South Asian Meteorological Association (SAMA)

World Ozone Day

Ozone for life: 35 years of ozone layer protection

This year, we celebrate 35 years of the Vienna Convention and 35 years of global ozone layer protection. Life on Earth would not be possible without sunlight. But the energy emanating from the sun would be too much for life on Earth to thrive were it not for the ozone layer. This stratospheric layer shields Earth from most of the sun's harmful ultraviolet radiation. Sunlight makes life possible, but the ozone layer makes life as we know it possible.

OZONE

Ozone is a gas made up of three oxygen atoms (O_3). It occurs naturally in small (trace) amounts in the upper atmosphere (the stratosphere). Ozone protects life on Earth from the Sun's ultraviolet (UV) radiation. In the lower atmosphere (the troposphere) near the Earth's surface, ozone is created by chemical reactions between air pollutants from vehicle exhaust, gasoline vapours, and other emissions. At ground level, high concentrations of ozone are toxic to people and plants.

Stratospheric "good" ozone

Ninety percent of the ozone in the atmosphere is found in the stratosphere, the layer of atmosphere between about 10 and 50 kilometres altitude. The natural level of ozone in the stratosphere is a result of a balance between sunlight that creates ozone and chemical reactions that destroy it. Ozone is created when the kind of oxygen we breathe—O_2—is split apart by sunlight into single oxygen atoms. Single oxygen atoms can re-join to make O_2, or they can join with O_2 molecules to make ozone (O_3). Ozone is destroyed when it reacts with molecules containing nitrogen, hydrogen, chlorine, or bromine. Some of the molecules that destroy ozone occur naturally, but people have created others.

The total mass of ozone in the atmosphere is about 3 billion metric tons. That may seem like a lot, but it is only 0.00006 percent of the atmosphere. The peak concentration of ozone occurs at an altitude of roughly 15-30 kilometres above the surface of the Earth. At that altitude, ozone concentration can be as high as 15 parts per million (0.0015 percent).

Ozone in the stratosphere absorbs most of the ultraviolet radiation from the Sun. Without ozone, the Sun's intense UV radiation would sterilize the Earth's surface. Ozone screens all of the most energetic, UV-c, radiation, and most of the UV-b radiation. Ozone only screens about half of the UV-a radiation. Excessive UV-b and UV-a radiation can cause sunburn and can lead to skin cancer and eye damage.

Tropospheric Ozone: a pollutant

Although ozone high up in the stratosphere provides a shield to protect life on Earth, direct contact with ozone is harmful to both plants and animals (including humans). Ground-level, "bad," ozone forms when nitrogen oxide gases from vehicle and industrial emissions react with volatile organic compounds (carbon-containing chemicals that evaporate easily into the air, such as paint thinners). In the troposphere near the Earth's surface, the natural concentration of ozone is about 10 parts per billion (0.000001 percent). The exposure to ozone levels of greater than 70 parts per billion for 8 hours or longer is unhealthy. Such concentrations occur in or near cities during periods where the atmosphere is warm and stable. The harmful effects can include throat and lung irritation or aggravation of asthma or emphysema.

Ozone Layer and Ozone Depletion

Severe losses of ozone over both the Arctic and Antarctic are the result of special meteorological conditions that occur over polar regions in the winter and early spring. As winter arrives in each hemisphere, a vortex of winds develops around the poles and isolates the polar stratosphere. Without milder air flowing in from the lower latitudes, and in the absence of sunlight, air within the vortex becomes very cold. At temperatures of −78°C or less, clouds made up of ice, nitric acid and sulphuric acid begin to form in the stratosphere. Called polar stratospheric clouds (PSCs), they give rise to a series of chemical reactions that destroy ozone far more effectively than the reactions that take place in warmer air. Once PSCs are created, the destruction of ozone begins with the return of sunlight in the spring. This starts a series of chemical reactions to free chlorine through photolysis. The destruction continues rapidly until all the available ozone is depleted. As the atmosphere slowly warms in the spring, the vortex dissipates and warmer temperatures prevent further PSCs from being formed.

Over the Antarctic, these processes commonly lead to the formation of a massive ozone hole every spring. Over the Arctic, similar processes occur, but ozone amounts have not fallen to the very low levels observed in Antarctica. This is partly because the Arctic has a higher concentration of ozone in the late winter and spring. It is also a result of the variable atmospheric circulation of the northern hemisphere, which makes the Arctic circulation vortex less stable. As a result, incursions of air from the south often keep the Arctic stratosphere too warm for PSCs to be formed.

In 1974, Mario Molina and Sherwood Rowland, two chemists at the University of California, Irvine, published an article in the journal Nature detailing threats to the ozone layer from chlorofluorocarbon (CFC) gases. At the time, CFCs were commonly used in aerosol sprays and as coolants in many refrigerators. As they reach the stratosphere, the sun's UV rays break CFCs down into substances that include chlorine.

The Ozone Hole

The ozone hole is not technically a "hole" where no ozone is present, but is actually a region of exceptionally depleted ozone in the stratosphere over the Antarctic that happens at the beginning of Southern Hemisphere spring (August–October). In 1956, the British Antarctic Survey set up the Halley Bay Observatory on Antarctica in preparation for the International Geophysical Year (IGY) of 1957. In that year, ozone measurements using a Dobson Spectrophotometer began. The Antarctic Ozone Hole was discovered in 1985 by British scientists Joseph Farman, Brian Gardiner, and Jonathan Shanklin of the British Antarctic Survey. Satellite instruments provide us with daily images of ozone over the Polar regions. From the historical record we know that total column ozone values of less than 220 Dobson Units were not observed prior to 1979. The total column ozone level of less than 220 Dobson Units is a result of catalyzed ozone loss from chlorine and

bromine compounds. For these reasons, we use 220 Dobson Units as the boundary of the region representing ozone loss.
Manmade chemicals containing halogens were determined to be the main cause of ozone loss. These chemicals are collectively known as ozone-depleting substances (ODSs). ODSs were used in literally thousands of products in people's daily lives around the world.
The most important ODSs were chlorofluorocarbons (CFCs), which at one time were widely used in air conditioners, refrigerators, aerosol cans, and in inhalers used by asthma patients. Other chemicals, such as hydrochlorofluorocarbons (HCFCs), halons and methyl bromide also deplete the ozone layer. Most of our computers, electronics and parts of our appliances were cleaned with ozone-depleting solvents. Car dash boards, insulation foams in our houses and office buildings, water boilers and even shoe soles were made using CFCs or HCFCs. Offices, computer facilities, military bases, airplanes and ships extensively used halons for fire protection. A lot of the fruit and vegetables we ate were fumigated by methyl bromide to kill pests.
When a CFC molecule reaches the stratosphere, it eventually absorbs UV radiation, causing it to decompose and release its chlorine atoms. One chlorine atom can destroy up to 100,000 ozone molecules. Too many of these chlorine and bromine reactions disrupt the delicate chemical balance that maintains the ozone layer, causing ozone to be destroyed faster than it is created.

Dobson Unit: The "Dobson Unit" is named after professor G.M.B. Dobson built the first "Dobson spectrophotometer", with which reliable measurements of the ozone layer became possible. Dobson unit is used for determining the total amount of ozone present in a vertical column of air above the surface of the earth. One Dobson Unit is the number of molecules of ozone that would be required to create a layer of pure ozone 0.01 millimetres thick at a temperature of 0 degrees Celsius and a pressure of 1 atmosphere (the air pressure at the surface of the Earth). Under normal conditions, earth's atmosphere contains about 300 DU of ozone.

Dobson spectrophotometer at India Meteorological Department, New Delhi

The Vienna Convention

The Vienna Convention for the Protection of the Ozone Layer was adopted in 1985 and entered into force in 1988. Nations that signed the Convention – called the parties – agreed to research and monitor the effects of human activities on the ozone layer and to take concrete action against activities that are likely to have adverse effects on the ozone layer.

Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer is a global agreement to protect Earth's ozone layer by phasing out the consumption and the production of most chemicals that deplete it. The landmark agreement was signed on 16 September 1987 – marked globally as

the World Ozone Day - and entered into force in 1989. The Protocol provides a set of practical, actionable tasks to phase out ozone-depleting substances that were universally agreed upon.
The Protocol is unique in having the flexibility to respond to new scientific information. Since its inception the Protocol has successfully met its objectives, and continues to safeguard the ozone layer today.

Alternatives of CFC

- The interim replacements for CFCs are hydrochlorofluorocarbons (HCFCs), which deplete stratospheric ozone, but to a much lesser extent than CFCs.
- Ultimately, hydrofluorocarbons (HFCs) will replace HCFCs. Developed countries will completely phase out HCFCs by 2020. Developing countries agreed to start their phase out process in 2013 and are now following a stepwise reduction until the complete phase-out of HCFCs by 2030.
- Unlike CFCs and HCFCs, HFCs have an ozone depletion potential (ODP) of Zero.
- HFCs are included in the Kyoto Protocol because of their very high Global Warming Potential and are facing calls to be regulated under the Montreal Protocol.

Kigali Amendment

Although the Montreal Protocol was designed to phase out the production and consumption of ODSs, some replacements of these substances, known as hydrofluorocarbons (HFCs), have proven to be powerful greenhouse gases. In fact, some HFCs are more than a thousand times more potent than carbon dioxide in contributing to climate change.
After several years of effort, the parties agreed on 15 October 2016 to amend the Protocol to include control measures to reduce HFCs (the Kigali Amendment). A successful HFC phasedown is expected to avoid up to 0.4 degree Celsius of global temperature rise by 2100, while continuing to protect the ozone layer.

Consequences of ozone layer depletion

- Increased UV
- Biological effects
  - Basal and squamous cell carcinomas
  - Malignant melanoma
  - Cortical cataracts
- Increased production of vitamin D
- Effects on animals
- Effects on crops

What We Can Do

- Protect yourself from ozone layer depletion
- Avoid excessive sun exposure
  Take extra precautions because unprotected skin and eyes will be damaged and can burn quickly. Wear sunglasses on bright days. When outdoors in the sun, use sunscreen, use umbrella or wear a wide-brimmed hat and protective clothing.

An easy way to tell how much UV exposure you are getting is to look for your shadow. If your shadow is taller than you are (in the early morning and late afternoon), your UV exposure is likely to be lower. If your shadow is shorter than you are (around midday), you are being exposed to higher levels of UV radiation. Seek shade and protect your skin and eyes.

- Take care of your appliances to minimize ozone layer impact

→ Use refrigerators, air conditioners and other equipment responsibly to assist in protecting the ozone layer and climate.

→ Dispose of appliances and equipment with refrigerants responsibly.

→ Have your car and home air conditioner and refrigerator checked for leaks.

→ Insulate your walls, doors and windows properly for improved energy efficiency and prolonged life of your equipment.

→ Set the thermostat of your refrigerator and freezer at the right temperature (avoid too low temperatures) and switch equipment off when not in use, as even a standby mode consumes energy.

→ Keep rooms cool at night with ventilation, without air conditioning if possible and also remember that a higher setting of your air conditioner's thermostat saves a lot of energy.

The ozone layer's status today

The Montreal Protocol is widely lauded as a huge environmental success. Whilst the damage we have done to the ozone layer has not yet been undone, thanks to this agreement and the collaborative effort of nations around the world, there is scientific evidence that the ozone layer is healing itself and is expected to recover by the middle of this century.

The Montreal Protocol has also considerably reduced climate warming because many ozone-depleting substances are also potent greenhouse gases that contribute to climate forcing when they accumulate in the atmosphere. Montreal Protocol controls have led to a substantial reduction in the emissions of ozone-depleting substances over the last two decades. These reduction, while protecting the ozone layer, have the additional benefit of reducing the human contribution to climate change. Without Montreal Protocol controls, the climate forcing due to ozone-depleting substances could now be nearly two and a half times the present value.

And at the end of 2018, the United Nations confirmed in a scientific assessment that the ozone layer is recovering, projecting that it would heal completely in the (non-polar) Northern Hemisphere by the 2030s, followed by the Southern Hemisphere in the 2050s and polar regions by 2060.

We've made a lot of progress, but we need to continue to work together to protect the ozone layer for the future. While scientists and researchers find new solutions and create earth-friendly products, there are things we can all do, like buying products that are labelled "ozone friendly" or "HCFC free". Healing the ozone layer is a major accomplishment, but it also proves something important as we look to the future, how to deal with other global environmental challenges. The message is clear: when people and countries around the world come together, united by a common goal, we can solve seemingly impossible problems. That is surely a cause for great optimism as we contemplate what else our global community is capable of!

(Acknowledgement: NASA Ozone Watch, UNEP Ozone Secretariat)