Effects of Ozone Depletion

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The Discovery

In 1985, using satellites, balloons, and surface stations, a team of researchers had discovered a balding patch of ozone in the upper stratosphere, the size of the United States, over Antarctica.
Total Ozone Mapping Spectrometer (TOMS)

- Used by NASA to measure ozone concentrations
- TOMS – a satellite-borne instrument
- TOMS launched in 1996 – makes 35 measurements every 8 seconds
- Levels of ozone are measured in Dobson units (DU), where 100 DU is equivalent to a 1 millimeter thick layer of pure ozone
Earth’s Atmosphere

- Exosphere
  - 400 km altitude
- Thermosphere
  - 300 km
- Mesosphere
  - 50 km
- Stratosphere
  - 40 km
- Troposphere
  - 10 km
The ozone layer

• Ozone is a triatomic form of oxygen (O3) found in Earth’s upper and lower atmosphere.

• The ozone layer, situated in the stratosphere about 15 to 30 km above the earth's surface.

• Ozone protects living organisms by absorbing harmful ultraviolet radiation (UVB) from the sun.

• The ozone layer is being destroyed by CFCs and other substances.

• Ozone depletion progressing globally except in the tropical zone.
• Ozone is a gas naturally present in the atmosphere
• Each ozone molecule contains 3 atoms of oxygen and is denoted chemically as O₃.
• It is found primarily in 2 regions of the atmosphere
• 10% ozone is in the troposphere – the region closest to the earth
The remaining ozone (about 90%) resides in the stratosphere between the top of the troposphere and about 50 Km altitude.

The large amount of ozone in the stratosphere is often referred to as the “ozone layer”.

Ozone is formed throughout the atmosphere in multistep chemical processes that require sunlight.
• In the stratosphere the process begins with the oxygen molecule (O₂) being broken apart by ultraviolet radiation from the sun

• In the lower atmosphere (troposphere) ozone is formed by different set of chemical reactions that involve naturally occurring gases and those from pollution sources
Hole Formation Based on Two different mechanisms:

- **Meteorological mechanism**
  - Movement of air from one place to another in the upper stratosphere
  - Cold temperature in the upper atmosphere causes nitric acid to freeze into crystals forming wispy pink clouds
  - Forms a vortex of tightly twisted winds thus forming a hole in the upper atmosphere
A combination of low temperatures and elevated chlorine and bromine concentrations are responsible for the destruction of ozone in the upper stratosphere thus forming a “hole”. (Kerr, 1987)


**Stratospheric Ozone and Ultraviolet Radiation (UVR)**

- **Ultra-violet radiation** (UVR) high energy electromagnetic wave emitted from the sun. It is made up of wavelengths ranging from 100nm to 400nm.

- **UV radiation includes UV-A**, the least dangerous form of UV radiation, with a wavelength range between 315nm to 400nm, **UV-B** with a wavelength range between 280nm to 315nm, and **UV-C** which is the most dangerous between 100nm to 280nm. UV-C is unable to reach Earth’s surface due to stratospheric ozone’s ability to absorb it. (Last, 2006)
Too much ultra-violet light can result in:

- Skin cancer
- Eye damage such as cataracts
- Immune system damage
- Reduction in phytoplankton
- Damage to the DNA in various life-forms
  - this has been observed in Antarctic ice-fish that lack pigments to shield them from the ultra-violet light (they've never needed them before)
- Possibly other things too that we don't know about at the moment
Effects of UV radiation on biological organisms

- **DNA damage** ........................................ Maximum effect on small and single cell organisms
- **Impaired growth and photosynthesis** ...poor crop yields
- **Phytoplankton**: ................................. Reduced uptake of CO2
  .................................................................................................................. mortality
  .................................................................................................................. Impaired reproductive capacity
- **Nitrogen-fixing soil bacteria** .......... Reduced, damaged
- **Human health effects**:
  Suppressed immune system....................Enhanced susceptibility to infection
  .................................................................................................................. Increase risk of Cancer
  Dermatology (skin).................................Sunburn
  .................................................................................................................. Loss of skin elasticity (Premature aging)
  .................................................................................................................. Photosensitivity
  Neoplasia (cancer).................................Melanocytic (malignant melanoma)
  .................................................................................................................. Squamous cell skin – cancer
  .................................................................................................................. Basal skin – cancer
  Still questionable if causes lip cancer or cancer of the salivary glands
  Oculur (Eye)..............................................Cataract
  .................................................................................................................. Pterygium

(last, 1993)
Phytoplankton

• UV-B penetrates water columns to depths of 30m

• Increased UV-B exposure
  – Reduces productivity by interfering with processes of photosynthesis
  – Damages DNA
  – Alters nitrogen metabolism
  – Inhibits mobility

• Studies (1993) conducted in the Weddle Sea
  – Evaluated effects of photosynthesis to UV exposure in the presence of vertical mixing, found:
    • photosynthesis by phytoplankton was strongly inhibited near the surface of the water
    • rapid mixing, photic zone is extended, severe inhibition of photosynthesis
- **Bacterioplankton**
  - Play critical role in aquatic system
    - **Decomposers** - absorb dissolved organic carbon and recycle it back into the environment
    - **Primary producers** – found at the center of food web
  - Prone to UV-B stress
    - Inhibits growth
    - Interferes with mechanisms for nitrogen fixation and carbon dioxide fixation
    - High mortality
  - Effects dependent on:
    - Where found in the water column
    - Amount of exposure
    - Amount of protection when moving from one mixing layer to another
  - Adaptive Strategy:
    - Pigmentation – absorb more than 90% of UV-B before it penetrates to the genetic material
    - Form external filaments which protect them from excess UV-B
Macroalgae and Seagrasses

- Are sessile and restricted to growth site
- Have diverse habitats
  - Above tidal zones
  - Intertidal zones
  - Some never exposed to air
- Have adapted to varying solar exposure
  - Able to protect themselves from excessive radiation using mechanisms of phototinhibition
    - mechanisms (electron transport) decrease photosynthesis during excessive radiation
Plants
The influence of the UV-B radiation on plant process.
DNA & UV-B

- DNA absorbs UV-B radiation

Changes shape in DNA

- Changes in the DNA molecule mean that enzymes cannot “read” the DNA code
- Results in mutated cells or the cells die

Cells have developed the ability to repair DNA

- A special enzyme arrives at the damage site
- Removes the damaged section of DNA
- Replaces it with the proper components

This makes DNA somewhat resilient to damage by UV-B
Higher Plants

Experiments were done to determine if increased UV-B is a threat to terrestrial vegetation:

- Found
  - High UV-B exposure does induce some inhibition of photosynthesis

However....

- Studies found no significant effects on photosynthetic productivity

- Some researchers have concluded that ozone depletion and increase of UV-B not a direct threat to photosynthetic productivity of crops and natural vegetation (Allen, 1998)
Difficult to Unmask UV-B Effects

- Limitations in controlled and field studies include:
  - Large differences in temperature, precipitation, soil types from year to year and in different locations
  - UV-B radiation masked by other stresses of land plants such as drought
- Drought produces large reductions in photosynthesis and growth masking the effects of UV-B
- Water stressed plants produce a high concentration of leaf flavonoids (for pigmentation) providing greater UV-B protection
Flowering

- UV-B radiation can alter both the time of flowering as well as the number of flowers in certain species.

- Differences in timing of flowering may have important consequences for the availability of pollinators.

- The reproductive parts of plants, such as pollen and ovules, are well shielded from solar UV-B radiation.
Can plants protect themselves against increased UV-B?

Plant adaptation:

- Have UV shielding
- Only a small proportion of the UV-B radiation striking leaf penetrates into the inner tissues
- When exposed to increasing amounts of UV-B, many species of plants can increase the UV-absorbing pigments in their tissues

Other adaptations include:

- Increased thickness of leaves reducing the proportion of inner tissues exposed to UV-B radiation
- Have repair mechanisms in plants
  - includes repair systems for DNA damage

www.unep.ch/ozone/faq-env.shtml -
Amphibians
Global Decline Seen In Amphibians

Range of explanations as to why amphibians are declining, which include:

- Habitat destruction
- Disease
- Parasites
- Introduction of exotic species
- Environmental contaminants and other aspects of global climate change
UV-B radiation is still high on the list for the decline in amphibians seen around the world

- Causes damage to many species of amphibians at every stage of their life cycle, from egg to adult
- Affects growth and development in larvae
- Causes
  - Changes in behavior
  - Deformities
  - Make amphibians more vulnerable to disease and death
  - In adults, causes retinal damage and blindness
UV-B Effects on Human Effects
Effects on Human Health

- Over exposure may:
  - Increase risk of non-melanoma and malignant melanoma skin cancer

- Higher risks of malignant melanoma from severe sunburns – especially in childhood

- Risk of malignant melanoma has increased 10%

- Risk of nonmalignant melanoma has increased 26%

www.ldeo.columbia.edu/.../lectures/ozone_health/
Over Exposure

- Suppress immune system
- Accelerate aging of skin due high exposure
- Cause an outbreak of rash in fair skinned people due to photo allergy – can be severe

[Images of affected skin]

dermis.multimedica.de/.../en/13007/image.htm
Skin Protection

- Protect the skin against the solar radiation using skin creams with SPF
  - The greater the numerical value of the SPF the greater the protection
- Use lip balm with SPF
- Cover up
Over Exposure to UV-B....

- Increases the risk of cataracts
  - Induces type of protein that provokes cleaving (splitting) in the lens
  - Leading cause of blindness
  - The prevalence of cataract after age 30 is doubling each decade
- Causes pterygium
  - A wedge-shaped growth over the central cornea
Manifestations of...

Cataracts

brought on by over exposure to UV-B

Cancer

Pterygium
Protection

- Sunglasses with 100% UV block
- Wrap around sunglasses
- Eye protection for children
- Hats
What Is Being Done to Counter the Effects of Ozone Depletion?

- **Montreal Protocol** (adopted in 1987) – panel of experts was formed to investigate substances responsible for hole formation
  - Established policies that prevent future use of certain types of chemicals
  - Stipulated that the production and consumption of compounds contributing towards depletion of ozone in the stratosphere were to be phased out by the year 2000 (2005 for methylchloroform)
The Environmental Protection Agency (EPA)

- Responsible for enforcing the Montreal Protocol within the U.S.
  - The EPA has several programs in place;
    - Regulating and enforcing on-road car and truck air-conditioning systems
    - Regulating most air-conditioning and refrigeration appliances
    - Technician certification
    - Service equipment
Signs of Recovery???
There have been some signs of recovery

- 1997 satellite showed a decline of several known ozone-depleting gases
- Satellite images show some slowing down of ozone loss

However....

Recovery is slow

www.coolantarctica.com/.../ozone_hole.htm
Images of Antarctica Taken Indicate A Slow Recovery
Understanding the future

Researchers would like to see:

- Stations that measure levels of ozone and surface radiation changes in relation to incidence rate of skin cancer and cataracts - installed in urban areas and in remote regions far from populations

- More studies to determine biological effects (including human) on UVR exposure

- Research on protective creams and ointments and their efficiency in preventing skin cancer and malignant melanoma

- More surveillance of UV-related damage to other species living in high latitudes for example.....
Reports of Sheep in Iceland developing eye disease – no research to support

(Last, 1993)
Future Evolution of Ozone

Remains unclear
- Current models are unable to reproduce ozone variability accurately
- Rates of future increases in greenhouse gases are not yet established
- Interactions between ozone depletion and climate change not yet fully understood

Continued monitoring of ozone and ozone-depleting substances is essential
- Ozone layer recovery expected by 2050
- Hinges on the complete elimination of atmospheric ozone-depleting substances
- Replacements for HCFCs, methyl bromide, and halons are still being sought, and studies of the new compounds must continue

Summing It All Up

- The Ozone is Earth’s only defense against harmful UVR
- Studies indicate ozone thinning throughout the globe due to 2 mechanisms:
  - Meteorological
  - Chemical
- Research indicates microorganisms, are extremely sensitive to increasing UV-B levels
- There is a lot of uncertainty and debate among researchers as to the degree in which land plants are affected by UV-B
- There is debate in the scientific community in the role UV-B radiation plays on the decline of amphibians seen globally
- In the last decade, there has been an increase in skin cancer and cataracts all related to increase UV-B exposure
Efforts Need to Be Continued

- Create reliable models
  - To gain a better understanding of the effects ozone depletion has on organisms living within different ecosystems

- Enforcement of Montreal Protocol
  - To reduce concentrations of chemicals responsible for ozone depletion

- Monitoring chemicals being emitted

- Gain a better overall understanding on just how ozone depletion is affecting our planet

...
A HEALTHY ATMOSPHERE, THE FUTURE WE WANT

- The Montreal Protocol has effectively phased out ozone-depleting chemicals, protecting both the ozone layer and the climate, saving millions of lives, and avoiding destruction of agricultural and natural ecosystems.

- Global leadership, including India’s success story, proved essential in the international effort to reverse the “ozone hole.”
The international community faces a new challenge – the super greenhouse gases known as hydrofluorocarbons (HFCs), which are growing rapidly as replacements for some uses of the ozone-depleting chlorofluorocarbons (CFCs).

The warming effect of HFCs is thousands of times higher, than carbon dioxide.
The 4 Partners:-

- The Council on Energy, Environment and Water (CEEW)
- The Natural Resources Defense Council (NRDC)
- The Institute for Governance & Sustainable Development (IGSD)
- The Energy and Resource Institute (TERI)
- in consultation with the Confederation of Indian Industries (CII), the Refrigeration and Air-Conditioning Manufacturers Association (RAMA) and the Society of Indian Automobile Manufacturers (SIAM), have issued a preliminary review of the business case for leapfrogging or phasing down the use of HFCs in room and vehicle air conditioners in India’s fast-growing markets.
India’s leadership was essential to the success of the global CFC phase-out.

India completed the phase-out of CFC production and consumption by 2008, more than a year and a half ahead of schedule!

India also phased out halons nearly ten years before the agreed deadline in 2003.
Indian government leaders created a comprehensive national regulatory framework and a robust private-sector engagement to ensure a smooth market transition for post-CFC compounds. India’s many policies to support market transformation included:

- creating a government-industry monitoring program
- securing technology transfers through cooperative agreements with developed country signatories to the Montreal Protocol
- developing industry phase-out strategies with the World Bank and the United Nations Environment Program
- convening state workshops held to raise awareness within industry of CFC phase-out
- establishing a support network focused on small and medium enterprises (SMEs) offering assistance for implementation
- providing financial incentives to bolster the development of new technology and discouraging the re-financing of outdated technology
Twenty-five years later, after the Montreal Protocol was agreed, India is presented with a new opportunity to lead and engage with domestic industry and international counterparts to phase down dangerous HFCs. Momentum for an HFC phase-down is coming partly from real world energy concerns.
With a booming economy, increasing disposable income, and high temperatures, air-conditioning is rapidly increasing in India. **Air-conditioners account for a staggering 40 to 60 percent of peak electricity demand during the summer months in many Indian cities.** Leading Indian air-conditioning manufacturers are actively exploring energy-efficient alternatives to HFCs while advancing their international competitive market share.
Air-Conditioning Units in a building in Kolkata
India could motivate its industry to lead a technological innovation process by supporting an accelerated global HFC phase-down under the Montreal Protocol.

India’s success story with the CFC phase-out provides a roadmap to transitioning HFC-dependent industries to safer and more marketable refrigerants.
As a global leader, India plays an essential role at the Montreal Protocol discussions in designing international cooperation in the orderly shift from HFCs to reduce these extremely potent greenhouse gases while maintaining momentum as a clean technology leader.
Key Achievements of the Montreal Protocol as released by UNEP

- Truly global participation – This is the only treaty ever to achieve universal ratification
- Healing the ozone layer – Results from continuing global observations have confirmed that by the middle of this century the ozone layer should return to pre-1980 levels
Achieving major reduction goals – by 2010 all parties reported compliance with their phase out obligations in respect of CFCs, halons, carbon tetrachloride methyl chloroform, n-propyl bromide and chlorobromomethane. The Protocol has now led to the phase-out of 98% of the historic levels of production and consumption of ozone depletion substances.
Supporting developing countries with the assistance of the multilateral funds or the implementation of the Montreal Protocol the developing countries has by mid 2011 permanently phased out 260,000 tonnes of ozone depletion substances.

High rate of compliances – 98% compliances achieved taking into account all parties.
Health benefits – enabled global community to avoid millions of cases of fatal skin cancer and eye cataracts. The United States estimates that by the year 2065 more than 63 million skin cancer deaths will have been avoided in that country alone and will have saved an estimated US $4.2 trillion in health care costs over the period 1990 – 2065. More than 22 million Americans born between 1985 and 2100 would avoid suffering from cataracts.
Climate benefits – The Protocol has also delivered substantial climate benefits because most ozone depleting chemicals are also greenhouse gases. The Protocol has already averted greenhouse gas emissions equivalent to more than 135 billion tonnes of carbon dioxide which made it the prime contributor to fight against global warming.
Thank you