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Review Article
Industrialization and its Backlash: Focus on Climate Change and its Consequences

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Abstract
Industrialization has always seemed to be the key to wealth and better living but in reality, it has been shown that, although it leads to better conditions of living in certain respects, it affects environment and ultimately contributes to climate change. Industrialization not only involves technological innovations, it also involves economic and social transformation of the human society. With industrialization come opportunities as well as challenges. The challenges include coping with higher temperatures, extreme weather conditions, changing human life styles and changing philosophies. Due to these challenges, industrialization must take into account climate change and its consequences. For example, changing human life styles and philosophies have major impacts on environment and this has to be considered. This study examines the links between industrialization and climate change and attempts to address some arguments, which always come up when the effects of human activities on climate change is discussed.

Key words: Industrialization, technological innovations, climate change, higher temperatures, changing human life styles, changing philosophies, environment

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INTRODUCTION

Industrialization is the process of transformational change of the human society socially and economically from an agrarian society into an industrial one. It involves vast economic and social changes such as a tendency to urbanization, a growing body of wage earners and increased technical and advanced education[1]. Industrialization is the extensive organization of an economy for the purpose of manufacturing[2]. Manufacturing has always involved large scale usage of energy and alteration of natural systems from their pristine states. From the above statements, it could be said that industrialization involves mainly technological innovations, economic and social transformation. Industrialization revolves around improved food production, improved infrastructure to increase ecotourism opportunities, more efficient conservation and use of resources, more efficient means of transportation, reducing dependence on fossil fuels and natural wood fuels and so on. Although, industrialization is the key to wealth and better living, it affects environment and ultimately contributes to climate change.

Climate change can be described as the persistent change in the weather pattern engendered by anthropogenic activities mostly linked to industrialization. It manifests in a long-term shift in the statistics of the weather (including its averages). For example, it could show up as a change in climate normal (expected average values for temperature and precipitation) for a given place and time of year, from one decade to the next[3]. One of the major drivers of climate change is the global warming. Global warming is a term often erroneously used interchangeably with climate change. Global warming refers to an average increase in the temperature of the atmosphere near the earth's surface. The last decade of the 20th century and the beginning of the 21st have been the warmest period in the entire global instrumental temperature record, starting in the mid 19th century[3].

GENERAL FACTORS RESPONSIBLE FOR CLIMATE CHANGE

The causes of climate change have been a serious subject of international debates. There is a consensus that the climate is changing but there has not been an agreement as to the causes. Both natural events and human activities are believed to be contributing to an increase in average global temperatures. There has not been an agreement as to whether humans are the chief culprits or not but one thing has been shown to be certain-humans have some effect on the global climate and heightened human activities have contributed to the alteration of the face of the earth.

Highlighting the natural causes of climate change, Pidwirny[4] stated that external and internal factors could lead to changes in the state of the earth's climate system (Fig. 1). External factors involve effects from extraterrestrial systems. For example, an external change may involve a variation in the sun's output which would externally cause variations in the amount of solar radiation received by the earth's atmosphere and surface. Internal factors involve ocean, atmosphere and land systems. For example, internal variations could be due to changes in the concentrations of atmospheric gases, mountain building, volcanic activity and changes in surface or atmospheric albedo. A study of past episodes of climate change has found evidence to suggest that only a limited number of factors are primarily responsible for the climate change. These factors include[4]:

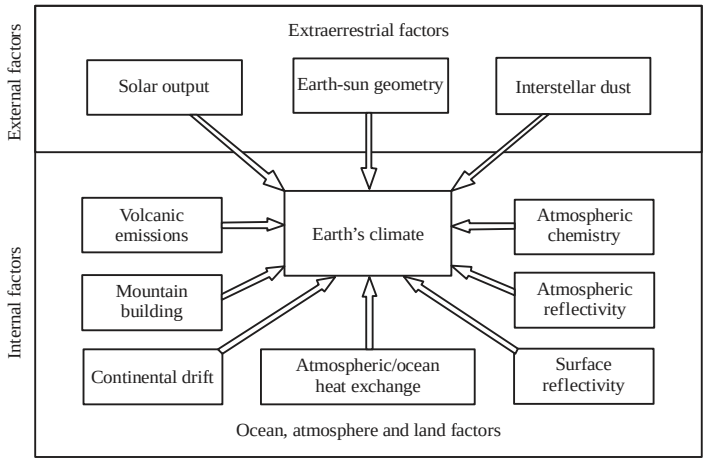


Fig. 1: Factors that influence the earth's climate[4]

- Variations in the earth's orbital characteristics
- Atmospheric carbon dioxide variations
- Volcanic eruptions
- Variations in solar output

These support the view that climate change is mainly due to natural effects.

Global warming has been generally agreed to be caused primarily by the emission of greenhouse gases (such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)), chlorofluorocarbons and other chemicals into the atmosphere[5]. The greenhouse effect is a natural effect, which helps prevent excessive loss of heat from the earth's surface. Without that effect, the earth would have been a lot colder and might have been less habitable for humans, animals and plants. It has been postulated that the earth's surface would have been about 33°C colder[6,7]. The accumulation of these gases in the atmosphere results in heightened "greenhouse effect", which leads to global warming and attendant anomalies in local temperature, humidity, wind speed, precipitation, soil moisture and sea level. Climate change has also been reported to have led to global cooling in some previous era[8]. An increase in aerosols in the atmosphere, also due to industrial emissions, cools the earth through a reflection of solar radiation back into space[9]. If the greenhouse effect becomes stronger, then more heat gets trapped than needed and the earth might again become less habitable. The aggravated emission of greenhouse gases is linked to human efforts towards industrialization. The objective of this paper therefore is to show that humans in the bid to become industrialized have as well adversely affected the environment exacerbating the climate change effects.

LINK BETWEEN ANTHROPOGENIC GREENHOUSE GASES, INDUSTRIALIZATION AND CLIMATE CHANGE

Greenhouse gases from human activities are the most significant driver of observable climate change since the mid-20th century. The indicators in this section characterize emissions of the major greenhouse gases resulting from human activities, the concentrations of these gases in the atmosphere and how emissions and concentrations have changed over time. When comparing the contribution of these gases, the concept of global warming potential is used to convert amounts of other gases into carbon dioxide equivalents. There are six main types of gases, which create the greenhouse effect. These are CO_2, N_2O, CH_4 (which is 20 times stronger than carbon dioxide in greenhouse effect), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Water vapor also has the ability to create a greenhouse effect, so it is also considered a greenhouse gas as well as nitrogen trifluoride (NF_3). Their global warming potentials are as shown in Table 1.

Although, carbon dioxide is not the most potent of greenhouse gases as can be seen from Table 1, it is the most significant due to its radiative forcing (Table 2). Radiative forcing is the measure of the influence a factor has in altering the balance of incoming and outgoing energy in the earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Studies carried out over a long period on climate change have shown that there is a link between the concentration of carbon dioxide in the atmosphere and mean global temperature. Carbon dioxide, like water vapor and methane is able to absorb and re-emit the longwave radiation emitted from the

Table 1: Atmospheric lifetime and global warming potential relative to CO_2 at different time horizon for various greenhouse gases[10]

		Global Warming Potential (GWP) for given time horizon (years)		
Gases	Atmospheric lifetime (years)	20	100	500
Carbon dioxide (CO_2)	50-200	1	1	1
Methane (CH_4)	12±3	56	21	6.5
Nitrous oxide (N_2O)	120	280	310	170
HFC-23	264	9,100	11,700	9,800
HFC-125	32.6	4,600	2,800	920
HFC-134a	14.6	3,400	1,300	420
HFC-143a	48.3	5,000	3,800	1,400
HFC-152a	1.5	460	140	42
HFC-227ea	36.5	4,300	2,900	950
HFC-236fa	209	5,100	6,300	4,700
HFC-4310mee	17.1	3,000	1,300	400
Tetrafluoromethane (CF_4)	50 000	4,400	6,500	10,000
Hexafluoroethane (C_2F_6)	10 000	6,200	9,200	14,000
(C_4F_{10})	2,600	4,800	7,000	10,100
Sulphur hexafluoride (SF_6)	3 200	16 300	23,900	34,900

Table 2: Levels of some greenhouse gases in the atmosphere along with their radiative forcing[11]

Gases	Abundance (year 1750)	Abundance (year 1998)	Increase	Radiative forcing (W m^{-2})
Gases relevant to radiative forcing only				
Carbon dioxide	278 ppm	365	87	1.46
Methane	700 ppb	1745	1045	0.48
Nitrous oxide	270 ppb	314	44	0.15
CF_4	40 ppt	80	40	0.003
C_2F_6	0 ppt	3	3	0.001
SF_6	0 ppt	4.2	4.2	0.002
HFC-23	0 ppt	14	14	0.002
HFC-134a	0 ppt	7.5	7.5	0.001
HFC-152a	0 ppt	0.5	0.5	0.000
Gases relevant to radiative forcing and ozone depletion				
CFC-11	0 ppt	268	268	0.07
CFC-12	0 ppt	533	533	0.17
CFC-13	0 ppt	4	4	0.001
CFC-113	0 ppt	84	84	0.03
CFC-114	0 ppt	15	15	0.005
CFC-115	0 ppt	7	7	0.001
CCl_4	0 ppt	102	102	0.01
CH_3CCl_3	0 ppt	69	69	0.004
HFCF-22	0 ppt	132	132	0.03
HFCF-141b	0 ppt	10	10	0.001
HFCF-142b	0 ppt	11	11	0.002
Halon-1211	0 ppt	3.8	3.8	0.001
Halon-1301	0 ppt	2.5	2.5	0.001

earth's surface and at the same time reflect some back to the earth's surface. The net result of this process of absorption, re-emission and reflection of longwave back to the earth's surface is the increase in the quantity of heat energy stored in the earth's climatic system. Again studies have shown that the oceans are the storehouse of carbon dioxide and that they control the movement of this gas to and from the atmosphere. The oceans cover more than 70% of the earth's surface and therefore represent a large reservoir of CO_2. But the amount of carbon dioxide that can be held in oceans is a function of water temperature, because the solubility of gasses is temperature-dependent. Carbon dioxide is released from the oceans when global temperatures become warmer and diffuses into the ocean when temperatures are cooler. Global temperatures have been shown to be affected by the variation in the sun's output. So putting these together, it implies that naturally, this type of greenhouse gas would be pumped into the earth's atmosphere even without the presence of humans. Although, CO_2 is pumped into the atmosphere by natural processes, increasing evidence of human contributions to this is becoming clearer. Human activity has caused an imbalance in the natural cycle of the greenhouse effect and related processes. In addition to the natural fluxes of carbon through the earth system, anthropogenic activities like fossil fuel burning and deforestation are also releasing carbon dioxide into the atmosphere. Figure 2 shows that one will easily notice that the natural flux is by far greater than the anthropogenic flux. However, doing the arithmetic of net values, it will be seen that the anthropogenic activities contribute a net value of about 6.1 billion metric tons of carbon, while the natural flux removes a net value of about 3 billion metric tons of carbon from the atmosphere. This leaves about 3.1 billion metric tons of carbon in the atmosphere.

Apart from burning fossil fuels, other ways by which humans effectively contribute to CO_2 emission include the release of carbon dioxide during blast furnace refining of iron ore and other base metals and during smelting processes. During mining of coal, oil refining and burning fossil fuels for transportation, heating, cooking, electricity generation and manufacturing, more carbon dioxide is released than is being removed naturally through the sedimentation of carbon, ultimately causing atmospheric carbon dioxide concentrations to increase. Clearing of forests for agricultural purposes and urbanization creates a disturbance in the earth's ability to stabilize atmospheric CO_2 concentration. Trees remove carbon dioxide from the atmosphere through the natural process of photosynthesis and store the carbon in their leaves, branches, stems, bark and roots[12]. By these actions, humans are adding ever-increasing amounts of extra carbon dioxide into the atmosphere. Figure 3 and 4 show the trend of the atmospheric carbon dioxide, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements.

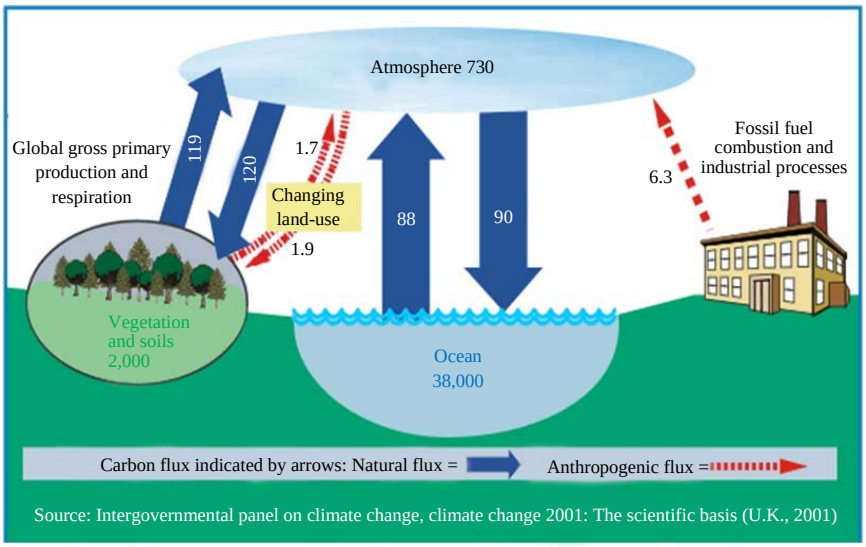


Fig. 2: Global carbon cycle (billion metric tons carbon)[11]

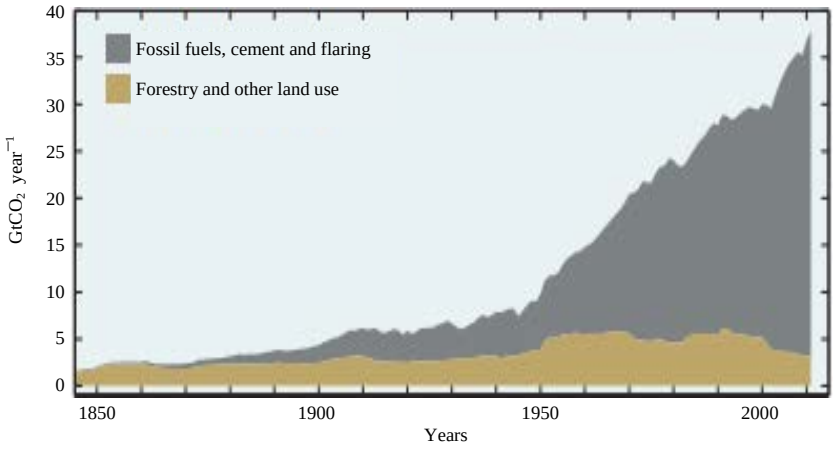


Fig. 3: Global anthropogenic CO_2 emission since 1850[13]

Human activities have also led to increases in the concentrations of other greenhouse gases and other pollutants in the atmosphere. Methane is emitted during coal mining, production and transport of natural gas and oil, decomposition of organic waste in municipal solid waste landfills and livestock droppings. Methane gas has been shown to be 20 times more potent than carbon dioxide. Nitrous oxide emission occurs during agricultural and industrial activities as well as during combustion of solid waste and fossil fuels. Halocarbons (HFCs and PFCs) and (SF_6) are also very powerful greenhouse gases and are not naturally occurring. They are emitted during the melting and processing of polymers and polymer-based materials and also in a variety of industrial processes. Certain industrial processes such as cement production, waste management systems, refrigeration, foam blowing and solvent use cause the release of the other greenhouse gases. The various economic sectors which account for such leftovers in the atmosphere are as shown in Fig. 5.

OBSERVABLE TREND OF GLOBAL AVERAGE TEMPERATURE RISE

Although, seemingly random variations have existed in global and local temperatures from as far back as records are available, an obvious upward trend has emerged in recent times. An estimated increase in temperature during the past century was between 0.4-0.8°C with the 10 warmest years

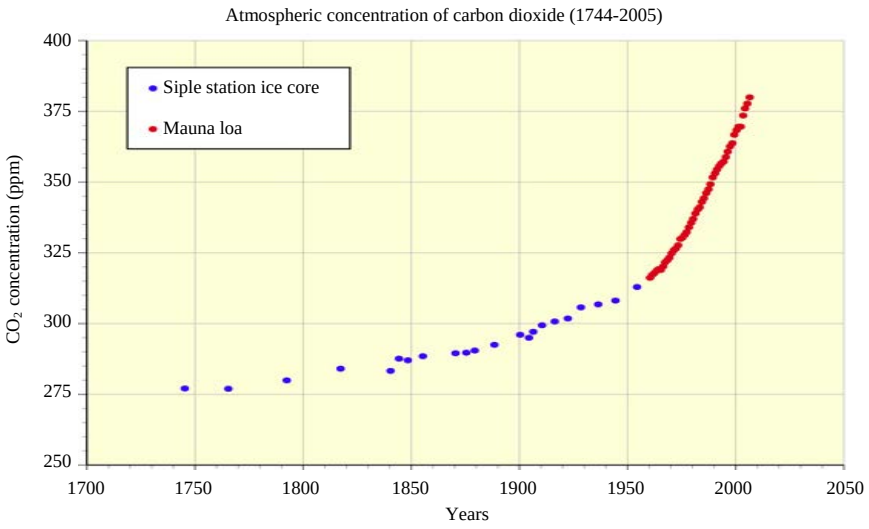


Fig. 4: Global carbon dioxide concentration[4]

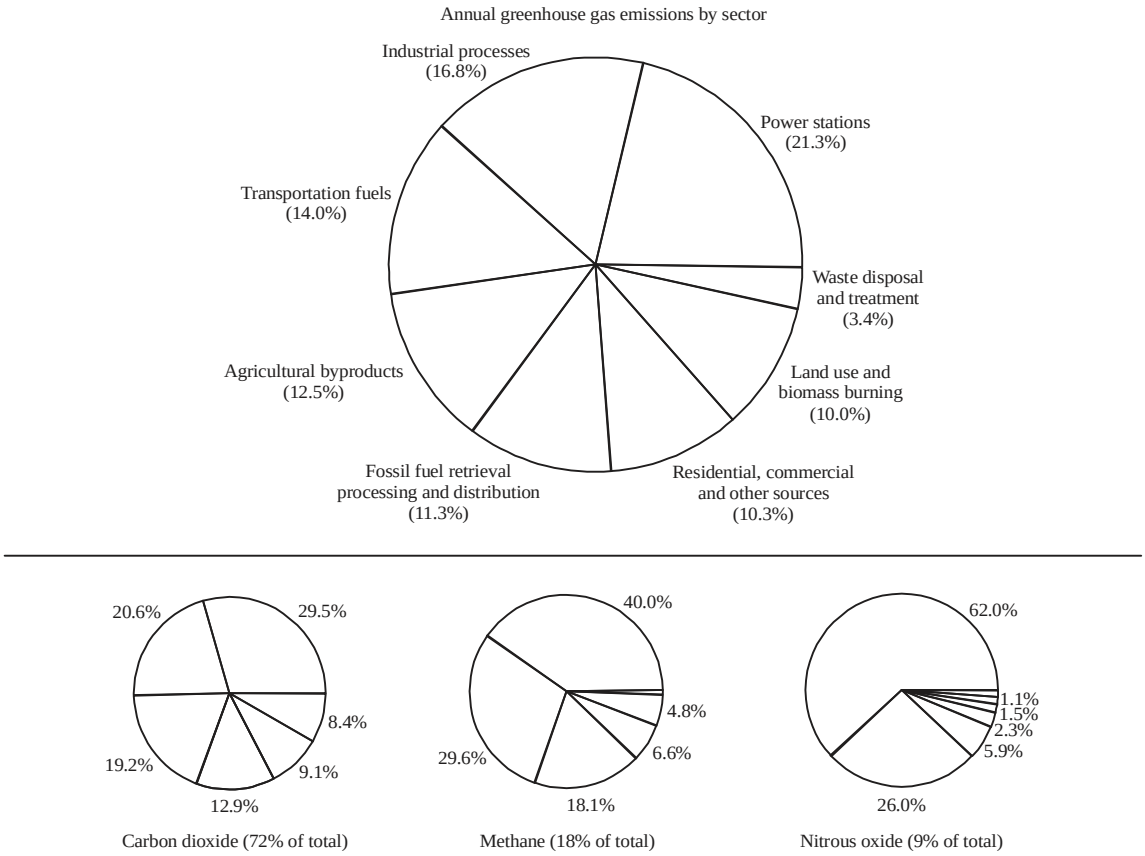
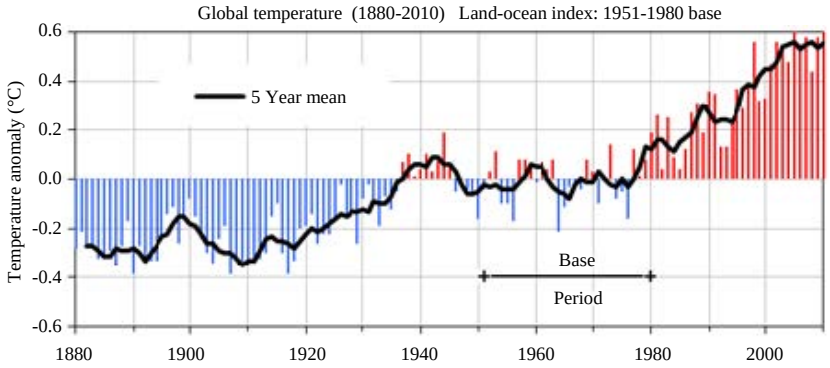


Fig. 5: Global anthropogenic greenhouse gas emissions of eight different sectors for the year 2000[14]

occurring within the last 15 years[15]. Although, it is uncertain how much of this warming can be attributed to greenhouse gases, there is evidence that human activities are causing an enhanced greenhouse effect or global warming. An international panel of scientists appointed by the United Nations reported in 1995 that part of the global warming of 0.5°C that occurred in the 20th century was attributable to human activity[16]. Figure 6 shows the trend of global warming expressed in terms of temperature anomaly. It can be observed that in the period 1880-1935, the temperature



Source: Goddard institute for space studies (GISS) and Climate Research Unit (CRU), prepared by process trends.com, updated by globalissues.org

Fig. 6: Trend of global warming[17]

anomaly was consistently negative. In contrast, since 1980 the anomaly has been consistently positive. The 1917 temperature anomaly (-0.47°C) was the lowest year on record. Since 1917, global temperature has increased with the most recent years showing the highest anomalies of +0.6°C in the past 120 years.

Studies have also shown that the resulting increase in global temperatures is attributable to human activities, which have changed the chemical composition of the atmosphere through the buildup of greenhouse gases and have caused most of the warming over the last 50 years. Fossil fuel burning is the dominant driving force of the enhanced greenhouse effect, which causes the rise in temperature. This has been on the increase as more energy is being required by the growing population of the earth. From Fig. 4 and 6, it will be noticed that the accelerated rise in global temperature coincides with the period of rise in global carbon dioxide concentration.

CONTRIBUTION OF INDUSTRIALIZATION TO EMISSIONS RATE

It has been shown that heightened human activities have led to increase in global temperatures causing climate change. These activities revolve around the bid to use available and abundant natural resources and processing them into products in order to improve the quality of life and standard of living. Incidentally, this altered the balance of nature and triggered off a near calamitous situation on earth. In the past two centuries, human activities have taken a different turn towards the use of machines and the mechanization of processes, which were erstwhile performed by hand. The result was technological innovations, rapid transformation of economies, territorial expansions, unprecedented population growth, emergence of urban areas and transformation of the global social system and so on. That was the beginning of the industrial revolution. The industrial revolution began about 1750 in the United Kingdom. This revolution spread throughout Western and Northern Europe due to the limited amount of arable land and the overwhelming efficiency of mechanized systems. Increased productivity along with boost in incomes characterized the industrialized nations. This accumulation of capital allowed investments to be made in the conception and application of new technologies, enabling the industrialization process to continue to evolve.

Ever since the industrial revolution, humans have tremendously increased the rate of alteration of the climate and the environment through changing agricultural and industrial practices and the pumping of greenhouse gases into the atmosphere. The population growth, which accompanied the industrial revolution gave rise to the need for more land for agriculture and urban development, leading to massive deforestation and changing of the environment. This population explosion also meant more people burning fossil fuels to satisfy their energy requirements. About 98% of carbon dioxide emissions, 24% of methane gas emissions and 18% of nitrous oxide emissions are due to fossil fuels burned to run cars and trucks, heat homes and businesses and power factories. But quite a significant share of emissions is due to increased agriculture, deforestation, landfills, industrial productions and mining[7]. Figure 7 compares the trends in atmospheric concentrations and anthropogenic emissions of carbon dioxide. It clearly shows the sharp rise in atmospheric concentration of carbon dioxide beginning from the industrial revolution period[18].

Industrialized nations emit far more carbon dioxide than the other nations. In fact records have it that in 1997, the

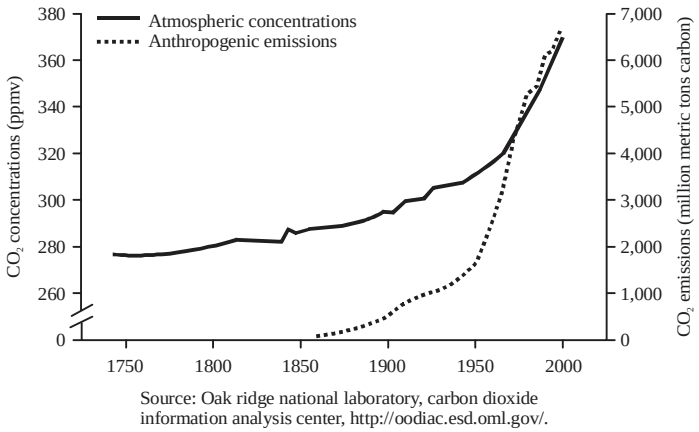


Fig. 7: Trends in atmospheric concentrations and anthropogenic emissions of carbon dioxide[18]

United States emitted about 20% of the total global greenhouse gases. Up until 2007, the US was the world's largest emitter of greenhouse gases in terms of total output and when measured per capita, the US still remains the largest emitter and accounts for some 40% of industrialized country emissions (Fig. 8). Due to its much longer period of industrialization, the US has emitted far more into the atmosphere than China. This is a serious situation because greenhouse gases such as carbon dioxide linger in the atmosphere for decades[7]. There is a huge contrast between developed/industrialized nations and poorer developing countries in greenhouse gas emissions, as well as the reasons for those emissions. According to Shah[17]:

- To date, industrialized countries account for roughly 80% of the carbon dioxide buildup in the atmosphere
- Annually, more than 60% of global industrial carbon dioxide emissions originate in industrialized countries, where only about 20% of the world's population resides
- Much of the growth in emissions in developing countries results from the provision of basic human needs for growing populations, while emissions in industrialized countries contribute to growth in a standard of living that is already far above that of the average person worldwide

CHALLENGES OF INDUSTRIALIZATION IN VIEW OF GLOBAL CLIMATE CHANGE

The effects of the emissions are not restricted to only those nations, which emit them but are extended to even the unindustrialized nations. So the effects of industrialization of the Western world are felt as far away as in the developing worlds of Africa and Asia. These effects could be described in terms of opportunities and challenges. The opportunities that

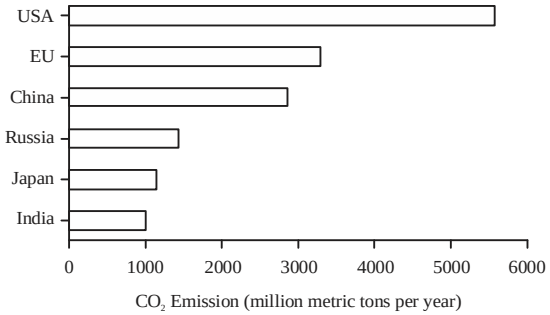


Fig. 8: Carbon dioxide emissions of industrialized nations[7]

arise from industrialization are well known, for example, economic transformation and growth, which result in better amenities, improved standard of living, accumulation of capital, employment creation, improved food production, more efficient water conservation, reducing dependence on fossil fuels and natural wood fuels, improved infrastructure and increased ecotourism potentials. The challenges of industrialization include impacts on global warming, higher energy demand, higher industrial wastes, exposure to dangerous machineries and equipment, health problems (noise, air, water and land pollution, poor nutrition, spread of diseases and ailments), imbalance in wealth distribution, changing human life styles and changing philosophies (impersonal work, destruction of communal living, changes in the family structure, isolation, poverty, homelessness and substance abuse), destruction of arable lands, over exploitation of natural resources, other forms of attacks on the environment, etc.

IMPACTS OF CLIMATE CHANGE ON MAN

Man is the ultimate recipient of the adverse effect of climate change. The world development report of the World

Bank 2010 summarizes the most important consequences of climate change above 2°C as follows:

- Significant loss from the Greenland and West Antarctic ice sheets and subsequent sea-level rise
- Increase of floods, droughts and forest fires in many regions
- Increase of death and illness from the spread of infectious and diarrhoeal diseases and from extreme heat
- Extinction of more than a quarter of all known species and
- Significant declines in global food production

Various areas respond variedly to climate change, depending on geographical location. More details on this could be found in Press and Siever[16]. Sadly, the developing countries are affected most by these challenges.

Impact on natural resources: The changing weather patterns and ocean temperatures affect agriculture, fish, wildlife, water and energy. Crop yields, affected by temperature and water stress as well as length of growing season fall by 10-25% and are less predictable as key regions shift from a warming to a cooling trend. As some agricultural pests die due to temperature changes, other species spread more readily due to the dryness and windiness- requiring alternative pesticides or treatment regiments. Commercial fishermen that typically have rights to fish in specific areas will be ill equipped for the massive migration of their prey.

Impact on carrying capacity: Today, carrying capacity, which is the ability for the earth and its natural ecosystems including social, economic and cultural systems to support the finite number of people on the planet is being challenged around the world. According to the International Energy Agency, global demand for oil will grow by 66% in the next 30 years, but it's unclear where the supply will come from. Clean water is similarly constrained in many areas around the world. Many point to technological innovation and adaptive behavior as a means for managing the global ecosystem. Indeed it has been technological progress that has increased carrying capacity over time. Over centuries we have learned how to produce more food, energy and access more water. But will the potential of new technologies be sufficient when a crisis like the one outlined in this scenario hits? Abrupt climate change is likely to stretch carrying capacity well beyond its already precarious limits. And there's a natural tendency or need for carrying capacity to become realigned. As abrupt climate change lowers the world's carrying capacity, aggressive wars are likely to be fought over food, water and energy. Deaths from war as well as starvation and disease will decrease population size, which overtime will re-balance with carrying capacity.

Impact on security: Violence and disruption stemming from the stresses created by abrupt changes in the climate pose a different type of threat to national security than it is accustomed to today. Military confrontation may be triggered by a desperate need for natural resources such as energy, food and water rather than by conflicts over ideology, religion or national honor. The shifting motivation for confrontation would alter which countries are most vulnerable and the existing warning signs for security threats.

IMPACT OF CLIMATE CHANGE ON HEALTH

Climate change gives rise to environmental conditions that can have far reaching effects on human health and existence. Direct effects are diseases and deaths as a result of extreme weather events like heat, flooding, mud slides, storms and hurricanes. Indirect effects are those that result from changes in the ecosystem, such as conditions that facilitate infectious diseases, changes in agricultural production and the availability of (clean) water. But climate change can also have indirect effects on health from the social and economic turmoil brought on by drought, flooding, famine, epidemics and movement of refugees[19]. Climate change affects health via a cascade of different mechanisms as shown in Fig. 9.

Extreme weather conditions normally associated with climate change, apart from causing physical discomfort can also affect the immune system as well as causing the proliferation of disease vectors and increasing the resistance of pathogens. Many infectious disease agents such as viruses and bacteria and vectors such as mosquitoes and rodents are influenced by seasonality and changes in temperatures, rainfall and humidity[20]. It has been suggested that climate change can lead to novel genetic changes in pathogens[21]. In some cases, it may be a genetic transfer that results in more virulence and increased resistance to antibiotics. This can be attributed to resilience resulting from the pathogens adaptation tendencies. McMichael[22] noted that the effect of climate change on health is partly due to changes in physical living conditions but mostly from the biophysical and ecological systems that determine the prospects of population health. Besides, the possibility of providing a conducive atmosphere for disease outbreaks, Mirski *et al.*[23] observed that stresses associated with energetically unfavourable conditions may also indirectly contribute to emergence of

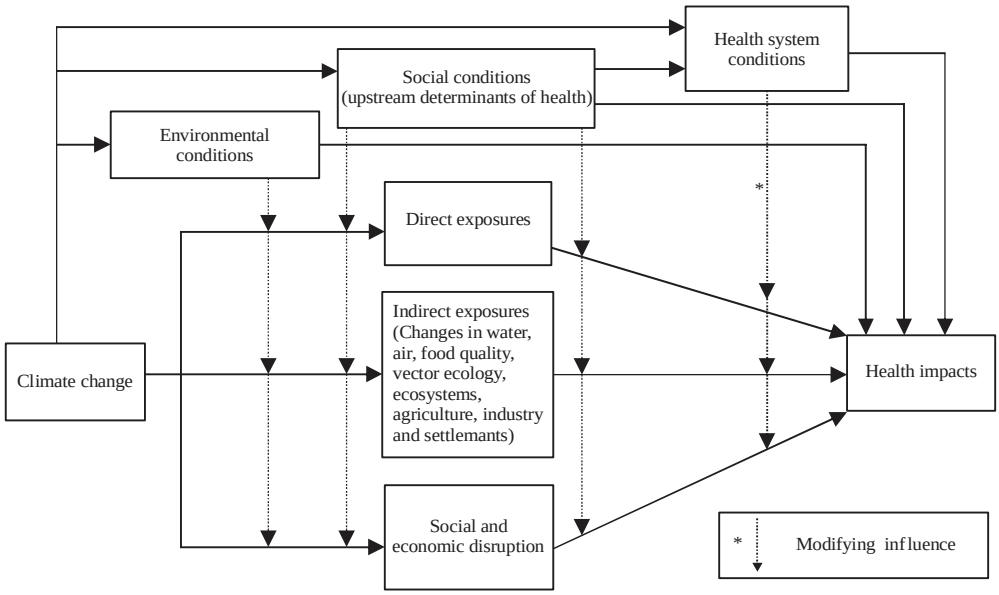


Fig. 9: Mechanisms of climate change affecting health[17]

new diseases and death through inhibition of the immune system. Emergence of new diseases can also result from non toxinogenic strains of microorganisms acquiring the toxinogenic gene from the environment. Increase in temperatures can also affect the incidence of animal infectious diseases spreading to humans by altering the range of animal hosts and insect vectors[24]. Climate change can also result in a geographical redistribution or spread of infectious diseases as a result of shift or broadening of certain climatic conditions. Hoberg and Brooks[21] stated that episodic shifts in climate and environmental settings, in conjunction with ecological mechanisms and host switching are critical determinants of parasite diversification. The timing, intensity and location of disease outbreak are affected by weather conditions[25].

In recent times, an upsurge in both frequency and number of outbreak of certain diseases especially in sub-Saharan Africa might not be unconnected with changing climatic conditions. Ebola virus disease which broke out in Guinea in March, 2014, eventually spread to Sierra Leone, Liberia and Nigeria. Ng *et al.*[26] noted that the cyclic and seasonal nature of the disease suggest that changes in factors such as climate may be useful predicators of the disease. Mirski *et al.*[23] noted that climate induced changes in intrinsic factors may induce stress responses, making certain pathogen more resistant as in the case of *E. coli* O157:H7. Gloud and Higgs[27] suggested that under the influence of rising temperatures and rainfall as well as changes in natural cycles that stabilize the climate, arbovirus may emerge in entirely new territories.

The effect of climate change on infectious diseases can be linked to how the vectors respond to environmental changes. Besides the direct interconnection between pathogens and climatic factor, it has been observed that climate change impacts on disease vector by either providing favourable conditions for their proliferation or causing them to migrate to entirely new areas carrying the parasites with them. In the case of migration to entirely new territories in search of favourable conditions, these vectors introduce the parasites to the community of human beings in their new habitat. This results in the eventual redistribution of the disease, which in some cases implies a widening of the geographical reach of the disease. Due to increase in global temperatures, tropical insects can expand their horizon further latitudes and find living conditions at higher altitudes that affect transmission of local viral pathogen[28]. In fact, Martin *et al.*[29] observed global warming conditions can expand the climate tolerance limits of vectors Southwards and Northwards, creating favourable conditions for vectors to colonize new ecosystems and animal populations in temperate regions. Ticks have been moving Northward in Sweden as winters warm and mosquitoes are appearing in Mountainous regions, where plant communities and freezing levels have shifted upward and glaciers are rapidly retreating[30,31]. Flash floods leave behind mosquito breeding grounds and drive rodents from burrows thereby increasing the incidence of malaria and other diseases. Ebi *et al.*[32] reported that heavy rainfall and three cyclones within a space of 6 weeks in Mozambique led to incessant flooding and a five-fold spike in malaria. However, when

environmental conditions are unfavourable, the distribution, rate of reproduction and survival of the disease vector will be impaired resulting in a subsidence in the rate of incidence of the associated disease. In the case of diseases associated with vectors that thrive in wet habitat such as malaria, prolonged drought and excessive heat usually results in a fall in incidence rate or total disappearance of the disease from the location. Table 3 summarizes the effect of specific climatic conditions on specific diseases.

INDUSTRIALIZATION EFFECTS IN THE DEVELOPING WORLD: THE CASE OF NIGERIA

In the developing world where regulations are lax and level of ignorance high, industrialization causes higher levels of pollution, uncontrolled exploitation and inability to link up between non-performances of social responsibilities to non-functionality of systems. For example, in Nigeria with the introduction of the plastic packaging, indiscriminate dumping of wastes resulting from such activities has led to blockage of drainage channels, flooding in some of the areas, rapid growth of malaria cases and other water-borne diseases. Oil exploration and exploitation have left trails of massive environmental devastation of the Niger Delta region in Nigeria. Change in people's philosophies accounts for a lot of irresponsibility where accumulation of wealth becomes the only goal of a people particularly in the developing nations. No care is given to the consequences on the environment. This is largely due to ignorance and the inability to establish a link between our lifestyles and the impact they have on our human environment. Indiscriminate erection of structures in guise of urbanization without regard to natural water causeways and flood plains result to devastating flooding.

Environmental and waste management policies have long been relegated and exist only in principle. Established agencies for the protection of the environment in most parts of the country have failed in their duty of environmental sanitation and protection due to poor management and funding. The result is that more that 60% of waste generated is not collected, giving rise to indiscriminate and improper disposal of waste by residents. For example in Lagos State

Table 3: Climate dependent infectious diseases

Disease	Causative organism	Effect of climate change	References
Avian influenza	H5N1 virus	Exreme weather conditions causing redistribution and migration cycles of wild water birds, the natural habitat of the virus	Cross and Hyams[33]
Blue tongue disease	Blue tongue virus	Climatic conditions favouring the abundance of insect vectors (*Colicoides*)	Mirski *et al.*[23]
Campylobacteriosis	*Campylobacter*	Increased ambient temperature	Mirski *et al.*[23]
Chikungunya fever		Drought (forcing people to store water around the homes thereby providing breeding ground for the vector, *Aedes aegypti* mosquito	Epstein[25]
Cholera	*V. cholerae* (non toxinogenic)	Climate induced gene transfer resulting in higher incidences of disease and resistance to antibiotics	Mirski *et al.*[23]
Ebola	Ebola virus	Reduced temperature and increased absolute humidity	Ng *et al.*[26]
Hemorrhagic diarrhea	*E. coli* O157:H7	Stress response to climate induced changes	Mirski *et al.*[23]
Leishmiasis	*Phlebotomus papatasi*	Vector depends on temperature and relative humidity	Lindgren and Jaenson[34]
Lyme borreliosis	*Borrelia burgdorferi*	Extremely low temperatures, recurrent droughts and flood favouring the vector Ixodes (a genus of tick)	Rogers *et al.*[35]
Malaria	*P. vivax*, *P. falciparum*	Increased temperatures resulting in increased rate of mosquito development, feeding and maturity of parasites. Possible reduction in survival of adult mosquitoes	Mirski *et al.*[23], Tersago *et al.*[36]
Nephropathia	Puumala virus	Prolonged high temperatures favourable to disease vector	Jacups *et al.*[37]
Rift valley fever	RFV virus	The vectors, aedes, anopheles and culex mosquitoes are favoured by heavy rainfall resulting in increased breeding frequency and egg production of vectors, reduction in length of development cycle and extrinsic incubation period	Martin *et al.*[29]
Ross river fever	Ross river virus	Increased temperature, rainfall and humidity	D'Souza *et al.*[38]
Salmonellosis	*Salmonella*	Increased ambient temperature	McCarthy *et al.*[39]
Staphyloccocus infection	*Staphylococcus aerus* (Methicilin resistant strain)	Rapid response to environmental changes	Mirski *et al.*[23]
Tick borne encephalitis	Tick borne encephalitis virus	Increase in temperature and reduced humidity	Mirski *et al.*[23] and Medlock *et al.*[40]
West Nile fever	West Nile virus	Increased temperatures in temperate regions thereby providing favourable conditions for mosquitoes	Gambrell[41]
Zika virus disease	Zika virus	Warmer and wetter conditions favour the survival and proliferation of *Aedes aegypti*, which is responsible for zika virus transmission	Epstein[25]

which is the most industrialized part of Nigeria, although the established agencies are working very hard, the attitude of the populace to waste disposal both, industrial and domestic leaves must to be desired. Pollution level of the environment is still very high and the canals serve as refuse disposal channels. This has resulted in constant flooding of the state with that of July, 2011 claimining 20 lives. With very low power supply from the national electricity grids, industries and the massive population had to rely on electric power generators which burn fossil fuels. The effects of the climate change with specific reference to Nigeria are:

- Coping with higher temperatures
- Extreme weather patterns such as longer spells of dry heat or intense rain
- Recent unprecedented flooding of Lagos state, Abakiliki, Ibadan and the flooding of agricultural lands in Northern Nigeria (Fig. 10) leading to loss of lives and food shortage
- Ecosystem impacts, for example the devastating erosions in the eastern parts of Nigeria
- Rising sea levels leading to loss of beach fronts in Lagos
- Increasing ocean acidification and declining ocean biodiversity
- Increase in pests and diseases
- Failing agricultural output
- Deserts encroachment in Northern Nigeria

Unless the people's philosophies and industrial attitude to the environment, waste disposal and to lifestyles changes, these detrimental effects on the climate will continue to be experienced.

CREATION OF EQUILIBRIUM BETWEEN INDUSTRIALIZATION AND CLIMATE CHANGE

The understanding of climate change has been immensely enhanced by adopting a multifaceted and multi-disciplinary approach. While the pure and applied sciences have thrown light on the causes, processes and activities leading to climate change as well as developing measures for climate change mitigation, the social sciences have focused mainly on adaptation. Figure 11 shows the link between industrialization, social behavior and climate change. Increased industrialization coupled with poor social behavior and a lack of commitment to social responsibility will aggravate the problem of climate change. Increased industrialization cannot be encouraged without considering the account of climate change and its consequences. What measures should be taken? On 11 December, 1997 in Kyoto, Japan 37 countries (Annex I countries) under a protocol committed themselves to a reduction of four greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride) and two groups of gases (hydrofluorocarbons and perfluorocarbons) produced by them. The Annex I countries agreed to reduce their collective greenhouse gas emissions by 5.2% from the 1990 level[42]. The Kyoto Protocol defined three flexible mechanisms namely: emissions trading, the clean development mechanism (CDM) and joint implementation for allowing Annex I countries to meet their GHG emission limitations by purchasing GHG emission reductions credits from elsewhere through financial exchanges, projects that reduce emissions in non-Annex I countries, from other Annex I countries or from Annex I countries with excess allowances. Countries like China, India,

Fig. 10: A flooded farmland in Gudinchin village in Jigawa state Northern Nigeria[41]

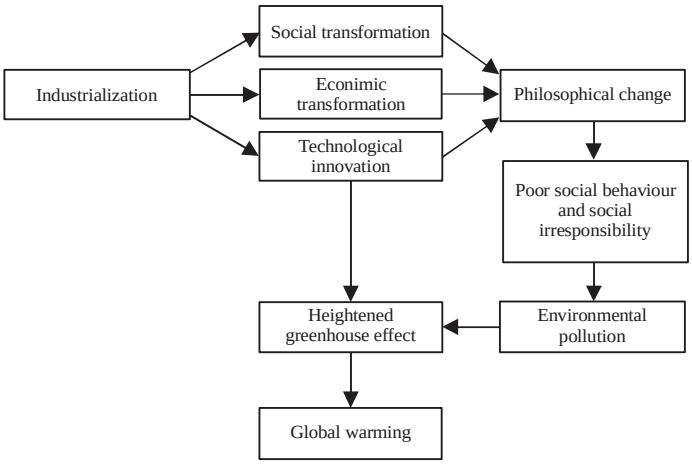


Fig. 11: Industrialization-social behaviour-global warming link

Thailand, Indonesia, Egypt and Iran do not belong to the Annex 1 countries. Most non-Annex I countries belong in the low-income group with very few classified as middle-income. They expressed their concern over how efforts to reduce emissions could affect their economies. The economies of these countries are highly dependent on income generated from the production, processing and export of fossil fuels. In several large developing countries and fast growing economies, greenhouse gas emissions have increased rapidly. For example, emissions in China have increased drastically over the 1990-2005 period, often by more than 10% per year[43]. Emissions per-capita in non-Annex I countries are still for the most part, much lower than in industrialized countries. Non-Annex I countries do not have quantitative emission reduction commitments, but they are committed to mitigation actions. China, for example has had a national policy programme to reduce emissions growth, which included the closure of old, less efficient coal-fired power plants[44].

United Nations has established a body named Intergovernmental Panel on Climate Change (IPCC) comprising hundreds of climate scientists around the world and they have released major, definitive reports detailing the progress in understanding climate change. Their report summarized that they were even more certain than before of human-induced climate change because of better scientific understanding[13]. They have made some recommendations based on their findings and deductions. From the outset they recommended that there be emission reductions. Their recommendations have been mainly in terms of mitigation of the effects and adaptation to the climate change.

Presently, there are mitigation measures being taken to cut the net emissions of greenhouse gases and so reduce climate change effect but there is need for adaptation to climate change since some of the causes are natural. Adaptation needs to begin immediately so we can keep up with the predicted shifts in conditions. Effective mitigation of and adaptation to the impacts of climate change require a common set of response priorities[8]. Water and energy efficiency are of primary importance, followed by pragmatic and future oriented reviews of standards, codes, regulations and other practices. Measures to assess risk and manage durability need to be developed and integrated into practice. Emergency preparedness and response programs need to be further improved. Finally, there is need to develop regulations and standards of professional practice designed to protect the environment at the same time as protecting the public and its infrastructure from increased weather hazards.

Some aspects of mitigation and adaptations which need to be imbibed to reduce the consequences of the climate change effects are[8,45]:

- Develop approach and practices for protecting and improving existing construction against effects of climate change
- Develop designs, operations and maintenance of buildings and machines
- Revise existing codes such as climate data to take into consideration the present realities
- Develop and adapt energy saving technologies
- Adopt clean and renewable energy usage
- Reduce the use of natural resources and emphasize the reuse and recyclingof industrial by-products
- Reduce waste at the design stage

Most importantly, industrialized nations need to vigorously pursue programmes and strategies that help in

emission reduction. Despite the annual international conferences on climate change i.e., United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) so far, there has still been little progress on emission reduction. Worse still, the industrialized nations who are actually the main polluters (at the COP16-Cancún Climate Conference held in Cancún, Mexico in December, 2010), managed to reduce their commitment to reduction of emissions, while increasing those of the developing countries. It is then necessary for the industrialized nations to realize that they are actually responsible for the rapid deterioration of our habitat and should therefore make more concerted efforts towards ameliorating the already bad situation. The natural carbon cycle and human-induced climate change differ in that the latter is rapid. This means that ecosystems have less chance of adapting to the changes that will result and so the effects felt will be worse and more dramatic if things continue the way they are now. Therefore, more commitment is required from the industrialized nations towards reduction of emissions. Sustainability should be the underlying principle or value in any industrialization oriented nation. Environmental Impact Assessment (EIA) should be a key part of every plan towards industrialization. Companies and industries should not gloss over environmental programs in order to increase profits or to survive in a tough business world. Environmental maintenance agencies should be more focused on the main goal of restoring and keeping the environment in a state fit for human habitation. Social transformation must also be planned for. Creation of awareness and education of the populace on the impact of their activities with respect to climate change should be embarked on. And lastly, people must be taught and properly sensitized on how they key into the climate change equation.

CONCLUSION

- Anthropogenic activities are largely responsible for the problem of climate change. One of the most noticeable signs of climate change is rising global temperature
- Man is the ultimate recipient of the adverse effects of climate change, hence the need to initiate necessary adjustment measures
- Most of the recent sporadic outbreak of infectious diseases can be attributed to climate change indicators such as rising temperatures and increased humidity
- Cutting down on emission of green house gases is a necessary but inadequate measure for climate change mitigation because some of the spin off effects of climate change cannot be ameliorated by emission reduction
- Besides there is need for social and behavioural adjustments for improved adaptation. The recent outbreak

REFERENCES

1. Williams, P.H., 1965. The industrialization of Nigeria. Proc. Oklahoma Acad. Sci. For., 45: 215-218.
2. O'Sullivan, A. and S.M. Sheffrin, 2003. Economics: Principles in Action. 2nd Edn., Upper Saddle River, Pearson Prentice Hall, New Jersey, USA., ISBN-13: 9780130630858, Pages: 592.
3. EPA., 2014. Climate Change Indicators in the United States. 3rd Edn., Environmental Protection Agency, USA., Pages: 107.
4. Pidwirny, M., 2006. Causes of Climate Change. In: Fundamentals of Physical Geography, James, P., D. Sack and R.E. Gabler (Eds.). 2nd Edn., Cengage Learning, Boston, MA., USA., pp: 210-213.
5. Hecht, L., 2007. What really causes climate change? Executive Intell. Rev., 34: 6-9.
6. Alvarez, J.M., F. Cecchi and A. Tilche, 1999. Emission of greenhouse gases from anaerobic digestion processes: Comparison with other MSW treatments. Proceedings of the 2nd International Symposium on Anaerobic Digestion of Solid Waste, June 15-18, 1999, Barcelona, Spain, pp: 274-277.
7. Evliya, H., 2007. Energy Storage for Sustainable Future-A Solution to Global Warming. In: Thermal Energy Storage for Sustainable Energy Consumption: Fundamentals, Case Studies and Design, Paksoy, H.O. (Ed.). Chapter 5, Springer, Dordrecht, Netherlands, ISBN: 9781402052903, pp: 87-99.
8. Morofsky, E., 2007. What Engineers Need to Know About Climate Change and Energy Storage. In: Thermal Energy Storage for Sustainable Energy Consumption: Fundamentals, Case Studies and Design, Paksoy, H.O. (Ed.). Chapter 3, Springer, Dordrecht, Netherlands, pp: 49-74.
9. Gilpin, A., 1982. Dictionary of Energy Technology. Butterworth Scientific, London, UK., ISBN-13: 978-0408011082, Pages: 392.
10. IPCC., 1996. Climate Change 1995: The Science of Climate Change: Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK., ISBN: 9780521564366, Pages: 572.
11. IPCC., 2001. Climate Change 2001: The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK., ISBN-13: 978-0521014953, pp: 358.
12. Johnson, I. and R. Coburn, 2010. Trees for carbon sequestration. http://www.forestrycorporation.com.au/__data/assets/pdf_file/0006/438234/Trees-for-carbon-sequestration.pdf

13. IPCC., 2014. Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change, Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani and S. Kadner *et al.* (Eds.). Cambridge University Press, Cambridge, UK., ISBN-13: 9781107058217, pp: 3-30.
14. Hidalgo, J., V. Masson, A. Baklanov, G. Pigeon and L. Gimeno, 2008. Advances in urban climate modeling. Annals New York Acad. Sci., 1146: 354-374.
15. Nordell, B., 2007. Global Warming is Large-Scale Thermal Energy Storage. In: Thermal Energy Storage for Sustainable Energy Consumption: Fundamentals, Case Studies and Design, Paksoy, H.O. (Ed.). Chapter 4, Springer, Dordrecht, Netherlands, pp: 75-86.
16. Press, F. and R. Siever, 2001. Understanding Earth. 3rd Edn., W.H. Freeman, New York, USA., ISBN-13: 9780716741176, Pages: 121.
17. Shah, A., 2011. Climate change and Global warming introduction. Global Issues. http://www.globalissues.org/article/233/climate-change-and-global-warming-introduction
18. EIA., 2004. Greenhouse gases, climate change and energy. Energy Information Administration, Washington, DC., USA., http://www.eia.gov/oiaf/1605/ggccebro/chapter1.html
19. Zacher, W., 2012. Climate change and health-time to act: Facts and conclusions for industrial and developing countries. Briefing Paper, January 2012, Germany, pp: 4-30. http://germanwatch.org/klima/health12.pdf
20. Bai, L., L.C. Morton and Q. Liu, 2013. Climate change and mosquito-borne diseases in China: A review. Global Health, Vol. 9. 10.1186/1744-8603-9-10.
21. Hoberg, E.P. and D.R. Brooks, 2015. Evolution in action: climate change, biodiversity dynamics and emerging infectious disease. Philos. Trans. R. Soc. B, Vol. 37. 10.1098/rstb.2013.0553.
22. McMichael, T., 1999. Global climate change: Does warming warrant a health warning? European Advanced Study Courses, Climate Change and Human Health Training Course at the London School of Hygiene and Tropical Medicine, UK.
23. Mirski, T., M. Bartoszcze and A. Bielawska-Drozd, 2012. Impact of climate change on infectious diseases. Polish J. Environ. Stud., 21: 525-532.
24. Parkinson, A.J. and J.C. Butler, 2005. Potential impacts of climate change on infectious diseases in the arctic. Int. J. Circumpolar Health, 64: 478-486.
25. Epstein, P., 2010. The ecology of climate change and infectious diseases: Comment. Ecology, 9: 925-928.
26. Ng, S., N.E. Basta and B.J. Cowling, 2014. Association between temperature, humidity and ebolavirus disease outbreaks in Africa, 1976 to 2014. Eurosurveillance, Vol. 19, No. 35.
27. Gould, E.A. and S. Higgs, 2009. Impact of climate change and other factors on emerging arbovirus diseases. Trans. R. Soc. Trop. Med. Hyg., 103: 109-121.
28. Zell, R., 2004. Global climate change and the emergence/re-emergence of infectious diseases. Int. J. Med. Microbiol. Supplem., 293: 16-26.
29. Martin, V., V. Chevalier, P. Ceccato, A. Anyamba and L. de Simone *et al.*, 2008. The impact of climate change on the epidemiology and control of rift valley fever. Rev. Sci. Tech., 27: 413-426.
30. Epstein, P.R., H.F. Diaz, S. Elias, G. Grabherr, N.E. Graham and W.J.M. Martens, 1998. Biological and physical signs of climate change: Focus on mosquito-borne diseases. Bull. Am. Meteorol. Soc., 78: 409-417.
31. Lindgren, E. and R. Gustafson, 2001. Tick-borne encephalitis in Sweden and climate change. Lancet, 358: 16-18.
32. Ebi, K.L., N. Chan, A. Milne and U.E. Confalonieri, 2005. Infectious and Respiratory Diseases. In: Climate Change Futures: Health, Ecological and Economic Dimensions, Epstein, P.R. and E. Mills (Eds.). The Center for Health and the Global Environment, Harvard Medical School, USA., pp: 32-52.
33. Cross, E.R. and K.C. Hyams, 1996. The potential effect of global warming on the geographic and seasonal distribution of *Phlebotomus papatasi* in Southwest Asia. Environ. Health Perspect., 104: 724-727.
34. Lindgren, E. and T.G.T. Jaenson, 2006. Lyme Borreliosis in Europe: Influences of Climate and Climate Change, Epidemiology, Ecology and Adaptation Measures. WHO Regional Office for Europe, France, Pages: 34.
35. Rogers, D., S. Randolph, S. Lindsay and S.G. Willis, 2001. Health effects of climate change in the UK, 2001/2001 report. Department of Health, UK., pp: 34-70.
36. Tersago, K., R. Verhagen, A. Servais, P. Heyman, G. Ducoffre and H. Leirs, 2009. Hantavirus disease (*Nephropathia epidemica*) in Belgium: Effects of tree seed production and climate. Epidemiol. Infect., 137: 250-256.
37. Jacups, S.P., P.I. Whelan, P.G. Markey, S.J. Cleland, G.J. Williamson and B.J. Currie, 2008. Predictive indicators for Ross River virus infection in the Darwin area of tropical northern Australia, using long term mosquito trapping data. Trop. Med. Int. Health, 13: 943-952.
38. D'Souza, R.M., N.G. Becker, G. Hall and K.B. Moodie, 2004. Does ambient temperature affect foodborne disease? Epidemiology, 15: 86-92.
39. McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and C.S. White, 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, ISBN-13: 9780521015004, pp: 812-814.
40. Medlock, J.M., K.R. Snow and S. Leach, 2005. Potential transmission of West Nile virus in the British Isles: An ecological review of candidate mosquito bridge vectors. Med. Vet. Entomol., 19: 2-21.

41. Gambrell, J., 2010. Flooding in Nigeria worsens food shortage. http://www.nbcnews.com/id/39384099/ns/world_news-africa/t/flooding-nigeria-worsens%20food-shortage#.Vxn1W_l94y4.3
42. United Nations, 2011. Fact sheet: The Kyoto protocol. United Nations Framework Convention on Climate Change. https://unfccc.int/files/press/backgrounders/application/pdf/fact_sheet_the_kyoto_protocol.pdf
43. Leggett, J.A., 2011. China's greenhouse gas emissions and mitigation policies. CRS Report for Congress, Congressional Research Service, 7-5700, R41919. https://www.fas.org/sgp/crs/row/R41919.pdf.
44. Carrington, D., 2016. China's coal-burning in significant decline, figures show. Guardian News and Media Limited. http://www.theguardian.com/environment/2016/jan/19/chinas-coal-burning-in-significant-decline-figures-show.
45. Abraham, K.F., R.L. Jefferies and R.T. Alisauskas, 2005. The dynamics of landscape change and snow geese in mid-continent North America. Global Change Biol., 11: 841-855.