

SSP-89/A5



# SCHOOLS SCIENCE PROGRAMME

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COURSE NOTES

**COST OF LIVING IN A DENATURING WORLD : GREENHOUSE EFFECT**

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## 1. Cost of Living

### 1.1 Introduction

Man-made activities are currently leading to changes in the global environment at virtually alarming rates, with potentially severe consequences for our future day to day life. It does not say that environmental degradation due to man-made or anthropogenic activities is being occurred only during industrialized era. It was four thousand years back, extensive irrigation of Euphratis and Tigris river Basins in Mesopotamia caused changes in the ancient civilization of samarians due to salination. It was not more than 25 years that most of the third world nations were threatened by Eutrophication. Direct discharge of untreated sewage into water courses and application of fertilizers lands are responsible for eutrophication. Eutrophication will result growth of nuisance algal blooms and water become unsuitable for human consumption. Since early sixties there was a strong controversy among developed nations in the western world on acid rain. Emission of gases and traces elements from massive factories change the hydrogen ion and trace elements in concentrations rain water, eventually acidifying standing water bodies while bioacumulating trace elements in food chains. Some of those acidified lakes in North America and Scandinavia have no organic life at all.

Global changes in the lithosphere, atmosphere or hydrosphere are quite different from those regional or local changes (ie., eutrophication, acid rain etc.,). However currently, increases in carbon dioxide and other greenhouse gases (ie,  $N_2O$ ,  $CH_4$ ,  $O_3$  and CFC), that are responsible for climatic changes, the appearance of the antarctic ozone hole and world wide depletion of the ozone shield, have captured the attention of scientists, the public and policy makers. The current problem of global environmental change is crucial and urgent remedy is necessary to mediate it.

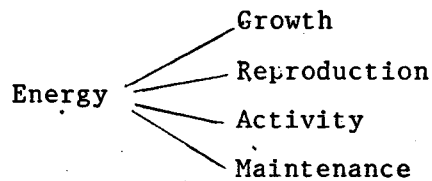
As an aquatic ecologist and fish biologist what I am trying to teach you during today's programme are:

1. Basic principle of energy allocation by organisms under natural and stressed condition
2. Greenhouse effect and its possible impact on Neo-Darwinian fitness of the organisms

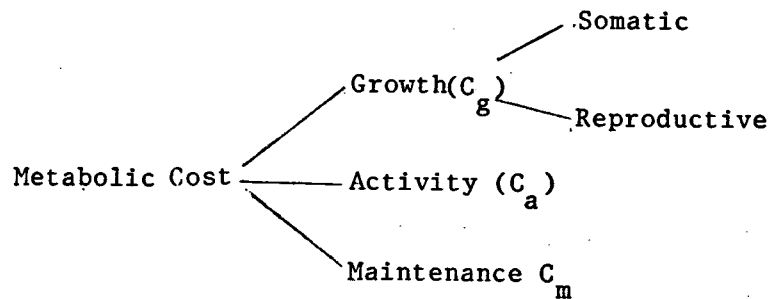
## 1.2 Energy allocation

Let me start with the principle of Energy allocation in brief. Organism need energy to fulfill their biological requirements or processes. Some organisms utilize direct solar energy while others depend on the same indirectly.

Accordingly, therefore, all living organisms are widely divided into autotrops and heterotrophs. Autotrophs are photosynthetic organisms while heterotrophs utilize stored energy in autotrophs directly or indirectly. However, energy is utilized by organisms for different biological processes, namely growth, reproduction activity and maintenance.



Total Energy required for those four major biological processes under natural conditions is basically known as metabolic cost or cost of living.



$$\text{Metabolic cost} = C_m + C_g + C_a$$

However according to the Neo-Darwinian theory organisms allocate energy for physiological processes to optimize their fitness, which is known as the Principle of allocation.

In simple, fitness of an organism is its contribution to the gene pool of the future generation. It can vary from zero to one. Also can be calculated mathematically using following characteristics (correlates of fitness) of an organisms.

1. Time of first maturity (t)
2. Fecundity (f)
3. Survivorship (s)

Time of first maturity is the age of an organism become mature to reproduce and fecundity is the number of offsprings produced by an organism during its life time. Survivorship is the number of offsprings that completed the life cycle. According to Neo-Darwinian evolutionary theory, organisms are adapted to increase their fitness by decreasing, age of first maturity while increasing fecundity and survivorship.

### 1.3 Stress conditions

Organisms are in their own physical chemical and biological environment where they live and also they are well adapted to those environmental conditions. Changes in physical chemical or biological environment may lead changes in physiological process of the organisms. However, organisms can tolerate environmental changes up to a certain extent which is known as **tolerance limit**. Beyond that level death may occur.

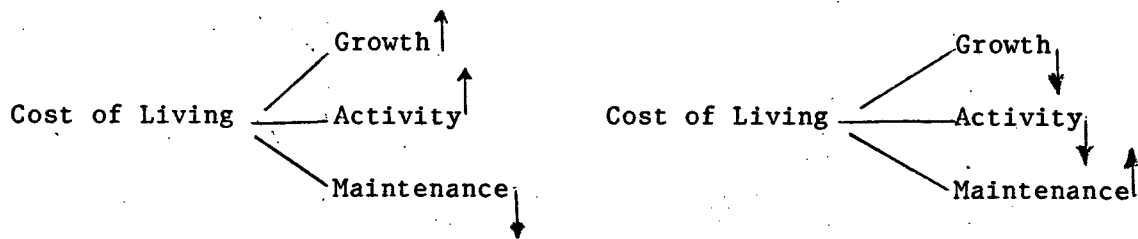
<u>Physical</u>	<u>Chemical</u>	<u>Biological</u>
Temperature	Oxygen	Competition
Humidity	Other gases	Predation
Wind	pH	Association
Light	Ionic concentration	
Pressure	Trace elements	
Salinity		

Table 1. Some parameters of the physical, chemical and biological environment

Dramatic changes in physical, chemical or biological environment lead organism into **stressed** condition. When **stress** can be seen by external features or appearance, or activity of the organism, it is called **acute stress**. However, in some instances environmental stress can not be seen externally but it interrupts, internal physiological processes. In this case stress is known as **chronic** which is more important than the **acute stress**. Because acute stress can lead sudden mortality of the organism while chronic stresses may affect the correlates of **Neo-Darwinian fitness**.

This simply can be explained by principle of allocation and simple cost of living model. When the environment is stressed, allocation of energy changes accordingly.

Under stressed condition organisms need more energy for maintenance and repair. They decrease their activity and less energy will be allocated for growth and reproduction eventually affecting correlates of Neo-Darwinian fitness. In other words, their contribution to the gene pool of the future generation will be reduced.



A. Under Natural Condition    B. Under Stressed Condition

#### 1.4 Multiple Stresses

It is easy to explain the energy allocation under single stress. However, in some instances, same environmental factor has multiple stresses. For example salinity or dissolved ionic content of the water has two stresses.

1. Ionic stress
2. Osmotic stress

When salinity is increased, ionic concentration and osmotic pressure of the solution will also increase. Higher concentration of specific ions are toxic, for freshwater

organisms while increasing osmotic pressure decreases energy requirement for the osmotic balance. Therefore, pattern of the energy allocation model is quite different from a single stress model. Explanation for this type of multiple stresses is complicated and beyond the scope of this programme. Second type of multiple stress can also be seen in the nature. In this case there are two or more environmental factors are being stressed on organism at the same time. Greenhouse effect is an excellent example for multiple stress of this nature.

## 2. Green-House Effect

### 2.1 Introduction

It has been observed that a global change is occurring in the earth's environment. All living beings are exposed to it. This gradual, change can not be seen felt or heard but it is being measured. The burning of fossil fuels, the destruction of tropical trees, and effluent discharge from industrial and agriculture processes are resulting in the release of large quantities of gases into the atmosphere. These gases are known as "greenhouse" gases and they can trap low energy radiation emitted from the earth surface and raise the atmospheric temperature. Increases in global temperature can directly be affected chemical or biochemical processes in turn total biological processes of the earth.

Increasing temperature can melted in the polar ice caps resulting inundation of small islands and coastal cities. Deserts can be expanded with wide spread storms and severe droughts due to high evaporation and evapotranspiration

Radiation emitted from the Sun's surface is know as electro magnetic spectrum. As you know it varies from relatively high energy ultra violet rays to radio waves of low energy. Most of the energy in the Sun's radiation is associated . with wavelengths that lie in the visible

spectrum. Ultra violet light (short wave radiation) is filtered out by the ozone layer of the stratosphere and the sun emits a relatively small amount of long wave (infrared or heat) radiation.

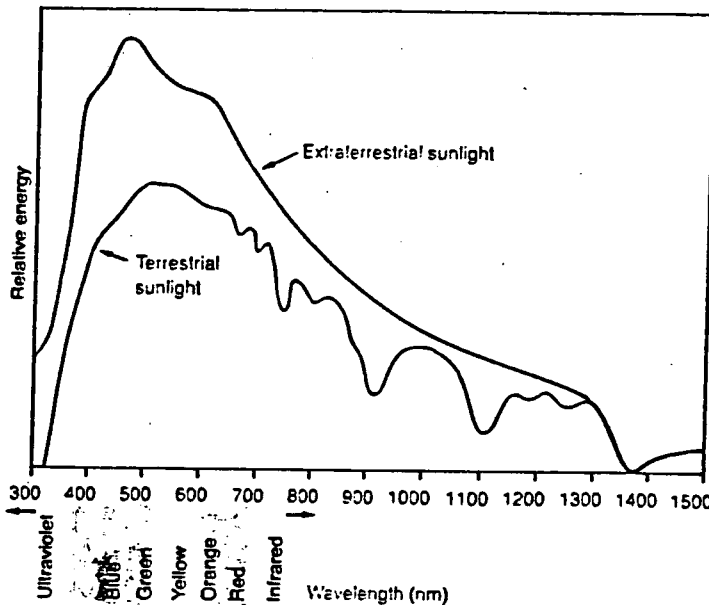


Fig 1. Spectrum of the solar radiation

Light energy passes through the glass or plastic and is absorbed by the plants, soil and other greenhouse components. The resulting molecular excitation in these objects warms them and they pass heat energy to the surrounding greenhouse air by conduction. Convection currents are set up but the air cannot escape from the enclosed greenhouse, so its interior becomes hotter. This is the simple reason for the heating up of greenhouses, whether they will be constructed of glass or plastic. Plants are seldom at a temperature more than 2% higher than the greenhouse atmosphere because they are cooled by due to evapotranspiration. Much of the light energy they absorb is

converted into latent heat of vaporization of water. When this vapor condenses on the greenhouse roof and walls, the latent heat is released, but because of the relative specific heats of glass and of air, about of 90% of the resulting heat yield is absorbed by the glass. This heat is conveyed by conduction and filtration to air both inside and outside of the greenhouse.

The greenhouse contents radiate infrared, and glass shows some selective permeability to these long wave-lengths (it does not let them pass out of the greenhouse). However, this effect accounts for only about 15% of the heating up of the greenhouse. 85% is from the warming of greenhouse air by conduction.

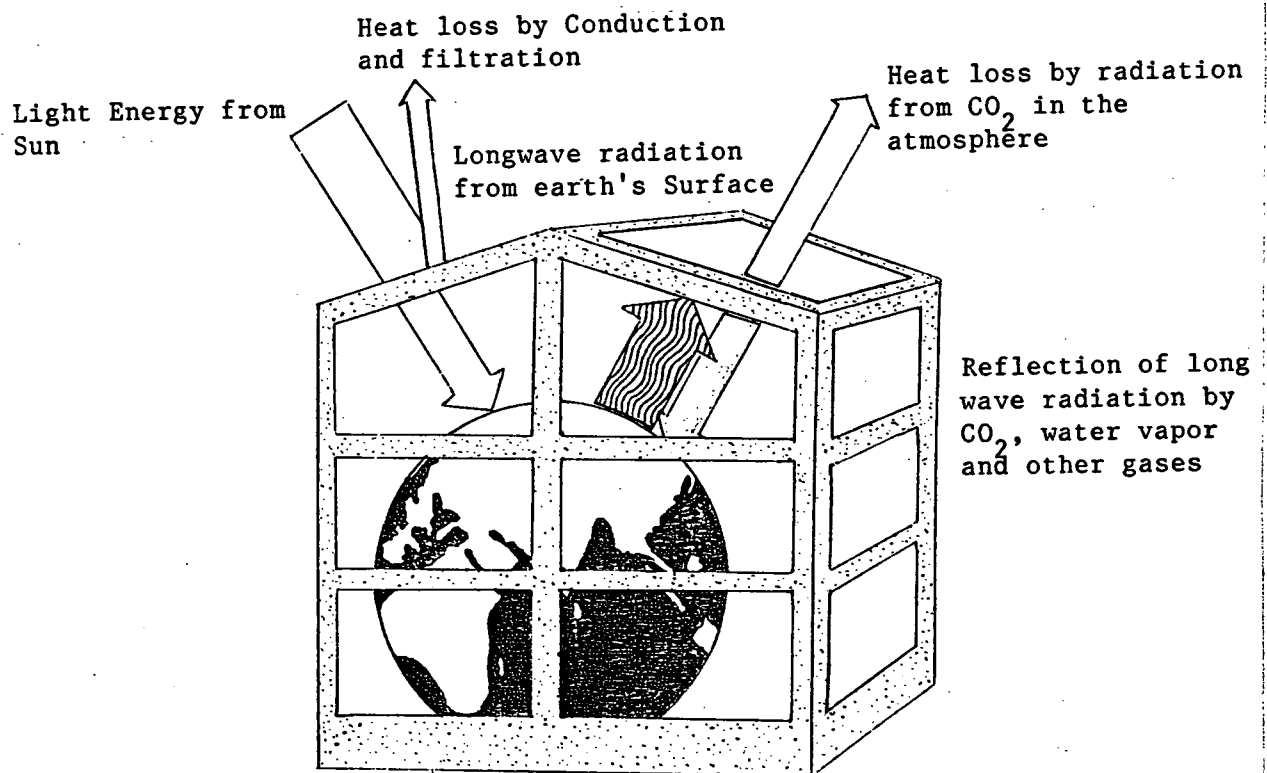


Fig. 2 A Typical green-house

## 2.2 The Earth's Atmosphere

The earth atmosphere is a mixture of transparent gases, mainly Nitrogen and Oxygen. About 90% of its mass is concentrated in a layer called the **troposphere**, some 11KM deep. It is in this region that weather is generated, the **troposphere** (weather layer) contains water vapor and clouds. The temperature in the **troposphere** drops gradually with light until the **tropopause** is reached at about 11km. There are no clouds above the **tropopause**. Above this is the **stratosphere** which is some 40km deep. Temperature is nearly constant in first 10km of the **stratosphere** then risen from  $-57^{\circ}\text{C}$  to  $+ 10^{\circ}\text{C}$  at the **stratopause**. The next layer is **measosphere** separated in turn by the **measopause** from the **thermosphere** out into **interplanetary space**.

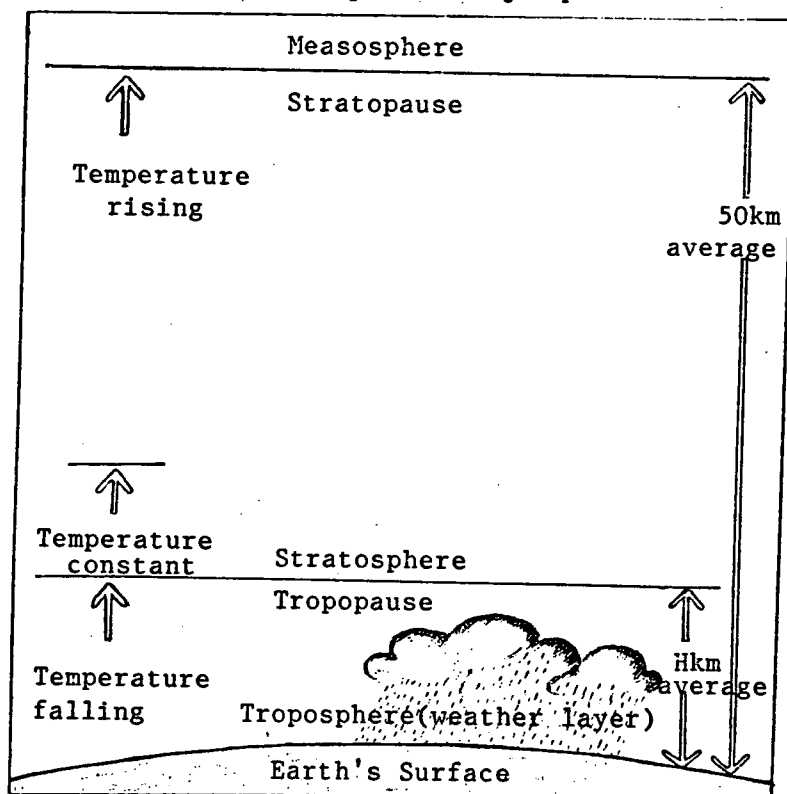
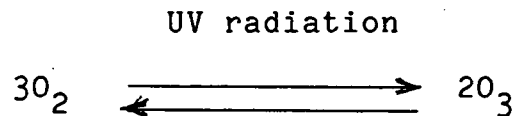


Fig. 3 The inner layers of the earth's atmosphere

Ultra violet (short wave) solar radiation transforms atmospheric oxygen into ozone, which decades back to  $O_2$ .



Ozone layer is located in the **stratosphere** some 25-35km above the earth surface.

Shorter waves of the electromagnetic spectrum such as **X-rays** and **gamma** radiation are almost entirely absorbed in the thermosphere.

### 2.3 Global Greenhouse

The wall of the **global greenhouse** is a blanket of carbon dioxide, water vapor, and other gases, and  $CO_2$  and water vapor are both strong absorbers of infrared radiation. Carbon dioxide is nearly uniformly distributed throughout the atmosphere. The concentration of water vapor varies with temperature, wind and other aspects of weather. In common with other atmospheric gases, water vapor is contained mostly in the **troposphere**. Solar radiation is able to pass through all atmospheric gases. It strikes the earth surface and warms it. Heat is transferred to the air by **conduction** (as in a greenhouse). It is also re-radiated from the earth surface as longer wave infrared in the 5-10 um wave band.

Here lies the major difference between the glass or plastic greenhouse and the global greenhouse. These reflected IR wave-lengths are absorbed by the  $\text{CO}_2/\text{H}_2\text{O}$  vapor "blanket" and are re-radiated in all directions including back into the earth's atmosphere. The "blanket" acts as a one way screen. It is transparent to visible wave lengths, where most of the energy of sun light is concentrated (Fig. 1), but it absorbs and re-radiates much of the long wave infrared radiation that would otherwise be transmitted back into space from the earth surface. This screen is the principal reason for the warming of the earth's atmosphere. It has been clearly shown that man-made activities (ie, burning fossil fuel, deforestation, effluent discharge etc.,) raise the carbon dioxide concentration, then the earth will become warmer. Major climatic effects, such as the melting of polar ice caps may occur. But we certainly do not know what will be the real impact of greenhouse effect. Elevated levels of atmospheric  $\text{CO}_2$  in greenhouses were seen to cause remarkable increase in certain plant growth due to the enhancement of photosynthesis, while other crop plant, may similarly affected by high concentrations of  $\text{CO}_2$ .

## 2.4 Causes of the Global Greenhouse

The major reason for global greenhouse is changes in the carbon dioxide content of the atmosphere. In order to understand this, it is worthwhile to understand the Global carbon cycle. The biggest carbon pool of the earth is the ocean. Other reservoirs such as fossil fuels, biosphere, and atmosphere are smaller in comparison.

<u>Carbon reservoirs</u>	<u>Amount</u>
	(billion, tones)
Ocean	40,000
Fossil fuels	4,000
Biosphere	1,800
Atmosphere	700

Atmospheric and dissolved carbon dioxide of the aquatic ecosystems are constantly being removed by green plants and used in the process of photosynthesis. At the same time all living organism constantly release  $\text{CO}_2$  to the atmosphere through respiration. Respiration is the oxidation of complex organic molecules to release energy.

In general, respiration is the reverse reaction of photosynthesis but the intermediate chemistry of photosynthesis is quite different from that of respiration.

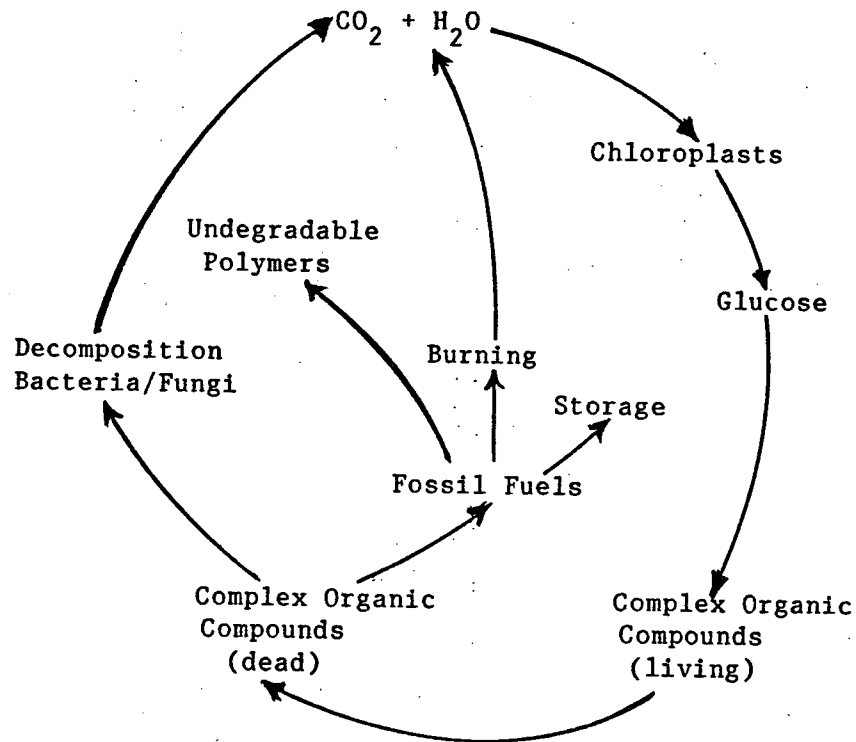
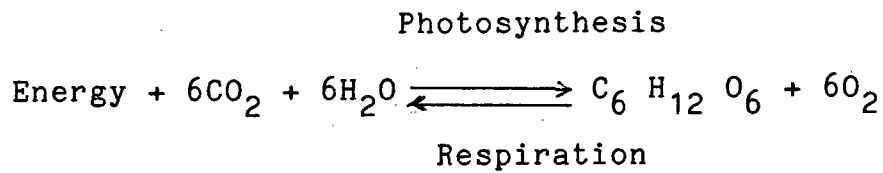


Fig 4. Global carbon Cycle

A portion of the  $\text{CO}_2$  fixed by green plants as carbohydrates is used for respiration by those organisms. A large part of it, however, becomes stored in complex organic chemicals made by animals and plants such as cellulose, chitin etc.

These materials decay when the organism dies. Decay means that micro-organisms such as bacteria and fungi use dead plant and animal material as food for their own respiration, in the course which they release more carbon dioxide. A great portion of dead organic matter does not decay, and vast quantities are 'stored' as fossil fuels such as coal and oil. When these are burned, the carbon they contain is oxidized by atmospheric oxygen to form carbon dioxide. Man's use of such fossil fuels has increased enormously in the last hundred years, and he is using up huge quantities of material in decades which took hundreds of million years to produce. As a result CO<sub>2</sub> level of atmospheric air is rising. At the same time man is felling huge areas of tropical rain forest whose photosynthetic activities remove CO<sub>2</sub> from the air.

#### **Statistics of deforestation**

Annual removal = 11 million ha  
throughout the world

Loss of Tropical rainforest = 45%

At this rate rainforest  
will be disappear in year 2000

Deforestation due to man-made activities or natural fire will be resulted in erosion and siltation. Removal of the canopy will also increase the evapotranspiration due to intense incident solar radiation. Therefore deforestation will lead rapidly to desertification. The annual Global increase of in desertification is estimated at about 2 million ha.

There is strong evidence that  $\text{CO}_2$  concentration has risen from 316ppm in 1958 to 345ppm in 1986. The rate of increase has been between 1.5 to 2.0ppm yr.

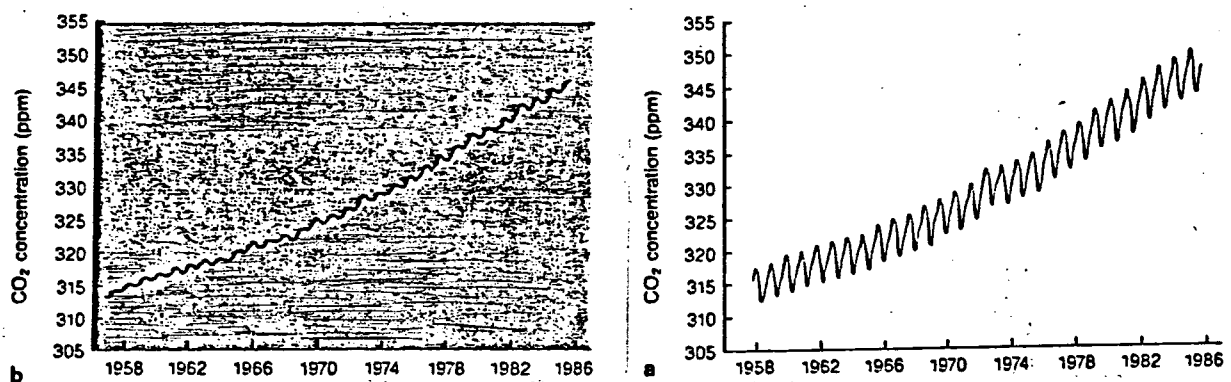


Fig 5. The rise in atmospheric  $\text{CO}_2$  concentration from 1958 to 1986

Ancient atmospheric CO<sub>2</sub> concentrations have been 'fossilized' in the polar ice cap and by analyzing samples of arctic ice core, western scientists have shown that concentration of CO<sub>2</sub> in the pre-industrial era were about 275ppm. The overall estimate is of a 15% increase in the level of atmospheric CO<sub>2</sub> during this century.

The primary cause is believed to be the increasing burning of fossil fuels by man. Fig 6. shows there results projected to the year 2050 (to a figure of 550-650ppm)

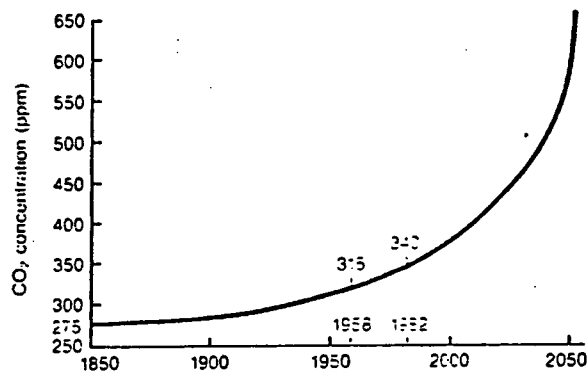


Fig 6. Projected levels of CO<sub>2</sub> concentration from 1850 to 2050

However, the big unknowns in the projection are the buffering effects of the ocean and the amount of extra CO<sub>2</sub> that might go into the "biological sink". This change in atmospheric CO<sub>2</sub> may have substantial effect on climate and vegetation which could in turn, significantly affect agriculture, food production, forestry and other requirements of mankind.

### **Carbon dioxide in the atmosphere**

Carbon dioxide is nearly uniformly distributed throughout the atmosphere but measurement should be taken from remote areas free from industries or large expanse of forests. There are several ways to determine the concentrations of atmospheric CO<sub>2</sub>, but most accurate equipment to measure is Infrared Gas Analyzer.

### **2.5 Effects of Global Greenhouse**

Most calculations indicate that the doubling of atmospheric carbon dioxide expected in the next 100 years will produce a rise in mean global temperature of between 1.5 and 4.5°C. Warming of the lower troposphere will result in regional climatic changes in temperature, soil moisture, evaporation, cloud cover, sunlight and rainfall. Mathematical models predict the temperature increase will be 2-3 times greater at the poles than over the tropics. The most obvious effect of such change might be the partial

melting of the polar ice caps. Melting of these ice caps would bring a substantial rise in sea level and the inundation of coastal areas. The estimates for the rise in sea level range from zero to 2 meters, in the next 100 years and from 2.5 - 4.5 meters in the next 300 to 500 years.

### **Other Greenhouse Gases**

It is suggested that some of other gases currently being discharged into the atmosphere by many activities, including chlorofluorocarbon compounds, methane, nitrous oxide and ozone will added to the greenhouse.

### **Greenhouse gasses**

- |                       |                  |
|-----------------------|------------------|
| 1. Carbon dioxide     | CO <sub>2</sub>  |
| 2. Methane            | CH <sub>4</sub>  |
| 3. Nitrous oxide      | N <sub>2</sub> O |
| 4. Ozone              | O <sub>3</sub>   |
| 5. Chlorofluorocarbon | CFC              |

Unfortunately we certainly do not know the mechanism of the production of some of those gases. Nevertheless, those gases may also have significant effects on the biological fitness of the organisms even at chronic levels.

## 2.6 Animals and plants

Now we certainly know that greenhouse effect will be resulted increases in temperature,  $\text{CO}_2$  and other greenhouse gases (viz.,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$ ,  $\text{O}_3$  and CFC). Increasing temperature accelerates the biochemical reactions up to a certain level. But each biochemical reaction has its temperature optima. Increasing reaction rate will rise the activity of most of the organisms resulting in more energy consumptions. This may also affect the fitness of the organisms. In the case of green plants,  $\text{CO}_2$  is a limiting factor for photosynthetic carbon fixation. Accordingly increasing carbon dioxide will increase the photosynthetic. Carbon fixation eventually increase the yield of green plants. Therefore greenhouse effect is theoretically beneficial for plant growth. However, situation in aquatic ecosystems is quite different. Increasing carbon dioxide will certainly affect the bicarbonate-carbonate equilibrium in the water resulting substantial changes in pH. Changes in pH would affect the most of the chemical and biochemical reactions of the aquatic ecosystem. Most of the aquatic life will be endangered or eliminated decreasing the diversity of aquatic communities.

## 2.7 Cost of Living in Humans

Global warming is an alarming signal for man-kind. Although protecting the environment is important for the health and welfare of the human race and for the survival of the plants and wild life, protection presents a number of economic challenges. Unless steps are taken to reverse present trends, global weather patterns resulting from the "greenhouse" effect could have devastating impacts, including the flooding of coastal cities, and the destruction of agricultural areas and marine life in many countries. Some of the results of these climatic changes will put public and private investment at risk. Sea level rise would cause flooding in many lowlying coastal areas, increases salt water intrusion in to rivers, inundate vital wetlands destroy commercially important spawning grounds. In addition, it would probably increase the frequency of storm damage to lagoons estuaries, and coral reefs.

For example in Bangladesh, one meter rise in sea level would affect lands housing of 9% of the population. Approximately 8.5% of Bangladesh's agriculture output comes from the areas that would be flooded out. These direct effects will have many important economic consequences. A sea level rise could put the homes and lives of millions of people living in deltas of Ganges, the Nile, the Mekong, the Yantze and Mississippi rivers at risk.

Hotter summer will mean increased energy and water demand in many areas. Shifting patterns of rain fall may turn some traditional agricultural areas to dust. If these changes occur quickly, the economic disruption and social dislocation they cause may multiply the damage costs substantially.

#### **Acknowledgment**

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## Glossary

Accelerate	-	න්වරණය
Acid rain	-	අම්ල වර්ෂාව
Acute	-	කිටු
Allocation	-	වෙන්කර කැබීම
Anthropogenic	-	මානව සම්බන්ධයක්
Autotrophs	-	ස්වයං පෝෂිත
Bioaccumilation	-	ලේඛ සංචිතය
Biological sink	-	ලේඛ කවානව
Buffering effects	-	ස්ථායීකරණ ආචරණ
Canopy	-	උඩුපියන
Carbon fixation	-	කාබන් නිරතරීම
Cellulose	-	සෙලියුලෝස්
Chitin	-	කපිත
Chronic	-	නිදර්ශක
Conduction	-	සන්නයනය
Convention current	-	සංවිභවාරාම
Correlates	-	ආනුබද්ධතාව.
Deforestation	-	වන සංඝාරය
Deltas	-	ඩෙල්ටා
Desertification	-	කැන්කාර ඇතිවීම
Destruction	-	ස්ථාන මාරුව
Dislocation	-	විනාශය
Diversity	-	විවිධත්වය
Ecosystem	-	පරිසර පද්ධතිය
Effluent	-	පිටට ගලායන අපද්‍රව්‍ය

Equilibrium	-	සමතුලිතතාව
Estuaries	-	ගංගා මෝය
Eutrophication	-	සුපෝෂිතරණය
Evapotranspiration	-	වාෂ්පිතරණ උත්ප්ලේදනය
Fecundity	-	ජීවිත නාලයේ ඇතිවන ජාතිකයින් සංඛ්‍යාව
Fitness	-	ප්‍රවේණිත යෝග්‍යතාව
Fossils	-	පෘෂ්ඨිකාශු
Fossilized	-	පෘෂ්ඨිකාශු වූ
Gene pool	-	ජාන කිටුව
Global	-	සමස්ත / ලෝකය පිළිබඳ වූ
Heterotrophs	-	විෂම පෝෂිත
Hydrosphere	-	ජල ගෝලය
Incident solar radiation	-	පතිත සූර්යය විකිරණය
Infrared	-	අධෝරක්ත
Interplanetary	-	අන්තර් ග්‍රහය
Inundation	-	ජලයෙන් වටවීම
Lagoons	-	තලපු
Laten heat	-	ගුප්ත තාපය
lithosphere	-	ශීලා ගෝලය
Maintenance	-	නඩත්තුව
Measopause	-	මධ්‍ය සීමාව
Measosphere	-	මධ්‍ය ගෝලය
Micro organisms	-	සූයු ජීවින්
Offsprings	-	ජාතිකයින්
Permeability	-	පාරගමයතාව
Photosynthesis	-	ප්‍රභාසංස්ලේෂණය

Preindustrial era	-	ප්‍රාග් කාර්මික යුගය
Polar ice caps	-	ධ්‍රැවීය ඛනිජ ගෝල
Reproduction	-	ප්‍රජනනය
Salination	-	ලාවණකරණය
Somatic	-	දෛහික
Spawning grounds	-	බිත්තර දමන ප්‍රදේශ
Stratopause	-	ස්ථර සීමාව
Stratosphere	-	ස්ථර ගෝලය
Stress	-	ආයතනය
Survivorship	-	නොනැසී ජීවත්වීම
Thermosphere	-	තාප ගෝලය
Tolerance	-	දරාගැනීමේ හැකියාව
Traditional	-	සම්ප්‍රදායික
Tropopause	-	ත්‍රෝපන සීමාව
Troposphere	-	ත්‍රෝපන ගෝලය
Ultra violet	-	ආරච්ඡිල