

Questions and answers about the effects of the depletion of the ozone layer on humans and the environment.

Coordinated by Pieter J Aucamp.

Ptersa, P O Box 915751, Faerie Glen, 0043, South Africa.

The ozone molecule contains three atoms of oxygen and is mainly formed by the action of the ultraviolet rays of the sun on the diatomic oxygen molecules in the upper part of the earth's atmosphere (called the stratosphere). Atmospheric pollution near the Earth's surface can form localized areas of ozone. The stratospheric ozone layer protects life on earth by absorbing most of the harmful ultraviolet radiation from the sun.

In the mid 1970s it was discovered that some manmade products destroy ozone molecules in the stratosphere. This destruction can result in damage to ecosystems and to materials such as plastics. It may cause an increase in human diseases such as skin cancers and cataracts.

The discovery of the role of the synthetic ozone-depleting chemicals such as chlorofluorocarbons (CFCs) stimulated increased research and monitoring in this field. Computer models predicted a disaster if no action was taken to protect the ozone layer. Based on this research and monitoring, the nations of the world took action in 1985 with the Vienna Convention for the Protection of the Ozone Layer followed by the Montreal Protocol on Substances that deplete the Ozone Layer in 1987. The Convention and Protocol were amended and adjusted several times as new knowledge that was obtained.

The Meetings of the Parties to the Montreal Protocol appointed three Assessment Panels to review the progress in scientific knowledge on their behalf. These panels are the Scientific Assessment Panel, the Technological and Economic Assessment Panel and the Environmental and Health Effects Assessment Panel. Each panel covers a designated area and there is a natural level of overlap. The main reports of the Panels are published every four years as required by the Meeting of the Parties. All the reports have an executive summary that is distributed more widely than the main report itself. It became customary to add a set of questions and answers – mainly for non-expert readers – to the executive summaries.

This document contains the questions and answers prepared by experts who comprise the Environmental Assessment Panel. It is based mainly on the 2006 report of the Effects Panel but also contains information from previous assessments. Readers who need detailed information on any question should consult the full reports for a more complete scientific discussion.

This set of questions refers mainly to the environmental effects of ozone depletion and climate change. The report of the Scientific Assessment Panel contains questions and answers related to the other scientific issues addressed by that Panel. All these reports can be found on the UNEP website: (<http://ozone.unep.org>).

Table of Contents

I Ozone and Human actions

Q1. Can human activities have any effects on worldwide phenomena such as depletion of the ozone layer and climate change?..... 4

II Ozone and Ultraviolet radiation

Q2. What is the relationship between ozone and solar ultraviolet radiation? 5

Q3.What determines the UV-B radiation at a specific place?..... 6

Q4. What is the effect of pollution of the lower atmosphere on UV-B irradiation? 7

Q5. What is the solar UV Index?..... 8

Q6. How does the UV index vary with location and time? 9

III Effects of Ultraviolet radiation on Man and the Environment

Q7. What are the effects of solar UV radiation exposure on the human eye and how can the eye be protected? 10

Q8. What are the effects of solar UV-B exposure on the human skin and how can the skin be protected? . 11

Q9. How does UV-radiation affect the immune system? 12

Q10. What are the adverse effects of increased UV-B radiation on crops and forests? 13

Q11. Does UV-B exposure affect aquatic life? 14

Q12. What risks do the breakdown products of HFCs and HCFCs present to humans and the environment? 15

Q13. How can I protect myself from the adverse health effects of UV-B while still receiving its benefits? ... 16

Q14. Does climate change alter the effect of UV radiation on aquatic ecosystems? 17

Q15. What effects does the depletion of ozone have on environmental processes and cycles? 18

Q16. Does increased UV-B radiation shorten the lifetime of plastics and wood products? 19

IV Ozone depletion and Climate change

Q17. Will stratospheric ozone depletion have an influence on climate change?..... 20

Q18. Is ozone depletion affected by climate change?..... 21

V Beneficial effects of Ozone depletion

Q19. Are there any beneficial health effects of solar UV-B radiation?..... 22

VI Sources of information

Q20. Where can I get more information about the science and effects of ozone depletion? 23

Q1. Can human activities have any effects on worldwide phenomena such as depletion of the ozone layer and climate change?

Yes - there is overwhelming evidence that human activities are influencing global phenomena.

Natural environmental cycles often span thousands of years but most scientific measurements have been made only over the past 150 years. It is often not easy to accurately determine the influence of humans on any natural activity. In the case of the ozone layer, the depletion of the ozone over the Antarctica cannot be explained by natural cycles but is caused by the increase of synthetic chemicals in the stratosphere. The relationship between these chemicals (e.g. chlorofluorocarbons also known as CFCs) and ozone depletion has been proven by experiments in laboratories, numerical modelling studies and by direct measurements in the atmosphere.

By absorbing the infrared radiation emitted by the earth, some gases control the way natural energy flows through the atmosphere. Such gases are known as greenhouse gases. Carbon dioxide, although only a tiny fraction of the atmosphere, is an important greenhouse gas.

Measurements show that its concentration has increased by almost 30% as a result of human activities since the beginning of the industrial revolution (around 1750), resulting in enhancement of the greenhouse effect. Methane and nitrous oxide emitted from agricultural activities, changes in land use, and other sources are also potent greenhouse gases.

The increase in greenhouse gases contributes to climate change in the form of increased temperatures on the earth and a rise in sea level. Carbon dioxide is produced when fossil fuels are used to generate energy and when forests are burned. Observations show that global temperatures rose by about 0.6 °C over the 20th century. Climate models of the emission of greenhouse gases predict that the global temperature will rise by about 1.4 – 5.8°C by the year 2100. If this happens, the change would be much larger than any temperature change experienced over at least the last 10,000 years.

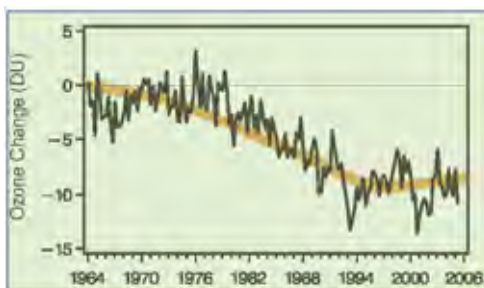


Fig Q1.1 The decrease in ozone concentrations since the 1970s, as depicted here, is much larger than can be explained by natural phenomena.

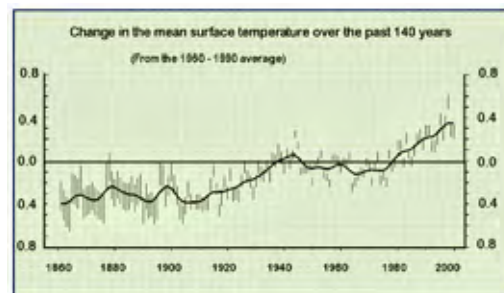


Figure: Q1.2 Global mean surface temperature change during the last 140 years, showing a marked increase over the past century

Q2. What is the relationship between ozone and solar ultraviolet radiation?

There is an inverse relationship between the concentration of ozone and the amount of UV-B radiation transmitted through the atmosphere.

Stratospheric ozone is naturally formed in chemical reactions involving ultraviolet sunlight and oxygen molecules. These reactions occur continually wherever ultraviolet sunlight is present. The production of stratospheric ozone is balanced by its destruction in chemical reactions. Ozone reacts continually with a variety of natural and anthropogenic chemicals in the stratosphere.

In the lower atmosphere ozone is produced by the chemical reactions between mainly nitrogen oxides and organic chemical pollutants produced by motor vehicle and industrial emissions. The ozone in both the troposphere and the atmosphere absorbs the UV radiation received at the surface.

The radiation emitted by the sun contains an ultraviolet component. This covers the range of wavelengths from 100 to 400 nm and is divided into three bands: UV-A (315 – 400 nm), UV-B (280 – 315 nm) and UV-C (100 – 280 nm). As the sunlight passes through the atmosphere, all the UV-C and approximately 90% of the UV-B are absorbed mainly by ozone and oxygen. UV-A radiation is less affected by the atmosphere. Therefore, the ultraviolet radiation reaching the Earth's surface is composed of mainly UV-A with a small UV-B component. A decrease in the concentration of ozone in the atmosphere results in increased UV-B radiation at the surface of the earth. DNA and other biological macromolecules absorb UV-B and can be damaged in this process.

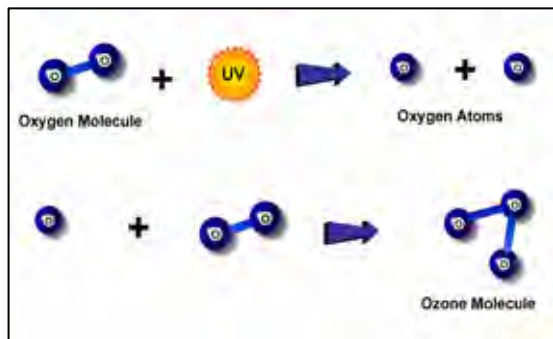


Figure Q2.1: Production of ozone in the stratosphere.

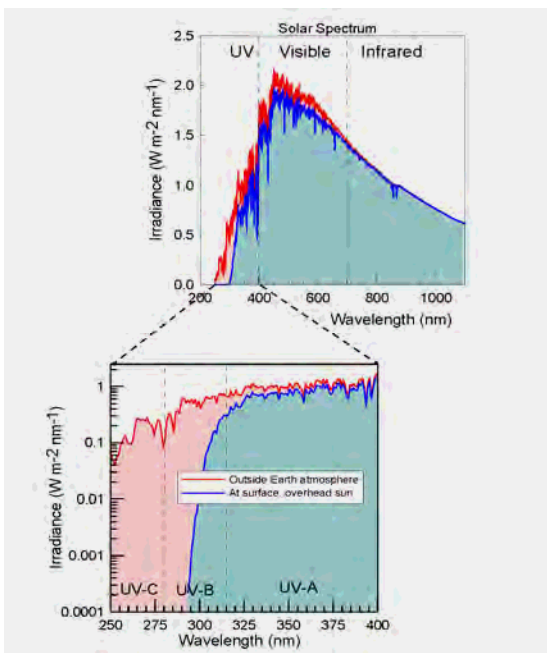


Figure Q2.2: UV-B radiation as part of the solar spectrum

Q3.What determines the UV-B radiation at a specific place?

The sun is the origin of the ultraviolet radiation reaching the earth. That radiation is partly absorbed by the components of the earth's atmosphere. The amount of potentially harmful ultraviolet radiation that is absorbed by one of these components, ozone, depends on the length of the path of the sunlight through the atmosphere.

The UV-B irradiation varies with the time of the day, geographic location and the season. The ultraviolet radiation that reaches the earth is greatest in the tropics and decreases towards the poles. For the same reason it is greatest near local noon and least near sunrise or sunset. Outside the tropics it is generally greater in the summer and least in the winter. Clouds, particulate matter, aerosols and air pollutants absorb and scatter some of the ultraviolet radiation and thereby diminish the amount reaching the earth's surface. Under clear skies the maximum irradiation occurs when the sun is directly overhead.

Locations at higher altitudes have less atmosphere overhead, as evidenced by the thinner air and lower atmospheric pressure therefore the radiation of the sun is less attenuated. This increase in UV radiation varies between 10% and 20% for each kilometre of height, depending on the specific wavelength, solar angle, reflections, and other local conditions.

Frequently, other factors besides the thickness of the atmosphere cause even larger differences in UV radiation between different altitudes. Surface reflection, especially from snow, ice and sand increases the irradiation at a particular site because the reflected radiation is redirected towards the surface through scattering by particles in the atmosphere or on the ground. In some conditions clouds will have the same effect..

Snow is more common at higher altitudes, and reflects as much as 90% of the ultraviolet radiation. Dry beach sand and sea foam reflects about 25% of UV-B radiation. Clouds also reflect an appreciable amount of radiation to the areas where they do not directly obscure the sunlight

The ultraviolet irradiation to which an individual is exposed is determined by a combination of all these factors

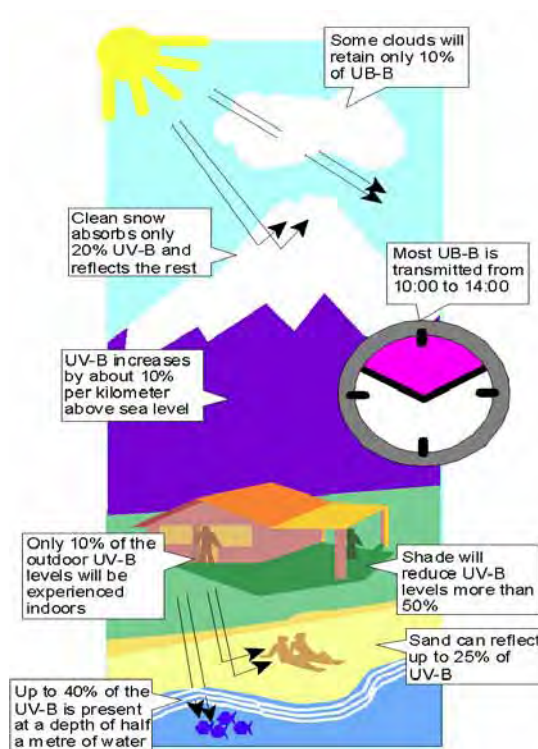


Figure Q 3.1: The effects of different surfaces on the UV-B received by an object.

Q4. What is the effect of pollution of the lower atmosphere on UV-B irradiation?

Pollutants emitted by human activities can absorb UV-B radiation near the surface, while particles may lead to enhancement by scattering.

While most of the atmospheric ozone is formed in the stratosphere, some ozone is produced in the lower atmosphere by the chemical reactions between pollutants such as nitrogen oxides and hydrocarbons. This ozone is a component of the photochemical smog found in many polluted areas. Airborne particles (smoke, dust and sulphate aerosols) block UV radiation, but at the same time can increase the amount of scattered light (haze) and therefore increase the UV exposure of side-facing surfaces (e.g., face, eyes). 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)

indicate the importance of particulate and pollution-related UV-B reductions.

At any particular location there is a direct relationship between UV-B irradiation and the amount of ozone in the atmosphere. UV-B increases with ozone depletion in the stratosphere but decreases with ozone formation in the lower atmosphere. The natural UV-B variability (e.g., from time of day, or clouds) can be larger than the effect of pollution, but goes in both directions, up and down. The cumulative amounts will depend critically upon local conditions and are therefore difficult to model in a general way. Many detrimental effects of UV-B are proportional to the cumulative UV-B exposure.

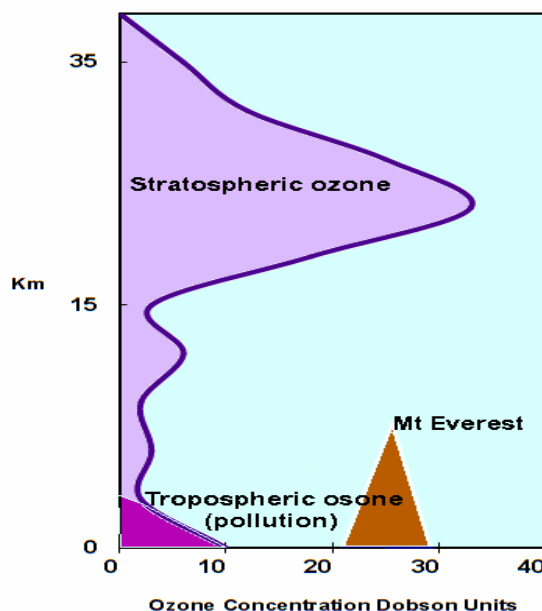


Figure Q4.1: Concentration of ozone at different altitudes in the atmosphere

Q5. What is the solar UV Index?

The solar UV Index (UVI) describes the level of solar UV radiation relevant to human sunburn (erythema).

The values of the UV index extend from zero upwards – the higher the index value, the greater the potential for damage, and the less exposure time it takes for harm to occur. The UVI was originally used in Canada, and was defined so the maximum value in the South of the country was 10 at midday in the summer, and about 1 at midday in the winter. For fair skinned individuals, a UVI of 10 or more is usually considered as “extreme” because under those conditions, skin damage can occur after less than 15 minutes of exposure. The UVI scale is an open-ended scale. When the Sun is below the horizon the UVI is zero, and at its maximum on the Earth’s surface, for example in the Altiplano region of South America in summer, the UVI can exceed 25. In the tropics at sea level the UVI can exceed 16.

Since the mid 1990s, information has been provided to the public about UV intensities in terms of the internationally adopted UVI scale along with appropriate health warnings, as shown in Table 1. The colours corresponding to the various ranges are also standardised.

Exposure Category		UVI Range
Low		< 2
Moderate		3 – 5
High		6 – 7
Very High		8 – 10
Extreme		11+

Table Q5.1: Exposure categories related to UVI ranges as adopted in mid-latitude countries

The UVI can be measured directly with instruments designed specifically to measure sun burning UV radiation. Alternatively, for clear sky conditions, the UVI can be calculated from knowledge of the ozone and the solar elevation. However, the UVI also depends strongly on the cloud cover. Other factors include the seasonally varying Sun-Earth separation, the altitude, atmospheric pollution, and surface reflection. When the surface is snow-covered, the UVI can be up to 90% greater than for snow-free surfaces. Several countries provide forecasts of UVI that take predicted changes in ozone and cloud cover into account.

Further details about the UVI can be found at

www.unep.org/PDF/Solar_Index_Guide.pdf

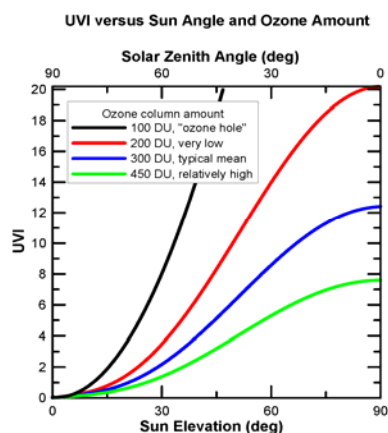


Figure Q5.1: Variation of the UVI as a function of sun elevation for four ozone amounts

Q6. How does the UV index vary with location and time?

The combination of total ozone, aerosols, clouds, pollution, altitude, surface reflectivity and solar zenith angle (that is determined by the geographical position, season and time of the day) are the main factors resulting in variation in the UV Index.

A global picture of the UVI can be derived by instruments on board satellites. They indicate that the index varies with the latitude and the time of the year, as can be seen from the two figures for September and March presented below. UV irradiation increases with altitude, and therefore the UVI is higher at mountain locations.

The presence of “patchy clouds” or snow-covered ground can result in very large UV indices. A good example is the high altitude desert Puna of Atacama in Argentina, where a UV index of 18 is common in January and December, with a maximum of 20 and even more on occasional days. A combination of small solar zenith angle near noon, high altitude, a naturally low total ozone column and a very clean atmosphere cause these exceptionally high values.

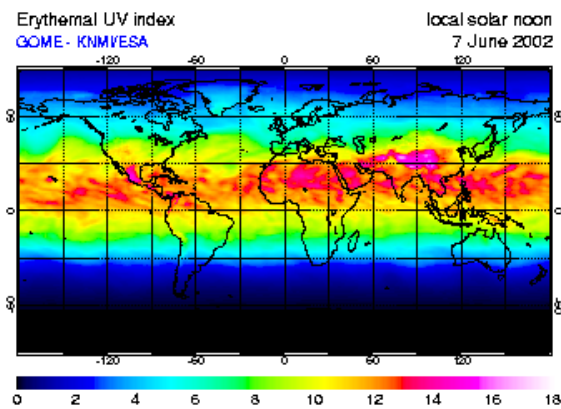


Figure Q6.1: UV Index for June

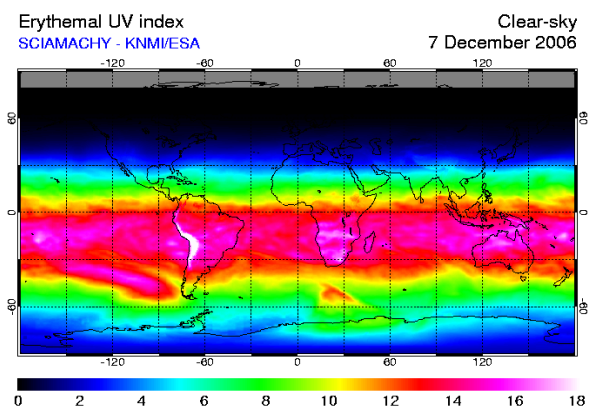


Figure Q6.2: UV Index for January

Q7. What are the effects of solar UV radiation exposure on the human eye and how can the eye be protected?

The effects of UV radiation on the eye may be acute (occurring often after a short, intense exposure usually after a latent period of several hours) or long-term after an acute exposure. There are also long-term effects following chronic exposure of the eye to levels of UV radiation below those required for the acute effects.

The commonest acute effect, photokeratitis (snow blindness) leaves few or no permanent effects, whereas cataract due to chronic exposure is irreversible and ultimately leads to blindness.

Avoidance of sun exposure is an effective but impractical means of avoiding exposure of the eyes to UV radiation. Despite these, additional protection is frequently needed under conditions of high ambient UV irradiation and/or reflective surfaces.

Appropriate glass and plastic lenses absorb all UV-B and much of the incident UV-A

Even clear spectacle lenses provide protection from UV-B. However, in the case of non-wrap around spectacles there is potential for ambient UV radiation to enter the eye from the side. This effect can be exacerbated by tinted sunglass lenses which encourage a wider opening of the eye. UV radiation-blocking soft contact lenses, that cover the entire cornea, effectively shield the cornea and ocular lens against UV radiation incident from all angles. They offer a UV protection alternative in those situations where the wearing of sunglasses is not practical or convenient.

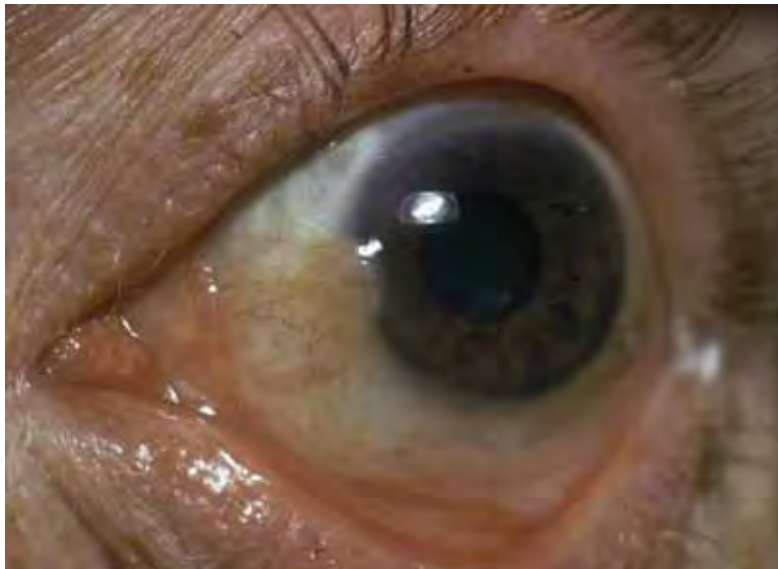


Figure Q7.1: Soft UV radiation-absorbing contact lens covering the entire cornea

Q8. What are the effects of solar UV-B exposure on the human skin and how can the skin be protected?

Acute exposure of the skin to solar UV radiation causes sunburn and in the long term skin cancers

The amount of UV radiation required to produce sunburn depends on the absorption in the superficial layers (varying with the amount of pigment) of the skin and on other genetic factors. The efficacy with which sunlight produces sunburn depends on the amount of UV-B radiation present; more UV-B is present at high altitudes and more is present in noontime sun than at earlier or later hours. Chronic exposure of the skin to UV radiation causes photo ageing (including wrinkling, thinning, and loss of elasticity); however, UV-A may be more important than UV-B in causing these latter changes.

Basal and squamous cell carcinomas occur most often and with high frequency in fair-skinned individuals living in sunny climates. Fortunately, most of these skin cancers are readily treated and rarely fatal. Cutaneous melanoma is considerably more dangerous, but occurs with much lower frequency than the other types of skin cancer. The relationship between melanoma and UV-B

radiation is not well understood, but exposure in early life seems to be an important factor in its development. Dark skinned persons have natural protection in their skin against sunlight. Although melanoma does occur in darker skinned persons, such cancers are often not related to sun exposure.

Methods of decreasing sun exposure of the skin include remaining indoors during the peak UV-B hours around midday and seeking shade at other times. Broad brimmed hats, sunglasses and full-body clothing that reduce the area of exposed skin are also effective.

Sunscreens are designed to protect against sunburn and can be highly effective. There is evidence that they reduce the incidence of squamous cell carcinoma and precancerous lesions in the skin. Obtaining a suntan will not usually help to prevent UV-B induced skin cancer and the UV radiation exposure needed to acquire the tan adds to the skin cancer risk.



Figure Q 8.1: Early cutaneous melanoma

Q9. How does UV-radiation affect the immune system?

The immune system can be altered by UV irradiation, leading to diminished immune responses to infectious agents and skin cancers

Some cells of the immune system, called antigen-presenting cells, reside in the skin. Their function is to survey the skin for foreign challenges, such as invading microorganisms or tumour proteins. They capture any molecules they find and carry them to the nearest lymph node where the active immune response is initiated. Exposing the skin to UV-B radiation causes several changes - one leads to a change in the antigen-presenting cells so that the immune response may induce suppression. Another is to stimulate the production of a particular range of immune mediators in the skin that also favour suppressing immune responses.

Numerous laboratory animal models of infectious diseases demonstrate that exposure to UV radiation at a critical time during infection can increase the severity and duration of the disease. UV exposure during immunization can reduce the effectiveness of vaccinations. How these observations may apply to human diseases remains a subject of intense interest and research. Although there are some examples such as with herpes virus infections (cold sores, shingles) in which UV exposure before or after immunisation can increase susceptibility to and the severity of an infection. The full implications of the immunological effects are not well understood.

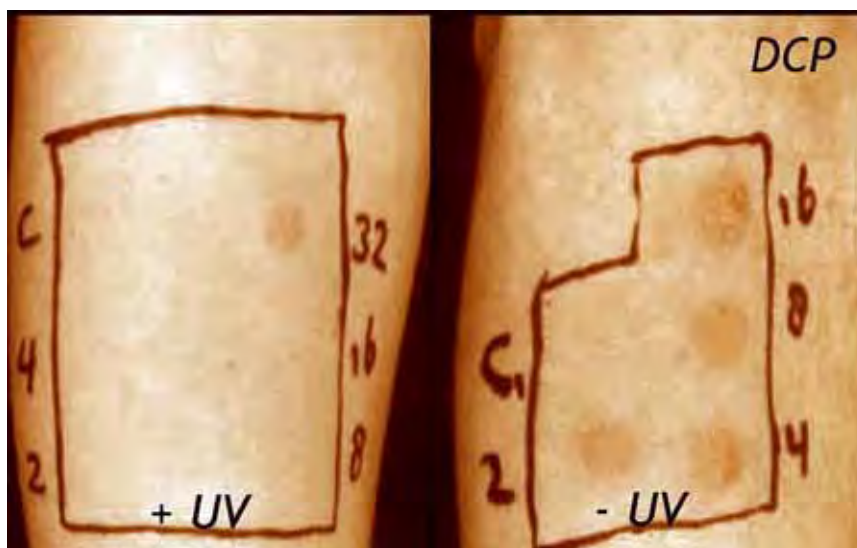


Figure Q9.1: Exposure to UV-B radiation decreases the effect of allergens on the human skin.

Q10. What are the adverse effects of increased UV-B radiation on crops and forests?

The UV-B radiation present in sunlight causes a wide range of responses in crops and forests but most plants have natural mechanisms that provide some UV shielding, but do not always have sufficient amounts for complete protection. Some types of crops and wild plants may suffer detrimental effects from increased UV-B radiation.

Only a small proportion of the UV-B radiation striking a leaf penetrates into the inner tissues. When exposed to enhanced UV-B radiation, many species of plants can increase the UV-absorbing compounds in their outer leaf tissues. Other adaptations include increased thickness of leaves, thereby reducing the proportion of inner tissues exposed to UV-B radiation and changes in the protecting waxy layer of the leaves. Several repair mechanisms exist in plants, including repair systems for damage to DNA and other vital biomolecules. The net UV damage a plant experiences is the result of the balance between the damage, protection and repair processes.

Some varieties of crops are UV-B-sensitive and produce reduced yield following an increase in UV-B. There are also UV-B-tolerant varieties, providing us with the opportunity to breed and genetically engineer for UV-B tolerant crops. Commercial forests, tree breeding and genetic engineering may be used to improve UV-B tolerant plants. While many forest tree species appear to be UV-B tolerant, there is some evidence that detrimental UV-B effects accumulate slowly from year to year in certain species.

The biochemistry and physiology of plants are influenced by UV-B exposure, such as in the accumulation of UV-B absorbing compounds. It is not possible to conclude yet whether changes in UV-B irradiation will have any appreciable impact on the quality of food. Changes in plant biochemistry induced by UV-B radiation have been shown to influence the interactions between crop plants and herbivorous insects.

During their evolution, plants and animals have adapted to particular environments. They have acquired protection and repair mechanisms appropriate for their particular situations. However, the present rate of global change is so rapid that evolution may not keep up with it, particularly in long-lived plants like trees. Plants adapt to a rather specific UV-B environment, and a change in UV-B may be detrimental even though it is smaller than the difference between the natural irradiation at the equator and higher latitudes. For example, herbaceous plants native to the southern tip of South America and the Antarctic Peninsula have been shown to be affected by the current high levels of ambient UV-B irradiation. Over a long time and many generations, there is the possibility that genetic adaptation can develop.

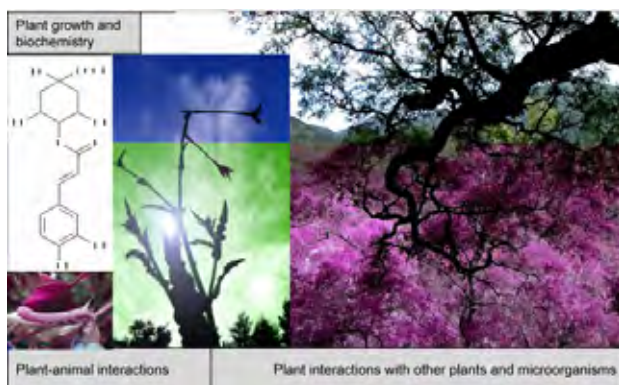


Figure Q 10.1: Multilevel effects of solar UV-B on plants and forests.

Q11. Does UV-B exposure affect aquatic life?

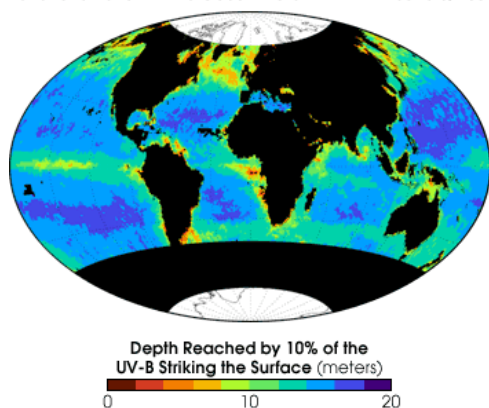
Yes UV-B radiation can penetrate to ecologically significant depths in the clearest natural waters.

In clear ocean and lake waters, ecologically-relevant irradiation by UV-B can penetrate to tens of metres. In turbid rivers and wetlands, however, UV-B may be completely absorbed within the top few centimetres. In aquatic ecosystems, most organisms, such as phytoplankton, live in the illuminated upper layer of a body of water that allows the penetration of enough light to support photosynthetic, or green, plants 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.

effects of UV-B radiation have been shown for phytoplankton, fish eggs and larvae, zooplankton and other primary and secondary consumers. Most adult fish are well protected from excessive solar UV since they inhabit deep waters. Some shallow-water fish have been found to develop skin cancer and other UV-related diseases.

UV-B radiation reaches different depths in ocean water depending on water chemistry, the density of phytoplankton, and the presence of dissolved and particulate matter. The map indicates the average depth UV-B penetrates into ocean water.

Penetration of UV-B into Ocean Water June 6, 2001



At the depth indicated, only 10 percent of the UV-B radiation that was present at the water's surface remains. The rest was absorbed or scattered back towards the ocean surface.

The eggs and larvae of many fish are sensitive to UV-B exposure. In the Gulf of Maine, UV penetrates to considerable depth where the embryos and larvae of the Atlantic cod develop. Exposure to UV equivalent to 10 m depth results in a significant mortality of developing embryos and a significant decrease in length of larvae. Such irradiance occurs at many temperate latitudes where these ecologically and commercially important fish spawn. In freshwater lakes and ponds, amphibian embryos are protected from UV-B by the enzyme photolyase, melanin pigmentation of eggs, jelly covering around eggs, water depth and dissolved organic matter in water. Larvae can seek shelter from sunlight by swimming into shaded areas and vegetation of pond. In contrast, lobster larvae seem to be tolerant to UV radiation even though they develop in the surface layers of the water column.

Figure Q11.1: The penetration of UV-B radiation into the global oceans by indicating the depth to which 10% of surface irradiance penetrates. (Image courtesy Vasilkov et al., JGR-Oceans, 2001;)

Q12. What risks do the breakdown products of HFCs and HCFCs present to humans and the environment?

The main breakdown product – trifluoroacetic acid (TFA) and other related short-chain fluorinated acids are presently judged to present a negligible risk to human health or the environment.

The hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) that are replacements for the chlorofluorocarbons (CFCs) are likely to become more widely used since they have a smaller effect on the ozone layer. The HFCs and HCFCs are largely degraded before reaching the stratosphere.

HFCs and HCFCs break down relatively rapidly into several products including the persistent substances such as trifluoroacetic acid (TFA) and chlorodifluoroacetic acid. The compounds are washed from the atmosphere by precipitation and reach surface waters, along with other chemicals washed from the soil. In locations where there is little or no outflow and high evaporation (seasonal wetlands and salt lakes), these products are expected to increase in concentration over time.

The effects of increased concentrations of these naturally occurring mineral salts and other materials would be greater and more biologically significant than those of breakdown products of the HFCs and HCFCs.

TFA, a final degradation product of some HFCs and HCFCs, is very resistant to breakdown, and amounts deposited in flowing surface water will ultimately accumulate in the oceans. Based on estimates of current and future use of HFCs and HCFCs, additional inputs to the ocean will add only fractionally (less than 0.1%) to amounts already present from natural sources such as undersea vents and volcanic activity.

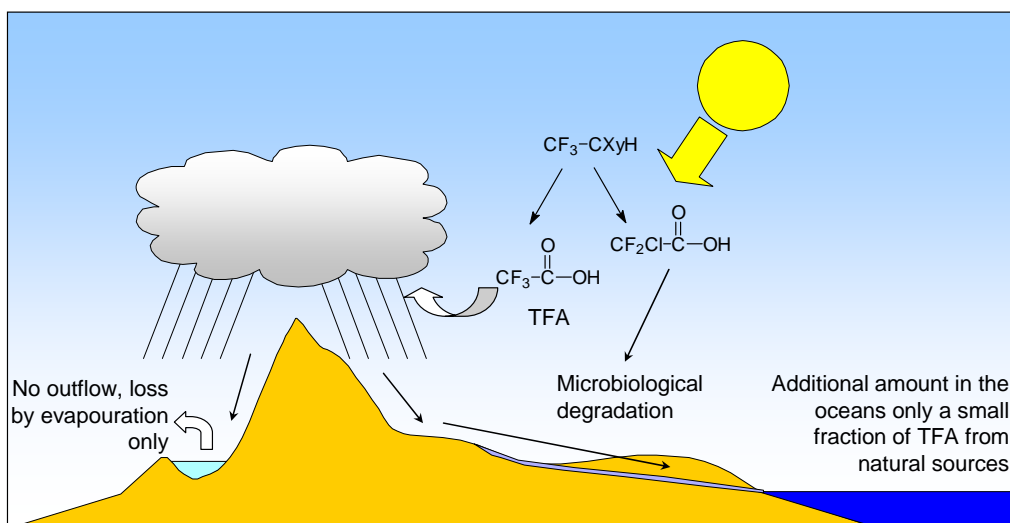


Figure Q 12.1: The breakdown of CFC replacements into TFA.

Q13. How can I protect myself from the adverse health effects of UV-B while still receiving its benefits?

The first step towards protection from any toxic agent is to be aware that the hazard exists and how to prevent unnecessary exposure. Many protective strategies against excessive exposure to sunlight have been developed and advocated by those concerned about the effects of UV radiation on the skin and the eyes.

The intensity of UV-B radiation is usually the greatest during the central hours of the day (about 10:00 to 14:00). Many news outlets and government websites report the daily UV-Index, with values ranging from 1 to more than 20. UV alerts are issued in some countries when unusually high UV-indexes are predicted.

When you go outside, particularly if you cannot avoid the midday hours, the general advice is to seek shade. The popular Australian advice “*to slip (on a shirt), slap (on a hat), slop (on some sunscreen)*” (modified by the New Zealanders to “*slip, slap, slop and wrap*” [add wrap-around sunglasses]) is useful.

Hats with brims more than 10 cm wide are recommended for head and eye protection and can reduce exposure of the eyes by up to 50%. The hood of a jacket, and similar headwear having sides, often provides protection from UV-B from the side. Wrap-around sunglasses are better at protecting the entire eye than conventional sunglasses with open sides.

If you must go out during the central hours in sunny countries, cover all exposed skin surfaces with a sunscreen of sun protection factor (SPF) 10 or greater, (depending on the location and irradiation of the sunlight and the susceptibility of your skin type to sunlight) but not as a way to stay out longer; you can get damage even through a sunscreen. The skin of children is very sensitive to UV-B radiation. They need protective clothing and should stay in the shade as much as possible during the central hours. Sunscreens, if used, need to be high SPF (20 -40) and need to be re-applied frequently especially when swimming. UV-B exposure during childhood appears to raise one’s susceptibility to UV-B damage later in life

While there have been concerns that under-exposure to UV-B radiation may impair vitamin-D status, the Auckland Cancer Society suggests that 30 minutes outside per day (not in the midday hours) should be sufficient to support adequate vitamin D status for most individuals.



Figure Q13.1: Wear protective clothes

Q14. Does climate change alter the effect of UV radiation on aquatic ecosystems?

Yes, climate change will influence various aspects of how UV-B radiation influences aquatic ecosystems including: temperature and sea-level change, shifts in the timing and extent of sea-ice cover, changes in wave climate, ocean circulation and salinity and alterations in the stratification of the water column.

These complex changes are likely to have significant effects on ecosystems, including biological production (e.g. human marine resources) as well as changes in the global hydrological cycle, vertical mixing and efficiency of carbon dioxide uptake by the ocean. However, the effects will vary over time and between different locations. Changes in temperature and the intensity and frequency of rainfall may alter the input of terrestrially-derived coloured dissolved organic matter (CDOM) to inland and coastal aquatic ecosystems. For example, decreased rainfall and increased temperature cause reductions in CDOM inputs and consequent increases in the depth to which UV penetrates. In addition, the amount of penetration that is dependent upon dissolved and suspended material in the water column, changes the ratio of UV-A to UV-B to PAR. These changing ratios, in turn, have various influences on decomposers, producers and consumers.

Climate change influences the amount of ice and snow cover in polar and sub polar areas. Ice and snow strongly attenuate the penetration of solar radiation into the water column. Any substantial decrease in ice and snow cover will alter the exposure of aquatic ecosystems to solar UV radiation.

Shifts in atmospheric circulation will change wind fields, influencing mixing and the depth of the upper mixed layer. Such changes and increases in temperature affect the stratification of the surface layer and the potential impact of UV-B on near surface organisms. Changing winds will also influence coastal upwelling systems and the potential for possible influence of these systems to UV radiation. Another aspect is the dependence of many physiological responses on temperature..

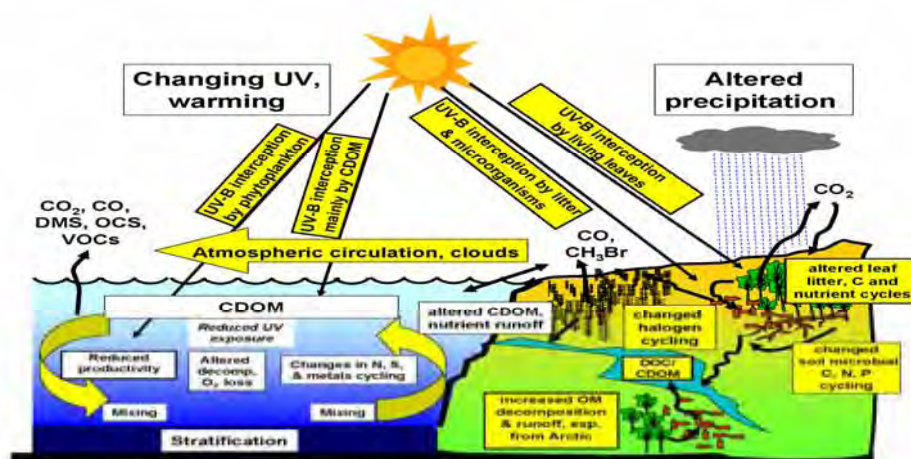


Figure Q14.1: The aquatic ecosystem

Q15. What effects does the depletion of ozone have on environmental processes and cycles?

Changes in the UV-B radiation impinging on the Earth's surface attributable to changes in ozone concentration causes complex alterations to atmospheric chemistry and the global elemental cycles such as the carbon cycle. It thus affects the entire biosphere with consequences for all organisms on Earth, including humans.

UV radiation influences the biological productivity of oceans, including the production of gases at their surfaces and their subsequent transfer to the atmosphere. Once in the atmosphere, trace gases such as carbon dioxide (CO₂) interact with the physical climate system resulting in alterations to climate and feedbacks in the global biogeochemical system. Since atmospheric CO₂ plays a central role in the distribution of heat in the atmosphere, its increasing concentrations may affect many components

of the physical climate system, such as wind, precipitation and the exchange of heat and energy between the air and the oceans. There are also similarly complex interactions between biogeochemical cycles on land and the integrated climate system that may have important implications for organisms on Earth. At this stage, it is not possible to predict the overall environmental effects of these complex interactions between changes in climate and UV radiation.

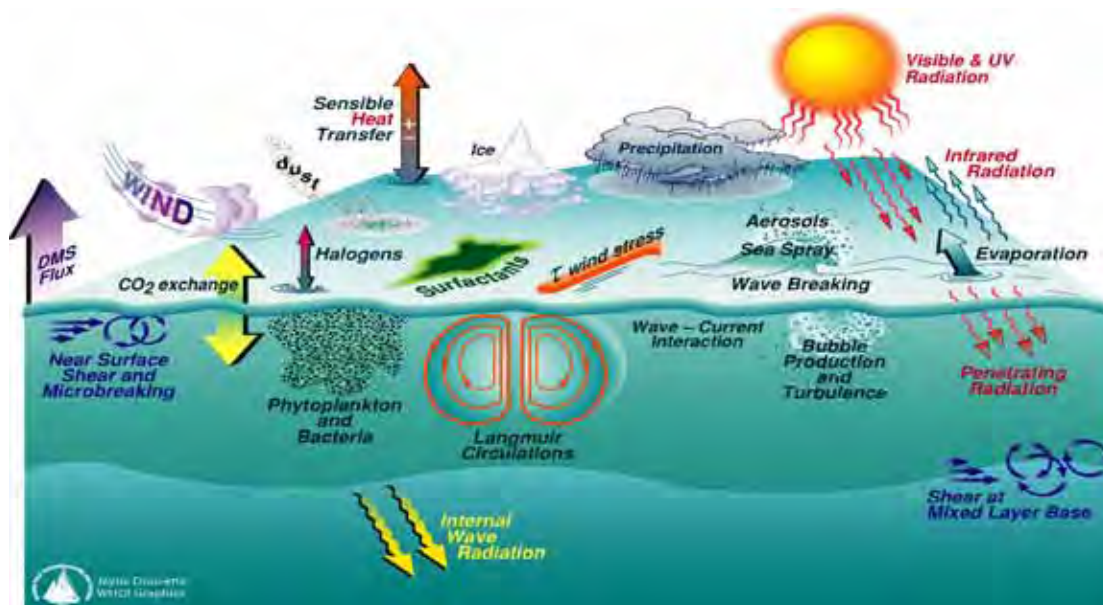


Figure Q 15.1: Interactions between environmental processes and cycles. (Figure provided by the US Surface Ocean Lower Atmosphere Study (SOLAS) and Woods Hole Oceanographic Institution (WHOI)).

Q16. Does increased UV-B radiation shorten the lifetime of plastics and wood products?

Yes - The outdoor service life of commercial plastics is often limited by their UV-stability and weatherability.

Available data on the degradation of plastics by the UV in sunlight show that for common polymers a portion of the damage that occurs over time is attributable to the UV-B radiation component. As any depletion of the stratospheric ozone layer would increase the UV-B content of the solar radiation reaching the earth's surface, this would therefore increase the rate of degradation of those plastics (and other natural materials such as wood). The extent to which the service life of these materials will be shortened by this phenomenon will of course depend on the type of polymer, the locations of exposure, and the light-stabilizers used in the formulation.

The outdoor lifetimes of plastics, however, depend not only on their chemical nature but also on their formulations and specifically on the type and concentration of photostabiliser additives used in them. Reductions in service life of plastics can probably be countered by using higher than normal concentrations of existing light stabilizers in the formulation, better surface protection of materials (e.g. painting wood) or by using different polymeric materials that are more UV resistant for outdoor applications. These approaches might be able to retain service life at present-day levels but at an increased cost of the products.

Climatic factors, particularly higher ambient temperatures due to climate change, will tend to accelerate UV-induced degradation to an extent that depend on the chemical nature of the plastic and the composition of the formulation used in the particular product.

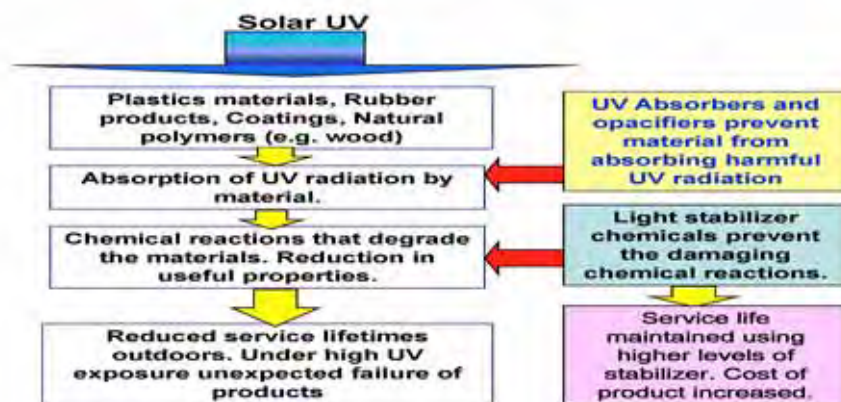


Figure Q 16.1: The effect of stabilisers on the degradation of polymers.

Q17. Will stratospheric ozone depletion have an influence on climate change?

Stratospheric ozone depletion has an influence on climate change since both ozone and the compounds responsible for its depletion are active greenhouse gases

Halocarbons such as CFCs have contributed to positive direct radiative forcing and associated increases in global average surface temperature. Ozone depletion due to ODSs has an indirect cooling effect of the ODSs. Warming due to ODSs and cooling associated with ozone depletion are two distinct climate forcing mechanisms that do not simply offset one another. Bromine-containing gases currently contribute much more to cooling than to warming, whereas CFCs and HCFCs contribute more to warming than to cooling. HFCs and PFCs contribute only to warming.

Actions taken under the Montreal Protocol have led to the replacement of CFCs with HCFCs, HFCs, and other substances and processes. Because replacement species generally

have lower global warming potentials (GWPs), and because total halocarbon emissions have decreased, their contribution to climate change has been reduced. Ammonia and those hydrocarbons used as halocarbon substitutes are very likely to have a negligible effect on global climate. The relative future warming and cooling effects of emissions of CFCs, HCFCs, HFCs, PFCs and halons vary. ODS indirect cooling is projected to cease upon ozone layer recovery, so that GWPs associated with the indirect cooling effect depend on the year of emission, compliance with the Montreal Protocol and gas lifetimes.

Substitution for ODSs in air conditioning, refrigeration, and foam blowing by HFCs, PFCs, and other gases such as hydrocarbons are not expected to have a significant effect on global tropospheric chemistry

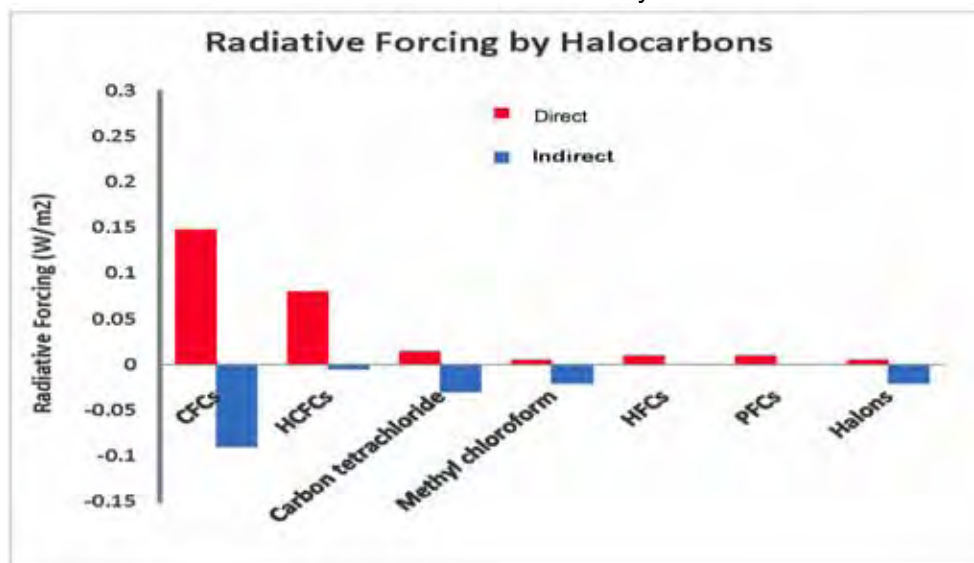


Figure Q 17.1: Ozone depleting compounds have both warming and cooling effects on the atmosphere.

Q18. Is ozone depletion affected by climate change?

Yes, climate change will affect ozone depletion through changes in atmospheric conditions that affect the chemical production and loss of stratospheric ozone. The interactions are complex, and not all of them are fully understood (see figure). Climate change is expected to decrease temperatures and water vapour abundances in the stratosphere. As a consequence ozone loss might increase in Polar Regions.

There are differences between climate change and ozone depletion. Climate change is due to a build-up of gases, especially CO₂, that absorb infrared radiation emitted from the Earth's surface, while ozone depletion is primarily due to a release of gases that under certain conditions destroy ozone. Ozone, the CFCs and their substitutes are minor greenhouse gases with a relative small ($\pm 13\%$) contribution to climate change. Several other gases involved in the chemistry of ozone depletion are also active greenhouse gases. They include water vapour, methane, and nitrous oxide. Increases in those will ultimately lead to increases in stratospheric gases that destroy ozone. Changes in solar output and future volcanic eruptions will influence both climate change and ozone depletion.

It seems that while current ozone depletion is dominated by chlorine and bromine in the stratosphere, in the longer term (~100 years) the impact of climate change will dominate, through the effects of changes in atmospheric circulation and chemistry. The result is that over the first half of the current century, increases in greenhouse

gases may contribute to a colder stratosphere. This will lead to a decrease in the rate of destruction of ozone outside Polar Regions. In Polar Regions however, the lower temperatures may lead to increased polar stratospheric clouds, thus exacerbating ozone depletion. The temperature changes will also lead to changes in atmospheric circulation. These changes may aid the mixing of long-lived CFCs from the troposphere to the stratosphere that will increase their rate of photochemical destruction. This will lead to more severe ozone depletion in the short term but will contribute to a faster ultimate recovery of ozone. Changes in polar ozone can also lead to changes in circulation patterns in the lower atmosphere, which in turn affect surface climate. The effects of climate change on UV radiation are twofold: those that influence total ozone directly, and those that depend on changes in other variables (such as clouds, aerosols or snow cover that influence solar UV directly).



Figure Q18.1: Interaction between ozone depletion and climate change.

Q19. Are there any beneficial health effects of solar UV-B radiation?

Yes - the main beneficial effect on human health, brought about by increased production of vitamin D in the skin.

In the majority of people, most of their vitamin D is acquired from exposure of the skin to sunlight. Vitamin D is very important for many aspects of general health. It has been known for many years that it is required for the growth, development and maintenance of bone. More recently, it has been suggested to play a protective role against the development of several internal cancers, autoimmune diseases and infectious diseases.

Although the human diet contains some items rich in vitamin D, such as oily fish, more than 90% of vitamin D is produced by exposure of the skin to solar UV radiation. Vitamin D is synthesised most effectively when the sun is at its height in the summer months, and

people with dark skin require more exposure than those with fair skin to make the same amount of vitamin D. Individuals deficient in circulating vitamin D can develop bone defects, resulting in an increased risk of osteoporosis and fractures in adults, and of rickets in children. Adequate vitamin D status is now implicated in the prevention of an increasing number of non-skeletal disorders. These include several internal cancers such as colorectal and prostate, autoimmune diseases such as multiple sclerosis and insulin-dependent diabetes, and infections, such as tuberculosis. Consideration is urgently required regarding how to balance this positive effect of solar UV radiation exposure with the negative effects on the skin and the eye of too much exposure.



Figure Q19.1: Two children with rickets next to a healthy individual

Q20. Where can I get more information about the science and effects of ozone depletion?

There are several websites that contain information on ozone, UV, environmental effects and related topics. The sites mentioned below belong to dependable organizations and contain reliable information. Most of these sites contain links to other sources of information

UNEP	http://ozone.unep.org
WMO	http://www.wmo.ch
WHO	http://www.who.int
IPCC	http://www.ipcc.ch
NOAA	http://www.noaa.gov/airquality.html
EPA	http://www.epa.gov
NASA	http://jwocky.gsfc.nasa.gov
NIWA	http://www.niwascience.co.nz
WOUDC	http://www.woudc.org
Environment Canada	http://www.ec.gc.ca