

CURIOSITY-DRIVEN RESEARCH

THE OZONE

- The photochemical mechanisms that give rise to the ozone layer are discovered by UK physicist Sidney Chapman
- The British Antarctic Survey discovers the ozone hole
- A UK–France initiative, ARMO, aims to help predict surface ozone pollution

What is it

Almost everyone in the western world is aware that the Earth's ozone layer is thinning. However, only a small minority understand what the ozone layer does and why it continues to diminish.

In essence, the Earth's atmosphere is composed of several layers. The lowest level is the troposphere, where most weather occurs, i.e. rain, snow and clouds. Above the troposphere is the stratosphere. Supersonic jets fly in the lower stratosphere, whereas subsonic commercial airliners fly in the troposphere – or sometimes in the boundary between the two.

Ozone forms a layer in the stratosphere, thinnest in the tropics (around the equator) and denser towards the poles. The amount of ozone above a point on the Earth's surface is measured in "Dobson Units", typically 260 DU near the tropics and higher elsewhere, although there are large seasonal fluctuations. In the UK it is around 300 DU, equivalent to 3 mm of pure ozone at standard pressure. Ozone is created when ultraviolet radiation (sunlight) passes through the stratosphere, splitting oxygen molecules (O_2) into atomic oxygen (O), the simplest form of oxygen. The atomic oxygen quickly combines with further oxygen molecules to form ozone.

Ozone is what protects us from the harmful radiation of the Sun, but at ground level ozone is actually a health hazard. For example, it is a major contributor to photochemical smog, which forms in large cities when chemical reactions take place in the presence of sunlight. However, our health and quality of life would quickly deteriorate without the ozone in the stratosphere. There it absorbs some of the potentially harmful ultraviolet radiation from the Sun (at wavelengths between 240 and 320 nm) which can cause skin cancer and damage vegetation.



The science

The hole in the ozone layer is often confused with the problem of global warming. While ozone contributes to the greenhouse effect, the hole is actually a separate issue.

Discovered in 1913 by French physicists Charles Fabry and Henri Buisson, the ozone layer's properties were explored in detail by the UK meteorologist GMB Dobson, who developed a simple spectrophotometer that could be used to measure stratospheric ozone from the ground. Between 1928 and 1958 Dobson established a worldwide network of

ozone-monitoring stations which continues to operate today. The Dobson Unit is named in his honour.

Over Antarctica, stratospheric ozone has been depleting over the last 25 years. This is mainly due to the release of manmade chemicals containing chlorine, such as chlorofluorocarbons (CFCs), but also industrially manufactured compounds containing bromine, halogen compounds and nitrogen oxides – all used to chill or freeze products. CFCs were (and sometimes still are) found in some products such as refrigeration systems, air conditioners, aerosols and solvents, and are created in the production of some types of packaging. Nitrogen oxides are a byproduct of combustion processes, including aircraft emissions.

In 1980 UK-funded investigations began and in 1985 the British Antarctic Survey (BAS) ascertained that the depletion in ozone in Antarctica had become so great that there was actually a hole, later discovering that the hole was increasing in size. Their findings were published in the internationally respected journal, *Nature*.

These discoveries led to the phasing out of CFCs and other substances harmful to ozone; however, the substitute chemicals are only marginally less harmful. Ongoing research into ways to replenish ozone continues, and the scientific community worldwide continues to search for ways to combat ozone depletion. The Montreal Protocol, an international treaty signed in 1987, and its extensions have led to a decrease in substances harmful to the ozone layer.

Ozone timeline

1913	The ozone layer is discovered by French physicists Charles Fabry and Henri Buisson.
1928	The ozone layer's properties are explored in detail by the UK meteorologist GMB Dobson, who develops a simple spectrophotometer that can measure stratospheric ozone from the ground. Between 1928 and 1958 Dobson establishes a worldwide network of ozone-monitoring stations which continues to operate today. The "Dobson Unit", a measure of the total amount of ozone in a column overhead, is named in his honour. The first patent is given for the formula for chlorofluorocarbons (CFCs).
1930	The photochemical mechanisms that give rise to the ozone layer are worked out by the UK physicist Sidney Chapman.
1973	Chemists Rowland and Molina discover that CFCs can destroy the ozone in the stratosphere.
1977	The United Nations Environmental Program holds the first international meeting to discuss ozone depletion.
1981	NASA scientist Donald Heath announces that satellite records show ozone has declined 1%.
1985	A British Antarctic Survey (BAS) research group, led by Joe Farman, ascertains that the depletion in ozone in the Antarctica (a 40% loss) is now so great that there is actually a hole, later discovering that the hole is increasing in size. The Vienna Convention, calling for additional research and exchange of information on ozone depletion, is signed by international negotiators. However, negotiators fail to agree on worldwide CFC regulations. Heath shows satellite photos confirming the existence of an ozone hole over Antarctica.
1986	CFC manufacturers suggest that safe substitutes for the chemicals might be possible for a high enough price.
1987	International negotiations on ozone protection resume in Geneva after a 17 month delay, eventually proposing worldwide CFC reduction of 95% by the next decade. The Montreal Protocol is signed, calling for eventual worldwide CFC reductions of 50%. The NASA Antarctic ozone expedition ends with chlorine chemicals found to be the primary cause of ozone depletion.
1989	European countries and the US agree to faster CFC reductions, but developing countries oppose the new timetable citing the costs of substitutes and scientific uncertainty.
1992	Worldwide ozone in the stratosphere drops to lowest levels in recorded history.
1993	DuPont's research and development arm produces substitutes for CFCs. These include partially hydrogenated chlorofluorocarbons (HCFCs) and totally hydrogenated chlorofluorocarbons (HFCs).
1995	Automobile manufacturers begin installing air-conditioning units in cars which use HCFC-134a, a substitute for CFC-12. The largest hole in the ozone over Antarctica begins to form. This is the earliest point in the year a hole has begun since records began. When its growth is complete, the hole encompasses the entire continent of Antarctica and is the largest hole ever recorded. (Most holes are now as large as the Antarctic.)
1997	180 countries, including the UK, sign the amended Montreal Protocol, agreeing to bring greenhouse emissions including HFCs to levels below those of 1990.
1998	The ozone hole over Antarctica grows to 16.4 million sq. km.
1999	Japan commits to reducing its emissions of HFCs and CFCs to 6% below 1990 levels.
2000	Ozone hole three times the size of the US is recorded.
2003	UN talks on protecting the ozone layer end without a deal, after the US asks to continue using a chemical it had earlier agreed to ban.
TODAY	The European Ozone Research Coordinating Unit, based at Cambridge University, warn the ozone layer will break down during very cold weather in January. The low ozone area is expected to spread over northern Europe, including the UK.

The future

The ARMO project (Air Rives Manche Ozone) aims to understand the levels of ground-level ozone in south-east England and northern France. Using field measurements to provide a clearer picture of the spatial distribution of ozone, researchers will also be able to improve a French computer model that can predict when high ozone pollution will occur.

In the UK, the project is coordinated by the National Society for Clean Air and Environmental Protection (NSCA), working with the Sussex Air Quality Steering Group and the University of Brighton. The French partners are Atmo Picardie and Air Normand.

Projects like this need to continue in order for solutions to this major problem to be found. Countries across the world have only truly become aware of the extent of the problem in recent years. Governments and research groups will need to work together, and quickly, to bring this problem under control. Even if no further damage is done to the layer, depletion will continue for the next 20 years.

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