selected countries (continued)

Country	WHO subregion	UVR (J/m ²)	Country	WHO subregion	UVR (J/m ²)
Lao People's Democratic Republic	Wpr B	4 735	Philippines	Wpr B	4 928
Latvia	Eur C	1 671	Poland	Eur B	1 749
Lebanon	Emr B	2 953	Portugal	Eur A	2 585
Lesotho	Afr E	4 439	Qatar	Emr B	4 905
Liberia	Afr D	4 926	Republic of Korea	Wpr B	2 535
Libyan Arab Jamahiriya	Emr B	3 861	Republic of Moldova	Eur C	1 910
Lithuania	Eur C	1 801	Romania	Eur B	2 071
Luxembourg	Eur A	1 687	Russian Federation	Eur C	1 795
Madagascar	Afr D	4 771	Rwanda	Afr E	5 130
Malawi	Afr E	5 019	Saint Kitts and Nevis	Amr B	5 009
Malaysia	Wpr B	5 225	Saint Lucia	Amr B	5 164
Maldives	Sear D	10 224	Saint Vincent and the Grenadines	Amr B	5 358
Mali	Afr D	5 617	Samoa	Wpr B	4 966
Malta	Eur A	3 091	San Marino	Eur A	1 932
Marshall Islands	Wpr B	5 325	Sao Tome and Principe	Afr D	4 422
Mauritania	Afr D	5 547	Saudi Arabia	Emr B	5 384
Mauritius	Afr D	5 055	Senegal	Afr D	5 356
Mexico	Amr B	4 974	Serbia and Montenegro ^a	Eur B	2 257
Micronesia (Federated States of)	Wpr B	4 587	Seychelles	Afr D	5 570
Monaco	Eur A	1 907	Sierra Leone	Afr D	5 087
Mongolia	Wpr B	2 226	Singapore	Wpr A	3 979
Morocco	Emr B	3 568	Slovakia	Eur B	1 795
Mozambique	Afr E	4 646	Slovenia	Eur A	2 256
Myanmar	Sear D	4 565	Solomon Islands	Wpr B	4 071
Namibia	Afr E	5 305	Somalia	Emr D	5 773
Nauru	Wpr B	3 022	South Africa	Afr E	4 111
Nepal	Sear D	4 130	Spain	Eur A	2 705
Netherlands	Eur A	1 662	Sri Lanka	Sear B	5 264
New Zealand	Wpr A	2 487	Sudan	Emr D	5 783
Nicaragua	Amr D	5 078	Suriname	Amr B	4 799
Niger	Afr D	5 811	Swaziland	Afr E	3 900
Nigeria	Afr D	5 251	Sweden	Eur A	1 587
Niue	Wpr B	4 687	Switzerland	Eur A	2 158
Norway	Eur A	1 439	Syrian Arab Republic	Emr B	3 501
Oman	Emr B	5 102	Tajikistan	Eur B	3 538
Pakistan	Emr D	4 227	Thailand	Sear B	4 862
Palau	Wpr B	5 175	The former Yugoslav Republic of Macedonia	Eur B	2 403
Panama	Amr B	4 898	Timor-Leste	Sear D	5 637
Papua New Guinea	Wpr B	5 377	Togo	Afr D	5 307
Paraguay	Amr B	4 038	Tonga	Wpr B	4 087
Peru	Amr D	5 906	Trinidad and Tobago	Amr B	5 245

Table A1.4 Population-weighted average daily ambient UVR level (1997–2003) for selected countries (continued)

Country	WHO subregion	UVR (J/m²)	Country	WHO subregion	UVR (J/m²)
Tunisia	Emr B	3 262	United States of America	Amr A	2 736
Turkey	Eur B	2 924	Uruguay	Amr B	3 235
Turkmenistan	Eur B	3 164	Uzbekistan	Eur B	3 172
Tuvalu	Wpr B	5 465	Vanuatu	Wpr B	4 555
Uganda	Afr E	5 499	Venezuela (Bolivarian Republic of)	Amr B	5 211
Ukraine	Eur C	1 843	Viet Nam	Wpr B	4 293
United Arab Emirates	Emr B	4 862	Yemen	Emr D	6 089
United Kingdom of Great Britain and Northern Ireland	Eur A	1 576	Zambia	Afr E	5 265
United Republic of Tanzania	Afr E	5 483	Zimbabwe	Afr E	4 918

^a It should be noted that only aggregate data are available for Serbia and Montenegro, although WHO recognizes both as Member States.

Table A1.5 Approximate estimates of disease burden from UVR by country, year 2002^a

Country	CMM	SCC	BCC	Photoageing/ solar keratoses	Sunburn	Cortical cataract	SCCC	Pterygium	RHL	Total
Afghanistan										
Deaths	58	37	15	0	0	0	0	0	0	110
DALYs	1 100	840	760	48	1 400	5 300	6	1 700	240	11 500
Albania										
Deaths	39	4	2	0	0	0	0	0	0	45
DALYs	440	38	59	7	170	83	0	3	31	830
Algeria										
Deaths	88	4	3	0	0	0	0	0	0	94
DALYs	930	43	110	6	980	15 100	4	2 100	320	19 600
Andorra										
Deaths	1	0	0	0	0	0	0	0	0	2
DALYs	13	2	2	0	3	1	0	0	1	22
Angola										
Deaths	200	1	0	0	0	0	0	0	0	200
DALYs	2 200	11	13	1	100	4 900	2	1 100	150	8 400
Antigua and Barbuda										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	0	1	1	0	1	11	0	0	1	15
Argentina										
Deaths	620	140	52	0	0	0	0	0	0	810
DALYs	5 900	1 300	1 700	130	2 100	6 400	6	64	420	18 000
Armenia										
Deaths	57	7	3	0	0	0	0	0	0	67
DALYs	540	74	110	10	190	140	0	5	39	1 100
Australia										
Deaths	1 000	84	31	0	0	0	0	0	0	1 200
DALYs	9 400	730	890	73	930	62	3	39	220	12 400
Austria										
Deaths	220	15	7	0	0	0	0	0	0	240
DALYs	2 200	120	190	24	350	110	1	10	80	3 000
Azerbaijan										
Deaths	31	12	5	0	0	0	0	0	0	48
DALYs	330	110	170	18	440	280	1	9	80	1 400
Bahamas										
Deaths	2	0	0	0	0	0	0	0	0	2
DALYs	14	2	2	0	4	41	0	0	4	68
Bahrain										
Deaths	1	1	0	0	0	0	0	0	0	2
DALYs	14	10	21	1	28	150	0	1	8	230
Bangladesh										
Deaths	180	24	15	0	0	0	0	0	0	220
DALYs	2 600	280	710	28	4 300	36 100	23	10 400	1 500	55 900
Barbados										
Deaths	3	0	0	0	0	0	0	0	0	3
DALYs	32	2	4	0	3	48	0	1	4	94
Belarus										
Deaths	250	12	6	0	0	0	0	0	0	260
DALYs	2 700	110	190	25	440	360	1	11	97	3 900
Belgium										
Deaths	230	16	7	0	0	0	0	0	0	260
DALYs	2 300	120	200	27	400	130	1	11	94	3 300
Belize										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	5	1	2	0	4	23	0	0	3	38
Benin										
Deaths	49	0	0	0	0	0	0	0	0	50
DALYs	400	2	1	0	42	2 500	1	480	71	3 500
Bhutan										
Deaths	4	1	0	0	0	0	0	0	0	5
DALYs	44	6	14	0	68	540	0	180	23	880

Country	CMM	SCC	BCC	Photoageing/ solar keratoses	Sunburn	Cortical cataract	SCCC	Pterygium	RHL	Total
Bolivia (Plurinational State of)										
Deaths	200	6	3	0	0	0	0	0	0	210
DALYs	1 900	100	180	4	310	1 400	3	870	100	4 900
Bosnia and Herzegovina										
Deaths	46	5	2	0	0	0	0	0	0	53
DALYs	610	52	87	11	190	160	0	5	41	1 200
Botswana										
Deaths	9	0	0	0	0	0	0	0	0	9
DALYs	86	1	1	0	12	690	0	110	19	920
Brazil										
Deaths	2 100	370	150	0	0	0	0	0	0	2 600
DALYs	23 100	4 000	6 700	320	8 100	23 100	37	280	2 200	67 900
Brunei Darussalam										
Deaths	0	0	0	0	0	0	0	0	0	1
DALYs	0	5	12	0	13	160	0	1	4	200
Bulgaria										
Deaths	150	21	9	0	0	0	0	0	0	180
DALYs	1 400	190	260	29	360	390	1	14	88	2 700
Burkina Faso										
Deaths	27	0	0	0	0	0	0	0	0	27
DALYs	290	3	2	0	84	4 200	2	930	140	5 700
Burundi										
Deaths	58	0	0	0	0	0	0	0	0	58
DALYs	560	1	1	0	46	2 200	1	480	78	3 400
Cambodia										
Deaths	15	3	2	0	0	0	0	0	0	20
DALYs	190	31	140	3	370	1 100	2	15	140	2 000
Cameroon										
Deaths	280	76	0	0	0	0	0	0	0	360
DALYs	2 200	740	2	1	100	6 500	3	1 400	180	11 100
Canada										
Deaths	730	49	21	0	0	0	0	0	0	800
DALYs	7 800	370	570	73	1 300	410	2	37	300	10 900
Cape Verde										
Deaths	4	0	0	0	0	0	0	0	0	5
DALYs	32	2	4	0	12	190	0	34	5	280
Central African Republic										
Deaths	45	0	0	0	0	0	0	0	0	45
DALYs	470	1	1	0	25	1 500	1	350	45	2 400
Chad										
Deaths	82	1	1	0	0	0	0	0	0	84
DALYs	900	10	32	1	110	3 200	2	720	93	5 000
Chile										
Deaths	210	57	21	0	0	0	0	0	0	290
DALYs	1 900	560	770	49	860	2 400	3	27	180	6 800
China										
Deaths	1 700	3 200	910	0	0	0	0	0	0	5 900
DALYs	19 900	22 500	33 200	3 300	67 800	163 000	160	1 800	14 000	325 000
Colombia										
Deaths	200	60	31	0	0	0	0	0	0	290
DALYs	2 300	610	1 500	39	1 600	5 200	11	72	570	11 900
Comoros										
Deaths	5	0	0	0	0	0	0	0	0	5
DALYs	56	0	0	0	5	290	0	59	9	420
Congo										
Deaths	31	0	0	0	0	0	0	0	0	31
DALYs	220	2	2	0	22	1 300	0	230	33	1 800
Cook Islands										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	1	0	0	0	1	3	0	0	0	5
Costa Rica										
Deaths	71	15	6	0	0	0	0	0	0	92
DALYs	400	160	280	11	230	510	1	7	52	1 700

Table A1.5 (continued)

Country	CMM	SCC	BCC	Photoageing/ solar keratoses	Sunburn	Cortical cataract	SCCC	Pterygium	RHL	Total
Côte d'Ivoire										
Deaths	94	0	0	0	0	0	0	0	0	94
DALYs	710	3	2	1	100	6 300	2	1 200	170	8 500
Croatia										
Deaths	190	7	3	0	0	0	0	0	0	200
DALYs	1 900	64	110	14	190	59	0	6	45	2 400
Cuba										
Deaths	220	35	14	0	0	0	0	0	0	270
DALYs	1 600	320	460	22	400	2 100	3	27	150	5 100
Cyprus										
Deaths	5	4	1	0	0	0	0	0	0	11
DALYs	58	35	42	3	41	230	0	2	9	420
Czech Republic										
Deaths	350	13	6	0	0	0	0	0	0	370
DALYs	3 400	110	180	26	430	130	1	11	97	4 400
Democratic People's Republic of Korea										
Deaths	19	2	2	0	0	0	0	0	0	22
DALYs	290	21	60	5	630	2 800	2	1 600	230	5 700
Democratic Republic of the Congo										
Deaths	340	1	0	0	0	0	0	0	0	340
DALYs	4 500	10	6	2	350	17 600	7	3 900	580	26 900
Denmark										
Deaths	210	10	4	0	0	0	0	0	0	230
DALYs	2 300	70	110	14	210	68	0	6	49	2 800
Djibouti										
Deaths	6	0	0	0	0	0	0	0	0	6
DALYs	87	1	2	0	8	290	0	64	8	460
Dominica										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	0	0	0	0	0	11	0	0	1	13
Dominican Republic										
Deaths	53	8	4	0	0	0	0	0	0	64
DALYs	470	82	180	6	290	990	2	13	110	2 100
Ecuador										
Deaths	85	8	5	0	0	0	0	0	0	98
DALYs	910	120	210	6	430	2 300	4	1 400	160	5 600
Egypt										
Deaths	28	16	10	0	0	0	0	0	0	55
DALYs	460	190	490	18	2 200	16 400	15	6 500	800	27 100
El Salvador										
Deaths	31	3	2	0	0	0	0	0	0	36
DALYs	290	32	100	2	220	710	1	10	82	1 400
Equatorial Guinea										
Deaths	6	0	0	0	0	0	0	0	0	6
DALYs	63	0	0	0	3	200	0	41	5	320
Eritrea										
Deaths	26	0	0	0	0	0	0	0	0	26
DALYs	290	1	1	0	27	1 400	1	370	49	2 100
Estonia										
Deaths	43	2	1	0	0	0	0	0	0	45
DALYs	370	15	26	4	59	52	0	2	13	540
Ethiopia										
Deaths	500	2	0	0	0	0	0	0	0	500
DALYs	5 300	18	14	3	440	25 200	15	5 700	780	37 500
Fiji										
Deaths	3	0	0	0	0	0	0	0	0	4
DALYs	20	4	10	0	28	130	0	1	10	200
Finland										
Deaths	150	6	3	0	0	0	0	0	0	150
DALYs	1 300	48	81	12	200	67	0	5	46	1 800
France										
Deaths	1 300	120	51	0	0	0	0	0	0	1 400
DALYs	13 400	900	1 300	160	2 400	740	4	76	570	19 500

Country	Photoageing/ solar					Cortical cataract	SCCC	Pterygium	RHL	Total
	CMM	SCC	BCC	keratoses	Sunburn					
Gabon										
Deaths	40	0	0	0	0	0	0	0	0	40
DALYs	330	0	0	0	8	560	0	140	14	1 100
Gambia										
Deaths	7	0	0	0	0	0	0	0	0	7
DALYs	64	0	0	0	9	630	0	130	16	850
Georgia										
Deaths	70	12	5	0	0	0	0	0	0	87
DALYs	540	110	150	16	240	220	1	7	52	1 300
Germany										
Deaths	2 000	150	70	0	0	0	0	0	0	2 300
DALYs	19 600	1 200	1 900	250	3 300	1 100	5	110	800	28 300
Ghana										
Deaths	170	1	0	0	0	0	0	0	0	170
DALYs	1 400	7	5	1	140	8 600	3	1 800	240	12 100
Greece										
Deaths	250	50	19	0	0	0	0	0	0	320
DALYs	1 800	420	520	48	480	150	2	23	120	3 600
Grenada										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	2	0	1	0	1	12	0	0	1	17
Guatemala										
Deaths	30	4	2	0	0	0	0	0	0	36
DALYs	440	42	120	3	390	1 800	3	990	140	3 900
Guinea										
Deaths	58	0	0	0	0	0	0	0	0	58
DALYs	560	2	1	0	52	3 300	1	640	90	4 700
Guinea-Bissau										
Deaths	13	0	0	0	0	0	0	0	0	13
DALYs	110	1	1	0	9	550	0	130	15	810
Guyana										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	12	2	8	0	19	88	0	1	12	140
Haiti										
Deaths	7	1	0	0	0	0	0	0	0	8
DALYs	82	8	10	1	70	1 300	1	730	100	2 300
Honduras										
Deaths	30	2	1	0	0	0	0	0	0	34
DALYs	410	20	64	2	220	600	1	8	77	1 400
Hungary										
Deaths	350	17	8	0	0	0	0	0	0	370
DALYs	3 400	140	230	30	430	380	1	13	99	4 800
Iceland										
Deaths	3	0	0	0	0	0	0	0	0	4
DALYs	25	1	2	0	10	3	0	0	2	43
India										
Deaths	1 400	350	220	0	0	0	0	0	0	2 000
DALYs	15 700	4 000	10 000	310	32 200	327 000	270	115 000	12 500	517 000
Indonesia										
Deaths	850	95	64	0	0	0	0	0	0	1 000
DALYs	7 200	950	3 400	71	7 000	122 000	51	370	2 900	144 000
Iran (Islamic Republic of)										
Deaths	470	170	63	0	0	0	0	0	0	700
DALYs	5 300	1 700	2 500	150	4 600	14 000	11	79	790	29 000
Iraq										
Deaths	26	38	15	0	0	0	0	0	0	79
DALYs	350	730	630	45	1 500	5 000	5	1 600	240	10 200
Ireland										
Deaths	79	4	2	0	0	0	0	0	0	85
DALYs	820	29	48	7	160	41	0	3	32	1 100
Israel										
Deaths	150	26	9	0	0	0	0	0	0	180
DALYs	1 200	230	290	20	320	59	1	11	72	2 200

Table A1.5 (continued)

Country	CMM	SCC	BCC	Photoageing/ solar keratoses	Sunburn	Cortical cataract	SCCC	Pterygium	RHL	Total
Italy										
Deaths	1 400	220	87	0	0	0	0	0	0	1 800
DALYs	13 500	1 800	2 300	240	2 500	790	7	110	630	21 800
Jamaica										
Deaths	12	1	0	0	0	0	0	0	0	14
DALYs	110	10	17	1	35	330	0	5	34	540
Japan										
Deaths	740	480	190	0	0	0	0	0	0	1 400
DALYs	5 600	4 000	5 300	540	5 500	520	16	250	1 400	23 100
Jordan										
Deaths	15	11	4	0	0	0	0	0	0	30
DALYs	160	120	190	13	450	980	1	6	72	2 000
Kazakhstan										
Deaths	250	18	8	0	0	0	0	0	0	280
DALYs	2 900	170	280	35	830	370	1	16	160	4 700
Kenya										
Deaths	200	1	0	0	0	0	0	0	0	200
DALYs	2 200	19	23	2	230	11 200	6	2 500	390	16 500
Kiribati										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	0	0	3	0	3	13	0	0	1	22
Kuwait										
Deaths	1	3	1	0	0	0	0	0	0	5
DALYs	13	37	73	4	120	520	0	3	24	800
Kyrgyzstan										
Deaths	36	8	3	0	0	0	0	0	0	47
DALYs	380	80	110	11	280	160	1	5	48	1 100
Lao People's Democratic Republic										
Deaths	13	1	1	0	0	0	0	0	0	15
DALYs	140	14	46	1	180	470	1	7	62	930
Latvia										
Deaths	79	3	1	0	0	0	0	0	0	83
DALYs	730	22	40	6	98	90	0	2	22	1 000
Lebanon										
Deaths	9	5	2	0	0	0	0	0	0	16
DALYs	120	50	73	7	190	810	0	3	34	1 300
Lesotho										
Deaths	15	15	15	15	15	15	15	15	15	15
DALYs	15	15	15	15	15	15	15	15	15	15
Liberia										
Deaths	57	0	0	0	0	0	0	0	0	57
DALYs	510	1	2	0	27	1 200	0	230	37	2 000
Libyan Arab Jamahiriya										
Deaths	23	10	4	0	0	0	0	0	0	36
DALYs	330	110	170	12	370	1 100	1	6	62	2 200
Lithuania										
Deaths	90	5	2	0	0	0	0	0	0	97
DALYs	890	39	67	9	160	120	0	4	35	1 300
Luxembourg										
Deaths	12	0	0	0	0	0	0	0	0	12
DALYs	120	4	7	1	17	5	0	0	4	160
Madagascar										
Deaths	150	2	1	0	0	0	0	0	0	0
DALYs	1 600	19	53	0	280	6 700	3	1 300	180	0
Malawi										
Deaths	120	14	2	0	0	0	0	0	0	140
DALYs	1 100	52	21	0	77	4 300	4	790	250	6 600
Malaysia										
Deaths	48	37	18	0	0	0	0	0	0	100
DALYs	370	410	910	23	960	12 700	6	38	290	15 700
Maldives										
Deaths	1	0	3	0	0	0	0	0	0	4
DALYs	7	6	250	0	8	69	1	43	5	390

Country	Photoageing/ solar						Cortical cataract	SCCC	Pterygium	RHL	Total
	CMM	SCC	BCC	keratoses	Sunburn						
Mali											
Deaths	37	0	2	0	0	0	0	0	0	0	39
DALYs	570	33	50	6	98	76	0	3	21		850
Malta											
Deaths	6	1	1	0	0	0	0	0	0	0	8
DALYs	61	14	17	2	19	5	0	1	4		120
Marshall Islands											
Deaths	0	0	0	0	0	0	0	0	0	0	0
DALYs	2	0	1	0	3	8	0	0	1		15
Mauritania											
Deaths	27	0	0	0	0	0	0	0	0	0	27
DALYs	220	1	0	0	18	1 200	1	240	33		1 700
Mauritius											
Deaths	2	1	0	0	0	0	0	0	0	0	3
DALYs	43	10	22	0	35	780	0	170	16		1 100
Mexico											
Deaths	850	76	40	0	0	0	0	0	0	0	970
DALYs	7 800	740	1 800	27	3 500	11 600	20	150	1 300		27 000
Micronesia (Federated States of)											
Deaths	1	0	0	0	0	0	0	0	0	0	1
DALYs	3	1	4	0	18	13	0	1	6		48
Monaco											
Deaths	1	0	0	0	0	0	0	0	0	0	1
DALYs	6	1	1	0	1	0	0	0	0		10
Mongolia											
Deaths	8	0	0	0	0	0	0	0	0	0	8
DALYs	60	2	6	0	78	200	0	2	24		370
Morocco											
Deaths	57	48	19	0	0	0	0	0	0	0	120
DALYs	810	510	750	58	1 700	7 100	4	32	320		11 300
Mozambique											
Deaths	150	22	3	0	0	0	0	0	0	0	170
DALYs	1 500	82	29	0	130	7 100	6	1 600	440		10 900
Myanmar											
Deaths	55	19	11	0	0	0	0	0	0	0	85
DALYs	620	260	540	4	1 500	5 400	13	5 100	590		14 100
Namibia											
Deaths	38	3	1	0	0	0	0	0	0	0	41
DALYs	450	17	14	0	23	770	1	170	39		1 500
Nauru											
Deaths	0	0	0	0	0	0	0	0	0	0	0
DALYs	1	0	0	0	0	2	0	0	0		3
Nepal											
Deaths	45	5	3	0	0	0	0	0	0	0	53
DALYs	600	58	140	0	780	6 300	4	2 000	260		10 100
Netherlands											
Deaths	450	23	10	0	0	0	0	0	0	0	490
DALYs	5 100	170	280	39	640	200	1	16	150		6 600
New Zealand											
Deaths	210	9	4	0	0	0	0	0	0	0	220
DALYs	2 100	77	100	11	170	12	0	6	40		2 500
Nicaragua											
Deaths	10	4	2	0	0	0	0	0	0	0	15
DALYs	120	62	89	2	190	780	1	410	61		1 700
Niger											
Deaths	38	0	0	0	0	0	0	0	0	0	39
DALYs	400	3	5	0	81	3 800	2	870	130		5 300
Nigeria											
Deaths	1 200	2	0	0	0	0	0	0	0	0	1 200
DALYs	9 300	26	16	0	770	47 300	19	9 700	1 300		68 400
Niue											
Deaths	0	29	13	0	0	0	0	0	0	0	42
DALYs	0	320	620	21	940	0	5	35	280		2 200

Table A1.5 (continued)

Country	CMM	SCC	BCC	Photoageing/ solar keratoses	Sunburn	Cortical cataract	SCCC	Pterygium	RHL	Total
Norway										
Deaths	200	6	3	0	0	0	0	0	0	210
DALYs	1 900	44	67	10	170	54	0	4	38	2 300
Oman										
Deaths	4	6	3	0	0	0	0	0	0	13
DALYs	47	77	160	6	160	500	1	3	30	980
Pakistan										
Deaths	270	32	20	0	0	0	0	0	0	320
DALYs	3 300	360	950	0	5 100	37 300	29	12 400	1 700	61 300
Palau										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	1	0	0	0	1	3	0	0	0	5
Panama										
Deaths	20	3	1	0	0	0	0	0	0	24
DALYs	180	26	59	1	99	380	1	5	37	790
Papua New Guinea										
Deaths	59	0	0	0	0	0	0	0	0	59
DALYs	710	2	4	0	40	600	1	0	61	1 400
Paraguay										
Deaths	30	1	1	0	0	0	0	0	0	32
DALYs	310	12	34	0	180	560	1	6	61	1 200
Peru										
Deaths	180	38	22	0	0	0	0	0	0	0
DALYs	1 700	650	1 200	14	970	4 800	13	3 300	360	0
Philippines										
Deaths	240	28	18	0	0	0	0	0	0	280
DALYs	3 200	290	930	4	2 600	35 600	14	110	950	43 600
Poland										
Deaths	1 300	43	21	0	0	0	0	0	0	1 300
DALYs	13 000	370	640	89	1 700	1 600	2	38	360	17 800
Portugal										
Deaths	220	35	14	0	0	0	0	0	0	260
DALYs	2 200	290	380	38	460	130	1	18	110	3 600
Qatar										
Deaths	0	1	1	0	0	0	0	0	0	2
DALYs	0	18	41	1	25	140	0	2	8	230
Republic of Korea										
Deaths	320	6	4	0	0	0	0	0	0	330
DALYs	2 800	53	170	0	1 200	6 400	3	58	500	11 200
Republic of Moldova										
Deaths	58	5	2	0	0	0	0	0	0	65
DALYs	700	41	71	10	200	120	0	4	41	1 200
Romania										
Deaths	570	37	17	0	0	0	0	0	0	620
DALYs	5 600	330	530	65	1 000	980	2	30	230	8 800
Russian Federation										
Deaths	2 100	160	82	0	0	0	0	0	0	2 400
DALYs	27 500	1 500	2 600	360	6 400	5 000	8	150	1 400	45 000
Rwanda										
Deaths	91	10	1	0	0	0	0	0	0	100
DALYs	770	37	14	0	54	2 900	3	550	180	4 500
Saint Kitts and Nevis										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	0	0	0	0	0	6	0	0	1	7
Saint Lucia										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	4	0	1	0	1	17	0	0	2	26
Saint Vincent and the Grenadines										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	0	0	0	0	1	14	0	0	2	18
Samoa										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	6	1	2	0	6	22	0	0	2	40

Country	CMM	SCC	BCC	Photoageing/ solar		Cortical		Pterygium	RHL	Total
				keratoses	Sunburn	cataract	SCCC			
San Marino										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	5	1	1	0	1	0	0	0	0	8
Sao Tome and Principe										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	10	0	1	0	6	62	0	15	2	96
Saudi Arabia										
Deaths	29	66	32	0	0	0	0	0	0	130
DALYs	350	830	1 900	56	1 400	4 300	6	33	270	9 100
Senegal										
Deaths	120	0	0	0	0	0	0	0	0	120
DALYs	1 100	3	7	0	79	3 900	2	780	110	5 900
Serbia and Montenegro^a										
Deaths	170	20	9	0	0	0	0	0	0	190
DALYs	2 200	190	290	34	490	460	1	16	110	3 800
Seychelles										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	11	0	1	0	3	52	0	7	1	75
Sierra Leone										
Deaths	45	0	0	0	0	0	0	0	0	45
DALYs	410	1	1	0	34	1 900	1	410	57	2 900
Singapore										
Deaths	20	12	5	0	0	0	0	0	0	36
DALYs	170	120	180	11	170	670	1	7	45	1 400
Slovakia										
Deaths	130	6	3	0	0	0	0	0	0	130
DALYs	1 500	52	88	12	240	220	0	5	51	2 100
Slovenia										
Deaths	70	3	2	0	0	0	0	0	0	75
DALYs	810	33	52	6	90	26	0	3	21	1 000
Solomon Islands										
Deaths	2	0	0	0	0	0	0	0	0	2
DALYs	9	0	0	0	4	49	0	0	5	68
Somalia										
Deaths	76	2	1	0	0	0	0	0	0	79
DALYs	1 100	39	63	1	130	3 400	2	810	120	5 700
South Africa										
Deaths	390	39	8	0	0	0	0	0	0	430
DALYs	4 500	350	270	14	700	21 600	10	3 600	800	31 800
Spain										
Deaths	890	130	54	0	0	0	0	0	0	1 100
DALYs	7 700	1 300	1 600	160	1 900	520	5	75	440	13 600
Sri Lanka										
Deaths	21	13	8	0	0	0	0	0	0	42
DALYs	210	120	380	0	590	12 700	5	40	260	14 300
Sudan										
Deaths	390	47	23	0	0	0	0	0	0	460
DALYs	6 300	1 000	1 400	32	990	14 600	11	3 100	390	27 900
Suriname										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	5	2	5	0	13	49	0	1	5	80
Swaziland										
Deaths	34	1	0	0	0	0	0	0	0	35
DALYs	290	4	2	0	8	390	0	63	21	780
Sweden										
Deaths	310	18	7	0	0	0	0	0	0	340
DALYs	2 700	120	180	24	340	110	0	10	80	3 600
Switzerland										
Deaths	220	20	8	0	0	0	0	0	0	240
DALYs	2 100	150	210	25	320	96	1	11	76	3 000
Syrian Arab Republic										
Deaths	17	20	8	0	0	0	0	0	0	45
DALYs	160	210	330	27	1 100	3 200	2	13	170	5 100

Table A1.5 (continued)

Country	CMM	SCC	BCC	Photoageing/ solar keratoses	Sunburn	Cortical cataract	SCCC	Pterygium	RHL	Total
Tajikistan										
Deaths	17	11	4	0	0	0	0	0	0	33
DALYs	230	110	160	12	390	160	1	6	64	1 100
Thailand										
Deaths	140	67	33	0	0	0	0	0	0	240
DALYs	1 300	680	1 500	31	2 200	39 500	14	120	840	46 100
The former Yugoslav Republic of Macedonia										
Deaths	61	3	2	0	0	0	0	0	0	66
DALYs	570	33	50	6	98	76	0	3	21	850
Timor-Leste										
Deaths	2	0	0	0	0	0	0	0	0	2
DALYs	23	4	16	0	31	0	0	1	11	88
Togo										
Deaths	40	0	0	0	0	0	0	0	0	40
DALYs	330	1	1	0	34	1 900	1	400	56	2 700
Tonga										
Deaths	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DALYs	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trinidad and Tobago										
Deaths	4	1	0	0	0	0	0	0	0	5
DALYs	33	6	18	0	28	190	0	3	18	300
Tunisia										
Deaths	22	20	8	0	0	0	0	0	0	50
DALYs	220	200	270	23	580	2 200	1	12	100	3 600
Turkey										
Deaths	260	100	42	0	0	0	0	0	0	400
DALYs	3 800	1 000	1 500	160	3 900	1 700	7	77	700	12 800
Turkmenistan										
Deaths	27	6	2	0	0	0	0	0	0	36
DALYs	360	61	92	9	270	130	0	4	45	970
Tuvalu										
Deaths	0	0	0	0	0	0	0	0	0	0
DALYs	0	0	0	0	0	2	0	0	0	3
Uganda										
Deaths	140	31	5	0	0	0	0	0	0	170
DALYs	1 200	120	58	0	170	7 700	8	1 400	510	11 100
Ukraine										
Deaths	1 100	71	34	0	0	0	0	0	0	1 200
DALYs	12 100	620	1 000	140	2 100	1 800	3	58	480	18 400
United Arab Emirates										
Deaths	2	4	2	0	0	0	0	0	0	8
DALYs	21	63	140	5	100	640	1	6	33	1 000
United Kingdom of Great Britain and Northern Ireland										
Deaths	1 700	11	5	0	0	0	0	0	0	1 700
DALYs	16 600	80	130	18	290	740	0	7	67	17 900
United Republic of Tanzania										
Deaths	400	48	8	0	0	0	0	0	0	460
DALYs	4 600	190	91	0	250	12 600	13	2 700	800	21 200
United States of America										
Deaths	7 700	770	290	0	0	0	0	0	0	8 800
DALYs	84 900	6 200	7 900	750	11 100	3 600	31	490	3 000	118 000
Uruguay										
Deaths	63	13	5	0	0	0	0	0	0	82
DALYs	650	120	140	11	160	660	1	6	38	1 800
Uzbekistan										
Deaths	110	35	14	0	0	0	0	0	0	160
DALYs	1 100	360	520	48	1 500	700	3	23	250	4 500
Vanuatu										
Deaths	1	0	0	0	0	0	0	0	0	1
DALYs	5	0	0	0	2	24	0	0	2	34
Venezuela (Bolivarian Republic of)										
Deaths	220	29	14	0	0	0	0	0	0	260
DALYs	2 100	320	730	16	900	2 900	6	40	320	7 300

Country	Photoageing/ solar									
	CMM	SCC	BCC	keratoses	Sunburn	Cortical cataract	SCCC	Pterygium	RHL	Total
Viet Nam										
Deaths	62	31	17	0	0	0	0	0	0	110
DALYs	750	280	720	6	2 700	8 800	11	110	970	14 400
Yemen										
Deaths	64	50	27	0	0	0	0	0	0	140
DALYs	1 200	1 100	1 800	35	1 200	3 400	8	1 400	220	10 400
Zambia										
Deaths	110	12	2	0	0	0	0	0	0	120
DALYs	910	49	23	0	73	3 600	3	570	210	5 400
Zimbabwe										
Deaths	82	14	2	0	0	0	0	0	0	98
DALYs	930	58	26	0	92	4 500	4	860	270	6 700

BCC: basal cell carcinoma of the skin; CMM: cutaneous malignant melanoma; RHL: reactivation of herpes labialis; SCC: squamous cell carcinoma of the skin; SCCC: squamous cell carcinoma of the cornea and conjunctiva

^a It should be noted that only aggregate data are available for Serbia and Montenegro, although WHO recognizes both as Member States.

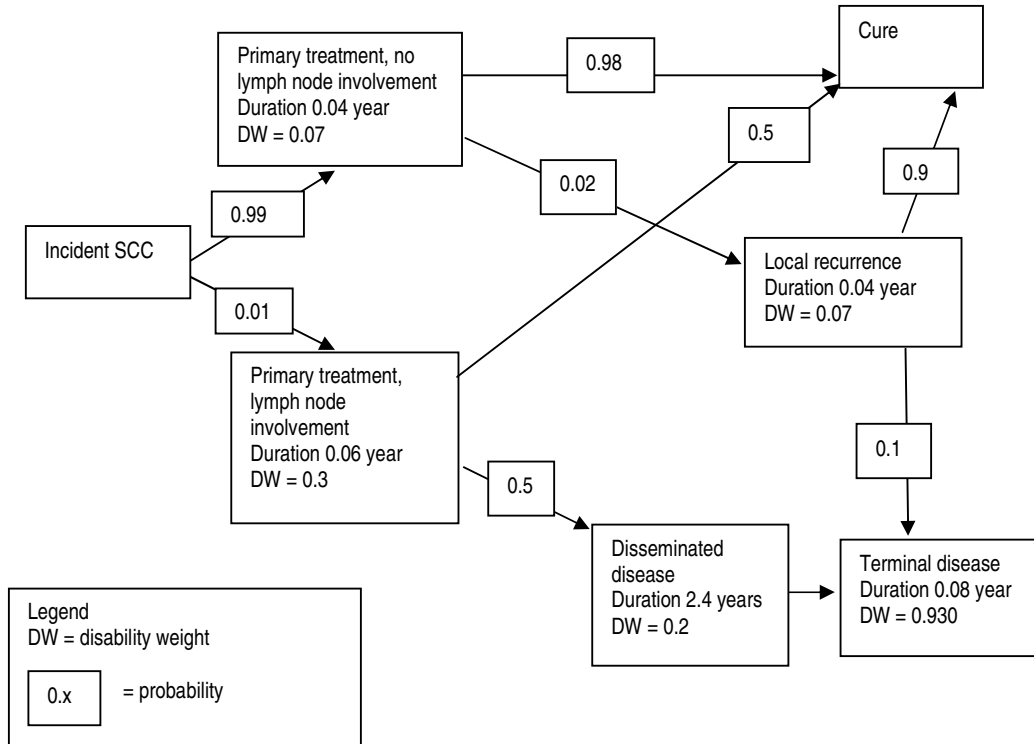
Notes:

1. Figures have been computed on the basis of a number of hypotheses and to ensure comparability; thus, they are not necessarily the official statistics of Member States, which may use alternative rigorous methods.
2. The total regional disease burden calculated from the sum of the disease burdens of the individual countries differs from the regional estimates for the year 2000 (Tables A1.1 and A1.2), in part because estimates of the total disease burden for certain diseases changed significantly between the years 2000 and 2002. Additionally, the models underlying the calculation tool have been adjusted slightly from those used for the global assessment, to allow the estimation of disease incidence data from the population-weighted ambient UVR level.

Appendix 2: Disease models

Figure A2.1 Disease model for SCC

ABC subregions



DE subregions

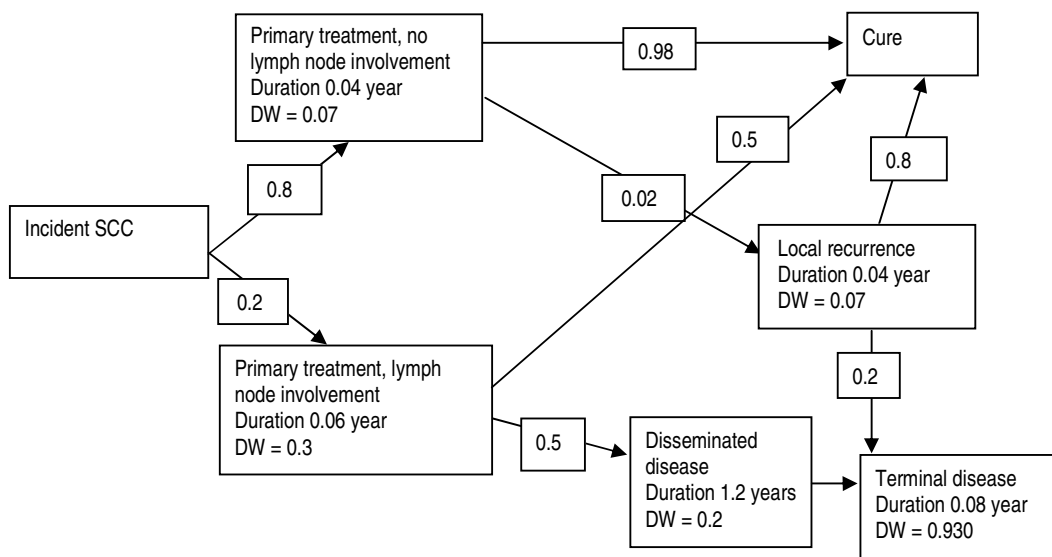


Figure A2.2 Disease model for BCC—all regions

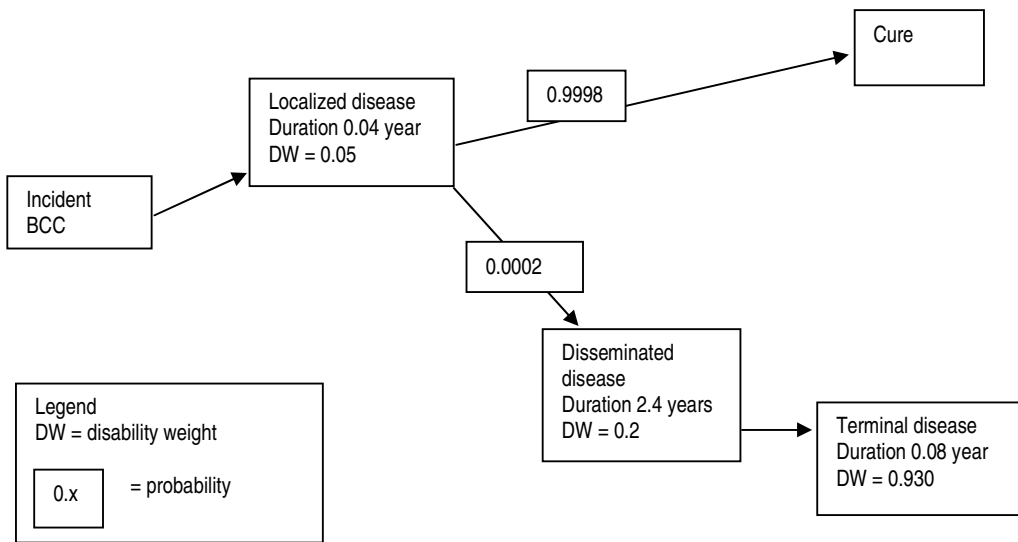


Figure A2.3 Disease model for solar keratoses—all regions

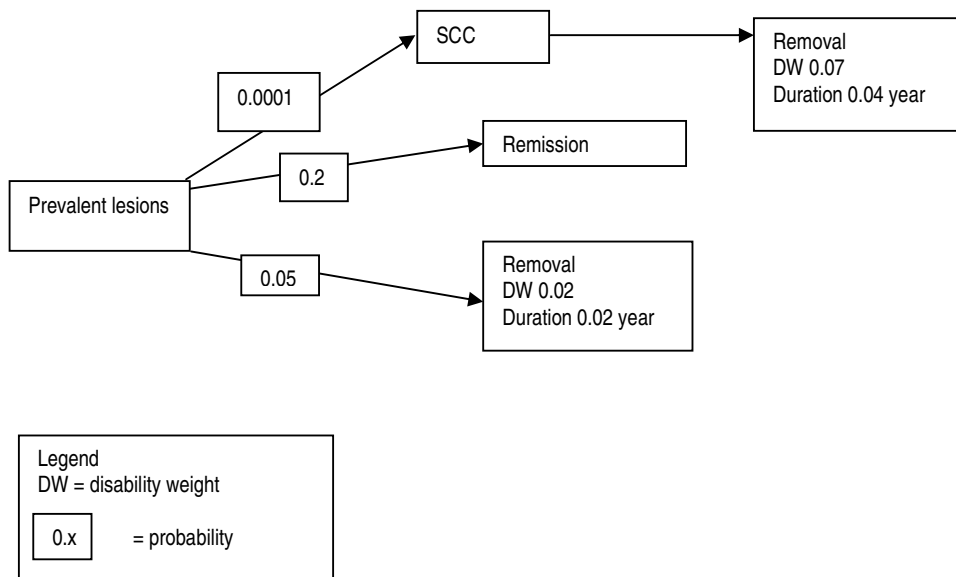


Figure A2.4 Disease model for sunburn—all regions

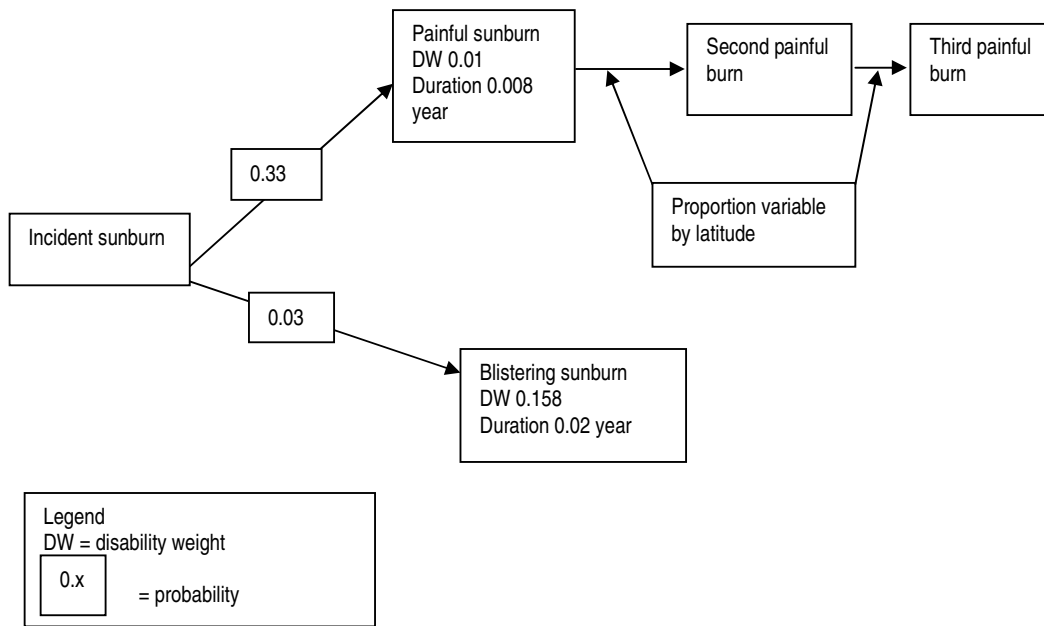


Figure A2.5 Disease model for pterygium—all regions

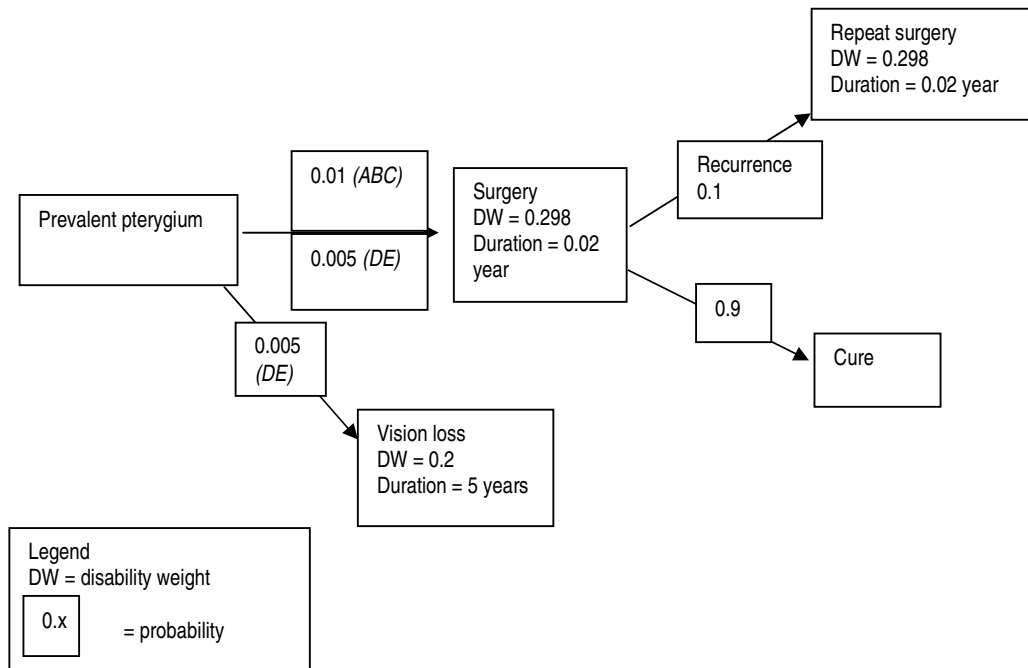
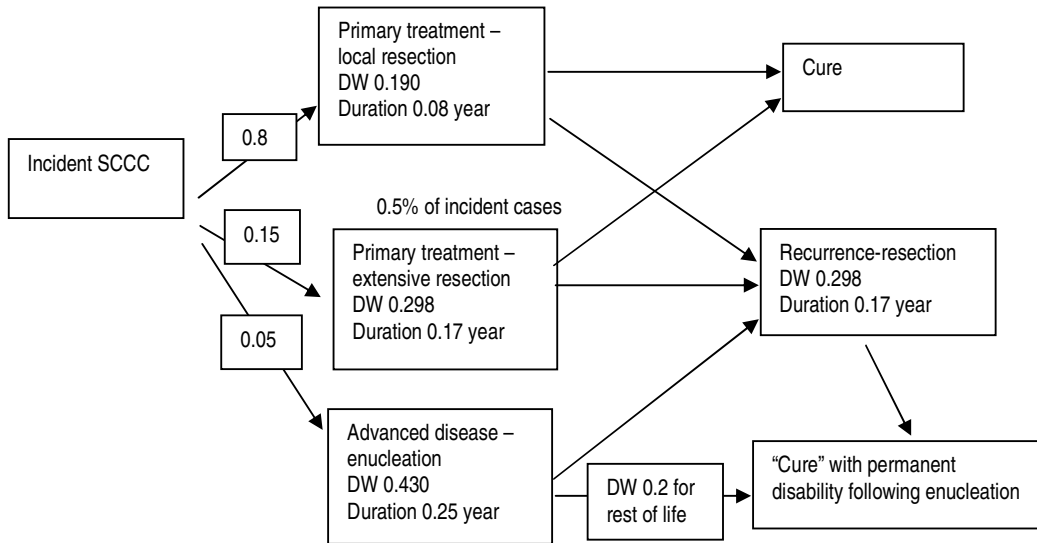
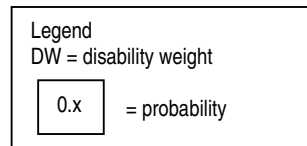
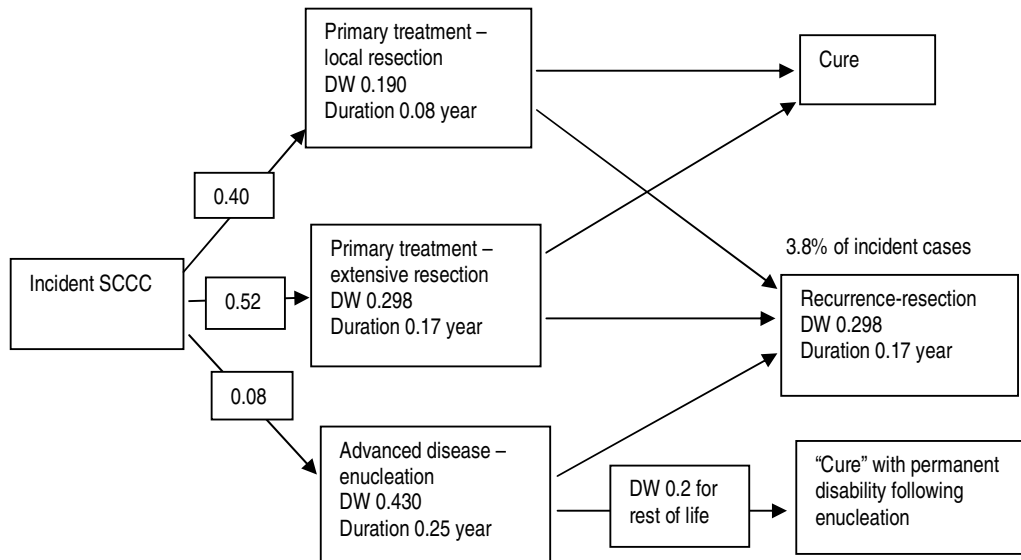


Figure A2.6 Disease model for SCCC

ABC subregions



DE subregions



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ENVIRONMENTAL BURDEN of DISEASE

This guide describes how to estimate the disease burden caused by exposure to solar ultraviolet radiation, on a national and regional level. It is one in a series of guides that describe how to estimate the burden of disease caused by environmental and occupational risk factors. An introductory volume to the series outlines the general method; subsequent volumes address methods for specific risk factors, such as outdoor air pollution, inadequate water, sanitation and hygiene or exposure to mercury.

The guide summarizes the evidence linking inappropriate exposure to ultraviolet radiation to health, and the methods for estimating its impacts on a population basis. This is done in a practical step-by-step approach that can be adapted to local circumstances and knowledge. First approximate estimates are provided by country, which can be refined with additional input data.

Quantitative assessment of the size and distribution of health risks can be an important tool in identifying which actions will be most effective to reduce disease and injury.

The web site www.who.int/phe provides additional information on environmental burden of disease and environmental risks to health. For further information: EBDAssessment@who.int.

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