Module 8: Some Environmental Concerns - Study Materials

Keyterms

- **Fossil fuels:** Fuel that is believed to originate from the natural decomposition of organisms and trapped in sedimentary rock. Such fuels consist of carbon containing compounds such as coal, petroleum and natural gas.
- **Acid rain:** Rain that is more acidic than expected. The increased acidity is attributed to oxides of sulfur and nitrogen, which dissolve in rain droplets and react with the water to form strong acids.

Acid Rain

How does this happen?

When atmospheric carbon dioxide dissolves in water it forms carbonic acid.

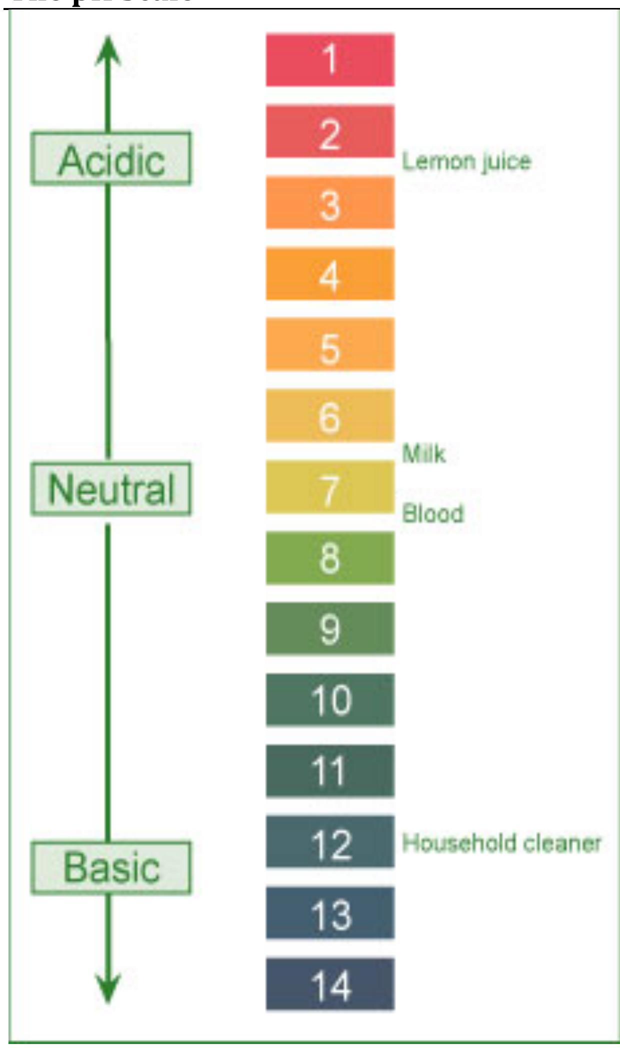
$$CO_2\ (g) + H_2O\ (\ell) \rightarrow H_2CO_3\ (aq)$$

The acid formed dissociates partially generating small amounts of hydrogen ions.

$$H_2CO_3\ (aq) \rightarrow H^+\ (aq) + HCO_3^-\ (aq)$$

The hydrogen ions formed are responsible for the weakly acidic nature of rain.

The pH Scale



The acidity (a measure of hydrogen ion concentration) of a solution is conveniently described in terms of pH scale.

According to this scale, if:

pH < 7: solution is acidic

pH > 7: solution is basic

pH = 7: solution is neutral

For example lemon juice is acidic.

Acid Rain

pH Laboratory

This virual laboratory provides a visual example of how different substances can effect the pH balance. This activity should also remind you of the health and safety aspects of working in a laboratory discussed in Module 4.

Virtual Laboratory: Determination of pH

It is very important to note that before working in a laboratory you must be aware of Good Laboratory Practices (GLP) as well as related Health and Safety aspects of the work you are planning to carry out.

As you learned in Module 4 of this course, you should be aware of various hazards and the location of appropriate control equipment, MSDSs and personal protective equipment such as safety glasses, appropriate gloves, lab coat, etc.

Objective: Many natural and synthetic dyes display different colors depending on the pH of the solution and can therefore be used as indicators monitoring pH. In this experiment you are going to monitor the pH of three samples: vinegar (5% aqueous solution of acetic acid), water, and an aquerous extract of a dishwashing detergent. The indicator used is a natural dye

Materials: Tube with stopcock containing the dye, beakers with samples and mixing device

Vinegar: pH < 7

Water: pH = 7

Detergent: pH > 7

↑ Acidity = ↓ pH

Based on the concentration of carbonic acid and small amounts of other natural acids, the estimated pH of rain (as well as fog, dew and snow) under normal atmospheric conditions should be around 5.3.

Field measurements in many areas, on the other hand, show much lower pH values (4.1- 4.5).

Higher acidity (lower pH) is due to the reactions of NO_x and SO_x present in the atmosphere.

Various reactions of these oxides lead to the formation of acids. The dissociation of formed acids generates hydrogen ions and hence higher acidity (or lower pH).

$$2\ SO_2\ (g) + O_2\ (g) + 2\ H_2O\ (\ell) \longrightarrow 2\ H_2SO_4\ (aq)$$

$$H_2SO_4\ (aq) \longrightarrow H^+\ (aq) + HSO_4^-\ (aq)$$

$$HSO_4^-\ (aq) \longrightarrow H^+\ (aq) + SO_4^{2-}\ (aq)$$

$$4\ NO_2\ (g) + O_2\ (g) + 2\ H_2O\ (\ell) \longrightarrow 4\ HNO_3\ (aq)$$

$$HNO_3\ (aq) \longrightarrow H^+\ (aq) + NO_3^-\ (aq)$$

Environmental Effects

Material Damage: Marble and limestone ($CaCO_3$) used in many historic and irreplaceable statues and buildings (e.g., the Parthenon in Greece, the Taj Mahal in India) react with acid in the rain.

The reaction leads the formation of calcium salts. The solubility of these salts in water is much greater than that of marble in water. The dissolution of formed calcium salts leads to roughened surfaces, removal of material and loss of carved details from the buildings and statues.

$CaCO_{3\,(s)} + 2H^+_{(ap)} \rightarrow Ca^{2+}_{(aq)} + CO_{2\,(g)} + H_2O_{(l)}$

Forest Damage: Considerable damage to trees has been reported in various parts of North America and Europe. Acid rain has been implicated with slower growth, injury and destruction of forests and has been attributed to be a contributing factor to the declining health of trees by damaging their leaves, limiting the nutrients available to them or exposing them to toxic substances released from the soil due to the change in pH.

Acid rain is implicated in depleting the nutrient supply to the trees by:

- Attacking the leaves whose protective coating has already been destroyed due to attack by other atmospheric pollutants such as O_3 and NO_x
- Mobilizing various metals (Al, Pb, etc.) in the soil in the attack the roots

Inadequate nutrient supply increases the possibility of destruction due to disease, drought, insects or high winds.

Corrosion of Metals: The corrosion process is accelerated in the presence of acid. Thus, iron structures, bridges, railroads, etc. show a faster rate of corrosion (rusting) in acid rain predominant areas. Studies indicate that even painted or plated iron corrodes more rapidly in such areas.

The reaction occurs in 2 steps with hydrogen ions (formed from the dissociation of acid) being involved in the first step of the reaction. The overall reaction, conversion of iron to its oxide (rust), can be represented as follows:

- $4Fe_{(s)} + 3O_{2\,(g)} \rightarrow 2Fe_2O_{3\,(s)}$

Aquatic Life: is quite susceptible to changes in pH. Reduced pH has led to lakes with no fish or other living beings. Acid rain has been shown to reduce fish population, kill individual fish and in some cases elimate fish species entirely from a body of water.

Adverse effects of acid rain on aquatic life are due to:

- Lowering of pH well below the required value of about 6.5 for healthy aquatic life.
- Increasing aqueous concentration of metals (Al, Pb, etc.) due to their higher solubility at lower pH.

Both low pH and increased aluminum levels are directly toxic to fish. In addition, low pH and increased aluminum levels cause chronic stress leading to smaller size and lower body weight. These factors in turn make the fish less able to compete for food and habitat

Control Strategies

Reduction of SO_x emissions by using emission control technologies:
Over the years, progress has been made in reducing the emissions of sulfur dioxide. The major strategies under consideration include:

- Using coal with low sulfur content
- Removing sulfur from the coal before using
- Using chemicals to neutralize acidic sulfur dioxide

In view of the substantial cost involved in using any of the above strategies individually or in combination, the progress in this direction has been rather slow in North America. In Japan, using the above technologies in particular the use of scrubbers (for the neutralization of acidic sulfur dioxide) has led to considerable decrease in sulfur dioxide emissions.

Reduction of NO_x emissions by using emission control technologies:
Catalytic converters are now in use in automobiles to reduce the emission of oxides of nitrogen

Using cleaner energy sources (such as alcohol and hydrogen) in transportations
These cleaner energy sources are being explored. A number of projects all over the globe are in progress. In some parts of the US there is limited use of alcohol to replace gasoline in cars. There are considerable numbers of investigations in progress pertaining to the use of hydrogen as fuel.

Developing and/or using alternate energy (i.e., hydroelectric, nuclear or wind) sources:
Hydroelectric, nuclear and wind power are being used in many parts of the world. However, the progress in their development is very slow primarily due to high initial costs and environmental issues.

Global Warming

How does this happen?

Global warming refers to an increase in the Earth's average temperature. This warming is the result of increased absorption by the atmosphere of infrared (IR), a major source of heat, radiated back from Earth's surface. This is due to an increase in concentration of gases that trap heat in the atmosphere. These gases are often called greenhouse gases.

The principal greenhouse gases that enter the atmosphere due to human activities include:

Carbon dioxide (CO_2)	**Methane (CH_4)**	**Nitrous oxide (N_2O)**	**Fluorinated gases**
It enters the atmosphere due to the burning of fossil fuels (oil, natural gas, and coal), waste materials, and as a result of other chemical reactions.	Main sources of emission are the production and transport of fossil fuels, livestock, agricultural practices and organic waste decay.	It is emitted during agricultural and industrial activities as well as during the combustion of fossil fuels and waste materials.	These fluorine containing compounds are emitted from a variety of industrial processes and are sometimes called High Global Warming Potential (GWP) gases.

Based on measured concentrations of various greenhouse gases, computer models have been developed to predict the extent of global warming. It is estimated that the temperature of the atmosphere may increase anywhere from 1.5 ^oC to 3.5 ^oC during the next fifty years.

Environment Effects

The possible environmental effects include:

Climatic changes: Human activities such as burning of fossil fuels, deforestation, industrial processes and some agricultural practices release greenhouse gases. These gases trap energy in the atmosphere causing it to warm.

Changes in sea level due to melting of polar ice caps: The North Pole is warming up faster than the rest of the world. The artic sea ice is in a state of ongoing decline as shown by the data from the National Snow and Ice Data Center (NSIDC) in the US.

Possibility of droughts and increased frequency of heat waves due to warning: Based upon detailed analysis using computer climate models and other relevant data, it is concluded that in the next few decades increasingly dry conditions may be encountered across much of the globe

Changes in ecosystem: As many animals and plants survive within a narrow range of climatic conditions, some animal species are shifting towards high elevations. Many species even face extinction. As ocean temperatures rise, the coral reefs will continue to decline

Effects on Human Health: Global warming may lead to increased temperature-related illnesses, air pollution due to higher temperatures, and possible spread of some infectious diseases.

Global Warming

Control Strategies

Some of the suggested control strategies include:

Reduction in CO_2 emissions: The governments all over the globe are working to reduce their country's carbon dioxide emissions by:

- Promoting that alternate non-fossil sources such as hydroelectric, solar, nuclear and wind are developed and used
- Capturing the carbon dioxide generated by burning fossil fuels
- Supporting new fuels and technologies (like electric cars) to reduce carbon dioxide emissions from transport
- Setting 'carbon budgets' to cap overall carbon dioxide emissions.

Encouraging energy conservation: This will lead to lesser energy consumption and hence lower production and reduced emissions.

Using carbon dioxide sinks: A carbon dioxide sink is any resource (natural or artificial) that captures and stores atmospheric carbon dioxide. Natural carbon dioxide sinks include forests, oceans and soil. Thus replanting forests is being encouraged globally.

Some of the artificial carbon dioxide sinks being studied involve removing carbon dioxide from the atmosphere and storing it in rocks, injecting it deep into the oceans or trapping it via chemical reactions.

Present Situation

Key Events to Limit Global Warming

1988-Intergovernmantal Panel on Climate Change

In 1988, United Nations Environment Program (UNEP) and World Meteorological Organization established Intergovernmental Panel on Climate Change (IPCC) to focus on:

- Assessment of scientific knowledge
- Examination of the environmental economic and social impacts
- Formulation of response strategies

2007 – Intergovernmental Panel on Climate Change

A report released by the Intergovernmental Panel on Climate Change (IPCC) in 2007 stated that global warming is clearly evident from diverse observations such as :

- Increases in average air and ocean temperatures
- Widespread melting of snow and ice

- Rising global average sea level

The report emphasizes that global warming could cause irreversible damage to the planet. It is concluded as strongly suggested by scientists that global, sweeping, concerted action. In addition, a report on the global economic impact of global warming (the Stern Report) suggests that it could shrink the global economy by 20%)

1997- Kyoto protocol

In order to limit global warming (due to trapping of heat in the atmosphere by greenhouse gases), the Kyoto protocol was signed in 1997. The document calls for industrialized nations to cut their emissions of greenhouse gases

Today – Kyoto protocol

Kyoto Protocal participation map as of February 2012

- Green indicates countries that have ratified the treaty (Annex I & II countries in dark green(
- Brown = intentions to ratify
- Red = Countries which have withdrawn from the protocol
- Grey = no position taken or position unknown

Summary: However, the progress in the implementation of diverse measures to control the emission of greenhouse gases and thereby limit the extend of global warming is going to be slow. The reason for this is the present situation of the global economy and hence the reluctance of governments to implement tighter environmental controls on emissions.

Ozone Depletion

How does this happen?

Ozone plays a double role in our environment:

- In our immediate atmosphere, it acts as an air pollutant contributing to photochemical smog
- In the stratosphere (in conjunction with oxygen), it filters the solar ultraviolet (UV) radiation, thus protecting us against its harmful effects

In our immediate atmosphere exposure to ozone may occur in operations involving:

- High-intensity UV light such as mercury vapor lamps, plasma torches, glass blowing, etc.
- High-voltage electrical equipment
- Welding

In all the above operations, the interaction of high energy with oxygen in the surrounding atmosphere leads to the formation of O_3:

$$3\ O_2\ (g) + \text{Energy} \rightarrow 2\ O_3\ (g)$$

Image: All life on Earth is protected by the ozone layer. This layer of gas acts as an invisible filter that protects all life forms from over-exposure to the sun’s harmful UV rays. Most incoming UV radiation is absorbed by ozone and prevented from reaching the Earth's surface. Without the protective effect of ozone, life on Earth would not have evolved the way it has (Source text and image: Environment Canada, Ozone Layer)

Ozone Depletion

Ozone Formation

Sunlight shining through clouds in Northumberland, UK (Source: Christopher Down, neuro, Wikimedia)

In the stratosphere, oxygen and ozone interact with energy (ultraviolet radiation) from solar radiation to form a dynamic system involving the following reactions:

When ultraviolet light strikes oxygen molecule, individual oxygen atoms are produced.

$$\mathbf{O_2 + Energy \rightarrow 2\ O}$$

The combination of atomic oxygen with oxygen molecule leads to the formation of ozone.

$$\mathbf{O_2 + O \rightarrow O_3}$$

The interaction of ozone molecule with ultraviolet light splits it into a molecule of oxygen and an atom of oxygen.

$$\mathbf{O_3 + Energy \rightarrow O_2 + O}$$

Recombination of ozone molecule with an oxygen atom leads to the formation of oxygen molecule.

$$\mathbf{O_3 + O \rightarrow 2\ O_2}$$

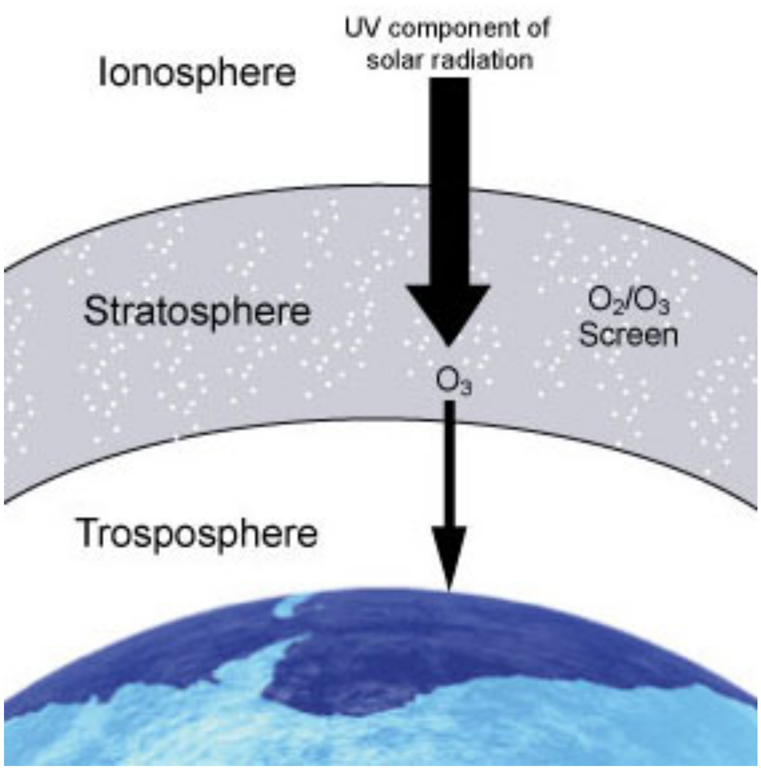
The above processes occur repeatedly and are together called ozone-oxygen cycle or Chapman cycle. This constitutes the O_2/O_3 screen that filters out the ultraviolet component of the solar radiation.

Slide 20:

Ozone Depletion

Environmental Concern

The environmental concern in the case of ozone is its stratospheric depletion, which leads to less efficient filtration of harmful solar UV rays. The depletion is caused by both natural (water vapour, nitric oxide) as well as human-made (chlorofluorocarbons, halons) sources.



These manufactured chemicals, containing chlorine and/or bromine are called "ozone-depleting substances" (ODS). The use and popularity of these chemicals is due to their stability and low toxicity.

Chloroflurocarbons (CFCs) and halons have been used as:

- Foam-blowing agents
- Fire-extinguishing agents
- Solvents
- Refrigerants

However, their stability and long lifetime (up to several centuries) allows them to reach the stratosphere. The interaction of these molecules with ultraviolet light in the stratosphere leads to the generation of chlorine and bromine which in turn destroy stratospheric ozone.

Ozone Depletion

Effects of Depletion

Introduction: Stratospheric ozone depletion leading to less efficient filtration of the ultraviolet radiation from the sun, will increase the intensity of ground level UV radiation. This increased intensity may have adverse effects on:

- Humans
- Agriculture and Forestry
- Material
- Marine ecosystems

Humans: Such adverse effects include:

- Higher probability of sunburns, skin cancer and premature aging skin

- More cataracts, eye diseases and blindness
- Immunosuppression (weakening of the human immune system)

Agriculture and Forestry

Physiological and developmental process of major crop species (such as barley, rice and wheat) may be affected. The data available on the effect of more intense ultraviolet radiation on commercially important trees shows that plant growth is harmed

Materials

Increased intensity of ultraviolet radiation may accelerate the degradation of materials such as fabrics, plastics, rubber, and wood.

Marine Ecosystems

Increased intensity of ultraviolet radiation may:

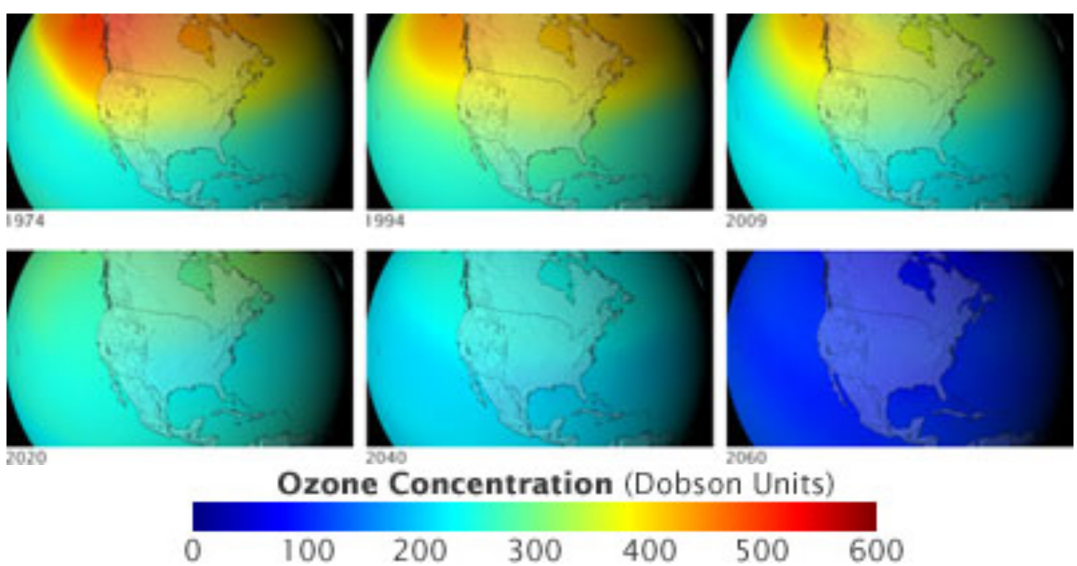
- Damage marine life by decreasing the plankton.
    - Such a decrease in plankton could disrupt food chains, leading to a shift in marine species in global water
- Lead to decreased reproductive capacity reducing fish yields.

Ozone Depletion

Control Strategies

In North America, the use of chlorofluorocarbons (as propellants in spray cans) was banned in 1978 in response to the threat of ozone depletion. The global response to the threat of ozone depletion came with the signing of the Montreal Protocol (in 1987). It set out to reduce and ultimately ban the manufacture and use of CFCs and other ozone depleting substances.

The international agreement has been effective in reducing risks in the long term; ultraviolet radiation remains a health hazard. In view of this, we as individuals should protect ourselves against it.



NASA projections of stratospheric ozone concentrations from 1974 to 2060 if chlorofluorocarbons (CFCs) had not been banned(Source: Earth Observatory, NASA, Wikimedia)

Click on image to enlarge.