# UV radiation; sources, effects and risks of human and environmental exposure

G.J. Eggink, H. Slaper
Laboratory for Radiation Research,
National Institute of Public Health and Environmental Protection
P.O.Box 1, 3720 BA BILTHOVEN, The Netherlands

**ABSTRACT**

*This paper summarizes the principal results of a review study on UV-exposure and UV related risks in the Netherlands. Both the present state of affairs and future developments are discussed, the latter partly based on model calculations.*

*The sun is the main UV source to which the whole population is exposed. Solar exposure is estimated to amount to at least 90% of the annual UV burden for the Dutch population. For certain groups in the population man made sources are estimated to contribute considerably to the yearly UV dose. Ozone depletion as a result of human activities, growing use of tungsten halogen lamps and increasing application of UV-sources in industry and medicine all tend to increase UV exposure.*

*UV exposure can lead to a wide variety of health effects, among which the induction of skin cancer, skin aging, cataract formation and suppression of immune responses. Risk estimates of these health effects are available for skin cancer and to a lesser extend for cataracts. The estimated UV related skin cancer incidence rate in the Netherlands is $10^{-3}$ per year (15 000 cases), and the associated mortality rate amounts to $6\text{-}25 \cdot 10^{-6}$ per year (90-400 deaths). The ozone depletion presently observed over the past decade (5% in the Netherlands), is expected to lead to an increased annual mortality rate due to skin cancer of $1{,}3 \cdot 10^{-6}$ per year.*

*Environmental exposure can influence plant physiology and lead to a decrease of biomass in aquatic as well as terrestrial ecosystems. This may result in adverse effects on the foodweb and biodiversity of ecosystems. Quatitative risk estimates for these effects are very uncertain or lacking.*

## INTRODUCTION

UV-exposure of man and the environment is caused by emissions from a number of sources. The UV-burden for man as well as for ecosystems is expected to increase due to:
- the depletion of the ozone layer (the main UV absorbing layer in the earths atmosphere)
- the increasing use of UV-emitting light sources (e.g. tungsten halogen lamps)
- the use of tanning equipment
- the use of UV sources in industry and laboratories (lasers, welding, lamps for paintdrying, copiers, etc.)
- the use of UV-sources in medical therapies (PUVA, UVB-therapy, lasers)

Based on the recent knowledge of exposure and effects, an estimation is made of the related risks of (over)exposure.
Based on the 'source-distribution-exposure-effect-risk chain' this UV issue will be presented.

## SOURCES, DISTRIBUTION AND EXPOSURE

The sun is the main and only natural UV source on earth. The spectral distribution peaks in the visible part of the spectrum with a relative large fraction in the UV. Due to the absorbing and scattering properties of the atmospheric layers (esp. the ozone layer) the radiation reaching the earth surface contains less UV.
The effectiveness of UV radiation is strongly dependent upon the wavelenght. The MED is used as a unit for effective UV-doses and corresponds to a UV-dose which is just sufficient to elicit erythema (in unadapted white skin). One MED is equivalent to a dose of 200 $J/m^2$ of monochromatic 297 nm radiation.
In the Netherlands the total amount of solar (erythema-effective) UV radiation is estimated to be 2200 MED/a (Schothorst, 1987; Slaper, 1987). Over 75% is available in the period May-August; less than 7.5% from November-February. Based on measurements with personal dosimeters indoor workers are estimated to be exposed to about 70 MED/a and outdoorworkers receive about 150 MED/a (Slaper, 1987). The dose acquired during holidays must be added to this and is estimated to be 2-50 MED for a three weeks period in the Netherlands and 60-150 MED for three weeks in the Mediterranean (Health Council, 1986).
Based on recent measurements by NASA satellites the ozone layer decreased with an average of 5% in the last 10 years in NorthWest Europe (Stolarski et al, 1991). Model calculations of the UV-transfer in the atmosphere indicate that this reduction leads to an increase in erythema-effective UV on the earth surface of about 6.5%. This in turn corresponds to an additional 6.5 MED/a for the average exposed person in the Netherlands and an

additional 13 MED/a for the group with highest sun exposure (5% of population).
Artificial UV-sources are found in various applications: regular lighting systems, tanning equipment, medical phototherapies, industrial lightsources, lasers etc. In the indoor environment exposure can be divided in intentional and unintentional exposure. Intentional exposure takes place during tanning and medical UV therapies.
Depending on the characteristics of the lightsources (e.g. temperature of tungsten lamps, quality of the glass envelope, pressure and gas used in gas discharge lamps etc.) the UV emission can vary by several orders of magnitude.
Assuming an exposure time of 500 h/a (= 1.5 h/d) a potential exposure of 10-500 MED/a for tungsten halogen lights and about 2 MED/a for fluorescent lamps is estimated (McKinlay et al, 1989). Personal dosimetry is lacking. It appears that tungsten halogen lamps are the most important UV emitting artificial lightsources for the general public.
The use of special UV emitting fluorescent lamps for tanning is widely spread in the Netherlands. About 7% of the population (≈ 1 million) uses tanning equipment. The average yearly dose received as a result of the use of these artificial sources is estimated to be 24 MED/a (Berghahn & Bruggers, 1986).

Since 1900 ultraviolet radiation is used in medical therapies, for treating tuberculoses, rachitis, and later on for treating several skin diseases. Nowadays UV is mainly used in treating psoriasis (ca 200 000 patients in the Netherlands). Two types of therapy are common: PUVA and UVB-therapy. In PUVA the skin is sensitized by means of psoralens and treated with UVA ('black-light). In UVB-therapy the skin is directly exposed to UVB. The average yearly dose is 250 MED/a, but doses of more than 500 MED/a are not unusual. For PUVA-therapy the UV dose depends greatly on the amount and type of psoralens. An average value can not be given. Figure 1 gives the estimated yearly doses for the general public and for some selected groups of the population. In this figure outdoors workers are farmers, fishermen, roadworkers etc. Halogenlamp users are assumed to be exposed to bare halogen lamps for 500 h/a at a distance of 30 cm.

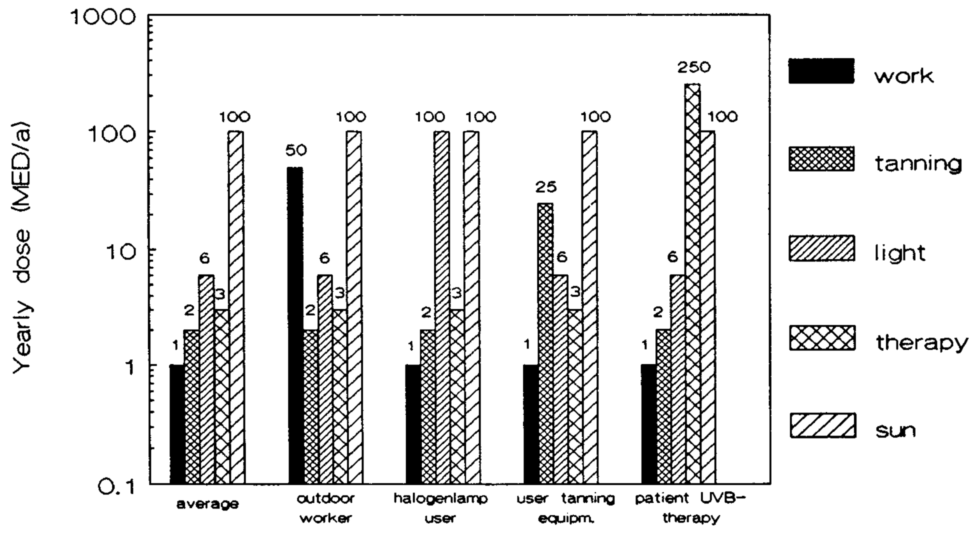


Figure 1. Estimated yearly effective UV dose for the general public and some selected groups in the Netherlands.

## EFFECTS AND RISKS

UV exposure can lead to several deleterious effects in man, some shortly after acute exposure (sunburn, snowblindness) and some after prolonged exposure (skin cancer, skin aging, damage to the immune system and cataract formation).
For skin carcinoma (basal cell carcinoma and squamous cell carcinoma) UV exposure is assumed to be the main cause. For melanoma and cataract it is believed that UV contributes to the incidences although the extend is uncertain. The incidence and mortality rate for skincarcinoma, melanoma and cataract operations in the Netherlands is given in figure 2a. Figure 2b provides estimates of the additional effects of a 1% increase in effective exposure (1 MED additional for average exposed group).

A 1% increase of the effective UV exposure is expected to lead to an increase in cataract incidence of 0.5%, corresponding to an increased incidence rate of $10^{-5}$ per year in the Netherlands. This implies an additional 100-150 cataract operations per year in the Netherlands.

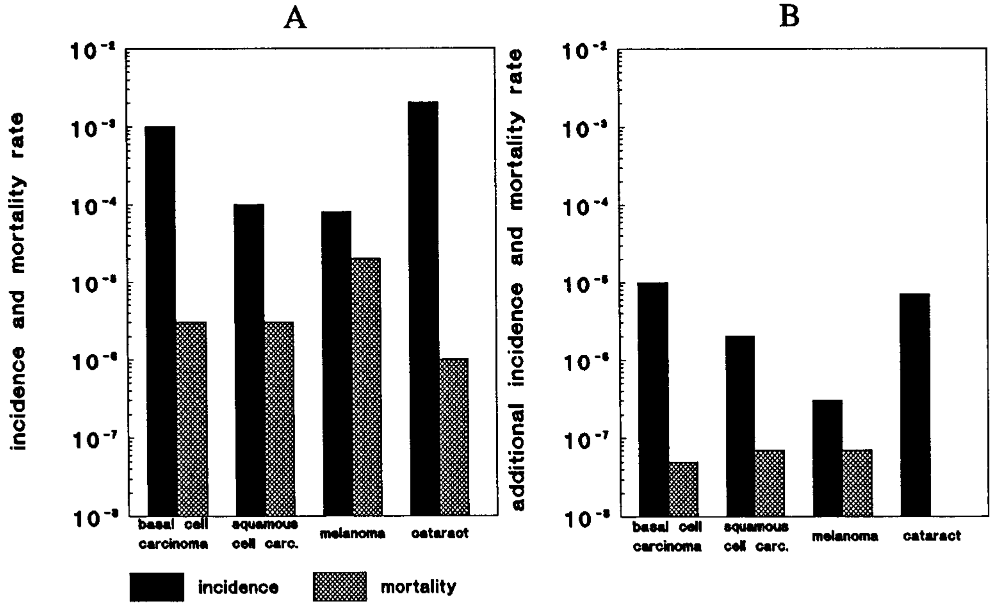


Figure 2. A. Incidence and mortalilty rate of carcinoma, melanoma and cataract (operations).
B. Additional incidence and mortality rate caused by an additional 1% effective UV.

Death rates due to skin cancer in the Netherlands are: 80-90 deaths per year due to skincarcinoma, 300 deaths per year due to melanoma. The estimated yearly mortality rate in the Netherlands associated with average UV exposure is $6\text{-}25\cdot10^{-6}$ per year. For 'highly-exposed' persons (200 MED/a) this is $25\text{-}55\cdot10^{-6}$. Based on models, the additional mortality rate for the 'average-exposed' group is calculated to be $2\cdot10^{-7}$ per MED. For the 'high-exposed' group this is estimated to be $4\cdot10^{-7}$. For persons with an extra sensitive skin the risks are $4\cdot10^{-7}$ and $7\cdot10^{-7}$ per MED respectively. Table 1 gives an overview of the estimated risks and mortality rates for various exposure situations.
Evidence has been gathered in experiments with animals and humans that UV exposure of the skin causes damage to the immune system. An assessment of the risks can not yet be made, due to a lack of information about the mechanism, the dose-reponse relation and the action spectra.

In terrestrial plants UV exposure can influence several processes that have a negative effect on the growth and development of plants, like smaller leaf size, less flowering, and a lower fotosynthetic activity. These effects can be reinforced by certain deficiencies and waterstress (UNEP, 1989). Although this is very species-specific (even great intraspecific (cultivar) differences have been observed) many of the observed effects lead to a decrease of biomass by influencing the primairy production. Further study is needed to get more information on the mechanisms of UVB-effects and the possible effects of ozone depletion on food plants.
Research indicates that also phytoplankton and zooplankton in aquatic ecosystems can be affected. This includes orientation, motility, photosynthesis and enzymatic reactions and the survival of small marine organisms during their first stadia of life (fish eggs and -young, shrimp larvae and crab larvae). These changes can lead to disturbance of stable ecosystems, and can have negative effects on the foodweb, the biodiversity of ecosystems, and finally on the human foodsupply. Based on the assumption of a 5% decrease in primairy production (estimated for a 16% ozone depletion) Häder calculated that fish yield would reduce by approximately 6-9% (a 7% reduction in fish yield, if it is on a global basis, would then represent a loss of about 6 million tons of fish per year) (Häder et al, 1989). However, uncertainties regarding the magnitude of these effects remain large, because of problems of extrapolating laboratory findings to the open sea and the nearly absence of data on long-term effects and ecosystem responses.

Further research on the ecosystem effects is necessary to get a proper view of their possible ecological impact.

| Sources | exposure | estimated group size | effective dose (MED/y) | mortality rate |
|---|---|---|---|---|
| outdoor environment | | | | |
| sun | normal | $15 \cdot 10^6$ (100%) | 100 | $6\text{-}25 \cdot 10^{-6}$ |
| | high | $7 \cdot 10^5$ (5%) | 200 | $25\text{-}55 \cdot 10^{-6}$ |
| | high, sensitive skin | $2 \cdot 10^5$ (1.3%) | 200 | $30\text{-}150 \cdot 10^{-6}$ |
| ozone depletion *) | normal | $15 \cdot 10^6$ (100%) | 7 (?) | $1,3 \cdot 10^{-6}$ **) |
| | high | $7 \cdot 10^5$ (5%) | 13 (?) | $5 \cdot 10^{-6}$ **) |
| | high, sensitive skin | $2 \cdot 10^5$ (1.3%) | 13 (?) | $9 \cdot 10^{-6}$ **) |
| indoor environment | | | | |
| tungsten halogen lamps | | | | |
| - 500 hours desk-lamp distance 30 cm | normal | $1 \cdot 10^5$ (0.7%) (??) | 100 (?) | $20 \cdot 10^{-6}$ **) |
| fluorescent lamps | | | | |
| - 500 hours distance 100 cm | normal | $1 \cdot 10^6$ (7%) (??) | 2 (?) | $0,4 \cdot 10^{-6}$ **) |
| tanning equipment | normal | $1 \cdot 10^6$ (7%) (??) | 25 (?) | $5 \cdot 10^{-6}$ **) |
| medical therapy | | | | |
| UVB-therapy (psoriasis) | normal | $1 \cdot 10^5$ (0.7%) (??) | 250 (?) | $50 \cdot 10^{-6}$ **) |

*) additional UV exposure caused by measured ozone depletion (5%)
**) additional risk caused by the indicated source
(?) estimated exposure
(??) groupsize not known (preliminary estimate)

Table 1. Estimated effective doses and mortality rates for different groups of the Dutch population due to different UV sources. The estimated group size is based on a total population of 15 million persons.

## REFERENCES


*Berghahn, A.J.; Bruggers, J.H.A.* Individueel gebruik van UV-toestellen en eventuele ongewenste gevolgen in Nederland. Rapport Stralenbescherming 18, Den Haag: Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 1986.

*Häder, D.P.; Worrest, R.C.; Kumar, H.D.* Aquatic ecosystems. In: UNEP, Environmental Effects Panel Report. Nairobi: UNEP, 1989.

*Health Council of the Netherlands.* UV radiation. Human exposure to ultraviolet radiation. A report of a committee of the Health Council of the Netherlands. report nr 09/1986. The Hague: Health Council, 1986.

*McKinlay A.F.; Whillock, M.J.; Meulemans, C.C.E.* Ultraviolet radiation and blue-light emissions from spotlight incorporating tungsten halogen lamps. NRPB-R228. Chilton: National Radiological Protection Board, 1989.

*Schothorst, A.; Slaper, H.; Telgt, D.; Alhadi, B.; Suurmond, D.* Amounts of ultravoilet B (UVB) received from sunlight or artificial UV sources by various population groups in the Netherlands. In: Passchier, W.F.; Bosnjakovic, B.F.M. (eds). Human exposure to ultraviolet radiation. Risks and regulations. Amsterdam: Exerpta Medica, 1987.

*Slaper, H.* Skin cancer and UV exposure: investigations on the estimation of risks. Ph D Thesis. Utrecht: University of Utrecht, 1987.

*Slaper, H., Eggink G.J.* Exposure to ultraviolett radiation. report nr 249104002., in Dutch. RIVM, Bilthoven 1991

*Stolarski, R.S.; Bloomfield, P.; McPeters R.D.* Total ozone treads deduced from nimbus 7 TOMS data. Geophys Res Lett 1991; 18(6): 1015-8.

*UNEP. United Nations Environment programme.* Environmental Effects Panel Report, november 1989.