# OZONE LAYER DEPLETION & HEALTH

- *How fast is the ozone layer thinning?*
- *Is it causing more skin cancer?*
- *Future trends.*

International undertakings under the 1987 Montreal Protocol promise the phase-out of CFCs[1] and other chemicals implicated in the thinning of the ozone layer. However, these measures will take time to work, and concern remains over how far levels of ultra-violet radiation (UVR) will rise at ground level with their potential to cause skin cancer.

***This note discusses the latest evidence on ozone depletion and UVR levels in the UK, their health implications and related issues.***

**POST note 102**

**July 1997**

*POSTnotes are intended to give Members an overview of issues arising from science and technology. Members can obtain further details from the PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (extension 2840).*

## OZONE DEPLETION AND 'HOLES'

Ozone in the upper atmosphere (stratosphere) plays a vital role in absorbing many of the most harmful components of sunshine through the mechanisms described in **Box 1**, and the so-called 'ozone layer' is one of the essential prerequisites for life to have developed on this planet. Atmospheric scientists have investigated the layer over many years and built up a good historical record of how its thickness varies naturally with latitude, the season, the sunspot cycle and events such as volcanic eruptions (Box 1). Researchers have also looked into the complicated chemistry involved in the layer's formation and, during the 1970s, US scientists postulated that some industrial chemicals starting to reach the stratosphere (particularly chlorofluorocarbons (CFCs)) might interfere with the mechanisms of ozone formation and destruction.

This theory triggered further research, but remained a theory until the discovery in 1985 by the British Antarctic Survey (BAS) that levels of ozone dropped substantially during the Antarctic Spring. This led to a re-examination of earlier satellite data which revealed that average springtime ozone levels had actually been dropping since the 1970s (**Figure 1**), and that there was now a well-established seasonal 'ozone hole' (actually a region of severe depletion) which appeared over the Antarctic early each spring (between late August and November), disappearing when ozone-rich air from lower latitudes mixed with polar air in the late spring / early summer. The exact location and size of the 'hole' vary with meteorological conditions, but the area covered has increased over the last 10 years or so (**Figure 2**) and extends over the entire Antarctic continent, occasionally including the tip of South America.

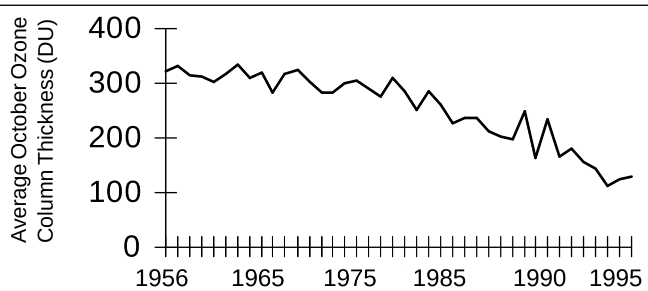
**Box 1 SUNSHINE AND OZONE**

Ozone (a form of oxygen containing three atoms instead of the usual two) is formed and destroyed by a complicated series of chemical reactions between atmospheric oxygen, sunlight and other trace substances in the stratosphere. Absorbtion of solar ultraviolet radiation (UVR) by the ozone layer has the effect of removing much of the more harmful parts of the UVR spectrum as they pass through the stratosphere (the upper atmosphere 10 to 50 km above ground). By the time UVR has passed through the stratosphere, virtually all of the shortest wavelengths (UVC) and most (70-90%) of the intermediate wavelengths (UVB) have been absorbed, leaving the least damaging UVA.

The amount of ozone depends on its rate of formation and destruction, and varies naturally according to:-

- **Regional factors** - most ozone is produced over the tropics (where levels of UVR are highest), but then carried away by stratospheric winds to higher latitudes, so that the ozone layer is thickest towards the poles and thinnest around the tropics.
- **Seasonal factors** - the thickness of the ozone layer remains relatively constant throughout the year in the tropics, but varies considerably at higher latitudes (both north and south), with peak levels occurring in the spring and minimum levels in the autumn.
- **Other factors** - ozone levels correlate with the 11 year solar sunspot cycle, and may also be influenced by volcanic eruptions (aerosols released by the Pinatubo eruption in 1991 depressed ozone levels for 2-3 years).

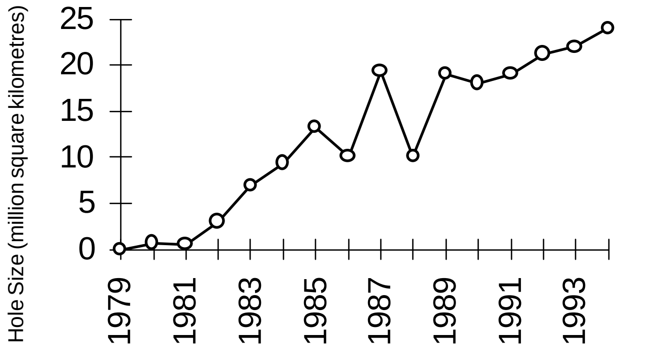
**Figure 1 TRENDS IN OZONE COLUMN THICKNESS AT THE BAS'S HALLEY BAY SITE**




Research also revealed that the Arctic is similarly affected during winter / spring - as in Antarctica, the greatest loss is near the Pole, but depletion is spreading to lower latitudes. In early 1995, the World Meterological Organisation (WMO) reported that ozone levels were 10% to 15% below long-term averages, with a 35% depletion over Siberia and below average ozone levels were reported as far south as Spain. Overall, losses over mid-latitudes in the Northern hemisphere are around 8% per decade in the winter and spring, and 2%-4% per decade in the summer.

1. CFCs are chlorofluoro carbons, which were developed as stable non-flammable chemicals for use as refrigerants, aerosol propellants, etc.

**Figure 2 TRENDS IN THE SIZE OF THE ANTARCTIC OZONE HOLE**




**Box 2 CHLORINE AND OZONE DEPLETION**

Most scientists now agree that the Arctic and Antarctic ozone holes are caused mainly by chlorine and bromine atoms in the stratosphere, and that these originate largely from CFCs and other closely related compounds (e.g. carbon tetrachloride, methyl chloroform, halons) used as refrigerants, propellants, solvents, etc. Such compounds are extremely stable, surviving in the troposphere for 10 to over 100 years without being broken down. However, once they reach the stratosphere they react with UVR breaking into a variety of different products. Some of these are relatively stable and harmless (so-called 'reservoir species' such as hydrogen chloride and chlorine nitrate). But others are highly reactive - most notably chlorine atoms and chlorine oxides - and it is these species that catalyse the destruction of ozone (each chlorine atom can destroy many thousands of ozone molecules during its lifetime).

Evidence for this mechanism comes from a variety of sources. For instance, ground and *in situ* measurements show that maximum ozone depletion coincides with peak levels of the active chlorine compounds and low levels of the inactive reservoir compounds. Laboratory studies also show that the proposed reactions can occur, and at rates high enough to account for observed depletion. The reactions are more likely over polar regions (particularly the Antarctic) for two main reasons. First, because circulating winds set up a stable vortex over the poles in the spring providing a gigantic 'reaction vessel' for depletion to occur. Second, because the low temperatures encourage the formation of polar stratospheric clouds, which enhance the production of the active chlorine species, and create a source of ice crystals on which the ozone-destroying reaction takes place.

The appearance of the Antarctic ozone hole gave credence to the theoretical predictions that CFCs and some bromine-containing chemicals (e.g. fire suppressants) would cause a loss of stratospheric ozone (**Box 2**), and led to action within the UN Vienna Convention on the Protection of the Ozone Layer. Specific controls on the production of ozone-depleting chemicals were first agreed through that Convention's Montreal Protocol in 1987, with an agreement aimed at halving CFC emissions by the year 2000. Subsequent research suggested that these measures would not reverse ozone depletion fast enough, and further agreements (in London in 1990, Copenhagen in 1992 and Vienna in 1995) have speeded up this schedule and extended the range of chemicals covered (**Table 1**).

**Table 1 PHASE OUT OF OZONE DEPLETING SUBSTANCES**

| Chemicals Covered | | Phase out date: *Developed countries* | *Developing* |
|---|---|---|---|
| Halons | | 1994 | 2010 |
| CFCs, Methyl chloroform | | 1996 | 2010 |
| Carbon tetrachloride | | 1996 | 2015 |
| Methyl bromide | - freeze | 1995 | 2002 |
| | - phaseout | 2010 | |
| HCFCs | - 90% cut | 2016 | |
| | - phaseout | 2030 | 2040 |

## IMPLICATIONS FOR HUMAN HEALTH

The main human health concerns[2] over a thinning ozone layer are that more UVR will reach the surface and increase peoples' exposure. As summarised in **Box 3**, the most serious potential effect is expected to be on non-melanoma skin cancers (NMSCs) as well as the less common but more serious malignant melanomas (MMs). Both of these have become more common in recent years; over 40,000 NMSCs are now registered in the UK each year, a rise of some 200% in the last 15 years, while the incidence of MM (currently ~4,000 cases a year) has been rising by around 5% per year. Experts consider, however, that this trend reflects changes in lifestyle in previous decades (e.g. a rise in the number of people taking holidays in the sun, an increased willingness to expose themselves to the sun) rather than any increase in the amount of UVR reaching the Earth. In addition to the cancers described in Box 3, UVR also causes other short- (e.g. sunburn) and long-term (e.g. photoaging) effects, can damage the eye (acute effects such as inflammation of the cornea and conjunctiva as well as chronic problems such as corneal lesions and cataracts), and can suppress some of the body's normal immune responses.

The key question on health effects is how far a thinning ozone layer leads to increased UVR (especially the potentially damaging UVB component) reaching the ground. In the clear unpolluted air of Antarctica, periods of maximum ozone depletion can triple UVB levels at the surface. In the UK and other Northern Hemisphere locations however, the relationship is less straightforward since the amount of UVR reaching the earth's surface depends not only on the thickness of the ozone layer, but also on weather conditions and local levels of air pollution, since ozone and other pollutants formed nearer the ground (in the troposphere) from the interaction of vehicle and other emissions with sunlight, also absorb UVR.

Information on ground level UVR in the UK is more limited, since continuous monitoring only started in 1988, when the National Radiological Protection Board (NRPB) set up a network of monitoring stations. So far this has shown little or no evidence of any consistent rise in UVB levels. Indeed, monitoring data from other countries (e.g. USA) suggests that UVB levels may even have fallen in recent years, particularly in urban areas.

**2. There are also concerns over the ecological effects of increased UVB at ground level. For instance, the increased levels in Antarctica appear to decrease plankton photosynthesis in the ocean. Differential susceptibility of species may also change the species balance in unpredictable ways.**

**Box 3 UVR and SKIN CANCER**

UVR is a major factor behind the development of both the main types of skin cancer. Non-melanoma skin cancers (NMSC) occur in two main types of skin cells (basal cells and keratinocytes), and while common are seldom fatal (accounting for ~5% of UK cancers but <0.5% of cancer deaths each year). Most (80-90%) NMSCs occur on parts of the body likely to be exposed to the sun, with risk increasing in proportion to the cumulative lifetime dose of UVR.

Malignant melanomas (MM) are less common and more often fatal (~1.5% of UK cancers and 0.8% of cancer deaths), and occur in the cells (melanocytes) that make skin pigment (melanin). The relation between UVR and MMs is more complex, since indoor workers are at highest risk and MMs most commonly occur on relatively unexposed parts of the body. Overall, the risk factors most closely associated with MMs include sunburn in childhood, skin type (those with red hair and fair skin are most at risk), exposure to intermittent high bursts of UVR, genetic factors (MM sometimes runs in families) and certain types of unusual moles.

Exactly how UVR contributes to skin cancers has been the subject of much recent research. UVR (particularly UVB) can directly damage DNA leading to mutations in genes responsible for controlling vital processes such as cell division, cell death, repair of DNA errors, etc. Analysis of tumour samples shows that skin cancer is often associated with mutations in specific genes, including the ras oncogene (a gene that can cause cancer if activated by a mutation) and the p53 tumour suppressor gene. As well as these direct mechanisms, it is also thought that UVR (particularly UVA) may act indirectly, for instance by reacting with other chemicals in the body (e.g. melanin) which in turn promote damage to DNA. Alternatively, excessive exposure to UVR is known to suppress the immune system, and this might increase the risk of cancers developing.

The most likely explanation is that levels of urban air pollution have more than offset the effects of ozone depletion in the stratosphere, since long term increases in UVB at monitoring sites unaffected by urban air pollution (e.g. in the Swiss Alps, and in New Zealand) have been detected.

Nevertheless, short-term increases in UVR can occur with the right combination of circumstances, and in March 1996, weather conditions conspired to allow the Arctic vortex to slip further south than usual, positioning it over the UK for several days. During this time, Meteorological Office monitors (operated on behalf of the DETR) at Lerwick and Camborne reported record low levels of total ozone, and the NRPB monitors at these and other sites registered large increases in UVR levels (**Table 2**). There is some evidence that short-term episodes like this are becoming an increasingly regular feature - for instance, unusually low ozone and high UVB levels were detected over the UK during a 4-5 day period in April-May 1997.

**Table 2 UVR AND TOTAL OZONE LEVELS**

| | CAMBORNE | | LERWICK | |
|---|---|---|---|---|
| Date | Daily UVR | Total Ozone[1] | Daily UVR | Total Ozone[1] |
| 1/3/96 | 240 | 294 | 125 | 269 |
| 2/3/96 | 604 | 246 | 154 | 209 |
| 3/3/96 | 902 | 206 | 518 | 211 |
| 4/3/96 | 450 | 254 | 170 | 225 |
| 5/3/96 | 520 | 241 | 342 | 195 |
| 6/3/96 | 166 | 302 | 340 | 220 |
| Normal | 420±200 | 363±95 | 280±130 | 392±115 |

*Source: Radiological Protection Bulletin 180, August 1996, NRBP*

Notes: 1 In Dobson Units for whole atmosphere

## ISSUES

If effects in the UK are transient and localised at present, how long will ozone depletion continue and what are the likely future implications for UVR levels and public health? The key factor affecting ozone depletion is the rate at which chlorine and bromine levels in the stratosphere decline, and here recent studies suggest that the international agreements are starting to have an effect, with levels of chlorine from CFCs and related compounds in the troposphere peaking in the mid 1990s. Because these chemicals take time to diffuse upwards, levels in the stratosphere are still rising, but the rate of increase has slowed significantly. Experts are now predicting that stratospheric chlorine will also peak by the turn of the Century, although best estimates are that it will take another 50 years or so for chlorine (and thus ozone) levels in the stratosphere to return to normal. The Antarctic ozone hole is thus expected to persist until at least the middle of the next century, and ozone depletion at mid-latitudes to get slightly worse than present (a further reduction of 1.5% - 2.5% on current levels over the next 10 years or so[3]) before levels start to recover.

Predicting the additional risk in the UK is complicated by the uncertainty over future trends in troposheric air pollution. Theory suggests that ozone depletion over Northern Hemisphere mid-latitudes between 1979 and 1989 **should already have resulted in rises in surface UVB levels of between 1.3% and 4.7%**, whereas, as pointed out above, no such trend has been detected. Whether this continues to be the case depends on how far current measures to reduce urban air pollution succeed in reducing ozone levels near the ground.

Despite such uncertainties, attempts have been made to model the likely impact of future ozone depeletion scenarios. For instance, the DETR's UVB Measurements and Impacts Review Group (UMIRG) calculated that a sustained 10% depletion of stratospheric ozone would increase the number of cases of NMSCs by 21-35% (depending on the exact type of cancer) in the future -this equates to nearly 17,000 extra cases of NMSCs each year. This is, however, a very unlikely scenario, ignoring as it does the moderating affect of tropospheric pollution and the anticipated recovery of the ozone layer itself.

**3. The implications of trends for the UK are considered by the Department of the Environment's Stratospheric Ozone Review Group.**

NRPB calculate that the maximum additional lifetime risk of NMSC for adults is 3-5% and 11-16% for children (both assuming continued ozone depletion at current rates). These risks fall significantly if the Montreal protocol provisions start to take effect and stratospheric ozone levels start to rise again. For instance, if ozone levels fall for a further 20 years at current rates and then revert to normal, the additional lifetime risk of NMSC in children is reduced to ~5-8%. Again, this ignores the impact of lower level pollution which has, so far, essentially cancelled out any extra risk.

Taken overall, such estimates suggest that the impact of ozone depletion on NMSC rates will be quite limited, with the worst case scenario projecting a rise of 10% over 50 years - at current rates this would be an additional 4,000 cases, although under-reporting means that the real figure could be higher than this (up to ~8,000 cases). This increase is relatively modest compared to recent trends (NMSCs increased by more than 200% in the last 15 years), which are attributed to changes in people's sun exposure habits. Skin cancer rates over the next 50 years or **so are thus much more likely to reflect changes in people's attitudes and behaviour than in ozone depletion/recovery rates.** The key to reducing skin cancer rates thus remains influencing people's attitude and behaviour towards exposure to the sun.

In this context, the Health of the Nation initiative in 1992 included a specific target to *"halt the year on year increase in the incidence of skin cancer by 2005"*. Initial campaigns were targeted both at the general public (e.g. via the Health Education Authority's (HEA) "Sun Know How" and "Shift to the Shade" campaigns) and at outdoor workers (e.g. through the Health and Safety Executive's (HSE) "Keep Your Top On" initiative. A recent NRPB review highlighted the importance of continued public awareness campaigns, early diagnosis, protective measures and research (priorities include the mechanisms and risks of UVR-induced cancer, and improved screening for MMs). Plans to implement the Health of the Nation target were outlined in the DH/DoE National Environmental Health Action Plan in July 1996, and included :

- Provision of information - e.g. on the risk of sunburn in weather forecasts through a freephone line and through the Health Information Service, and by funding TV and radio 'slots' on skin cancer risks.
- Continued DH support for HEA activities, particularly those aimed at high risk groups (e.g. teenagers.
- Continued NHS involvement in local campaigns, the development of an 'interventions database' of succesful skin cancer projects.
- On-going assessment of public attitudes knowledge and behaviour (funded by DH).
- Research into skin cancer (£1.2M over 3yrs).
- Government collaboration with other countries to continue phasing out of ozone depleting substances.

Overall, the international response to ozone layer depletion is seen by many as one of the first effective responses to a global environmental problem, and looks likely to succeed in reversing the environmental damage involved, albeit over a protracted timescale. There remain, however, a number of continuing challenges if the progress so far is to be sustained. Firstly, under the Montreal Protocol, production of the most depleting substances has ceased in developed countries only, while production in developing countries may continue until 2010 (Table 1). Meanwhile, demand for some (e.g. for CFC-12 in car air conditioning units in the US) continues. Since supplies of old inventory or recovered material in some countries are running out, prices are soaring (e.g. that for CFC-12 rose 60-fold from 1995 to 1997 in the USA) creating a major incentive for smuggling, both into the USA and the EU.

Questions are now being raised over whether the EU and national responses are taking this matter sufficiently seriously. No cases of CFCs being smuggled into the UK have been detected to date, although cases have been reported in other EU countries (e.g. Italy and Spain). The Royal Institute of International Affairs also sees circumstantial evidence of wider involvement in the EU (including the UK). For instance, while demand for CFCs has remained high, prices have stayed fairly stable, suggesting that the chemicals are still readily available. Demand for 'retrofitting' to allow machinery to operate with CFC replacements has also been much lower than expected.

A clearer picture should emerge for the UK when a recently completed Strategic Threat Assessment conducted by HM Customs & Excise is published. Options for tackling CFC smuggling include three main approaches:-

- end supply (Russia is the main target here and the World Bank has proposed special funding to accelerate production phase-out).
- reduce demand (e.g. a ban on CFC sales, ban on stockpiles, encouragement of retrofitting).
- control illegal trade by closer monitoring of CFC production and imports.

The second issue concerns the rate of technical progress towards 'substitutes for the substitutes' since the main transitional replacements for CFCs (HCFCs) still have some ozone-depleting potential and also contribute to global warming. In addition to the research needs to develop better substitutes, there is also a debate between countries over whether the phase out date for HCFCs should be brought forward (Table 1).