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REVEIW ARTICLE

A review on biogeochemical linkages of climate change and change in intensity of ultra violet radiation

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SUMMARY

Changes in climate and intensity of ultraviolet radiation can both have substantial impacts on the biological, geological, chemical, and physical processes that control the exchange of matter and energy between the major components of the environment – the atmosphere, the biosphere, the hydrosphere, and the lithosphere. The carbon cycle is of central importance in the climate change issue because human disruption of the natural carbon cycle, through the burning of fossil fuels and the clearing of forests, is largely responsible for the modern increase in atmospheric concentrations of carbon dioxide, the most abundant anthropogenic greenhouse gas. One of the more important links in the carbon cycle from an atmospheric perspective is the so-called "marine biological pump". This is a process in which plankton, the microscopic plants and animals that live near the surface of the oceans and freshwater lakes remove carbon from the air and then transfer it to the ocean bottoms and lakebeds when they die. Ozone depletion, particularly severe episodes such as the spring ozone holes in the Antarctic, present a potentially serious threat to this process, because plankton cannot take shelter from solar radiation. A serious decline in their numbers as a result of exposure to more intense ultraviolet radiation could therefore decrease the rate at which carbon dioxide is removed from the atmosphere. Similarly, biological changes initiated by changes in climate might have some effect on ozone depletion. Methyl chloride and methyl bromide are two ozone-depleting compounds. However, because natural sources of these gases are larger than the human industrial sources, anything affecting the ecosystems and natural processes that produce these gases could also have consequences for the ozone layer. Coastal marshes appear to be important contributors of natural source. Fungi, crops such as rapeseed, and soils rich in organic matter are also thought to be substantial sources. Warming of the atmosphere and oceans or changes in sea level could affect all of these sources by altering the ecosystems and climatic conditions that support the natural production of these gases. Climate change could also affect the rate at which these gases are removed from the atmosphere by the oceans. Studies of the natural production and removal of these gases are still in their early stages, however, and it is not yet possible to predict how climate change might affect the quantities of these gases in the atmosphere.

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Climate change is the change in statistics of weather in long-term. Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as global warming (America's Climate choices : Panel on Advancing the science of climated change : National Research Council, 2010). The climate change has emerged as the most challenging environmental risk of current and future generation. Climate change is not evenly distributed over the globe. Its effects are likely to be greater in some areas and less significant in others, but current understanding of global climate patterns is insufficient for making reliable regional predictions.

The outline of development followed since the age of industrialisation has caused devastation to the global environment. Two aspects of environmental problem are commendable. First the environment cannot be divided between countries like province. In underlines, more than anything that human beings and countries are mutually dependent. Second, the present problem of environment or climate change is the collective effect of unsuitable growth pursued for centuries. The message is that if we follow the path of sustainable growth now, it will correct the ecological imbalances. The problem of global warming and far-reaching climate change has assumed such urgency in 21st century that it cannot wait for a durable solution any more. If the global community fails to take suitable action against this approaching crisis, the consequences shall be disastrous. The problem is so large that it cannot be solved by individual approach, but it can be achieved by effective co-operation of international community members.

The transport and transformation of substances in the environment, through living organisms, water, land, and the atmosphere are known collectively as biogeochemical cycles. The term "biogeochemical" tells us that biological, geological and chemical factors are all involved. The circulation of chemical nutrients like carbon, oxygen, nitrogen, phosphorus, calcium, and water etc. through the biological and physical world are known as biogeochemical cycles. In effect, the element is recycled, although in some cycles there may be places (called reservoirs) where the element is accumulated or held for a long period of time (such as an ocean or lake for water).

Green house effect:

The arrest of atmospheric carbon dioxide by green plants in photosynthesis and its storage in plant tissues is the elemental process that supports existence of life in the biosphere. The addition of dead organic matter in soils also supplies carbon, making it less available as a greenhouse gas in the atmosphere. In contrast, the microbial respiration of organisms that decompose dead organic matter in the soil, together with the respiration of other organisms in the biosphere, return carbon to the atmosphere where it adds to existing greenhouse gases. Sometimes the gases released, such as methane and carbon monoxide, are chemically active and could alter atmospheric chemistry.

Intergovernmental Panel on Climate Change (IPCC) in 2014 has drawn some general conclusion about the penalty of an increasing greenhouse effect. These include that sea level will increase somewhere between 15 and 95 centimetres by 2100 (IPCC Fourth Assessment Report: Climate Change, 2007). Sea-level rise is caused by an amalgamation of melting glaciers and ice caps and the fact that water expands as it warms. The rising sea level would sink many low lying coastal areas throughout the planet. Another forecast is that there will be supplementary exceptionally warm days and fewer exceedingly cold days. The global temperature would rise from 1.1^{0}C to 4.6^{0}C depending upon the efforts of global community to check the green house gases. The possibility of both droughts and floods is expected to amplify. The major temperature increases are predicted for winters in the northern part of the northern hemisphere. But the more noteworthy fall out of the global warming is changes in the climatic patterns leading to irregular rainfall, droughts, floods, cyclones and damage to agriculture. The rising temperature shall have many serious consequences for the health and well being of human community. The enhanced emission of green house gases such as carbon dioxide, methane, nitrous oxide, fluorocarbons and sulphur hexa fluorides, in the environment leads to rise in temperature. These gases trap the solar radiation and don't allow the solar heat to escape from the environment of earth. The modern day industrial and commercial activities are the chief source of emission of these gases.

Other sources of greenhouse gases are burning of fossil fuels and deforestation, that contribute carbon dioxide. Methane adds to warming of the atmosphere with emissions from rice field, farm animals, and wetlands. Exploitation of natural gas also contributes methane. Nitrous oxide is a naturally-produced greenhouse gas, but the flux has amplified, mainly because of heavy fertilizer use on farmland. CFCs are man-made and highly efficient as greenhouse gases. However, because of their detrimental effect on the ozone layer, their net contribution to global warming is difficult to determine. Other greenhouse gases include ozone and a range of CFC related compounds. One type of human emission, sulphur dioxide, seems to reduce warming over industrialized areas, since it forms sulphate aerosols that act as a screen against the sun.

Eleven of the last twelve years (1995-2006) rank among the 12 warmest years in the instrumental record of global surface temperature since 1850. The 100 year linear trend (1905-2000) of temperature rise of 0.74^0C is larger than the corresponding trend of 0.6^0C during 1901-2000. The temperature increase is wide spread over the globe and is greater at higher northern latitudes. Land regions have warmed faster than the oceans. If and when the global temperature rises beyond 2^0C above the pre-industrial level, severe climate change conditions would result. Thus, at present, the basic objective of global efforts is to limit the global rise in temperature to 2^0C above the 1850 level by adopting measures to put a cap on the global emission of green house gases.

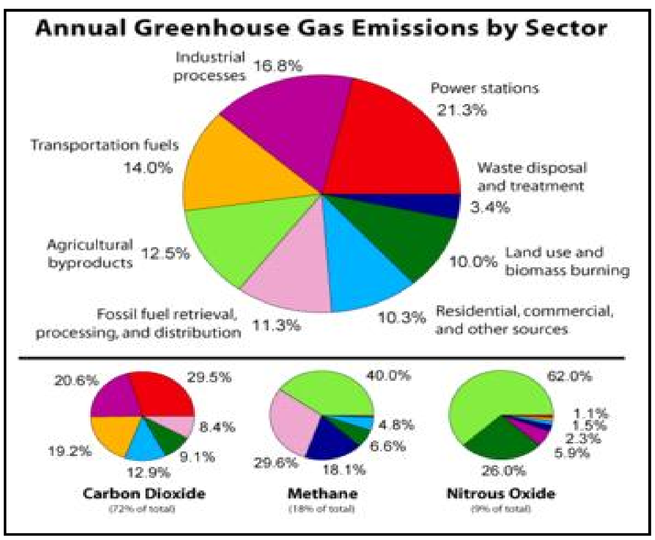

Fig. 1 : Showing percentage contribution of different sectors towards green house gas (source wiki/Image: Greenhouse_Gas_by_Sector.png)

Ozone depletion:

Ozone is a gas in the atmosphere, which plays a critical role in blocking harmful ultraviolet (UV) radiation from reaching the Earth. The highest concentration of ozone is in the stratosphere, 25 to 40 kilometres above Earth's surface. The amount of ozone in the stratosphere is currently decreasing, especially in the Polar Regions, which has raised concern that plants and animals will be damaged by increased ultraviolet radiation. Moreover, a decrease in ozone also affects the temperature structure of the atmosphere and, therefore, has implications for climate. Also, climate change may enhance ozone depletion by cooling the stratosphere and by changing circulation patterns in a way that brings low-ozone air into the Arctic. The major emissions responsible for depletion of the ozone layer are chlorofluorocarbons (CFCs), but there are several other manmade compounds that also contribute. The use and production of such substances are controlled by the Montreal Protocol on substances that deplete the ozone layer.

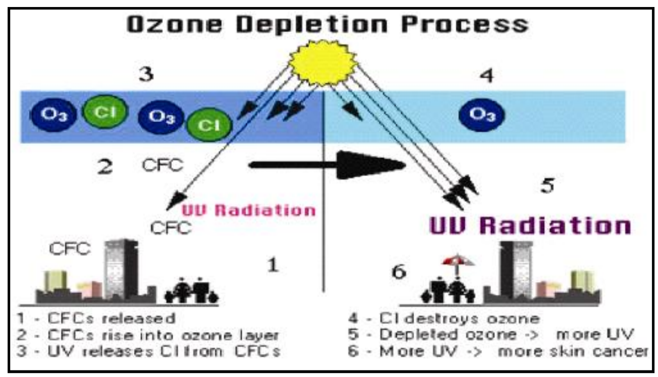

Fig. 2 : Showing consequences of ozone layer depletion (Source : Ozone hole)

Effects of increased ultraviolet radiation:

Ultraviolet (UV) is an electromagnetic radiation with a wavelength from 10 nm (30 PHz) to 400 nm (750 THz), shorter than that of visible light but longer than X-rays. It is present in sunlight which produced by electric arcs and specialized lights such as mercury-vapour lamps, tanning lamps, and black lights. Although lacking the energy to ionize atoms, long-wavelength ultraviolet radiation can cause chemical reactions and causes many substances to glow or fluoresce. Consequently, biological effects of UV are greater than simple heating effects, and many practical applications of UV radiation derive from its interactions with organic molecules (King *et al.*, 2012 and Song *et al.*, 2013). The Sun emits ultraviolet radiation at all wavelengths, including the extreme ultraviolet where it crosses into X-rays at 10 nm. Extremely hot stars emit proportionally more UV radiation than the sun. Sunlight in space at the top of Earth's atmosphere is composed of about 50 per cent infrared light, 40 per cent visible light and 10 per cent ultraviolet light, for a total intensity of about 1400 W/m^2 in vacuum (Chen*et al*., 2012).

UV has such disastrous effect that it can damage upto cell level. One of the most outstanding examples is how direct and reflected sunlight on a bright spring day can cause a painful inflammation of the surface of the eyeball and snow blindness. One of the primary targets for UV damage is the hereditary material, the DNA, in all living cells. Other sensitive molecules include proteins that function as building blocks or as chemical helpers in the cells, for example, the photosynthetic machinery that makes it possible for plants and phytoplankton to capture solar energy and grow (Bruhn *et al.,* 2014). Ultraviolet radiation can also damage cell membranes and affect the ability of cells to take up nutrients. Ultraviolet radiation has always been a stressor in the environment, and some organisms have developed various strategies to protect themselves. For example, many plants and animals can produce their own sunscreen in the form of protective pigments, and most cells also have some ability to repair UV damage. The decrease of growth rate is related to the extra energy required for activation of repairing processes following UVB damage. These UV-induced changes in plant tissue chemistry generally involve stimulation of the production of phenolic compounds that function in the protection of plants against UV radiation (Searles *et al.,* 2001). Although concentrations of other chemical constituents (e.g. C, N, P, K, lignin, C:N) can change as well (Song *et al.,* 2013). UV-B induced changes in leaf chemistry need further evaluation for their potential role in photo-degradation.

In the past, UV-A was considered not harmful or less harmful than UVB, but today it is known to contribute to skin cancer via indirect DNA damage (free radicals such as reactive oxygen species). UV-A can generate highly reactive chemical intermediates, such as hydroxyl and oxygen radicals, which in turn can damage DNA. The DNA damage caused indirectly to skin by UV-A consists mostly of single-strand breaks in DNA, while the damage caused by UV-B includes direct formation of thymine dimers or other pyrimidine dimers, and double-strand DNA breakage (Svobodová *et al.,* 2012). UV-A is immunosuppressive for the entire body (accounting for a large part of the immunosuppressive effects of sunlight exposure), and is mutagenic for basal cell keratinocytes in skin (Halliday *et al.,* 2011).

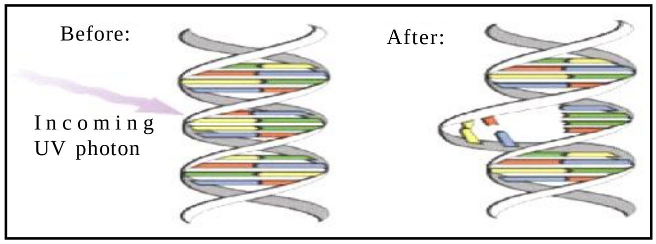

Fig. 3 : Showing DNA distortion due to Ultra violet radiation (Source : Credit: NASA's Earth Observatory/David Herrin)

Ultraviolet photons harm the DNA molecules of living organisms in different ways. In one common damage event, adjacent thymine bases bond with each other, instead of across the "ladder". This "thymine dimer" makes a bulge, and the distorted DNA molecule does not function properly.

Rather than looking at the immediate impact of ultraviolet radiation on isolated cells or organisms, research on effects of ultraviolet radiation has, therefore, put increasing emphasis on ecological studies, where various adaptations are implicitly taken into account.

Lake life is often stressed by high UV radiation:

In some freshwater ecosystems, ultraviolet radiation already seems to be an important stress factor for plankton. A further increase could, therefore, be detrimental, especially in clear, shallow lakes, where organisms have no protection from the light. Studies from Norway and Canada show that ultraviolet radiation affects the flagella of certain plankton, which are important for movement, as well as the uptake of phosphorus and the growth rate and structure of the cell wall. The changes in the cell wall also seem to make the phytoplankton less digestible for the zooplanktons that normally eat them.

Marine plants are inhibited by ultra violet radiation:

Numerous studies have shown that the algae at the base of the marine food web are sensitive to ultraviolet radiation. For example, the ozone hole in Antarctica reduces their ability to sequester carbon dioxide from the atmosphere. But sensitivity seems to vary, both in time and among different plankton communities. With current knowledge, it is, therefore, difficult to predict any overall effects on algae productivity in the Arctic Ocean.

In the shelf areas, sea grasses and macro algae also play an important role and account for more that 50 per cent of primary productivity. Moreover, they are known to produce compounds that might be important in the trace-gas chemistry of the atmosphere. But again, it is impossible to estimate how large impact ozone depletion could have on these plants, even if ultraviolet radiation is known to inhibit their growth and productivity.

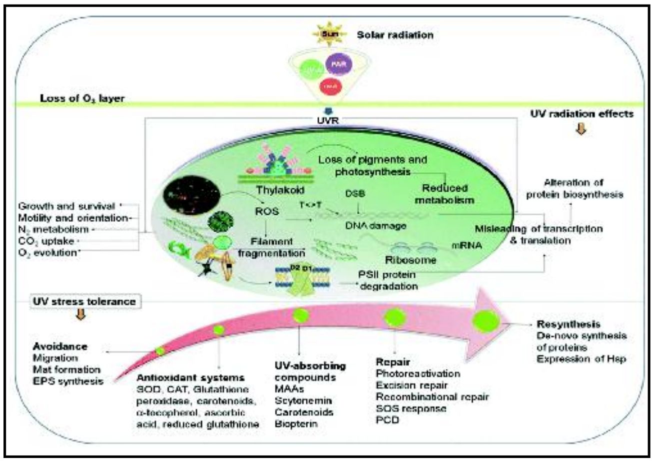

Fig. 4 : Showing impairs of UV radiation on the physiology of plants and aquatic animals. Sunlight can damage zooplankton and fish (Hader, 2005)

Temperature is an important factor that determines bio-geographical distribution and rates of metabolism of marine macrophytes (Perlwitz, 2011) and different macro-algal species may have different temperature tolerance due to their local temperature ranges (Bussotti *et al.*, 2014).

Zooplankton, as well as their eggs and the drifting nauplii, can be very sensitive to sunlight. In experiments with short-term exposures, even normal levels of ultraviolet radiation can kill some species. However, some of the zooplankton will probably be able to adapt to increases in ultraviolet radiation by using protective pigments, by avoiding the surface water, or by better repair mechanisms. The most likely change in the marine ecosystem is, therefore, that sensitive species will decrease in abundance, which could change the food webs. Fish are also vulnerable. The most threatened species would be those that have eggs or larvae in shallow waters in the early spring or pelagic eggs floating close to the sea surface. This includes many commercially important fish such as herring, pollock, cod, and salmon. The solar rays can also damage the adult fish by causing lesions on the skin and gills. For higher animals, whether terrestrial or marine, the effects of ultraviolet radiation have hardly been studied. One of the major concerns would probably be damage to the eyes and any skin that is not protected by fur or feathers. Ocean warming will expand warm water species to formerly colder regions, while cold water species will be driven to formerly even colder regions, a conclusion which is supported by North-Atlantic rocky intertidal model predictions (Robinson and Erickson, 2014).

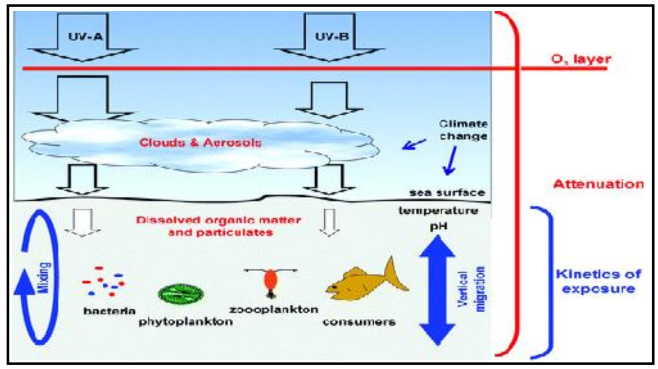

Fig. 5 : Showing impact of UV radiation on different zone of earth atmosphere

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