**Topic: CFCs and Depletion of the Ozone Layer**

# 1. Factsheet

CFCs are chlorofluorocarbons, a type of organic molecule (one that contains carbon atoms). In addition to carbon atoms, CFC molecules contain chlorine and fluorine atoms.

CFCs have some useful properties. For example:

* they are chemically inert (unreactive)
* they have a low boiling point (so they turn into gases easily)
* they are insoluble in water

These properties made CFCs very useful in the past. They were used as refrigerants (the substances needed in refrigerators to remove the heat from inside). They were also used in aerosol cans as propellants (the gases that push the product out through the nozzle).

**CFCs and ozone**

* CFCs have been responsible for depleting the ozone layer. The ozone layer is a high level layer of gas in the stratosphere. The ozone helps to keep out harmful UV rays, which cause sunburn and damage plants.
* CFCs destroy ozone molecules in the ozone layer when they escape into the atmosphere. The resulting ozone holes allow more harmful ultraviolet radiation to reach the Earth’s surface and add to the problems of the greenhouse effect and global warming.
* When scientists discovered that CFCs were damaging the ozone layer, they suggested that CFCs should be banned.
* Governments around the world, including the UK, agreed to ban them in the mid-1990s.
* Today, CFCs have been replaced by alkanes or by hydrofluorocarbons (HFCs). These substances do not damage the ozone layer.
* Some scientists now say the hole in the ozone layer over Antarctica could disappear within 50 years as ozone levels are stabilising.

**Damaging ozone**

It is the chlorine atoms in CFCs that destroy ozone in the stratosphere (upper atmosphere). There are three main steps in this process:

1. CFC molecules reach the stratosphere. Ultraviolet radiation breaks them down, releasing highly reactive chlorine atoms. For example:

CCl3F → •CCl2F + •Cl

The chlorine atoms are called chlorine radicals. They are shown as •Cl in equations.

2. Chlorine radicals react with ozone molecules, breaking them down

3. The reactions in step 2 regenerate the chlorine radicals, so they can go on to destroy more ozone molecules.

* CFCs are broken down slowly by ultraviolet radiation, so they are only slowly removed from the stratosphere.
* The atoms in a CFC molecule are joined together by covalent bonds. A covalent bond is a shared pair of electrons.
* When a CFC molecule absorbs ultraviolet radiation, a carbon-chlorine bond breaks. One of the shared electrons goes with the released chlorine atom, while the other stays with the remainder of the CFC molecule.
* These unpaired electrons are shown as dots in formulae for radicals, such as •Cl (a chlorine radical).

A small number of chlorine radicals can destroy many ozone molecules.

Once a chlorine radical has been released, it can go on to destroy many ozone molecules.

This means that CFCs released in the past will continue to deplete the ozone layer.

# 2. Graph - Annual Global Temperatures

3. Newspaper Article

# **China factories releasing thousands of tonnes of illegal CFC gases, study finds**

**Levels of ozone-depleting gas spiked when air from industrialised areas of China arrived, say researchers**



Previous studies have suggested Chinese foam factories were behind the rise in CFC pollution. Photograph: Thomas Peter/Reuters

Industries in north-eastern China have released large quantities of an ozone-depleting gas into the atmosphere in violation of an international treaty, scientists have said.

Since 2013, annual emissions of the banned chemical Chlorofluorocarbon-11 (CFC-11) from that region have increased by about 7,000 tonnes, according to a report in peer-reviewed journal Nature.

“Our measurements showed ‘spikes’ in pollution when air arrived from industrialised areas” in China, said co-lead author, Sunyoung Park from Kyungpook National University in South Korea.

CFC-11 was widely used in the 1970s and 1980s as a refrigerant and to make foam insulation. The 1987 Montreal Protocol banned CFCs and other industrial aerosols that chemically dissolve protective ozone 10-40km (six to 25 miles) above Earth’s surface, especially over Antarctica and Australia.

Lead author Matt Rigby, an atmospheric chemist at the University of Bristol, said: “CFCs are the main culprit in depletion of the stratospheric ozone layer, which protects us from the sun’s ultra-violet radiation.”

After the ban came into force, global concentrations of CFC-11 declined steadily until about 2012. However, last year scientists discovered the pace of that slowdown slowed by half between 2013 and 2017. Because the chemical is not naturally occurring, the change could only have been produced by new emissions.

[Evidence pointed to east Asia](https://www.theguardian.com/environment/2018/jul/09/mysterious-source-of-illegal-ozone-killing-emissions-revealed-say-investigators), but could not nail down the exact origin. “Our monitoring stations were set up in remote locations far from potential sources,” explained co-author Ron Prinn, a professor at MIT.

Reports last year from the Environmental Investigation Agency blamed Chinese foam factories in the coastal province of Shandong and the inland province of Hebei, which surrounds Beijing. Suspicions were strengthened when authorities subsequently shut down some of these facilities without explanation.

To probe further, an international team of atmospheric scientists gathered additional data from monitoring stations in Japan and Taiwan.

The team also ran computer simulations that confirmed the origin of the CFC-11 molecules. “We didn’t find evidence of increased emissions from Japan, the Korean peninsula or any other country,” added Luke Western, a post-doctoral researcher at the University of Bristol.

The findings also has implications for the fight against climate change.

Joanna Haigh, a professor at Imperial College London, said last year in reaction to the initial report: “Perhaps even more serious is the role of CFCs as long-lived greenhouse gases.”

Pouring more CFC-11 into the air could also delay ozone levels from returning to normal levels, scientists warn. “If emissions do not decline, it will delay the recovery of the Antarctic ozone hole, possibly for decades,” said Paul Fraser, an honorary fellow the CSIRO Climate Science Centre in Australia.

CFC-11 persists in the atmosphere for about half a century, and still contributes about a quarter of all chlorine – the chemical that triggers the breakdown of ozone – reaching the stratosphere. Two decades ago, CFCs – more potent by far as greenhouse gases than carbon dioxide or methane – accounted for about 10% of human-induced global warming.

At its most depleted, around the turn of the 21st century, the ozone layer had declined by about 5%.

Today, the “hole in the ozone” over the South Pole is showing clear signs of recovery. But a study last year found that the ozone layer was unexpectedly declining in the lower stratosphere over the populated tropical and mid-latitude regions.

Up to now, CFCs and other molecules have mainly eroded ozone in the upper stratosphere, and over the poles. That study identified two possible culprits: industrial chemicals not covered by the Montreal Protocol – called “very short-lived substances” (VSLSs)– and climate change.

(Source: <https://www.theguardian.com/world/2019/may/23/china-factories-releasing-thousands-of-tonnes-of-illegal-cfc-gases-study-finds>)

# 4. Science Daily Article: Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are to blame for global warming since the 1970s and not carbon dioxide, according to a researcher from the University of Waterloo in a controversial new study published in the *International Journal of Modern Physics B* this week.

CFCs are already known to deplete ozone, but in-depth statistical analysis now suggests that CFCs are also the key driver in global climate change, rather than carbon dioxide (CO2) emissions, the researcher argues.

"Conventional thinking says that the emission of human-made non-CFC gases such as carbon dioxide has mainly contributed to global warming. But we have observed data going back to the Industrial Revolution that convincingly shows that conventional understanding is wrong," said Qing-Bin Lu, a professor of physics and astronomy, biology and chemistry in Waterloo's Faculty of Science. "In fact, the data shows that CFCs conspiring with cosmic rays caused both the polar ozone hole and global warming."

"Most conventional theories expect that global temperatures will continue to increase as CO2 levels continue to rise, as they have done since 1850. What's striking is that since 2002, global temperatures have actually declined -- matching a decline in CFCs in the atmosphere," Professor Lu said. "My calculations of CFC greenhouse effect show that there was global warming by about 0.6 °C from 1950 to 2002, but the earth has actually cooled since 2002. The cooling trend is set to continue for the next 50-70 years as the amount of CFCs in the atmosphere continues to decline."

The findings are based on in-depth statistical analyses of observed data from 1850 up to the present time, Professor Lu's cosmic-ray-driven electron-reaction (CRE) theory of ozone depletion and his previous research into Antarctic ozone depletion and global surface temperatures.

"It was generally accepted for more than two decades that the Earth's ozone layer was depleted by the sun's ultraviolet light-induced destruction of CFCs in the atmosphere," he said. "But in contrast, CRE theory says cosmic rays -- energy particles originating in space -- play the dominant role in breaking down ozone-depleting molecules and then ozone."

Lu's theory has been confirmed by ongoing observations of cosmic ray, CFC, ozone and stratospheric temperature data over several 11-year solar cycles. "CRE is the only theory that provides us with an excellent reproduction of 11-year cyclic variations of both polar ozone loss and stratospheric cooling," said Professor Lu. "After removing the natural cosmic-ray effect, my new paper shows a pronounced recovery by ~20% of the Antarctic ozone hole, consistent with the decline of CFCs in the polar stratosphere."

By demonstrating the link between CFCs, ozone depletion and temperature changes in the Antarctic, Professor Lu was able to draw almost perfect correlation between rising global surface temperatures and CFCs in the atmosphere.

"The climate in the Antarctic stratosphere has been completely controlled by CFCs and cosmic rays, with no CO2 impact. The change in global surface temperature after the removal of the solar effect has shown zero correlation with CO2 but a nearly perfect linear correlation with CFCs -- a correlation coefficient as high as 0.97."

Data recorded from 1850 to 1970, before any significant CFC emissions, show that CO2 levels increased significantly as a result of the Industrial Revolution, but the global temperature, excluding the solar effect, kept nearly constant. The conventional warming model of CO2, suggests the temperatures should have risen by 0.6°C over the same period, similar to the period of 1970-2002.

The analyses support Lu's CRE theory and point to the success of the Montreal Protocol on Substances that Deplete the Ozone Layer.

"We've known for some time that CFCs have a really damaging effect on our atmosphere and we've taken measures to reduce their emissions," Professor Lu said. "We now know that international efforts such as the Montreal Protocol have also had a profound effect on global warming but they must be placed on firmer scientific ground."

"This study underlines the importance of understanding the basic science underlying ozone depletion and global climate change," said Terry McMahon, dean of the faculty of science. "This research is of particular importance not only to the research community, but to policy makers and the public alike as we look to the future of our climate."

Professor Lu's paper, "Cosmic-Ray-Driven Reaction and Greenhouse Effect of Halogenated Molecules: Culprits for Atmospheric Ozone Depletion and Global Climate Change," also predicts that the global sea level will continue to rise for some years as the hole in the ozone recovers increasing ice melting in the polar regions.

*(Source:* [*https://www.sciencedaily.com/releases/2013/05/130530132443.htm*](https://www.sciencedaily.com/releases/2013/05/130530132443.htm)*)*

# 5. Questions

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| 1. What does CFCs stand for and what do these molecules contain? |
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| 2. What are CFCs blamed for? |
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| 3. Which two substances have replaced the use of CFCs in society? |
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| 4. To what extent is the Industrial Revolution relevant to global warming? |
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| 5. What happens when a CFC molecule absorbs ultraviolet radiation? |
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| 6. What factors influence the strength of UV rays reaching the ground? |
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| 8. What is significant about the relationship between chlorine radicals and ozone molecules? |
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| 9. What does CRE stand for and who established the theory in relation to ozone depletion? |
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