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Global climate change: A cause of concern

Sasmita Mohanty[1] and B.P. Mohanty[2,*]

[1]*School of Biotechnology, KIIT University, Bhubaneswar-75102, India.*

[2]*Central Inland Fisheries Research Institute, Barrackpore, Kolkata-700120, India.*

**Correspondence : bimalmohanty12@rediffmail.com*

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Abstract

Climate change has been recognized as the foremost environmental problem of the twenty-first century and has become a subject of considerable debate. It is predicted to lead to adverse, irreversible impacts on earth and the ecosystem as a whole. Although it is difficult to connect specific weather events to global warming, increases in global temperatures have been predicted to cause broader changes, including glacial retreat, arctic shrinkage, and worldwide sea level rise. Climate change has been implicated in mass mortalities of many aquatic species, including plants, fish, corals, and mammals. Climate change is an emerging threat to global public health and is predicted to affect human health in many ways including heat stress (stroke), air pollution, food scarcity, spread of infectious diseases and intensity of disease outbreaks. Thus, 'Global Climate Change' has been a major issue that has created global concern and this has been highlighted by awarding the 2007 Nobel Peace Prize for this cause, on the Intergovernmental Panel on Climatic Change (IPCC) and Albert Arnold (Al) Gore Jr., the former American Vice-President, jointly. The present paper focuses on different aspects of 'global climate change'; the causes, predicted impacts, probable steps for mitigation and the need for greater understanding of climate change and bringing global awareness on the issue.

(Keywords: Climate change, global warming, greenhouse gases, impacts of climate change, IPCC)

Climate change is the variation in the earth's global climate or in regional climates over time. It involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years. The United Nations Framework Convention on Climate Change (UNFCCC) uses the term 'climate change' for human-caused change and 'climate variability' for other changes. 'Global warming' is a specific example of global climate change. Global warming refers to the increase in the average temperature of the Earth's near surface air and oceans since the mid-twentieth century and its projected continuation, and implies a human influence. In last 100 years, ending in 2005, The average global air temperature near the Earth's surface has been estimated to increase at the rate of $0.74 \pm 0.18^{\circ}C$ ($1.33 \pm 0.32^{\circ}F$)[1]. The term 'climate change can also refer to other periods of overall temperature change such as 'global cooling'. These changes can be caused by dynamic process on earth, external forces including variations in sunlight intensity, and more recently by human activities. In recent usage, especially in the context of environmental policy the term 'climate change' often refers to changes in modern climate.

Causes of climate change

The earth's climate changes in response to external forcing, including variations in its orbit around the Sun (orbital forcing), volcanic eruptions, and atmospheric greenhouse gas concentrations. Changes in atmospheric concentrations of greenhouse gases and aerosols, land-cover and solar radiation alter the energy balance of the climate system and causes warming or cooling of the earth's atmosphere. There are both natural processes and anthropogenic activities affecting the earth's temperature. A graphical representation of global anthropogenic greenhouse gas emissions is shown in Fig. 1.

Natural processes affecting the earth's temperature

The sun is the primary source of energy on earth. Though the sun's output is nearly constant,

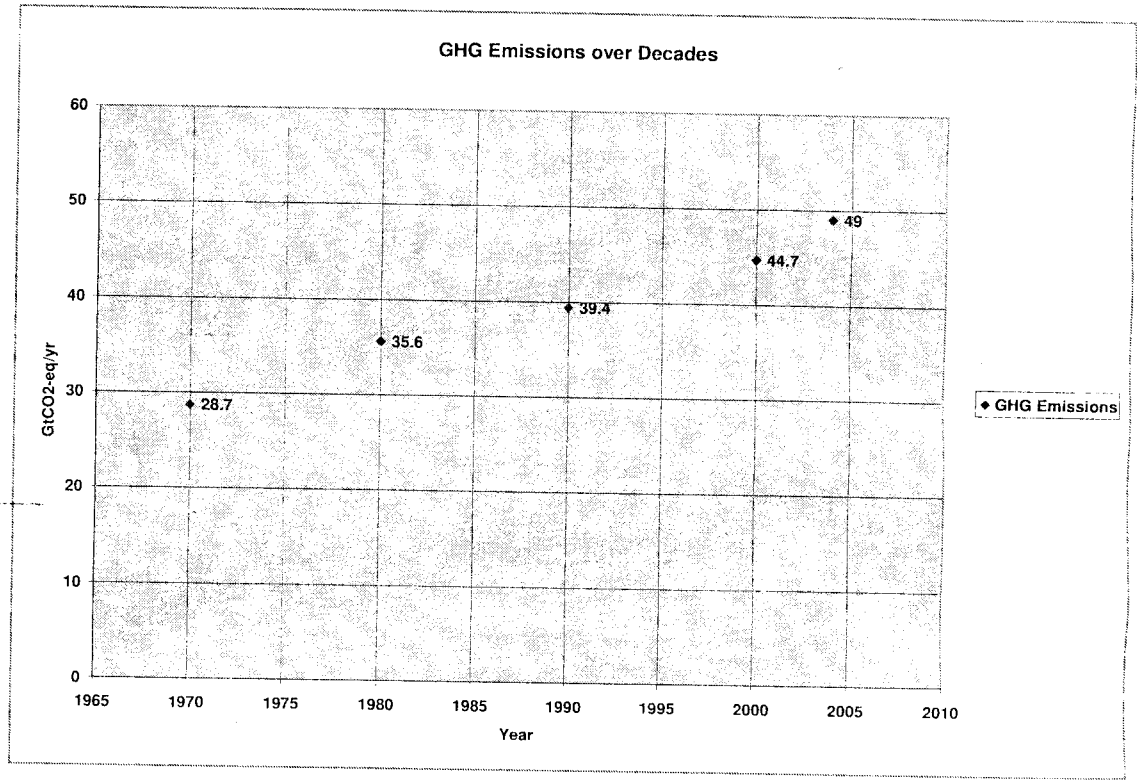

Fig. 1– Global anthropogenic greenhouse gas (GHG) emissions over decades (Data used from IPCC-Fourth Assessment Report-Climate Change 2007: Synthesis Report, ref. 2).

small changes over an extended period of time can lead to climate change. The green house effect is necessary to life on Earth; without heat-trapping greenhouse gases (GHGs), Earth would have been a lifeless, frozen planet, with average temperature -18°C, in stead of its present rich, diverse biosphere. Volcanic eruptions emit many gases and one of the most important of these is sulfur dioxide (SO_2) which forms sulfate aerosol (SO_4) in the atmosphere.

Greenhouse effect

The 'Greenhouse effect' is often referred to as enhanced greenhouse effect which is an increase in the concentration of greenhouse gases in the atmosphere leading to an increase in the amount of infrared or thermal radiation near the surface. Greenhouse effect is not some peripheral phenomenon only of importance to global warming; rather it is at heart of the Earth's natural climatic systems. It is the consequence of having an atmosphere. The atmosphere acts like a blanket trapping lower-frequency radiations. It functions just as the glass of greenhouse does by allowing in higher-frequency light, but trapping some of the lower-frequency heat; hence the term greenhouse effect. If there were not an atmospheric blanket, we would freeze during the night, like some of the other planets or our moon.

Greenhouse gases

Greenhouse gases (GHGs) are those gaseous constituents of the atmosphere, both natural and anthropogenic, that are responsible for the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances. Halocarbons such as CFCs (chlorofluorocarbons) are completely artificial (man-made), and are produced from the chemical industry in which they are used as coolants and in foam blowing.

Carbon dioxide (CO_2) has both natural and human sources. The increase in CO_2 levels is

primarily because of the use of fossil fuels, deforestation and other land use changes. Increases in CO_2 are the single largest climate forcing contributing more than 60% of human-enhanced increases and more than 90% of rapid increase in past decade. Most CO_2 emissions are from the burning of fossil fuels such as coal, oil, and gas. Rising CO_2 is also related to deforestation, which eliminates an important carbon sink (carbon sinks are reservoirs that absorb or take up released carbon from another part of the carbon cycle; the 4 major sinks on the planet are the atmosphere, the terrestrial biosphere (e.g. trees and freshwater systems), oceans, and sediments[3,4]. Currently, the atmosphere contains about 370 ppm of CO_2, which is the highest concentration in 420000 years and perhaps as long as 2 million years. Estimates of CO_2 concentrations at the end of the 21st century range from 490 to 1260 ppm, or a 75% to 350% increase above preindustrial concentrations[4, 5].

Methane (CH_4) has both natural and human sources, and atmospheric methane concentration have significantly increased since pre-industrial times. It is thought that more than 50% of the methane flux to the atmosphere is anthropogenic, such as agriculture, raising livestock, growing rice, filling landfills and using natural gas (which releases methane while being extracted and transported). The remainder is natural, such as from wetlands [6].

Nitrous oxide (N_2O) is a powerful greenhouse gas emitted through soil cultivation practices, especially the use of commercial and organic fertilizers, fossil-fuel combustion, nitric acid production, and biomass burning.

Ozone (O_3), the triatomic form of oxygen, is a gaseous atmospheric constituent. In the troposphere it is created both naturally and by photochemical reactions involving gases resulting from human activities (photochemical "smog"). In high concentrations, tropospheric ozone can be harmful to a wide-range of living organisms. Tropospheric ozone acts as a greenhouse gas. In the stratosphere, ozone is created by the interaction between solar ultraviolet radiation and molecular oxygen (O_2). Stratospheric ozone plays a decisive role in the stratospheric radiative balance. Its concentration is highest in the ozone layer. Depletion of stratospheric ozone, due to chemical reactions that may be enhanced by climate change, results in an increased ground-level flux of ultraviolet-B radiation. Ozone (O_3) forms naturally in the upper atmosphere, where it creates a protective shield that intercepts damaging ultraviolet radiation from the sun. However, ozone produced near the earth's surface via reactions involving CO_2, hydrocarbons, nitrogen oxide, and other pollutants is harmful to both animals and plants and has a harmful effect. The concentration of O_3 in the lower atmosphere is increasing as a result of human activities [6].

Halocarbons such as Chlorofluorocarbons (CFCs) have no significant natural sources and are completely man-made and was once described as 'miracle chemicals' (Fig 2)[7]. They were first manufactured in the 1930s, and industries soon found a wide variety of applications for them due to their chemical unreactivity and heat-absorbing properties. CFCs, commonly known as Freons, have been used as refrigerants in air conditioners and refrigerators, in aerosol spray cans, in manufacturing foams as industrial solvents, and as cleaning agents in the manufacture of electronics. Chemically, CFCs are a subset of the more general class of compounds known as halocarbons (carbon- and halogen-containing compounds). CFCs contain only the elements carbon, chlorine, and fluorine. The most common CFCs are small molecules containing only one or two carbon atoms. For example, a common refrigerant has the chemical formula of CCl_2F_2, commonly known as CFC-12. In addition to being potent greenhouse gases, CFCs also cause the breakdown of the ozone layer that protects the earth from the sun's ultraviolet (UV) radiation. The ozone layer is important to humans and other life on earth because it protects the earth from the sun's ultraviolet (UV) radiation (O_3 acts as UV 'shield'). Long-term effects on humans' excessive UV exposure include skin cancer, eye damage (cataracts), and suppression of the immune system [7].

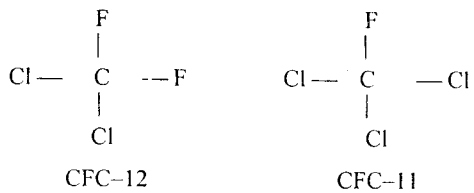

Fig 2– Chlorofluorocarbons, CFCs

Anthropogenic activities affecting the earth's temperature

Aerosols, may be of either natural or anthropogenic origin, influence the climate. Aerosols are a collection of airborne solid or liquid particles, with a typical size between 0.01 and 10 mm that reside in the atmosphere for at least several hours. Aerosols may influence climate in two ways: directly through scattering and absorbing radiation, and indirectly through acting as condensation nuclei for cloud formation or modifying the optical properties and lifetime of clouds. Aerosols produced by industrial processes such as sulfate (SO_4) cool the planet by reflecting sunlight back to space. Some aerosols cool the earth indirectly by increasing the amount of sunlight reflected by the clouds.

Black carbon particles or 'soot' produced when fossil fuels or vegetation are burned, generally have a warming effect because they absorb incoming solar radiation. Black carbon particles settling on snow or ice are a particularly potent warmer. Deforestation and other changes in land use modify the amount of sunlight reflected back to space from the earth's surface.

Impacts of climate change

Although it is difficult to connect specific weather events to global warming, an increase in global temperatures may in turn cause broader changes, including glacial retreat, arctic shrinkage, and worldwide sea level rise. Changes in the amount and pattern of precipitation may result in flooding and drought. Other effects may include changes in agricultural yields, addition of new trade routes, reduced summer stream flows, species extinctions, and increases in the range of disease vectors [6].

Most models on Global climate change indicate that snow pack is likely to decline on many mountain ranges in the west, which would bring adverse impact on fish populations, hydropower, water recreation and water availability for agricultural, industrial and residential use. NASA data show that Arctic sea ice shrunk to a new record low in 2007; 24% lower than the previous record (2005), and 40% lower than the long-term average [6]. Partial loss of ice sheets on polar land could imply metres of sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands. Such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded[6]. Current models of climate change predict a rise in sea surface temperatures of between 2 °C and 5 °C by the year 2100[8, 9].

The effects of increasing temperature on marine and freshwater ecosystems are already evident, with rapid poleward shifts in distributions of fish and plankton in regions such as North East Atlantic, where temperature change has been rapid[10]. Climate change has been implicated in mass mortalities of many aquatic species, including plants, fish, corals, and mammals [11, 12].

Climate change will affect ecosystems and human systems like agricultural, transportation and health infrastructure. The regions that will be most severely affected are often the regions that are the least able to adapt. Bangladesh is projected to lose 17.5 % of its land if sea level rises about 1 meter (39 inches), displacing millions of people[6]. Several islands in the South pacific and Indian oceans may disappear. Many other coastal regions will be at increased risk of flooding, especially during storm surges, threatening animals, plants and human infrastructure such as roads, bridges and water supplies.

A number of ecosystem changes, such as plants flowering earlier in the year and declines in animal species that depend on sea ice for habitat, have been attributed to the strong warming observed at northern latitudes.

There are many ways in which climate change might affect human health, including heat stress, heat (sun) stroke, increased air pollution, and food scarcities due to drought and other agricultural stresses[13]. Because many disease pathogens and carriers are strongly influenced by temperature, humidity and other climate variables, climate change may also influence the spread of infectious diseases or the intensity of disease outbreaks. During the last 100 years, anthropogenic activities related to burning fossil fuel, deforestation and agriculture has led to a 35% increase in the CO_2 levels in the atmosphere and this has resulted in increased trapping of heat and the resultant increase in the earth's atmosphere. Most of the observed increase in

globally-averaged temperatures has been attributed to the greenhouse gas concentrations. Eleven of the last 12 years (1995-2006) rank among the 12 warmest years in the instrumental records of global surface temperature. The globally averaged surface temperature rise has been projected to be 1.1-6.4 degrees centigrade by end of the 21st century (2090-2099) which is mainly due to thermal expansion of the ocean [13]. The global mean sea level is projected to rise by 30-60 cm by the year. The global average sea level rose at an average rate of 1.8 mm per year from 1961 to 2003 and the total rise during the 20th century was estimated to be 0.17 m (The Fourth Assessment Report of IPCC) [2]. Due to such surface warming it is predicted that heat waves and heavy precipitations will continue to become more frequent with more intense and devastating tropical cyclones (typhoons and hurricanes). Due to the resultant disruption in ecosystem's services to support human health and livelihood, there will be strong negative impact on the health system. IPCC has projected an increase in malnutrition and consequent disorders, with implications for child growth and development. Increased burden of diarrhoeal diseases and infectious disease vectors are expected due to the erratic rainfall patterns.

Current and emerging climate-change related health risks in the Asia-Pacific region include heat stress and water- and food-borne diseases like cholera and other diarrhoeal diseases associated with extreme weather events like heat waves, storms, floods and flash floods and droughts; vector-borne diseases like dengue, malaria and filarial; respiratory diseases due to air pollution, aeroallergens, food and water security issues; malnutrition and psychological concerns resulting from displacement. The limited facilities available in the developing countries to cope with such potentially increasing levels of risks and diseases will not be enough and therefore, awareness among general public about climate change-related problems and its health impacts and preparedness for disaster management have to be given priority. Such regional and global concerns have led nations to jointly develop regional frame work to guide regional and national action towards reducing the potential burdens and human suffering[13].

Climate change is likely to lead to some irreversible impacts. Approximately 20- 30% of species assessed so far are likely to be at increased risk of extinction if increases in global average warming exceed 1.5-2.5°C (relative to 1980-1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40-70% of species assessed) around the globe. Some projected regional impacts of Climate Change have been systematically listed in the IPCC Fourth Assessment Report [2].

Steps for mitigation of climate change

Mitigation is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases. There are many potentially cost-effective technological options that could also help stabilize greenhouse gas concentrations. Personal, national, and international choices have an impact: for example driving less, regulating emissions, and sharing energy technologies would also help reducing emissions.

Governments can work together to reduce or reverse negative human impacts on nature. A classic example is the successful international effort to phase out use of CFCs in aerosol sprays and refrigerants, which were destroying the earth's protective ozone layer.

Carbon dioxide emissions can be reduced either by switching to alternative fuels that produce less or no carbon dioxide or by using energy more efficiently. Another way to reduce emissions is to collect carbon dioxide from fossil-fuel-fired power plants and sequester it in the ground or the ocean. If successful, carbon sequestration could weaken the link between fossil fuel use and green house gas emissions [2].

There are many alternatives to producing energy from fossil fuels. Electricity can be produced without significant carbon emissions using nuclear power and renewable energy technologies, such as solar, wind, hydropower and biomass (fuels made from plant matter). Biofuels can also be used to power vehicles [2].

Adaptation is adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or

expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation. Selected examples of planned adaptation to Climate Change by different sectors have been described in the IPCC Fourth Assessment Report [2]

The 2007 Nobel Peace Prize for Global Climate Change

'Global Climate Change' has been a major issue and has created global concern and anxiety and this has been reflected by the fact that the 2007 Nobel Peace Prize has been awarded for this cause. Nobel Peace Prize for 2007 has been awarded jointly to the Intergovernmental Panel on Climatic Change (IPCC) and Albert Arnold (Al) Gore Jr., the former US Vice-president, 'for their efforts to build up and disseminate greater knowledge about man made climate change, and to lay the foundations for the measures that are needed to counteract such change'[14].

IPCC : IPCC, founded jointly by World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) in the year 1988, aim to provide a comprehensive, objective, open and transparent source of information about the cause of climate change, its potential environmental and socio-economic consequences and the adaptation and mitigation option to respond to it[15]. Its role is to assess the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human induced climate change, its observed and projected impacts and options for adaptation and mitigation. Its headquarters are at Geneva, Switzerland. Dr Rajendra Pachauri, the Director-General of the New Delhi-based TERI (http://www.teriin.org), is heading IPCC as its Chairman since April, 2002.

The findings of the first IPCC assessment report of 1990 played a decisive role in leading to the United Nation Framework on Climate Change (UNFCCC), which was opened for signature in the Rio de Janeiro Summit in 1992 and entered into force in 1994. The IPCC 2nd Assessment Report of 1995 provided key input for the negotiations of the Kyoto Protocol in 1997 and the 3rd Assessment Report of 2001 provided further information relevant for the development of the UNFCCC and Kyoto Protocol. IPCC's 4th Assessment Report was issued in 2007. This report is based on 100's of simulation, computer models, numerous studies and gathered data. 450 primary authors have written what is to date the most exact description of what has occurred to the temperature in the atmosphere since 1800. This 4th UN Climate Change Report had a total of 2500 experts collaborating over the course of 6 years [15,16].

Al Gore's Contribution : Albert Arnold (Al) Gore Jr., has been one of the world's leading environmentalist politicians who has actively worked on global climatic challenges. His strong commitment, reflected in political activity, lectures, films and books has strengthened the struggle against climate change. His documentary, 'An Inconvenient Truth' is widely acclaimed as a work of great importance in creating awareness among the world-mass [17, 18]. The Nobel Prize Committee credited him as the single individual who has done the most to create greater worldwide understanding of the measures that need to be adopted [14].

Epilogue

It is recently reported that ocean temperature and associated sea level increases between 1961 and 2003 were 50% larger than estimated in the 2007 IPCC report [19]. Analyzing climate model data from 13 different modeling groups, an international team of researchers compared climate models with improved observations that show sea levels rose by 1.5 mm per year in the period from 1961-2003. This equates to an approximately 2 ½ -inch increase in ocean levels in a 42-year span. Thus, the ocean warming and thermal expansion rates are more than 50% larger than previous estimates for the upper 300 m of oceans. Although observations and models confirm that recent warming is greatest in the upper ocean, there are widespread observations of warming deeper than 700 m. It's a fact that the oceans store more than 90% of the heat in the Earth's climate system and act as a temporary buffer against the effects of climate change. This report has indicated that some climate change impacts may be

of much higher magnitude than that predicted in the IPCC's Synthesis Report 2007.

There are opposing view points on the predicted impacts of 'global warming' also. Scientists warn against overselling climate change. Some experts feel that the data produced by models used to project weather changes risks being over-interpreted by governments, organizations and individuals keen to make plans for a changing climate, with dangerous results. The point made is that the Global Climate Models (GCMs) help us understand pieces of the climate system, but that does not mean we can predict the details. Impact of retreat of Gangotri glacier on the flow of river Ganga can be taken as a case study from the global warming perspective; in fact, this has been systematically analyzed and argued in a recent paper [20]. The Himalayan glaciers form the largest body of ice outside the polar caps and there are nearly 10,000 glaciers in the Indian Himalaya. After Siachen (73 km long), Gangotri is the next largest of the Himalayan glaciers (30 km). There are widespread views and concerns that the Gangotri glacier may disappear by the year 2035, if the present rate of recession continues and it could become a seasonal river in the near future as a consequence of climate change. There is apprehension and fear that global warming may result in the drying up of river Ganga [20]. Not only millions of people depend on its waters, but Ganga is an integral part of the Indian national culture and heritage and has strong bondage with religious sentiments of many more millions also. It is believed that in the last 4000 years the retreat of the Gangotri glacier has been 18 km. In the late 1960s, the retreat rate was about 30 m/yr and over the past few decades the recession rate has been between 22 and 27 m/yr. Assuming the recession rate to be 40 m/yr, a glacier of 30 km stretch will take about 700 years to completely melt away. In conservative estimate, the time-span could be hundreds of years and thus, even though there is retreat, the rate is not catastrophic and they are not going to disappear in the near future. Another important point is Ganga is not totally dependent on glaciers for its water, even in the headwaters region. More than 70% of the flow at Haridwar, place where the river enters the plains, is due to rainfall and the river has significant amount of base flow downstream. Beyond Haridwar, the influence of Gangotri glacier on river flow becomes progressively lesser and it is less than 4% at Allahabad, where river Yamuna, a major tributary contributes about 61% of the total flow at Allahabad and beyond Allahabad there are several large tributaries in Bihar and West Bengal contributing to the flow. Hence, the possibility of the Ganga becoming a seasonal river downstream of Haridwar in the near future is low. Climate change will not change temperature alone, other variables such as precipitation intensity and quantity, cloud cover, wind, etc. will also change and thus it is a complex task to predict with confidence, the overall scenario. Long-term studies on glacier dynamics and mass balance are necessary to understand the impact of climate change on glaciers [20]. [Thus, indications of changes in the earth's future climate must be treated with the utmost seriousness and with the precautionary principle uppermost in our minds.] Extensive climate change may alter and threaten the living conditions of much of mankind. They may induce large-scale migration and lead to greater competition for the earth's resources. Such changes will place particularly heavy burdens on the world's most vulnerable countries. There may be increased danger of violent conflicts and wars, within and between states. A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change.

Although the understanding of climate change has advanced significantly during the past few decades, many questions remain unanswered. The task of mitigating and adapting to the impacts of climate change will require worldwide collaborative input from a wide range of experts from various fields. The common man's contribution will play a major role in reducing the impacts of climate change and protecting the earth from climate change-related hazards.

To conclude, 'how we handle the issue of Climate Change is more of an ethical question' says John Broome, Professor at the University of Oxford [21]. The future generations will suffer most of the harmful effects of global climate change. So, the present generation must decide, whether to aggressively reduce the chances of future harm at the cost of sacrificing some luxuries or to let our descendants largely fend for themselves. So we must decide now how to move further and act accordingly.

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