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Appendix

Frequently asked questions (FAQ)

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1. Health effects

1.1. How do we balance the good and bad effects of sunlight on human health?

In general, moderate exposure to sunlight in the course of everyday life is not detrimental. This basic exposure evidently allows us to function normally, and it proves to be sufficient to maintain an adequate level of vitamin D (in combination with our dietary intake). While sunlight is important for physical health, it also causes various adverse health effects such as skin cancer, ageing of the skin, eye disorders and suppression of the immune system. It is clear that excessive ultraviolet (UV) exposure should be avoided to minimize the risk of development of such disorders.

1.2. How strong is the evidence that UV-B radiation causes skin cancer in humans?

The evidence is strong. The earliest experimental evidence that UV-B radiation causes skin cancer was acquired with animals; in humans there was a clear association between sun exposure and skin cancer, but that did not point specifically to UV-B. In recent years the advancement of molecular biology has provided us with analyses producing direct evidence that genetic alterations found in human skin carcinomas are indeed caused by UV-B radiation.

1.3. Should one have all moles removed to decrease the risk of skin cancer?

No, there is no evidence to suggest that removing all moles would reduce the risk of skin cancer. However, it is important to be alert to atypical moles, especially those exhibiting changes in appearance (in colour or at the edges), and to screen those individuals that are known to run a high risk of skin cancer, either from a family history of melanoma mortality or of atypical moles.

1.4. Do sunglasses protect against cataracts?

Sunglasses that markedly reduce the UV exposure of the eyes will reduce UV damage, such as cataracts. The best protection is achieved by a combination of UV-absorbing glasses and a shielding against light coming into the eyes from the sides. However, some sunglasses may not effectively block UV radiation and eye damage may occur.

2. Duration of exposure to UV-B radiation

2.1. Is the amount of UV radiation one receives as a child important even in later years?

Yes. Children should not be overexposed to UV radiation: sunbathing should be strongly discouraged. UV exposure, and especially sunburns, in early life can substantially increase the skin-cancer risk later in life (especially the risk of basal cell carcinoma and melanoma).

Even if the risk is related to total accumulated exposure, as appears to be the case for a part of the non-melanocytic skin cancers (SCC), exposures early in life still may carry a greater risk. There is a long lag time, typically of several decades, between exposure and the development of a tumour. Therefore, early exposures have a greater probability of a tumour resulting.

3. Are animals at risk?

3.1. Are hair-covered animals at any risk?

Yes. Skin cancer is found in almost all animals that have been studied in the long term, for example, cattle, goats, sheep, cats, dogs, guinea pigs, rats and mice. Direct effects of UV-B radiation on body parts that are covered by thick hair are negligible. However, even furred animals usually

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have exposed skin around the mouth and nostrils, and sometimes on some other parts of the body. These parts, unless they are heavily pigmented, can be damaged by radiation.

3.2. Will penguins be affected by the ozone hole?

To our knowledge there are no studies concerning UV-B effects on penguins. As their eyes are exposed to a lot of UV radiation due to the high reflectivity of snow and a marked enhancement of UV during the ozone hole, investigation into the impact on penguins is desirable. The fact that penguins are visual predators, eating krill or fish in the water column, would make any eye damage an important issue for survival.

3.3. Is UV-B radiation a factor in the decline of frogs and other amphibians?

Possibly. Amphibian populations are in serious decline in many areas of the world, and scientists are seeking explanations for this. Most amphibian population declines are probably due to habitat destruction or habitat alteration. Some declines are probably the result of natural population fluctuations. Other explanations for the population declines, as well as the reductions in range of habitation, include disease, pollution, atmospheric changes and introduced competitors and predators. UV-B radiation is one agent that may act in conjunction with other stresses to affect amphibian populations adversely. Field studies in which embryos of frogs, toads and salamanders were exposed to natural sunlight or to sunlight with UV-B radiation removed have shown conflicting results. Some studies resulted in increased embryonic mortality after UV-B exposure, whereas others show that current levels of UV-B radiation are not detrimental. Factors such as water depth, water colour and the dissolved organic content of the water at the sites of egg deposition effectively reduce UV-B penetration through the water and reduce exposure to UV-B radiation at all life-history stages. Biotic factors, such as jelly capsules around eggs, melanin pigmentation of eggs, and colour of larvae and metamorphosed forms, further reduce the effects of UV-B exposure.

4. Aquatic life

4.1. Does water effectively shield aquatic organisms from UV exposure?

No. Pure water is quite transparent to UV radiation; a beam of UV-B radiation must travel over 500 m through pure water in order to be completely absorbed. Natural waters do contain UV-absorbing substances, such as dissolved organic matter, that partly shield aquatic organisms from UV-B, but the degree of shielding varies widely from one water body to another. In clear ocean and lake waters ecologically significant levels of UV-B can penetrate to several tens of metres; in contrast, in turbid rivers and wetlands UV-B may be completely absorbed within the top few decimetres. Most organisms in aquatic ecosystems, such as phytoplankton, live in the illuminated euphotic zone close to the water surface where exposure to UV-B can occur. In particular, UV-B radiation may damage those organisms that live at the surface of the water during their early life stages.

5. Terrestrial plant life

5.1. What will be the effects of an increased UV-B radiation on crop and forest yields?

There are some UV-B-sensitive varieties of crops that experience reductions in yield. However, there are also UV-B-tolerant varieties, providing the opportunity to breed and genetically engineer UV-B-tolerant varieties. For commercial forests, tree breeding and genetic engineering may be used to improve UV-B tolerance. For unmanaged or natural forests, these methods are not an option. While many forest tree species appear to be UV-B tolerant, there is some evidence that UV-B effects, sometimes detrimental, can slowly accumulate from year to year. If this finding is a general phenomenon, this would be a cause for concern since it would greatly complicate breeding efforts in commercial forests and negatively affect natural forests.

5.2. Can plants protect themselves against increased UV-B?

Yes, partly. Plants already have reasonable UV shielding; for most plants only a small proportion of the UV-B radiation striking a leaf actually penetrates very far into the inner tissues. Also, when exposed to an enhanced UV-B level, many species of plants can increase the UV-absorbing pigments in their tissues. Other adaptations include increased thickness of leaves, which reduces the proportion of inner tissues exposed to UV-B radiation. Several repair mechanisms also exist in plants, as is the case for other organisms. These include repair systems for DNA damage or oxidant injury. The net damage a plant experiences is the result of the balance among damage, protection and repair processes. For many plants, the net damage is negligible.

6. Location-specific issues

6.1. Is the increase in UV-B radiation caused by ozone depletion equivalent to that incurred by moving several hundred kilometres towards the equator?

Yes, but this comparison does not nullify the serious impact of an ozone depletion, as is sometimes suggested by questions like this. The suggestion is based on a fallacy, namely, comparing a personal risk perception with the effect on a population. An elevation of say 10% in risk would not be noticeable for the person involved. For a population it is quite different. With regard to skin cancer, such an increase could mean 100–200 extra cases a year per million people. This would be an important public health effect. However, movements of entire populations, or even ecosystems, do not usually occur in a human lifetime, and the comparison is therefore inappropriate.

6.2. Can organisms adjust to a changed UV environment?

Yes, many organisms can respond physiologically with changes such as development of UV-screening compounds and additional layers of protective tissues. However, there are genetic limitations to the degree to which these physiological adjustments can take place for each organism. Some can adjust more effectively than others. Over long periods of time and several generations of populations, there is the possibility that genetic adaptation can develop as well. However, in organisms with moderately long life spans and small population sizes, the genetic adaptation is likely to be very slow.

6.3. Does ozone depletion pose any danger in the tropics?

Probably not. Increases in UV-B radiation are unlikely, since no significant trend in stratospheric ozone has been observed in the tropics. However, viewing the biosphere as a unit, there may be indirect effects of ozone depletion at other latitudes on tropical ecosystems. If ozone were to be depleted in the tropics, this would constitute a serious danger because of the naturally occurring high levels of UV-B radiation due to the high solar angles and already relatively low normal stratospheric ozone levels.

6.4. Do we need to worry about relatively small increases in UV-B due to ozone depletion, when natural variability is so much larger?

Yes. The change in UV-B from ozone depletion is systematically upward. The natural variability (e.g., from time of day, or clouds) can be larger, but goes in both directions, up and down. While the evidence for ozone depletion is very strong, there is little evidence for long-term changes in cloud cover.

Many detrimental effects of UV-B are proportional to the cumulative UV-B exposure. For example, skin cancer results from the total exposure accumulated over many years under both sunny and cloudy conditions. Any systematic increase in UV-B radiation will increase incidence among a population (as well as individual risk) regardless of the natural variability of the UV-B radiation.

6.5. Does one get higher UV exposures at higher altitudes?

Yes. Higher altitudes have less atmosphere overhead, as evidenced by the thinner air and lower atmospheric pressure. The increase in sunburning UV radiation is typically about 5–10% for each kilometre of elevation, the exact figure depending on the specific wavelength, solar angle, reflections and other local conditions. Frequently, other factors besides thickness of the atmosphere cause even larger differences in UV radiation between different altitudes. Snow is more common at higher altitudes, and reflections from it can lead to very large increases in exposure.

Lower locations tend to have more haze and more polluted atmosphere, which can block some UV radiation.

6.6. Does air pollution protect one from UV-B radiation?

Yes, but at a high price. Air pollution is generally undesirable due to the numerous other serious problems associated with it, including respiratory illness, eye irritation and damage to vegetation. While most of the atmospheric ozone resides in the stratosphere, some ozone is also made in the troposphere by the chemical interactions of pollutants such as nitrogen oxides and hydrocarbons. This tropospheric ozone is a component of the photochemical smog found in many polluted areas. Airborne particles (smoke, dust, sulphate aerosols) can also block UV radiation, but they can also increase the amount of scattered light (haze) and therefore increase the UV exposure of side-facing surfaces (e.g., face, eyes).

No single value can be given for the amount of UV-B reduction caused by pollution, because pollution events tend to be highly variable and local. Comparisons of measurements made in industrialized regions of the Northern Hemisphere (e.g., central Europe) and in very clean locations at similar latitudes in the Southern Hemisphere (e.g., New Zealand) suggest pollution-related UV-B reductions can be important.

7. Clear skies versus cloud cover

7.1. Can changes in cloudiness cause larger UV changes than ozone depletion?

Long-term trends in cloud type and amount are largely unknown due to the relatively short data record of comprehensive cloud observations, and the high variability of clouds on inter-annual and longer time scales. Some evidence exists showing that, at least over the time span of satellite-based ozone measurements, changes in cloud cover have been much less important than stratospheric ozone reductions in causing surface UV changes.

7.2. Are the risks of UV exposure at the beach less on a cloudy day?

Not necessarily. The effect of clouds on UV radiation is as varied as the clouds themselves. Fully overcast skies lead to reductions in surface UV irradiance. On average, scattered or broken clouds also cause reductions, but short-term or localized UV levels can be larger than for cloud-free skies if direct sunlight is also present. Clouds tend to randomize the directions of the incoming radiation (because of scattering), so that a hat may provide less protection on a cloudy day relative to a clear day.

Furthermore, people often change their behaviour on cloudy days. If they spend more time out in the open, or forego the use of sunscreen, they may end up with a very bad sunburn. In general, less UV radiation is received per hour under an overcast sky than under a clear sky, but extending one's stay at the beach may easily compensate for this effect. A completely cloud-covered sky may still transmit substantial amounts of UV-B radiation. In principle, any amount of UV-B radiation exposure contributes to the skin-cancer risk.

8. Sunbathing

8.1. Will sunscreens protect one from the harmful effects of increased UV-B radiation?

Not always. Sunscreens applied to human skin limit the penetration of UV radiation into the skin, and thus sunburn can be prevented. Sunscreens were primarily developed for this purpose. The effectiveness of sunscreens in protecting against skin cancer and immune suppressions is under debate. Any effectiveness in these respects may well be lost if the sunscreen is used to stay out in the sunlight longer than would be done without the sunscreen. It should also be kept in mind that there are other ways to protect the skin. These include staying out of the sunlight during the hours when the UV-B is maximal around solar noon, seeking the shade, wearing clothes, and especially hats.

8.2. Will getting a suntan help prevent skin cancer?

No. There is no evidence that getting a suntan will help prevent skin cancer. The UV exposure needed to acquire the tan adds to the skin-cancer risk. The fact that one is able to tan well does, however, signify that the personal risk is lower (by a factor of two to three) than for people who do not tan. Naturally dark-skinned people have a built-in protection of their skin against sunlight.

8.3. Is tanning with UV lamps safer than with sunlight?

No. The risks are approximately equal. For some time it was hoped that UV lamps could be made safer by making more use of long-wavelength (UV-A) radiation. That type of radiation is much less carcinogenic than the shorter-wavelength UV-B radiation, but one needs more UV-A than UV-B for acquiring a tan.

9. Economic consequences

9.1. Has the benefit of the Montreal Protocol been worth the cost?

Yes. Several attempts have been made to investigate the economic impacts of the problem of a depleted ozone layer. Such attempts meet with many problems. There are good reasons for concern about effects on humans, animals, plants and materials, but most of these cannot be estimated in quantitative terms. Calculating the economic impact of such effects is uncertain. Moreover, economic terms are applicable only to some of the effects, such as the cost of medical treatments, the loss of production in fisheries and agriculture, and damage to materials; but what is the cost equivalent of suffering, of a person becoming blind or dying, or the loss of a rare plant or animal species?

In spite of all these difficulties, attempts have been made. The most comprehensive example is a study initiated by Environment Canada for the 10th anniversary of the Montreal Protocol on Substances that Deplete the Ozone Layer. In this study, Global Costs and Benefits of the Montreal Protocol (1997), the costs were calculated for all measures taken internationally to protect the ozone layer, such as replacement of technologies using ozone-depleting substances. The benefits are the total value of the damaging effects avoided in this way. The total costs of the measures taken to protect the ozone layer were calculated to be 235 billion US (1997) dollars. The effects avoided world wide, though far less quantifiable, were estimated to be worth almost twice that amount. This latter estimate included only reduced damage to fisheries, agriculture and materials. The cataracts and skin cancers, as well as the potential associated fatalities avoided, were listed as additional benefits, and not expressed in economic terms.