The healing of the ozone layer

Vicky Wong

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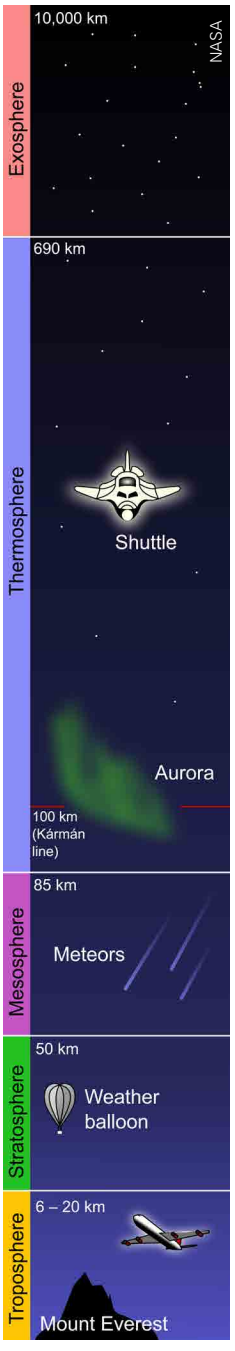
ozone layer
CFCs
international cooperation

The Ellsworth mountain range in Antarctica; the thinning of the ozone layer is greatest above the poles.

*In 1974, the chemists **Mario Molina** and **Sherwood Rowland** showed that ozone can be destroyed by chlorine atoms produced when chlorofluorocarbons (CFCs) are decomposed by sunlight. **Susan Solomon** showed that these manufactured chemicals were causing a hole in the ozone layer. International cooperation led to the banning of CFCs and research carried out by **Susan Solomon** in 2016 showed that the ozone hole is reducing.*

Chlorofluorocarbons are molecules with a chain of carbons, each of which is bonded to chlorine and fluorine atoms. There are a huge variety of these such as CF_2Cl_2 and $CFCl_2$-$CFCl_2$. They are gases and were used widely in refrigerators and as propellants in aerosols as they are have low reactivity, low flammability and low toxicity so were thought to be ideal, safe chemicals for use in a variety of applications. As they are not reactive, they do not react when released into the atmosphere and so can stay around for a long time, in some cases up to 50-100 years. However, when sunlight hits them they can break apart to release a chlorine atom. This has a single unpaired electron and is very reactive, but there is not much for it to react with in the atmosphere.

Ozone is a form (allotrope) of oxygen. Unlike most oxygen, which has a chemical formula of O_2, ozone is O_3 and is far less stable than O_2. It has a much lower concentration in the atmosphere than oxygen, only 0.6 parts per million. It does, however, have a very important role. There is a part of the stratosphere which has a higher concentration of ozone, from 2 to 8 parts per million, which is called the ozone layer. It absorbs ultraviolet light, preventing too much ultraviolet from reaching the Earth's surface, where it can damage plants and animals. More ultraviolet light (UV) would increase the effects that UV has on human health including positive effects such as enabling people to produce more vitamin D and negative effects including sunburn and skin cancer. The effects may not be only on humans. In 2010 scientists at the Institute of Zoology in London found that whales off the coast of California have shown a sharp rise in sun damage, and these scientists feared that the thinning ozone layer was to blame.



The layers of the atmosphere; the ozone layer is in the stratosphere, roughly 25 km above the Earth's surface.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Mario Molina

In 1995 Mario Molina became the first person born in Mexico to receive the Nobel Prize for Chemistry, which he shared with Sherwood Rowland, for showing how CFCs can destroy ozone. Molina continues to serve on various national and international scientific and environmental boards and committees. In 2013, President Obama gave him the highest civil award in the United States, the Presidential Medal of Freedom, calling him 'a visionary chemist and environmental scientist'.

CFCs destroy ozone

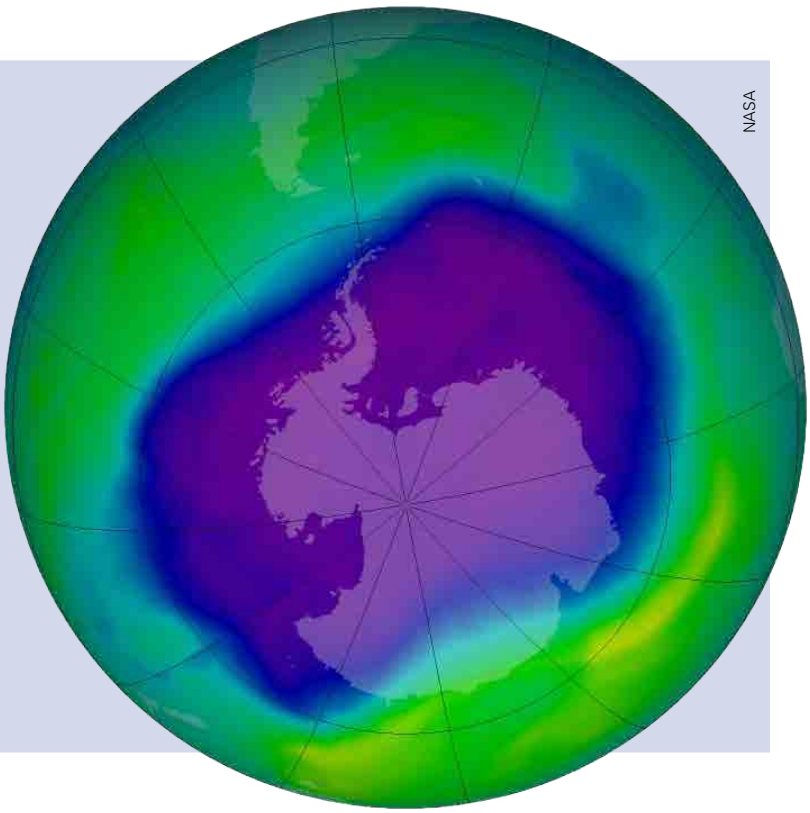
Molina and Sherwood showed in the mid-1970s that the chlorine atoms produced from CFCs can act as catalysts and destroy ozone, but nobody was very interested at first. The trouble with the chlorine atoms being catalysts is that they could destroy very large numbers of ozone molecules without being used up themselves. In the mid-1980s satellite data from NASA confirmed that there was a hole in the ozone layer over Antarctica and that it was getting bigger. Some pressure groups from industry claimed that ozone depletion was a natural process and it was nothing to do with manufactured chemicals.

Susan Solomon led two expeditions to Antarctica in 1986 and 1987 and these showed that it was manufactured chemicals which were causing the problem and it was not the result of natural processes.

As many countries were using and manufacturing CFCs because they were useful in such a wide range of applications, individual countries acting to reduce their use of CFCs would not have the effect needed, international action was needed. In 1987 an international treaty, the Montreal Protocol, was signed which agreed to protect the ozone layer by phasing out the production of the numerous substances that are responsible for ozone depletion. This treaty has been ratified by 197 parties, 196 different international states and the European Union, and is the first universally ratified treaty in United Nations history. It is remarkable because it only took 14 years from the scientific research discovery by Molina and Sherwood to the signing of the national agreement. When compared to the difficulties with establishing international policy on climate change it is particularly impressive. But would phasing out CFCs work to reduce the hole in the ozone layer?


Encyclopedia of New Zealand

Refrigerators must have the CFCs removed from their cooling systems when dumped.


NASA

In September 2006, the Antarctic ozone hole was one of the largest recorded at 10.6 million square miles (27.5 million square kilometres). Satellite instruments monitor the ozone layer, and NASA uses their data to create these images that depict the amount of ozone. The blue and purple colours are where there is the least ozone, and the greens and yellows are where there is more ozone.

A NASA balloon is prepared for launch in McMurdo Station, Antarctica. McMurdo is where Susan Solomon conducted her research in the 1980s to show that manufactured CFCs are the cause of ozone depletion.

Susan Solomon

In 1986 and 1987, chemist Susan Solomon served as the Head Project Scientist of the National Ozone Expedition at McMurdo Station, Antarctica, and made some of the first measurements there that pointed towards chlorofluorocarbons (CFCs) as the cause of the ozone hole. She was the only woman on the team. In 1994, an Antarctic glacier was named in her honour in recognition of that work. In 1999 she was awarded the US National Medal of Science and in 2004 the Blue Planet Prize which recognizes outstanding efforts in scientific research or applications of science that contribute to solving global environmental problems. In 2008 Time magazine elected her as one of the top 100 most influential people in the world.

Antarctic spring

The holes in the ozone layer open up during the polar spring. During the cold, dark, winter nitric acid and water condense out of the atmosphere and form wispy clouds. The surfaces of the cloud particles host chemical reactions that release chlorine that came from CFCs. The chlorine, in turn, goes on to destroy ozone—but only in the presence of light. That is why, over Antarctica, the destruction of ozone really gets going in September, the beginning of the southern spring, when light returns to the pole.

Susan Solomon, who had shown that it is manufactured chemicals causing the depletion of ozone, has continued to study ozone levels over Antarctica. In June 2016, using a combination of measurements from satellites, ground-based instruments and weather balloons her team found that, since 2000, the September hole has shrunk by 4 million square kilometres—an area bigger than India.

They have used a 3D atmospheric model to show that it is a decline in pollutants which is the reason for the recovery and the healing of the ozone hole. Although it will not be fully restored until at least 2050, for Solomon there are reasons for optimism: "The fact that we've made a global choice to do something different and the planet has responded to our choice can't help but be uplifting," she says.

Vicky Wong is Chemistry editor of Catalyst.